



Light Absorbing Properties of Brown Carbon Generated from Pyrolytic Combustion of Household Biofuels

Tejas Rathod, Sanjay Kumar Sahu, Mahesh Tiwari, Ajmal Yousaf, Rahul C. Bhangare, Gauri Girish Pandit*

Environmental Monitoring and Assessment Section, Bhabha Atomic Research Centre, Mumbai – 400085, India

ABSTRACT

The light absorption properties of brown carbon aerosols generated in a lab scale experiment from wood (*Magnifera indica*) and dung cake were studied. Mie theory along with experimentally derived values for imaginary refractive index was used to estimate mass absorption coefficient for the samples. It was observed that for both wood and dung cake major portion of brown carbon were generated above 150°C. The light absorbing properties of brown carbon from wood depended on temperature of pyrolysis which was not the case for dung cake. The spectral dependence of absorption for brown carbon samples was estimated in terms of Absorption Angstrom Exponent and found to be greater than 2. The brown carbon aerosols from dung cake pyrolysis were having twice the light absorbing potential (in the wavelength range 280 nm to 750 nm) than brown carbon emitted from mango tree wood pyrolytic combustion.

Keywords: Carbonaceous aerosols; Mass absorption coefficient; Angstrom exponent; UV Visible spectroscopy; Mie theory.

INTRODUCTION

Since last few decades there is a growing concern on effects of aerosols on climate. Intergovernmental Panel on Climate Change (IPCC, 2007) reviews climatic effects of aerosols and brings to focus its highly uncertain role. Aerosols can absorb sunlight causing direct warming of atmosphere and also scatter light resulting in cooling effect. The indirect effects of aerosols include their impact on cloud microphysics. Among different types of aerosols, carbonaceous aerosols have significant impact on earth's radiative balance. Carbonaceous aerosols form major fraction of atmospheric aerosols (IPCC, 2001). These aerosols can be grouped as visible light absorbing black carbon (BC) and scattering organic carbon (OC) aerosols. BC is noted to be the second largest contributor to radiative forcing after CO₂ (Ramanathan and Carmichael, 2008) whereas OC is considered to be negligible absorber of light (Ma *et al.*, 2012). However experimental measurement suggests some part of organics in aerosols (OA) to be light absorbing in blue and ultraviolet region (Andreae and Gelencser, 2006; Mosmuller *et al.*, 2011). This light absorbing OC is called as brown carbon (BrC). Filter paper collected OA generated from biomass burning and extracted with acetone show light absorption

which increases towards shorter wavelength of visible range (Kirchstetter *et al.*, 2004, Chen and Bond, 2010). Presence of organic matter in atmospheric aerosols is very profound, especially in biomass burning regions (Hand *et al.*, 2012). Organics in atmospheric aerosols account for 10 to 70% of its total dry mass (Murphy *et al.*, 2006). OC is found to be 3 to 12 times more than BC by mass (Molnar *et al.*, 1999; Husain *et al.*, 2007). Modelling studies consider OC to be scattering in nature and relates negative climate forcing to these aerosols. Consideration of BrC contribution to light absorption can distinctly affect this negative bias in forcing (Chung *et al.*, 2012). Studies have shown that BrC aerosols can contribute appreciably to total light absorption in areas where it is extensively present (Yang *et al.*, 2009; Park *et al.*, 2010; Chung *et al.*, 2012). Ambient aerosols can be studied using online techniques or by methods which require prior collection of particles on filter paper. The ambient OA consists of primary aerosols emitted directly from different sources, as well as secondary aerosols formed in atmosphere from primary OA and allied processes. Moreover, the ambient atmospheric aerosol samples often consists mixture of BC and OC. BC being highly light absorbing overshadows light absorption due to OC aerosols. There is also possibility for presence of BC aerosols spheres coated with OC, which can lead to lensing effect (Bond *et al.*, 2006; Lack and Cappa, 2010). Sampling ambient aerosols and studying its light absorbing properties may depict real life scenario but it lacks the detailing nature of sampled aerosols. Particularly, it is difficult to identify light absorption contribution from specific type of OA constituting the

* Corresponding author.

Tel.: +912225590233; Fax: +912225505151
E-mail address: ggp@barc.gov.in

ambient aerosols. Thus estimating light absorption properties of OA especially BrC remains non trivial. The understanding related to light absorption from primary OA emitted by specific sources is quite limited.

Biomass combustion is main source of carbonaceous aerosols in atmosphere. Global inventory calculations (Bond *et al.*, 2004) suggest that 88% of total carbonaceous aerosol mass results from biomass combustion. Biomass combustion affecting environment includes forest fires, specific burning events and combustion for domestic energy consumption. Biomass is one of the most common cooking and heating fuels in developing countries. Around 95% of domestic energy consumption in low income countries can be accounted to biomass fuel combustion (World energy outlook, 2006). Household biomass combustion can be considered as a continuous incessant source for OC aerosols. The major sources of domestic biomass fuels are wood, dung, and crop residue. The emissions from different types of wood, dung cake samples and crop residues have been examined earlier by Habib *et al.* (2008) in household cooking setups, which includes OC and EC. We have made an attempt to estimate and compare the light absorbing characteristics of BrC aerosols emitted from wood and dung cake source at a lab scale experiment. Light absorbing properties discussed here are important from the point of view of estimating radiative forcing capabilities of these aerosols. It must be noted here that to truly relate the notion of BrC to absorption spectra it is necessary to identify the OC components or group of components that cause increase in light absorption at shorter wavelengths. The bulk OC absorption spectra having enhanced absorption in UV visible range (Angstrom exponent > 2) are usually related to presence of BrC (Kirchstetter and Thatcher, 2012; Feng *et al.*, 2013).

METHODS

Laboratory scale experiments were performed to generate and sample OC aerosols. Biomass was pyrolysed in temperature controlled, nitrogen gas environment. The experimental setup as shown in Fig. 1 consists of an electrical resistive heating combustion chamber (15 cm × 15 cm × 30 cm) in which biomass pieces undergo pyrolysis.

The presence of heat during combustion cause thermal degradation of biomass resulting in release of volatile material and their heterogeneous reactions. The biomass combustion process proceeds through different stages (Lobert and Warnatz, 1993). When heat energy is first provided, the biomass undergoes thermal distillation. The water and volatile contents of the fuel (such as alcohols, aldehydes, and terpenes) are removed from the biomass or diffuse into the inner layers of it. The initial distillation process is followed by a pyrolytic step at 127°C. During this step cracking of fuel molecules occurs decomposing high molecular weight components to compounds of lower molecular weight and are released in formation of char, tar and volatile compounds. These emissions form a flammable mixture in the presence of oxygen. Flaming combustion converts the complex mixture of relatively reduced species emitted during pyrolysis to simple molecules, particularly CO₂, H₂O, NO, NO₂, N₂ and SO₂. In the event of incomplete flaming combustion, BC gets emitted. Since, our aim is to sample OC aerosols emitted directly from the biomass and which escapes flaming combustion; the experiments were performed in presence of nitrogen environment. The nitrogen environment ensures that there is no flaming combustion inside the reactor and thus no formation of black carbon aerosols. The OC aerosols thus generated enters a dilution chamber (40 cm × 40 cm × 80 cm) from which they are sampled in the sampling unit. The particulate free air at flow rate of 12 dm³ min⁻¹ is used for dilution to allow cooling of pyrolytic aerosols. The sampling unit consists of PM_{2.5} inlet and filter holders. The dilution allowed cooling of gas streams and aerosols up to 40°C as measured at the inlet of sample holders. Aerosols particles of size less than 2.5 μm are collected on quartz fiber filter paper (Whatman QM-A quartz filters) at a flow rate of 16 dm³ min⁻¹. Quartz fiber filter paper is known to adsorb gas causing positive artifact in sampling particulate matter. To remove this positive artifact, a combination of teflon filter paper and backup quartz filter paper was used in parallel to original quartz filter paper. The flow rate and face velocity in both lines were maintained identical. The maximum contribution of gas adsorption to the sampled particulate organic mass was found to be less than 20%.

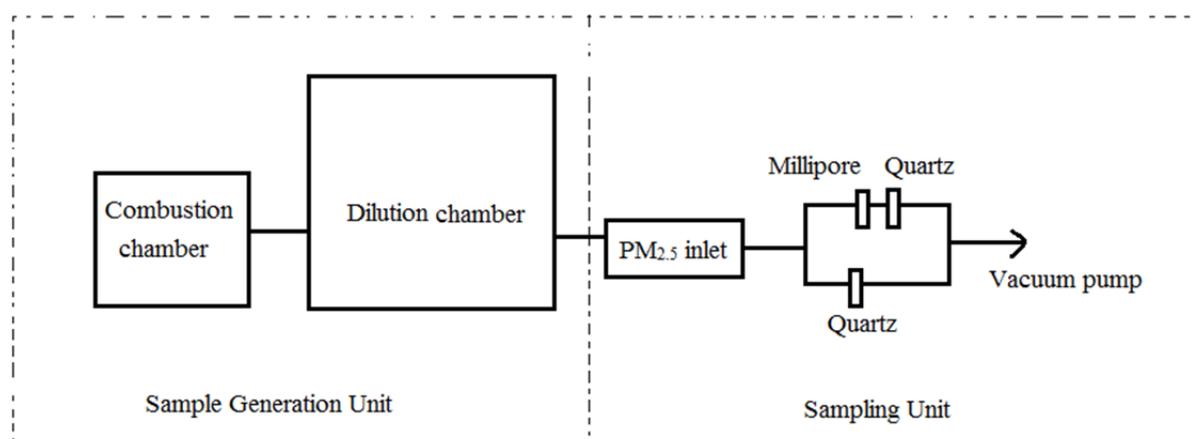


Fig. 1. Schematic of experimental setup for collection of brown carbon aerosols generated due to biomass pyrolysis.

Biomass combustion is known to show inconsistency in its emission rates and chemical properties of OA. Large variation is depicted even during combustion of biomass having similar composition (Roden *et al.*, 2009). Measurement of OC aerosol properties emitted for every type of biomass combustion becomes difficult due to large variability observed. In such situation it is convenient to isolate the variables controlling these properties and then study emissions from different biomass types and combustion conditions. In our experiments, commonly used biomass fuels namely, wood and dung cakes were tested for OA emissions. The wood samples tested were of mango tree (*mangifera indica*) procured from local market in Mumbai and dung cake samples prepared from cow dung were brought from the central part of India. The samples were dry in nature with moisture content less than 10%. The biomass pieces were chosen such that they were void of any air spaces or cavities. We have performed experiments to examine OC aerosols emissions from highly controlled thermal degradation of biomass. At temperatures 300°C to 600°C flaming combustion begins in the presence of oxygen (Omni, 2005). We want to sample organic aerosols formed due to condensation of organic vapors emitted at around temperatures below which flaming could occur. Thus, temperatures range up to 380°C chosen for the present study. Further, temperature range was divided to see if any light absorbing characteristics of OC aerosols can be mapped to temperature of generation. The temperatures were measured near the surface of the biomass. Two approaches have been adopted for this study labelled as case 1 and case 2. The sampling duration was optimized to provide maximum sample collection for temperature and source mass considered.

Case 1 (Ramped Temperature)

The temperature of pyrolysis was gradually increased from room temperature and simultaneous collection was done. Samples were collected in three different temperature ranges. Table 1 shows the temperature ranges and corresponding sampling duration. The motivation is to understand nature of the OC emitted in distinct temperature ranges due to biomass pyrolysis.

Case 2 (Constant Temperature)

To study the low temperature and high temperature pyrolysis products, experiments were conducted for pyrolysis at 210°C and 380°C respectively, as displayed in Table 1. The sampling of OA was done for 60 min for both high and low temperature pyrolysis. It mimics the situation where the biomass is directly exposed to high heat energy.

SAMPLE ANALYSIS

Sample Extraction

The samples collected for both cases were extracted using organic solvent. Different solvents can be used to extract OC collected on quartz filters. Chen and Bond (2010), tried different solvents and estimated their efficiencies for extraction of OC from quartz filters. The efficiency was estimated by subtracting OC in the residual filter from OC in the filter before extraction by organic solvent. They reported that acetone and methanol have similar extraction efficiencies of around 90%. In the current study as well it was observed that methanol provided OC extraction efficiencies more than 90%. The part of sample laden filter papers were cut and dissolved in methanol solvent. The samples were subsequently extracted ultrasonically (PCI Analytics) for 1 h and kept at room temperature for 20 h to let the solution reach equilibrium, thereafter further sonicated for 1 h (Chen and Bond, 2010). Sonication process is known to increase extraction efficiencies (Polidori *et al.*, 2008). In order to remove impurities during the extraction process all extracts were filtered by Whatmann Disposable Syringe Filters having 0.2 μm pore size. The amount of OC in extracts was estimated by subtracting the amount of OC in quartz filter paper before and after extraction. The OC content of sample laden quartz filter paper was determined using Total Organic Carbon analyser (TOC, Shimadzu) coupled with Solid Sample Combustion Unit SSM-5000A. The 680°C combustion catalytic oxidation method to efficiently oxidize hard to decompose organic compounds, including insoluble and macromolecular organic compounds was used. The 680°C combustion catalytic oxidation method achieves total combustion of samples by heating them to 680°C in an oxygen rich environment inside TC combustion tubes filled with a platinum catalyst. The carbon dioxide generated by oxidation is detected using an infrared gas analyzer (NDIR). The typical values of OC on sample filters ranged from 60 to 800 $\mu\text{gC cm}^{-2}$ depending upon pyrolysis conditions. The methanol solvent after extracting OC from filter paper was then allowed to evaporate at room temperature leaving behind the OC extracts. These extracts were dissolved in known volume of acetonitrile for light absorption studies.

Light Absorption Analysis

UV-Visible spectrophotometer (SHIMADZU, UV-3101PC) was used to investigate the light absorbing properties of the sampled OC. The absorption studies were performed with acetonitrile as solvent. Negligible absorbance background of acetonitrile in the range of 250 nm to 800 nm makes it ideal solvent for absorption studies. The

Table 1. Temperature for pyrolysis combustion and corresponding sampling time for Case 1 and Case 2 approaches.

	Temperature	Sampling Time (min)
Case 1 (Ramped temperature)	T < 150°C	40
	150°C < T < 250°C	40
	250°C < T < 380°C	40
Case 2 (Constant temperature)	210°C	60
	380°C	60

validity of Beer-Lambert law was checked using dilution tests to identify the wavelength range where absorbance is proportional to concentration. Accordingly, the wavelength range of 280 nm to 750 nm was considered for UV-Visible analysis. From data obtained, properties like imaginary part of the complex refractive index, mass absorption coefficient and angstrom absorption exponent were attributed to OC aerosols generated from pyrolysis of biomass. The UV-Visible absorption measurement can be used to estimate absorption per mass of carbon in the bulk liquid solution (α/ρ in the unit of $\text{cm}^2 \text{g}^{-1}$). It is the absorption coefficient (α) for the bulk OC divided by dissolved OC density (ρ). This quantity α/ρ derived from measured spectra can translate to radiative transfer models (Sun *et al.*, 2007). The wavelength dependent value of α/ρ is estimated using Eq. (1).

$$\frac{\alpha}{\rho} = \frac{A}{C.L} \times \ln(10) \text{ cm}^2 \text{g}^{-1} \quad (1)$$

Here, A (absorbance) comes from the spectrophotometer, L is the optical path length of the spectrophotometer, which equals to 1 cm, and 'C' is the concentration of OC (g cm^{-3}) in the acetonitrile solvent. Though α/ρ has same units as those of Mass absorption coefficient by particulate matter, there is marked difference between the two. Mie theory combined with a refractive index is used to determine the MAC values for particulate matter. The extraction process and light absorption measurements were repeated for different part of the same sample laden filter paper. The α/ρ values showed less than 3% variation. Similarly, for two samples obtained from same pyrolysis condition the α/ρ were reproducible within 16%.

Imaginary Part of Complex Refractive Index (k)

The optical constant k cannot be directly measured but it can be derived from measurable quantities by interposing a suitable theory (Bohren and Huffman, 1983). It relates to electromagnetic radiation absorbing strength of the material. Lorentz oscillator model gives k as follows,

$$k = \left(\frac{\alpha}{\rho} \right) \times \left(\frac{\lambda}{4\pi} \right) \times \rho \times 10^{-7} \quad (2)$$

To obtain an imaginary refractive index from α/ρ we must choose a density. While calculating mass absorption coefficient using Mie theory, it too requires a density. If same density is used in both calculations, it has little effect on particulate absorption.

Mass Absorption Coefficient (MAC)

It is defined as absorption cross section per unit particle mass and has units of $\text{m}^2 \text{g}^{-1}$. Theoretically; MAC can be calculated for each aerosol type using Mie theory with particle size, mixing state and refractive index (Bohren and Huffman, 1983; Martins *et al.*, 1998; Taha *et al.*, 2007; Lack and Cappa, 2010). Using the wavelength dependent k values obtained for the sampled OC, MAC for aerosols generated due to pyrolysis was determined. The Mie codes

(Bohren and Huffman, 1983) implemented in MATLAB (Maetzler, 2002; Bond *et al.*, 2006) were used for calculations. The k value acts as an input to Mie algorithm, along with density, geometric standard deviation, and count median diameter to give MAC.

Absorption Angstrom Exponent (AAE)

It is a measure of the spectral dependence of aerosol light absorption. AAE is the exponent in a power law expressing the ratio of the absorption coefficients at two vacuum wavelengths λ_1 and λ_2 as a function of the ratio of these wavelengths (Moosmuller *et al.*, 2009) as given in Eq. (3).

$$\frac{\alpha(\lambda_1)}{\alpha(\lambda_2)} = \left(\frac{\lambda_1}{\lambda_2} \right)^{-AAE} \quad (3)$$

Measurement or calculation of the AAE requires determination of the absorption coefficient $\alpha(\lambda)$ at two wavelengths λ_1 and λ_2 making the AAE specific for this wavelength pair and complicating comparison of different determinations if the AAE is wavelength dependent. In such a case, definition of the AAE as a negative log-log slope of the absorption spectrum is helpful. It captures the variation of wavelength dependent absorption. AAE was determined by performing a linear regression of $\ln(\text{MAC})$ against $\ln(\lambda)$ through the valid wavelength range for each sample using Eq. (4).

$$AAE = \frac{-d\ln(\text{MAC})}{d\ln(\lambda)} \quad (4)$$

RESULTS AND DISCUSSION

All the OC extracts absorbed light in UV Visible range. Important properties in the context of light absorption by OC aerosols generated in laboratory are discussed in the following sections.

Imaginary Refractive Index (k)

Imaginary index for the OC in extracts was estimated using Eq. (2). The OC density of 1.1 g cm^{-3} was chosen as provided by Schkolnik *et al.* (2007). From Eq. (2), it's apparent that imaginary refractive index values reported from our study are dependent directly on the choice of density. But this choice of density has negligible effect on particle absorption values. Density was varied by 10% to obtain variation in k values. The corresponding variation in MAC values was found to be less than 0.1% when appropriate density values were used. The wavelength dependent k values derived using Eq. (1) indicated increase in absorption towards shorter wavelength side of UV Visible spectrum. The Fig. 2 depicts the trend observed in k for both the cases considered.

Case 1 (Ramped temperature): The pyrolytic aerosols emitted from wood in temperature range $150^\circ\text{C} < T < 250^\circ\text{C}$ had highest derived k values, hence were more light absorbing. The results for wood and dung cake are depicted in

Figs. 2(a) and 2(b) respectively. For dung cake the absorbing nature of particles generated in temperature range $250^{\circ}\text{C} < T < 380^{\circ}\text{C}$ is higher than other temperature ranges considered. From Figs. 2(a) and 2(b), it is also clear that major light absorbing particles for both wood and dung cake were generated above 150°C .

Case 2 (constant temperature): The results for wood and

dung cake are plotted in Figs. 2(c) and 2(d) respectively. The k values for OA from wood emissions at temperature 210°C are comparable to aerosols emitted due to pyrolysis at 380°C . Whereas, the k values for OA from dung cake emitted at temperature 210°C are slightly lower than 380°C . The derived k values for 210°C and 380°C at different wavelengths is compared to other works in Table 2.

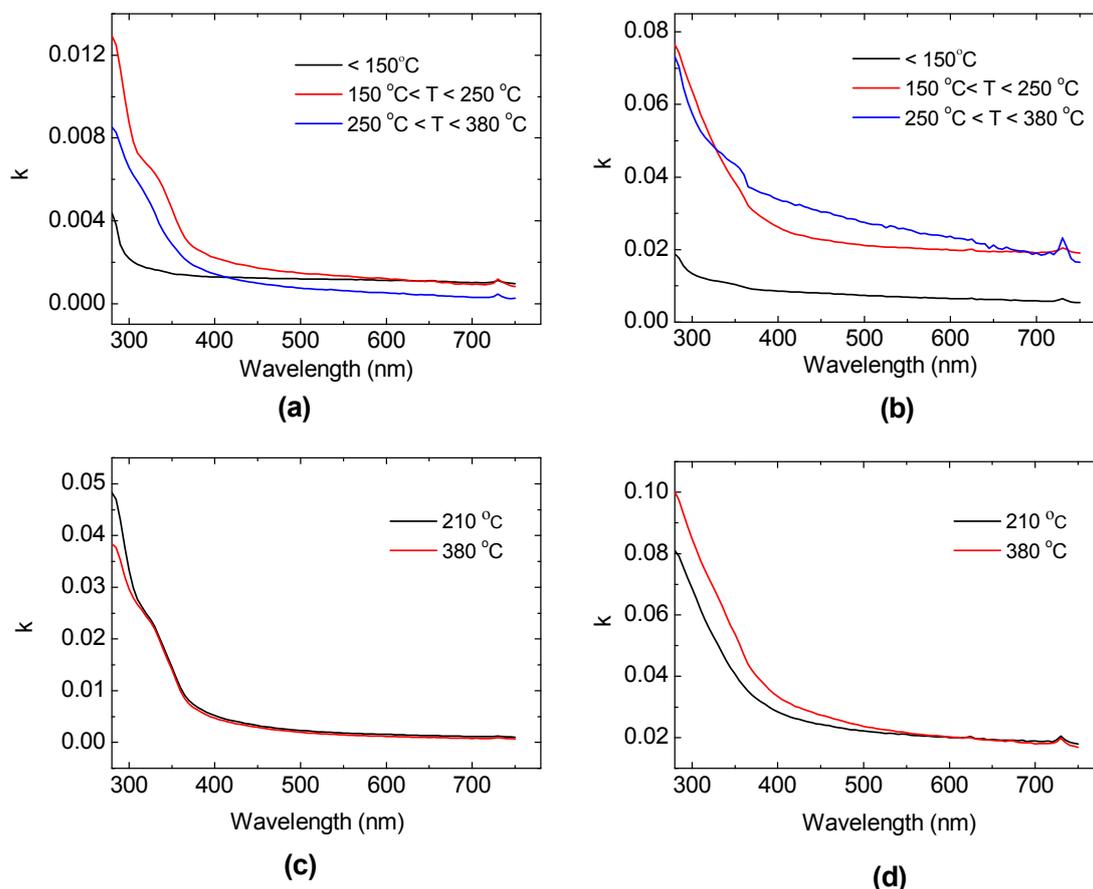


Fig. 2. Wavelength dependence of imaginary part of complex refractive index ($m = 1.55 + ik$) for different combustion conditions. Case 1 (Ramped temperature) - (a) Wood (b) Dung cake and Case 2 (Constant temperature) - (c) Wood (d) Dung cake.

Table 2. Comparison of derived imaginary part of complex refractive index ($m = n + ik$) and mass absorption coefficient (MAC) values with other works.

Wavelength (nm)	k				MAC ($\text{m}^2 \text{g}^{-1}$)			
	350	450	550	650	350	450	550	650
Wood ^a								
210°C	0.0145	0.0032	0.0018	0.0013	0.78	0.13	0.05	0.03
380°C	0.0140	0.0029	0.0014	0.0010	0.76	0.12	0.04	0.02
Dung cake								
210°C	0.0407	0.0243	0.0210	0.0194	1.96	0.90	0.60	0.43
380°C	0.0537	0.0273	0.0216	0.0191	2.46	1.00	0.60	0.42
Kirchstetter <i>et al.</i> (2004)	0.168	0.063	0.03	0.005	5.0	1.5	0.6	0.1
Chen and Bond (2010) ^b	0.1	0.02	0.006	1×10^{-4}	2.25	0.4	0.08	0.001
Feng <i>et al.</i> (2013) ^c	0.075	0.02	0.003	0.0003	2.25	0.63	0.08	0.006

^a Values for the pyrolysis of mango tree wood studied in this paper (Case 2).

^b Methanol soluble BrC OAK_L_360 in Chen and Bond (2010).

^c Values calculated for moderately absorbing BrC in Feng *et al.* (2013).

Mass Absorption Coefficient (MAC)

MAC indicates the light absorbing nature of the OC. As discussed before, wavelength dependent MAC values were obtained using Mie theory. The complex refractive index was chosen as $1.55 + ik(\lambda)$. The parameters like count median diameter (150 nm), geometric standard deviation (1.5) and density (1.1 g cm^{-3}) representative for freshly generated aerosols due to biomass combustion were assumed (Schkolnik *et al.*, 2007; Chen and Bond, 2010). The MAC values are sensitive to size distribution and density used in Mie calculations. To check the sensitivity of MAC values w.r.t. size distribution, the CMD was varied by 10% keeping other parameters constant. Then Mie calculations showed 6% variation in MAC values. Similarly, 10% variation in GSD gave 16% variation in MAC values. The general trend in MAC values was observed that it increases with decreasing wavelength. This is because of increase in absorbance value with decrease in wavelength. The MAC values reported here are analogous with the field measurements of BrC over the tropical Indian Ocean (Srinivas and Sarin, 2013). The MAC values obtained for wood pyrolysis are unusually low compared to other wood types examined earlier (Chen and Bond, 2010). Such low values were also observed for humic like substances in fine fraction of biomass burning aerosols (Hoffer *et al.*, 2006). It asserts that properties of OC aerosols are source specific.

Case 1 (Ramped temperature): Comparison of MAC values for wood and dung cake reveals that emissions from dung cake results in particles having higher MAC. The trend observed for k values is reflected in trend for MAC as well. The MAC values for wood emissions in temperature range $150^\circ\text{C} < T < 250^\circ\text{C}$ is higher compared to other two temperature ranges as shown in Fig. 3(a). For dung cake, MAC for particles emitted in temperature range $150^\circ\text{C} < T < 250^\circ\text{C}$ is comparable to that of $250^\circ\text{C} < T < 380^\circ\text{C}$. The results for dung cake are plotted in Fig. 3(b).

Case 2 (constant temperature): Wavelength dependent MAC for wood and dung cake is plotted in Figs. 3(c) and 3(d) respectively. MAC values for the wood generated OC aerosols emitted at temperature 210°C are comparable to high temperature pyrolysis at 380°C . It shows that higher wood temperature does not invariably means emission of higher light absorbing particles. This is in contrast with that reported by Chen and Bond (2010). For dung cake, MAC values for particles emitted at temperature 210°C are found to be less, compared to 380°C pyrolysis emitted aerosols. The MAC decreases with increasing wavelength for both wood and dung cake as seen for ramped temperature as well. The MAC values for the OC aerosols from dung cake were twice that of the OC aerosols from wood.

It is evident from the Fig. 3 that sudden exposure to heat for wood releases particles having high MAC values thus

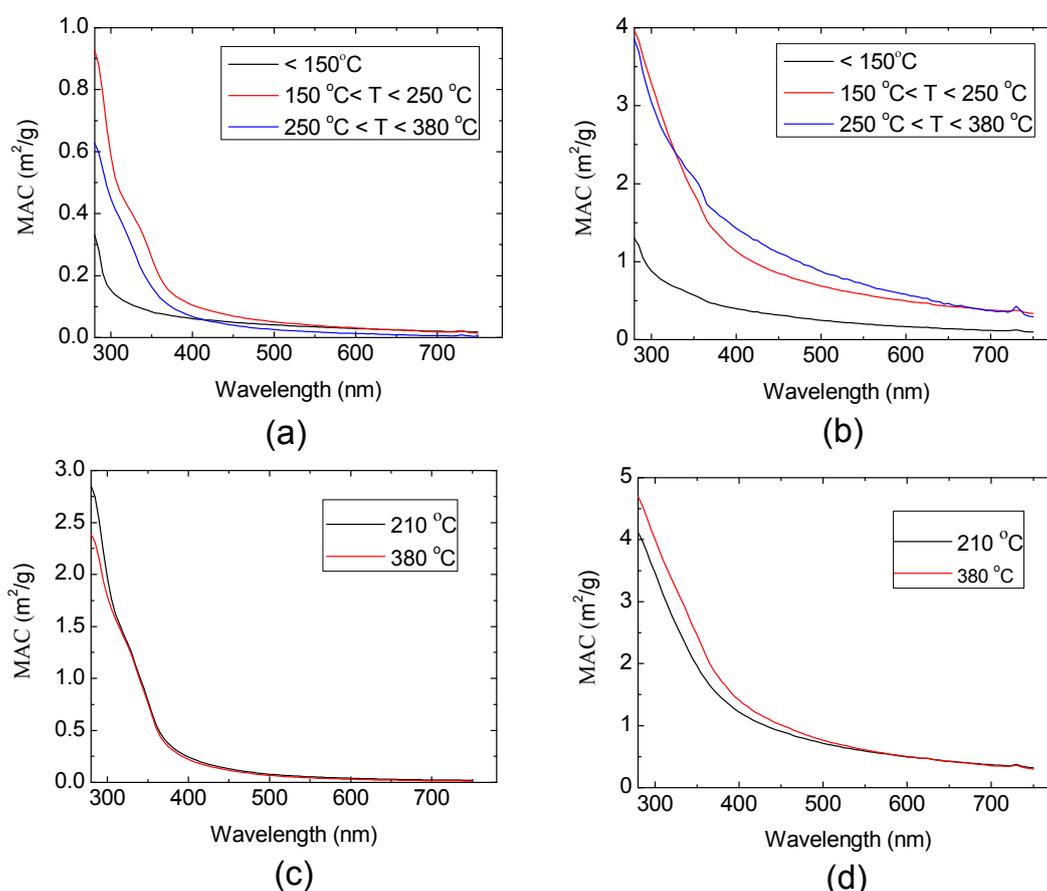


Fig. 3. Wavelength dependent MAC values obtained from Mie calculations for different combustion conditions. Case 1 (Ramped temperature) - (a) Wood (b) Dung cake and Case 2 (Constant temperature) - (c) Wood (d) Dung cake.

Table 3. AAE values obtained for different temperature and wavelength ranges.

Temperature	Wood (<i>Magnifera Indica</i>)			Dung cake		
	UV range (280 nm– 400 nm)	Visible range (400 nm– 750 nm)	Whole range (280 nm– 750 nm)	UV range (280 nm– 400 nm)	Visible range (400 nm– 750 nm)	Whole range (280 nm– 750 nm)
T < 150°C	4.04	1.94	2.24	3.12	2.18	2.32
150°C < T < 250°C	6.30	2.89	3.79	3.70	1.84	2.38
250°C < T < 380°C	6.67	4.06	4.74	3.76	2.41	2.41
210°C	7.28	3.89	5.05	3.60	2.03	2.49
380°C	7.14	4.43	5.44	3.51	2.34	2.77

more absorption (constant temperature), compared to that of slow increase in heat exposure (ramped temperature). For dung cake such a phenomenon is not observed as MAC values for dung cake generated OC aerosols are more or less similar with respect to heat exposure rate. This shows that the optical characteristics of OC aerosols emitted from dung cake are weakly associated with pyrolysis conditions, which is not the case for wood as a source. The MAC values obtained for the OC from dung cake were significantly larger compared to that of OC from wood. Therefore, dung cake pyrolysis generated more light absorbing OA than wood pyrolysis. The MAC values for 210°C and 380°C at different wavelengths are compared to other works in Table 2.

Absorption Angstrom Exponent (AAE)

AAE was determined by performing a linear regression of $\ln(\text{MAC})$ against $\ln(\lambda)$ through the valid wavelength range for each sample ($280 \text{ nm} < \lambda < 750 \text{ nm}$). The values of AAE for the OC from biomass pyrolysis were greater than 2. This is comparable with the values for acetone extractable OC reported earlier (Kirchstetter *et al.*, 2004). AAE value greater than 2 is attributed to presence of BrC (Laskin *et al.*, 2015). The results for AAE values obtained for both cases are displayed in Table 3. It is clear from AAE values that BrC aerosols have strong spectral dependence in UV range as compared to that of the visible range. The AAE values in Table 3 and absorption spectra in Fig. 3 for wood pyrolysis experiments indicate that there is strong change in absorption throughout UV light, and much flatter within the visible range. This is different for the BrC from dung cake pyrolysis whose absorption spectra are more consistent throughout the entire spectrum as indicated by their AAE values.

Case 1 (Ramped temperature): AAE values for wood samples were found in range of 1.76 to 4.28 and for dung cake this ranged from 1.87 to 2.18. For wood samples, AAE value increases as the temperature range increases. This implies spectral dependence of absorption increases as the temperature of the range specified increases for the case of wood. For dung cake generated aerosols, AAE values do not show significant difference with temperature. The AAE values for UV range is higher than that of visible, for all the temperature ranges considered. The pyrolysis aerosols have strong spectral dependence in UV range as compared to that of visible range, which is the feature of BrC aerosols.

Case 2 (constant temperature): Higher generation

temperature seems to generate particles having higher AAE values for both wood and dung cake. The BrC from wood pyrolysis showed higher spectral dependence of absorption compared to the BrC from dung cake. The average AAE value found for wood pyrolysis aerosol emissions was 5.2 and for dung cake it was 2.6.

CONCLUSIONS

Laboratory scale experiments were performed for sampling of OC aerosols generated during pyrolytic combustion of wood (*Magnifera indica*) and dung cake. The OC was extracted using methanol. The absorption study of extracts was conducted using UV-Visible spectrophotometer. The OC extracts had a strong spectral dependence of absorption. This spectral dependence of absorption was quantified in terms of AAE. The wavelength dependence of aerosol absorption as measured by AAE was greater than 2 for almost all the samples. This is taken as signature for presence of BrC. The derived imaginary part of refractive index increased with decreasing wavelength in the region analysed (280 nm–750 nm). Light absorption for the BrC from dung cake showed minimum correlation to pyrolytic combustion conditions, which was not observed for the BrC aerosols from wood pyrolysis. The dung cake pyrolysis generated BrC aerosols having the MAC values ranging between 4.4 and $0.30 \text{ m}^2 \text{ g}^{-1}$ (280 nm–750 nm). The BrC MAC values for wood pyrolysis experiments ranged between 2.61 and $0.02 \text{ m}^2 \text{ g}^{-1}$ (280 nm–750 nm). It is also concluded that major BrC aerosols are emitted above 150°C for the both wood and dung cake samples considered.

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