

Minireview Article

Black Carbon - A silent contributor to climate change

Abstract

Black carbon is a potent climate-warming component of particulate matter formed by the incomplete combustion of fossil-fuels, wood and other fuels. Complete combustion would turn all the carbon in the fuel into carbon dioxide, but combustion is never complete, and CO₂, CO, volatile organic compounds, organic compounds, and black carbon particles are formed in the process. It contributes to warming by converting incoming solar radiation to heat. When deposited on ice and snow, BC and co-emitted particles reduce surface albedo thereby melting the glaciers. The complex mixture of particulate matter resulting from incomplete combustion is referred as soot. When suspended in the atmosphere, black carbon contributes to warming by converting incoming solar radiations to heat. It also influences cloud formation and impacts regional circulation and rainfall pattern. The Arctic and the glaciated regions such as Himalayas are particularly vulnerable to melting as a result. The present paper aims to review the work done on black carbon and its mitigation measure.

Keywords: Combustion; Global Warming; Particulate matter; Rainfall pattern; Glaciated regions

Introduction

Black carbon (BC) is a solar radiation absorbing particulate matter which absorbs high number of solar radiations and studies suggests that it has the capacity of absorbing approximately 1 million times more solar radiations than carbon dioxide [1]. It is said to be a product of incomplete combustion of fossil fuels, agricultural crop residues, power generation and other industrial activities [2]. Black carbon is a short-lived particulate matter with a life span ranging from few days to weeks [3]. According to Shrestha et al., although being the significant air pollutant BC had received little less attention when air pollutants are talked about [4].

BC is considered nearly pure elemental carbon with some oxygen and hydrogen bound layered and hexagonal structure [5]. It has small particle size i.e. less than 2µm. The smaller particle size favours them to remain airborne and promotes transport to long distances [6] [7]. According to United States Environment Protection Agency (2011), BC has been referred as global environmental issue which not only adversely affects the climate but also have devastating effects on human health [8]

BC has been considered as an environmental problem globally. It has adverse effects on climate as well as human health. Respiratory diseases, cardiovascular diseases, cancer and even the birth defects are some of the health disorders which adversely affects the human

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health. It has the ability to absorb the heat, therefore it contributes to global warming and climate change also.

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The unnatural absorption rate of heat due to BC has its impact on polar ice. BC when deposits on snow and ice, it decreases the ability of the earth to reflect back the sunrays to the atmosphere thereby increasing the melting rate of snow and ice. [9]

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Properties of black carbon

Origin of BC and short life span: It is released as a particle in the atmosphere and not as a gas, hence it does not fall in the category of greenhouse gases. It is made up of very fine particles and remains in the atmosphere from few days to a few weeks [10]. BC is basically a product which owes its formation from incomplete combustion of fossil fuel or biomass, pyrolysis, domestic cooking, wildfires, etc. [11][12]. Due to the decreased particle size, BC have ability to remain in the atmosphere and transport to long distances [13]. In case of fires, BC particles larger than 1µm are unable to be airborne and fall on the nearby surface and reach the soil and aquatic body through precipitation and runoffs. [14]

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Radiative property: BC aerosol is said to be light absorbing. It is known to be the second most anthropogenic pollutant after CO₂ which contributes to global warming [15]. BC absorbs most of the solar radiation and warms the atmosphere and thereby reducing the radiations reaching the earth's surface. This property influences the global and regional climate and weather both. [16][17]

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Temperature: Black carbon has the distinctive physical and optical properties. It absorbs the light, traps the heat in the atmosphere and contributes to global warming. Emissions of black carbon are estimated to be present about 4800–7200 Gg yr⁻¹ on the global scale (Klimont et al., 2017; Kang et al., 2020).[18][19]

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Albedo is a reflective property of a surface. The amount of light when hits the surface, gets absorbed by the surface while some amount of light gets reflected back to the space. More radiation absorbed by the surface makes the temperature of the earth's surface to rise, while higher amount of reflection lowers the temperature of the earth's surface.

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The most worrisome is the deposition of black carbon on snow. The snow is considered to be among the whitest natural surface which reflects the sunlight to the great extent but its contamination due to the deposition of black carbon had decreased the amount of light reflecting back to the space (Lack et al., 2014; Nicholas et al., 2020) [20][21]

Black Carbon- Threat to Himalayan Ecosystem

The negative impact of black carbon includes the darkening of the entities of cryosphere by depositing on it. The darkening of snow/ice increases the absorption of the sun's radiations thereby melting the snow/ice more rapidly. The life span of particles of black carbon varies from few days to few weeks but as it settles down on snow/ice then it becomes more reflective and increases the melting of the cryosphere entities (Kang et al., 2020) [22].

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Deposits of black carbon and the particulate pollution has been observed in the studies of

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Himalayan region (Santra et al., 2019) [23].

The Glaciers in the Himalayas are the invaluable source of freshwater. The lives of the people in the Himalayan countries are dependent on the glaciers-fed rivers which are in turn affected by the changes in rainfall during monsoon, river discharges and the regional climate (Dahal et al., 2019) [24]. Therefore, the studies of black carbon in context of Himalayan region, its chemistry, rate of deposition, washout rate and its effect on Albedo reduction become important.

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Impact of black carbon on Hindu Kush Range: The Hindu-Kush Himalayan Region is experiencing temperature rise, change in rainfall's time, location and amount, change in snowfall, reduced snow cover and retreating glaciers. A study by ICIMOD in the year 2016 suggests that globally climate change is not only escalated by greenhouse gases, but aerosols also play significant role. HKH region which absorbs the aerosols contains significant amount of black carbon and also play a role of key indicator in changing the climate of the region. Deposition of black carbon reduces the albedo effect i.e. the ability of the surface to reflect the sunlight. Thus, this albedo effect may also hold responsible for the melting of the snow in the Himalayan region. [25]

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Impact of black carbon on vegetation and ecosystem: Studies suggests that black carbon has the ill-effects on ecosystem. It can deposit on the leaves of the plants and thereby can increase the temperature. Change in rainfall pattern effects the plant and its nature of growth, blooming, flowering and fruiting. Experimental studies infers the physical changes like stomatal plugging, leaf shading and increased temperature of the leaves due to the deposition of black carbon. (Yamaguchi and Izuta, 2017) [26]

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Change in pattern of rainfall may affects the ecosystems and human life both. Changing erratic monsoon patterns due to climate change/global warming can become critical or limiting factor for the agriculture in the Himalayan region.

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Conclusion

The short life span of black carbon means that if its emissions are reduced then its adverse effects on global warming, climate change and air pollution will also disappear in short time and its concentration will be reduced. Lowered black carbon emissions will prevent global warming and its negative effect on snow. The cleaner fuels must necessarily be promoted around the world. Lower emissions vehicles can become replacement for the old and higher emissions vehicles. Electric vehicles can become answer for the problem of soot producing vehicles and thereby decreasing the emissions of black carbon. Reduction in the emissions of black carbon will have benefit to the human health also. Inhalation of particles of black carbon causes asthma and other respiratory disorders. Serious efforts are required to mitigate effects of BC.

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Many mitigations measures exist for controlling the incomplete combustion at it source. If followed properly the emissions of black carbon can be reduced. Some of the measures are as follows

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- Fuel choices
- Regular flue-gas cleaning
- Exhaust filtration
- Use of clean technologies in vehicle manufacturing
- Use of electric vehicles

Mainly, the developing countries needs to implement the cleaner and greener technologies. As the particles of black carbon are short-lived in nature, their immediate mitigation may give solution at the source of the problems associated with it. Their mitigation measure at source will produce better air quality and the health benefits. This will also curb the cost of air pollution which is being spent all over the world.

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