SEQUESTRATION OF CO_2 FROM FLUE GAS OF THERMAL POWER PLANT BY USING MICROALGAE – BATCH STUDY

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Abstract
Carbon dioxide (CO_2) plays a vital role in climate change at present scenario. Though there are various mode of CO2 emission into the atmosphere, emission from Thermal Power Plant using Coal as fossil fuel stands first as per IPCC data. A study for control of CO2 emission from point source in Thermal Power Plant is presented. Though there are various methods available for sequestration of CO2 is available, Biological mode of sequestration is adopted in this study due to its several advantages. The study was conducted in two modes: (i) Batch mode and (ii) Continuous mode. The result obtained in the batch mode operation was presented. Mixed algal cultures were used in the study for sequestering CO2 from raw flue gas obtained by burning Lignite coal. As a result, the efficiency of CO2 sequestration from flue gas using microalgae, species identification, calculation of algal biomass, utilization of wastewater as nutrients which is generated in the thermal power plant and modifications to be made in the continuous operation were discussed.

Index terms: Coal, Carbon dioxide, Biological Sequestration, Microalgae, Wastewater.

I INTRODUCTION

Coal is the primary fuel for electricity generation in India and its usage is continuously increasing to meet the energy demands of the country. Emissions of green house gases and other pollutants are increasing in India with the increasing demand for electricity (Mittal et.al., 2010). Main emissions from coal fired and lignite based thermal power plants are CO_2, NO_x, SO_x, and air-borne inorganic particles such as fly ash, carbonaceous material (soot), suspended particulate matter (SPM), and other trace gas species. Thermal power plants, using about 70% of total coal in India (Garg et. al., 2002), are among the Large Point Sources (LPS) having significant contribution (47% each for CO2 and SO2) in the total LPS emissions in India. As per the data available from Central Electricity Authority of India 86 power plants with total installed capacity of 77682MW were installed in India in the year 2009 – 10. CO2 emission which is the main cause for global warming will stands first in the emission rate from thermal power plants using coal as a fossil fuel. CO_2 emissions are increasing at an average annual rate of 5.6% on the all India basis in these power plants during the period 2001-02 to 2009-10. The present estimates show the CO_2 emissions from coal and lignite based 86 power plants during April 1, 2007 – March 31, 2008 as 455 million tons. The electric power generated by these 86 thermal power plants during 2007-08 was 476992 GWH. This is about 85% of the total electric power 558990 GWH generated in 2007-08 by thermal power plants in India. Thus, the total CO_2 emissions can be an estimated as about 523 million tons from all the thermal power plants in India (Mittal et.al., 2010). CO_2 emissions per unit of electricity from power plant range between 0.82 and 1.0 kg/kwh. Hence, the datas clearly indicates thermal power plants in India contributes major rise in CO2 level in the atmosphere. The threat of global warming is becoming severe because of increasing CO2 concentration in the atmosphere (Kumar et.al., 2014).

It is the time to take major steps in controlling CO2 emission form Large Point Source (LPS). This study as the initiative for controlling CO2 from thermal power plants in India, presently CO2 is contributing nearly 52% in total global warming (Velea et.al., 2009). Of these, these Thermal Power plants alone contributes 50% of the total emission.

Though there are various methods available for capturing and storage of CO2 emission, in this study, Biological mode of sequestration is used. Biological CO2 sequestration from flue gas is gaining attention because of its eco-friendly and cost effective nature (kumar et.al., 2013). Use of Microalgae for CO2 sequestration has multiple advantages. Photosynthetic efficiency of microalgae is nearly 10 times greater than that of terrestrial plants (SKjanes et., 2007). In addition, they are the source of renewable energy and their biomass can be utilized for the production of high value products. Figure 1 shows the schematic representation of sequestration of CO2 using microalgae and possibility of various by-products.

II Materials and Methods

A. Collection of Lignite coal from Thermal power plants

Samples were collected from nearby Thermal Power Plant, Neyveli Lignite Corporation (NLC), Neyveli, TamilNadu which is located in southern part of India. NLC is a major power source for most of the regions in India which generates around 2740 MW of electricity per year. Special permission was obtained from NLC and collected samples for analysis. Figure 2 shows Lignite Coal samples collected from NLC.

Fig. 1. Collected Lignite Coal.

B. Collection of flue gas

Flue gas collected from Thermal Power Plant – I expansion, NLC in Electratostatic precipitator (ESP) line and the flue gas is analyzed using flu gas analyzer kid and the results are listed in Table 1.0.

Fig. 2 Collection of flue gas sample from Thermal Power Plant

Table 1. Composition of flue gas used for the study

S.No.	Component	Percentage
1.	Nitrogen	78 – 80%
2.	Carbon dioxide	10 – 12%
3.	Oxygen	2 – 3%
4.	Carbon monoxide	70 – 110ppm
5.	Nitrogen oxides	50 – 70 ppm
6.	Sulphur dioxides	180 – 250ppm
7.	Hydrocarbons	60ppm

C. Collection of ground water samples, algal samples and Sewage samples

Sewage samples were collected from Sewage Treatment Plant inside Thermal power plant. Sewage samples were used as a nutrient source for Microalgae production. Similarly ground water samples also collected from inside NLC premises. Algal samples were collected from nearby ponds within 5 km radius of the NLC. The samples were collected and analyzed for their characteristics and it is listed in table 2, 3 and 4 respectively.

Fig. 3 Collection of Sewage sample @ NLC

Fig. 4 Collected Microalgae samples

Table 2. Characteristics of Sewage collected at NLC

S.N.	Parameter	Unit	Values
1.	pH @ 31° C		8.21
2.	Electrical Conductivity @ 31° C	mS/cm	1.071
4.	Biochemical Oxygen Demand (BOD)	mg/L	200
5.	Chemical Oxygen Demand (COD)	mg/L	300
6.	Total solids (TS)	mg/L	2000
7.	Total Dissolved Solids (TDS)	mg/L	1500
8.	Total Suspended Solids (TSS)	mg/L	500
9.	Total Volatile Solids (TVS)	mg/L	900
10.	Total Volatile Dissolved Solids (TVDS)	mg/L	600
11.	Total Volatile Suspended Solids (TVSS)	mg/L	300
12.	Nitrogen	mg/L	30
13.	Phosphorous	mg/L	12

Table 3 Characteristics of Pond water (algal samples) collected at NLC

S.N	Parameter	Unit	Values
1.	pH @ 27° C		7.56
2.	Electrical Conductivity @ 27° C	mS/cm	0.535
3.	Chemical Oxygen Demand (COD)	mg/L	410
4.	Total solids	mg/L	663
5.	Total Dissolved solids	mg/L	643
6.	Turbidity	NTU	0.6
7.	Total Hardness	mg/L	352
8.	Total Alkalinity	mg/L	180
9.	Chlorides	mg/L	164
10.	Iron	mg/L	0.1
11.	Fluoride	mg/L	1.28
12.	Sulphate	mg/L	172
13.	Nitrate	mg/L	0.3
14.	Calcium	mg/L	71
15.	Magnesium	mg/L	42
16.	Copper	mg/L	BDL
17.	Manganese	mg/L	BDL
18.	Lead	mg/L	0.0142
19.	Zinc	mg/L	BDL
20.	Total Coliform	MPN/100 ml	4

D. Batch study

Batch reactors were made by using 10 litres plastic can. The number of Batch reactors used for the study is 3Nos. Each reactor contains various proportions of algae samples and sewage as nutrients. As the sewage source is rich in Phosphorous and Nitrogen. Batch - mode studies were carried out by burning the collected lignite and exposing them to the algal samples as shown in Fig.6. This study was carried out for a period of 3 months and study was done to ascertain the effect of flue gas the resulting physico-chemical changes on the sewage and algal samples. Raw sewage collected from local treatment was utilized to support the growth of algae and being itself treated during the course of CO_2 sequestration. Lignite burnt flue gas is projected downwards on to the algal water samples, thereby ensuring the effect of CO_2 sequestration on algal samples. Basically this has given an insight into the extent of CO_2 sequestration on the algal samples. The Lignite burnt flue gas composition is given in Table 1.0. The details of the batch reactors with different ratios of raw sewage: algal inoculum for CO_2 Sequestration is given in Table 5.0. Experimental conditions prevalent during the batch study is given in Table 6.0 and the monitoring and their variation during the batch process is given in Table 7.0.

Fig. 5. Typical Batch setup of the experiment

Table 4. Batch Reactors with Different Ratios of Raw sewage: algal inoculum - Carbon dioxide Sequestration

Batch Reactor	Raw Sewage (%)	Algal Inoculum (%)
01	80	20
02	84	16
03	88	12

Table 5. Experimental conditions during the Batch study test

Parameters	Range	Optima
Temperatur (^OC)	16 – 27	18 – 24
Salinity (g/L)	12 – 40	20 – 24
Light Intensity (lux)	1,000 – 10,000 (depends on volume and density)	2,500 – 5,000
Photoperiod (light: darx, hours)		16:8 (Minimum) 24: 0 (Maximum)
pH	7 – 9	8.2 – 8.7

III Results and Discussions

A. Effect of pH and EC on cell growth

From below figure 7. It is clearly observed that the pH of the culture is normally maintained from 8.1 to 8.6 which is said to optimum pH for growth of microorgansims (Lopez et.al., 2009). The pH of the culture medium is compared with growth of the cell density. When the pH is increased, cell density also gradually increasing when the pH of the medium is goes beyond 8 the cells started to attain its death phase. So, it is observed that the pH to be maintained below 9 for the better culture. pH and Electrical conductivity of the each Batch reactor were measured using HACH digital pH meter

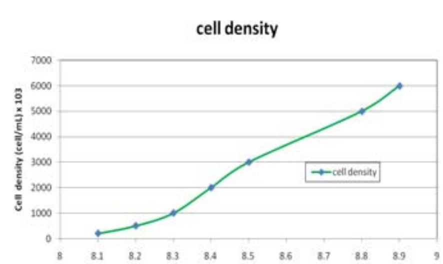

Fig. 6. pH versus cell density

B. Effect of Total Solids, Total Suspended Solids and Total Dissolved Solids

The total solids, total suspended solids and total dissolved solids started increasing over the months due to the passage of CO2 gas. The increase in solids represents the growth of cell density in the medium.

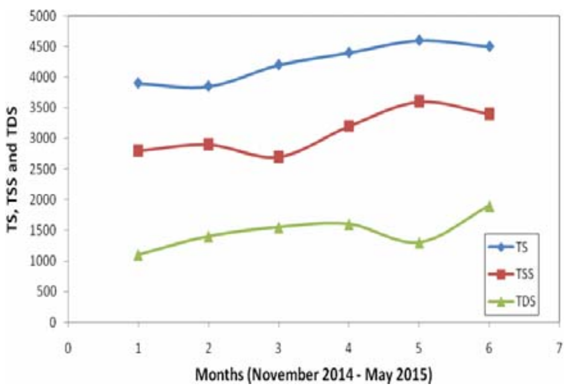

Fig. 7. Variation in TS, TSS and TDS over the months

C. Effect Light intensity with cell density

The below curve shows that the light intensity is low in the month of December to February and it is gradually increasing during the months March to May. It is clearly indicated that the cell growth is highly depends upon light intensity and pH of the culture. During month of December to February where the light intensity is comparably low and the cell density is also very low in the range of 200 – 500 (cell/mL) x 103 and it is gradually increasing with light intensity and it is maximum in the month of May. This happens due to summer days that sunlight is very high during the month of April to May in Tamilnadu and Pondicherry. The light intensity and biomass density was finding using Digital Luximeter and Online algal Biomass sensor.

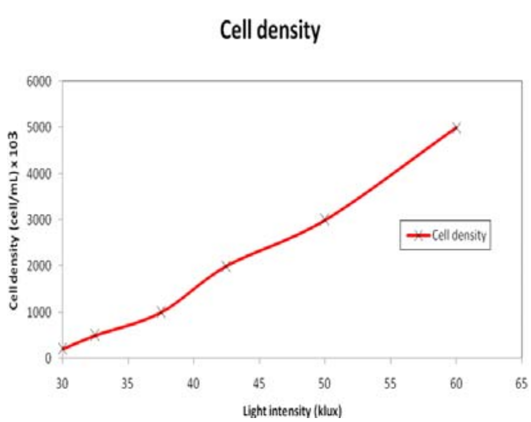

Fig.8 Light intensity versus cell density

D. Identified Algal species

The prominent genera's of microalgae identified are: ***Anabaena, Diatoms, Hyalophacus, Monoraphidium, Navicula, Oscillatoria Spirogyra.***

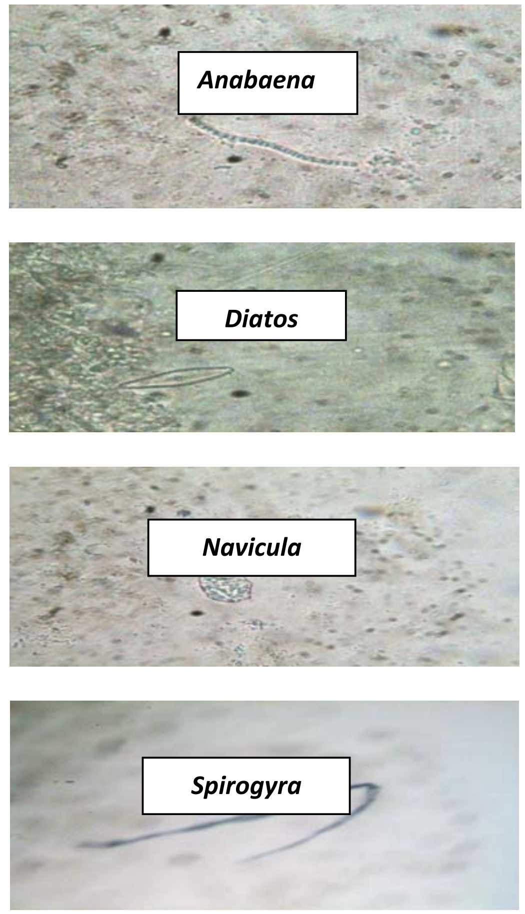

Fig. 9 Microscopic view of prominent genera of microalgae

V CONCLUSION

It is concluded that, the optimum dilution ratio for the production of algal biomass concentration 8:2 (raw sewage: algal inoculum). It is also concluded that municipal wastewater could support the growth of algal species isolated from water bodies. After 107 days of cultivation, five genera's, namely, Anabaena, Diatoms, Spirogyra, Hyalophacus, Monoraphidium were identified and the maximum uptake of N and P were found to be 58% and 82% respectively for the raw : algal innoculum of 8 : 2. The maximum algal growth was found to be 1.11gm/litre (not cummulative). The optimum ration obtained in Batch mode operations is to be developed in continuous operation using closed reactor (Photobioreactor) and the maximum CO_2 uptake was optimized. It is inreferred that the biomass produced can be used for the combined benefit of sustainable biofuel production and wastewater treatment with simultaneous CO_2 sequestration.

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