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Impacts and Mitigation Approach of Flue Gas (SO₂) in Coal Fired Power Plant of Bangladesh

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Abstract

Energy demand of Bangladesh is rising continuously. Therefore, several power plants have been establishing, where the main fuel is a coal to satisfy this requirement. In Barapukuria, a coal-based power plant has already been activated to produce 250 MW electricity. The coal-fired power plant in Matarbari (1200 MW), Payra Thermal Power Plant (1320 MW), Rampal Power Plant (1320MW) are under construction in addition to add 3840 MW. While boasting our power grid, it raises the concern of environmental adversity that may occur by the emission of flue gases (SO₂, NO_x, CO₂) and particulate material from the chimney. This exhaust emission causes a discrepancy in human health and the environment. Among these flue gases SO₂ is prime concern here. Hence, this study is done to identify the adversity of this pollutant. For this reason, the amount of flue gas (SO₂) is calculated which will help to understand the deviation from standard values. If any deviation is identified, mitigation steps should be taken to prevent the adversity. There are various methods to mitigate the flue gas (SO₂), for example, wet scrubber, limestone/gypsum system, ammonia scrubbing, lime/limestone scrubbing for mitigation of sulfur dioxide (SO₂). According to the suitability and efficiency of these processes, the best methods are explained to capture the flue gas (SO₂) for saving our environment.

Keywords: Energy demand of Bangladesh, SO₂, CPPs, Impacts, Mitigation.

Introduction

Electricity is the key source of power for most aspects of the economy in the world. Bangladesh's overall installed electricity generation capacity (including captive power) was 15,351 MW as of January 2017 (Wikipedia, 2020) and 20,000 MW in 2018 (Dhakatribune, 2019). The main energy users in Bangladesh are the factories and the housing sector, followed by the commercial and horticultural sectors. Bangladesh has seen a robust economic growth of approximately 6.5 percent (Rahman et al, 2012). By 2030, Bangladesh will need an additional 34,000 MW of exactly to support its economic growth of more than 7% (Sied et al., 2015). So, several power plants are planned to establish where coal-fired plants are favorable due to high efficiency and low cost.

In Bangladesh, at Barapukuria in January 2006, the first coal-fired power station started commercially manufacturing at 250 MW. This coal-fired power plant operates under subcritical vapor.

Another 2000MW coal-based power is also signed. Payra Thermal Power Plant 1320 (MW), Rampal Power Plant 1320 (MW) The Matarbari 1200MW power station, Banshkhali power station 1,224 (MW) are ongoing projects. Therefore, these power plants will

help us to enhance our capability and boost our energy sector (www.cpgcbl.gov.bd, 2019).

Along this, it raises the concern of environmental impacts of our country. As the primary constituents of coal are formed by soil, volatile matter, carbon, sulfur and so on, coal-fired electricity generation creates unsustainable pollution. In one year, coal-based power stations burn enormous amounts of coal, emitting enormous volumes of sulfide oxide (SO₂). However, among the other sources, the largest source of SO₂ is known as the fossil fuel combustion (Bayırhan, et al., 2019; Ülker et al., 2018; Zhang et al., 2017) national energy policy also gives priority to the use of mainly domestic fossil resources for energy production in the future. As a prime trace gas, SO₂ plays a substantial role in the troposphere in atmospheric complex processes such as haze and photochemical smog (Mersin et al., 2019; Tokuşlu 2020). Additionally, SO₂ causes acid rain when water is present in the atmosphere. Acid rain destroys forests and ecology, disrupts the acidic balance of the aquatic environment, and causes corrosion on building materials (Arslan and Akyürek, 2018; Fioletov, et al., 2013). Studies showed that SO₂ is associated with cardiovascular abnormalities irritates the respiratory system affects lung functions, causes eye irritation, and increases susceptibility to respiratory infections by weakening the immune system (Lin et al., 2018). Yet, the consequences can be plumed

utilizing various control measures and recovered SO₂ from flue gas can be used to produce.

Methodolog

Study area

Until now, there is only one coal fired power plant is operating and the rest of them are in under construction. The figure 1 represents location of the plants. At Phulbari Upazila of Dinajpur District, Barapukhuria power station is established in the northern part of the Bangladesh whereas other three will be established in the southern part of the country. Matarbari Power station, Payra Thermal Power Plant, Rampal Power Plant are developed in Maheshkhali Upazila of Cox's

Bazar District, Sapmari, Rampal Upazila of Bagerhat District, Kalapara Upazila of Patuakhali District respectably. Having population over 0.1 million within 229.5 square km, Phulbari Upazila consisting population density 1781 per square km, where literacy rate is only about 32.48. Moreover, a lack of health consciousness is prevailing there at a great instance. On the other hand, Rampal Upazila has occupied 335.46 square km with population over 0.1 million. Besides, Rampal Upazila is close to largest mangrove forest called Sundarban. Kalapara Upazila and Maheshkhali Upazila are occupying 483.1 km² and 362.2 km² respectably (Islam et al., 2016, Rashidin et al., 2019).

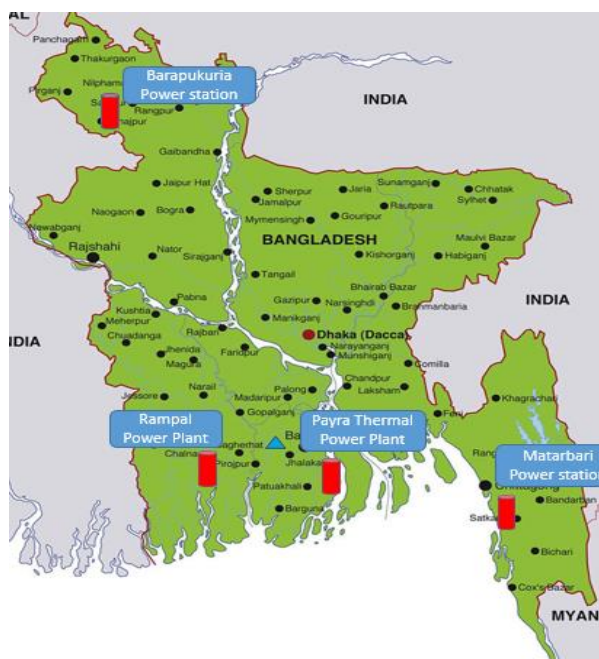


Figure 1. Position of coal fired power plant of Bangladesh.

Emission estimation

The amount of SO₂ emits is calculated by mass balance equation

$$S_{in} = S_{ash} + S_{SO2}$$

$$S_{in} = \text{amount of coal} \times \text{percentage of sulfur}$$

$$S_{ash} = S_{in} \times \text{percentage of ash}$$

The amount of Sulfur available for conversion to SO₂

$$S_{aSO2} = S_{in} - S_{ash}$$

The amount of Sulfur dioxide formed is then $\frac{64}{32}$ of the sulfur available for conversion.

$$S_{SO2} = \frac{64}{32} \times S_{aSO2}$$

The amount of Sulfur dioxide formed in the flue gas in unit kg/h calculated by

$$SO_2 \text{ (kg/h)} = \text{amount of coal} \times \text{percentage of sulfur} \times (1 - \text{percentage of ash}) \times 2 \times \frac{907.15}{365 \times 24}$$

A table is shown, where coal properties such as ash content and sulfur content are provided and coal will be used from the tabulated country.

Results and Discussion

Emission of SO₂

The main source of the SO₂ emission is coal since sulfur is one of the constituents of it. The coal, which is found in Bangladesh having sulfur approximately 0.53 percent. On the contrary Bangladesh is going to import coal from Australia, South Africa and Indonesia where sulfur percentage higher than the domestic one. Table 1 reveals the properties of the imported coal. The present scenario of coal-fired power plants is shown in table 2 where operating technologies, coal types, Planned/operating power (MW), State, Coal Use ton per year are mentioned. The amounts of sulfur dioxide will be produced by using coal imported from different countries in four coal-fired power plants are mentioned in table 3.

Table 1. Coal properties (Safiullah, et al., 2011).

Countries for coal	Ash content (approximate)	Sulfur content (approximate)
Bangladesh	12.4%	0.53%
Australia	13.60%	0.63%
South Africa	14.2%	0.6%
Indonesia	13.18%	2.32%

Table 2. Information on operating and proposed CPPs in Bangladesh

CPPs	Technology	Coal type	Planned/operating power (MW)	State	Coal use ton per year
Barapukuria Power station	--	Domestic (Anthracite)	525	Operating	481800
Matarbari Power station	Ultra-super critical	Imported (Sub-bituminous)	1200	Proposed	3730000
Payra Thermal Power Plant	Ultra-super critical	Imported (Sub-bituminous)	1320	Proposed	4120000
Rampal Power Plant	Ultra-super critical	Imported (Sub-bituminous)	1320	Proposed	4720000

Table 3. SO₂ (kg/h) produce by coal combustion

CPPs	SO ₂ (kg/h) produce by using coal from different countries			
	Bangladesh	Australia	South Africa	Indonesia
Barapukuria Power station	463.2	543.1	513.7	2009.9
Matarbari Power station	3586.6	4205	3976	15560.4
Payra Thermal Power Plant	3961.7	4644.6	4392.7	17187.3
Rampal Power Plant	4538.6	5321	5032.5	19690.4

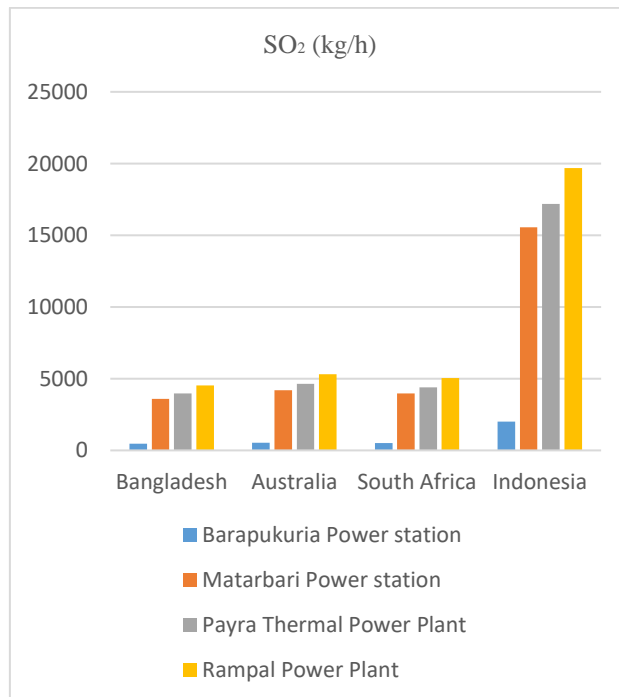


Figure 2. A comparison of SO₂ emission by using coal of different countries.

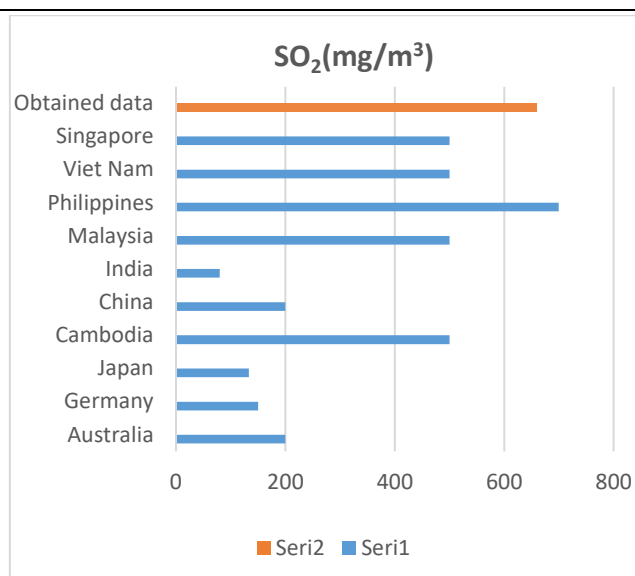


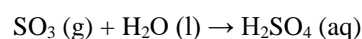
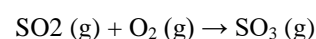
Figure 3. Comparison of SO₂ emission.

Deviation Determination: Here, obtained data represents the SO₂ concentration that is produced from Barapukuria Power station, depicting considerably higher rate than other countries.

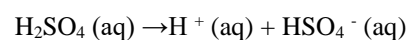
Deviation impact: Here, measured values show that the deviation is not too much. Though the values are small in quantity, it has significant impact on human being and environment.

Deviation impact on human: Sulfur dioxide amuses the ears, mouth, neck, and organs (lungs) skin and sinuses membranes. High SO₂ levels, particularly during intense physical activity, can trigger infection and discomfort of the respiratory tract. The ensuing signs may include pain in deep breathing, coughing, inflammation of the neck, and difficulty breathing. High levels of SO₂ in delicate communities may influence lung function, worsen migraines, and worsen current heart disease. This fume can also respond with other airborne chemicals and turn into a tiny particle that would enter the lungs and trigger comparable impacts on wellness. The minimum level of pulmonary structure alterations in asthma exercise is of the range of 1144 µg / m³, although tiny shifts in airway resistance of 286 µg / m³ in two sensitive objects (Craig, et al., 2008). The concentration of SO₂ in the area of Barapukuria around 4 kilometer is 0.2300 mg/m³ (maximum concentration), where Bangladesh permit 2 mg/m³ (Alam, 2013).

Deviation impact on environment: The gas SO₂, that is emitted contribute to acid rain. Acid rain is described as any type of moist precipitation that has a pH of less than 5.6 in mist, dew, snow, hail or rain. Pure water has a pH of 7.0 (balanced), but conventional, unpopulated rainwater has a pH of approximately 5.6 (aromatic). Rainwater is mildly acidic, of course. The acidity of rainwater is due to the normal existence in the reduced atmosphere of three components (CO₂ coal carbonate, NO nitric oxide and SO₂ sulfur dioxide) (Prinn and Fegley, 1987). The following reactions describe how this contribute,



Sulfuric acid is a powerful acid, so it dissociates easily in water, giving an H⁺ proton and an HSO₄⁻ element. To deliver H⁺ and SO₄²⁻, the HSO₄ ion can further separate. Thus, the existence of H₂SO₄ drastically increases the amount of H⁺ electrons, so the rainwater p^H falls to dangerous concentrations.



Mitigation Approach

The coal used by Barapukuria has less sulfur percentage as well as consume less amount of coal per year compare to other three power plants that are under construction. Moreover, to meet the demand coal are to be imported from abroad having higher percentage of sulfur which means higher amount of SO₂ will be produced soon. Therefore, mitigation approach should be applied to protect our inhabitants and us.

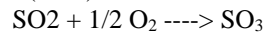
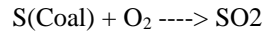
Mitigation Approach for SO₂

Different techniques for SO₂ monitoring are focused on either SO₂ pollution reduction or the end of pipe extraction process for flue gas. The simplest one is use coal, which has less amount of sulfur or mix with coal containing less amount of sulfur. Because SO₂ emission is proportional to amount of sulfur content of coal. To reduce sulfur coal can be washed before putting in to fire. Washing coal act as desulfurizing treatment. Despite this simple process, SO₂ can be removed from exhaust gas by using FGD system. Flue gas desulfurization (FGD) process has various classification. These are wet scrubber, limestone/gypsum system, ammonia scrubbing, lime/limestone scrubbing etc. Other than FGD system, Dry and semi-dry scrubbing, Wet regenerative processes are also applicable to prevent SO₂ emission.

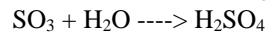
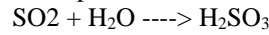
Table 4 Overall comparisons of SO2 control systems

System	Percent SO2 reduction	Capital cost (\$/kw)
Sorbent injection	30-70	50-100
Dry flue gas desulphurization	70-90	80-170
Wet flue gas desulphurization	>90	80-150

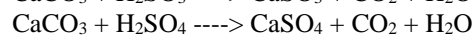
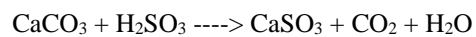
Considering all the treatment procedure for Barapukuria power plant lime/limestone scrubbing washing the coal properly. Bangladesh has a biggest deposit of limestone in Naogaon. It will be a cost-efficient choice. Moreover, this process is the most popular method. Usually the vertically focused spray tower use counter current for the absorbent application. When the CaSO₄ percentage exceeds 15, the gypsum scale is created. The method of lime stone forced oxidation (LSFO) avoids the development of this scale by pushing oxidation of CaSO₃ to CaSO₄ by pumping air into the conversion tank or an extra reserve tank. More than 90% of the U.S. flue gas desulfurization system capacity in the United States utilizes lime or calcareous. This trend is probable to proceed into the next stage of federally mandated decrease of SO₂ from coal-fired power stations. This is about 80% of the market share and is used in big utility boilers. This is due to the high effectiveness of removal of SO₂ and low expenses (Roy and Sardar, 2015). Wet FGD treatment can also apply for our future power plants that will have 700 MW or 1200 MW. These will consume more coal and coal will be imported so sulfur percent will not same as Barapukuria coal field. This treatment has removal efficiency from 97 to 99.3% (Initiative, 20003). The process includes the following reactions.



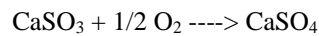
Absorption



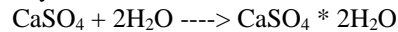
Neutralization



Oxidation



Crystallization



After separation of SO₂ this can be used to produce H₂SO₄. The gases are cooled to lower temperature and then go through a multi-stage converter system. The conversion has two steps. The SO₂ convert into SO₃ then absorption of SO₃ in H₂SO₄ to form H₂SO₄, an appropriate amount of water is added to maintain the concentration of sulfuric acid (Flytzani-Stephanopoulos, et al., 2000).

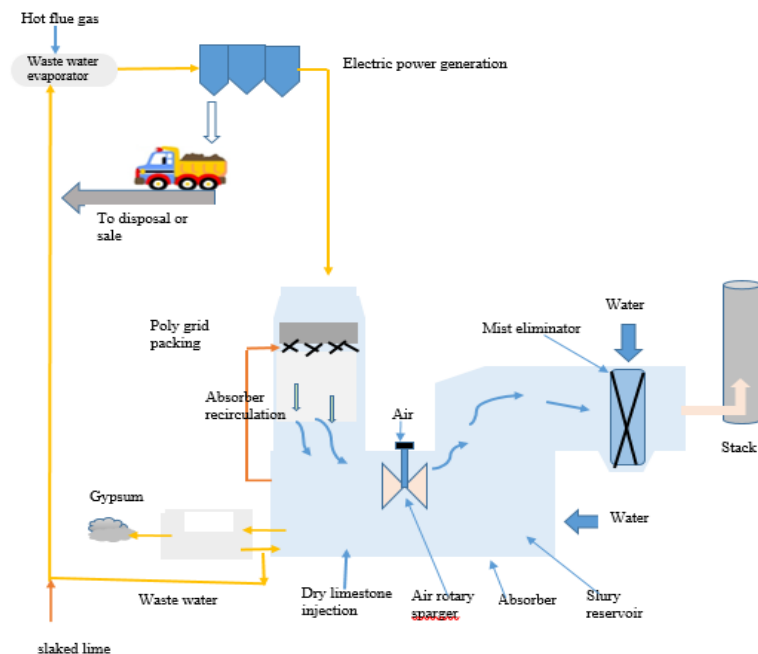


Figure 4. Demonstration of wet FGD process for power plant.

Conclusion

Though Bangladesh is a small county, it has a large population with great degree of population density and to push its economic growth various types of plans are under taken by the present government among them

power generation is most important one. Government is focusing on coal-based power plant due to its higher efficiency and low production cost compare to the others. Therefore, three more plants are under construction. Yet, these power plants will help to achieve our energy demand, it will perpetuate great calamity to

human health and environment. Therefore, mitigation process has become an essential one to overcome the future worries. The proposed process is highly efficient, but it costs us some extra charge. We need widen our view while achieving our goal. The activities of human are destroying our habitable world. Today's world is so much concern about our environment. In addition, our energy sector is one of them is responsible for world climate change. So, for the better future, it has become logical to pay some extra money while achieving our prosperity in energy sector.

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