Studying the Effect of the Fuel used on the Pollutants Emission from the Power Plants west Cairo

Ahmed I. Elshahat[1], Ahmed A. Soliman[2], and M. F. Elshahat[3]

[1]Cairo Electricity Production Company, The Egyptian Electricity authority, Ministry of Electricity and Renewable Energy, Cairo, Egypt
[2]Department of Chemistry, Faculty of Science, Cairo University, 12613 Giza, Egypt.
[3]Department of Chemistry, Faculty of Science, Ain Shams University, Cairo, Egypt.
Ahmed.shahat80@gmail.com

Abstract: In most cases, pollutants emit into the air such as nitrogen oxides, sulfur oxides and carbon monoxide (NO_X, SO_2, CO). These gases have an important role in deter orating air quality and in smog formation. Furthermore, when these gases interact with oxygen in the presence of hydrocarbons and ultraviolet light they form very dangerous secondary pollutants such as ozone (O_3), which causes inflammation of the mucous membranes of respiratory system as well as eye irritation, coughing, inflammation of the lungs, and other disease symptoms. This paper presents predictions of air pollutants (dust and gases) emitted from a power plant that will be constructed in Greater Cairo the capital of Egypt. The main target of this paper is to exam the effect of replace mazout as fuel by coal fuel contraction of pollutants emitted. Different type of data such power plants emission "Cairo electricity production company", Metrology data during 2015 "Egyptian Meteorological authority" are evaluated. Also different types of programs as "ISC3" which evaluate the dispersion analysis, MM5 Model which analysis the metrological data, and GIS to representation the relation between data from dispersion model and metrology data are used. Different scenarios are applied on this data to give largest percent of emission improvement. The NO_x highest concentration is (5.4 µg/m^3) with using 75% mazout and 25% NG, where the highest concentration of PM_{10}, and SO_2 are (1.9 µg/m^3, and 1µg/m^3) using 100% mazout. The NO_x highest concentration is (5.4 µg/m^3) with using 75% mazout and 25% NG, where the highest concentration of PM_{10}, and SO_2 are (1.9 µg/m^3, and 1µg/m^3) using 100% mazout.

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1. Introduction

The range impacts to human's welfare and the environmental assessment has been investigated by measurement and modeling method. Cairo, Egypt is generally classified as one of the world's "megacities", with an estimated population in excess of 20 million people in the greater Cairo/Giza area (World Bank, 2013). Cairo, Egypt suffers from high ambient concentrations of atmospheric pollutants (Nasralla, 1994; Abu-Allaban. et al, 2007), including Particulate Matter (PM), Carbon monoxide (CO), Oxides of Nitrogen (NO_x), Ozone (O_3), and Sulfur dioxide (SO_2). A source attribution study was performed (Abu-Allaban. et al, 2006, 2007) to assess the contributions of specific pollutant source types to the observed Particulate Matter (PM) levels in the greater Cairo Area using the Chemical Mass Balance (CMB) receptor model. PM_{10}, $PM_{2.5}$, and Polycyclic Aromatic Hydrocarbons (PAHs) were measured on a 24-hour basis at six sampling stations distributed among the greater Cairo Area. The average PM_{10} mass ranged 100- 175 µg/m^3 in excess of the annual Egyptian standard for PM_{10} (The Egyptian environmental protection). A source attribution study that have been made within the scope of the Greater Cairo area with respect to the sources (World Bank, 2013). The responsibility of the industrial sector for about 22.1% of the outstanding thoracic dust suspended PM_{10} ambient air in addition to responsibility for approximately 30.85% of dust lingering chest. The PM - the responsibility of cement companies based in Greater Cairo, for about 6% of the outstanding dust thoracic level PM_{10} that proportion to about 30% in the areas surrounding those factories and companies.

Air is essential for life and the absence of clean air can lead to severe health problems and even to death. Since air pollution seems to be constantly increasing both in the industrialized and in the developing parts of the world, many studies have been conducted throughout the world to examine its characteristics and its effects on human health. There are several known reasons for the increase in air pollution (see e.g. Stern, 1968), among which are the increasing amount of cars, factories and power stations, which emit various pollutants typical of urban and industrial sources.

The United States Environmental Protection Agency (EPA) is mainly concerned with emissions which are or could be harmful to people. EPA calls this set of principal air pollutants, criteria pollutants. The criteria pollutants are carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2).

There are many sources of emissions. These have been grouped into four categories: point, mobile, biogenic, and area.

Point sources include things like factories and electric power plants.

Mobile sources include cars and trucks, of course, but also lawn mowers, airplanes and anything else that moves and puts pollution into the air.

This study focuses on the major sources of air pollution in Western Greater Cairo area. Examples of cost implications of the relevant pollution abatement measures for cement, bricks and energy production are presented. The costs of pollution abatement measures for a specific plant depend on a number of parameters including the relevant measures for that plant. In such case, detailed technical, economical and environmental studies have to be conducted considering the priority pollutants, emission sources, current status, targeted emission levels and other related aspects.

Also source attribution study that have been made within the scope of the Greater Cairo area with respect to the sources that affect the following results: PM_{10}, PM and caused loads of air pollution especially dust suspended pending bra 2.5 airborne PM - the responsibility of the industrial sector for about 22.1% Of the outstanding thoracic dust suspended PM_{10} ambient air in addition to responsibility for approximately 30.85% of dust lingering chest 2.5 air of the ocean. The PM - the responsibility of cement companies based in Greater Cairo, for about 6% of the outstanding dust thoracic level 10 Cairo Major general, and that proportion to about 30% in the areas surrounding those factories and companies.

Site Location

Cairo west power station (Long. 31.168552, lat 30.141032) with capacity 1360 MW. four steam unit two with capacity 330 MW (1 & 2) start on 1994 plus two with capacity 350 start 2010.

Fig (1) Cairo west power station from google earth

Air Pollution in Greater Cairo

Cairo is classified as one of the most polluted cities in the world. Accordingly, monitoring of heavy and toxic elements in air are mandatory. The increase in ambient contamination has become a serious problem to public health. Cement and other industrial activities are often the origin of environmental pollution, although they play a vital role in creating income, they also impose a heavy burden on the ecological system.

Type of Fuel Used

The combustion process is a special form of oxidation in which oxygen from the air combines with fuel elements. The environmental impact of combustion varies significantly depending on the fuel used. There are three main commercial fuels that are fired in boilers, namely:

• Heavy fuel oil, commercially known as 'Mazout'

• Light fuel oil, commercially known as 'Solar'

• Natural gas (NG)

Other types of fuels are used in insignificant amounts:

• Kerosene

• Liquefied petroleum gas (LPG)

• Biogases and agricultural wastes

Air emissions are directly related to the type of fuel. Agricultural wastes generate more ashes and particulate matter than allowed by environmental regulations.

Fuel Oil (Mazout)

Mazout is a brownish-black petroleum fraction consisting largely of distillation residues from asphaltic-type crude oils, with a relative density of about 0.95. The fuel is highly viscous at atmospheric condition. Preheating is therefore necessary before combustion. For proper atomization, a maximum viscosity of about 24 c Stoke at the burner tip is commonly adopted. For storage precautions, the minimum flash point is commonly 66 °C and a minimum temperature must be set for storage and handling of the fuel.

Sulfur content may reach about 3.0 - 3.5 per-cent by mass and is considered to restrict corrosion problems. The maximum water-content is specified as 0.25 percent. The mineral matter retained in petroleum residues appears as ash during combustion, and may contain hazardous materials. Hence, a maximum ash-content of about 0.25 percent is also specified. Mazout is generally used for heating in furnaces and kilns and for steam-raising (boilers). Mazout shows advantages over other petroleum-based fuels for furnace applications due to its high luminosity.

Natural Gas

Natural gas (NG) consists mainly of methane, some proportions of ethane to heptane components, together with traces of N_2, CO_2 and H_2S. The concentration of H_2S in natural gas is 0.2 % by volume. Although pentane and heavier hydrocarbons boil above ambient temperature, they vaporize in small proportions below ambient temperature.

Natural gas is an extremely important source of energy for reducing pollution and maintaining a clean and healthy environment. In addition to being a domestically abundant and secure source of energy, the use of natural gas also, offers a number of environmental benefits over other sources of energy, particularly other fossil fuels. This section will discuss the environmental effects of natural gas, in terms of emissions as well as the environmental impact of the natural gas.

Liquefied Petroleum Gases

Commercial butane and propane are essentially by-products of petroleum processing. The mixture of the two gases in varied ratio form what is called petroleum gas. Both gases have high heating values and are easily liquefied at low pressure forming liquefied petroleum gas (LPG), sometimes referred to as refinery gas. LPG is widely used as bottled fuels. On vaporization, the vapour liquid volume ratio can reach a value of 250/1 bottled fuels.

Biogas and Other Agricultural Wastes

Biogases are a low-density waste, which must be disposed of. It has always been used as a fuel in sugar cane factories. It has a fibrous structure, with a maximum dimension of about 50-mm and moisture content of 45-55%, as supplied to the boilers.

Measurements and Methods

The distribution of power plants emissions measurement of dust and gaseous emissions that record actual on each power station during the time period of measuring, can be used to estimate emissions for different operating periods. The emission data were provided from of MOEE (the ministry of electricity and energy, Egypt) (http://www.moee.gov.eg) and Ministry of Environment. The metrological data available commercially from the Egyptian Meteorological authority were used to conduct the dispersion analysis. Different types of programs were used such as:

(**1**) The short-term industrial source complex model (ISC3ST-Prime) has been used in this study. The model is an advanced Gaussian dispersion model approved by the United States Environment Protection Agency (USEPA) for use in regulatory assessments undertaken within the United States. It is one of the most widely used regulatory models in the world.

The ISC3ST-PRIME model uses the steady state Gaussian dispersion equation to simulate the dispersion of a plume from point, area or volume sources.

The model takes account of dry and wet deposition and includes mechanisms for determining the effect of terrain and buildings on plume dispersion. The **ISC3ST-Prime** model meteorological inputs are extracted from MM5.

The ISC short term model for the stacks uses the steady -state Gaussian plume equation for a continuous elevated source [**17**].

For a steady - state Gaussian plume, the hourly concentration at downwind distance x (meters and crosswind distance y (meters) is given by:

$$x = \frac{QKVD}{2\pi \cup_s \sigma_y \sigma_z} exp[-0.5\left(\frac{y}{\sigma_y}\right)^2]$$

where

Q= pollutant emission rate (mass per unit time)

K= a scaling coefficient to convert calculated concentration to desired units

v= vertical term

D=decay term

$\sigma_y \sigma_z$=standard deviation of lateral and vertical concentration distribution.

$\cup_s$= mean wind speed (m/s) at release height.

(2) MM5 (weather model) is the numerical weather prediction part to simulate the meteorology data [18]. and creating weather forecasts and climate projections. Thus MM5 generated meteorological fields are often used to drive a diagnostic meteorological model that can be run at finer resolutions than is operationally practical with MM5. The MM5 modeling system software is mostly written in FORTRAN. A schematic diagram (Fig. 2) is provided showing a flow-chart of the complete modeling system.

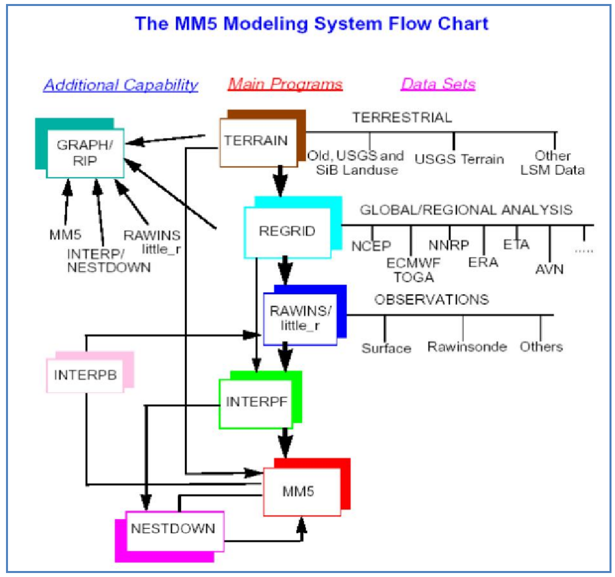


Fig. (2) The MM5 Modeling System Flow Chart

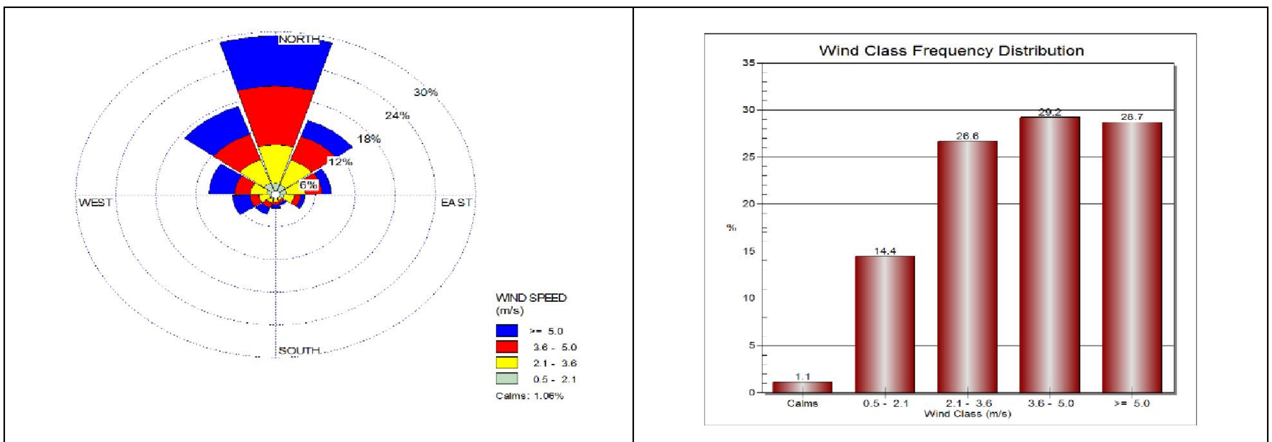


Fig. (3) Annual Wind rose and wind speed frequency distribution

(3) GIS (Geographic Information System) for representation the output dispersion data.

Geographical Information System (GIS), which is a general-purpose technology for handling geographic data in digital form, is being emphasized currently in air dispersion modeling. Its abilities include (i) preprocessing data into a form suitable for easy analysis, (ii) supporting spatial analysis, and (iii) modeling directly, and post-processing results. GIS offer a spatial representation of air dispersion pattern adding the spatial dimensions to the traditional air quality database, and it has the ability to present an integrated global view of air pollution.

Meteorological data for the studying area

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.

Meteorology Data were available from the monitoring station of the Egyptian Meteorological Authority. The wind rose wind speed frequency distribution is plotted to determine the prevailing wind direction and the highly polluted area for the year 2015 (Figure 3). Also, Stability Class is illustrated in figure (4).

It is clear figure (3) that the prevailing wind direction is North so, the highly polluted area is the West. Wind speed frequency distribution given that the wind speed from 3.5 to 5m/s has the highest percent for the year 2015. Also, Stability Class D and C have the highest percent figure (4). A complete hourly meteorological data of studying area includes, wind speed, wind direction, atmospheric stability classes, mixing layer and ambient temperature are analyzed.

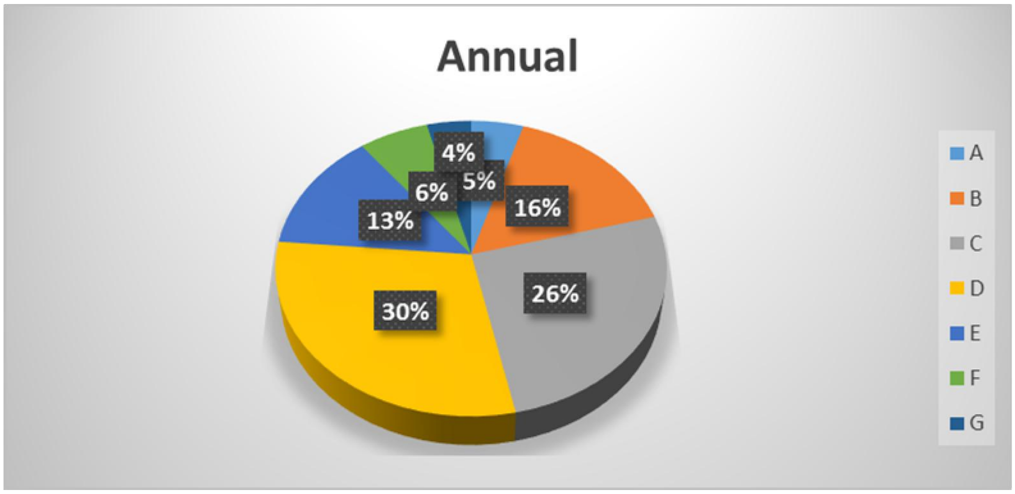


Fig (4) annual of Stability Class

U is the wind speed at the stack height = 3.87 m/s, D_i is the internal stack diameter = 4.5 m

D_e is the external stack diameter = 4.7 m, SO_2 emission rate = 263 g/s

NO_2 emission rate = 31.63 g/s, NO_2 (NG) emission rate = 45 g/s

Stack height =122.9 m, Flow rate= 243m3/s

Result and discussion

In this study we concerned on the largest pollutant area "Greater Cairo" which have the oldest power plants. emissions (dust and gases emissions) emitted from this fuels as following:

In this scenario we suggested that coal is used as fuel instead of mazout and NG & in Cairo west power station. Then used this data in the dispersion model. The results are drawn by GIS. Then camper between these From the figures illustrated that the dispersion of dust, sulpher dioxide, and nitrogen oxides emissions with using different types of fuels in west power station which gives that the direction of dispersion of pollution effected on the west area surrounded the station using different types of fuel, with high concentration on the center of the contour map which decrease with faring from the source of emissions.

In this Section, the operating unit in the same operating conditions, but with pure mazout only and pure NG only.

Table (1) gives SO_2, NO_x emissions on west power stations using different fuel (monthly 2015)

Month	**Using NG fuel**	**Using Mazout fuel**	
	NO_x mg/m^3	**SO_x** mg/m^3	**NO_x mg/m^3**
January	188	1084	124
February	169.3	1045.3	135.7
March	184.3	1073.3	130.3
April	184.7	1065.3	128
May	195	1044.3	115.3
June	182	1056.3	133.7
July	191	1127.7	132.3
August	183	1124	129.7
September	193.7	1130.3	138
October	193.7	1107.7	130
November	195.3	1103	132
December	172.7	1023.3	133.3

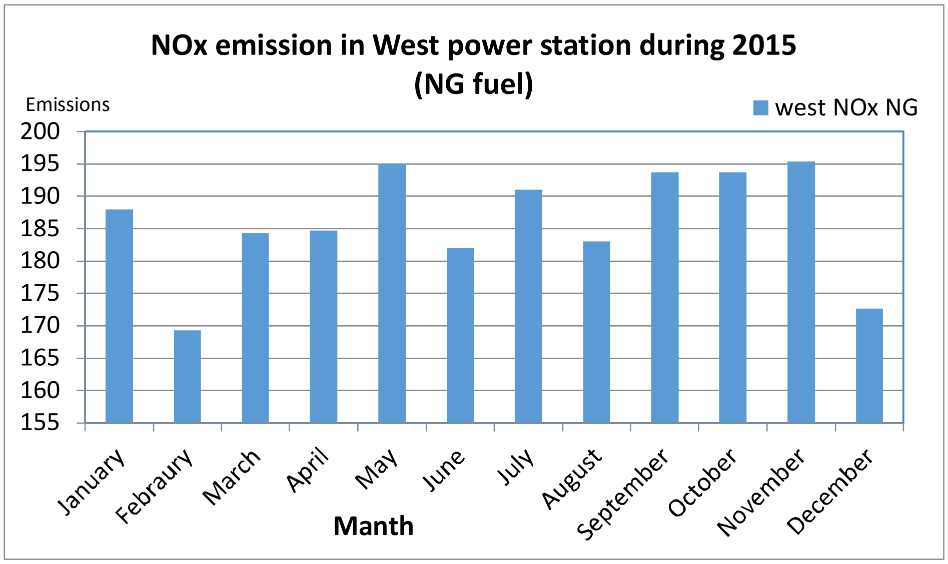


Figure (5) gives NO_x emissions on west power stations using NG fuel (monthly 2015)

In the cause of using NG only, in the NO_x emission the greatest value was195.3333 mg/m^3 in November, and the lowest value was 169.3 mg/m^3 in February.

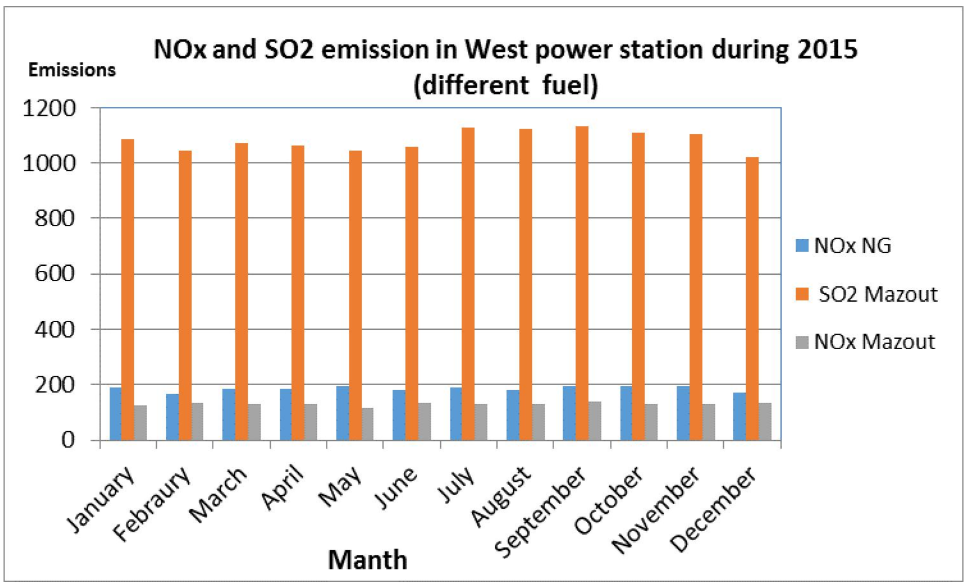
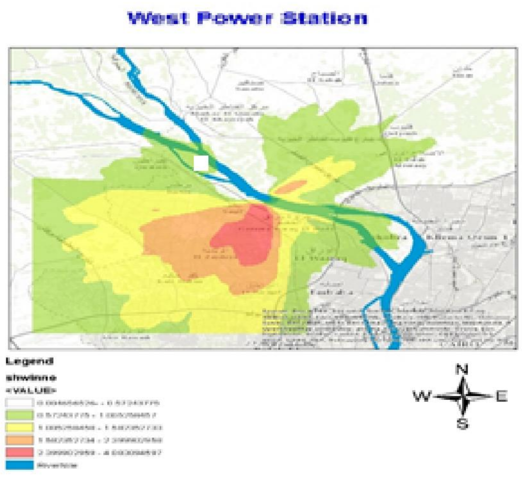


Fig. (6) gives SO_2, NO_x emissions on west power stations using different fuel (monthly 2015)

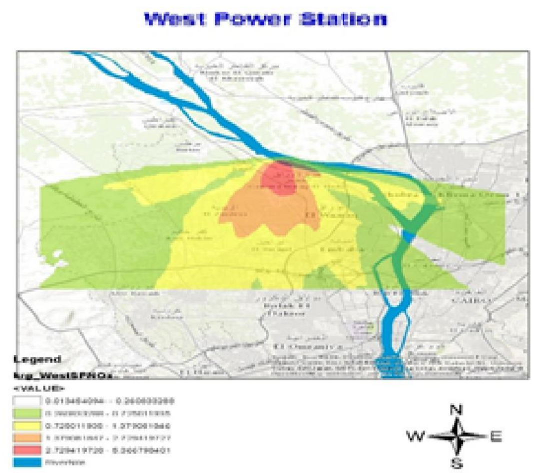
In the cause of using mazout only, in the NOx emission the greatest value was 138mg/m^3 in September, and the lowest value was 115.333 mg/m^3 in May. in the SO_x emission the greatest value was 1130.333mg/m^3 in September, and the lowest value was1123.333 mg/m^3 in December.

West power station emissions:

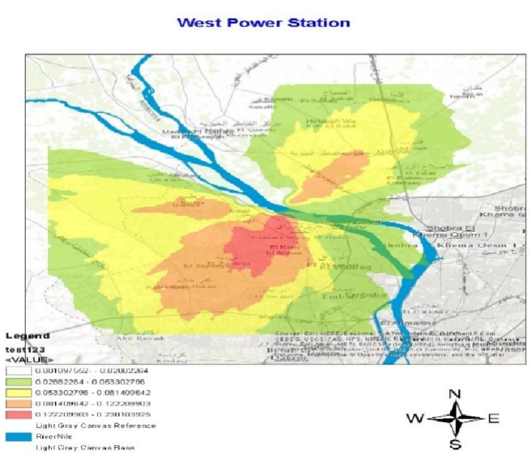
a. NOx emissions using different percent of fuel:



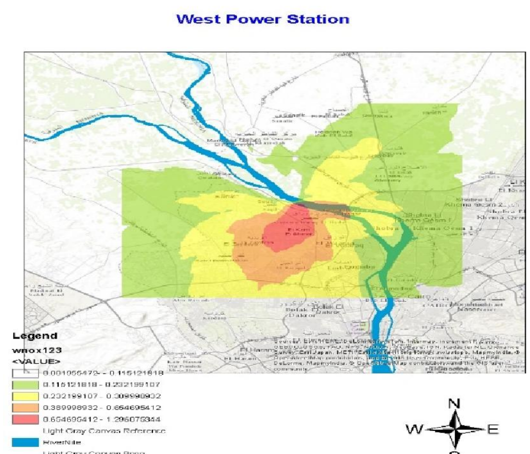
NO_x emissions using 100% Mazout



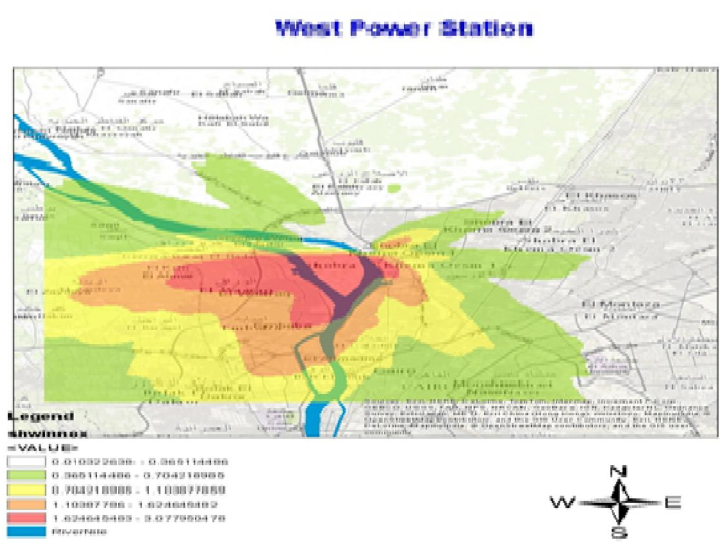
NO_x emission using 75% Mazout and 25 % NG



NO_x emissions using 50% mazout and 50% NG



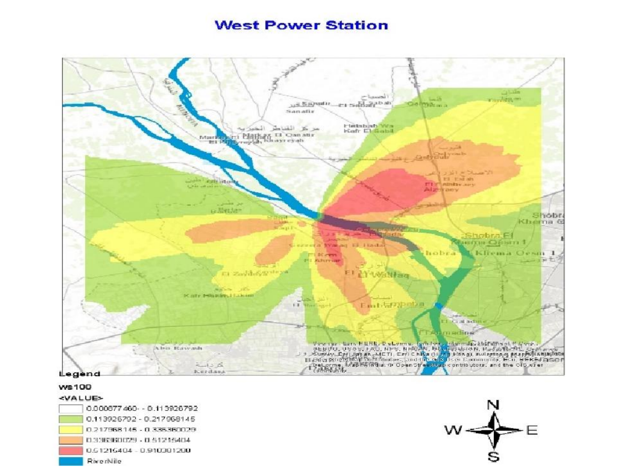
NO_x emissions using 25% mazout and 75% NG



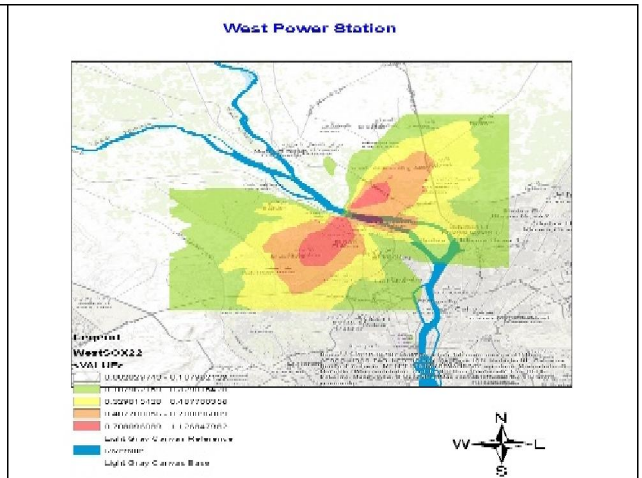
NO_x emissions using 100% NG

Fig. (8) West power station NOx emissions using different percent of fuel

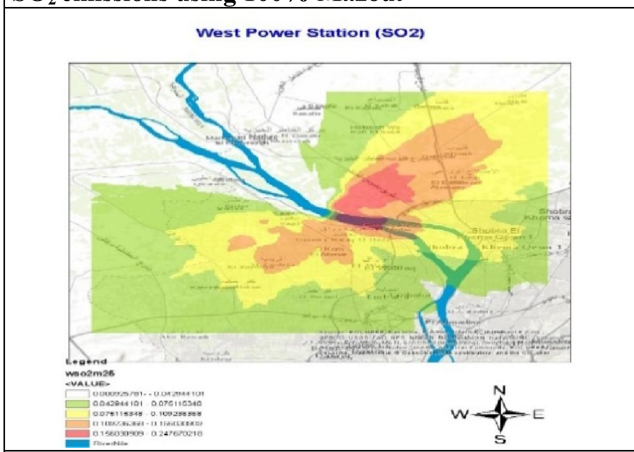
b. SO_2 emissions using different percent of fuel:



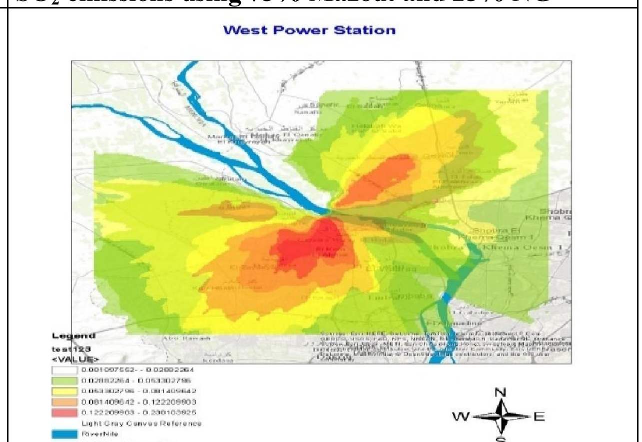
SO_2 emissions using 100% Mazout



SO_2 emissions using 75% Mazout and 25% NG



SO_2 emissions using 50% mazout and 50% NG



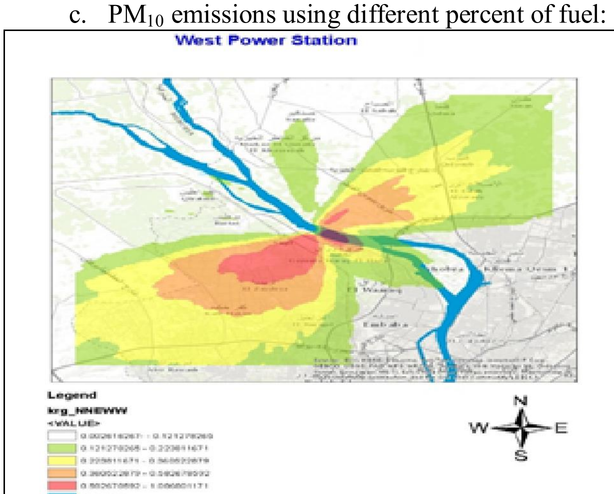
SO_2 emissions using 25% mazout and 75% NG

There is no SO_2 emissions

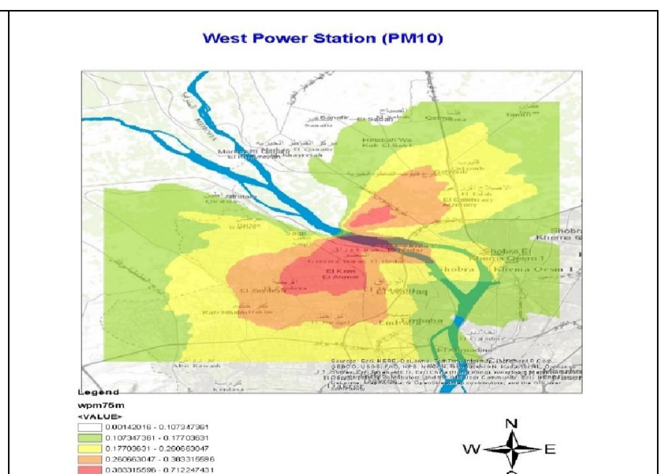
SO_2 emissions using 100% NG

Fig. (9) West power station SO_2 emissions using different percent of fuel

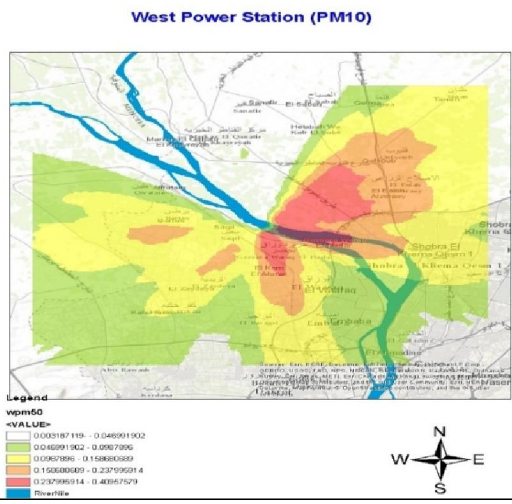
c. PM_{10} emissions using different percent of fuel:



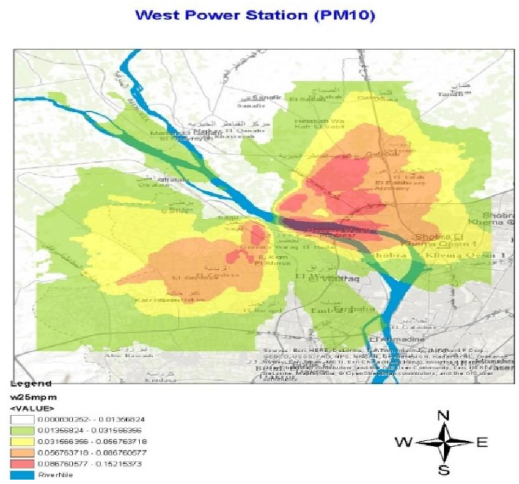
PM_{10} emissions using 100% Mazout



PM_{10} emissions using 75% Mazout and 25% NG



PM_{10} emissions using 50% mazout and 50% NG



PM_{10} emissions using 25% mazout and 75%NG

There is no dust emissions

PM_{10} emissions using 100% NG

Fig. (10) West power station PM_{10} emissions using different percent of fuel

Figures (9,10) clarifies that the NO_x highest concentration is (5.4 μg/m^3) with using 75% mazout and 25% NG, where the highest concentration of PM_{10}, and SO_2 are (1.9 μg/m^3, and 1μg/m^3) using 100% mazout.

Table (2) gives the comparison between largest concentrations PM_{10}, SO_2, and NO_x plume using different percent of fuel

west power station						
fuel	largest PM_{10} concentration (μg/m^3)	Lowest PM_{10} concentration (μg/m^3)	largest SO_2 concentration (μg/m^3)	Lowest SO_2 concentration (μg/m^3)	largest NO_x concentration (μg/m^3)	Lowest NO_x concentration (μg/m^3)
100% Mazout	1.89	0.12	0.91	0.11	4.09	0.57
75%Mazout:25% NG	0.71	0.1	0.73	0.1	5.37	0.27
50% mazout:50%NG	0.41	0.04	0.25	0.04	0.23	0.02
25% mazout: 75% NG	0.15	.01	0.23	0.02	1.30	0.12
100%NG	--		--		3.08	0.5

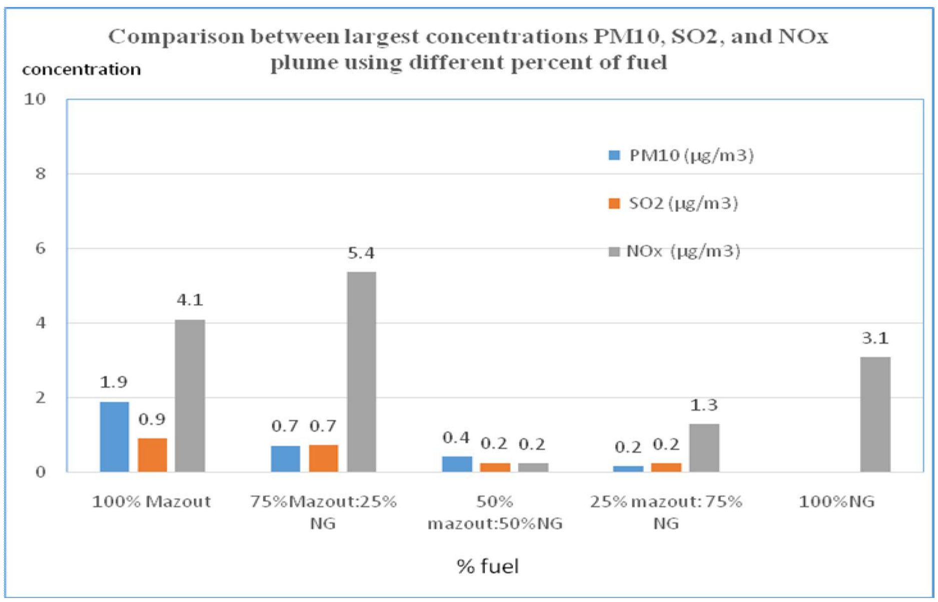


Fig. (11) illustrated the comparison between largest concentrations PM_{10}, SO_2, and NO_x plume using different percent of fuel

The NO_x highest concentration is (5.4 µg/m^3) with using 75% mazout and 25% NG, where the highest concentration The concentration of NO_x reduced from 4.09 to0.57 g/m^3 (86.1%) at of PM_{10}, and SO_2 are (1.9 µg/m^3, and 1µg/m^3) using 100% mazout.

Conclusion

The quality and quantity of the associated emitted pollutants during operation of power plant were evaluated with the change the type of fuel used such as mazout, NG using all the same other inputs such as time of operation, meteorological parameters, dimension of the plant and all other conditions of operation using the short-term industrial source complex model (ISC3ST-Prime). The meteorological parameters such as wind speed, wind direction, temperature and stability classes were evaluated for one complete year 2015. All these parameters were prepared to simulate the meteorology data and creating weather forecasts and climate projection using MM5 model. Finally GIS (Geographic Information System) are used for representation the output dispersion data. And then the results were compared. Using mix of a Fuel 50%mazout 50% NG gave the lowest percent of NOx and particulate matter where the NG gives the highest concentration of NOx. Finally the study proved that the type of fuel used has a significant impact on the quality and the quantity of the pollutants emitted during operation of power plants.

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