Black carbon

Black carbon is formed from incomplete combustion of organic compounds with lack of oxygen to fully oxidize the organic species to carbon dioxide and water.

Black carbon (BC) is the term for a range of carbon containing compounds. It covers partly large polycyclic species, charred plants to highly graphitized soot. Black carbon originates from fossil fuel and biomass combustion and the properties of the resulting BC such as atmospheric lifetime and optical properties, are dependent on combustion temperature, oxygen concentration during combustion and for biomass burning also of wood moisture (Ramanathan and Carmichael, 2008;Shrestha et al., 2010). BC is considered to consist mostly of graphitised carbon or elemental carbon (EC) with unpolar and hydrophobic properties with minor contribution from organic carbon (OC) (Quinn et al., 2011), however the composition of EC/OC depends on the specific source. Fossil fuel combustion engines emit more EC than OC whereas open biomass combustion gives more OC than EC (Quinn et al., 2011). Therefore BC is to a good approximation equal to EC from fossil fuel sources.

Freshly emitted BC is mostly found in particles with a size of a few tenth of nm (Slowik et al., 2004). In the atmosphere the surface of BC particles will be attached by e.g. OH radicals and the particle will coagulate with other particles and absorb gases. As a result the surface is becoming more hydrophilic within hours (Swietlicki et al., 2008) and can easier be washed out by in cloud scavenging (e.g. Huang et al., 2010). It is only very close to the emission sources that pure BC particles exist (Swietlicki et al., 2008). Therefore BC particles change properties after emission. This is very important for the measurements of BC as the optical properties are changed as well. A conceptual description is of this process is shown in Figure 1.

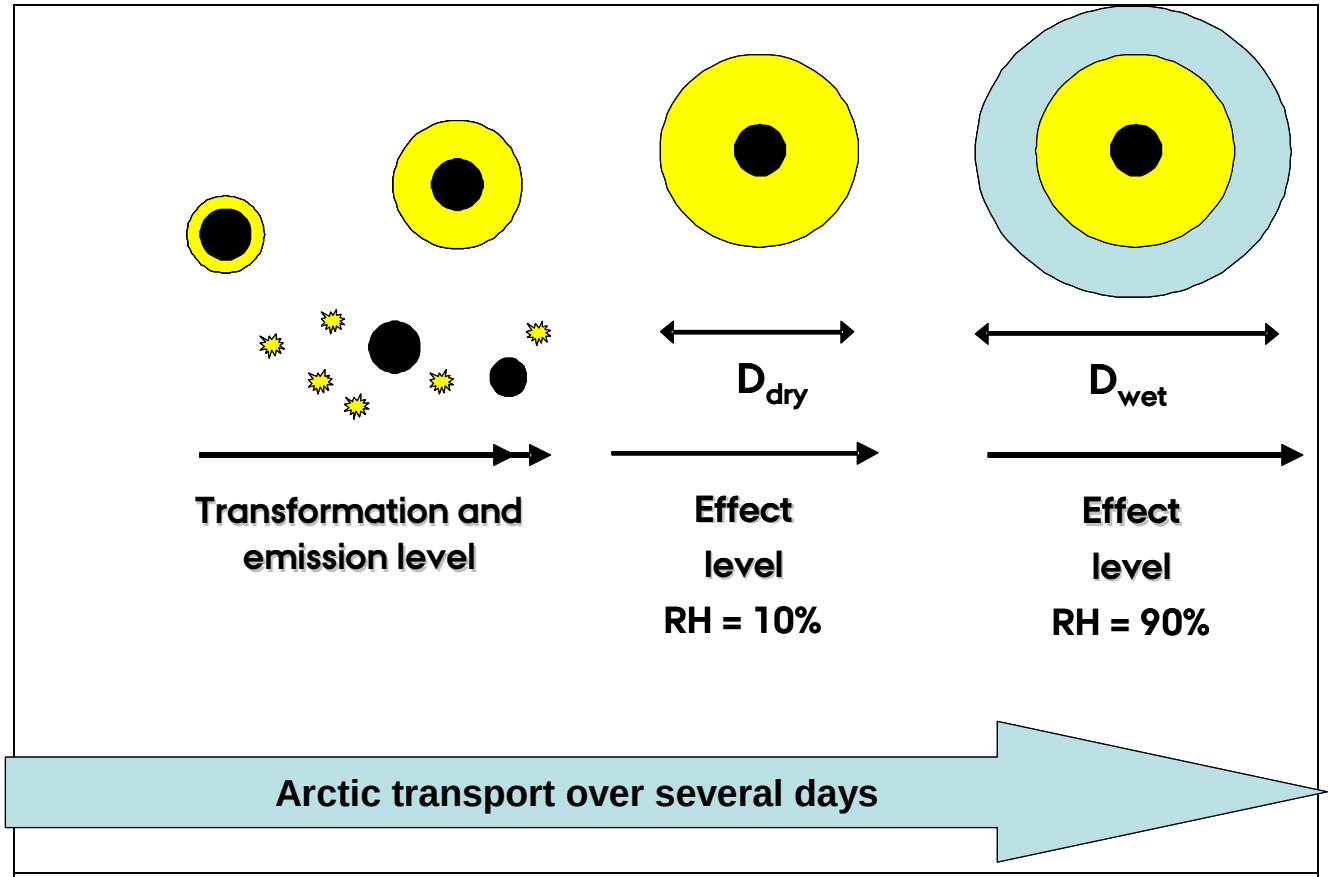

Figure 1 A conceptual description of the conversion of BC (black dots) to more hydrophilic particles (black dots with yellow enclosure) to finally particles consisting of black carbon, polar enclosure and water (blue area).

BC is often measured by filter based absorption technology using particle soot absorption photometer (PSAP) or aethalometer because they are easily operated, are robust and have a low cost. The absorption measured is converted to a concentration using mass absorption cross section (MAC). For new BC particles the MAC value is determined to be in a narrow range of 7.5±1.2 $m^2 g^{-1}$. Far from sources this calibration factor is considerably increased and e.g. in the Arctic it is typically 19 in winter to 29 $m^2 g^{-1}$ in summer (Quinn et al., 2011 and references in there). These changes in MAC make it necessary to calibrate the measurements for each measurement site and season especially far from sources in order to get reliable measurement of concentrations and estimates of emissions. An uncertainty of typically 20 – 30% is used. Because of the changes in MAC values many papers are using Equivalent BC or EBC to emphasise the side specific dependency of MAC using e.g. PSAP.

Other measured can also be used Photoacoustic spectrometer gives results with indicated 5% uncertainty but this instrument is also expensive compared with PSAP and suffers from the same problem as PSAP that it needs a calibration towards another method. For example Filters have also widely been analysed off-line by OC/EC monitors. The principle is that the filter is heated in inert gas to release OC where after the filter is heated in the presence of oxygen to combust BC. Different analytical method has been used after evaporation. Heating of OC might lead to charring of OC giving an artefact in the OC/EC ratio and thus most instruments apply a temperature ramping and make correction for the charring.

The fate of BC in the atmosphere depends very much on its history. The longer time it has been in the atmosphere the more it has undergone chemical and physical transformations as described above. As a result the surface is becoming more hydrophilic and can easier be washed out by in cloud scavenging (e.g. Huang et al., 2010) whereas below cloud scavenging depends more on the size of particles than the chemical properties (Seinfeld and Pandis, 2006). Therefore the changes in morphology due to coagulation will change the lifetime of the BC. Particles with diameters in the range of 0.2 to 0.7 µm has the smallest deposition velocity {Seinfeld, 2006 530 /id}. Typically diameters of primary emitted BC aerosols are below < 50 nm and they need to grow in order to stay in the atmosphere.

References

Huang, L., S. L. Gong, C. Q. Jia and Lavoue´, Relative contributions of anthropogenic emissions to black carbon aerosol in the Arctic, *Journal of Geophysical Research, 115*, 1-11, 2010.

Quinn, P. K., A. Stohl, A. .Arneth, T. Berntsen, J. F. Burchart, J. Christensen, M. Flanner, K. Kupiainen, H. Lihavainen, M. Shepherd, V. Shevchenko, H. Skov and V. Vestreng, AMAP, 2011. The Impact of Black Carbon on Arctic Climate, p. 128 pp., Arctic Monitoring and Assessment Programme (AMAP), P.O. Box 8100 Dep., N--]0032 Oslo, Norway, 2011.

Ramanathan, V. and G. Carmichael, Global and regional climate changes due to black carbon, *Nature Geoscience, 1*(4), 221-227, 2008.

Saathoff, H., K. H. Naumann, M. Schnaiter, W. Schock, O. Mohler, U. Schurath, E. Weingartner, M. Gysel and U. Baltensperger, Coating of soot and (NH4)(2)SO4 particles by ozonolysis products of alpha-pinene, *Journal of Aerosol Science, 34*(10), 1297-1321, 2003.

Seinfeld, J. H. and S. N. Pandis, Atmospheric chemistry and Physics: from air pollution to climate change, John Wiley & Sons, Inc., Hobeken, New Jersey, 2006.

Shrestha, G., S. Traina and C. Swanston, Black carbon's properties and role in the environment: a comprehensive review, *Sustainability, 2*(1), 294-320, 2010.

Slowik, J. G., K. Stainken, P. Davidovits, L. R. Williams, J. T. Jayne, C. E. Kolb, D. R. Worsnop, Y. Rudich, P. F. DeCarlo and J. L. Jimenez, Particle morphology and density characterization by combined mobility and aerodynamic diameter measurements. Part 2: Application to combustion-generated soot aerosols as a function of fuel equivalence ratio, *Aerosol Science and Technology, 38*(12), 1206-1222, 2004.

Swietlicki, E., H. C. Hansson, K. Hameri, B. Svenningsson, A. Massling, G. McFiggans, P. H. McMurry, T. Petaja, P. Tunved, M. Gysel, D. Topping, E. Weingartner, U. Baltensperger, J. Rissler, A. Wiedensohler and M. Kulmala, Hygroscopic properties of submicrometer atmospheric aerosol particles measured with H-TDMA instruments in various environments - a review, *Tellus Series B-Chemical and Physical Meteorology, 60*(3), 432-469, 2008.