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Environmental Impact of Conventional Power Plant in Normal and Accidental Conditions

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The prevention and simulation of chemical leakage has become one of the most important topics in the fields of environmental protection and process safety. Thermal Power plants are the major source of generation of electricity for any developing country. A power plant can affect the environment during its construction and its operation. These effects, or impacts, can be either temporary or permanent. A power plant and its auxiliary components (e.g. natural gas pipelines, water intakes and discharge, coal delivery and storage systems, new transmission lines and waste disposal sites) occupy space on the ground and in the air, use water resources, and, in most cases, emit pollutants into the air.

Before construction of any electric facility it is required to study its impact on the environment. The environmental impact study shall cover the impact of the plant on the environmental in case of normal operation and accident condition through air. This paper covers the analysis of the meteorological parameters and calculates the concentration of pollutants emitting from two stacks of Electric Station-Power Plant, Damanhur, Egypt by simulating seasonal dispersion of pollutant. This plant uses mainly natural gas as fuel. The most likely pollutants emitted from the stack of the plant are nitrogen oxides, carbon monoxide, sulfur oxides, and particulate matter.

For normal emission the AirPacts module was used in the Simplified Approach for Estimating Impacts of Electricity Generation (SIMPACTS) to calculate the physical impacts and the associated damage costs for the following types of pollutants namely, sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO).

For risk assessment, the Hybrid Single-Particle Lagrangian Integrated Trajectory (ALOHA) Model was used with different scenarios. Through this study, dispersion models are derived for nitrogen dioxide and methane concentrations for different scenarios, which result from the fuel combustion process, to determine the distance to a defined toxic endpoint and develop a prevention/emergency response program accordingly.

Key words: Air pollutants, SIMPACTS, AirPacts, ALOHA, Electric Power Plant.

Introduction

Damanhour power station site is located 4.5 km to the northwest of the city of Damanhour (Fig.1). The existing power station site encompasses a total area of approximately 412,000 m^2. This includes 240,000 m^2 for the new Damanhour CCGT generating units inclusive of all supporting structures and administrative buildings. The existing power station consists of the following older generating units: 3x65 MWe heavy fuel oil fired plants; one 300 MWe gas fired plant; one 158 MW Combined Cycle Gas Turbine which consists of 4 gas turbines (25 MW each) and one steam unit (58 MW) [1]. The proposed power plant is a 1,800 MWe Combined Cycle Gas Turbines (CCGT) comprising two 900 MWe modules. Each module will include two gas turbines, each with a nominal electricity generating capacity of 300 megawatts (MWe) and two heat recovery steam generators (HRSG) feeding one steam generator with a nominal electricity generating capacity of

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300MWe. The overall generating capacity of the power plant will be 1800MWe.
A more significant concern is the nitrogen dioxide NO_x and Sulpher dioxide SO_2 emissions from power plants that burn coal or natural gas. These compounds are part of a complex chemical reaction in the atmosphere that creates nitrate- and sulfate-based fine particulates.

Materials and Methods

The first step is concerned with the analysis of hourly meteorological data in the area. This meteorological data includes, wind speed, wind direction, atmospheric stability classes, mixing layer and ambient temperature.

Meteorological analysis of the site

Climate and Meteorology Data were available from the Damanhour climate monitoring station of the Egyptian Meteorological Authority. The Climate in the study area (Zawyet Ghazal, Damanhour, Elbeheria Governorate) is semi-arid. The total annual rainfall is 99.6 mm per year. The maximum rainfall values are recorded in December and January ranging between 22.3 mm and 35.1 mm. Atmospheric temperature: The minimum temperature values are recorded during January and February (7.6 C°). Maximum temperatures occur during the period of July/August, the highest temperature value of 32.1 C° is recorded in July. The annual mean temperature is 19.4 °C. Wind is most frequently from North and North West directions during most of the year as in Table 1.
Relative humidity is almost stable all over the year ranging from 65 to 85% with an average of about 70%. Low values occur in the autumn. Precipitation is highest in December, January and February. The total annual rainfall is 99.6 mm per year. Wind, in the study area, is most frequently from North and North Westerly directions. The wind roses wind speed frequency distribution are plotted to determine the prevailing wind direction and the highly polluted area for the 12 months of the year 2014 are shown in Figures (2) to (13). The Stability Class for the year 2014 is illustrated in Figures (14) to (25).

Normal emissions

In this section, a detailed estimation of emissions during normal operations is presented. Nitrogen dioxide is the only significant pollutant emitted to the atmosphere from a gas fired power plant, which induces human health effects. The other combustion products of natural gas are CO_2 and H_2O. When fuel oil is burnt, SO_2 and particulate matter become significant emissions of concern.
For normal operation conditions, it is necessary to build up an air pollution model to identify and assess dispersion from potential air pollution sources at the site.
The potential impact of air pollution emissions from various sources can be explored through analysis of models under some simplifying assumptions. Under certain conditions, the mean concentration C of a pollutant emitted from any type of source (point, area or volume) can be solved numerically. Numerical models such as SIMPACTS plume model [2, 3] is accepted by IAEA and is widely used to estimate and predict the concentration of different pollutants dispersed in the atmosphere. The result is used to predict the impact of different sources such as industrial sources to population and surrounding area.
SIMPACTS calculates the physical impacts and the associated damage costs for the following type of pollutants: particulate matter (PM), sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), and secondary species such as nitrate and sulfate aerosols. The primary or precursor pollutants (PM, SO2, NOx and CO) are emitted directly into the air at the source location. Regional concentrations can be predicted using Eulerian or Lagrangian transport models such as the Windrose .The program consists of separate modules (AirPacts module) for estimating the impacts resulting from routine atmospheric emissions of pollutants from energy facilities. Input and output data of the SIMPACTS are shown in Fig. (26).

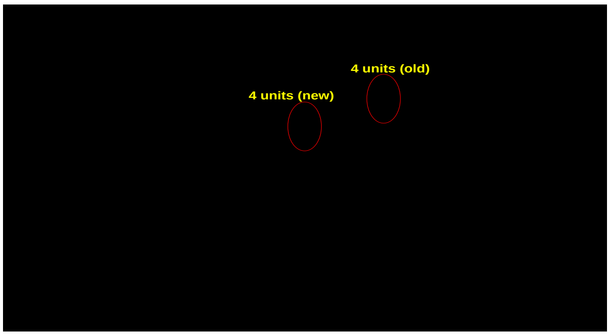


Fig. (1): Layout of Damanhour Electric Station –Power Plant, Alex Egypt

Table (1) average Minimum and maximum temperature Damanhour climate monitoring station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Avg. (Max)	19.4	20.3	22.6	26.3	19.9	31.7	32.1	32	31.2	29.2	25.2	21	26.6
Avg. (Min)	7.6	7.7	7.5	12	15.4	18.6	20.3	20.6	19	16.7	13.7	9.5	14.2

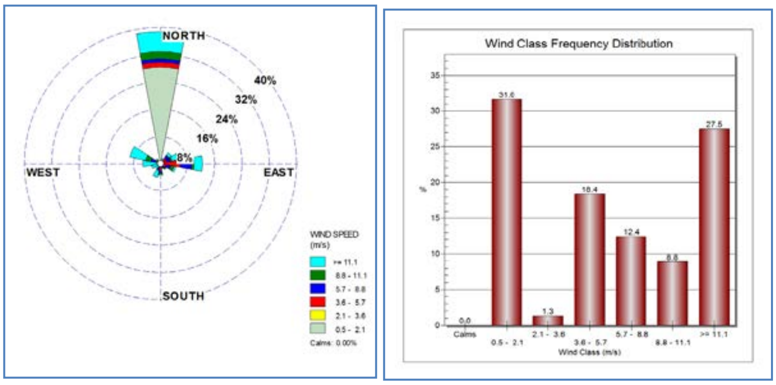


Fig. (2): Wind-rose and wind speed frequency distribution for January 2014

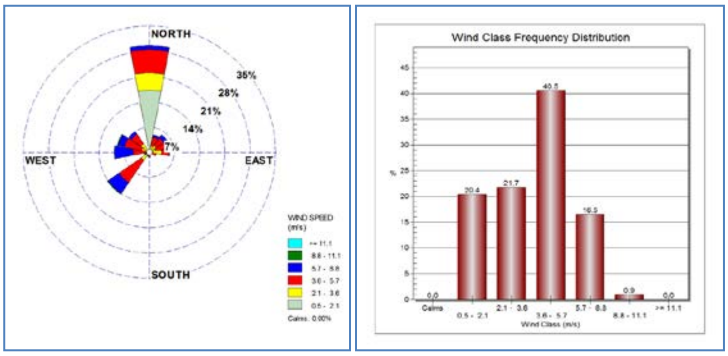


Fig. (3): wind-rose and wind speed frequency distribution for February 2014

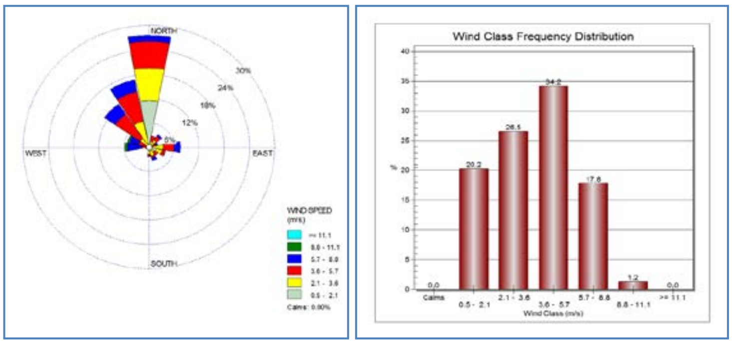


Fig. (4): wind-rose and wind speed frequency distribution for March 2014

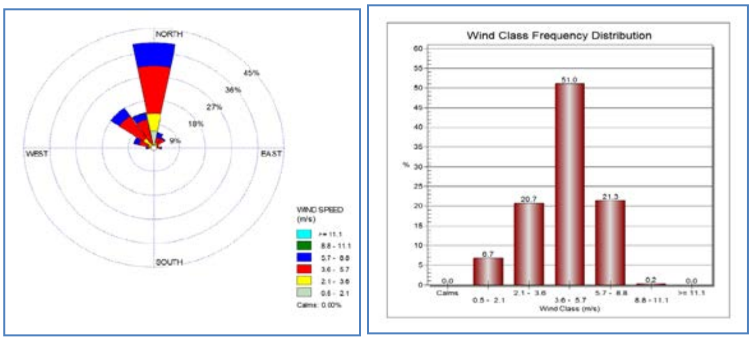


Fig. (5): wind-rose and wind speed frequency distribution for April 2014

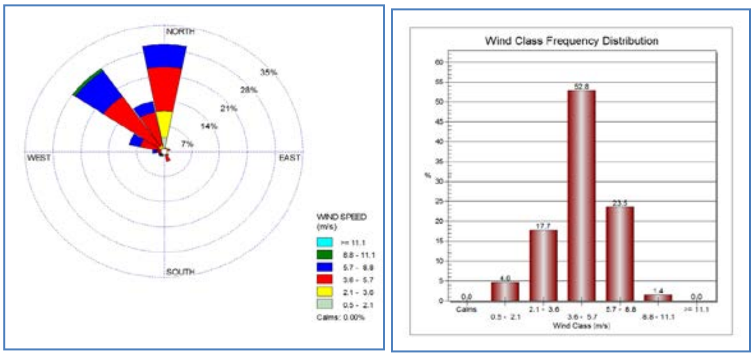


Fig. (6): wind-rose and wind speed frequency distribution for May 2014

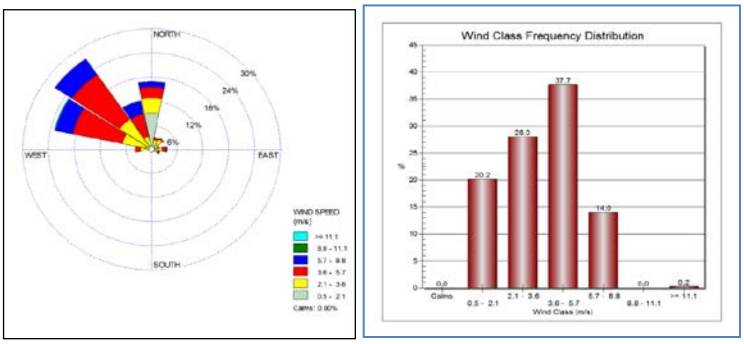


Fig. (7): wind-rose and wind speed frequency distribution for June 2014

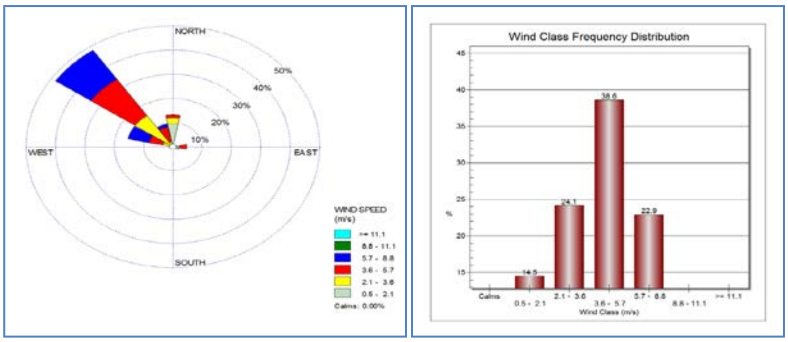


Fig. (8): wind-rose and wind speed frequency distribution for July 2014

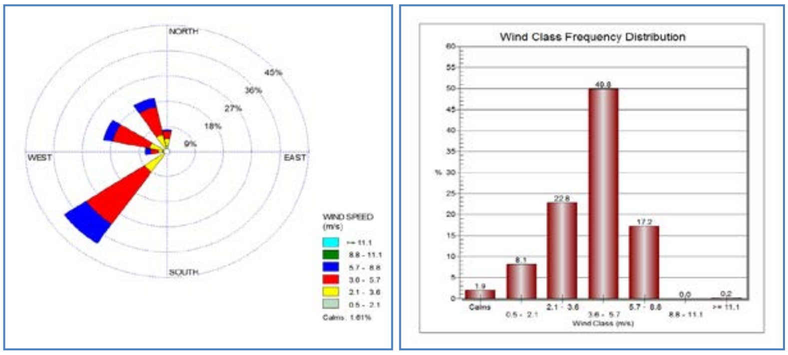


Fig. (9): wind-rose and wind speed frequency distribution for August 2014

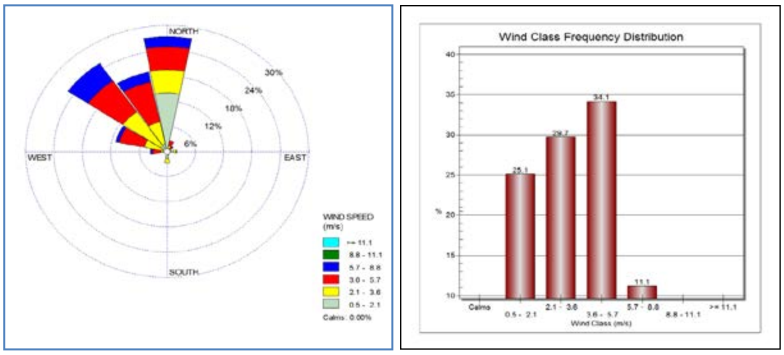


Fig. (10): wind-rose and wind speed frequency distribution for September 2014

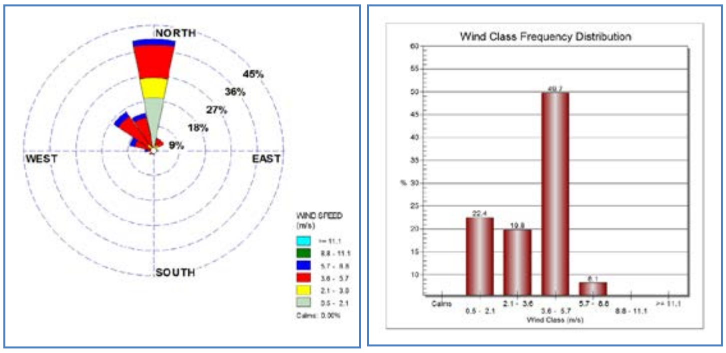


Fig. (11): wind-rose and wind speed frequency distribution for October 2014

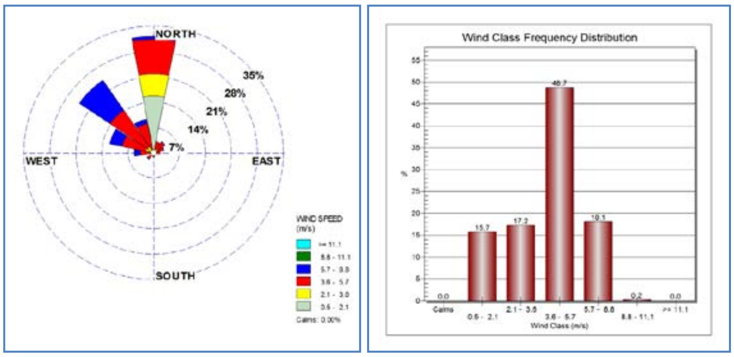


Fig. (12): wind-rose and wind speed frequency distribution for November 2014

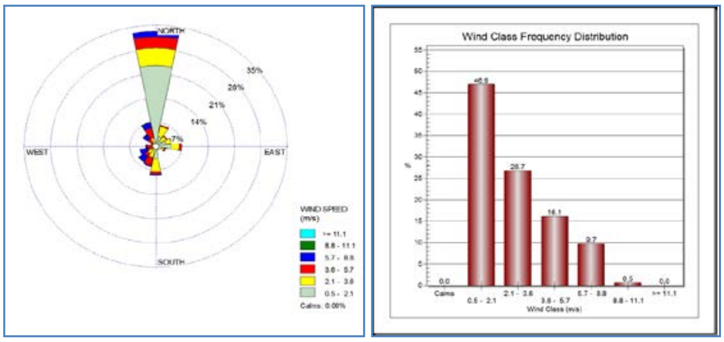


Fig. (13): wind-rose and wind speed frequency distribution for December 2014

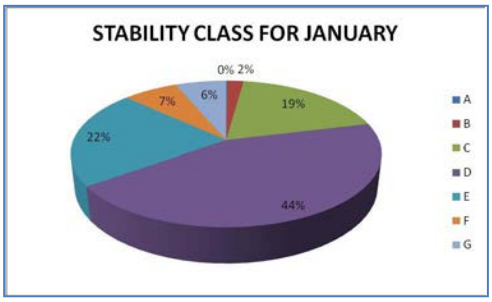


Fig. (14): Stability Class for January 2014

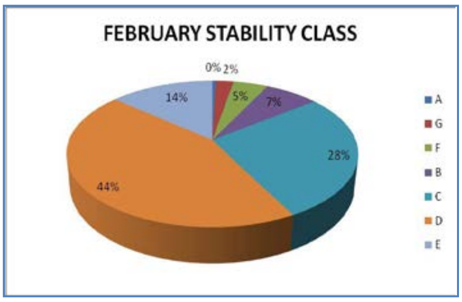


Fig. (15): Stability Class for February 2014

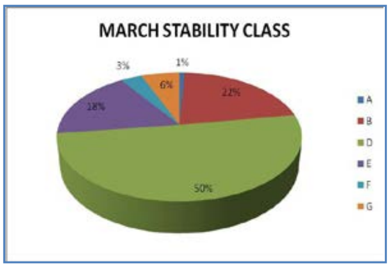


Fig. (16): Stability Class for March 2014

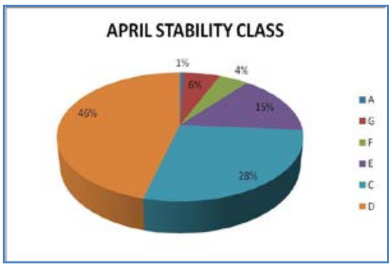


Fig. (17): Stability Class for April 2014

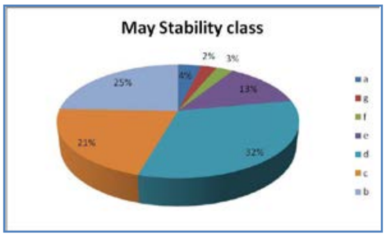


Fig. (18): Stability Class for May 2014

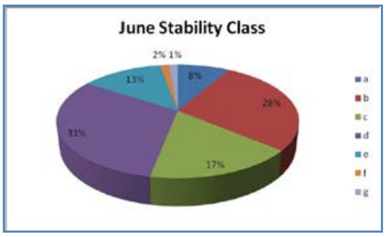


Fig. (19): Stability Class for June 2014

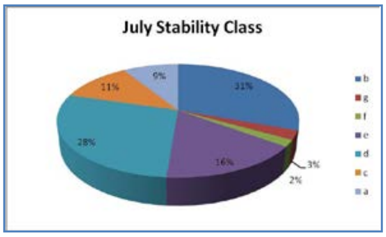


Fig. (20): Stability Class for July 2014

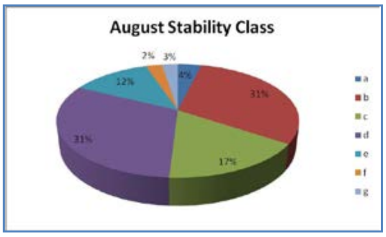
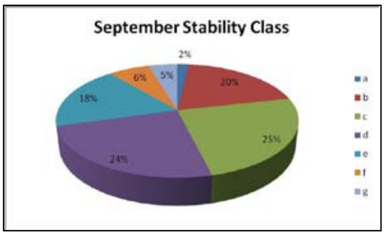


Fig. (21): Stability Class for August 2014



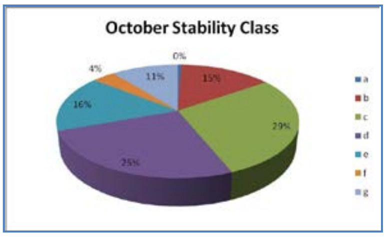
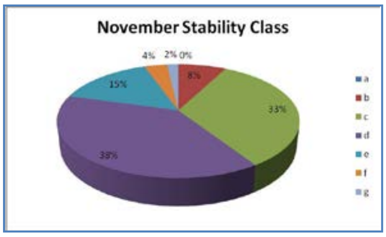


Fig. (22): Stability Class for September 2014   Fig. (23): Stability Class for October 2014



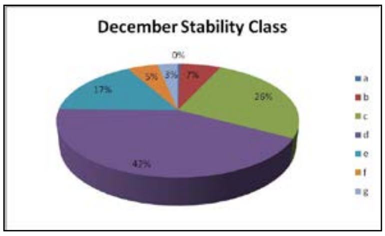


Fig. (24): Stability Class for November 2014. Fig. (25): Stability Class for December 2014

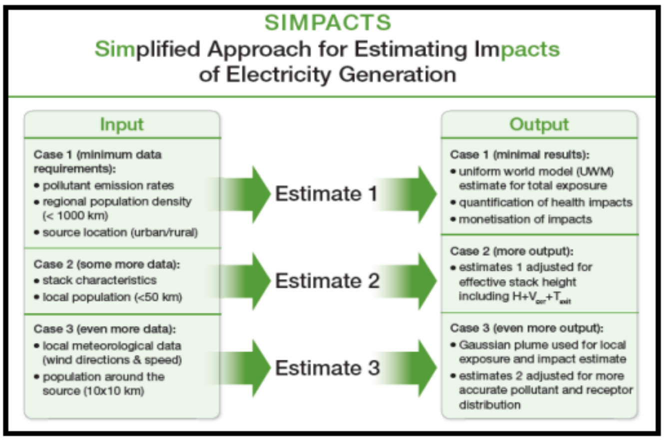


Fig: (26): Input and output data of the SIMPACTS

Results are evaluated through:

Model parameters

There are two stacks for the power plant with the following specification:

Table (2): Approx. location of the two stacks in UTM coordinates

Stack1 (766.015, 3448.7870)

Stack2 (766.015, 3448.7034)

Stack height	46.5 m	Regional Population (pers/km2)	80
Stack diameter	6.7 meter	Local Population (pers/km2)	1013
Exit Temperature	597 °K	Radius of Local Domain (km)	56
Exi velocity	48.5 m/s		

Source emission rate in case of using Natural Gas as fuel:

NOx = 30 g/s
CO = 14.97 g/s
SO2 = 0.3 g/s
PM = 2.02 g/s

Model Results:

AIR PACKTS predicts seasonal dispersion of pollutant emitted from two stacks of Damanhour Electric -Power Plant, Alex Egypt. This plant uses mainly Natural Gas as fuel. The most likely pollutants emitted from stack of the plant are nitrogen oxides, carbon monoxide, sulfur oxides, and particulate matter.

Carbon monoxide concentrations range from 1*10-5 to > 0.01 mg/m3 which are far below the maximum permissible limit (30 mg/m3 per hour in urban and industrial areas) according to the Egyptian Environmental Law 4/1994 (Table (3)) and its amendment modified by the ministerial decrees 1095/2011 and 710/2012. Nitrogen dioxide concentrations range from 1*10-5 to > 0.01 mg/m3 which are equivalent to (0.01 and 10 µg/m3 respectively) and are far below the maximum permissible limit (300 µg/m3 per hour in urban and industrial areas) according to law 4/1994. Sulfur dioxide concentrations range from 1*10-3 to > 0.1 mg/m3 which are equivalent to (1 and 100 µg/m3 respectively) and are below the maximum permissible limit (300 µg/m3 per hour in urban areas) according to law 4/1994 and do not constitute any measurable risk.

Figures (26-42) illustrate Contour map of the monthly average of NOx , CO, PM10 and SO2 Concentration distribution in mg/m3 for December(Winter) , April(Spring), August(Summer) and October(Autumn). It is clear that all results are far below the AQL and do not constitute any measurable risk.

Projection Dispersion Model for Carbon Monoxide emission from Damanhur Power Plant during winter, spring, summer and autumn are presented in Figures. (43-46).

Risk assessment of accidental releases

Aloha is an emergency response model, intended for rapid development by responders and for emergency planning. It incorporates source strength as well as Gaussian and heavy gas dispersion models [5, 6]. Model output is in both text and graphic form, and includes a "foot print" plot of the area downwind of a release where concentration may exceed user-set threshold levels. It can predict rates of chemical release from broken gas pipes, leaking tanks, and evaporating puddles, and can model the dispersion of both neutrally-buoyant and heavier than air gases.

This section describes hazards identification and calculations of end distance point as per AEGLS guidelines for selected scenarios using ALOHA model.

The following scenarios are simulated for an accident:

- Direct Source with stable atmospheric condition
- Direct Source with unstable atmospheric condition.
- Flammable gas escaping from pipe (not burning)
- Flammable gas escaping from pipe (burning) .

Configurations of the release Scenarios are presented in Tables (4, 5)

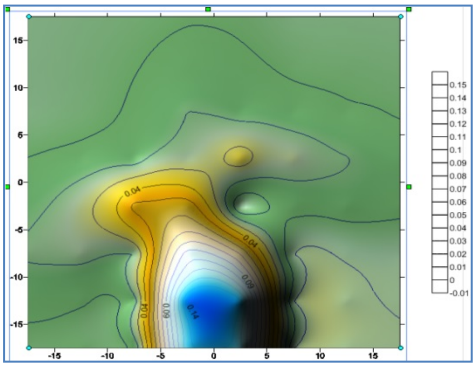


Fig. (27): NOX Concentrations for January 2014

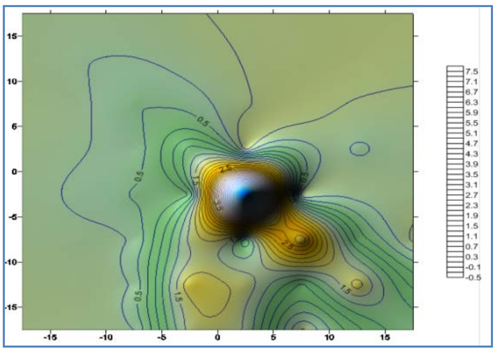


Fig. (28): Nox concentrations for May 2014

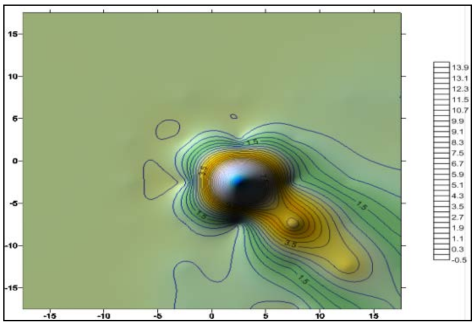


Fig. (29): Nox concentrations for July 2014

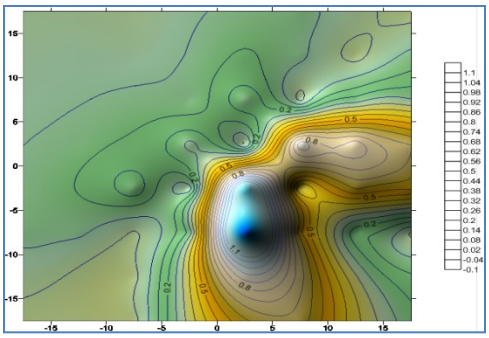


Fig. (30): Nox concentrations for November 2014

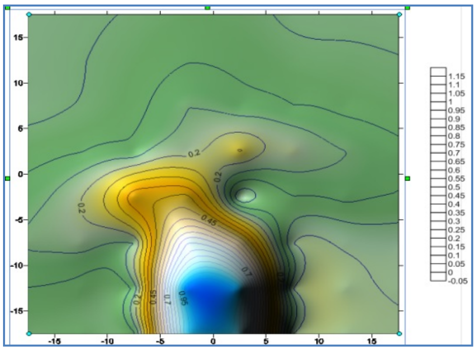


Fig. (31): CO Concentrations for January 2014

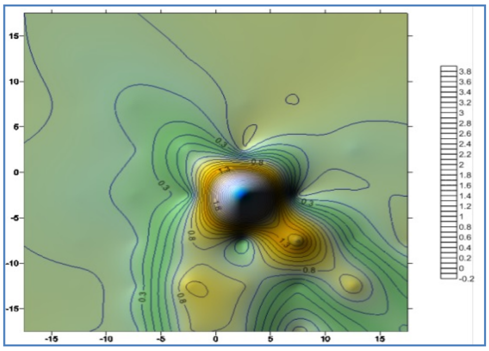


Fig. (32): CO Concentrations for May 2014

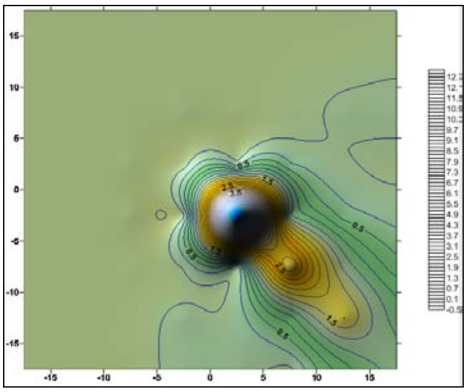


Fig. (33): CO Concentrations for July 2014

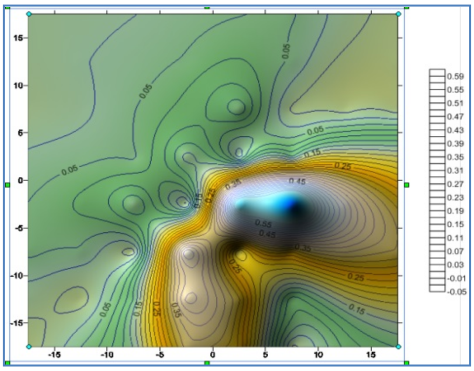


Fig. (34): CO Concentrations for November 2014

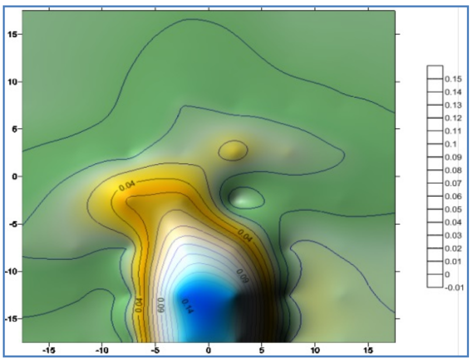


Fig. (35): PM 10 Concentrations for January 2014

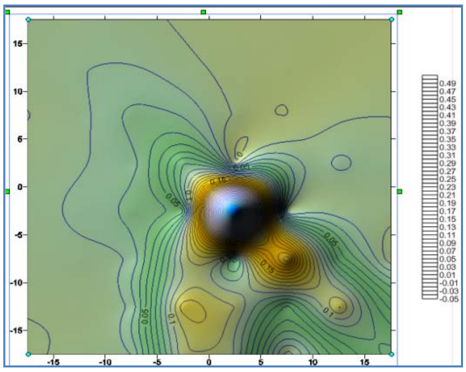


Fig. (36): PM 10 Concentrations for May 2014

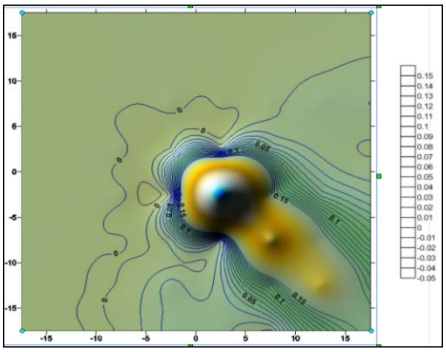


Fig. (37): PM 10 Concentrations for July 2014

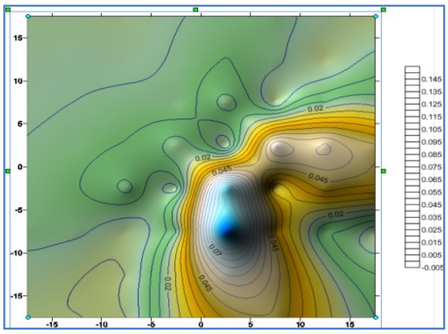


Fig. (38): PM 10 Concentrations for November 2014

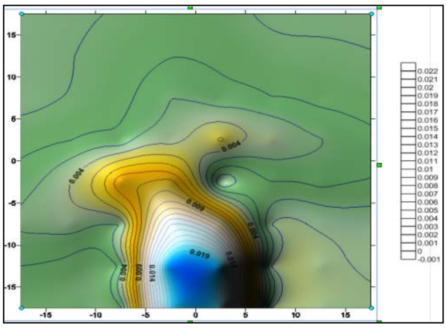


Fig. (39): SO2 Concentrations for January 2014

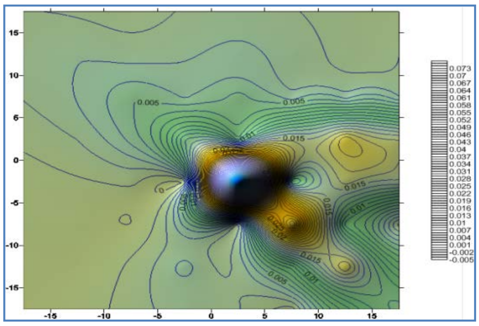


Fig. (40): SO2 Concentrations for May 2014

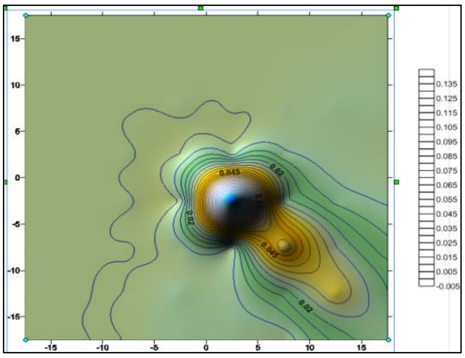


Fig. (41): SO2 Concentrations for July 2014

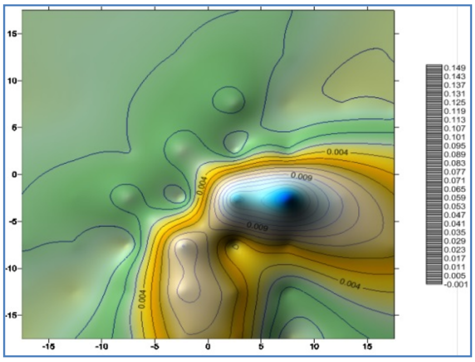


Fig. (42): SO2 Concentrations for November 2014

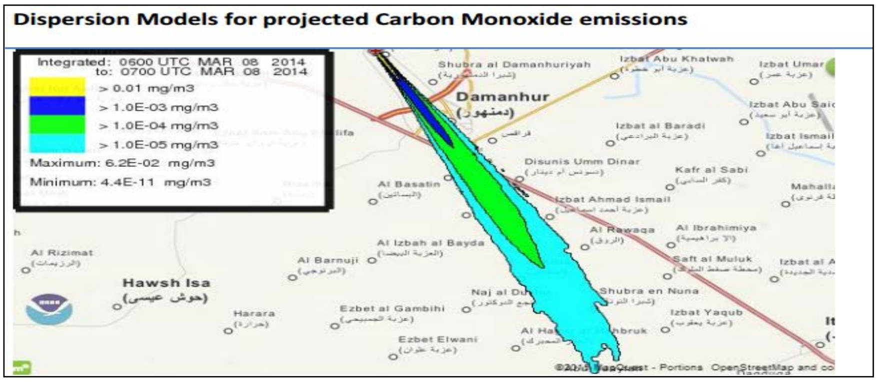


Fig. (43): Dispersion Model for CO emission from Damanhur Power Plant during winter

Fig. (44): Dispersion Model for CO emission from Damanhur Power Plant during spring

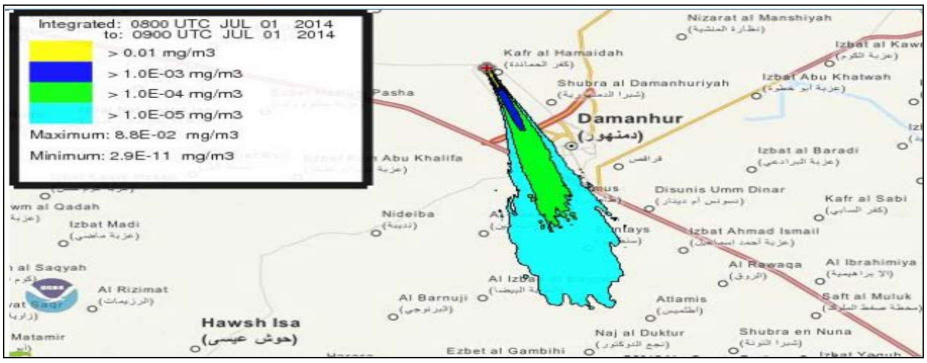


Fig. (45): Dispersion Model for CO emission from Damanhur Power Plant during summer

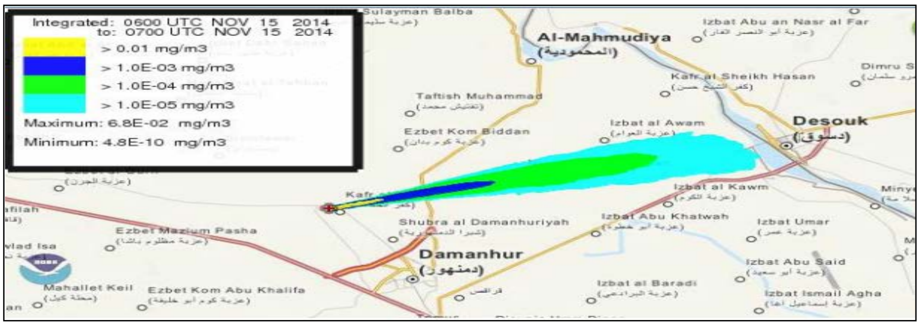


Fig. (46): Dispersion Model for CO emission from Damanhur Power Plant during autumn

Table (3): Maximum (permissible) limits for gaseous emissions from fuel combustion sources (energy generation) according to law 4/94[4]

Fuel Type	Maximum limits for emissions (mg/m^3)			
	TSP	CO	SO_2	NO_X
Natural Gas	50	100	150	500
Diesel	100	250	1300	500

Table (4): Configurations of the release Scenarios (1, 2)

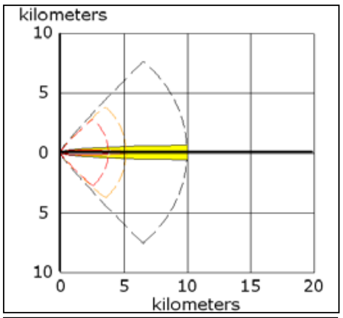
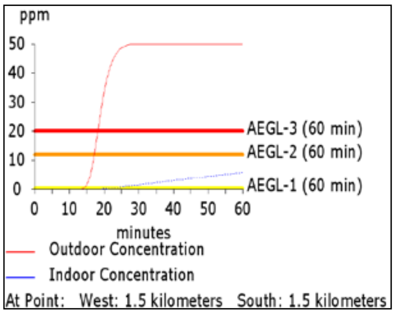
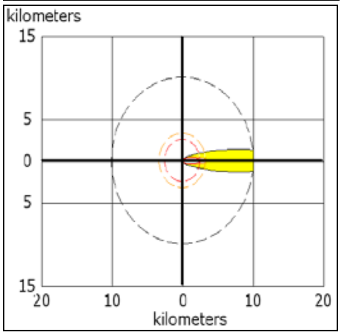
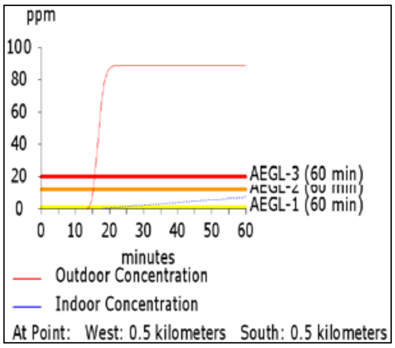
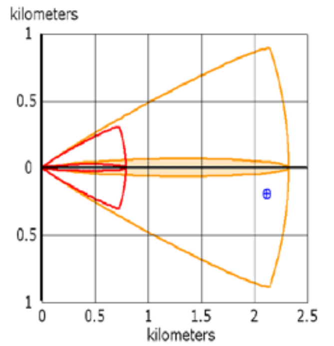
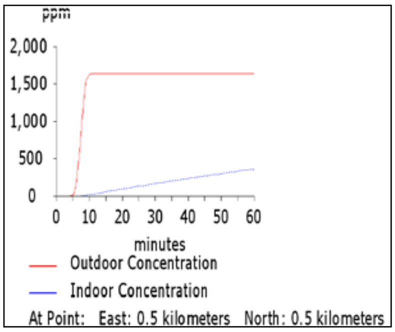
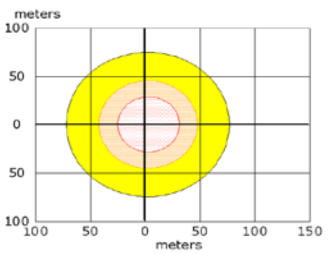
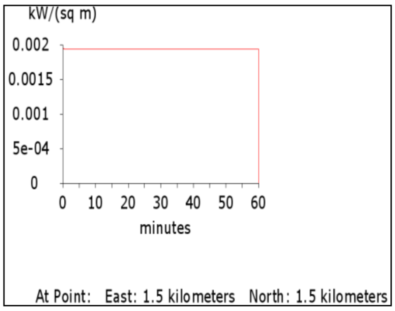
Hypothetical scenario of simulation	Scenario 1	Scenario 2
Chemical Name	Nitrogen dioxide	Nitrogen dioxide
Building Air Exchanges Per Hour	0.18	0.18
Model of Release	Direct release	Direct release
Time of accident	December, day 4, hour 21	December, day 8, hour 12
Temperature	19^0C	19^0C
Relative humidity	50%	50%
Elevation of wind speed measurements	10m	10m
Atmospheric Stability Class	F	B
Wind Speed	2.1m/s from NE at 10m	1m/sec from NE at 10m
Cloud Cover	5	5
Ground roughness	Open Country	Open Country
Ambient Saturation Concentration	747,217 ppm	747,217 ppm
Release Rate	120 Kg/min	120 Kg/min
Total amount released	7200 Kgs	7200 Kgs
Release duration	60min	60min
Model Run	Heavy Gas Dispersion	Heavy Gas Dispersion

Table (5): Configurations of the release Scenarios (3,4)

Hypothetical scenario of simulation	Scenario 3	Scenario 4
Building Air Exchanges Per Hour	0.18	0.18
Model of Release	Flammable gas escaping from pipe (not burning)	Flammable gas escaping from pipe (burning)
Time of accident	month 12, day 10, hour 3	December 10, 2014 at 03:20
Temperature	12° C	19^0C
Elevation of wind speed measurements	10m	10m
Atmospheric Stability Class	F	F
Wind Speed	2.6 m/sec from 220° at 10m	2.6 m/sec from 220° at 10m
Cloud Cover	5	5
Ground roughness	Open Country	Open Country
Chemical Name	METHANE	METHANE
Release Rate	120 Kg/min	120 Kg/min
Total amount released	66,171 Kgs	7200 Kgs
Release Duration	60 min	60 min
Ambient Saturation Concentration	1,000,000 ppm	1,000,000 ppm
Ambient Boiling Point	-161.5° C	-161.5° C

Results summary of hazard evaluation are illustrated in Table (6).

Table (6): Result Summary of Hazard Evaluation

Scenario	Threat modeled	Concentration Estimates at point	Toxic Threat Zone		
			Red	Orange	Yellow
Scenario 1			3.8 Km	5.2 Km	> 10 Km
Scenario 2			2.6 Km	3.3 Km	> 10 Km
Scenario 3			794 m	2.3 Km	2.3 Km
Scenario 4			31 m	48 m	77 m

Conclusion

From the previous results, it is clear that the plant operation is safe on the environment and that the concentrations of all gases emitted from the stacks during operation are within the international limits and follow the Egyptian law limits.

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6- ALOHA® (AREAL LOCATIONS OF HAZARDOUSATMOSPHERES) 5.4.4, Seattle, Washington, November 2013.