# MONITORING AND CONTROL OF PARTICULATE EMITTED BY BIOMASS BURNING USING SCRUBBER VENTURI

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Abstract. *The particulate material is one of the pollutants which cause most concern due to its harmful effects to people's health, mainly the particles smaller than 10 µm. Those fine particles are produced mainly by the combustion in engines and fuel burning at industrial plants. The monitoring and control of pollutants emitted into the atmosphere by industrial chimneys is a very important piece of information to a depolluting project. The aim of this work was to assess the performance of a Venturi scrubber in collecting fine particles. The sampling, concentration and the size distribution were done using a DataRAM 4 monitor.*

***Keywords:*** *Venturi Scrubber, Emission Control, Environmental Protection, Biomass, Fine Particle, Sugarcane*

## 1. INTRODUCTION

In this work, the focus is biomass burning as a source of industrial energy. Biomass refers to all kinds of organic matter that can be burned, decomposed or recycled, and can generate, directly or indirectly, some sort of energy. Hence, agricultural, urban organic and industrial plant residues such as sugarcane and cotton pulp as well as those from wood treatment processes can be used as fuel in biomass burners through biodigestion, pyrolysis, gasification or direct burning. (Arbex, M.A. *et. al*., 2004).

According to Grauer e Kawano, (2008), in Brazil, the present use of biomass as a source of energy has increased at plants, reaching around 30% of national energy needs as wood for direct burning at baker's shops and ceramic plants, vegetal coal for pig-iron refining in blast furnaces and alternative fuel in cement plants, fuel for chemical plants, vapour generation for electricity production, where sugarcane pulp and other residues such as those from wood are widely used, besides the sugar and ethanol plants and wood mills, as well as in wood panel production, saw mills and pulp and paper plants, since frequently, they do not require another kind of alternative fuel in their production processes, on the contrary, large amounts of that energy residue available in the market. Besides the direct burning, there are several other uses for wood residues, such as brickets and pellets, widely used in several countries.

In comparison with other oil based fuels, Grauer and Kawano (2008) show that using wood residues as a source of energy both electric and as vapour, boilers or kilns, present some advantages such as low purchase cost, no sulphur dioxide emission, the ashes are less harmful to the environment than those from fossil fuels, less equipment corrosion (boilers and kilns), less environmental risk and it is a renewable resource.

Despite the advantages that biomass presents for energy generation when compared with other existing sources, and its growing offer in the market as an alternative fuel some measures should be considered regarding its use, keeping in mind certain environmental issues involved, such as gaseous effluent discharge. When burning biomass, toxic gases such as carbon monoxide (CO), carbon dioxide (CO2), methane (CH4), other volatile organic carbon compounds and particulates are emitted (Fundação Estadual do Meio Ambiente – FEAM, 2009). The particulate formed contain a high ratio of carbon and hydrogen, known as Black Carbon. Those particles emitted interfere with the local, regional and global radiation due to its light absorption and reflection effects and it affects cloud formation (Langmann, *et.al*., 2009). The basic constitution of black carbon is a nucleus of elementary carbon, to which a large range of organic and inorganic toxic constituents may be combined, which increases the harmful effects of the emission of that pollutant.

Rebelatto (2005) reports that black carbon is also very important in climate studies; some of its effects are absence of clouds, reflection of sunlight back to space, and other effects due to specific properties of those particles, which influence climate changes, including the intensification of greenhouse effect. More attention should be placed on the emission of particulates smaller than 10um, which are called fine particulates.

Fine or respirable particles are well known for being dangerous to human health, especially to lungs and heart. The particulate material is one of the pollutants which cause most concern due to its harmful effects to people's health, mainly the particles smaller than 10 µm; it could also act as the vehicle for several chemical compounds such as sulphur dioxide, arsenic, selenium, etc. Those compounds are adsorbed on the surface of the particulate material or absorbed in it. The adsorbed compounds have different degrees of volatility or solubility in a liquid medium. The extremely volatile chemical compounds may go back to the gas state because the temperature of the alveolar environment is 37 °C, being transferred to the inner environment by diffusion. Some hydrosoluble compounds (sulphates, nitrates and some metals), may dissolve in the aqueous fluid of the alveolar surface, occasionally crossing the existing barrier in that region and reach the circulation. The smaller the particles, the higher the change of those components reaching the internal environment of the organism. Those fine particles are produced mainly by the combustion in engines, fuel burning at industrial plants, thermoelectric power plants, forest burning and in several stages of different industrial processes. Several studies show emission of those particles by domestic biomass heaters as well, in the shape of pellets, or even by those which still run on oil. Most of the plants emit that type of pollutant, which is the result of fuel burning and from several stages of the process. Even if we adopt cleaner technologies with new sources of energy, such as biomass, that pollutant will be present. Many industrial processes use mixed fuels formed by biomass, natural coal and vegetal coal among others, emitting pollutants with specific features which must be sampled, characterized and controlled. The monitoring and control of pollutants emitted into the atmosphere by industrial chimneys is a very important piece of information in order to assess the viability of a depolluting project and the description of the current environmental status of plants. Those data make up an important inventory for environmental adjustment and plant management. Companies, regardless of their size, should increasingly invest in the solution of their problems related to emission of pollutants in the environment. There are several kinds of equipment for particulate emission control, such as sleeve filters, electrostatic precipitators, scrubbers, among others.

Venturi scrubbers are a good option for companies which plan to efficiently remove 0.5 to 10 µm particles, besides the possibility of controlling gas emissions. This scrubber consists of a round or rectangular throat, divided into three parts: the converging section, where the gas stream enters the device and the gas is accelerated; the throat, where the gas velocity is the highest and where liquid is normally introduced and the diverging section, where the clean gas stream and droplets exit and at this section there is a partial recovery of pressure drop.

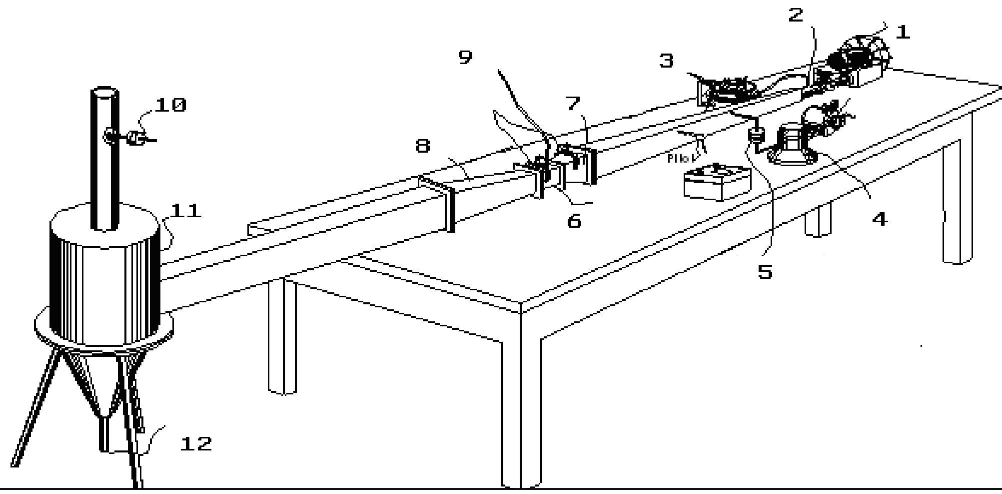
## 2. Purpose

The main goal of this work was to assess the performance of a rectangular throat Venturi scrubber in collecting fine particles suspended in a gaseous stream by means of an experimental assessment involving the basic phenomena which affect Venturi scrubber performance. For this pilot equipment, the particulate sampling was carried out isokineticaly. Stationary sources of two industrial processes were also monitored and sampled - a sugarcane ethanol plant and a mixed-fuel ferro-alloy plant (biomass and vegetal and mineral coal). Those plants have pollution control equipment, spray gas scrubbers and sleeve filters, respectively. At those plants, sampling, concentration and size distribution were carried out using DATARAM 4 equipment. Filho, F.A. et.al. (2009) and Filho, F.A. et.al (2010) showed gaseous emission data for the ferro-alloy plant in his studies.

## 3. MATERIALS AND METHODS

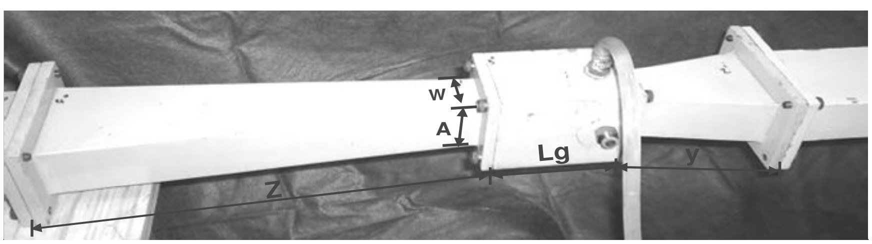
This work was carried out in three different stages: 1) Tests carried out using a model size pilot Venturi scrubber, 2) Monitoring tests carried out at an industrial chimney of an ethanol plant using spray gas scrubbers as control equipment and 3) Monitoring tests carried out at an industrial chimney of a ferro-alloy plant using sleeve filters as control equipment.

Figure 1 shows the test unit used to simulate an industrial chimney in line with a Venturi scrubber. The particulate material used was coal from burning coal chippings (forest biomass) used as fuel at paper and cellulose plants. The granulometric distribution of this pollutant was determined using a Malvern Mastersizer unit, with average diameter of 17.30 um. The sampling was carried out using an isokinetic probe system, comprised of a vacuum pump, flow meter, fine-wall nozzle and filters, placed at both ends of the Venturi scrubber. Fig.2 shows the rectangular Venturi studied. The variables involved in the assessment of the fractionary efficiency were: diameter (0 to 10 um), scrubber geometry (rectangular), number of liquid injection inlets (1 and 2), length of scrubber throat (Lg = 64, 90 and 117 mm), gaseous stream velocity (Vg = 20, 22 and 24 m/s) and liquid spray inflow and liquid flow at throat ($Q_L$ =0.4, 0.6 and 0.8 L/min.




| | | |
|---|---|---|
| 1 – Blower | 5 – Sampling probe (1) | 9 – Throat |
| 2 – Dust Inlet | 6 – Venturi scrubber | 10 – Sampling probe (2) |
| 3 – Dust feeder | 7 – Converging section | 11 – Cyclonic separator |
| 4 – Sampling system | 8 – Diverging section | 12 – Water outlet |

Figure 1. Test unit




| Symbol | Dimension (m) |
|---|---|
| A | 0.035 |
| Z | 0.280 |
| Y | 0.090 |
| w | 0.023 |

Figure 2. Rectangular throat Venturi scrubber

The particles were sucked by the probe placed at the center of the duct by a vacuum pump, and the particulate was collected in a filter medium inside the probe for analysis. The clean air was directed to the cyclone which separated droplets and air. In order to calculate the fractionary efficiency, the filter media with collected particulate were stored and sent to size distribution analysis in a Malvern Mastersizer unit. Then, once the granulometric distribution of the sample particulate at both ends of the Venturi scrubber had been determined, the efficiencies were calculated.

For the sampling carried out at plant chimneys, CETESB and ABNT standards were used, as described by Filho, A.F. (2009). The CONAMA ruling 03/90 sets parameters for industrial plants and states that the maximum concentration of emitted respirable particles is 150 µg/m³ within 24 hours, and that figure cannot be exceeded more than once a year. The DataRAM 4 monitor was used to measure concentration, temperature, humidity and particle diameter in real time. Fig.3 shows the sampling system for stationary sources.

The data from the ethanol plant and ferro-alloy plant chimneys are: diameters: 3.20 m and 2.5 m; gas temperature: 368 and 350 °C, gas velocity: 16.3 and 8.02 m/s, respectively. Fig.4 shows the DataRAM 4 model DR4000.

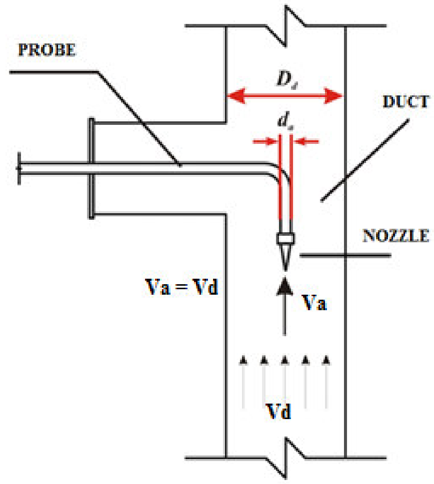



Figure 3 – Chimney and sampling probe


Figura 4 – Illustrative pictures of DataRAM 4 and peripherals

The DataRAM is a dual wavelength nephelometer, which incorporates two sources of light with peaks of 660 nm and another with 800 nm. The system operates with an active air sampling, while two light beams are symmetrically emitted at the same angle. Particle diameter reading is done by means of a ratio directly proportional to the amount of light emitted by the system and reflected by a regular scatterer, placed at 60° (+/- 18 °C) from the direct receptor of the emitted signals. The difference between the reflected and non-reflected signals generates the average aerodynamic diameter of the distribution of scattered particles in the sensitive region of DataRAM. The equipment is adjusted to collect a sample of particles ranging from 0.08 to 4 um. The system is able to detect, besides diameter, concentration, temperature and relative humidity of the particulate going through the system. The last two parameters, temperature and humidity, correct particle diameter due to the effect caused by ambient air. Concentration is measured by the amount of samples collected considering a 2.6 g/cm3 density, equipment standard and approximate reading of most particulates sampled in our tests. For tests inside the ducts, it was used an isokinetic probe, PM 2.5 particle selector and a heater in order to reduce particle humidity and a dual-pipe radiator to cool the gas at the analyser entrance.

## 4. RESULTS

### 4.1 – Model size Venturi scrubber pilot

Figures 5 and 6 show the fractionary efficiencies for one and two liquid flow inlets, respectively. These results were obtained for a gas velocity at throat of 20 and 24 m/s and throat length of 90 and 117 mm.

We noticed that even for Vg = 20 m/s, which would have less impact on the atomization of the liquid jet, we observed high efficiencies for particulates from 5 to 10 um, ranging from 95% to 98%, for one and two liquid flow inlets inside the throat. For 0 to 2.5 um particles, the collecting efficiencies were 75 to 94%, values for Lg = 90 mm. It is important to emphasize that, for two liquiq flow inlets, in all tests carried out, the efficiencies were higher and above 90%, considering that the liquid flow was the same, but distributed between two inlets.

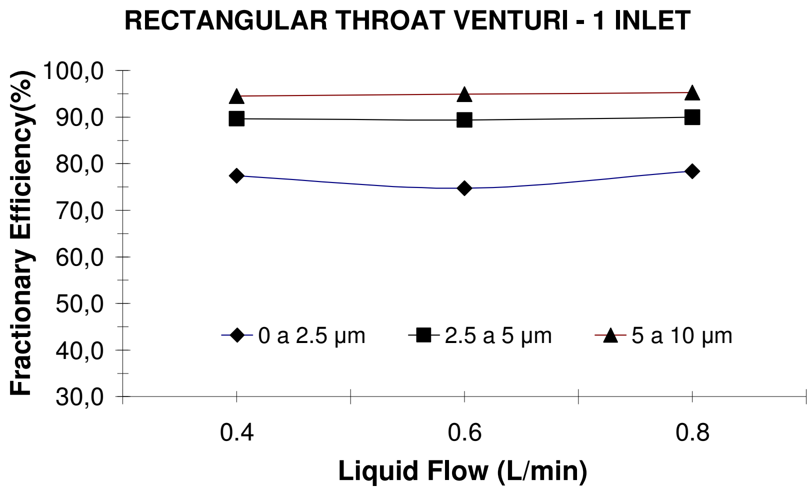



Figure 5 – Fractionary efficiency for Vg = 20 m/s, Lg = 90 mm
and one liquid injection inlet at throat

The fractionary efficiencies for Lg = 64 mm were higher than 75%; for Lg = 90 mm and gas velocities 22 and 24 m/s, they were 80%. For Lg = 117 mm and gas velocities 22 and 24 m/s, the results obtained for the fractionary efficiencies assessed were 85% and 90%.
It is observed that the best results were obtained for liquid flow of 0.6 and 0.8 L/min, higher gas velocities and longer throat. The uniform droplet distribution inside the throat, jet penetration up to central region and larger-sized droplets increased the fractionary efficiency.

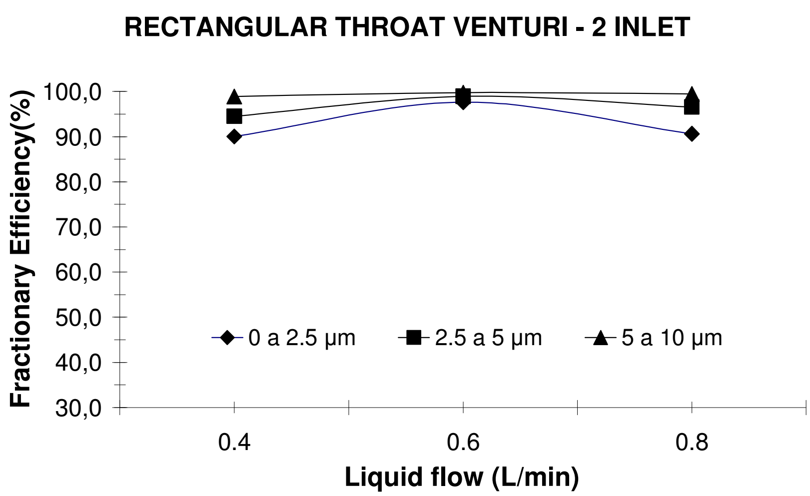



Figure 6 – Fractionary efficiencies for Vg = 24 m/s and Lg = 117 mm with two liquid injection inlets at Venturi throat

### 4.2 – Results for Sugar and Ethanol Plants and Ferroalloy Plants

Figures 7 and 8 show diameter distribution and average concentration of particles below 2.5 um, sampled using DataRAM 4 at the aforementioned plant chimneys. Three tests were carried out at each stationary source. We could notice a variation in industrial process during the analysis, which is due to the fuel feeding process. It is observed that the diameters emitted after the collection by the spray scrubbers were below 1 um, while for two tests, the diameters collected ranged from 0.1 to 0.2 um. As to the ferroalloy plant, it is observed that the diameters were slightly larger, ranging from 0.5 to 1.7 um, however, in both cases, the particles are fine and hard to collect.

To assess the concentration of particles emitted by the industrial processes considered, it is observed in figure 8 that the highest concentrations were obtained for the ethanol process, which uses a gas scrubber.
For the ferro-alloy plant, the concentration figures were clearly smaller. In this case, it was sampled the chimney of a kiln which has a sleeve filter fitted. It is fitting to emphasize that the spray scrubber under consideration is being assessed and undergoing variable optimization during its environmental inventory.

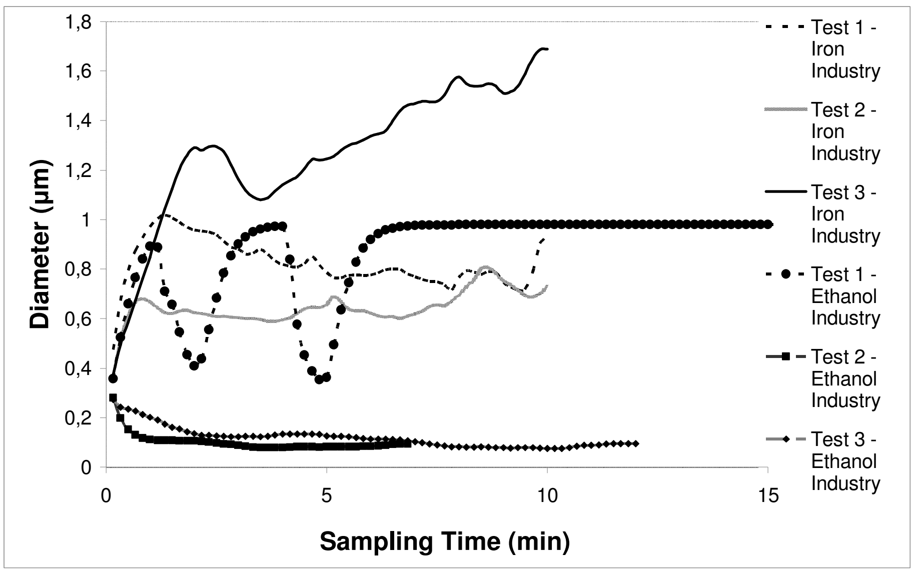



Figure 7 – Distribution of diameters sampled after the collecting devices at plant chimneys

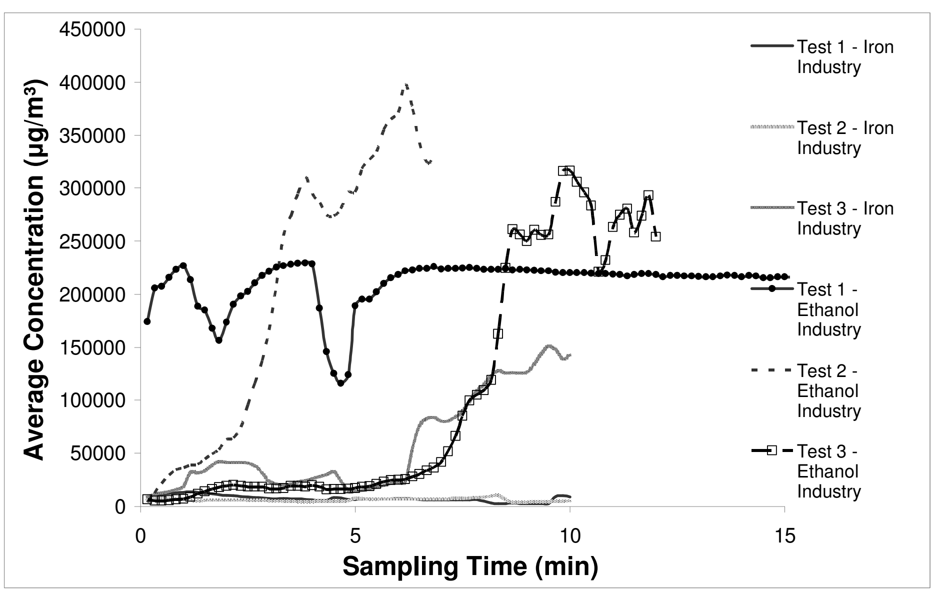



Figure 8 – Average concentration sampled after the collecting devices at plant chimneys

## 5 – CONCLUSIONS

The results obtained in this experimental work made it possible to conclude: The pilot Venturi scrubber proved efficient to collect particulates under optimization phases; the diameters sampled at both plants range from 0.1 to 1.7 um. They are quite fine and harmful to our health and the concentration of such pollutants with distribution diameters within the respirable range was relatively high for the ethanol plants and within a lower concentration range for the ferro-alloy plants, this being within the limits imposed by the current environmental ruling.

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## 8. RESPONSIBILITY NOTICE

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