Discussion paper - BC methodologies for Fugitive emissions (1B) – Version 2

In the fugitive sector (1B), coke production, refining of oil products and flaring are reviewed in relation to BC emission. For the remaining fugitive sources BC emissions are assumed not occurring or negligible.

Coke production

Coke production leads to emissions of black carbon as the production process involves high-temperature processing of coal in a reducing environment and BC emissions likely occur from both coke oven leaks and pushing activities (Weitkamp et al., 2005).

Weitkamp et al. (2005) has measured concentrations of OC and EC among other pollutants using a fence line approach round a large coke plant. The measurements provided the following $PM_{2.5}$ emission profile:

Pollutant	Share of $PM_{2.5}$ mass, %	Share of PM_1, % / Share of PM_{TSP}, %	Share of PM_{10}, % / Share of PM_{fine}, %	Share of PM, %	CleanAIR Task Force presentation by Joe Chaisson, 2009
	Weitkamp et al. (2005)	Kupiainen & Klimont (2004)	SPECIATE 3.2 §	Bond et al (2004)	(Clairton Coke Works, US CleanAIR Task Force presentation by Joe Chaisson, 2009)
BC		49 / 15 **	90 / 74	48 ****	0,04 g/kg of coke produced (recovery oven facility
EC	25 ±5 *				
OC	40 ±9 *	35 / 11 ***	3.3 / 1.9	48 ****	

§ Profile 26208 for a coke cooler (might underestimate OC according to Kupiainen & Klimont (2004))
* µg-C/µg $_{PM2.5}$
** (0.75 kg BC/ton coke) / (1.535 kg BC/ton coke). It is not clear how the 0.75 has been estimated (1.535*0.95*0.5 = 0.73)
*** (0.54 kg BC/ton coke) / (1.535 kg BC/ton coke) It is not clear how the factor of 1.4 to calculate OC from EC has been estimated
**** 95 % of PM is carbonaceous, of which 50 % is BC and 50 % is OC

Comment [PMS1]: EFs are updated in Bond et al (2007) from 4.8 and 3.4 to 3.8 and 6.2 g/kg coal for uncaptured ovens. No text on the transformation from % to g/kg coal, and therefore not included here. Might need further review

Comment [PMS2]: Table 5 in the reference gives 34 % which corresponds with the factor 1.4 between BC and OC, but this is not described in the text, which states that PMcarboneous = 95% *PM and BC = 50 % * PMcarboneous and OC = 50 % * PMcarboneous

Weitkamp et al. (2005) is based on measurements carried out in 2002, and is supposed to be the best source of BC EFs for coke production under European conditions. The measurement of BC corresponds well with the shares given by Kupiainen & Klimont (2004) and Bond et al (2004). The BC-share for PM_1 given in Kupiainen & Klimont (2004) is applied for $PM_{2.5}$ in lack of better data. The major part of BC is expected in the fine and ultrafine fraction, which might lead to an overestimation of BC in $PM_{2.5}$, but the possible error is within the uncertainty of the EF and is supported by the similar EF in Bond et al. (2004).

The following BC EFs are proposed for use in the GB:

Pollutant	Share of TSP, %	Share of PM_{10}, %	Share of $PM_{2.5}$, %	Reference
BC	15	25	49	Kupiainen & Klimont (2004), Weitkamp et al. (2005)

Refining

Olmez et al. (1988) reported shares of EC and OC measured with thermal methods for an oil refinery catalytic cracker, after ESP. The mass fraction in fine ($PM_{2.5}$) particles was 97 per cent with the rest in coarse mode (coarse mode refer to PMs with 2.5µm<diameter<7-20µm).

$EC_{PM2.5} = EC_{PM10} = 0.16$ %

Cooper et al. (1987) include three species profiles for catalytic cracking of which one has data on EC and OC;

EC = 0.16 (±0.05) % of $PM_{2.5}$

OC = 0.28 (±0.99) % of $_{PM2.5}$

Chow et al. (2004) include species profiles for a number of sources, here among a catalytic cracker;

EC = 0.0703 (±0.05) % of $PM_{2.5}$

OC = 0.4732 (±0.99) % of $_{PM2.5}$

No BC emission factors have been found for fluid coking units.

The following BC emission factors are proposed for implementation in the guidebook:

Tier	Source	GB Table	BC	OC	Unit	Reference
2	Catalytic cracking unit regenerators	3-2	0.1301	0.3766	% of $PM_{2.5}$	M
2	Catalytic reforming units	3-3	0		% of $PM_{2.5}$	A
2	Fluid coking units	3-4			% of $PM_{2.5}$	

M: mean value of EFs from Olmez et al. (1988), Cooper et al. (1987) and Chow et al. (2004) (OC is mean of value of Cooper et al. (1987) and Chow et al. (2004))

A: assumption as no PM EFs are included in the EF table for catalytic reforming units in the guidebook

Flaring

A literature review has been carried out in search for emission factors for flaring. The knowledge on emissions from flaring are rather limited, which has been stated recently e.g. by CLRTAP Ad-Hoc Expert Group on Black Carbon (2010): "In fact there are no established BC emission factors for flaring and only recently a research group in Canada undertook an effort to estimate and validate numbers in use." and by Arctic Council Task Force on Short Lived Climate Forcers (2011): "There is still considerable uncertainty regarding the quantification of black carbon emissions, particularly from sources such as open burning and gas flaring."

US EPA (1995) gives soot emission factors for flare operations. The EFs are based on tests using crude propylene containing 80 % propylene and 20 % propane. EFs between 0 and 274 lb/10^6 Btu are reported in table 13.5-1. These values are not consistent with the values given in the footnotes to the same table. According to the original source (US EPA (1983)) the values in the footnote are correct. US EPA 1983 gives soot EFs between 0 and 274 µg/L.

McEwen & Johnson (2012) found current emission factors to be questionable or based on measurements not comparable to open-atmosphere flaring. They have carried out quantitative emission measurements in laboratory-scale for a number of different conditions. A simple empiric relationship has been found for burners with large diameters between the volumetric heating value (HV) and the emission factor for soot:

EF_{BC} = 0.0578 (HV)-2.09

A HV value of 45 MJ/m3 has been suggested for estimation of a standard BC emission factor for flaring. This HV corresponds well with the HV given by Norway at 48 MJ/Sm3 (Climate and Pollution Agency, 2012). The corresponding Danish heating value for flare gas is 47 MJ/Nm3 (unpublished data based on EU ETS reports).

The correspondence between HV and EF_{BC} is made probable, as the HV to some extend correlates with the carbon content of the flare gas.

Based on the formula and the HV given by McEwen & Johnson (2012) it is proposed to implement the following BC EF in the revised EMEP/EEA Guidebook:

EF_{BC} = 0.51 kg soot / 1000 m^3 fuel = 0.01 g/GJ

EF_{BC} = 1.3 % of PM_{10}

The measurements by McEwen & Johnson (2012) indicate that 80 % of total C is BC and the remaining 20 % is OC. This leads to an EF_{OC} = 0.13 kg soot / 1000 m^3 fuel

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