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A REVIEW OF STANDARDS RELATED TO BIOMASS COMBUSTION

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ABSTRACT Different countries have set up various regulatory frameworks to ensure excellent air quality for general human health. The concentration of particulate matter (PM) per unit of air volume is used to assess air quality. PM_{10} is defined as all particles with a diameter smaller than 10 micrometers (µm). The acceptable levels of PM_{10} established by the European Commission are less than 20 µg/m³ annually and less than 50 µg/m³ daily. The rules are less precise when it comes to assess the amount of PM that can be emitted from a furnace's chimney. Quebec province allows up to 340 mg/m³ of PM for large furnaces (> 3 MW) and 600 mg/m³ for smaller furnaces (< 3 MW); it allows burning wood products but forbids all other biomasses (straw, stover, grass). The City of Vancouver has stricter emissions standards for PM: 50 mg/m³ for large furnaces and 35 mg/m³ for smaller furnaces. The large difference is explained because most furnaces in Quebec are used in rural areas whereas the City of Vancouver, a densely populated area, must control emissions at the source. A universal standard on combustion emissions is not feasible because of different socio-economic conditions and population density. However, furnaces should emit levels of PM which decrease as the surrounding area population concentration increases. Technology such as chimney height, bag filters, multicyclones, and precipitators may help to meet stricter regulations.

Keywords: Biomass combustion, Particulate matter, Air quality standards, Emissions.

INTRODUCTION Biomass is a renewable energy source whose increased use could reduce the consumption of fossil fuels in Canada and elsewhere (Satyanarayan, 2010). Biomass may be converted into energy by various pathways that are more or less complex. Combustion remains an interesting pathway because it is readily available from small to large scale, with a wide range of furnace technologies adaptable to various sources of biomass. Legislation related to combustion is generally based on the type of pollutant released in the atmosphere. Some biomasses are relatively clean, such as wood pellets, and their atmospheric emissions can be easily limited or filtered while others require more sophisticated technologies to limit emissions (Schmidt, 2009).

The monetary value of a biomass fuel tends to increase with its heat output, the cost of alternative fuels and the relative cleanliness of its emissions (Wit, 2009). The type of biomass will influence the technology used for processing, storage, handling and combustion. Figure 1 illustrates a complete biomass boiler system that uses chipped wood biomass as a fuel source.

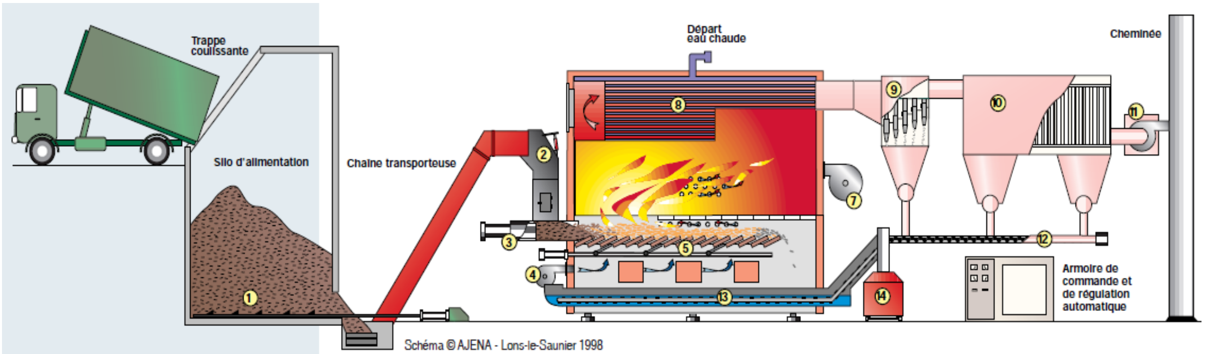

Figure 1. Biomass boiler process (Source: Ajena, 2010). (1) Storage bin and moving floor; (2) Pre-combustion storage hopper with fire protection; (3) Push-type auger for biomass fuel injection; (4) Primary air fan; (5) Mobile grate combustion chamber; (6) Gas combustion chamber; (7) Secondary air fan; (8) Flux gas heat exchanger; (9) Multi-cyclone dust filter; (10) Bag filter; (11) Smoke stack; (12) Dust removal auger; (13) Ash removal auger; (14) Ash container.

Standards vary from country to country and even within a same country where each province or state may have its own local legislation (CCME, 2000). In general, combustion guidelines are more stringent in Europe and in densely populated areas. This paper reviews combustion standards that are applied in Canada, especially in the province of Québec, in the USA and in Europe. Comparison of different legislations can be helpful to develop more general standards with broader application.

Combustion standards can be expressed in different ways, but the most common measures are an emission factor per unit of volume of exhaust gas or per unit of energy. Combustion standards are often presented with the following units: mg/m^3, $\mu g/m^3$, ppm, ppb (Table 1). The size of particulate matter in combustion exhaust gases is an important characteristic because of the relationship with respiratory health problems. The environmental protection agency (EPA) in the United States of America is concerned with particles that are 10 micrometers (µm) in diameter or smaller. These particles generally pass through the throat and nose and enter the lungs. A comparison of different particle sizes is made in figure 1. The EPA identifies particle pollution in two categories:

-"Inhalable coarse particles" ($PM_{10-2.5}$), such as those found near roadways and dusty industries. These particles are larger than 2.5 µm and smaller than 10 µm in diameter. The EPA recommends that the existing standards which group all particles smaller than 10 µm be replaced by this sub-group ($PM_{10-2.5}$) to consider specifically all particles between 2.5 and 10 µm.

-"Fine particles" ($PM_{2.5}$), such as those found in smoke and haze, are 2.5 µm in diameter and smaller. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

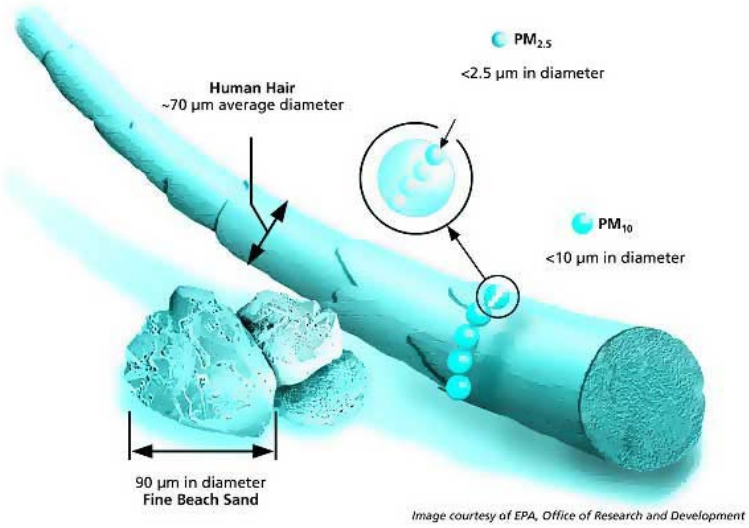

Figure 2. Particle pollution image (Source, EPA, 2010)

METHODOLOGY

Environmental advantages of biomass combustion. The utilization of biomass for power and heat production offers the advantage of a renewable and CO_2 neutral fuel (Demirbas, 2003). With the hypothesis that CO_2 emitted during combustion is absorbed by the energy crops during their growth cycle, heating with solid biomass fuels would enable a reduction in greenhouse gas emissions of up to 90% when compared with fossil fuels (Segrest, 2002). Thus, on a CO_2 emissions basis, biomass combustion can be considered neutral and a negligible factor in global warming.

The carbon cycle of biomass for energy is very short when compared with fossil fuels (a few years versus millions of years). Moreover, biomasses that decompose in the natural environment will return the same amount of CO_2 as combustion into the atmosphere, but over a prolonged period of time at a slower rate. Also, biomass heating is not an important contributor to acid rain because most biomass fuels have very low sulphur content (Environment Canada, 2010). The boilers used must be well maintained and adapted to the type of biomass fuel that is burnt in order to limit the emission of fine particles that contribute to the formation of smog in densely populated areas.

Carbon credits (CO_2). The interest in assessing greenhouse gas emissions (CO_2) is to compare biomass with fossils fuels commonly used today. If properly grown and managed, biomass does not contribute to climatic change because it absorbs the same amount of carbon during growth as it releases when consumed as a fuel. Thus, switching from fossil fuels to renewable biomass is a powerful way to reduce atmospheric CO_2 emissions that can be traded as carbon credits (Wahlund, 2003).

Carbon credits may become a major factor in investment decisions in the future. As an example, in Europe, where emission reduction targets are more stringent than in Canada, carbon trading has grown and the cost of a ton of CO_2 emission credit steadily increased from 2000 to 2005 (EU ETS, 2005).

Environmental regulations and constraints. Biomass combustion systems can involve additional costs and requirements such as fire insurance, meeting air quality standards, ash removal procedures and general security (Papadopoulos, 2001). When installing a new biomass boiler, the unit must meet environmental standards and regulations specific to biomass combustion. Theses regulations can be of national, provincial or municipal order and are often cumulative.

Furthermore, the combustion of biomass is often linked to the formation of pollutants which must be attenuated. The formation of pollutants is in most cases linked to the following three reasons:

1. Incomplete combustion which can lead to the formation of unburned pollutants such as CO, slag, condensable organic matter (tar), as well as polycyclic aromatic hydrocarbons (HAP). The formation of HAP is intimately linked to the presence of CO. It is therefore imperative to have complete combustion to minimize these atmospheric pollutants.
2. Pollutants such as NO_x and particulate matter are due to natural compounds of fuel such as N, K, Cl, Ca, Na, Mg, P and S.
3. Biofuels can be carriers of contaminants such as heavy metals or chlorine, which in turn can lead to the emission of heavy metals, HCl, dioxin and furan.

The combustion of biomass emits high concentrations of NO_x when compared with the combustion of natural gas and light oil. Furthermore, the combustion of biomass contributes to the increase of fine particles (PM_{10}), ozone and NO_2 in ambient air. According to the procedure "The Ecological Scarcity Method" developed by the Federal Office for the Environment (FOEN) of the Swiss government, it is possible to determine the life cycle analysis (LCA) of a modern wood combustion system (Frischknecht et al. 2006). According to this method, it was determined that 38.6 % of the environmental impact of such systems is due to NO_x, 36.5 % to PM_{10}, and only 2 % to CO_2. The remaining 22.9 % corresponds to a series of other pollutants. The conclusions of this analysis showed that it is important to improve the supply chain of biomass so that total environmental impact is as negligible as possible. These conclusions are only valid when the biomass combustion is well controlled. In the case of poor combustion conditions, the negative environmental impacts are superior to that of natural gas. The levels of atmospheric pollutant emissions vary according to the type of fuel that is burned (Table 6).

A concern voiced regularly in Europe refers to the combustion of biomass and its levels of fine particles (PM) that can have severe health effects in the general population. According to the World Health Organization (WHO), fine particulate matter (PM) is linked to numerous cardiovascular and respiratory diseases and affects both developed and underdeveloped countries in urban areas (WHO, 2005). The WHO recommends that levels of PM remain below specific thresholds (Table 2).

According to the WHO, diesel engines and biomass combustion are the two main sources of PM in the atmosphere. It is therefore imperative that combustion of biomass be performed while limiting the production of PM, especially in urban areas.

Rules and regulations applied in Quebec. In Quebec, the use of biomass fuels is legislated according to *le Règlement sur la qualité de l'atmosphère* (c. Q-2, r.20) which is part of the *Loi sur la qualité de l'environnement* (MDDEP, 2009). Regulations concern all activities and equipment that may change the air quality. The regulation is a general guideline for the entire province of Quebec. However, municipalities are free to adopt more restrictive regulations. At the municipal level, information can be confusing because of regulatory differences regarding biomass combustion.

According to the provincial law, the installation or use of a wood combustion unit smaller than 3000 kW (10.2 MBTU/h) does not require an authorisation certificate. However, smaller units which burn products other than wood such as incinerators and industrial ovens for residual dangerous materials require a certificate for all power levels.

A new boiler for wood combustion with a capacity inferior to 3000 kW must maintain particulate matter emissions below 600 mg / m³. When the boiler has a capacity exceeding 3000 kW, the emissions of PM must not exceed 340 mg / m³. This standard applies only to wood combustion. Agriculture biomass such as switch grass, miscanthus, corn stover, etc., can be burned only in furnaces equipped with a second combustion chamber. Moreover, the user must demonstrate with a series of tests that the non woody biomass (dedicated crop or agricultural residue) meets the applicable air quality standards in Quebec (Gagné, 2010). As of April 1st 2010, the Canadian standard association (CSA) standard CSA B415 came into application in Quebec, thereby modifying the existing emission standards. The revised standard is applicable to smaller capacity boilers, 2000 kW (6.8 MBTU/h) and limits emissions to 137 mg/m³. Table 3 details Quebec air quality regulations in force in 2009.

Rules and regulations applicable in Quebec (Municipal administration). The provincial law allows municipalities to establish more stringent local regulations as long as they are not contrary to the original goals of the law. All provincial laws are continuously updated and available on the National Assembly Website: http://www.assnat.qc.ca/fra/39legislature1/Projets-loi/Publics/index.htm. Municipal regulations are not continuously updated and it is necessary to contact each municipality before beginning a new combustion project. Local regulations can change more quickly than the provincial law because of simpler procedure at the local level. Promoters have the responsibility to obtain the information related to regulation, zoning, permits and other local requirements for new projects.

Comparison of regulations between provinces and countries. Table 4 is a summary of regulations regarding allowable emissions in various jurisdictions. In general, most jurisdictions recommend a PM_{10} concentration lower than 50 μg/m³. In several areas near industrial sites and near chimneys, higher daily maximum levels are tolerated. Table 5 details acceptable emissions factors directly emitted by chimneys for boilers in the City of Vancouver (Weilbach, 2005) and in the province of Quebec. Regulations in urban areas tend to be more stringent than those on a broad territory such as the province of Quebec.

CONCLUSION

Discrepancies exist between Canadian and provincial air emissions standards. The definition of what a biomass fuel also varies between provinces. Québec only allows the combustion of woody biomasses while most other jurisdictions in Canada define biomass fuel as all none contaminated biomass (including agriculture biomasses) as long as its combustion meets emission standards. The combustion of biomasses other than wood is allowed in Quebec according to certain determined conditions on a case by case basis which requires testing and certification by the Department of the Environment (MDDEP).

A more extensive study of current regulation across all jurisdictions would be useful to develop more uniform standards on the combustion of biomass. It may allow the development of national biomass fuel quality standards and help avoid the combustion of polluting and toxic materials.

Table 1. Units of particulate matter emissions.

mg/m^3	milligrams per cubic meter of gas at normal pressure and temperature
$\mu g/m^3$	micrograms per cubic meter of gas at normal pressure and temperature
Ppm	parts per million
Ppb	parts per billion

Table 2. World Health Organization recommendations regarding acceptable levels of fine and gross particulate matter (PM) in ambient air (WHO, 2005).

	Size of particles (µm)	Annual average (µg/m³)	24 hour average (µg/m³)
$PM_{2.5}$	< 2.5	10	25
PM_{10}	< 10	20	50

Table 3. Quebec air quality standards (MDDEP, 2009).

Nature of contaminants	Average value µg/m³	Average value ppb	Averaging Period
total suspended particulate	0-150		24 h
total suspended particulate	0-70		Annual
Dust fall	0-7.5 t/km²		30 d
Sulphur dioxide (SO_2)	0-1310	0-500	1 h
Sulphur dioxide (SO_2)	0-288	0-110	24 h
Sulphur dioxide (SO_2)	0-52	0-20	Annual
Carbon monoxide (CO)	0-34,000	0-30,000	1 h
Carbon monoxide (CO)	0-15,000	0-13,000	8 h
Ozone (O_3)	0-157	0-80	1 h
hydrogen sulphide (H_2S)	0-14	0-10	1 h
hydrogen sulphide (H_2S)	0-11	0-8	2 h
Nitrogen dioxide (NO_2)	0-414	0-220	1 h
Nitrogen dioxide (NO_2)	0-207	0-110	24 h
Nitrogen dioxide (NO_2)	0-103	0-55	Annual
Lead (Pb)	0-2		Annual

Table 4. Comparison of standards on particulate matter in breathable air between Canada, the United States of America, Europe and the WHO in 2009.

	Total suspended particulate ($\mu g/Nm^3$)	PM_{10}	$PM_{2.5}$
Canada (Provinces and Territories)			
Alberta	100	NA	30
British-Colombia	160-260	50	25
Prince-Edward-Island	NA	NA	30
Manitoba	NA	NA	30
Ontario	120	NA	30
New Brunswick	NA	NA	30
Nova Scotia	120	NA	30
Quebec	0-150	NA	30
Saskatchewan	120	NA	NA
Newfoundland & Labrador	120	50	25
North-West Territory	120	NA	30
Yukon	NA	NA	30
Nunavut	120	NA	30
United States	160-260	150	35
Europe	75	50	25
WHO	**NA**	**50**	**25**

Table 5. Comparison of particulate matter (PM) in chimney exhaut air from biomass combustion according to two regulations in Canada.

Capacity of Boiler	Total Particulate Matter, filterable (mg/m^3 of dry gas corrected at 12% CO_2) Boiler (new or existing) Applicable	Effective Sept. 1st 2010
Province of British-Colombia (Town of Vancouver)		
< 3 MW	50	35
≥ 3 MW	100	50
Province of Québec		
	Boiler (existing)	Boiler (new)
< 3 MW	600	600
≥ 3 MW	450	340

Table 6. Comparison of pollutant emissions based on energy capacity of combustion units smaller than 50 MW (industrial sector or district heating) (Source: CITEPA, 2003)

	Coal	Heavy oil	Light oil	Natural gas	wood
SO_2 (g/GJ)	618	819	95	0,5	20
NO_x (g/GJ)	160	170	100	60	200
VOC non-methane (g/GJ)	15	3	1,5	4	4,8
CO (g/GJ)	200	15	15	19	250
Dust (g/GJ)	100	48	3	0	100
Dioxins (ng i-TEQ* /GJ)	3,85	2,5	0	0	40
HAP (µg/GJ)	1920	5	0	0	8000

* I-TEQ stands for International Toxicity Equivalent

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