Air Today, Gone Tomorrow – The changing face of air pollution

John A. O’Brien
Air Pollution

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Air Pollution
Colour palette for PowerPoint

Dark blue
R17  G52  B88

Gold
R217  G171  B22

Mid blue
R64  G150  B184

Secondary colour palette

Light grey
R63  G69  B72

Pea green
R121  G163  B42

Forest green
R0  G132  B82

Bottle green
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R233  G69  B140

Red
R200  G30  B69

Orange
R238  G116  29

Dark grey
R63  G69  B72
For first time in 135 years, Britain set to go without coal power for whole day

By Rachel Millard
City Correspondent

BRITAIN yesterday looked set to go a whole day without using electricity made with coal – for the first time since the Victorian era.

Barring an energy emergency late last night, it marked the first full day without coal-fired power since the first coal power station opened in 1882.

The station was instead powered by electricity from gas, nuclear energy, wind, water and biomass.

Campaigners hailed it as a milestone in the UK’s efforts to stop using coal-fired power plants altogether by 2025, in a bid to reduce carbon emissions.

Hannah Martin, from Greenpeace UK, said: ‘The first day without coal in Britain since the Industrial Revolution marks a watershed in the energy transition. A decade ago, a day without coal would have been unimaginable and in ten years’ time, our energy system will have radically transformed again.’

‘It is a clear message to any new government that they should prioritise making the UK a world leader in clean, green technology,’ she added.

The West Burton A coal power station was the last to be switched off the National Grid at 10.59pm on Thursday.

As the Mali went to press yesterday, the National Grid said it had no plans to switch back on, barring a major failure with other plants. Cordi O’Hara, of the National Grid, said: ‘The UK benefits from highly diverse and flexible sources of electricity. Our energy mix continues to change.’

‘It is important to remember coal is still an important source of energy as we transition to a low carbon system.’

The world’s first coal-fired power station kick-started an economic revolution when it opened in Holborn, London, in 1882.

Coal was used to generate about 35 per cent of the UK’s electricity until the early 1950s but since has been partly replaced by gas and renewables. In 2016 it made up about 9 per cent of UK electricity generation and over the last four weeks it has supplied only around 2 per cent.

In the last month around 50 per cent of UK electricity has come from low-carbon sources such as nuclear, solar and wind, while 45 per cent came from gas, and the rest from imports and coal.

Coal use started to be cut completely from April last year.

Dr Simon Evans, of the website Carbon Brief, said: ‘Symbolically it is hugely important. The UK was the first country in the world to have a coal-fired public electricity generation system.

‘Now we are getting to the stage where the UK is one of the major industrialised economies to be going towards stopping using coal.’

Engineer and energy expert Dr Andrew Crossland said: ‘I think it’s a real demonstration that we can keep the lights on without coal, which is really important. It shows that renewables can make such a big contribution.’

But Dr Crossland said attention must also shift to using less gas.

‘If we continue to run the system with this much gas we will miss the carbon targets,’ he said.
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Great Smog of December 1952

- Estimated 12000 deaths
- Prompted the clean air acts of 1956 and 1968
Kids Get ‘Smog Day’ As Pollution Shuts Down Chinese City

Choking pollution measured at 40 times what the WHO says is safe

By Emily Rauhala / Beijing | Oct. 21, 2013

Winter is coming, that’s for sure. The northeastern city of Harbin today ushered in the season with smog so thick that visibility was reportedly limited to 10 meters in places. Classes were canceled, roads closed, and planes grounded.

State media said the PM 2.5 reading (which measures the level of harmful particulate matter in the air) “exceeded” 500. A Reuters report put the figure at 1000, or 40 times higher than what the World Health Organization deems safe. Photographs from the city show air so murky it would be easy to mistake Monday morning for deep, dark night.

A woman wearing a mask walk through a street covered by dense smog in Harbin, northern China, Oct. 21, 2013.
China’s Youngest Lung-Cancer Patient Is Just 8 Years Old, and Pollution Is to Blame

Smog-related cancer deaths in China are soaring. Now children are being affected

By Emily Rauhala / Beijing | Nov. 05, 2013

To the list of China’s environmental horrors, add one: an 8-year-old with lung cancer. Doctors at a hospital in coastal Jiangsu province blamed the girl’s condition on pollution, according to a state media. The child, who has not been identified, reportedly lived near a busy road and was exposed to harmful particles and dust. She is being called China’s youngest-ever lung-cancer patient.

The news comes amid growing concern about the health effects of air pollution. Last month the World Health Organization for the first time classified air pollution as a cause of cancer. The agency said air pollution caused 220,000 cancer deaths in 2010 and that more than half of lung-cancer deaths from
Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015


Summary

Background Exposure to ambient air pollution increases morbidity and mortality, and is a leading contributor to global disease burden. We explored spatial and temporal trends in mortality and burden of disease attributable to ambient air pollution from 1990 to 2015 at global, regional, and country levels.

Methods We estimated global population-weighted mean concentrations of particle mass with aerodynamic diameter less than 2.5 μm (PM$_{2.5}$) and ozone at an approximate 11 km×11 km resolution with satellite-based estimates, chemical transport models, and ground-level measurements. Using integrated exposure–response functions for each cause of death, we estimated the relative risk of mortality from ischaemic heart disease, cerebrovascular disease, chronic obstructive pulmonary disease, lung cancer, and lower respiratory infections from epidemiological studies using non-linear exposure–response functions spanning the global range of exposure.
Disability Adjusted Life Years

**DALY**
Disability Adjusted Life Year is a measure of overall disease burden, expressed as the cumulative number of years lost due to ill-health, disability or early death

\[ \text{DALY} = \text{YLD} + \text{YLL} \]

- **YLD** (Years Lived with Disability)
- **YLL** (Years of Life Lost)

![Diagram showing the concept of DALY](image)
Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015

- Ambient PM$_{2.5}$ was the fifth-ranking mortality risk factor in 2015.
- Caused 4·2 million deaths and 103·1 million disability-adjusted life-years (DALYs) in 2015.
- Deaths attributable to ambient PM$_{2.5}$ increased from 3·5 million in 1990 to 4·2 million in 2015.
- Exposure to ozone caused an additional 254 000 deaths and a loss of 4·1 million DALYs from chronic obstructive pulmonary disease in 2015.
### Global risk factors for death

#### 1990 Rank
1. High systolic blood pressure
2. Smoking
3. Childhood under nutrition
4. Ambient particulate matter pollution
5. Household air pollution from solid fuels
6. High Total cholesterol
7. High fasting plasma glucose
8. Diet high in sodium
9. High body mass index

#### 2015 Rank
1. High systolic blood pressure
2. Smoking
3. High fasting plasma glucose
4. High Total cholesterol
5. Ambient particulate matter pollution
6. Diet high in sodium
7. High body mass index
8. Diet low in whole grains
9. Diet low in fruits
## Global Risk for DALYS

### 1990 Rank
1. Childhood undernutrition
2. Unsafe water source
3. High Systolic blood pressure
4. Household air pollution from solid fuels
5. Smoking
6. Ambient particulate matter pollution
7. Unsafe sanitation
8. Suboptimal breastfeeding
9. No handwashing with soap

### 2015 Rank
1. High Systolic blood pressure
2. Smoking
3. High fasting plasma glucose
4. High body-mass index
5. Childhood undernutrition
6. Ambient particulate matter pollution
7. High total cholesterol
8. Household air pollution from solid fuels
9. Alcohol use
Air Pollution

• We do not see this picture in developed countries
• So why are we worried?
• Current pollution is more insidious and invisible
• But still has significant health effects
Changing pollutants

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Changing pollutants

**1980s–2000s**

**Across this period in time:**

- **Nitrogen dioxide**
- **Particulates**

**Lead in fuel restricted 1998**

- **Nitrogen dioxide**
- **Particulates**

**Vehicle distance travelled 1949–2012**

- **30% Decrease in walking**

**Distance travelled 1995–2003**

- **2000 14% of new cars were diesel**

**2014 50% of new cars were diesel**

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How big is the health problem in the UK?

• Outdoor pollution estimated to be responsible for 40 000 deaths annually in the UK
“Pyramid of Effects”

- Death
- Hospital Admissions
- Doctor visits

- Asthma attacks, medication use, symptoms
- Lung function changes, immune cell responses, heart rate or heart rate variability responses

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Every breath we take
The lifelong impact of air pollution
Report of a working party
February 2016
Risks of air pollution

- Cancer
- Asthma
- COPD
- Stroke
- Diabetes
- Obesity
- Dementia
Risks of air pollution

- Prenatal
- Life long
- Particular risk for young
- Vulnerable during growth and development
- Long term impact
Risks of air pollution

- Worse for vulnerable populations
- Economically disadvantaged
- Areas of higher pollution
- Pre-existing medical conditions or vulnerability
Major pollutants in developed countries

- Sulphur Dioxide (SO₂)
- Nitrogen Oxides (NOx) including Nitrogen dioxide (NO₂)
- Volatile organic compounds (VOCs)
- Particulate matter
- Ammonia (NH₃)
- Ozone (O₃)
Major pollutants in developed countries

• SOx gases are formed when fuel containing sulphur is burned, when gasoline is extracted from oil and when metals are extracted from ore.

• Respiratory and cardiac effects – acute and chronic effects - concentration dependent

• Acid rain effects on vegetation and materials and paints
Major pollutants in developed countries

- Nitrogen Oxides (NOx)
- Main source is high-temperature combustion
- Road traffic is dominant source
- They react with hemoglobin producing inert compounds including methemoglobin hampering the oxygenation of tissues causing tachycardia, high blood pressure, and arrhythmia
Major pollutants in developed countries

• Volatile Organic compounds VOCs)

• Organic chemical compounds that have sufficiently high vapour pressures under normal conditions to vaporise significantly and enter the atmosphere

• A wide range of carbon-based molecules, such as aldehydes, ketones and other light hydrocarbons
Major pollutants in developed countries

• Ammonia \((\text{NH}_3)\)
  • Common by product of animal waste
  • High protein with surplus nitrogen which is excreted - released into the air during manure decomposition
Pollutant definitions

- **Particulate matter (PM)**
- Historically black smoke – Air passed through a filter
- Now replaced by metrics – Aerodynamic

Thus PM$_{10}$ is the amount of particulate matter that is generally less than 10 µm in diameter.

PM$_{2.5}$ is the smaller fraction of PM$_{10}$ and consists of particles <2.5 µm across (often referred to as ‘fine’ particles).

Coarse PM is the difference between PM$_{10}$ and PM$_{2.5}$ referred to as ‘fine’ particles).

Ultra-fine particles are the smallest fractions of PM$_{2.5}$ and are <0.1 µm (100 nm) in diameter.
Particulate Matter

- Composition varies –
  - near to roads - vehicle emissions
  - rural areas – chemical reactions in the air

- Primary particles
  - Directly emitted to the air

- Secondary particles
  - formed by atmospheric processes
Major pollutants in developed countries

• Ozone ($O_3$)
• Not emitted directly
• Formed by reactions between NOx and VOCs in the presence of heat and sunlight

\[ \text{NOx + VOCs + sun radiation} \rightarrow O_3 + \text{Photochemical pollution} \]

Photochemical smog occurs in sunny periods with high temperatures, low moisture and relatively high levels of nitrogen oxides and hydrocarbons.
How do we know about the effects of Pollution?

• Acute events e.g Smog of 1952
• Mortality trends and regional pollution
• Biological evidence of disease mechanisms
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AN ASSOCIATION BETWEEN AIR POLLUTION AND MORTALITY IN SIX U.S. CITIES

Douglas W. Dockery, Sc.D., C. Arden Pope III, Ph.D., Xiping Xu, M.D., Ph.D.,
John D. Spengler, Ph.D., James H. Ware, Ph.D., Martha E. Fay, M.P.H.,
Benjamin G. Ferris, Jr., M.D., and Frank E. Speizer, M.D.
Annual Average Concentrations of Total Particles, Fine Particles, and Sulfate Particles in the Six Cities.
Crude Probability of Survival in the Six Cities, According to Years of Follow-up.

Crude Probability of Survival in the Six Cities, According to Years of Follow-up.

- Controlled for smoking rates, education level, diabetes and work place pollution
- Worst affected city had a death rate around 30% higher than the least polluted city
• Reductions in air pollution accounted for
• as much as 15% of the overall increase in life expectancy in the study areas.
• A decrease of 10 μg per cubic meter in the concentration of fine particulate matter was associated with an estimated increase in mean life expectancy of 0.61 year (P=0.004)
Contributors to air pollution

• Increased use of motor vehicles
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Vehicle contributions to pollution

• Fuel combustion

• New petrol car emits 1/20 level of Nitrogen oxides compared to 20 years ago. Lead free fuels. Regulated sulphur.

• Increasing use of diesel for small vehicles and less efficient emission control. Ultra low sulphur diesel

• Reduction in marine fuel sulphur

• Tyres, brakes and the road
Indoor air pollution

- Outdoor air
- Biological pollutants – humans, pets, insects, HDM
- Ground house is built on – radon
- Second-hand smoke
- Cookers, boilers, fires
- Construction materials – glues, fabrics, cleaning and DIY
Fig 3. Sources and types of indoor pollution encountered in homes. VOCs = volatile organic compounds. Please note that these lists are not exhaustive and that the actual pollutants present, and their amounts, will vary from household to household.
Air Pollution and climate change

• Linked
• Pollution contributes to climate change
• Climate change has significant health risks
Annual Changes in Mean Surface-Air Temperature, 1880–2016.
Air Pollution and climate change

- Average temperatures are predicted to rise by 1.7 to 5.6°C within the lifetimes of children now being born.
- Summer heat waves increase mortality. Higher temperatures also increase ozone levels, compromising lung function and exacerbating asthma.
- Earlier and longer pollen seasons elevate exposure to allergens, increasing allergic sensitization and asthma episodes.
Air Pollution and climate change

• Warmer water temperatures - facilitate the growth of pathogenic waterborne organisms

• The distribution of vector borne diseases such as Lyme disease, West Nile virus, Rocky Mountain spotted fever, plague, and tularemia expands as the range of their vectors changes

• The mosquito vectors of pathogens such as dengue, chikungunya, and Zika, may find more favorable conditions.

• Food production — crops, livestock, and fisheries — is projected to decline in some regions of the world
Air Pollution and climate change

• Extreme heat leads to more aggression and violence
• Extreme weather events can cause stress and anxiety, exacerbating depression and other mental illnesses.
The effects and interactions between the different domains constituting the exposome (specific and general external environments and internal environment [2]) and health risk.

Tools for the assessment of the exposome.

**Questionnaires**
- Residential, occupational, smoking history, etc.

**Mobile devices**
- Smartphone
- Accelerometer
- Environmental sensor, etc.

**High-throughput ‘omics technologies**
- Epigenomics
- Transcriptomics
- Proteomics
- Metabolomics, etc.

**GIS-based environmental model**
- Air pollution
- Green space
- Noise, etc.

**Pictures**
- Cosmetic use
- Food
- Cleaning products, etc.

**Biomarkers in different tissues**
- Urine
- Blood
- Exhaled breath condensate, etc.

Schematic diagram of some of the ‘omics layers and pathways of influence of the exposome on health.

Conclusions

• Air pollution has significant impact on mortality and morbidity

• International co-operation is required - distant impacts of pollution

• Individual choices are also important

• Understanding of mechanisms of effects is progressing
Thank you for your Attention