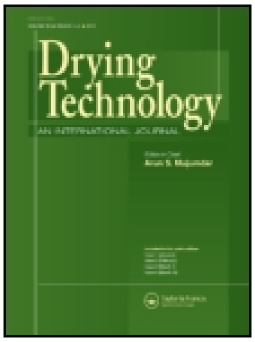

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Rubén D. Piacentini & María Isabel Micheletti

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GUEST EDITORIAL

Connections between black carbon (soot) emission and global warming

KEYWORDS Aerosol; black carbon; climate change; global warming; particulate matter; soot

In previous Guest Editorials[1–4] and articles,[5,6] different analyses were made that related global warming and industrial processes, with particular attention to drying. New results indicate that not only are greenhouse gases (GHG), like carbon dioxide (CO_2), methane (CH_4), halocarbons (CFC), and nitrous oxide (N_2O), among others, directly or indirectly related to the increase in the mean earth ambient temperature, mainly in the last decades, but also some kinds of microscopic particulate matter suspended in the atmosphere, commonly called *aerosols*,[7,8] contribute as well. The last report published in 2013 by the Intergovernmental Panel on Climate Change (IPCC)[9] presented results that demonstrate that the contribution to global warming of black carbon aerosols (BC or soot) is even larger than N_2O, mainly produced by soil fertilization.

Analysis of the relative increase in temperature due to different atmospheric components in gas or solid state can be done by comparing their *radiative forcing* from the beginning of the Industrial Era (about the 1750s) and the present time. Radiative forcing is defined as the net difference between the incident radiation coming from the sun and the reflected and emitted radiations from the soil, clouds, and the atmosphere at the level of the tropopause (the boundary between the troposphere and stratosphere, around 15 km high in the tropical regions to 10 km high in the polar regions). This quantity is measured in irradiance units (W/m^2), and it is quite small compared with the extraterrestrial solar irradiance (outside the atmosphere) of 1361 W/m^2.[10] However since its net value is positive ($+2.44\ W/m^2$), it produces a warming of the atmosphere, which the last IPCC report[9] estimates to be 0.78°C from the mean of the 1850–1900 period to the 2003–2012 period. The total *positive* contribution of gases and aerosols is $+4.05\ W/m^2$ and the BC is $+0.64\ W/m^2$, the third one after CO_2 and CH_4 gases. It must be pointed out that other gases and aerosols contribute negatively to climate change, giving rise to the temperature increase described above.

One possible analysis of the impact of the drying (or any industrial) process on the environment is the use of the *exergy* concept—the available energy that produces useful work, being a measure of waste energy and atmospheric contamination. A detailed study is given in the recent book by Dincer and Zamfirescu,[11] especially in their Chapter 9, Sustainability and Environmental Impact Assessment of the Drying Systems.

An example of a very major reduction of contamination in the pulp and paper drying in Sweden is the decrease of emitted Kg of CO_2/ton of material (pulp and paper) from 120 in 2003 to around 45 in 2013.[12]

Black carbon is a term derived from the property of soot particles to absorb light. Most of the light absorption that takes place in urban atmospheres is due to these particles. BC is a universal term for many particles that originate in combustion processes: combustion engines (mainly diesel), residential burning of wood and coal, power stations using heavy oil or coal, and biomass burning originated in intentional or natural fires.[13] Black carbon aerosols have an impact in many ways: visibility of the atmosphere (aviation, radiative transfer of UV and visible light of importance for astronomical/astrophysical/solar applications); plant growth and photosynthesis; climate change; weather; health and ecosystems; degradation of monuments/buildings/art pieces; glaciers melting. As the Environmental Protection Agency (EPA)[14] details, black carbon influences climate by (a) directly absorbing light, (b) reducing the reflectivity of snow and ice through deposition, and (c) interacting with clouds. BC as part of the particulate matter content of the atmosphere is linked to adverse impacts on ecosystems, from visibility impairment to reduced agricultural production in some parts of the world to materials soiling and damage.

Also, black carbon, along with other atmospheric contaminants, is responsible, according to the World Health Organization, for 7 million premature, preventable deaths per year.[15,16] So, if we eliminate or reduce significantly emission of black carbon, we will solve (at least partially) two important problems: a disease of the planet and a disease of persons (mainly those below the poverty line who burn wood, etc., for heat production).

Possible solutions to the problem of *emission of contaminant black carbon* due to industrial processes (and in particular drying processes) and transportation are: (a) designing and employing sustainable engines (in particular driers); (b) using diesel engines with diesel particulate filters that normally remove 85% or more of the soot; (c) reducing the use of high-sulfur diesel, (d) using biodiesel (that produce less BC), or even better, replacing non-renewable energy sources by renewable ones that do not emit BC, like solar, wind, water, or subsurface geothermal energies; (e) improving energy efficiency, in particular of diesel engines; and (f) reducing GHG and soot emissions, or compensating their emissions (by capturing the emitted gases and particles) if it is not possible to reduce to zero the atmospheric contamination. Industrial dryers today use fossil fuels to provide thermal energy. It is necessary to enhance both the first law and second law efficiencies for reduction in their climate change potential.

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Rubén D. Piacentini
Area Física de la Atmósfera, Radiación Solar y Astropartículas, Instituto de Física Rosario (CONICET – Universidad Nacional de Rosario), Rosario, Argentina
Laboratorio Eficiencia Energética, Sustentabilidad y Cambio Climático, IMAE/FCEIA/UNR, Rosario, Argentina
ruben.piacentini@gmail.com

María Isabel Micheletti
Area Física de la Atmósfera, Radiación Solar y Astropartículas, Instituto de Física Rosario (CONICET – Universidad Nacional de Rosario), Rosario, Argentina
Facultad de Ciencias Bioquímicas y Farmacéuticas, UNR, Rosario, Argentina
maria.i.micheletti@gmail.com