Woody Debris Disposal by Fire

Combustion Efficiency and Black Carbon

Why Air Curtain Burners should be used to help reduce Greenhouse Gas emissions

Introduction

Greenhouse Gas emissions from anthropogenic (man-made) sources are undesirable under any circumstance. The most critical gases are carbon dioxide (CO_2), Methane (CH_4) and Black Carbon (C) where Black Carbon or BC is actually an aerosol, a solid rather than a gas, as are the other two examples. We perceive the negative effect of Greenhouse Gases, especially the much mentioned CO_2, by their apparent harmful effects they have on earth, and the atmosphere near the earth as "Global Warming". There is an ongoing controversy as to what constitutes Global Warming, but what is certain is the detrimental effect that Black Carbon has on the alarming rate by which the polar ice caps and glaciers have melted in recent decades, as well as the undisputed fact that Black Carbon contributes in some recognizable way to a warming of the earth which could well be related to Global Warming by converting sunlight to infrared heat while the particles reside in the atmosphere relatively close to earth.

As Black Carbon is a byproduct of the combustion of fossil fuel, biofuel or biomass (woody debris, vegetative waste, etc.), optimizing the combustion process will reduce the amount of Black Carbon released. Black Carbon is the same as soot, black smoke or particulate matter (PM) from a burning process. Furthermore and importantly, as Black Carbon is not a gas, but a solid substance that is temporarily suspended in the near atmosphere, it has the tendency to fall back (gravitate back) onto earth in a relatively very short time span, often as short as months and weeks which translates into near immediate positive results on earth, once the black carbon emissions are effectively mitigated.

Black Carbon and Biomass Combustion

Black Carbon matter is carbon (C) in form of smoke, soot, or particulate matter (PM) from a combustion process. BC results from the incomplete combustion of fossil fuels, biofuel, or biomass, including wood waste and agricultural green waste. The black exhaust from a truck, bus, locomotive, airplane or marine vessel is Black Carbon from the incomplete combustion of Diesel (fossil) fuel. The smoke from a wood stove, camp fire or forest fire is pure Black Carbon from biomass burning. Most of the Black Carbon is anthropogenic in nature which means it derives from human activity. BC from a forest fire or volcano would not be anthropogenic.

The cleanliness of a burning process of waste material is often gauged by the opacity level of the effluent (smoke) where 100% would be total black smoke and 0% would be none. It must be noted that in the field, the assessment of visible smoke or PM by "smoke reading" may be somewhat skewed by some dust, water vapor (steam) or fly ash particles emanating from the combustion source itself or its immediate surrounds.

If an incomplete combustion has an undesirable effect, then a "complete" combustion of at least wood waste or biomass should be acceptable or actually desirable. But how can we achieve that? A basic understanding of the make-up of wood and what happens when it burns will help shed light on this question.

Byram[1] suggested a chemical model for wood as $C_6H_9O_4$, an (organic) molecule mainly made up of carbon, hydrogen and oxygen.

In case of an ideal combustion, the only resultants from the burn process are CO_2 and H_2O that is Carbon Dioxide and gaseous water:

$$4(C_6H_9O_4)+Heat+25(O_2)=24(CO_2)+18(H_2O)$$

From a practical view point this means that, if wood were burned with just the right amount of heat and oxygen, then there would be no emissions of smoke or Black Carbon, as well as no such gases as Carbon Monoxide or organic gases, such as Methane, only CO_2 and H_2O would escape.

Let us examine what the circumstances of an incomplete combustion are: If the amount of available oxygen is less than perfect and decreases and/or if the available heat energy is reduced, then CO (carbon monoxide), CH_4 (methane), and NMHC (non-methane hydrocarbons) are produced. Additionally, unburned carbon particulates escape with the produced hot gases upwards into the atmosphere as smoke, soot or Black Carbon. The worse the combustion efficiency, the more BC or black smoke is released along with the carbon contained in organic gases. Of course, only the Black Carbon (BC as PM) is visible to the naked eye.

Combustion Efficiency (CE) is the quotient or ratio of the carbon in the released CO_2 compared to the carbon contained in all of the emissions from combustion or the totality of emissions, including PM:

$$\frac{\mathbf{CO_2}}{\mathbf{CO_2}+CO+CH_4+C_2H_2+C_2H_4+C_2H_6+\ldots+C}$$

Where, in the divisor after the CO_2 and CO, $CH_4+C_2H_2+\ldots$, etc. represent the total of the carbon contained in organic gases, and the C at the end the carbon in particulate compounds (called BC, PM, soot or smoke).

If the combustion were perfect, the only gas produced would be CO_2, and the combustion efficiency (CE) would be 100%, because $CE=CO_2/CO_2=1$ or 100%.

As the quantity of carbon (C or actually BC) plus the carbon of the organic chemical compounds, such as Ethyne (CH_2H_2), being the yield of incomplete combustion, increases, the CE in turn decreases. The lower the CE, the more smoke, PM or Black Carbon is released along with the other gaseous compounds. An acceptable clean burn would have a CE in the very high nineties, such as 98% or 99%.

There will always be a small amount of ash residue, even with perfect combustion, resulting from components in the plant materials that do not combust at all and remain solid. This residual wood ash has a beneficial value, as it is high (30%-40%) in calcium carbonate ($CaCO_3$) and includes, among a few other minor components, some potash. Even though nitrogen is absent, the ash has a value as a fertilizer or rather a soil amendment. Due to its high pH, it acts as a liming agent and can be used to deacidify soil or soil material used as a daily landfill cover at landfills.

In the field, a quick method to determine the combustion efficiency is by "smoke reading" or estimating the opacity of a burn event. A perfect CE of 98% to 100% would equate to an opacity reading of 5% to 6%. To put this in perspective, PM opacity of 7%-8% is barely visible to the naked eye and appears as near perfect. For example, the US-EPA sets the maximum PM opacity limit for an air curtain FireBox burning biomass in full operation at 10%.

Sources of Black Carbon Released as "Greenhouse Gas"

Biogenic versus Non-biogenic Carbon

The basic make-up of Black Carbon is just that, Carbon, and it is the same whether anthropogenic or not, whether emitted for example, from a bus, factory chimney, forest fire or agricultural burn. The reduction of emissions from any such sources will have a positive result and reduce the harmful effects of Black Carbon as a Greenhouse Gas. All sources should be vigorously examined and limits on emissions imposed, limits that are scientifically, economically and socially reasonable and achievable.

Even though all Black Carbon is basically the same from a chemical perspective, there is one significant and very important difference between the perceived overall harmful effect of two distinct classifications of sources: BC from the combustion of hydrocarbons, such as coal or petroleum and, on the other hand, "biogenic" Black Carbon from the combustion of biomass, such as wood waste, forest slash, or agricultural green waste. We have shown that especially at ideal combustion efficiency (CE) of 100%, a large amount of CO_2 is released from any combustion process. CO_2 is classified as a serious Greenhouse Gas by

the Intergovernmental Panel on Climate Change (IPCC) and deserves serious attention. It is for this reason that it is important to understand the significant nature of biogenic CO_2.

The adjective biogenic is derived from "biogenisis" meaning the production of a (new) life form or a chemical compound by a living organism. The original Greek word for biogenisis stands for 'life source" or "life origin" and described the (philosophical or theological) notion that one life form can only be derived from another life form or living being and, of course, it did not include the modern scientific interpretation of biogenic organic or inorganic matter that is a chemical compound. An example of a chemical compound that is biogenic is carbon sequestered in some form in a plant, such as woody biomass, no matter whether the plant is alive or not.

This carbon was stored in the plant (i.e. tree) for a relatively short period of time over the life of the tree or other plant and, through the natural biogenic process of photosynthesis, this carbon was absorbed from the CO_2 in the air surrounding the plant in exchange for which oxygen was released, oxygen which is needed to make most life on earth possible. The carbon was sequestered in the wood while the tree was alive and growing, and the same carbon was returned to the atmosphere in the combustion process, making this burn process "carbon neutral" or giving it a net zero carbon footprint.

The biomass burning process does not free up any CO_2 that did not already exist in the atmosphere near earth prior to the tree's life cycle. Its biogenicity stems from the fact that the carbon of the released CO_2 molecule was taken from the surrounding CO_2 while the plant was alive at which time it was converted into carbon (sequestered in the plant) and simultaneously, life sustaining oxygen was released into the atmosphere.

In contrast thereto, the carbon that is converted into CO_2 from combustion processes of hydrocarbons, such as petroleum or coal was sequestered deep in the earth for millions of years. It would not escape naturally ever at any appreciable rate, and combusting these hydrocarbons in Diesel engines or turbines, etc. puts vast quantities of additional CO_2 into the atmosphere as a pollutant and true "Greenhouse Gas". This CO_2 is non-biogenic.

Finally, if biomass, for example, trees in the forest killed by beetles, were allowed to decompose or rot naturally, large amount of biogenic CO_2 would also be released, though some carbon would be sequestered in the soil, and that is a good thing; but additionally CH_4 or Methane would be released in fairly large quantities (as is sadly also the case with routine commercial composting or useless mulch piles gone septic). Methane is a Greenhouse Gas that is much more harmful than CO_2, because methane is over 20 times more effective in trapping heat in the atmosphere than CO_2 over a 100-year period[2].

Doing nothing at all with massive amounts of woody debris, including chips and mulch at landfills, on woodlands and forests is certainly not a better idea with respect to potential Greenhouse Gas emissions. This issue is actually of great concern, as presently there are millions of dead trees killed by beetle infestations slowly decomposing in North America, if not dealt with by prudent disposal technologies in due course.

The Nature of Black Carbon and Its Effects on Earth

Black Carbon is a solid carbon particle, however small it may be. It is considered an aerosol due to its very small size, as it remains suspended in the air for some time, and it is carried by air movement or turbulence into higher layers of our atmosphere. Because BC is a solid element and not a gas, it eventually gravitates back to earth and falls onto its surface throughout the world.

While suspended in the atmosphere, the carbon particles absorb sunrays and release infrared rays as heat that raise the temperature of the layers in the atmosphere where they reside thus contributing to the warming of the planet. As they fall back onto earth, the Black Carbon causes reduction of "albedo", the ability of an object or particle, such as snow or ice crystals, to reflect sunlight (heat). When BC is deposited on snow and ice, it accelerates the melting of the snow, ice, or glaciers in areas where typically no appreciable reduction of frozen mass occurs naturally. The perma-snow and perma-ice regions of the polar ice caps and the snow caps of the Himalayan Mountains are examples. The BC on the ice or snow absorbs heat from the sun and transfers it to the ice or snow surface thereby speeding up the melting process. Naturally, the ice crystals, because of their albedo, reflect a large amount of the heat from the sun's rays back into the atmosphere, and this keeps the ice crystals from melting rapidly or melting at all.

Black Carbon is a potent climate forcing agent, estimated to be the second largest contributor to Global Warming after Carbon Dioxide (CO_2). Because BC remains in the atmosphere only for a few weeks to a few years (depending on its particle size), reducing Black Carbon emissions may be the fastest means of slowing climate change in the near-term. CO_2 in contrast has an atmospheric lifetime of more than 100 years. Reducing CO_2 emissions today would have a positive effect on earth a hundred years in the future, and today's population would never benefit from its CO_2 mitigation efforts.

Concentrating on the immediate reduction of Black Carbon is a high priority for the IPCC[3]. As fossil fuel or biofuel combustion releases a high level of BC, Greenhouse Gas mitigation actions are first directed at sources that use fossil fuels, such as marine vessels, trucks, buses, locomotives, aircraft, power plants and other fossil fuel powered systems. The burning of (woody) biomass can be significantly curbed in forestry and agricultural industries, but not easily relative

to certain other sources, such as the myriad of wood stoves and wood cooking implements in developing countries and, of course, the periodic forest fires some of which are of gigantic magnitude and gaseous emissions from volcanoes.

Environmentally Responsible Reduction of Wood Waste

Greenhouse Gas mitigation efforts are primarily directed at regulating the emissions from engines and combustion facilities that consume fossil fuels and not enough concern is directed at controlling planned or deliberate open pile or broadcast burning of biomass or woody debris in forestry, agriculture and land clearing. Little can be done to reduce emissions from natural wildfires and from wood stoves in developing countries. Much can be accomplished, however, by banning deliberate open burning of wood waste in forestry, agriculture and even industrial wood processing in favor of prudent technology: the use of air curtain burners.

Air curtain burners or FireBox burners[4] are machines designed as pollution control devices to overcome the detriment of open (pile) burning: the release of excessive amounts of Black Carbon or smoke. Air Curtain FireBoxes by virtue of their design achieve nearly 100% combustion efficiency and by definition, they release almost no Black Carbon[5].

They release CO_2, but as we have shown above, the carbon in that CO_2 is biogenic as it was previously, that is during the life of the tree or plant, converted from surrounding CO_2 into carbon in the wake of which oxygen was freed. The biomass burning in the air curtain burner, therefore, is carbon neutral. No additional CO_2 was turned into a Greenhouse Gas that was not already present in the surroundings. This is not the case regarding the CO_2 escaping the exhaust of a Diesel powered bus, for example, where CO_2 is released that was not present prior to fueling the combustion.

Air Curtain Burners not only eliminate wood waste in an environmentally responsible way, but also efficiently and cost effectively. They are portable, easy to operate and affordable and less expensive to operate, compared with any other disposal method for wood waste that could be an alternative to open burning of biomass. They meet applicable US EPA regulations and have been used for many years worldwide. Some FireBox models even convert some of the BTU content of the biomass from the combustion process into electricity that can be sold back to the power company or used on-site[6], or the energy could be used to heat a greenhouse or shop building. No special pre-processing of the wood waste is required, such as chipping the waste to a specified size, a mandatory requirement for traditional stationary biomass cogeneration or biomass-to-energy plants. Find more information here http://www.airburners.com/principle.html on air curtain burner technology.

Summary

Carbon Dioxide and Black Carbon (smoke) are understood to be undesirable Greenhouse Gases and efforts must be implemented worldwide to reduce the emissions of them. Black Carbon is the result of incomplete combustion of fossil fuels and (woody) biomass. Carbon Dioxide is released by any combustion process.

Carbon Dioxide remains in the atmosphere for more than 100 years whereas Black Carbon stays there for only days or a few weeks. Curbing emissions of Black Carbon would have a very near term effect on earth and would slow down the melting of the polar ice cap and glaciers in high mountain ranges and have some positive effect on Global Warming.

The sources of Black Carbon are Diesel trucks, ships and similar devices that burn fossil fuels, as well as the combustion of biomass. Most such sources emit BC, because of an inherent incomplete combustion process yielding low combustion efficiency. The burning of woody debris is a very large contributor worldwide to the overall emissions of Black Carbon. Although not all burning of biomass can be controlled, there will be wildfires and cooking stoves in many areas of the world, the BC from widespread deliberate or planned woody debris burning for agricultural clearing and in forestry can be reduced by modern technology.

Air curtain burners are based on such technology, because they burn wood waste with nearly 100% combustion efficiency in an economical manner. Wherever practical, all open pile burning should be banned in favor of the use of air curtain burners. For more information, access www.airburners.com. Air curtain burners in forestry, agriculture and land clearing release biogenic Carbon Dioxide from near 100% combustion efficiency of the burn process, making this wood waste disposal process by fire carbon neutral and very environmentally friendly and desirable[7].

By N. Fuhrmann, December 2010/March 2017

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