Co-Firing of Coal and Biomass Blends - Experimental Studies of Ambient Air Emissions

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Abstract

The observed increase of the pollutants SOX, NOX and CO2 concentrations in the atmosphere, with its negative effect on the global climate, is predominantly caused by the combustion of fossil fuels. Fossil fuels are the major source of energy in the world and will continue to be so for the foreseeable future. Major efforts are therefore being invested in making use of these fuels more efficiently and environmentally acceptable As industrialization increases, so will the amount of waste materials and the environmental problems associated with their disposal. Waste generation in ever increasing quantities is an important issue facing the world.. As regards to India, agricultural wastes like biomass, cane trash, rice husk is being used for firing in harvest season when they are abundantly available by some industries just to utilize them. They have not been fired along with coal.

The above mentioned problems of increasing pollution and waste generation can be tackled by using coal waste Co-firing technology which can offer an environmentally sound, economic approval to both waste remediation and energy production. Co-firing of coal with agricultural wastes has been shown to be the lowest cost method for generating GREEN POWER and at the same time reducing the emissions in to the atmosphere. This paper discusses the results of the experiments conducted in a 18.68 MW power plant in Tamilnadu, with a tangentially fired travelling grate boiler. The `gaseous emission characteristics namely NOX and SO2 were studied, when biomass was co-fired with bituminous coal in 3 proportions of 20%, 40% and 60% by mass. Bagasse, wood chips (Julia flora), sugarcane trash and coconut shell are the biomass fuels co-fired with coal in this study. The air quality status in the vicinity of the plant was assessed when co-firing was done on the basis of the air pollutants namely SPM, SOx, NOx and compared with that when only coal was fired. The ambient air Quality status data obtained from experiments was also validated with SCREEN 3 and ISCST 3 air Modeling software. It was seen that the emission concentrations are higher using SCREEN 3 model, since it predicts the maximum incremental value under the worst case scenario to arrive at most optimum fuel combination. The values obtained from Industrial Source Complex Short Term (ISCST3) modelling software indicates minimum impact if 80/20 combination of biomass/coal is used and these results match well with the experimental results, thus justifying the use of co-firing in sugar mills in India.

Key words: Co-firing, biomass, $NO_{X,}$ SO_2 and CO_2

I. INTRODUCTION

With the present major worldwide agenda to reduce greenhouse gas emissions, the emphasis is on conventional coal-fired utilities to burn renewable fuels such as biomass residues or energy crop-derived biomass fuels as a low-cost option for reducing greenhouse gas emissions. The need for finding new renewable sources of energy together with the necessity of searching new technologies to reduce the negative impact of waste accumulation has led to the possibility of using biomass as an alternate fuel. Most of the industrial sources of pollution come from coal fired power plants which necessitate the need to find ways to decrease the greenhouse gas emissions from these sources. Also, the ratification of the Kyoto Protocol would need countries to implement measures to meet Kyoto standards by 2008. One of the options that need to be considered is the application of co-firing technologies to coal fired power plants.

Co-firing is the simultaneous combustion of a supplementary fuel with a base fuel. Selectively, utilities and independent power producers have used biofuels, particularly wood waste to generate electricity in small stand alone generating stations with less than 50 MWe capacity. In more recent years, utilities have become interested in co-firing biofuels with coal and other fossil fuels, applying wood wastes and other solid forms of biomass to high efficiency, higher capacity generating plants [1,2,3,4,5]. Initially, co-firing was seen as a means for reducing greenhouse gas emissions from fossil energy generation. Biomass co-firing with coal is proving to be the cheapest method for generating green power in utility plant demonstrations [1,6,7,8,9,10,11]. Those savings come not only from replacement of coal, but also from displacement of materials being sent to landfill, that ultimately decompose and form both CO2 and another more powerful greenhouse gas: namely methane.

A.Objective of the work

The present work carried out, discusses gaseous emissions and particulate matter measured in ambient air when a 18.68 MW traveling grate boiler is used to co-fire a combination of coal and different types of biomass.

II. PLANT DESCRIPTION

A study to measure co-firing emission characteristics is done in a 18.68 MW power plant, situated in Virudachalam district of Tamilnadu, the southern most state of India. This plant is a cogeneration plant, attached to the sugar mill. The plant has been generating power to meet its own requirements and the rest is being given to the main grid. The boiler is provided with two fuel feeder routes, one each for coal and biomass. Coal feeding is done from a height of 8 m and biomass from a height of 9.8 m above the base. The maximum amount of steam generation from the plant has been kept at 70 tonnes/hour for the tests conducted. The generated steam has a maximum temperature and pressure of 485°C and 65 kg /cm2.

A. Boiler specifications:

The pressure and temperature rating of our boiler is as follows :

Design pressure of boiler : 51 kg/cm2(g)

Working pressure of boiler : 42 kg/ cm2 (g)

Boiler temperature : 256°C

Boiler super heater outlet steam temperature : 410 +/- 15°C

The Total heating surface of our boiler : 3396 m2.

The size of the travelling grate is 3842mm wide x 5664mm long: 2 No's.

The speed of the travelling grate : 0.027 rpm to 0.27 rpm.

III. FUEL CHARACTERIZATION

Bituminous coal, lignite, bagasse, wood chips, sugarcane trash and coconut shell are the fuels used for the tests. The proximate and ultimate analysis were carried out for all the fuels and the results are presented in Table1. It should be noticed that, in comparison to the primary fuel (coal), biomass contains much less carbon and more oxygen. With regard to the ash content, values for biomass are much lower that for coal. Bituminous coal, which costs Rs.3000/tonne, was mixed with lignite abundantly available in the state of Tamilnadu, but inferior quality than bituminous coal. Biomass materials which were required for co-firing tests, were procured from the neighboring areas, whose cost varies from Rs.700 to Rs.900 per tonne.

A. Fuel handling prior to feeding

The type and extent of the necessary preparation of the biomass fuels depend on the combustion system and the type of biomass. [15,17,18,19,20]. In general, bituminous coal mills are not suitable for biomass. Therefore, separate biomass milling and feeding devices were required. The raw coal, procured was around 165 mm to 185 mm in length. It was milled down to around 20 mm length by the use of crushers. Due to the fibrous structure of the biomass materials used in our tests, it was difficult to determine an exact particle size distribution. The biomass materials were milled to the required dimension of 70 mm length and 15 mm thickness by the use of fibrizers. The biomass was fed in to the boiler by screw feeders.

B. Co-firing tests

A.Methodology

Co-firing tests were conducted in the plant, with various combinations of biomass fuels in different proportions. The fuels were fed in to the boiler through conveyors which carry about 8-10 tonnes/hour of fuel. The mass of secondary air supplied varies from 14% to 25% of the total air supplied. The temperatures and pressures were measured at various points along the path of flue gases. The gaseous emission tests were conducted at the stack. Emission tests were conducted in two phases. In the first phase, bituminous coal, lignite, bagasse, woodchips, sugarcane trash and coconut shells were fired individually (100%), to generate 70 tonnes/hour of steam. In the second phase of testing, each of the above mentioned biomass fuels, were fired in three proportions namely 20%, 40% and 60% by mass with bituminous coal, to generate 70 tonnes/hour of steam. The ambient air emissions were measured. as shown in Figures 1 to 3. The Ambient air emissions were modeled using SCREEN3 and ISCST3 models for individual and co-fired fuels. [12,13,14,16]

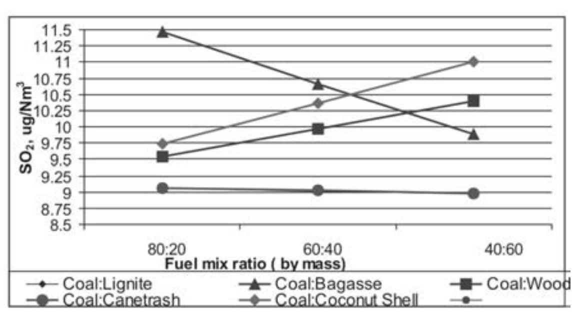

Fig.1 Variation of SO2 ambient air emissions for different co-fired fuel combinations and for various proportions of fuel blends.

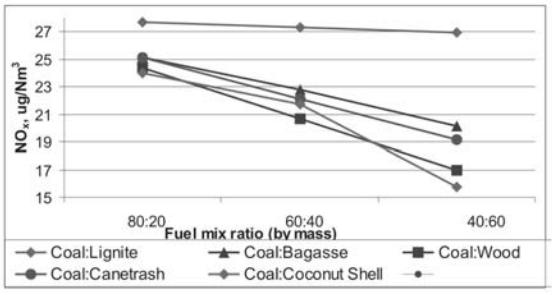

Fig. 2. Variation of NOx Ambient Air Emissions for Different co-fired Fuel Combinations and for Various Proportions of Fuel Blends.

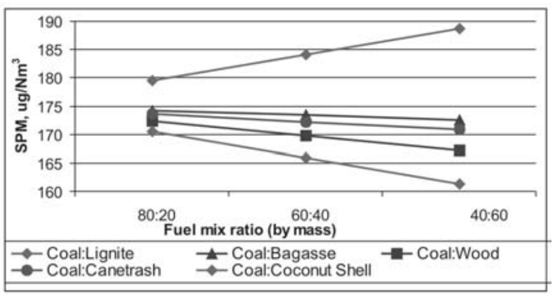

Fig. 3 Variation of SPM ambient air emissions for different co-fired fuel combinations and for various proportions of fuel blends.

V. AIR QUALITY MONITORING

The sampling and analysis of air pollutants were done as per the procedures suggested by Central Pollution Control Board (Emission Regulations Part-III) and also the Bureau of Indian Standards. High Volume Sampler (Envirotech APM 410) was used for measuring Suspended Particulate Matter with a provision for measuring pollutant gases.

A. Monitoring Frequency

Suspended Particulate Matters, Sulphur dioxide (SO2) and Nitrogen oxides (NOX) were monitored on 24 hours basis. High volume samplers were run continuously for 24 hours twice a week for one month. The timer fitted with the high volume sampler provided the actual period of operation.

B. Output of SCREEN 3 and ISCST3 Models

SCREEN3 model was applied to combustion of individual fuels and later by co-firing of biomass with coal in various proportions. The ambient air emissions output of SCREEN3 and ISCST3 models are presented in Table 5.16 to 5.20.

It can be seen that the emission concentrations are higher using SCREEN 3 model, since it predicts the maximum incremental value under the worst case scenario to arrive at most optimum fuel combination. The ISCST 3 model predicts the maximum incremental value using local meteorological conditions.

Table 1. Ambient air emissions concentration in g/m³ for individual fuel combustion

S.No.	Fuel type	SO_2	NO_X	SPM
1	Coal	192.6	23.98	17.97
2	Lignite	302.3	61.06	21.16
3	Bagasse	0	86.78	6.444
4	Wood chips	0	51.53	0.9446
5	Sugarcane trash	0	47.11	4.081
6	Coconut shell	20.89	42.19	13.66

Table 2. Ambient air emissions SO2 concentration in g/m³ for various co-fired fuel mixtures and proportions using SCREEN 3

S.No.	Fuel mix	80: 20	60 : 40	40:60
1	Coal:Lignite	214.7	236.4	258.4
2	Coal:Bagasse	154.2	115.5	77.04
3	Coal:Wood chips	154.2	115.5	77.04
4	Coal: Cane Trash	154.2	115.5	77.04
5	Coal: Coconut Shell	158.4	123.9	89.54

Table 3. Ambient air emissions SPM concentration in g/m³ for various co-fired fuel mixtures and proportions using SCREEN 3

S. No.	Fuel mix	80: 20	60: 40	40: 60
1	Coal:Lignite	18.60	19.21	19.90
2	Coal:Bagasse	15.65	13.31	10.96
3	Coal: Wood chips	14.55	11.13	7.767
4	Coal:cane trash	15.17	12.39	9.614
5	Coal:Coconut shell	17.09	16.21	15.32

Table 4. Ambient air emissions NOX concentration in g/m³ for various co-fired fuel mixtures and proportions using SCREEN 3

S. No.	Fuel mix	80: 20	60: 40	40: 60
1	Coal:Wood chips	36.69	40.40	44.11
2	Coal:Coconut Shell	34.84	36.70	38.41
3	Coal:Lignite	38.60	44.21	49.83
4	Coal:Bagasse	43.74	54.51	65.28
5	Coal:Cane trash	35.81	38.63	41.46

Table 5. Comparison of output emission concentration of SCREEN 3 and ISCST modeling software in g/m³ for coal:wood co-fired fuel mixture and proportions

Parameter	MODEL TYPE	Coal 80% + Wood 20%	Coal 60% + Wood 40%	Coal 40% + Wood 60%
SO_2	SCREEN 3	154.2	115.5	77.04
	ISCST 3	5.68323	4.25816	2.83929
NO_X	SCREEN 3	36.69	40.40	44.11
	ISCST 3	1.35218	1.48897	1.63488
SPM	SCREEN 3	14.55	11.13	7.767
	ISCST 3	0.53614	0.41003	0.28625

VI. CONCLUSIONS

Following are the conclusions from the experiments conducted:

- ❖ Within the range of experimental conditions tested, it has been observed that, the optimum proportion of fuels, for co-firing of biomass with coal in view of SO2, NOx and SPM is 60% biomass fraction and 40% bituminous coal. Taking in to account, all the above parameters for deciding on the optimal fuel combination and proportion, in such a way, that the power producers are benefited largely, it has been found that the coal : wood chips combination for a 40:60 proportion, is the best optimal choice for co-firing for this plant and under the given conditions. The reasons for choosing this fuel blend and proportion, because wood is available in plenty in the area around the plant site and has better calorific value and the blend has better characteristics as explained above. The second best choice, would be coal : coconut shell for a 40:60 proportion
- ❖ The SPM levels in the Stack have been found to be high. ESP needs to be maintained and operated at 99% efficiency to reduce the particulate emission. This will result in negligible increase in particulate emission from the Biomass Power Plant.
- ❖ The Sulphur in Coal & Lignite are very high. Hence it is appropriate to use biomass as the major fuel. The studies carried by means of carrying out actual monitoring & various modeling carried out corroborate this to a great extent. However 100% use of biomass due to availability and supply constraints is not possible, so a small fraction of fuel used can be coal. The most appropriate ratio with least impact was found to be 60% of biomass & 40% of coal.
- ❖ SCREEN3, model which predicts maximum incremental value under worst case scenario was used to arrive at most optimum fuel combination.
- ❖ The values obtained from Industrial Source Complex Short Term (ISCST3) modelling software indicates minimum impact if 80/20 combination of biomass/coal is used & ESP works at 99% efficiency.
- ❖ Thus it can be recommended that the coal:wood co-firing at 40:60 proportion would lead to lower ambient air emissions in the atmosphere.
- ❖ The above results from the SCREEN 3 and ISCST 3 software validates our experimental results that higher the biomass proportion, the lesser the emissions.

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