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Emission from Thermal Power Plant having stacks of heights 100m and 275m

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Abstract
*Power is a basic demand of today's world, therefore many power plants are set up across the world to supply the demand of the power and they are of various different categories, Thermal power plant is one ofthe type of such plants uses thermal energy for power generation or to produce electrical energy. Despite having so many advantages thermal power plants are a threat to environment. Thermal power plant causedair pollution by emitting pollutant like PM, NOx, SOx, TPP are one of the examples of point source. Air pollution is a threat to environment, impact flora and funa and fine particles from industrial plants and numerous other sources are particularly dangerous to human health. Main pollutants from these plants areSOx, NOx, and PM. Ministry of Environment Forest and Climate Change (MoEF&CC) look after such plants and suggest measures, and set limits to emissions from these plants. MoEF&CC previously suggested that the height of 275m for the stack to emitted flue gas into the atmosphere, it got amended in 2017, suggested that power plant with a power generation capacity of mini 100MW or more with wet FGD system installed, should construct a stack of mini 100m height or H=6.902(Q*0.277)^0.555. Pollutant dispersion in the atmosphere varies as the stack height vary thereare max chances for worst condition the GLC from the same source will vary as the stack height varies. This study focused to found out GLC emission from the same plant for two different stack heights i.e., 100 and 275. A case study of Odisha Thermal Power Corporation Limited (OTPCL), the 2400MW (3*800MW)thermal power plant near Kamakhyanagr Dist. Dhenkanal, Odisha is taken, and results show that if the stack height is 275 the max GLC (worst case) obtained will be under National Ambient Air Quality Standard but for stack height 100m max GCL (worstcase) exceeding the NAAQ standard and huge air pollution will happen.*

Keywords Air pollution . Thermal Power Plant . Stack Height . AERMOD

1. Introduction

Both the ancient and the present world are closely interwoven with energy. Energy is of the various different form i.e., mechanical, electrical, work, heat, electricity, and radiation. The thermal power plant uses thermal/ heat energy to produce electricity from thermal energy. Energy is the basic need of the present world. The thermal power plant uses coal, lignite, naphtha, gas, MSW (non-hazardous) fuels to generate electricity. Coal-based thermal power plants are practices on a large basis in India as India isranked 3rd among the top ten coal producing countries in the world. The coal-based thermal power plant usespulverized coal in boilers, therefore, a large number of harmful flue gasesare emitted from these plants including SOx, NOx, and PM. If these pollutants exceed their National Ambient Air Quality (NAAQ) standard which is set up by CPCB (table no. 1) than they aretermed as air pollutant. Air pollutant has various damaging effect over humans, plants, andanimals. Air quality is measured by the Air Quality Index (AQI). AQI is an index for reporting daily airquality. It tells you how clean or polluted the air isand there consequence health effects. In order to control the emission from TPP limits are set up by MOEF&CC. The MoEF&CC set a notification, norms and rules forthe thermal power plants. The flue gases emitted from the stack are released into the atmosphere where it disperses, diffuses or reaches to the ground level, depending over which the plume dispersion behavior is predicted/studied. In this project we study the emission of OTPCL at two different stack heights i.e, 100m and 275m.

Table 1: National Ambient Air QualityStandards, 2009

Pollutant	Time Weighted Average	Concentration in ambientair (μg/m³)	
		Industrial Area Residential, Rural & otherAreas	Ecologically sensitive area (Notified by Central Govt)
Sulphur Dioxide (SO_2)	Annual*	50	20
	24 hours**	80	80
Oxides Nitrogen (NO_2)	Annual*	40	30
	24 hours**	80	80
Particulate matter (size Less than 10μm) or PM10	Annual*	60	60
	24 hours**	100	100
Particulate matter (size Less than 2.5μm) or PM2.5	Annual*	40	40
	24 hours**	60	60

2. Theory

Sources of air pollution are categorized as point source, line sources, area sources and volume sources. This study focuses on emissions form point sources and their effects on surrounding environment/atmosphere. In an atmosphere various condition prevails like temperature, wind velocity, wind speed, weather conditions (sunny or cloudy) etc. The emission from stack forms different types plumes in atmosphere. The dispersion of such plumes varies with the atmospheric conditions like sub-adiabatic, super- adiabatic, isothermal and neutral conditions [7] and the description of these condition are given as:

ELR > DALR, Then it is the super-adiabatic and unstable condition.
ELR < DALR, Then it is the sub-adiabatic and stable condition.
ELR = DALR, Then it is a neutral case.

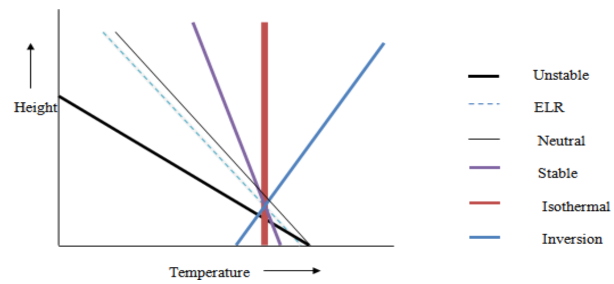

Figure 1: Stability class diagram.

2.1 Gaussian Model:

In order to determine the concentration of a pollutant from a point source/ single source eitheron ground level or at a point of stack height we uses Gaussian Dispersion Model. The concentration of air pollutant at a particular location under the plume depends on the sampling time. Plume dispersion is a function of downwind it also depends on the intensity of turbulence, the distribution of eddy sizes and the dimension of the plume. Scorer suggested that the appropriate sampling time is equal to about the time for the wind to carry the plume from the source to the point of observation.
Gaussian Dispersion Modeling is a steady state and deterministic modeling which follow a normal distribution curve or Gaussian curve [7].

2.1.1 Assumptions:

This theory has some assumptions which aregiven below as[7]:

a) Steady-state conditions.
b) Homogeneous flow.
c) A pollutant is conservative and no gravityfallout.
d) Perfect reflection of the plume at the underlying surface (no ground absorption).
e) The turbulent diffusion in X-direction is neglected relative to advection in the transport direction.
f) Average wind speed is greater than 1m/s.
g) Flat terrain
h) All variable are averaged i.e. an average of 8 hr.

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2.1.2 Disadvantages:

Gaussian dispersion model also have some disadvantages which are explain below[7]:

a) No interaction between plumes is taken.
b) Gaussian model is not designed to model the dispersion under low wind conditions or at sites closed to the source i.e. distance than 100m. This model does not work for the site at a distance less than 100m.

2.1.3 The formula for calculating the concentration of the pollutant [7]:

$$X(x, y, z, H = \left(\frac{Q}{2*\pi*\sigma y*\sigma z*U}\right)*\exp\left[-\left(\frac{1}{2}\right)*\left(\frac{y}{\sigma y}\right)^2\right]* \left[\exp\left[-\left(\frac{1}{2}\right)*\left(\frac{Z-H}{\sigma z}\right)^2\right]+\exp[-\left(\frac{1}{2}\right)*\left(\frac{z+H}{\sigma z}\right)^2]\right]$$

Where:
X= concentration in g/m³
Q= Source strength in g/sec
U= average wind speed in m/sec
σy, σz= diffusion coefficient in y and z direction in meters
H= effective height of source emission in meters.

X is the concentration of a pollutant at distances more than 10m from the source. The dispersion of the pollutant in the atmosphere depends on various factors i.e., wind speed, wind direction, pressure, temperature, stability class, solar radiation, cloud cover, humidity, terrain, the concentration of plume, mixing height, particle velocity, night and day time. Pollutant maximum concentration is found at time average plume centerline as we move away from the time average plume centerline the concentration starts decreasing. The concentration at a various point can be determined by using a diffusion coefficient, diffusion coefficient varies with the direction and is represented by symbol σ (sigma). If the distance from the source is known then the value of sigma's can be determined from the chart given in Annexure A & B. The alternate method of calculating sigmas is explained below.

2.1.4 Table to find the dispersion coefficient [2]:

$$\sigma y = a \times x^b$$
$$\sigma z = c \times x\text{^}d + f$$

Where,

x is distance in a unit of km.

σy, σz is dispersion coefficient in a unit of m.

Table 2: Table for finding the dispersion coefficient.

	All		X < 1 km			X > 1 km		
Class	A	B	C	D	F	C	D	F
A	213	0.894	440.8	1.941	9.27	459.7	2.094	-9.6
B	156	0.894	106.6	1.141	3.3	108.2	1.098	2.0
C	104	0.894	61.0	0.911	0	61.0	0.911	0
D	68.0	0.894	33.2	0.725	-1.7	44.5	0.516	-13.3
E	50.5	0.894	22.8	0.678	-1.3	55.4	0.305	-34.0
F	34.0	0.894	14.35	0.740	-0.35	62.6	0.180	-48.6

Table 3: Guidelines for determining pasquil Gifford stability class [7].

Surface wind speed (m/sec)	Day Incoming solar radiation			Night Thinly overcast Or >= 4/8 low cloud	<=3/8 cloud
	Strong	Moderate	Slight		
< 2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

NOTE: Turner, 1970 says: The neutral class D should be assumed for overcast conditions during day or night.

From Turner (1970) maximum concentration is explained as a function of (XU/Q) max. This can be better understood by the graph given below.

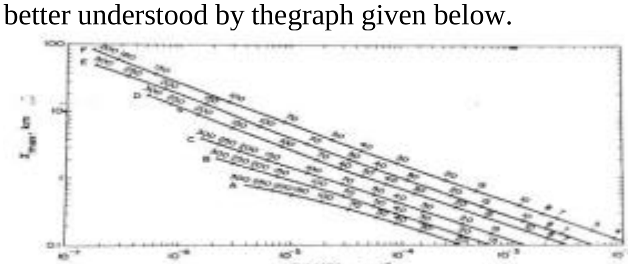

Fig. 2: Distance of maximum concentration and maximum XU/Q as a function of emission [7].

3. Air pollutants and their effects

3.1 Oxides of Sulfur[7]:

The sulfur dioxide is another atmospheric pollutant which is produced by the combustion of fossil-fuel in thermal power plant. Sulfur dioxide is a non-flammable, colorless gas with a pungent, irritating odor. In power plant combustion processes SO_2 forms in the ratio of 40-80 parts per part of SO_3. The major oxide emitted is therefore SO_2. The term SOx is defined as the mixture of sulfur oxides emitted into the atmosphere. In the atmosphere, several reactions occur which remove SO_2 from the atmosphere. Some metal oxides SO_2 directly into sulfate. SO_2 in the atmosphere reacts with water to form H_2SO_3 (sulfurous acid) and sulfur trioxide react with water vapor to form H_2SO_4 (sulfuric acid). It causes various types of diseases and pollutes the environment if it exceeds a certain limit in the atmosphere; these limits are set up by CPCB.SO_2 have both short term and long-term effect on human health. Short term exposure causes pulmonary and respiratory diseases and it is recommended that a value of 500 µg/m3 (0.175 ppm) should not be exceeded over averaging periods of 10 minutes [16]. SO_2 causes skin, eyes, throat and lungs irritation can also causes inflammation to respiratory system coughing, worsen asthma attack. If the emissions exceed the prescribed value, then the emission of SO_2 in the environment is needed to be controlled and it is done through adopting various technologies. Physical processes in controlling the gaseous emission into the atmosphere depend on processes namely adsorption, absorption and catalytic conversion. There are some methods are available to reduce sulfur component from the coal-based power plant one is switching to low sulfur fuel, limestone injection process, catalytic oxidation process, sodium-based scrubber process. For coal base TPP we generally use an FGD system to control the Sox emission from the stack.

3.2 Oxides of Nitrogen[7]:

Oxides of Nitrogen are pollutant which have a harmful effect over the atmosphere. Nitrogen oxides must be controlled or reduced from the present ambient air quality standard because NO oxidized and produce NO_2 as its product after oxidation. If NO_2 in the atmosphere exceeds the Ambient Air Quality standard, then it has an adverse health effect.There are several oxides of nitrogen in the air but there are two important oxides in the air which cause air pollution and those are nitric oxide (NO) and nitrogen dioxide NO_2. NOx represents the combined concentration of NO and NO_2. Nitrogen dioxide is corrosive to materials and toxic to man can damage human respiratory tract and increase vulnerability to respiratory infection and asthma. Long terms exposure to NOx causes chronic lung diseases. The main contributors of NOx are motor vehicles and fuel combustion in stationary sources and theyare concentrated in the urban areas. Man-caused emission resulting in increased concentrations in urban areas is cause for alarm. The resident time of NO_2 is about 3 days and for NO it is approx 4 days. Thermal power plant combustion process produced NOx is very dependent upon the thermodynamic process (Temperature, air/fuel ratio, and the type of combustion equipment).

3.3 Particulate Matter [7]:

Coal-burning plants generate huge quantity of particulate matter which, even if controlled by most efficient collection devices, still emits considerable amount to the atmosphere. Very small particles escape even the most efficient collectors and cause a maximum reduction in atmospheric visibility. Particulate matters form a major part of air pollutants and needed to be controlled by applying various technologies in order to meet the ambient air quality standard. Particulate matters come from diverse sources like automobiles, steel mills, cement plants, and construction project. Suspended particulates are measured by gravimetric test. Solid particles can vary in shape from spherical to highly irregular. The shape and size distribution of particles are important parameters as the cleansing technique specifically depends on the type/size of particles which is to be removed. Particulate matter is removed from the air by sedimentation process (fallout). For spherical particles in free fall, the terminal velocity is given by Stokes law.

3.4 Mercury[14]:

Mercury is a hazardous trace element of the coal. In a thermal power plant, as the coal starts to burn,the mercury available in coal is released. Once themercury is released it is evaporated into the atmosphere whereas some part is trapped in pollution control instruments such as electrostatic precipitator (ESP), bag filter, etc and the remaining goes with the bottom and fly ash. Mercury at a low level can be tolerated without many harmful effects. The exceedance limit of Hg is 0.03 mg/Nm3. Industries at one place have some concentration, at that place the concentration level keeps on increasing and the cumulative concentration has a destructive consequence on the human. The irony here is that the impact of current emissions is seen after a very long period of 20- 25 years. Thus, while selecting the site of TPPs, the mercury pollution study must be done for the site apart from other factors polluting the site. Among various toxic elements Hg emission from coal-based are topics of concern, mercury emitted in flue gases are disposed off to the ash ponds and enters the hydrological system, wherein mercury can be converted into methyl mercury. This methyl mercury can enter into the human food chain through the consumption of the fish, which can harm the brain, heart, lungs, kidney and immune system of the people. Indian coal ash has an average mercury concentration of 0.53 mg/kg. In India, Coal based thermal power plants are the second largest source of mercury emission (77.91 tons per annum). To control emission from TPP various system may be used like Electrostatic Precipitator (ESP) and Flue Gas Desulphurising System (FGD).

4 Tools and Technology used in the research:

The AMS/EPA Regulatory Model (AERMOD)was specially designed to support the EPA's regulatory modeling programs. AERMOD is a regulatory steady-state plume modeling system. In order to predict the impacts due to any plant or source, AERMOD modeling system is used. The USEPA AERMOD model was issued towards theend of 1998 and has replaced the ISCST3 model as the USEPA's standard dispersion model.AERMOD is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.

In the stable boundary layer (SBL), theconcentration distribution is assumed to be Gaussian in both the vertical and horizontal direction. In the convective boundary layer (CBL), the horizontal distribution is assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (p.d.f.). Thus, it is applicable to rural and urban areas, flat and complex terrain, surface and elevated releases, and multiple sources (including, point, area, and volume sources). The most important feature of the AERMOD model over theISC model is its modification of the basic dispersion model to account more effectively for a variety of meteorological factors. In particular, it uses the Monin-Obukhov length scale rather than the Pasquill Gifford stability categories to account for the effects of atmospheric stratification. However, it remains essentially a Gaussian model. The modeling system consists of one main program (AERMOD) and two pre-processors (AERMET and AERMAP). The major purpose of AERMET is to calculate boundary layer parameters for use by AERMOD. The meteorological INTERFACE, internal to AERMOD, uses these parameters to generate profiles of the needed meteorological variables. In addition, AERMET passes all meteorological observations to AERMOD.

The growth and structure of the PBL are driven bythe fluxes of heat and momentum, which, in turn, depend upon surface effects. Surface characteristics (land use) in the form of albedo, surface roughness and Bowen ratio, plus standard meteorological observations (wind speed, winddirection, solar radiation, temperature, and cloud cover), are input to AERMET. AERMET then calculates the PBL parameters: friction velocity, Monin-Obukhov length, convective velocity scale, temperature scale, and surface heat flux(H). These parameters are then passed to the INTERFACE (which is within AERMOD).

5 Results and Discussion:

OTPC Limited proposes to set up a coal-based supercritical thermal power plant of 2400 MW (3x800 MW) capacity Super-Critical TPP at village **Annapurna Khamar, Taluk Kamakhyanagar, Dhenkanal Distt., Odisha**, is taken for a case study. The met data excel sheet of the OTPCL is collected and on the basis ofdata available stability class for each hour of a day forthe months of Oct-Dec is determined. Data ofOTPCL is feed into AERMET to generate the met file, and the met file is given as input data to AERMOD. Here we found out the max concentration of the pollutant for various atmospheric classes used for two different stack heights (100m and 275m) all other data are kept constant. In this study here some assumptions are taken which are bulleted as below:

a) When wind speed is less than 1m/s during night time stability class E is taken.
b) When the wind speeds less than 2m/s, then according to Langley chart for moderate solarradiation stability class is A-B hence for we have taken class B.
c) When wind speed greater then 1m/s and less than 2m/s stability class is not defined for night time. Hence stability class E is taken.
d) It is very complicated to give each hour stability class value as an input in AERMOD so we have taken that duration which is occurring maximum no. of times i.e.,
e) For stability class, A duration is taken 10:00 AM-14:00PM for each day of study duration.
f) Similarly for E 1:00AM-7:00AM &18:00PM-24:00AM and for D 8:00AM, 9:00AM, 15:00PM,16:00PM,17:00PM.

5.1 Theory referred:

Here to find out stability class during night time turner stability class table is preferred. And forday modified method criteria [13], solar radiation is taken in the unit of

Langley/hour.

The data taken for study is of three months, the month of October, November, and December. The stack height suggested by MoEFCC for power plant with a power generation capacity of mini 100MW or more with wet FGD system installed, should construct a stack of mini 100m height or *H=6.902(Q*0.277)^0.555.* [15].

As per the formula provided in the Ministry's Notification dated 28.06.2018, the minimum stack height is obtained as 84.4 m. however, as per the notification if stack height is less than 100m, it is to be consider as 100m.

The area of study was focused for winter season that is Oct-Dec, 2016. Number of days comes out for stability class A, B, C, D, E and F were 434, 128, 0, 363, 1282 and 1 respectively. This study compares data for stability class A, D & E. 1- hour average concentration is taken for the study.

6. Metrological Data:
2016 Metrological data was taken for winter season (October – December) for calculations of results and the parameters were Temp (deg C) ranging between 12-35.3, Humidity (%) ranging between 3.2-96.6, pressure ranging between 1000- 1007, wind direction (deg) ranging between0-360, wind speed (m/s) ranging between 0-4.83, Solar (Langley/hour) ranging between 0-120, Cloud cover ranging between 1-8. Stability class calculated for every hour for each day for the month of Oct-Dec.

Stack No.	Height (m)	Height (m)	Top Dia. (m)	Flow Rate Nm³/h	Exit Vel. (m/sec)	Temp. °C	Emissions (g/s)		
	Case I	Case II					PM	SO_2	NOx
1	275	100	8	3289004	25	140	27.41	91.36	91.36
2	275	100	8	3289004	25	140	27.41	91.36	91.36
3	275	100	8	3289004	25	140	27.41	91.36	91.36

Figure 3: Input data

Table 1: Pollutants concentration for stabilityclass E at stack height of 100m and 275m.

Stability class E			
Stack height	Pollutant concentration (µg/m³)		
	PM10	**NOx**	**SO_2**
100	388	1293	1293
275	0.681	2.06	2.06

Table 2: Pollutants concentration for stabilityclass D at stack height of 100m and 275m.

Stability class D			
Stack height	Pollutant concentration (µg/m³)		
	PM10	**NOx**	**SO_2**
100	122.63	409.00	408.77
275	9.01	30.00	30.00

Table 3: Pollutants concentration for stability class A at stack height of 100m and 275m.

Stability class A			
Stackheight	Pollutant concentration (µg/m³)		
	PM10	**NOx**	**SO_2**
100	14.6	48.6	48.6
275	13.1	43.7	43.7

6 Comparison of results obtained:

Graphical representation of results are shown below, where X-axis represents stability class and Y-axis represents Concentration of air pollutants (PM, SOx and NOx).

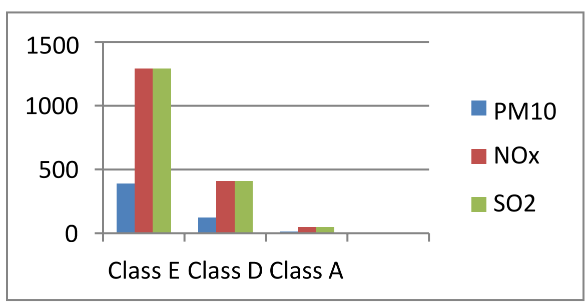

Figure 4: Emission from 100m stack height

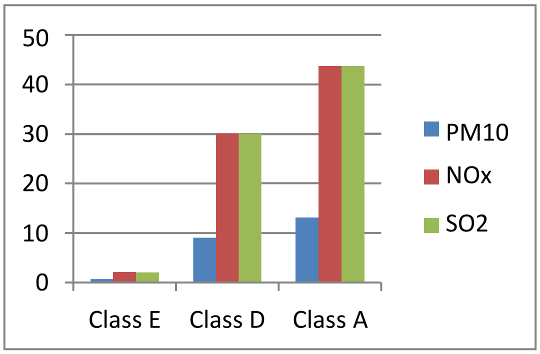

Figure 5: Emissions from 275m stack height

7 Conclusion

Air pollution is a major problem in today's world, it is a threat to human life. This study focuses on the environmental impact assessment of the thermal power plant, here the main focus is towards air pollution due to the coal-based thermal power plants. In this study, OTPCL plant emission is studied by taking two stack heights that are 100m and 275m, in order to justify the MoEF&CC notification. The Ministry of environment forest and climate change suggested the stack of 275m height to the power plant of capacity equal to or more than 100MW, but this is amended in 2018 that the stack height should be 100m or H= 6.902(Q*2.077)^0.555. This study focuses on the effect of plants emission due to these two stack heights, and it is found here that during the worst case scenario when the stability class E and D occurs the GLC value found in case of 100m stack height is much higher than the NAAQ standard when compared with the emission from the stack of 275m height. Whereas both heights are suitable when the atmosphere has stability class A, which is the most practical situation all values of GLC for each pollutant lies under the NAAQ emission standard.

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