Science of the Total Environment 479–480 (2014) 181–188

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

An approach to a black carbon emission inventory for Mexico by two methods

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HIGHLIGHTS

- Black carbon emissions are estimated between 53 and 473 Gg/year on a fuel consumption method.
- Black carbon emissions are estimated between 62 and 89 Gg/year on a sector method.

ARTICLE INFO

Article history:
Received 19 October 2013
Received in revised form 17 January 2014
Accepted 17 January 2014
Available online 20 February 2014

Keywords:
Back carbon
Emission inventory
SLCF
Mexico

ABSTRACT

A black carbon (BC) emission inventory for Mexico is presented. Estimate was performed by using two approaches, based on fuel consumption and emission factors in a top-down scheme, and the second from PM25 emission data and its correlation with black carbon by source category, assuming that black carbon = elemental carbon.

Results show that black carbon emissions are in interval 53–473 Gg using the fuel consumption approach and between 62 and 89 using the sector method. Black carbon key sources come from biomass burning in the rural sector, with 47 percent share to the National total. Mobile sources emissions account to 16% to the total. An opportunity to reduce, in the short-term, carbon dioxide equivalent (CO2-eq) emissions by reducing black carbon emissions would be obtained in reducing emissions mainly from biomass burning in rural housing sector and diesel emissions in the transport sector with important co-benefits in direct radiative forcing, public health and air quality.

1. Introduction

Black carbon (BC) is the main component in atmospheric aerosols that absorbs solar radiation (Ramanathan and Carmichael, 2008) thus reducing incident radiation at the surface. However, its net effect on the surface-atmosphere system, known as radiative forcing, is an increase in temperature (Ramachandran and Kedia, 2010; Bahadur et al., 2011). Radiative forcing of BC and ozone precursors are equivalent to 40 to 70% of that produced by carbon dioxide (Wallack and Ramanathan, 2009). Black carbon has a residence time in the atmosphere of approximately 4 to 7 days, depending on weather conditions that allow or delay its deposition (Reddy and Boucher, 2007). However, such a residence time is enough to be transported from region to region and even from continent to continent (Bridgman et al., 1989). Methane, ozone and BC have lifetimes shorter than that of CO2. Substances with lifetimes shorter than 100 years are called short-lived climate forcers (SLCF) (IPCC 2007).

Despite its important role as climate forcer, BC was not included in the Kyoto Protocol (Bond, 2007; Wallack and Ramanathan, 2009) due to several barriers including, i) a lack of scientific knowledge on physical and chemical processes in the atmosphere; ii) large uncertainty on its radiative forcing effect; iii) local and regional effects rather the global ones; and, iv) because it is addressed on local air pollution policies, equivalency metrics is more difficult to obtain (Bond and Sun, 2005; Rypdal et al. 2005; Bond, 2007). Recently, the declaration of the Group of the Eight emphasized the commitment to take rapid action to address short life agents, such as BC, without drawing away the action from long life greenhouse gases (Group of the Eight 2009). The increasing concern about health and welfare impact as well as the agricultural and climate impacts of BC is growing fast (UNEP, 2011) and it is recognized the contribution of BC to 10% or more to current climate change (Steiner, 2010).

Some BC emissions estimations have been done for Mexico from global or regional data (Penner et al., 1993; Bond et al., 2004). For instance, Penner et al. (1993) estimated Mexico's black carbon emissions from BC/S ratio, where S is sulfur concentration estimated from a similar country. In this work we report the first estimates using National data.

Is the purpose of this work to estimate a BC emission inventory for Mexico by following two separate methodological approaches, a top-down method that uses fuel data and emission factors, and a bottom-up method, that uses particulate matter in aerodynamic diameter of 2.5 μm (PM2.5) emission inventory and a BC/PM2.5 relationship.

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http://dx.doi.org/10.1016/j.scitotenv.2014.01.064

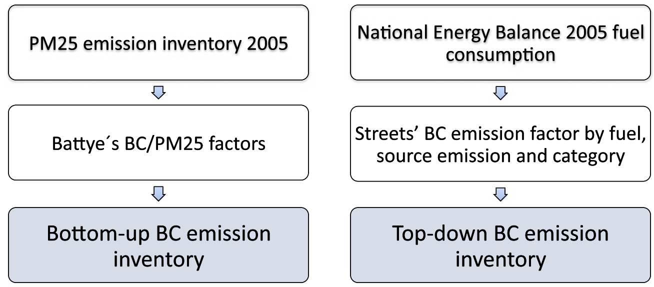

Fig. 1. Diagramatic emission inventory process: On the left side. A bottom-up, or sector, procedure based on criteria pollutants 2005 National Inventory and, on the right side, a top-down method based on the 2005 National Energy Balance and emission factors.

Table 1
Estimated emissions of black carbon by the method of emission factors and fuel consumption, 2005.

Source category	Emissions (Gg BC)		Mitigation potential (Gg CO2 eq.)	
	Central	High	100-year	20-year
1 Energy industries	**8.20**	**77.47**	**45,042**	**138,591**
2 Manufacturing industries and construction	**4.83**	**55.25**	**32,776**	**100,848**
3 Transport	**16.97**	**161.06**	**93,657**	**288,176**
a Civil aviation	1.71	18.67	11,023	33,916
b On-road transportation	13.87	132.25	76,950	236,768
c Railways	0.62	6.75	3984	12,258
d Navigation	0.77	3.39	1701	5235
4 Other sectors	**19.38**	**176.46**	**102,098**	**314,147**
a Commercial/institutional	0.02	0.26	154	474
b Residential	17.10	171.07	100,076	307927
c Agriculture/forestry/fishing	2.26	5.13	1868	5747
Total	**49.38**	**470.2**	**275,818**	**848,672**

2. Data and method

2.1. Top-down method

Fuel use data from the 2005 National Energy Balance (Semarnat, 2008) and some detailed BC emission factors from Streets et al. (2001) under the 1995 grouping, that is, emission factors containing some sort of emission control systems, are used. An Intergovernmental Panel of Climate Change (IPCC)-like approach was made for those sector sources were fuel combustion is involved in the IPCC Guidelines (IPCC-NGGIP 1997; IPCC 2006). IPCC Good Practice Guidance (IPCC-NGGIP, 2000) was applied. The same activity data for combustion sources already reported in the Mexico's Fourth National Communication to the United Nations Framework for Climate Change Convention (UNFCCC) (Semarnat, 2008) is used.

2.2. Bottom-up method

For the bottom-up estimation we used the reported particulate matter in an aerodynamic diameter less than or equal to 2.5 μm (PM2.5) ratio to BC from combustion processes reported by Battye et al. (2002)[1]:

$$BCe = PM2.5e * BC/PM2.5 \quad (1)$$

Out of the 32 federal entities, the Federal District (SMA GDF, 2010), and the State of Mexico (SMA EM, 2010) have published local BC emissions inventories following the PM2.5 ratio method. Estimates from local entities will allow, in the near future, a detailed improvement in the black carbon National Emission Inventory.

A diagram showing both methods is shown in Fig. 1.

[1] Where BCe is Black carbon emissions; PM2.5e is the particulate matter in an aerodynamic diameter less than or equal to 2.5 micrometer emissions; BC/PM2.5 is the ratio of Black carbon to PM2.5 in a given sector combustion, dimensionless.

2.3. Emission categories

Emission inventory format varies from region to region. Methodology in UNFCCC follows IPCC source classification; the EDGAR conversion tables include also IPCC source classification. The USEPA defined its own categories that are different from those of the UNFCCC. In Mexico the emission inventory of greenhouse gases follows the format of the UNFCCC while the emissions inventory criteria gases and particulate matter has historically been presented in the format of its counterpart in the United States of America. This presents a problem when standardizing emission categories and species, such as a GHG emission inventory and criteria emission inventory, both sharing black carbon and some indirect GHG, such as NO2.

Homogenization of emission categories is a national and regional priority as GHG, criteria gases and suspended particles should be handled and presented in the same format for comparison purposes, completeness, transparency, reproducibility and to avoid gaps or duplication of information on counting of emissions.

In calculating emissions UNFCCC IPCC categories were used for the top-down methodology and categories of the USEPA classification for estimating bottom-up methodology were used.

BC carbon emissions are highly process dependent. Thus, an initial uncertainty range by providing both lower and upper limits is estimated. For both methods (columns 2 and 3 in Tables 1 and 2), the uncertainty of such estimation, i.e., the difference between both estimations, central and high, comes from the range between a) the emission factors used in the first approach, and b) the distribution of the emissions, in the second approach. In the latter, the upper bond corresponds to emissions from the few great polluters. This assessment of uncertainty is included according to the analysis by Bond (2000).

An initial estimate of the mitigation potential in terms of carbon dioxide equivalent (CO_2-eq) is also provided. It was obtained as the difference between the higher and lower bonds multiplied by an average global warming potential (GWP) (IPCC 2007). The average GWP values of 650 and 2000 were used for 100 and 20 years time horizons