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The Impact of PG Classes and Addition of FGDB on Air Pollution Emitted from Shuaibah III (IWPP) Plant: Screening Model

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A B S T R A C T

The objective of the present work is the studying of air quality that contained pollutant gases (SO_2, NO_x, CO), and PM released from the Shuaibah III (IWPP) plant as a case study. Also, we tried to evaluate the effect of Flue gas desulfurization byproduct (FGDB) on SO_2 that turned into carried out within the studied place. For the determination of dispersion, the source of pollution was taken into consideration to be in a rural area. The screening model was used to calculate concentrations dispersion of gas pollutants at different Pasquill-Gifford stability classes' conditions. The levels C_{max} (maximum concentrations) decreased from A-class to F-class, and the influence distance D_{max} (maximum distance of downwind concentrations) quickly grows. The SO_2 dispersion became affected by the FGDB system. The results confirmed that the C_{max} of air pollutants released from the stack may additionally decreases than the Saudi Arabian standard.

1. Introduction

The power generating plants are the main source of gas pollutants in the rural and urban in addition to industrial activations. It's usually agreed that SO_2 decreases the visibility in any region, harm several materials, crops and health of human [1]. Once SO_2 is changed and hydrolyzed, it offers rise to air pollution. The quantitative estimation of the long-time period common of SO_2, NO_2, CO, and PM has been handled by means of several researchers [2–5]. Chih-Chung and Hui-Hsuan [6] investigated, however, region air pollutants (PM, SO_2, NO, CO) and environmental conditions (wind speed) have an effect on region turbidity. The relation between the concentration of SO_2 within the air and also the degree of injury to nearby became studied with the aid of Navara and Kaleta [7]. In closed environments, the concentration of CO will simply rise to total levels. On average, 170 people within the United State die each year from CO made by non-automotive users produces [8]. The energy created by power stations comes from the combustion of oil and natural gas fuel. The combustion method of fuel is accompanied *via* emission to the surroundings of huge quantities of exhaust waste gases, with an increasing rate annually corresponding to that of conventional electric power produced.

To satisfy clean air requirements, moist scrubber generation presently used eliminates lots of SO_2 to produce large quantities of (FGDBs), flue gas desulfurization by-products [9,10]. However, FGDB is additionally called a potential environmental waste material at each regional and international levels [11]. Thus, FGDB represents a good useful use to low disposal of the waste material. A number of investigators work on the influence of FGDB as changing in some applications lead to many organizations and institutes at dispersed spaces over all the world [12–15].

Computational science has come to be a significant tool in forecasting and examining many systems of emissions. With increasing interest in numerical methodologies, software tools are established for demonstrating the plant releases and its effect on air dispersion [16–18]. This consists of the progress and support of different computational software, additionally as optimization of plant abilities to improve the air feature. Those simulations are not essential to forecast the emission of pollutant concentrations only but also to identify the relations between changed measures in the air [19,20].

The target of this research aimed to use a screen view to estimate ground-level concentration of emission gases pollutant from the Shuaibah III (IWPP) plant in Jeddah, Saudi Arabia. The special effects of variations for Pasquill-Gifford stability classes in the model, and the Flue gas desulfurization by-products (FGDBs) those are predicted to affect the pollutant dispersion in air were investigated.

2. Study Area

The Shuaibah III (IWPP) plant is a power and desalination station on the coast of the Red Sea, south of Jeddah in the Kingdom of Saudi Arabia. Figure 1 shows the location of the study area.

Figure 1. Location of Shuaibah Phase III Power and Desalination Plant in Saudi Arabia.

3. Meteorological Description of The Study Area

The dispersion of pollution inside the atmosphere is substantially dependent on the atmospheric conditions. So, an evaluation of some meteorological parameters became completed. The period of time from 1980 to 2016 that considered for determined temperature, the amount of cloud cover, ambient and wind speed, and direction, as shown in Figure 2 (a to d), respectively. These parameters are for King Abdul-Aziz airport meteorological station in Jeddah city.

3.1. Temperature

The average of excessive temperature is above 37°C for the hot season. The hottest day is with an average (39 - 27°C). Furthermore, the common every day excessive temperature below 30°C for the cool

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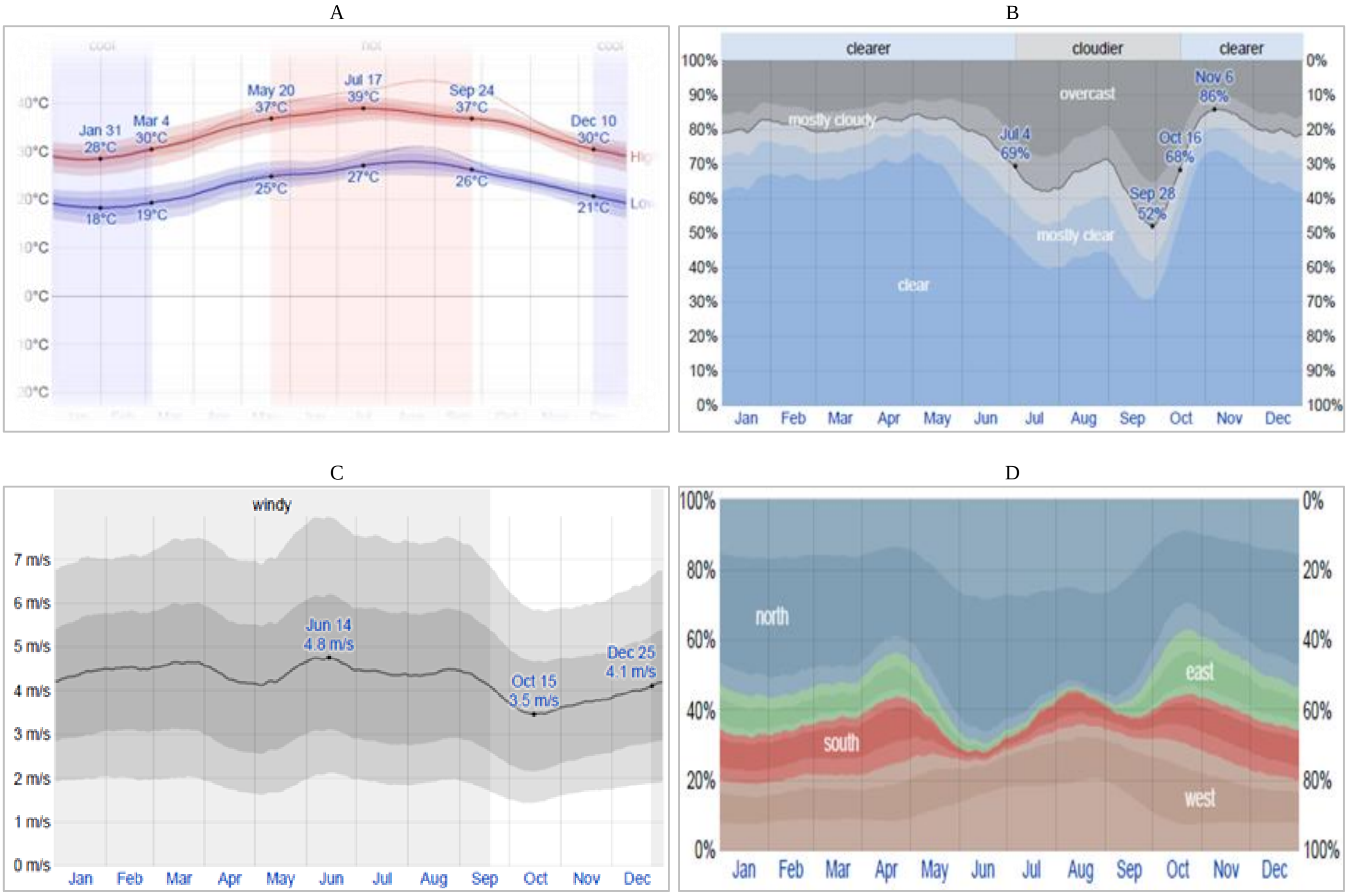

Figure 2. (a) Average High and Low Temperature, (b) Cloud Cover Categories, (c) Average Wind Speed and (d) Wind Directions

time of year. The coldest day is with an average low of 18°C and excessive of 28°C. At Figure 2(a), the red and blue lines represent the daily average high and low temperatures, respectively.

3.2. Clouds

The percentage of the most part cloudy skies is 48% of the year, and the percentage of the most part clear skies is 52% of the year. Here cloud cover mark is 10 which designed for completely clear, dropping to 9 which designed for the most part clear, and to 1 which designed for completely cloudy.

3.3. Wind speed and directions

Almost, the average wind speed is calm over the year. The windier days has more than 4.1 m/s wind speed. The calmest day has 3.5 m/s wind speed. The prevailing wind direction is north during the year.

4. Methods and calculations

The objective of this case examine is to estimate gaseous pollutants concentration emitted constantly by a point source (chimney stack). The predicted values are obtained considering ground level, under plume center-line, in the function of distance from the source and the source of pollution is considered to be in a rural area. In addition, the effluent plume consists of a mixture of the following pollutants: SO_2, NO_x, CO and PM (particulate matter) in suspension. These pollutants are known to be emitted by electric power plants functioning with solid fuel [21–25].

In this study, SCREEN3 software was used to simulate the dispersion from the stack of a plant, after 1 hour of emission. The SCREEN3 is a software (Likes Environmental Software, Waterloo, Ontario, Canada) [23], established by the EPA established on the Gaussian plume dispersion model [23]. It is a version of the ISC3 model [25,26]. To evaluate the concentrations air pollutants, the using model includes several input parameters associated with the source of emitting and meteorological characteristics. The requested input parameters to run the software contain:

- emission source type
- pollutants emission rate
- stack height
- stack inside diameter
- stack exit velocity
- temperature of exit gas
- ambient air temperature
- receptor height
- wind speed and direction

The Pasquill-Gifford stability classification categorizes six classes of atmospheric stability: A (very unstable), D (neutral), B (unstable), E (slightly stable), C(slightly unstable) and F (stable). Table 1 illustrated Pasquill-Gifford stability classification [27,28].

Table 1. Pasquill-Gifford Stability Classes

Wind Speed (at 10m) (m/s)	Day Time Solar Insolation (W/m^2)			Radiation Overcast
	Strong >600	Moderate 300-600	Slight <300	
<2	A	A-B	B	C
2-3	A-B	B	C	C
3-5	B	B-C	C	C
5-6	C	C-D	D	D
>6	CA-B	D	D	D

To express real conditions of atmospheric dispersion phenomenon, as emission conditions, considered input data for simulations were taken the following experimentally measured parameters at the proposed Shuaibah III, Independent Water, and Power Plant (IWPP) and presented in reference [29] that is provided below in Table 2.

Moreover, the effect of flue gas desulfurization by product (FGDB) on SO_2 was conducted in studied area has evaluated.

Table 2. General description and specifications for Shuaibah III (**IWPP**) Stack emissions.

Parameter	Standard IWPP 0% FGDB (Flue gas desulfurization byproduct); 2.0% S-fuel Content; 35° C Sea-water Temperature	Mitigated IWPP 95% FGDB (Flue gas desulfurization byproduct); 2.0% S-fuel Content; 35oC Sea-water Temperature	Units
Stack Coordinate	20° 41' N, 39° 31' East	20° 41' N, 39° 31' East	Degree / direction
Stack Height	150	150	m
Equivalent Stack Diameter[2]	7.0	5.7	m
Thermal Input	4,182	4,182	MWt
Flue Gas Flow Rate, STD, Wet, Actual O2[1]	1,995,000	1,927,500	Nm^3/h
Flue Gas Flow Rate, STD, Dry, 3% O_2	1,631,510	1,631,510	Nm^3/h
Exhaust Gas Velocity2	25	25	m/s
Flue Gas Temperature	190	46.6	°C
Sulfur Content in Fuel[1]	2.0	2.0	%
SO2 Emissions	5,710	375	Kg/h
NOx (as NO_2) Emissions	653	653	Kg/h
Particulate Matter Emissions	82	82	Kg/h
CO Emissions	2.72E-7	2.72E-7	Kg/h

1 Estimate/Assumed by Siemens.
2 Estimate/Assumed by WSP Environmental Ltd.
STP: Standard Temperature and Pressure (273 K, 1013 hPa).

5. Results and discussion

As the emission conditions listed above (Table 2), were considered the same for all pollutants, except the emission rates. For analyzed pollutants, maximum 1-hour concentration values are given in Figures (3-7) for SO_2, NO_x, CO, PM, and that related to the effect of FGDB on SO_2 pollutant, respectively, for the six stability classes. Further, pollutant concentrations decrease with distance from the source.

As the release occurs from the stack, the plume first increases with distance reach a maximum value and then decreases as shown in Figures from 3 to 7.

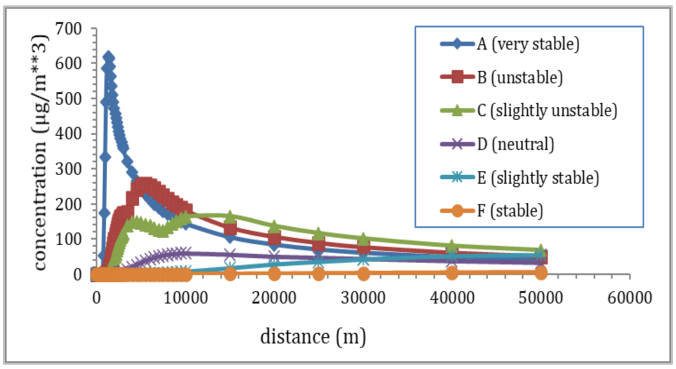

Figure 3. SO_2 concentration as a function of distance from the stack.

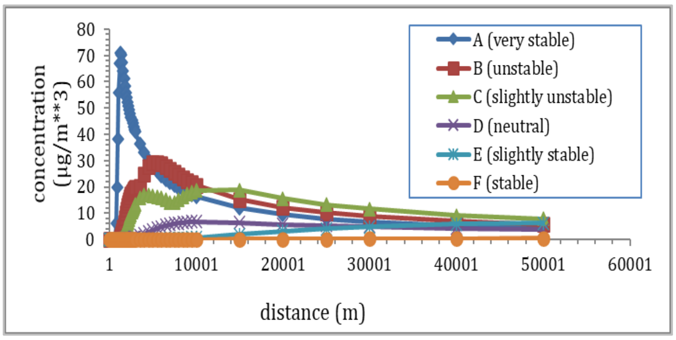

Figure 4. NO_x concentration as a function distance from the stack.

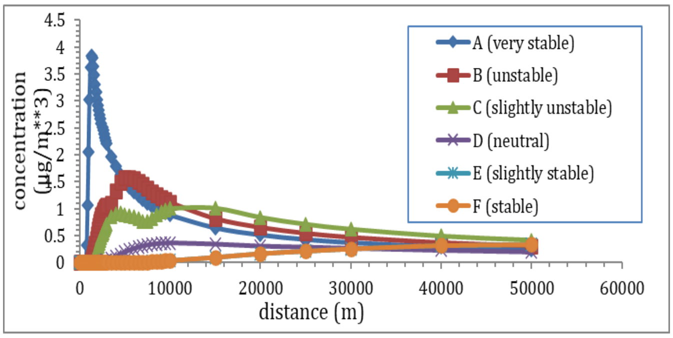

Figure 5. CO concentration as a function distance from the stack.

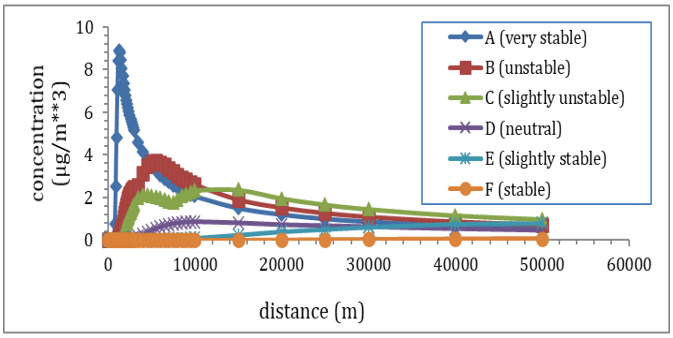

Figure 6. PM concentration as a function distance from the stack.

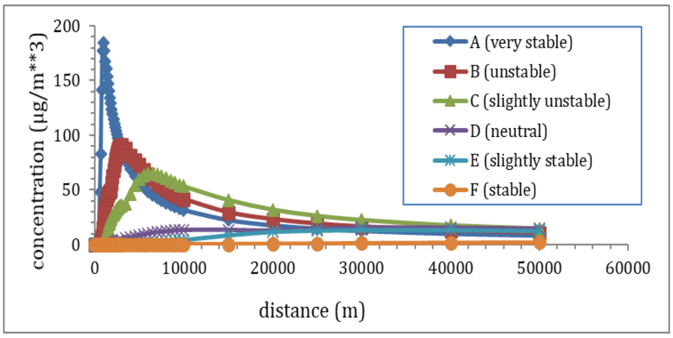

Figure 7. FGDB on SO2 concentration as a function distance from the stack.

Great concentrations of pollutants occur under unstable category at ground level adjacent to stack. These due to the high grade of convective turbulence (strong instabilities) which associated with clear sky conditions that go together with strong heating and small winds. Pollutants disperse fairly extended distances before dropping on the ground in weighty amounts, occurs in the neutral category. These due to the small scale and stable turbulence associated with moderated overcast and strong winds. At the very stable category, which associated with a little turbulence at a considerable ground distance above the stack, will be occurred.

Maximum predicted concentration established at ground level of SO_2, NO_x, CO, PM, and these aimed at the influence of FGDB on SO_2 emission, dispersion simulated by the user model for the six stability classes are offered in Figures 8 (a and b) and 9 (a and b).

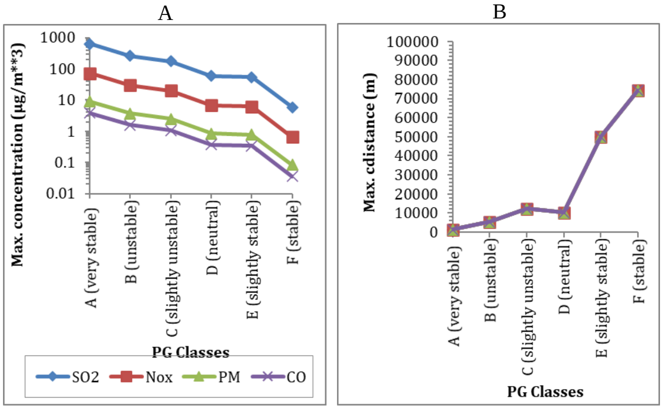

Figure 8. (a) The relation between C_{max} And PG Classes for all studied pollutants, (b) The relation between D_{max}. distance (m) and PG Classes for all studied pollutants.

The very stable conditions F class causes great dispersion area of the toxic cloud, the contrasting very unstable A class conditions interprets during a very small affected region around the source. D_{max} will increase as increasing of categories from A to F.

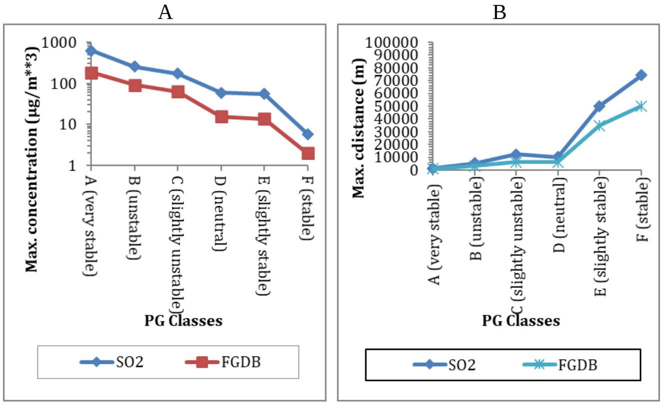

Figure 9. (a) C_{max}. concentration (µg/m^3) and PG Classes for case SO_2 and FGDB system, (b) The relation between max. distance (m) and PG Classes for case SO_2 and FGDB system.

Under the presented conditions, over the whole thought of vary (as much as 5 km faraway from source), the concentration values do not go above the 1-hour limit value needed by the AQI (air quality index) in Kingdom Saudi Arabia. For comparison, in Table 3 are given the pollutants maximum allowable concentrations standards required by AQI in Saudi Arabia.

Table 3. Pollutants maximum admissible concentrations (*AQI Saudi Arabia)*

Pollutant	Average admissible concentrations [µg/m3]			
	8 hours	1 hour	24 hours	Annual
SO2	-	730	365	80
NOx	-	660	-	100
CO	10	40	-	-
PM 10	-	-	340	80
PM 2.5	-	-	35	15

6. Conclusions

This study shows the results of modeling air dispersion of four types of gaseous pollutants (SO_2, NO_x, CO, and PM) which may be emitted by Shuaibah III, Independent Water and Power Plant (IWPP) plant which functions on P-G stability, and addition of FGDB system. By the used software, the ground level concentration of pollutants and the FGDB system was estimated. The turbulence falls from category A to F thus rapid dispersion of pollutants at F stability category, so that C_{max} decrease with the same path and D_{max} rapidly raises. The addition of the FGDB system decreased the dispersion of SO_2. Also, it was determined the concentration of the maximum pollutant and compared with the admissible values required by the AQI in Saudi Arabia and found that the concentration values do not exceed the 1-hour limit value required by the Saudi AQI.

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