Black carbon and short-lived climate pollutants

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Climate impact of BC compared with other GHGs
What is Black Carbon?

BC can be defined as the carbonaceous component of PM that absorbs all wavelengths of solar radiation. It is commonly referred to as “soot”. Per unit of mass in the atmosphere, BC can absorb a million times more energy than carbon dioxide (CO2).
## Radiative effects of different particles

<table>
<thead>
<tr>
<th>Particle</th>
<th>Type</th>
<th>Radiative properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Particle" /></td>
<td>Black carbon (^a)</td>
<td>Absorbing (all solar wavelengths)</td>
</tr>
<tr>
<td><img src="image" alt="Particle" /></td>
<td>Brown (or yellow) carbon (^b)</td>
<td>Absorbing (UV and some visible)</td>
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<td><img src="image" alt="Particle" /></td>
<td>Non-absorbing carbon (^b)</td>
<td>Scattering</td>
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<td><img src="image" alt="Particle" /></td>
<td>Nitrate (^c)</td>
<td>Scattering</td>
</tr>
<tr>
<td><img src="image" alt="Particle" /></td>
<td>Sulfate (^c)</td>
<td>Scattering</td>
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</tbody>
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Ozone: Monthly mean baseline ozone at Mace Head, Ireland
HFCs
Ranges of GWP Estimates for BC (CO$_2$ = 1)
Global temperature response to LLGHG and SLCF reductions

a) long term response to a reduction of emissions of a long-lived climate forcer

b) near term response to a reduction of emissions of a short-lived climate forcer

- inherent response time of the climate system
- atmospheric life time
- temperature response time
- concentration
- global mean temperature
- emission
- time
Figure B. BC Emissions, 2000, Gg (T. Bond)
PM2.5 composition in world regions

Central Europe, regional background (PM2.5 = 11 µg/m³)

- EC: 8%
- dust: 4%
- sea salt: 1%
- OM: 24%
- SO4: 23%
- NH4: 11%
- NO3: 10%
- unacc.: 19%

Central Europe, urban background (PM2.5 = 20 µg/m³)

- EC: 13%
- dust: 4%
- sea salt: 1%
- OM: 24%
- SO4: 18%
- NH4: 10%
- NO3: 12%
- unacc.: 18%

Eastern USA, regional background (PM2.5 = 10 µg/m³)

- EC: 3%
- dust: 20%
- OM: 19%
- SO4: 31%
- NH4: 13%
- NO3: 5%
- unacc.: 8%

Eastern USA, urban background (PM2.5 = 14 µg/m³)

- EC: 8%
- dust: 20%
- OM: 21%
- SO4: 23%
- NH4: 11%
- NO3: 8%
- unacc.: 7%

Northern India, regional background (PM2.5 = 87 µg/m³)

- EC: 9%
- dust: 5%
- sea salt: 5%
- OM: 48%
- SO4: 16%
- NO3: 7%
- NH4: 7%
- unacc.: 3%

Eastern India, urban background (PM2.5 = 122 µg/m³)

- EC: 10%
- dust: 3%
- sea salt: 10%
- OM: 55%
- SO4: 13%
- NO3: 7%
- NH4: 2%
- unacc.: 7%

Black carbon
Diesel PM2.5 Chemical Composition

- Elemental Carbon: 75% (33-90%)
- Organic Carbon: 19% (7-49%)
- Sulfate, Nitrate: 1% (1-4%)
- Metals & Elements: 2% (1-5%)
- Other: 3% (1-10%)

Radiative forcing from BC and OC - both are *regional*
Effect of BC on albedo of Asian glaciers (Ming et al 2009)
Integrated Assessment of Black Carbon and Tropospheric Ozone
Summary for Decision Makers
Assessment Objectives

• To review the scientific literature on black carbon (BC), tropospheric ozone and its precursors and assess the state of knowledge of their influence on climate and impacts as air pollutants.

• To assess the extent by which carefully identified measures using existing technology to address BC and ozone can help protect near-term global and regional climate change.

• Determine the co-benefits of the selected measures on health and crops.

• Identify how the selected measures can be widely implemented with reference to case studies.
Emission Control Measures in the Analysis

IIASA ranked mitigation measures by the net GWP of their emission changes (considering CO, CH$_4$, BC, OC, SO$_2$, NO$_x$, nmVOCs, and CO$_2$), picked the top measures

‘Methane measures’

- extraction and long-distance transport of fossil fuels (~25%)
- waste management; municipal, landfills & wastewater (~10%)
- agriculture; livestock manure & intermittent rice aeration (~5%)

(% reduction in 2030 relative to reference)
Black Carbon Measures

‘BC Measures’ that reduce emissions of black carbon and co-emissions (e.g. OC, CO)

- Diesel vehicles (particle filters+)
- Coal briquettes replacing coal in residential stoves
- Pellet stoves & boilers replacing residential wood burning in industrialized countries
- Clean-burning cookstoves in developing countries
- Modern brick kilns
- Modern coke ovens
- Ban of open burning of agricultural waste
Effect of DPFs on BC emissions

Some of the largest emission reductions are obtained using diesel particle filters on high emitting vehicles. The exhibits above are actual particulate matter (PM) collection samples from an engine testing laboratory (International Council of Clean Transportation (ICCT)).
Uncertainty ranges on effects of BC measures

Integrated radiative forcing (W/m²/yr) vs. # of cases (out of 1000)

- Power generation
- Brick kilns
- Coke ovens
- Pellet stoves
- Advanced cook stoves
- Filters for coal stoves
- Particle filters for diesel vehicles
- Particle filters for non-road machinery
- Ban of burning of agricultural residuals
• Modelling using ECHAM5-HAMMOZ and GISS-PUCCINI climate impacts and concentrations
• Climate simulations with GISS-E2-S model + mixed-layer ocean
• FASST tool (JRC)
• Health impacts from long-term exposures to PM$_{2.5}$ and ozone
• Crop impacts from ozone
SLCF and CO$_2$ measures are complementary not mutually exclusive
Regional temperature impacts of SLCF measures

The diagrams illustrate the temperature change (in °C) over a period from 2010 to 2070 in different scenarios:
- **CH₄ measures**
- **CH₄ + BC Group 1 measures**
- **CH₄ + all BC measures**
- **GHG measures**

Each scenario is color-coded and represents different regions:
- Global
- SH extratropics
- Tropics
- NH mid-latitudes
- Arctic

The graphs show a decrease in temperature change over time, with varying impacts depending on the scenario and region.
As well as climate benefits there are also major benefits for health and food security.
Main policy messages of the UNEP/WMO Assessment

• There are important public health and food security benefits from tackling SLCFs as well as for climate
• SLCF abatement is complementary to measures on GHGs—both are needed
• Swift action is beneficial
• Abatement of SLCFs is feasible with existing technologies and policies
• ...BUT international governance is lacking
How would these scientific findings be translated into policies and action?
Climate and Clean Air Coalition launched in 2012 by US State Department

Five areas for first phase of action:

• Heavy Duty Diesel Vehicles and Engines
• Brick Production
• Waste
• HFC alternatives
• Oil and Natural Gas production

• Members: Bangladesh, Canada, Columbia, Ghana, Japan, Mexico, Norway, Sweden, USA, European Commission, UK, France, Germany, Italy, Russia
Brick Kiln Modernization
Ciudad Juarez, Mexico

- Conventional brick kilns (left) burn waste wood, oil and tires in open-topped kilns
- New kilns (right) use same fuels but filters exhaust into underground channels, reducing emissions by 80% and using 50% less wood.
Cookstoves used around the world

Turbococina, El Salvador

LPG Cookstoves – Senegal

Oorja smokeless biomass stove, India

HELPs “ONIL” stove - Guatemala

Solar cooker

Patsari stove in Mexico
CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION
51 Parties in Europe, North America and Central Asia
Revised Gothenburg Protocol May 2012

- Sets national emissions targets for 2020 for PM$_{2.5}$
- Parties should:
  - "in implementing measures to achieve their national targets for particulate matter, *give priority, to the extent they consider appropriate, to emission reduction measures which also significantly reduce black carbon* in order to provide benefits for human health and the environment and to help mitigation of near-term climate change."
- “Each Party should, to the extent it considers appropriate, also *develop and maintain inventories and projections for emissions of black carbon*, using guidelines adopted by the Executive Body.”
Revised Gothenburg Protocol

• The Parties shall encourage research, development, monitoring and cooperation related to:
  - The improvement of the *scientific understanding of the potential co-benefits for climate change mitigation associated with potential reduction scenarios for air pollutants (such as methane, carbon monoxide and black carbon) which have near-term radiative forcing and other climate effects*;
  - The quantification and, where possible, economic evaluation of benefits for the environment, human health and the impacts on climate resulting from the reduction of emissions of sulphur, nitrogen oxides, ammonia, volatile organic compounds and particulate matter;
UK Options for Black Carbon reductions?

• Emission inventories are not well known
• Particularly the mix of BC(EC) and Organic Carbon in each source sector
• Policies on PM will reduce BC from most sources – transport (DPFs)
• Scope for speeding this up
  - Retrofit incentives
  - Low Emission Zones for HGVs
  - Non-road Mobile Machinery (incl. Trains, ships/IMO)
• BC from North Sea flaring? Arctic?