DISPERSION OF AIR POLLUTANTS FROM KHULNA POWER PLANT

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ABSTRACT

Urban air pollution is an increasing concern worldwide due to rapid industrialization, urbanization and energy production. Air pollution due to power plant sector using Heavy Fuel Oil (HFO) is required to be assessed due to very limited studies especially for the Bangladesh context. This study focused on the emission and dispersion of criteria air pollutants (PM, CO, NOx, SO_2 and Lead) from Khulna Power company limited (KPCL - I). Emission estimation technique was used to calculate the emission of criteria air pollutants. The dispersion and concentration of air pollutants from Khulna power plant was analyzed using Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) dispersion model. This study revealed that 3290 kg of SO_2, 1400 kg of NO_X, 150 kg of CO, and 345 kg of Particulate matter (PM) per day are released to the atmosphere from the KPCL unit-I. The dispersion model also showed that the maximum concentration of SO_2 in the surrounding areas of the power plant was obtained as 24.55μg/m^3. This study will provide essential guideline for the emission estimation and air dispersion modeling approaches for policy making issues from the power plant sector to reduce the industrial air pollution.

Keywords: *Air pollutants; Dispersion modeling; Emission estimation technique; HYSPLIT*

1. INTRODUCTION

Air pollutants are hazardous to human health and at high enough concentrations can even be internecine. Air pollutants are categorized as 'criteria' and 'hazardous', where the criteria pollutants refer to the commonly and frequently observed six chemicals which are carbon monoxide (CO), lead, nitrogen dioxide(NO_X), ozone(O_3), particulate matter(PM), and sulfur dioxide(SO_2) and hazardous pollutants are toxic pollutants which cause cancer and other serious health problems or lead to adverse environmental effects (Yerramilli et al.2010) . The long-range transport of pollutants to different locals, globally, is a pertinent issue within the climate science community (Kolb et al. 2010). As a direct atmospheric pollutant, resulting from biomass burning and fuel combustion, it is a vanguard to the formation of tropospheric ozone; measurements of carbon monoxide (CO) have been used extensively to forecast and monitor air quality (Kleinman et al. 2002; Thompson et al. 2008; Morris et al. 2010; Rappengluck et al. 2008; Crutzen et al. 1979; Logan et al. 1981; Badr and Probert 1994; Forster et al. 2001; Novelli et al. 2003; Colarco et al. 2004; Yurganov et al. 2008; Engel-Cox et al. 2005; Morris et al. 2006). Generally the emission pf pollutants in air due to the use of fossil fuels in thermal power plants are the following: emissions of gases causing acidification such as sulphur dioxides and nitrogen oxides, greenhouse gas emissions such as carbon dioxide, methane, sulphur hexafluoride, etc, ashes and dust emissions to air.

Dispersion modeling uses mathematical equations, describing the atmosphere, dispersion and chemical and physical processes within the plume, to calculate concentrations at various locations. Whilst, there have been various review papers on atmospheric modeling and their approaches to dispersion (Vardoulakis, Fisher et al. 2003) and comparisons between different models using test meteorological data(Caputo, Gimenez et al. 2003), these have focussed on modeling gaseous dispersion. Dispersion is difficult to understand and estimate due to presence of different scales of eddies and their complex interaction. Pollutants in the atmosphere get transported longer distances by large scale atmospheric wind flows and dispersed in the atmosphere by small scale turbulent flows and mix with environment. Atmospheric dispersion models include the physical and chemical processes of transportation, transformation and dispersion of pollutants in the atmosphere to provide estimates of pollutant concentrations with the information of emission sources and concentrations (yerramili et al., 2010). The air dispersion modelling deals with the atmospheric conditions, chemical and physical processes and provides the archived and predicted air pollutants concentration of the surrounding areas from emission sources.

The emission estimation technique (EET) is assisting Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). According to EET manual for fossil fuel electricity generation published by Austalian government, There are five types of emission estimation techniques (EETs) that may be used to estimate emissions from provided facility, a) Using direct measurement to estimate pollutant emissions, b) Using CEMS (Continuous Emission Monitoring Systems) data,c) Using Fuel Analysis Data, d) Using a mass balance approach – Trace element behaviour during combustion and e) using Emission Factors. When the Emission factors usually relate the quantity of substances emitted from a source to some common activity associated with those emissions.To estimate the emission using emission factors, the factors are obtained from US, European and Australian sources, and are usually expressed as the weight of a substance emitted for a unit mass, volume, distance, or duration of the activity emitting the substance (e.g. kilograms of sulfur dioxide emitted per tonne of fuel consumption).

HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) model version 4, developed jointly by National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory (ARL) and Australian Bureau of Meteorology, is a computational tool designed to produce air parcel trajectories, and to carry out simulations on different spatial and time scales from local, regional and long-range transport, dispersion, and deposition of air pollutants. HYSPLIT computes simple trajectories to complex dispersion and deposition simulations using puff or particle approaches. The dispersion computation consists of three components: particle transport by the mean wind, a turbulent transport component, and the computation of air concentration. Pollutant particles are released at the source location and passively follow the wind field. The mean particle trajectory is the integration of the particle position vector in space and time (Draxler and Hess, 1998).

Bangladesh is a developing country (Rahman, 2002).But Bangladesh's energy infrastructure is quite small, insufficient and poorly managed (Chowdhury, 2004) .So Bangladesh is facing huge load shedding of electricity. In Bangladesh electricity power is not generating as much as our demand. According to the official statistics, the country's electricity shortage gone up 1000 megawatts (MW) to 1259 MW (Saifullah, 2009).So Bangladesh aims to develop the indigenous energy resources which play a vital role in the socio-economic development of the country. Government has declared its vision to make electricity available for all by 2020. To fulfil this vision, Government plans to increase power generation (Asian Development Bank, 2011). So now it is high time to focusing on the emission from power generation and its effect on environment as well as on human health. The objective of this study is to estimate the emission from Khulna power company limited, KPCL-I and KPCL-II; to show the dispersion of pollutants emitted from power plants using HYSPLIT dispersion model. This study will lead to greater understanding of emission effect from power generation.

2. METHODOLOGY

2.1 Selection of emission source

Limited studies have been conducted on air dispersion modeling in Bangladesh (Guttikunda & Begum., 2012), among them most of the studies were focused on the air pollution from brick kiln and motor vehicles in Dhaka city, however other industrial sectors like Power plant can be considered as a potential source of air pollution because the pollutants are emitting from power plants are PM_{10}, $PM_{2.5}$, SO_2, NO_X, CO and lead compounds. For this study, Khulna power plant was selected as the source of emission. As Khulna is the 3rd largest city in Bangladesh. The power plants are running under the Khulna Power Company Limited, located at goalpara of khalishpur. The Power generating capacity of KPCL-I is 110 MW. In KPCL-I, two floating barges named Tiger I and Tiger – III are using. 19 generators of Wärtsilä 18V32 DG Sets are using in which nine generating units are mounted on one barge and ten on the other. In Unit- I the barges shipped as deck cargo on submersible dry tow ships are moored in a closed basin. Each barge is approximately 91 metres long and 24 metres wide.

2.2 Emission estimation

Emission of pollutants from fuel oil based power generation was estimating using the generelized formula given bellow,

$$E_{kpy,i} = AR \times EF_{ix} [1 - (CE_i/100)]$$

where , $E_{kpy,i}$= emission rate of pollutant i, kg/yr AR = activity rate (fuel use), t/yr (AR = t/hr x Ophrs) Ophrs = operating hours, hr/yr, EF_i= uncontrolled emission factor of pollutant i, kg/t CE_i= overall control efficiency for pollutant i, %. Emission factors are based on fuel consumption. In case of Khulna power plant 600MT heavy fuel oil used for generating 110 MW of electricity and the operating hour is 24 hour of everyday in a year. Emission was calculated considering uncontrolled emission hence power is generating using generator. In this study emission was estimated for sulfure dioxide (SO_2), Oxides of Nitrogen (NO_X), particulate matter (PM_{10}, $PM_{2.5}$), Carbon monoxide (CO) and lead compounds. According to National Pollutant Inventory of Australian

Government, emission factor for ozone is not applicable because from residual fuel oil burning ozone is not emitted from plume as the primary pollutant. The emission was calculated considering 100% pant load factor.

2.3 Dispersion modeling

To show the dispersion of pollutants, HYSPLIT dispersion modeling was done for the month of December 2014. In dispersion modelling GDAS (1 Degree, global, 2006-present) was used. The GDAS archive is a latitude/longitude global grid with a resolution of 1 degree, is a weekly one-degree, pressure-level, Global Data Assimilation System (GDAS) model output (ARL's GDAS1 archive). Dispersion simulation is done over a range of 200 km around the sources. A horizontal grid of $4^\circ \times 4^\circ$ with resolution of $0.02^\circ \times 0.02^\circ$ (roughly 2 × 2 km) and with 40m above ground level is considered in HYSPLIT dispersion model. Pollutant concentrations are sampled every time step and averaged over every 24 hour. Dispersion is determined by the prevailing wind (speed, direction), atmospheric stability, mixing layer height, and the diurnal and spatial variation in these quantities. The emissions from this hypothetical source are considered to assign pollutant mass to each virtual particle represented in the HYSPLIT model. The dispersion calculations are made for SO_2 species and no seasonal or diurnal variations in the load factor are considered in the present study. The pollutant plume is treated as top-hat puffs in the horizontal and particle in the vertical. In dispersion modeling main dominating parameters are emission rate, averaging period and meteorological data such as wind direction, and wind speed. Naturally in our country, during the dry season the direction of wind is north to southward. All the meteorological factors are assimilated in GDAS. Averaging period indicate the sampling interval of pollutants concentration. Small sampling interval gives the greater concentration as the dispersion of pollutants is also controlled by the passage of time. In this study averaging period was taken as 24 hour.

3. RESULTS AND DISCUSSION

3.1 Emission from power plant

Using emission estimation technique the mass of SO_2, NO_X, CO, $PM_{2.5}$and PM_{10} were calculated released from KPCL-I of 110MW generation capacity. Table-1 gives the mass of air pollutants released from power plant due to electricity generation using heavy fuel oil. Table 1shows that daily massive amount of pollutants are emitting from the plume. The emitted sulfur dioxide and nitrogen oxides arise into the atmosphere, where they come in contact with water vapor and they form sulfuric, sulfurous acid, nitric acids etc. Those acids then fall to the ground mixed with rain and damage plants, which affects animals and pollutes the environment, as well as cities, because those acids react with some metals and other materials that are commonly found on buildings or monuments. Another process occurs on fine and cloudy days. Airborne acids come directly through winds, and deposit themselves on trees, buildings, and even human respiratory systems. These deposited acids increase acidity in soil, lake water etc.

Table 1: Emission from HFO based Khulna power plant

Compounds	Emission(kg/ day)
SO_2	3,290
NO_X	1,400
CO	150
PM_{10}	207.7
$PM_{2.5}$	138.5
Leadcompounds	0.045

The results indicate that, the power plant will release 987 t/annum of SO_2, 420 t/annum of NO_X, 45 t/annum of CO, 62.31 t/annum of PM_{10}, 41.55 t/annum of $PM_{2.5}$ and 13.5 kg/annum of Lead compounds. According to the EURELECTRIC, 2003; from a power plant of 1,000 MW generation capacity using the fuel oil of energy content 42.2 MJ/kg emits SO_2 and NOx of 3,134 t/annum though the diversity of fuel mixes in each country gives different average values. From this comparision it is clear the the emission of pollutantas are largely depends on the energy contnt of fuel oil.

3.2 Evaluation of dispersion modeling

From HYSPLIT dispersion modeling developed for the month of December, 2014 the dispersion of pollutant released from power plant is generated though map. The differences among the concentration ensemble members in the dispersion simulated by the coupled modeling system are analyzed following the method given in (Wamer et al., 2002). In this approach, the plume spread in the range of 200 km from the source and the time of evolution of the area exposed above a particular concentration limit are considered.

Dispersion results from different simulations show variation in plume distribution pattern and concentration. Hence the modeling were done for the entire month but in figure 1, only 6 days interval dispersion maps are showing to describe the effect of wind direction on pollutnts dispersion. The dispersion map shows that the pollutant concentration is gradually decreasing with the time and distance. From source the dispersion of pollutant varies with the meteorology specifically with the wind speed and wind direction. The dispersion of pollutant is horizontally more than 200m with the range of concentration is >0.01mg/m^3-0.00001 mg/m^3. The dispersion map of 6 days interval shows that the pollutant particles in the first day was in south-east direction and gradually it is changing towards south-west direction. The map indicates that the pollutants from Khulna power plant contributing to the air quality in great mangrove forest Sundarban. This effect is only in winter season only because in winter season the wind direction is from north to downstream which in monsoon is from south to upstram direction.

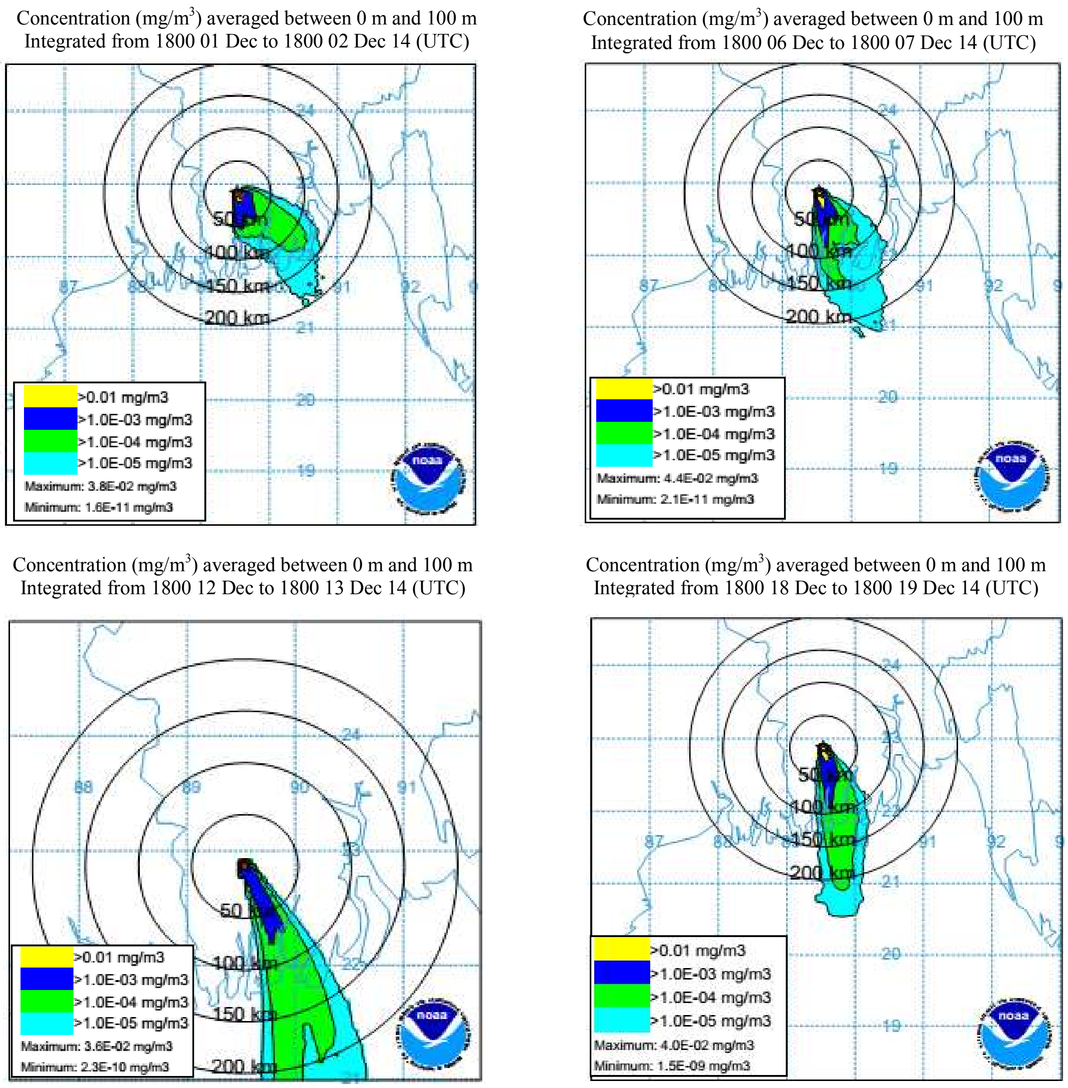

Figure 1: Dispersion scenario of emitted SO_2

Concentration (mg/m^3) averaged between 0 m and 100 m
Integrated from 1800 25 Dec to 1800 26 Dec 14 (UTC)

Concentration (mg/m^3) averaged between 0 m and 100 m
Integrated from 1800 30 Dec to 1800 31 Dec 14 (UTC)

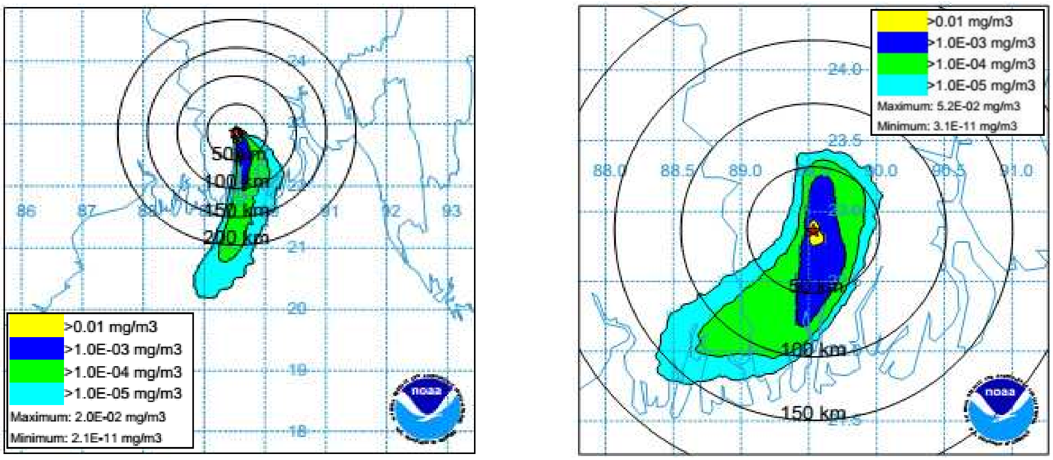

Figure 2: Dispersion scenario of emitted SO_2

From model output concentration of SO_2, NO_X, CO, PM_{10} and $PM_{2.5}$ are simulated. Figure 2 and figure 3 show that maximum concentration of gaseous pollutants and particulate pollutants respectively. In December 2014, the maximum SO_2 concentration is simulated as 24.55 µg/ m^3 which is quite below to the national ambient air quality standards for Bangladesh.

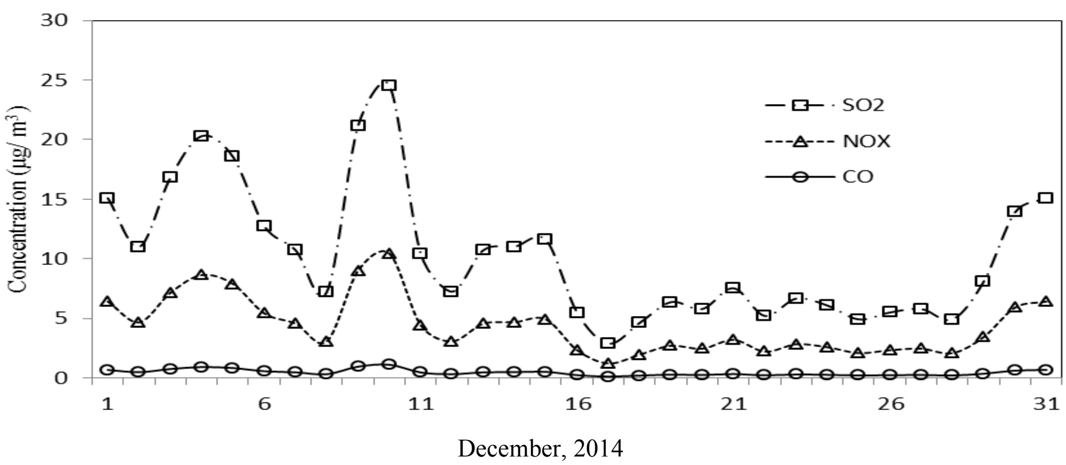

Figure 2: Simulated mean concentration of SO_2, NO_X and CO in December 2014 from HYSPLIT

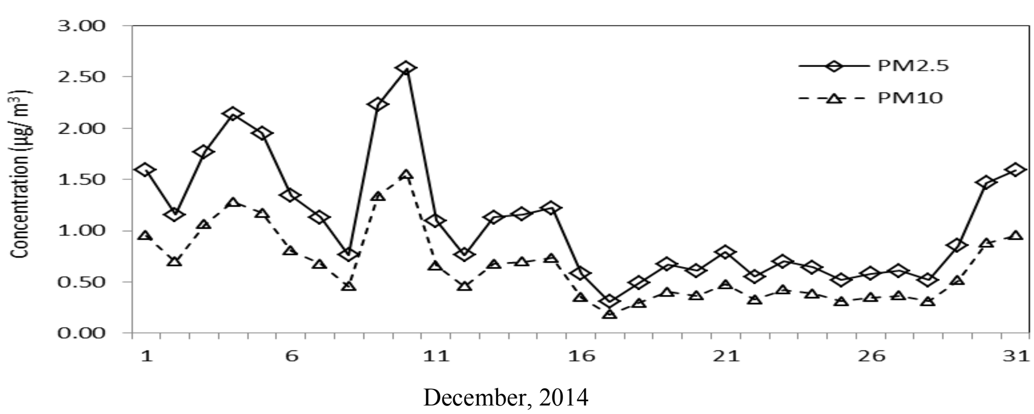

Figure 3: Simulated mean concentration of $PM_{2.5}$, PM_{10} in December 2014 from HYSPLIT

The maximum concentrations for NO_X, CO, PM_{10} and $PM_{2.5}$ were 10.45µg/ m^3, 1.12µg/ m^3, 1.55µg/ m^3 and 1.03µg/ m^3 respectively. The main drawback of HYSPLIT dispersion modeling is the secondary reaction of gaseous pollutants are not considered. In HYSPLIT meteorology is not directly coupled with the concentration grid, hence grid dependent (Eulerian) chemistry computations that are sensitive to meteorological parameters are difficult to code. In table 2, a comparison between model output and the national ambient air quality standards for Bangladesh is given.

Table 2: Pollutant concentration in December, 2014 emitted from Khulna power plant

Pollutants	24-hour average concentration (µg/m3)	NAAQ Standards for Bangladesh (µg/m3)
SO_2	10.26	365
NO_X	4.37	100
CO	0.46	9(ppm)
PM_{10}	0.65	65
$PM_{2.5}$	0.43	150
Lead compounds	0.0006	0.5

4. CONCLUSIONS

This study showed that power sector which is not considered as a potential source of air pollution, emitting huge amount of pollutants everyday as the power generation is continuous process. From HFO based power plant in Khulna SO_2, NO_X, CO, $PM_{2.5}$, PM_{10} and Lead are released in Khulna air shed which are the Criteria pollutants. The emission of SO_2 and NO_X are 3290 kg and 1400 kg which after emission contribute in acid deposition both in atmosphere and ground after secondary reaction. The maximum concentration of SO_2 obtained 24.555µg/m^3 contributing to the ambient air quality, which is quite below the National Ambient Air quality Standard. HYSPLIT dispersion model showed that the pollutants are dispersed in a long distance more than 200km from source. Hence the maximum concentration of SO_2 is not ground level but the deposition occurs in the ground. From this study it can be conclude that power sector is one of the important air pollution sources. Policy makers should not only make emission control policy but also implement this policy properly to reduce the emission to air.

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