

Black Carbon Particles Needs Attention in Climate Change Mitigation Policies

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Abstract

Climate change poses enormous challenges to human civilization in food security, water security, and health security. Anthropogenic emissions of Greenhouse Gases (GHGs) are made responsible for climate change. The climate change mitigation agreements and treaties, from the Kyoto Protocol (1997) to the Paris Agreement (2015), are mainly focusing on emission reduction of GHGs. The Copenhagen Accord (2009) set the target of emission reduction of GHGs to the level of 1990, intending to keep the global warming below 2-degree centigrade (°C) above the temperature level of the pre-industrial era. The Paris Agreement (2015) further pursued efforts to limit the temperature increase to 1.5°C by reducing emissions of GHGs to 40 Gigatonne (Gt CO₂-eq) by 2030. However, assuming the countries will achieve the target of emission reduction of GHGs by 2030, the target of keeping global warming below 1.5°C is unlikely to achieve because the Paris Agreement (2015) has not included emission reduction of black carbon (BC) particles in the intergovernmental negotiation. The BC particles are strong climate warming agents whose climate forcing is more than half of that of carbon dioxide (CO₂) – the main GHG. This article argues for the inclusion of BC mitigation measures in the climate change mitigation measures. As BC also causes severe health impacts, BC mitigation will bring multiple co-benefits for health and environment, including a quick fixing of climate change problems in a few weeks, since the residence time of BC in the atmosphere is about a week.

1. Introduction

Changing climate of the Earth system is significantly affecting the global temperature, ecosystem, agriculture production, water cycle, and water resources, including the melting of glaciers, which are creating enormous challenges to human civilization in water security, food security, and health security (Kang et al., 2009, Turrall et al., 2011). Precisely, the global average temperature has increased by 0.85 [0.65–1.06] degree centigrade (°C) in between 1880 to 2012; global average sea level raised by 0.19 [0.17–0.21] meter (m) between 1901 to 2010; and glaciers and ice sheets including Alaska, Arctic, Greenland, and Himalaya melted by 226 [91–361] Gt per year in between 1971 to 2009 (\approx 0.62 mm sea level rise per year) (IPCC, 2013). The rate of global temperature rise, sea-level rise, and melting of glaciers and ice sheets were large during the last few decades and the projections made by the Intergovernmental Panel on Climate Change (IPCC) considering various scenarios of the representative concentration pathways, the changes in the climate system will be continued in this century (Hansen et al., 2010; Rignot et al., 2011, Watson et al. 2015, IPCC 2013).

Anthropogenic emissions of the heat-trapping gases, such as (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆), which are collectively termed as the Greenhouse Gases (GHGs), are made responsible for climate change. The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC, 1997) called for the commitment from the Parties (countries who signed the Kyoto Protocol) to limit the emissions of GHGs to avoid further changes in the climate system. The Copenhagen Accord (2009) requested the countries to reduce the emissions of GHGs to the level of 1990 to keep global warming below 2°C, above the temperature level of the pre-industrial era. Evaluation of the Copenhagen Accord's progress was made during COP21 (21st Session of the Conference of Parties) in Paris in 2015. The COP21 came up with an agreement, named the “Paris

Agreement (2015)” to hold the increase in global average temperature to below 2°C and pursue the efforts to limit the temperature increase to 1.5°C by reducing the emissions of GHGs to 40 Gt by 2030. The Agreement entered into force in November 2016.

Assuming the countries will achieve the target of emission reduction of GHGs of 40 Gt by 2030. Yet, the target of holding the increase in global average temperature to below 2°C or even limiting the temperature rise to 1.5°C may not be achieved because the Paris Agreement (2015) has not included the emission reduction of black carbon (BC) particles.

This article presents a policy-based assessment of BC mitigation and argues that special attention is needed for inclusion of the BC mitigation measures in the climate change mitigation measures or policies, because without that the target of holding the increase in global average temperature to below 2°C may not be possible. This article also highlighted that mitigation of BC will bring multiple co-benefits for health and the environment, including a quick fixing of climate change problems in a few weeks since the residence time of BC is about a week in the atmosphere.

2. Bc Particles And Their Climate Impacts

BC particles, morphologically resemble with graphite-like structure with an aerodynamic size resolution of 100–400 nanometer (nm), are strongly absorb incoming solar radiation in the atmosphere in the visible range (400–700 nm) and act as a strong climate warming agent (Clarke et al., 2004; Jacobson, 2001). BC particles are produced during incomplete combustion of fossil fuels, biofuels, agriculture residue, and open biomass burning. They are the main constituents of particulate matters (e.g., PM_{2.5}), constituting 10–15 percent in PM_{2.5} composition in most urban regions, sometimes even 30–35 percent in highly polluted regions. (Snider et al., 2016; Begum et al., 2012; Marrapu et al., 2014).

Radiative forcing (RF, also referred to as climate forcing), global warming potential (GWP), Global Temperature-change Potential (GTP) are the key parameters to check a potentiality of a chemical species to influence the climate (cooling or warming effects). RF is the measurement of the capacity of a gas or particle to affect the Earth’s energy balance. If the RF of a forcing agent is positive, it absorbs solar radiation in the atmosphere, results in warming effects. Else, if the RF is negative, it scatters or reflects solar radiation, causes cooling effects. While GWP is a relative measure of the amount of heat traps by a certain mass of gas or particle to the amount of heat trapped by a similar mass of CO₂. Recently, GTP has been in use in parallel with GWP to estimate the global warming matrix in different time horizons (Shine et al., 2005; Sarofim, 2012; Wang et al., 2013).

Figure 1 (a – e) shows a comparison of RF, GWP, and GTP of BC with those of major GHGs. In Fig. 1, *BC_direct* is a total direct climate forcing by all BC sources without subtracting pre-industrial background, whereas *BC_total* is an industrial-era climate forcing of BC through all forcing mechanisms, including clouds and cryosphere forcing (Bond et al., 2013). Comparison of GWP and GTP of BC (*BC_direct* and *BC_total*) with those of major GHGs has been shown in 20 years and 100 years of time horizons. The RF of *BC_direct* and *BC_total* are +0.88 (0.17–1.48) W m⁻² and 1.1 (0.17–2.1) W m⁻², respectively. These values are 0.52 and

0.65 times of + 1.68 (1.50–1.86) $W m^{-2}$ RF of CO_2 (Fig. 1a). Thus, the RF of BC is more than half of that of CO_2 – the main GHG, making the BC the second most climate-warming agent after the CO_2 . In the case of GWP, the GWP of *BC_direct* and *BC_total* are 2100 and 3200 times higher than that of CO_2 , respectively, in 20 years of time horizon (Fig. 1b) and 590 and 910 times higher than that of CO_2 , respectively, in 100 years of time horizon (Fig. 1c). Whereas, in the case of GTP, the GTP of *BC_direct* and *BC_total* are 600 and 925 times higher than that of CO_2 , respectively, in 20 years of time horizon (Fig. 1d) and 80 and 130 times higher than that of CO_2 , respectively, in 100 years of time horizon (Fig. 1e). The comparison of RF, GWP, and GTP of *BC_direct* and *BC_total* with other GHGs (e.g., CH_4 , halocarbons, and N_2O) has been shown in Fig. 1(a – e).

The climate impacts of the BC are not as straightforward as those of GHGs. The GHGs create a heat-trapping blanket in the atmosphere, which resulted accumulation of heat and causes an increase in temperature on the Earth's surface. On the contrary, the impacts of BC particles are manifolds. BC absorbs incoming solar radiation in the atmosphere as a direct effect and causes indirect effects, such as affecting cloud properties, which affects patterns and level of precipitation or rain (Koch et al., 2010; Hansen et al., 1997). BC heat the air and decreases relative humidity in their immediate proximity, resulting in a positive RF known as the semidirect effect. This lowers cloud cover at the altitude of the aerosols while rising cloud covers below by inhibiting convection. This effect induces a decrease in cloud cover at sufficiently low altitudes without a compensating rise at much lower levels. As a result, BC has a strong warming effect at the surface but a minor warming effect higher up. The elevation of the efficiency of BC forcing is mainly due to this effect.

Over the past decades, the Asian monsoon is weakening, and these changes in the Asian monsoon have been attributed to higher BC emissions in the Asian region (Ramanathan et al., 2005; Ramanathan and Carmichael, 2008; Meehl et al., 2008; Menon et al., 2002). The deposition of BC on the Himalayas and the Arctic is resulting in the rapid melting of the glaciers (Xu et al., 2009); Nair et al., 2013; Ming et al., 2008). The impacts of BC particles on climate are mostly confined to the region of the emissions. The heating of the atmosphere and dimming at Earth's surface was found to coincide with the distribution patterns of emissions of BC particles (Ramanathan and Carmichael, 2008).

The estimate of global BC emission from all sources is 7.53 (2.020–28.800) $Tg yr^{-1}$ with contribution from diesel engines (20%), coal combustion in industries (9%), solid fuels used in residential activities (25%), open biomass burning (40%), and other sources (10%). The residence time (RT) of BC particles in the atmosphere is about a week (3–10 days) (Bond et al., 2013). Whereas the RT of GHGs, for example, CO_2 , is a decade to a century, 114 years for N_2O , and 10–12 years for CH_4 . Also, BC particles with co-emitted other air pollutants cause severe health impacts and globally cause over 7 million premature deaths annually (WHO, 2014). Thus, emission reduction of BC particles could provide an opportunity for quick fixing of the climate change in the near term and with multiple co-benefits in terms of health, environment, and climate.

3. Conclusion

Studies suggested that without incorporating BC emission reduction measures in the climate change mitigation policies, the target of 2 °C is unlike to be achieved. However, implementing the identified total

mitigation measures for BC and CH₄ could avoid global temperature rise by 0.5 °C (Ramanathan and Xu, 2010; Shindell et al., 2012; Steven and Andrew, 2013). An opportunity was lost in December 2015 when the COP21 made the Paris Agreement. BC particles emission reduction could have been included in the Agreement. Since BC's climate warming effects are quite large, a legally binding agreement is needed among the countries for BC emission reduction. BC emissions reduction will provide multiple co-benefits in terms of health and the environment, including a quick fixing of climate change problems in a few weeks since the RT of BC is about a week in the atmosphere. The uncertainty in emission inventories is complicated by physical uncertainties, especially in indirect impacts, resulting in a broad range of estimates of black carbon's exposure to Earth's radiative budget. Improved global emission inventories, standardized reporting of the simulation model, and more research into aerosol and cloud microphysics and aerosol transport to and deposition on snow and ice-covered regions, both would help to reduce critical uncertainties. The mitigation community needs to engage with countries on this issue and jointly think of other enabling conditions to put in place to support the resiliency of BC emission and climate change mitigation policy.

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Figures

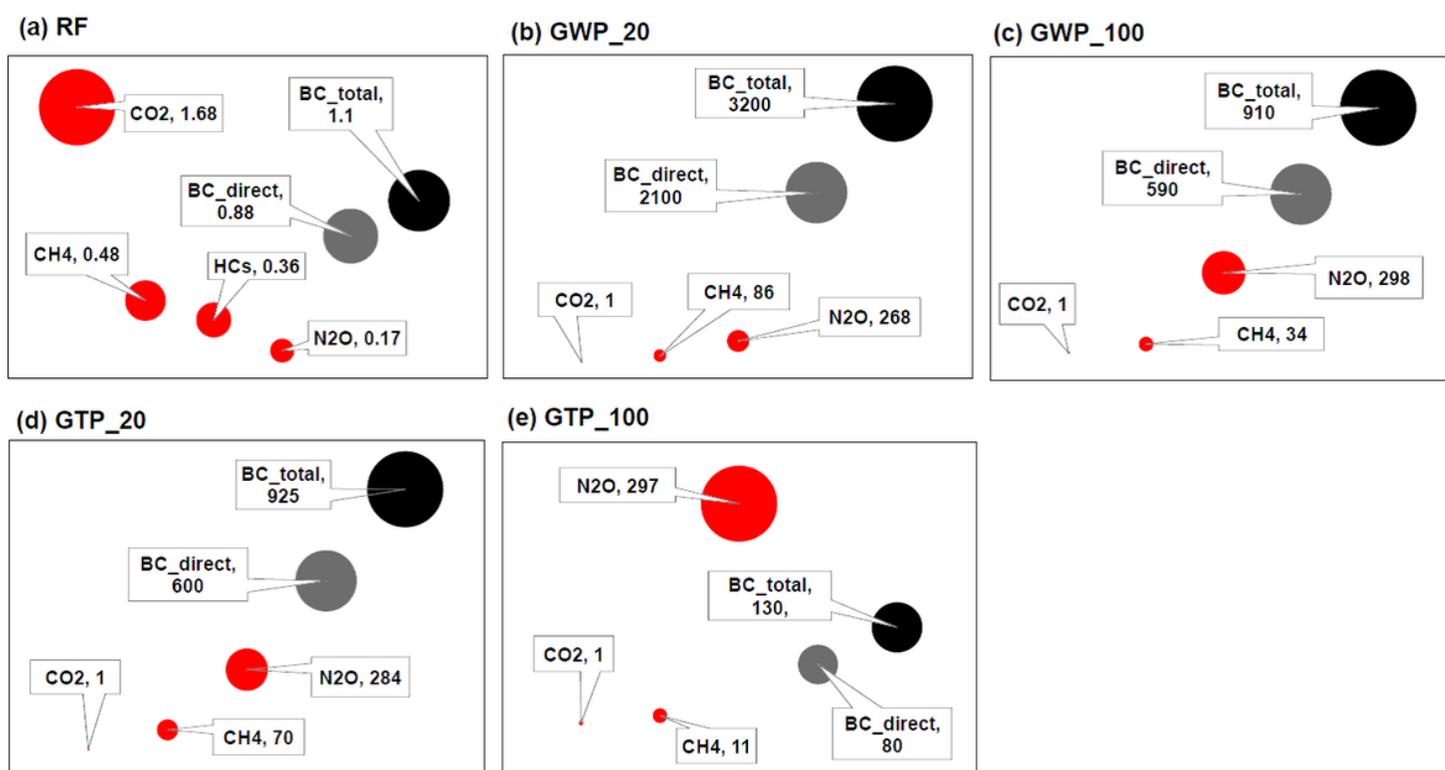


Figure 1

Comparison of the key climate influencing parameters of the BC particles with those of the major GHGs, (a) RF (expressed in $W m^{-2}$), (b) GWP in 20 years of time horizon, (c) GWP in 100 years of time horizon, (d) GTP in 20 years of time horizon, and (e) GTP in 100 years of time horizon. The values of RF, GWP, and GTP of the BC were adopted from Bond et al. (2013), while the values of RF, GWP, and GTP of the GHGs were adopted from the IPCC (2013). The sizes of the circles are relative to the size of the CO₂.

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