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AIR POLLUTION

TARGET AUDIENCE & OBJECTIVES: This document introduces and briefly describes air pollution, its impact, the existing institutional framework and its links with the built environment. This paper is intended for a wide range of readers interested in getting a brief and balanced overview of air pollution and particularly with a focus on the built environment.

Background

Air pollution has been one of the most visible human impacts on the environment, affecting human health, ecosystems and the built environment. Air pollutants are any substance present in ambient air that is likely to have harmful effects on human health and/or the environment as a whole.

Fossil fuel combustion is usually the most important sources of air pollution with industrial processes, solvent use, agricultural activity and natural processes following suit. The sheer number of atmospheric pollutants and their sources renders the minimisation of their emission a challenging task. Several studies have highlighted the significant reduction of air pollution across the EU and the UK over the past decades[1]. This has been achieved through the successful regulation of polluting activities and has provided some of the most telling success stories of environmental legislation.

Pollutants

Only the most important air pollutants will be discussed in this factsheet. All pollutants discussed are primary pollutants, with the exception of particulate matter (primary or secondary pollutant) and ozone (secondary pollutant). It should be noted that this information sheet does not focuses on the effects of certain air pollution on climate change. Certain pollutants such as methane and ozone are greenhouse gases in the own right so their climate impact will be discussed in the "Green House Gases (GHG) and Global Warming" information sheet S-PO1

Particulate Matter (PM): PM is the most complex air pollutant in the sense that it consists of a wide range of materials with various structures (solids/liquids), sizes and chemical compositions[2]. According to its size, PM can be divided in different categories with PM10, PM2.5 and PM1 being the most policy relevant. These notations refer to particles with a diameter of less than 10nm, less than 2.5nm and less than 1nm respectively (1 nm a thousand-millionth of a meter).

In the UK, the main sources of primary PM are road transport (fuel combustion, brake and tyre wear and re-entrainment of dust from road surfaces), stationary combustion (built environment) and industrial processes. Secondary PM is a result of complex chemical processes that take place in the atmosphere. Secondary PM has attracted interest given its ability to travel significant distances and affect areas far away from the initial point of emission (transboundary pollution). It should be noted that natural processes can also be large contributors of PM with forest fires, dust storms and sea spray being only some examples.

Nitrogen oxides (NO_x): NO_x refers collectively to nitrogen monoxide (NO) and nitrogen dioxide (NO_2). NO_x are the outcome of high temperature combustion processes. In the UK the main NO_x source is road transport which contributed almost half of the total emissions in 2001. Transport and domestic/commercial activity expected each to be responsible for approximately a third of the total NO_x emissions in 2010[3]. Most NO_x is emitted in the form of NO. NO_2 is also directly emitted, but in smaller quantities, especially from diesel vehicles. However, certain chemical reactions in the atmosphere transform NO to NO_2 which is a pollutant with far more significant health impacts.

Carbon monoxide (CO): CO is a poisonous atmospheric pollutant whose main anthropogenic source is the incomplete, or inefficient, combustion of fossil fuels[4].

Sulphur dioxide (SO_2): SO_2 is an atmospheric pollutant emitted after the combustion of fuel that contains sulphur, particularly coal and crude oil. Power generation is the most important SO_2 source in the UK[4] with industrial processes playing a minor role. On a global scale much greater quantities of SO_2 are emitted by volcanoes.

Volatile Organic Compounds (VOC): VOC refers to a big family of pollutants which encompasses hundreds of different compounds with varying chemical structures. Methane (CH_4), a potent pollutant and greenhouse gas, is the most famous VOC. The term NMVOC refers to the other Non-Methane Volatile Organic Compounds with toxic NMVOCs including benzene and 1,3-butadiene. VOCs main source, like for most other air pollutants, is inefficient fuel combustion. Industrial processes, solvent use, distribution of fuel and the use of household products (e.g. paints, cleaning agents, fertilisers, glues, building materials etc) are other important sources[5].

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Additionally, natural sources such as trees, burning biomass (forest and grass fires) and wetlands can be important emitters of VOCs.

Heavy Metals: This category refers to a number of chemical elements that may have a negative impact on health and the environment. In the UK the emission of heavy metals is usually a result of industrial processes, waste incineration and less commonly fuel combustion[5]. Lead (Pb) has been the main exception in the rule with transport historically being the main emission source of this pollutant. The most important heavy metals include cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), chromium (Cr) and Nickel (Ni).

Tropospheric Ozone (O_3): O_3 is a secondary gaseous pollutant that is a product of a series of chemical processes in the lower atmosphere. These chemical reactions are initiated by sunlight and in a nutshell they involve the oxidation of VOCs in the presence of NO_x[4]. In a similar manner to secondary PM, the formation of O_3 can take a significant amount of time and as a result O3 can impact areas very far away from where its precursors (VOCs, NO_x) have been originally emitted.

Impacts

Air pollution can have a significant impact on human health, ecosystems and the built environment. Another important impact is that several of these air pollutants in one way or another affect the global climate. O_3 and CH_4 are GHGs in their own respect and as a result their increased emission (and of the precursors of O_3 such as NO_x and VOC) can increase human induced climate change. On the other hand PM and SO2 can affect the formation of aerosols and as such affect the climate. This dual nature of these air pollutants greatly complicates their regulation[6]

Table1: Impacts of environmental pollution[7].

	PM	NO_x	CO	SO_2	VOC	Heavy Metals
O3 formation leading to effects on health, crops, materials and ecosystems		√			√	
Health impacts from primary and secondary pollutants.	√	√	√	√	√	√
Ecosystem acidification (e.g. acid rain)		√		√		
Ecosystem eutrophication (excessive nutrient levels)		√				
Ecosystem toxicity						√
Damage to buildings and national heritage		√		√		
Effects on climate (direct and indirect)	√	√		√	√	

Table 2: Health impacts of main air pollutants[8,9]

	Impact
PM	Pollutant with the most adverse health impacts. PM10 and finer particles can enter deep into the lungs and cause damage with the extent of the harm depending on the PM's chemical composition. PM can affect the respiratory and cardiovascular systems potentially causing lung cancer, asthma attacks or aggravating the health of people with existing respiratory and cardiovascular diseases leading to their premature death. PM2.5 may lead to vascular inflammation and atherosclerosis. PMs annual health impacts across EU25 are estimated at some 3.7 million years of life lost annually which can also be expressed as 348,000 premature deaths (approximately 2.5 times more than traffic accidents)[7]. The WHO estimates an average life expectancy of 8.6 months lower within the EU due to exposure to PM2.5.
NO_2	Highly toxic. Can cause serious lung damage, with a delayed effect, in high concentrations. Other health effects include shortness of breath and chest pains.
CO	Poisonous. When inhaled, it combines with haemoglobin and prevents it from taking up oxygen from the air. Lack of oxygen causes cells and tissues to die.
SO_2	Can affect the respiratory system, the functioning of the lungs as well as cause irritation of the eyes. Even moderate concentrations may result in a fall in lung function in asthmatics. SO_2 pollution is considered more harmful when particulate and other pollution concentrations are high.
VOC	Several VOCs such as benzenes are carcinogenic. Leukaemia and lymphoma risk can increase through prolonged exposure of VOCs long-term exposure to low concentrations, particularly in the indoor environment. At higher concentrations they may result in liver or kidney damage. Prolonged exposure at high concentration may also cause irritation of the respiratory tract.
Heavy metals	Carcinogenic or toxic even in small amounts. Different elements can affect the central nervous system, kidneys, liver, skin and bones.
O_3	It can affect lung function and cause irritation to the respiratory tract, breathing problems and trigger asthma and lung diseases. It can cause irreversible damage to the respiratory tract and lung tissue in high quantities. Asthmatics are more susceptible while O_3 is associated with about 21,000 premature deaths per year within Europe.

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Policy framework

Given its adverse effect on human health, air pollution has been one of the first forms of environmental pollution that have been targeted through elaborate policies. A classic example has been the effort that followed the 1952 smog episode in London. It is estimated that between 3,500 and 4,000 people (other sources claim as much as 12,000 people) may have died during this event. This incident has been the catalyst for the development of the 1956 and 1968 UK Clean Air Acts which among others regulated the use of coal in urban centres[10].

In an EU context, air pollution constitutes perhaps the first environmental issue that has been targeted. The origins of this process lay in the 1973 European Communities Programme for Action on the Environment which essentially established a procedure under which member states were asked to agree on maximum levels of pollutant concentrations on ambient air. These targets were binding and were supposed to be met before a given deadline. The first such Directive, covering smoke and SO_2, came into effect in 1980.

Since then there has been a large number of similar legislation. The last important initiative has been Directive 2008/50/EC which amongst others sets maximum concentration levels and regulatory instruments for PM10, PM2.5, NOx, SO2, CO, Pb, Benzene and O_3[11]. This Directive represents a long effort to bring together the disparate air pollution legislation, particularly the Air Pollution Framework Directive and three of its daughter directives.

Directive 2004/107/EC (Fourth Daughter Directive) sets limits for the emission of toxic air pollutants including heavy metals such as arsenic, cadmium and nickel[11] and is expected to be integrated later on in the existing framework.

Directive 2001/81/EC is another example of air pollution legislation which defines the maximum quantities of certain pollutants such as NO_x, SO_2 and VOCs that can be emitted annually by each member state[11]. Additionally, there is a large number of additional legislation concerned pollutant emission standards in transport and industrial activities[11]. These policies have been implemented in Scotland through a series of legislation and other initiatives of the Scottish Government[12].

Currently, each local authority ought to ensure that the aforementioned quality objectives are met by the dates specified by the UK Government, and set in the original EU Directives. Reviewing and assessing air quality within their area through the measurement of air pollution (monitoring) and predicting how it will change over time (modelling) are key elements of each local authority's responsibility.

If a local authority identifies areas where the objectives are not likely to be achieved, it must declare an Air Quality Management Area (AQMA) and suggest a plan to meet the air quality objectives in the future[4].

Monitoring of different pollutants is presently performed in about 1500 monitoring sites across the UK[4]. Prediction is performed through the assessment of the potential effects on air pollution of large scale projects and policies. Tools that are being employed by local governments, national government departments and consultancies include dispersion models such as ADMS and AerMod. A legal requirement regarding the selection of the appropriate model is presently lacking so the choice is left to the entity that is carrying out the modelling exercise.

The Scottish Government has developed a website that has exhaustive information on local air quality trends including the monitoring data from different stations across the country[13]. As of 2008, Scotland has met some of the legislative limits for NO_x and PM. In some occasions this has been the first time that these limits have been met so significant work needs to be done to ensure the long term compliance of the air quality limits. Seventeen AQMAs in twelve Scottish local authorities (out of thirty-two) have been declared.

Built environment

As it is discussed in another factsheet, the built environment is one of the most important consumers of energy both used during the operation of the building as well as embodied in the construction materials. Most of the pollutants introduced in this factsheet are emitted due to the inefficient combustion of fossil fuel.

As a result the minimisation of the energy used during the construction and operation of a building can go a long way towards decreasing the environmental impact of the built environment. These concerns have been integrated in the BREEAM suite of tools which includes indicators such as NO_x emissions and the fraction of renewable energy used within the building[14].

Construction activity can also result in the emission of significant amounts of dust (PM75) and PM10. Even though PM75 does not pose a serious risk to health, it can cause irritation and increase cost due to deposition on property. On the other hand PM10 can be very dangerous to human health as already discussed. There is a number of policy mechanisms in place that aim to ensure the safety of those

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working in construction sites and those living in their vicinity (e.g. Building Act 1984, Building Regulations 2000).

As a result a number of mitigation measures which aim in the minimisation of emitted PM from construction sites have been suggested. Such measures target different construction activities such as site planning, construction traffic, demolition works, earth moving works and site activities[15].

The built environment can also affect human health through indoor air pollution. Even though this form of air pollution is not as severe in developed nations as it used to be, it still constitutes a potent health threat. Of the pollutants discussed earlier NO_2, VOCs and CO are the most significant indoor health hazards in the UK. Indoor NO2 exposure can amount to 70% of the total exposure with gas cookers being the most important source. It has been suggested that a reduction in NO_2 exposure can be achieved through the use of kitchen extractor hoods, fans and minimisation of the time spent in the kitchen when cooking[16].

Concentration of VOC can also be significantly higher indoors. Their sources include several building materials (e.g. paint, furnishings) as well as domestic products and office supplies. Choice of appropriate materials and good housekeeping can reduce the associated risks on human health.

CO release in the indoor environment can result from wrongly installed or poorly maintained appliances such as room and water heaters, fires and cookers. NHS has provided detailed information regarding the causes and effects of CO release as well as suggested certain tips to avoid CO poisoning within the indoor environment[17].

For all three pollutants good housekeeping and the choice of high quality material can reduce the risks on human health. Additionally, building codes and building material classification systems can provide mechanisms that improve indoor air quality. Sufficient mechanical or natural ventilation is also considered a key element in removing pollutants from indoor air[9].

REFERENCES

	DESCRIPTION	LINKS
1	NAEI - UK Emissions of Air Pollutants 1970 to 2006. Type: report	"http://www.airquality.co.uk/reports/cat07/0810291043_NAEI_2006_Report_Final_Version(3).pdf"
2	"DEFRA - Particulate Matter in the United Kingdom. Type: report"	http://www.defra.gov.uk/environment/airquality/publications/particulate-matter/index.htm
3	"DEFRA - Nitrogen Dioxide in the United Kingdom. Type: report"	"http://www.defra.gov.uk/environment/airquality/publications/nitrogen-dioxide/index.htm"
4	UK Air Quality Archive. Type: various resources within the website	http://www.airquality.co.uk/index.php
5	" NAEI - Emissions of Air Pollutants in the UK. Type website"	http://www.naei.org.uk/
6	"DEFRA - Air quality and climate change: a UK perspective. Type: report"	"http://www.defra.gov.uk/environment/airquality/publications/airqual-climatechange/index.htm"
7	"AEAT - CAFE CBA: Baseline Analysis 2000 to 2020. Type: report"	"http://www.cafe-cba.org/assets/baseline_analysis_2000-2020_05-05.pdf"
8	"Manchester Metropolitan University - Encyclopedia of the Atmoshperic Environment. Type: website"	http://www.ace.mmu.ac.uk/eae/english.html
9	"WHO Europe - Air quality and health. Type: various resources within the website"	http://www.euro.who.int/air
10	"Greater London Authority - 50 years on The struggle for air quality in London since the great smog of December 1952. Type: report"	"http://www.london.gov.uk/mayor/environment/air_quality/docs/50_years_on.pdf"
11	"European Commission - Air quality legislation. Type: website"	http://ec.europa.eu/environment/air/legis.htm
12	"The Scottish Government: Air Quality in Scotland. Type: website"	"http://www.scotland.gov.uk/Topics/Environment/waste-and-pollution/Pollution-1/16215"
13	The Scottish Government: Air Quality in Scotland. Type: website	http://www.scottishairquality.co.uk/index.php
14	"BRE - BREEAM: the Environmental Assessment Method For Buildings Around The World. Type: website"	http://www.breeam.org/
15	Greater London Authority and London Councils - The control of dust and emissions from construction and demolition. Best Practice Guidance. Type:report	"http://www.london.gov.uk/mayor/environment/air_quality/docs/construction-dust-bpg.pdf"
16	Institute foe Environment and Health - Indoor Air Quality in the Home. Type: leaflet	"http://www.cranfield.ac.uk/health/researchareas/environmenthealth/ieh/ieh%20publications/iaq.pdf"
17	NHS - Carbon monoxide Are you at risk? Type: leaflet	"http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_090124"

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GENERAL

TITLE	DESCRIPTION	LINKS
DEFRA	Exhaustive information on air pollution and the UK government's air pollution policy targets	http://www.defra.gov.uk/environment/airquality/
Scottish Government	Information on air quality policies in Scotland	http://www.scotland.gov.uk/Topics/Environment/waste-and-pollution/Pollution-1/16215
Air Quality in Scotland	Comprehensive information on all aspects of air quality in Scotland, including pollution data and LAQMs	http://www.scottishairquality.co.uk/
"National Atmospheric Emissions Inventory (NAEI)"	Estimates of emissions to the atmosphere from UK sources such as cars, trucks, power stations and industrial plant.	http://www.naei.org.uk/
UK Air Quality Archive	Comprehensive information on all aspects of air quality in the UK, including monitoring data and LAQMs	http://www.airquality.co.uk/index.php
"Encyclopedia of the Atmospheric Environment"	Information on a range of atmospheric issues, including air quality, acid rain, global warming and ozone depletion.	http://www.ace.mmu.ac.uk/eae/english.html
European Commission	Information on air quality policies across the EU	http://ec.europa.eu/environment/air/index_en.htm
Wold Health Organisation	General information regarding the health impacts of air pollution	http://www.euro.who.int/air
NHS	Information regarding the health impacts of air pollution within the UK	http://www.dh.gov.uk/en/Publichealth/Healthprotection/AirPollution/index.htm
"Convention on Long-range Transboundary Air Pollution"	Transboundary air pollution	http://www.unece.org/env/lrtap/
US Environmental Protection Agency	Exhaustive information regarding the effects of different air pollutants on health and the environment	http://www.epa.gov/ebtpages/airairpollutants.html
European Environmental Agency	Air pollution information within the EU	http://www.eea.europa.eu/themes/air
Sustainable Build	Pollution from construction	http://www.sustainablebuild.co.uk/PollutionFromConstruction.html
Peter Brimblecombe (Editor), 2003	"The Effects of Air Pollution on the Built Environment"	Book from Imperial College Press
Wold Health Organisation	Information on indoor air pollution	http://www.who.int/indoorair/en/
BRE	Information on indoor air quality	http://www.bre.co.uk/page.jsp?id=720
Office of Public Sector Information	"Building regulations in the United Kingdom. Contains information about indoor and outdoor air quality"	http://www.opsi.gov.uk/si/si2006/20060652.htm