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ANALYSIS AND CONTROL OF EMISSIONS FROM PULP AND PAPER MILL

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ABSTRACT

Pulp & Paper industry is considered as one of the most polluting sector in the world. They are recognized as a source of green house gas emissions in the paper manufacturing sector since they produce CO_2, CH_4 and N_2O during the production process. The major air emissions of the industry come from sulfite mills as recovery furnaces and burners, sulfur oxides (SO_x), from Kraft operation as reduced sulfur gases and odor problems, from wood-chips digestion, spent evaporation and bleaching as volatile organic carbons (VOC_s), and from combustion process as nitrogen oxides (NO_x) and SO_x. It would be interesting to analyze and quantify these green house gas emissions from Pulp & Paper mill. The proposed study is an attempt in this direction. The estimation of green house gases from different Pulp & Paper mill of region situated near west of Uttar Pradesh such as Rama paper mill, Kiratpur, Bijnor, Mohit paper mill, Nagina, Bijnor etc has been done using the IPCC 2006 guidelines by calculative methodology. For each mill, daily quantity of fuel burned has been collected for fifteen days using either digitally available meters representing the quantity of fuel burned or by theoretical values suggested by the mill workers. Also, the data has been calculated using formula suggested by IPCC 2006 guidelines and a comparison has been done between observed values and calculated result. Results reveal that significant quantities of GHG emissions are produced using different qualities of fuel such as Charcoal, Tel Rahit Bhussi, Petroleum coke etc. It has also been observed that the emissions coming from petroleum coke is in lesser amount as compared to

other fuels. Also the profiles of observed and calculated GHG emissions could not match well. It is suggested that extensive attempts should be made for correct monitoring of GHGEs from pulp & paper mills. Further, it is strongly suggested that continuous monitoring of fuel should be taken care with replacement of Bhussi and coke with pet coke and also quantity of emissions should be monitored before and after each unit of paper production to have better quantification of GHG emissions. Also I have taken a graphical representation of all the fuel in terms of GHG emissions they are emitting respectively.

KEYWORDS: GHGE (Green House Gas Emissions), CO_2 (Carbon Dioxide), CH_4 (Methane), N_2O (Nitrous Oxide), VOC_s (Volatile Organic Carbons), NO_x (Nitrogen Oxides).

OBJECTIVES

a) To identify the GHG emissions of different fuels from Pulp & Paper industry theoretically.
b) To estimate green house gas (GHG) emissions using calculation methodology (GHG inventory) given by IPCC (2006) of various mills situated in and near district Bijnor, Uttar Pradesh.
c) To carry out a comparative analysis of emissions coming from calculative methodology with theoretical version.
d) To provide certain alternative measures for reducing the emissions such that it comes out to be viable for getting sustainable environment.

2.1 INTERNATIONAL STATUS

Ashaier et al. (2015) reviewed the implementation of acetone as a pulping agent for pineapple leaves. Mixtures of water and acetone with concentration of 1%, 3%, 5%, 7%, and 10% were used. The effects of soaking and delignification time on the paper properties were investigated. Thermal and physical properties of paper sheet were studied using thermo gravimetric analysis (TGA) and tearing resistance test respectively. The morphological properties were observed using microscope at 200× magnification. The paper sheet produced from pulping with 3% acetone concentration shows the highest mechanical properties. Papers strength was improved by increasing the delignification time. The delignification time was reduced by cooking the pineapple leaves at a temperature of 118 °C under applied pressure of 80 kPa which has remarkable effect on paper strength.

Main et al. (2014) conducted a study in the suitability of coir fibers as an alternative material in making Pulp & Paper. Maceration process was used to characterize the fiber. Soda-AQ pulping with various combinations of active alkali (18-22%) and cooking time (90-150 minutes) at fixed temperature was done. Physical properties evaluated were density, brightness, opacity, scattering coefficient, tear, burst and tensile index. As concentration of active alkali and cooking time increased, the physical properties values also increased, except for the opacity and scattering coefficient. The optimum condition for producing the strongest paper is using 22% active alkali in 120 minute.

Andrés et al. (2015) analyzed the production process for producing recycled pulp cellulose, there are waste generated by the raw material entering the system. This residue is separated from the pulp by physical methods, and is mainly composed of plastics, paper, laminated papers and other materials in smaller proportions. In order to recycle this waste, in this paper we analyze the viability of use in the production of insulated panels. With the untreated residue extracted from the plant, panels of 30 cm side and thickness of approximately 6 cm were made. On these panels, parameters such as density and compression strength were evaluated for the study of the homogeneity of the material obtained.

Masrol et al. (2015) stated the physical, optical and mechanical characteristics of Pulp & Paper made from waste durian rinds as an alternative raw material for papermaking were investigated according to TAPPI and MS ISO standards. The durian rinds pulp was produced through chemi-mechanical pulping (CMP). Naturally dried durian rinds were treated with 10% Sodium Hydroxide (NaOH) based on oven dry (o.d) weight of durian rinds in room temperature for 2 hours and pulped by the refiner mechanical pulping (RMP) process. Experimental results show that durian rinds have great potential characteristics as newly explored non-wood based raw material for Pulp & Paper industry.

Brown et al. (2012) stated industrial processes are highly energy intensive and account for one-third of global energy use. Around 70% of this energy is supplied by fossil fuels, and CO_2 emissions from industry make up 40% of total CO_2 emissions worldwide. Since the 1990s, the energy consumption of industry per unit of value added in developed countries, has fallen by around 1.3% per year on average (once adjusted for structural changes),but at a lower rate than the average reduction of 2.8% per year during the 1970s and 1980. Moreover, improvements in energy intensity have been more than offset by increased total production, such that energy consumption and CO_2 emissions have continued to rise dramatically.

Demand for manufactured goods is expected to at least double by 2050(relative to 2006 levels), and, if industrial emissions remain unchecked, total CO_2 emissions are projected to increase by up to 90% by 2050 compared to 2007.Reducing emissions from industry requires a sustained and focused effort. This Briefing Paper outlines the options for reducing industrial CO_2 emissions, concentrating on those sectors which make up the largest share (>70%) of emissions, i.e. iron and steel, cement and chemicals and petrochemicals. The paper gives an overview of industrial mitigation technologies, both those that are process-specific and those that apply broadly across the whole of industry. The abatement potential of these technologies, their cost effectiveness and barriers to uptake, as well as the policies to overcome these barriers is discussed.

Moon et al. (2015) examined GHG emissions and the economic effects of logging and mill residues, which are employed as raw materials for various purposes in Maniwa, Japan. In 2012, 23,710 tonnes of woody biomass resources was collected and used in Maniwa, of which roughly 79% were logging residues. These resources are manufactured into several types of wood products, such as chips, bark, and chip dust. The manufactured products are then transported and consumed for paper, poultry litter, and fuel. Based on this, three scenarios were organized by changing the type of woody biomass resource use as follows: the business-as-usual (BAU) scenario, the logging-residues-only utilization (LRU) scenario, and the mill-residues-only utilization (MRU) scenario. Under the LRU scenario, the expected regional effect is almost 204 million JPY, whereas the MRU scenario achieves almost 20 times more financial benefits than the LRU scenario with the integrated woody biomass station. However, approximately 13 full-time jobs can be created under the LRU scenario, which is roughly 2.1 times higher than the 6 jobs created under the MRU scenario. In terms of GHG emissions, the LRU scenario can reduce GHG emissions by up to roughly 211 t CO_2eq/t compared to the MRU scenario. Overall, the promotion of logging residue use for manufacturing wood products has significant advantages over mill residues in both the reduction of GHG emissions and the growth of regional economies.

Chang et al. (2016) assessed the eco-efficiency of China's Pulp & Paper industry at the national level and provincial level. An overview regarding the cleaner production of China's Pulp & Paper industry was presented to reveal the measures for reducing environmental impact in the last two decades. Slacks-based measure was used to analyze the efficiency levels of 16 provinces' Pulp & Paper industries. To uncover the underlying causes of eco-efficiency performance, Malmquist-Luenberger index was calculated to discover the drivers of productivity growth of Pulp & Paper industries. Our results showed that the pollution treatment of China's Pulp & Paper industry has made progress in terms of water consumption and water pollution, although the absolute amount of pollution discharge is still large. Chemical oxygen demand emissions are still the first critical influencing factor of Pulp & Paper industry's inefficiency. Furthermore, efficiency progress was the dominating contribution of the industry's productivity growth between 2010 and 2013. The policies for adjusting the industrial structure of Pulp & Paper industry have resulted in the scale effects through eliminating backward production capacity and accelerating merger and acquisitions. Moreover, the productivity of Pulp & Paper industry was underestimated when the undesirable outputs were ignored. It indicates that the stricter environmental regulations have positive effects on paper companies to internalize environmental pressures in the production activities through environmental management. In the future, Pulp & Paper companies should further internalize the cost of pollution treatment through scale effects and technology improvement.

Kong et al. (2015) compiles available information on energy savings, environmental and other benefits, costs, and commercialization status for 25 emerging technologies to reduce the energy use and CO_2 emissions. The purpose is to provide a well-structured comprehensive review on these emerging energy-efficiency technologies for engineers, researchers, investors, policy makers, pulp and/or paper companies, and other interested parties such as Pulp & Paper industry accounts for approximately 5% of total industrial energy consumption and contributes 2% of direct carbon dioxide (CO_2) emissions from industries. World paper and paperboard demand and production are increasing significantly, leading to an increase in this sector's energy use and CO_2 emissions. Although current studies identify a wide range of energy-efficiency technologies that have already been commercialized for the Pulp & Paper industry, information is limited or scattered regarding new energy-efficiency technologies that are not yet fully commercialized. Development of emerging or advanced energy-efficiency technologies and their deployment in the market will be crucial for this industry's mid- and long-term energy saving and climate change mitigation strategies.

Wang et al. (2016) based upon an analysis of China’s Pulp & Paper Industry (CPPI), provides estimates of each of the following: carbon emissions from energy consumption, pre-treatment sector, combustion of condensed black liquor, and methane emitted from incomplete aerobic digestion during sewage treatment of CPPI. It provides not only detailed information about CPPI's carbon emissions, but also a calculation framework for studying carbon emissions from Pulp & Paper sector in the other regions. It suggests that the local carbon emissions inventory should be used for estimating carbon emissions and to reduce the fossil fuel energy, increase energy recovery from biomass, and that promoting cleaner production is essential to achieve a low carbon development of the Pulp & Paper industry. According to this study's estimation, the emissions caused by the recovery of biomass energy contributed 26–29% of the total CO_2 emissions. CH_4 generated from sewage treatment accounted for 9–11% of the total carbon emissions. The CO_2 intensity dropped during the study period, which reflected the improvement of energy efficiency in the Pulp & Paper industry. During the study period (2005–2012), total CO_2 emissions ranged from 126.0 Mt to 155.4 Mt. Energy consumption was estimated to be the largest source of carbon emissions, however, due to the application of the local emission inventory rather than the IPCC inventory, energy consumption decreased by 4.7%, a lower percentage than was calculated in a previous study.

2.2 NATIONAL STATUS

Sharma et al. (2015) presents the results of a preliminary assessment towards the potential estimation of solar process heating in paper industry in India. To begin with, data for (i) classification of paper mills on the basis of size and feedstock used (ii) extent of cogeneration in paper mills (iii) annual paper production (feed stock wise) (iv) specific thermal energy requirement for process heating etc. have been collected. Annual process heating requirement for paper production (based on feed stock used) in paper mills in India has been estimated. Availability of adequate solar resource in different states of the country was assessed for potential estimation. Some commercially available solar collectors that can supply heat at required temperature of paper industry (50-250^{0}C) have been selected and an assessment of their performance has been made. Majority of paper mills in India are those using agro residues and recycled fibers as raw feedstock are located in the states with adequate DNI availability (1900kWh/m^2). Annual process heating potential for the paper industry in India has been estimated at 43 PJ.

Bajpai et al. (2015) justified Chemical additives used in papermaking fall into three groups- general (commodity) and two classes of specialty chemicals- process and functional. Process chemicals are used to optimize the production process by increasing machine speed, runnability, providing deposit control and reducing steam consumption. Retention aids, defoamers, fixative agents, biocides, and defoamers/antifoam additives are some typical examples of process chemicals. Functional chemicals directly affect paper quality and paper properties- color, water repellency, strength, printability, etc. Typical examples of such functional chemicals are dyes, coating binders, and strength and sizing additives. The boundary between process and functional chemicals is not very definite as process chemicals may either significantly influence performance of functional chemicals and/or affect sheet properties directly. About 90% of all chemical additives belong to functional additives. The remaining 10% are process chemicals, with retention aids (including fixatives, coagulants, flocculants and micro particles) representing the biggest and most important part. The in-depth and thorough coverage of chemical additives in the Pulp & Paper industry are presented. Various sections deal with pulping chemicals, bleaching chemicals, process chemicals, functional chemicals, pigments for fillers, coating pigments, aluminum, starch, chemicals used in paper recycling, and chemicals used for stickies control and tissue and towels.

Gaps in Existing Knowledge

Earlier studies accounted that GHG emissions from a paper and pulp mills can also contribute in global warming of earth. In 2000 it has been released that gases emitting from production process was of major concern and there was no protocol to measure GHG emissions. Later on emphasis was given on calculating CO_2 & CH_4 emissions. **Karthik chandaran (2009)** was first to tackle N-GHGs. Later on, using **IPCC (2006)** GHG protocols many scientists calculated only CH_4 & N_2O emissions frequently by using the amount of fuel that is burned in manufacturing process of a pulp. The fuel used in manufacturing of a pulp can be any wood material or petroleum coke, coal etc. No rigorous study for quantification of CO_2 has been done which is the major contributor to global warming. This study involves the quantification and analysis of major three GHG's emitted. This study also involves certain measures to be taken for attaining sustainability through a pulp mill.

METHODOLOGY

Study Area

For the purpose of carrying out the objectives, a total of 8 Pulp & Paper industry of Bijnor district of Uttar Pradesh were considered. A brief description of these mills along with their technical characteristics is given in the next section.

Pulp & Paper mills in Uttar Pradesh (Bijnor district)

Presents the summary of all the mills being investigated for carrying out my study in the state of Uttar Pradesh. From the given tabular data we can conclude the total number of mills carrying out three different fuels is 1 and two different fuels are 5 and the mills carrying out one fuel are 2.

Table: Summary of Pulp & Paper industry in Bijnor district Uttar Pradesh.

Location of industry	Types of fuel being used to manufacture paper
Mohit paper mill Mohit Paper Mill, 9 KM Stone, Bijnor - 246701 (U.P.)Nagina Road	Charcoal Pet coke Tel rahit bhussi
Rama paper mill Paper Mill Rd, Himmat Nagar, Saharanpur, Uttar Pradesh 247001	Tel Rahit Bhussi Charcoal
Chandpur enterprise Chandpur Enterprise, Chandpur , Bijnor	Pet Coke Charcoal

RESULTS AND DISCUSSION

As per the specific methodology firstly, the GHG emissions for Pulp & Paper mill in or near Bijnor district were calculated using IPCC guidelines and are presented in below table.

4.1 GHG emissions from Pulp & Paper industry

Following table shows GHGE in various Pulp & Paper mills and example calculations has been shown further.

a) Mohit paper mill

Mohit Paper Mill, 9 KM Stone, Bijnor -246701 (U.P.) Nagina Road.

Table 4.1: GHG emission in Mohit paper mill observed for fifteen days for charcoal.

Periodic days	Quantity of fuel burned	CO_2 emission in metric tonnes	CH_4 emission in metric tonnes	N_2O emission in metric tonnes	Total emission in terms of CO_2 equivalent
1	45.145	115452.9201	11180.6107	1765.1695	897448.2898
2	42.774	109389.3721	10593.4084	1672.4634	850314.6118
3	45.784	117087.0859	11338.8654	1790.1544	910151.1242
4	44.398	113542.5572	10995.6088	1735.9618	882598.4975
5	42.774	109389.3721	10593.4084	1672.4634	850314.6118
6	44.698	114309.7712	11069.9068	1747.6918	888562.2695
7	44.655	114199.8039	11059.2573	1746.0105	887707.4622
8	45.100	115337.838	11169.4660	1763.4100	896553.7240
9	45.000	115082.100	11144.7000	1759.5000	894565.8000

10	44.738	114412.0664	11079.8138	1749.2558	889357.4391
11	41.445	105990.6141	10264.2687	1620.4995	823895.1018
12	42.774	109389.3721	10593.4088	1672.4634	850314.6118
13	45.236	115685.647	11203.1476	1768.7276	899257.3006
14	45.338	115946.4944	11228.4098	1772.7158	901284.9831
15	42.774	109389.3721	10593.4084	1672.4634	850314.6118

Total emission suggested by the mill owner according to a study carried out by a renowned consultant such as new con industries are as follows

Total emission = 600000

CO_2 emission factor suggested by IPCC = 2557.38

CH_4 emission factor suggested by IPCC = 247.66

N_2O emission factor suggested by IPCC = 39.11

Figure 1 presents the scatter diagram between observed and calculated values of GHGE for the mills that are using pet coke as a fuel burned.

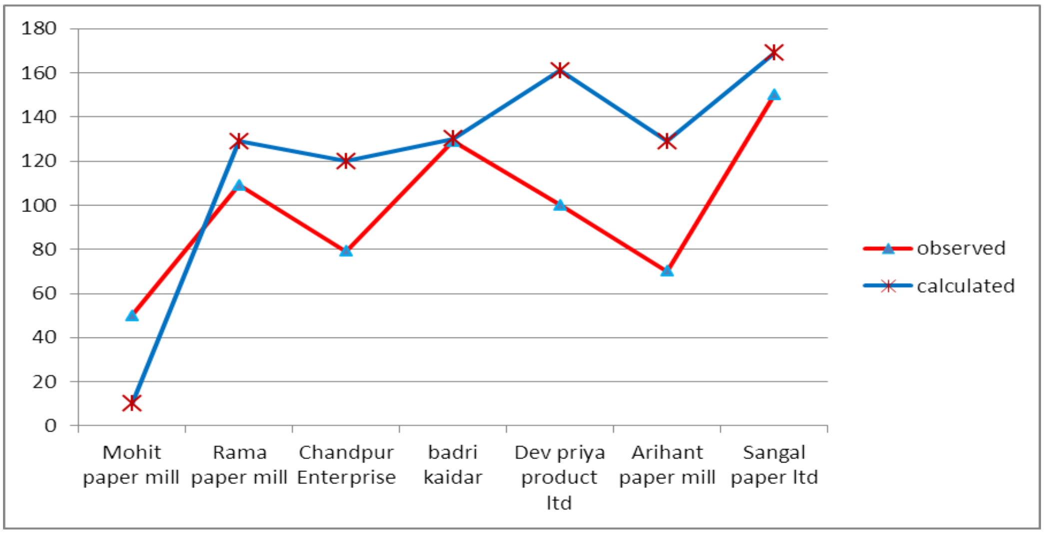

Fig.1: Figure shows the observed and calculated portions of pet coke as a fuel.

Therefore it is observed from the above figure that the values observed of quantity of fuel burned are following reasonably good trend with most of the points lying in or around pet coke as a fuel so that it shows pet coke as a fuel which can be used more efficiently. Hence it is concluded that the observed and calculated values differ so that different methodology should be suggested so that to make the observed and calculated values in close vicinity of each other. This proves the utility of the standard equations available in the text for the estimation of GHGE.

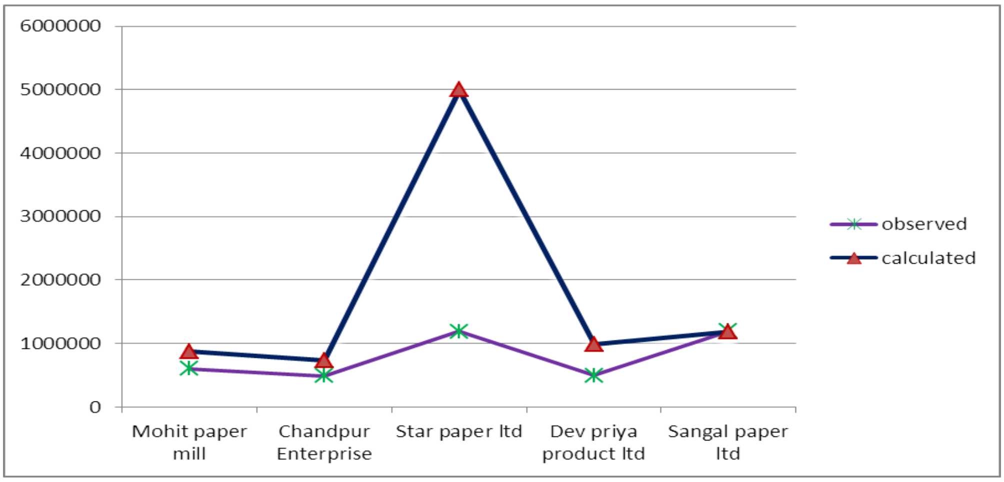

Fig.2: Figure shows the observed and calculated values for charcoal as a fuel

Figure 2 presents the scatter diagram between the observed values and calculated values for charcoal as a fuel. It is observed that the values calculated and observed are following a reasonably differing trend with most of the points varying in the calculated version. Thus it can be concluded that the predicted values of gas production are not in close proximity to the observed values. This proves the utility of the standard equations available in the text for the estimation of GHGE.

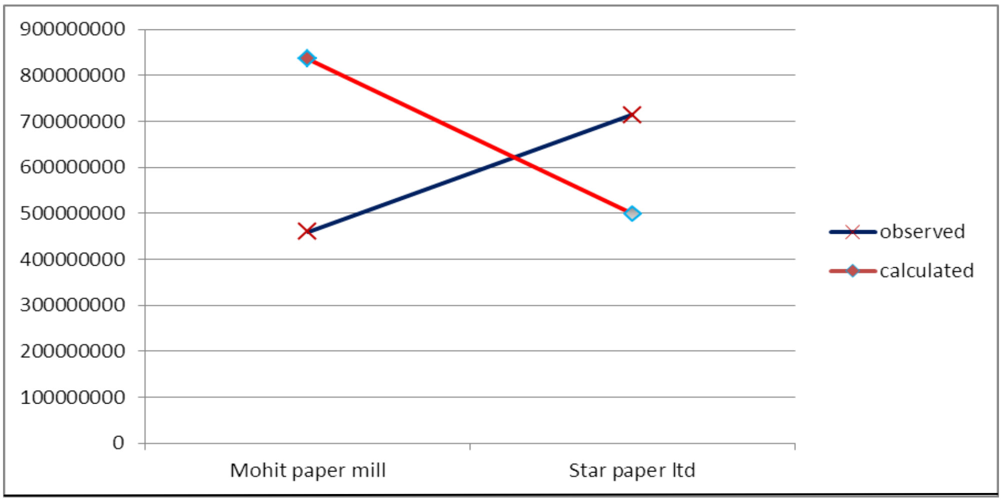

Fig. 3: Figure shows the observed values of Tel Rahit Bhussi as a fuel.

Figure presents the scatter diagram between the observed values and calculated values for Rice husk and coal as a fuel. It is observed that the values calculated and observed are following a reasonably differing trend with point varying in the calculated version. Thus it can be concluded that the predicted value of gas production are not in close proximity to the observed value. This proves the utility of the standard equations available in the text for the estimation of GHGE so that certain measures can be taken so that to avoid discrepancies in between calculated and observed value.

The above graphs shows the relation between different calculated and observed values with respect to different fuels being utilised by the mill owner which states that certain measures needs to be taken to activate the actions. It is also observed that the constant use of pet coke as a fuel in comparative to other fuels produce less pollution in terms of GHG emission as compared to other fuels. The gas produced in different mills is observed and seen on above representation and it is observed that the values of gas production are varying in respect to the calculated values being used by IPCC calculation methodology. It is observed that there are various peaks (high and low) in the values of gas production. Such large variation could possibly be on account of non uniform functioning of treatment plant which could be because of several reasons such as varying quantity of fuel being burned and not measured properly. Therefore certain measures need to be analysed so that to possibly reduce the amount of emission in order to enhance the environment in more effective manner. I hereby attach the values being recorded on daily basis for different mills so that to observe the difference between calculated and observed value.

CONCLUSIONS

Pulp & paper mills have been recognized as a major source of GHG emissions in recent years. There are considerable efforts going on to determine cases on footprint of pulp mills with respect to GHG emission, energy usage, etc. In order to determine GHG from a mill an inventory has been designed by IPCC in which inventories of all GHG's has to be calculated and appropriate global warming potential(GWP) of each gas has to be applied. This present study titled "Analysis & Control of emission from pulp & paper using GHG protocols" was attempted in direction and calculations for GHG emissions from different pulp & paper mills situated in or near district Bijnor through IPCC guidelines 2006 have been done. Data of four months i.e. February, March, April, May have been collected from different paper mills on a daily basis of gas production and calculation of GHGE using those data through earlier defined standard equations have been done. Also, comparative study in collected data and calculated data is done. On the basis of the results the following conclusions have been made:

a) Significant quantities of GHG's are produced from pulp &paper mills. However, inaccuracy of these results can be ruled out because of lack of data, assumptions are made in the analysis, lack of monitoring etc.
b) The profiles of observed and stimulated GHG emission from different paper mills could not match well. This is largely on account of poor quality of monitoring, interruptions in

plant functioning because of power crisis or it may be due to lack of data monitoring system available in mills.

c) The calculated value was not in proper stimulation with the value given by a recognized environmental consultant for various pulp mills situated in Bijnor. Therefore the calculated results from various types of quantity of fuel burned are determined.

These variations may be due to other reasons also. Some of them are listed below.

i. The data may not be recorded properly. As, the gases emitting from every unit may not be recorded in the metering gauge so that some of the gases may be blown in atmosphere.

ii. The standard equations may not be very much applicable in finding or evaluating such emissions or we may say that the equations are absurd.

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