Scientific Journal for Damietta Faculty of Science 6 (2) 2016, 122-131 ISSN Print 2314-8594
ISSN Online 2314-8616

Evaluation of NO_x, SO_2, CO and total greenhouse gases, emissions for thermal power plant units using natural gas and heavy fuel oil

Maie I El-Gammal[1], Omnya A ElBatrawy[1], Sara M Enan[*2]

[1] Environmental Sciences Department, Faculty of Science, Damietta University, Damietta, Egypt.
[2] Environmental Specialist, Environmental Affairs General Administrator, East Delta Generation Production Company, Egypt.

Received: 17 Sept. 2016 /Accepted: 22 October 2016
[*] Corresponding author: sara.anan86@gmail.com

Abstract

The environmental situation has become increasingly worrisome, even as great progress has been made in social and economic development. The objective of this study is to measure atmospheric emissions, NO_x, SO_2, CO**,** from thermal electricity generation. In this paper, a comparison greenhouse gases emission (CO_2, N_2O and CH_4) (in terms of emissions factor) was carried out between thermal cycle for both natural gas and heavy fuel-oil consumption.
Emission of flue gases were conducted for thermal power plant with the total installed capacity of 600 MW over the period 2011- 2014 with regard to the power plant' operation characteristics including fuel type.
The emission of NOx, SO_2, CO and Greenhouse gases emission (CO_2, N_2O and CH_4) emissions were found to be 357.55µg/m^3, 2854.92µg/m^3, 122.56µg/m^3 and 432036.4 Ton CO_2 Eq. The emission factor was calculated Greenhouse gases emission (CO_2, N_2O and CH_4) emissions was1420.75 g CO_2 Eq/KWh^{-1}
According to this comparison, emission of flue gases emitted from the thermal power plant will experience an intensive decline if heavy oil is replaced totally with natural gas, power plants' efficiency is increased and continuous emission monitoring systems and power plant pollution reduction systems are utilized..

Keywords: Emission, Emission factors, Comparison, Thermal power plant

Introduction

The main effects of energy from fossil fuels on health are related to ambient air, called air pollution; resulting from the combustion**.** Air pollution is becoming increasingly more international. Nowadays, most pollutants enter the atmosphere from the burning of fossil fuels in power plants and factories and in motor vehicles **(Dockery and Brunekreef, 1996)**.
The power plants are using resources like fuel and water to provide electricity that is one of the essential needs for sustainable

development and life. Energy is the social and economic growth engine and it is the essential foundation in bringing about overall development in all societies; therefore countries seek to secure their needs of different energy sources. This activity produces and discharges all different kinds of pollutants such as, gaseous, liquid, electromagnetic fields, and noise which endanger our lives and environments **(Ghiasseddin, 2004)**.

The electricity sector is a major source of several air pollutants associated with adverse health and ecological effects. Fossil fuel-based power plants (such as coal, oil, and natural gas) are associated with emissions of sulfur dioxide (SO_2), which contributes to acid rain and nitrogen oxides (NO_x), fine particle concentrations in the atmosphere (PM)which contribute to both of these pollution problems and to ground level ozone, mercury, which is a toxic substance linked to neurological and other health problems, carbon dioxide (CO_2), which contributes to global warming and a variety of organic contaminants such as mercury and volatile organic compounds (VOCs) **(Palmer *et al.*, 2006; Stackelberg, 2011)**.

The major pollutants emitted from power plants are Carbon Monoxide (CO) and Hydrocarbons (HC). Carbon Monoxide (CO) which is a colorless, odorless, toxic gas produced by the incomplete combustion of organic compounds. The primary health effect of carbon monoxide is to reduce the oxygen carrying capacity of the blood. In ambient concentrations, CO can affect the functions of the brain, lungs, heart and the ability to exercise, all of which are sensitive to blood oxygen content. Hydrocarbons (HC), which results when unburned or partially burned fuel is emitted from the engine as exhaust, and also when fuel evaporates directly into the atmosphere. HC includes many toxic compounds that cause cancer and other adverse health effects. These emissions affect human health and the environment and are the primary cause of air pollution in many urban areas **(EPA 2003, WHO 2003).**

Like other developing countries, Egypt's electric power demand has been growing steadily, with an average annual growth of 20% over the past 30 years. The Ministry of Energy and Natural Resources predicts 7% annual growth until 2020. Thermal power plants (with a total installed power capacity of 29074.5 MW) are generally used to meet the electricity demand **(Moee report 2012).**

The concern over 'global warming' and 'acid rain', stands out the possibility of re-converting fuel-oil boilers into natural gas, because SO_2 emissions would be almost annulled but also because it would mean a great decreasing of 'carbon' in the fuel matrix, reducing also CO_2 emissions. Another important fact is the progressive substitution of conventional power plant schemes for combined cycles, due mainly to their higher efficiency **(Blanco *et al.*, 2006).**

This study was conducted in order to compare between the emission concentrations of NO_2, SO_2, CO and total CO_2 from different power generation units, **Abu Sultan** using different types of fossil-fuel and to estimate the emission factor and emission coefficient

2. Experimental Methodology

2.1 Design and technical details

The amount of the direct NOx, SO_2 and CO and indirect total greenhouse gases (CO_2, N_2O and CH_4) emissions according to the EPA equation (**EPA, 2001**) were measured from the natural gas, or heavy oil –fed, **Abu Sultan** power plant, Egypt.

In this study, the exhaust emissions of gaseous pollutants; NO_2, SO_2, CO and total CO_2, emissions between natural gas and fuel oil consumption in **Abu Sultan** power plant**.**

2.2 Overview Of Observational units for Abu Sultan Steam Power Plant

Abu Sultan power station was established in 1986 to add 600 MW of electricity to the national unified grid to electrical support the electricity need for the industrial and agriculture projects as well as residential needs. The plant located on the northern west bank of " Al Bohaerat Al Mora " lake in the Suez canal region near Abu Sultan village 28 kilo meter south Ismailia city (Map 1). The station includes

4 steam units (U1, U2, U3 and U4) with a capacity of 150 MW for each unit.

In these four units, measurement on flue gas was carried out in the vertical stack at a height of 60m from ground level. Heavy oil, natural gas or mixture of both was used as fuel. Each unit consists of; boiler or steam generator, steam turbine, generator and transmitter.

2.3 Experimental Process

2.3.1Measurement of Gaseous Emission; NOx, SO_2, CO for Abu Sultan Power Plant

Gaseous Emission; NOx, SO_2, CO, and Total Greenhouse Gases (CO_2, N_2O and CH_4): in Abu Sultan Power Plant were measured, using computerized exhaust gas analyzer, LANCOM Series II Flue Gas Analyzer for four generating units of varying ratings in **Abu Sultan** power plant over a period of 3 years during 2011–2014.

2.3.2 Calculating of the Total Green House Gases Emissions and Emission Factor:

The total greenhouse gases emissions (CO_2, N_2O and CH_4) were calculated and expressed in Ton CO_2 equivalent according to the EPA equation (**EPA, 2001**) Calculating the mass emission of CO_2, CH_4 and NO_x according to fuel type from the (**IPCC/OECD/UEA/UNEP,1991**).

3. Results and Discussion

Comparative analysis of gaseous pollutants; NO2, SO2, CO and total CO_2, emissions were carried out between four thermal power plants with natural gas and heavy fuel oil combustion in Abu Sultan power plant during the study period from July 2011 to June 2014.

Table (1) Average Emission of Nitrogen Oxides (NOx), Sulfur Dioxide (SO2) and Carbon monoxide (CO) as µg/m3 from The Four Natural Gas/ Heavy Oil Fueled Units of Abu Sultan Power Plant from July 2011-2012-2013 to June 2014

	2011- 2012			**2012- 2013**			**2012- 2014**		
	NOx	**SO_2**	**CO**	**NOx**	**SO2**	**CO**	**NOx**	**SO2**	**CO**
Unit (1)	283.59	2862.38	200.53	337.12	2499.64	119.27	347.54	2263.05	229.04
Unit (2)	403.94	2086.94	71.88	350.23	3575.86	46.75	390.61	2622.3	26.98
Unit (3)	348.22	2933.82	87.81	364.18	3723.36	89.11	330.38	2524.77	85.16
Unit (4)	338.08	2636.6	58.19	405.05	3626.77	178.47	399.79	2856.71	133.91

3.1 NOx Emissions from four Natural Gas/heavy oil Fueled Units

From Table 1, it is seen that the average NOx emission in the four natural gas/heavy oil fueled units of Abu Sultan power plant was 357.55µg/m^3 during the study period from July 2011 to June 2014. The mean annual amount of NOx was 322.75, 381.59, 347.59 and 380.79µg/m3 in U1, U2, U3, and U4, respectively, (Fig.1). The average NOx emission rate from U2 (381.59 µg/m^3) was highest amongst the four units followed by 380.79 µg/m_3 measured for U4. The average NOx emission (322.75µg/m^3) from the unit U1 was the lowest. The median values of NOx emission ranged from 240.53 to 532.87µg/m^3 during the study period.

For the year July 2011 to June 2012, the average emission of NOx was 340.58µg/m^3. The mean annual emissions of NOx were 283.59, 403.94, 348.22 and 338.08 µg/m^3 in U1, U2, U3, and U4, respectively (Fig.1). It is also evident from table (1) that the average NOx emission rate from U2 (403.94µg/m^3) was highest amongst the four units, followed by 348.22µg/m^3 measured for U3. Whereas that of unit U1 (283.59 µg/m^3) was the lowest. The median values of NOx emissions ranged from 254.6 to

513.22µg/m^3 at the four units of Abu Sultan power plant.

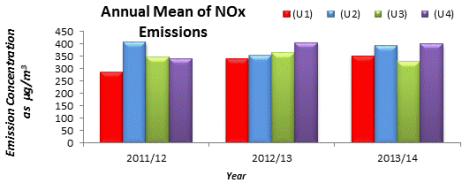

Fig. 1: Annual Mean Concentrations of Nitrogen Oxides (NOx) as µg/m^3 in The Four Units of Abu Sultan Power Plant (U; 1, 2, 3 and 4) in Years 2011/12, 2012/13 and 2013/14

For the year July 2012 to June 2013, the average emission of NOx was 363.51µg/m^3. The mean annual emissions of NOx were 337.12, 350.23, 364.18 and 405.05µg/m^3 in U1, U2, U3, and U4, respectively (Fig. 1). It is also evident from table (1) that the average NO_X emission rate from U4 (405.05µg/m^3) was highest amongst the four units, followed by 364.18µg/m^3 measured for U3. The average NOx emission (337.12µg/m^3) from the unit U1 was the lowest. The median values of NOx emission ranged from 240.53 to 532.87µg/m^3 in the four units of Abu Sultan power plant.

For the year July 2013 to June 2014, the average emission of NOx was 368.56µg/m^3. The mean annual emissions of NOx were 347.54, 390.61, 330.38 and 399.79µg/m^3 at U1, U2, U3, and U4, respectively, (Fig.1). It is also evident from table (1) that the average NOx emission rate from U4 (399.79µg/m^3) was highest amongst the four units, followed by 390.61µg/m^3 measured for U2. The average NOx emission (330.38µg/m^3) from the U3 was the lowest. The median values of monthly NOx concentration ranged from 288.1 to 448.06µg/m^3 at the four units of Abu Sultan power plant. The heavy oil fired thermal power plant emitted much more nitrogen oxides than the natural gas fired thermal power plant to be 0.158 and 0.083 Tg from using natural gas and heavy oil respectively **(Nazari *et al.* 2010)**.

Ghiasseddin (2004) who Compared Iran Power Plants Air Pollutants before and After Shifting to Natural Gas and found the Nitrogen oxides in four power plants changed from 274ppm to 150ppm, 249ppm to 50ppm, 195ppm to 143ppm and 254ppm to 62ppm.

3.2 SO_2 Emissions from four Natural Gas/heavy oil Fueled Units:

From table (1), the average annual mean of SO_2 emission in the four natural gas/heavy oil fueled units of Abu Sultan power plant during the study period for the year July 2011- June 2014 was 2854.92µg/m^3. The mean annual emissions of SO_2 were 2541.69, 2761.7, 3060.65 and 3040.02 µg/m^3 for U1, U2, U3 and U4, respectively, (Fig.2). It is seen that the average SO_2 emission (3060.65 µg/m^3) for U3 was maximum whereas that of unit U1 was (2541.69 µg/m^3) minimum. The median values of SO2 emission ranged from 0.00 to 4519.52 µg/m^3.

For the year July 2011 - June 2012 It is also evident from table (1), that the average annual mean of SO_2 emission was 2671.75 µg/m^3 in the four natural gas/heavy oil fueled units. The mean annual emissions of SO_2 were 2862.38, 2086.94, 2933.82 and 2636.60µg/m^3 in U1, U2, U3 and U4, respectively, (Fig.2). It is seen that the average SO_2 emission (2933.82 µg/m^3) for U3 was maximum whereas that of unit U2 (2085.94 µg/m^3) was minimum. The median values of SO_2 emission ranged from 2086.94 to 2933.82 µg/m^3.

For the year July 2012 - June 2013 the average annual mean of SO_2 emission in the four natural gas/heavy oil fueled units was 3315.62 µg/m^3. The mean annual emissions of SO_2 were 2499.64, 3575.86, 3723.36 and 3626.77 µg/m^3 in U1, U2, U3 and U4, respectively, (Fig.2). It was also noted that the average SO_2 emission (3723.36 µg/m^3) for U3 was maximum whereas that of unit U1 (2499.64 µg/m^3) was minimum. The median values of SO_2 emission ranged from 2499.64 to 3723.3µg/m^3.

For the year July 2013 - June 2014, it is also evident from table (1) that the average annual mean of SO_2 emission was 2577.39µg/m^3. The mean annual emissions of SO_2 were 2263.05, 2622.30, 2524.77 and 2856.71 µg/m^3 in U1, U2, U3 and U4, respectively, (Fig.2). It is seen that the average SO_2 emission (2856.71µg/m^3) for U4 was maximum whereas that of unit U1 was (2263.05 µg/m^3) minimum. The median values of SO_2 emission ranged from 2263.05 to 2856.71µg/m^3 in the four units of Abu Sultan power plant. SO_2 emission will vary as a result of differences

in the sulfur content of the fuel combusted. There are several reasons for the wide variation in SO_2 emission rates among which is the fuel used and its level of pollution control **(Miller and Chris, 2004)**. **Nazari *et al* (2010)** measured also sulfur dioxides emissions from thermal power plant to be 0 and 0.508 Tg from uing natural gas and heavy oil respectively. **Beer (2007)** found in power generation in response to environmental challenges that sulfur dioxides from power plant using natural gas produced a non-detectable amount of sulfur dioxides**. Silveira *et al.* (2007)** produced a non- detectable amount of sulfur dioxides per kWh while 1000 diesel engines each with 1 MWh produce 826.45 mg of sulfur dioxides per kWh. However, **Liu *et al.* (2013)** evaluated the SO_2 emissions in 7 power plants: Hsiehho, Linkou, Taichung, Talin, Hsinta, Tunghsiao and Nanpu, during the period 2001 - 2008 that uses oil, coal, coal coal/oil/natural gas, natural gas, natural gas and natural gas respectively and estimated the annual average of excess SOx to be 9215, 5667, 1104, 7462, 3631, 3057 and 46.5 tons/year, respectively.

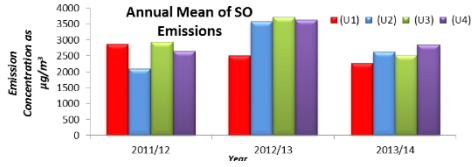

Fig. 2: Average Emission of Sulfur Dioxide (SO_2) as µg/m^3 in The Four Units of Abu Sultan Power Plant (U; 1, 2, 3 and 4) in Years 2011/12, 2012/13 and 2013/14

3.3 CO Emissions from four Natural Gas/heavy oil Fueled Units:

From table (1), the average annual mean emission of CO in the four natural gas/heavy oil fueled units of Abu Sultan power plant during the study period from July 2011 to June 2014 was 112.07µg/m^3. The mean annual emissions of CO were found to be 284.77, 67.07, 108.09 and 137.87 µg/m^3 in U1, U2, U3 and U4, respectively, (Fig.1). The maximum annual mean emission of CO was 284.77 µg/m^3 in U1 followed by 108.87 µg/m^3 recorded at U4, whereas that of unit U2 (67.07 µg/m^3) was the minimum. The median values of CO emission rom all the four units lie in the range (0.0 to 263.42µg/m3).

For the year July 2011- June 2012, it is also evident from table (1) that, the average annual mean emission of CO was 106.68µg/m^3. The mean annual emissions of CO were 200.53, 71.88, 87.81 and 58.19 µg/m^3 in U1, U2, U3 and U4, respectively, (Fig.3). It is seen that the average CO emission (200.53 µg/m^3) for U1 was maximum followed by 87.81 µg/m^3 recorded at U3 whereas that of unit U4 was (58.19µg/m^3) minimum. The median values of CO emission rom all the four units lie in the range (0.0 to 256µg/m^3).

For the year July 2012 - June 2013, It is seen from table (1) that the average, the average annual mean emission of CO in the four natural gas/heavy oil fueled units was 133.91µg/m^3. The mean annual emissions of CO were 119.27, 46.75, 89.11 and 178.47 µg/m^3 in U1, U2, U3 and U4, respectively, (Fig.3).

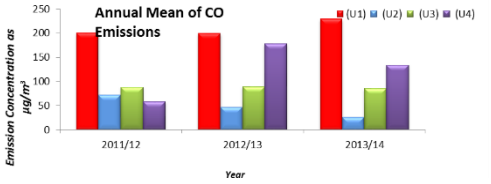

Fig. 3: Annual Mean Concentrations of Carbon Monoxide(CO)as µg/m^3 in The Four Units of Abu Sultan Power Plant (U; 1, 2, 3 and 4) in Years 2011/12, 2012/13 and 2013/14

It is also evident that the average CO emission (178.47 µg/m^3) for U4 was maximum followed by 199.27 µg/m^3 recorded at U1 whereas that of unit U2 (46.75 µg/m^3) was the minimum. The median values of CO emission rom all the four units lie in the range (0.0 to 264.58µg/m^3).

For the year July 2013 - June 2014, it is seen that table (1), the average annual mean concentration of CO in the four natural gas/heavy oil fueled units was 114.82µg/m^3. The mean annual concentrations of CO at Abu Sultan power plant were 229.04, 26.98, 85.16 and 133.91µg/m^3 in U1, U2, U3 and U4, respectively, (Fig.3). It is also evident that the average CO emission (229.04 µg/m^3) for U1 was maximum followed by 133.91 µg/m^3 recorded at U3 whereas that of unit U2 (26.98 µg/m^3) was the minimum. The median values of CO emission rom all the four units lie in the range (0.0 to 264.58µg/m^3). **Ghiasseddin, (2004)**

estimated the CO emission in 5 different heavy oil fueled Iran thermal power plants before and after shifting to natural gas, from plant(1),plant(2), plant(3),plant(4) and plant(5) to be 2, <1, 56, 630 and 31 ppm respectively. However, **Mahlia, (2002)** who studied emissions from electricity generation in Malaysia and found that the CO emissions factor from oil were higher than from natural gas as the CO emissions factor for coal, petroleum, gas, hydroelectric power and other technologies were 0.0002, 0.0002, 0.0005, 0.00, 0.00 kg/kWh, respectively.

3.4Total Greenhouse Gases Emission (CO_2, N_2O and CH_4) from four Natural Gas/heavy oil Fueled Units:

Considering (CO_2, N_2O and CH_4) to be the major contributor to the greenhouse effect, the measured emission in the four natural gas/ heavy oil fueled units of Abu Sultan power plant was 432036.4 ton CO_2 eq for the year January 2012 to December 2013. The maximum annual mean of total greenhouse gases emission was 569941.9 ton CO2 eq recorded in July 2012 has been compared with the calculated value (163129.3 ton CO2 eq) obtained for the year December2013 which was found to be the lowest value (Fig 4;a,b).

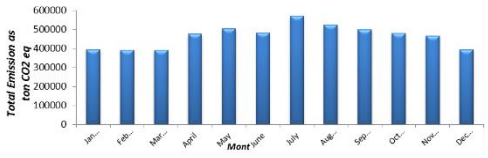

Fig. 4-a: Monthly Mean total emission of Total Green House Gases in Abu Sultan Power Plant from January 2012 to December 2012

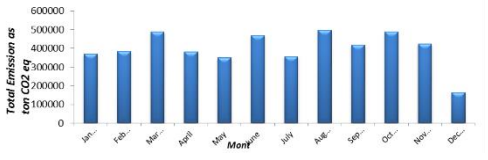

Fig. 4-b: Monthly Mean of total emission of Total Green House Gases in Abu Sultan Power Plant from January 2013 to December 2013

The average emission of total Green House Gases Emission (CO_2, N_2O and CH_4) was 464096.05 Ton CO_2 Eq. for the year January 2012 to December 2012. The maximum annual mean of total greenhouse gases emission was 569941.9 Ton CO_2 Eq recorded in July 2012 has been compared with the calculated value 390849.41 Ton CO_2 Eq) obtained for the year February 2012 which was found to be the lowest value.

The average emission of total Green House Gases Emission (CO_2, N_2O and CH_4) was 399976.74 Ton CO_2 Eq. for the year January 2013 to December 2013, The maximum annual mean of total greenhouse gases emission was 497751.53 Ton CO_2 Eq recorded for September 2013has been compared with the calculated value 163129.3 Ton CO_2 Eq obtained for the year December2013 which was found to be the lowest value.

3.5Total Greenhouse Gases Emission Factor ($CO2$, N_2O and CH_4) from four Natural Gas/heavy oil Fueled Units:

The measured emission factor in the four natural gas/heavy oil fueled units of Abu Sultan power plant was 1453.62 g CO_2 Eq/$KWh^{-1}$for the year January 2012 to December 2013. The maximum annual mean of total greenhouse gases emission factor was 1598 g CO_2 Eq/KWh^{-1} recorded in July 2012 has been compared with the calculated value (672 g CO_2 Eq/KWh^{-1}) obtained for the year December2013 which was found to be the lowest value (Fig 5;a,b)
The average emission factor of Total Green House Gases (CO_2, N_2O and CH_4) was 1486.49 g CO_2 Eq/KWh^{-1} for the year January 2012 to December 2012. The maximum annual mean of total greenhouse gases emission was 1541 g CO_2 Eq/KWh^{-1} recorded for July 2012 has been compared with the calculated value (1479 g CO_2 Eq/KWh^{-1}) was detected for the year February 2012 which was found to be the lowest value.

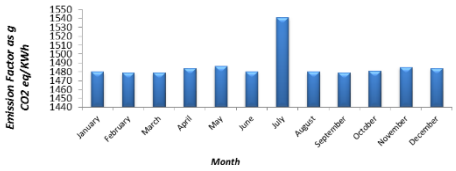

Fig. 5-a: Monthly Mean of Total Green House Gases Emission Factor in Abu Sultan Power Plant from January 2012 to December 2012

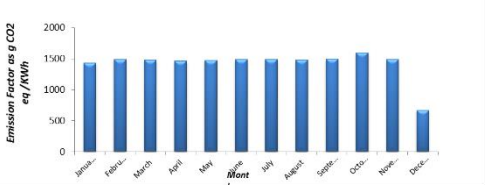

Fig. 5-b: Monthly Mean of Total Green House Gases Emission Factor in Abu Sultan Power Plant from January 2013 to December 2013

The average emission factor of Total Green House Gases (CO_2, N_2O and CH_4) was 1420.75 g CO_2 Eq/KWh^{-1}. for the year January 2013 to December 2013. The maximum annual mean of total greenhouse gases emission was 1598 g CO_2 Eq/KWh^{-1} recorded for September 2013 has been compared with the calculated value 672 g CO_2 Eq/KWh^{-1} was detected for the year December 2013 which was found to be the lowest value. CO emission factor of gas-turbine and combined-cycle power plants ranges between 450e622 g kWh_1 and 782e1048 g kWh_1 based on fuel type (**Nazari *et al.*, 2010)**. **Weisser (2007)** studied the lifecycle greenhouse gas (GHG) emissions from electric supply technologies in Austria and mentioned that the total carbon dioxide emitted from operating lignite power plants ranged from 1100 to 1700 g CO_2 eq/kWh and oil power plants ranged from 700-800 g CO_2 eq/kWh and natural gas from 360-575 g CO_2 eq/kWh. **Alavijeh *et al*. (2013)** studied the greenhouse gas emission measurement and economic analysis of Iran natural gas fired power plants and estimated the NO_X annual emission from power plants in year 2002 to be 461126 tons. And they estimated the CO2 annual emission from power plants in year 2002 to be 122446515 ton and the emission factor to be 0.73 kg/kWh.

According to the above mentioned results, the following conclusions must be detailed: For U1, U2, U3 and U4, the amount of NO_x are around 21%, 29%, 25% and 25% respectively, in the four natural gas/ heavy oil fueled units of Abu Sultan power plant during the study period for the year July 2011- June 2014. For U1, U2, U3 and U4, the amount of SO_2 are around 27%, 20%, 28% and 25% respectively, in the four natural gas/ heavy oil fueled units of Abu Sultan power plant during the study period for the year July 2011- June 2014. For U1, U2, U3 and U4, the amount of CO are around 48%, 17%, 21% and 14% respectively, in the four natural gas/ heavy oil fueled units of Abu Sultan power plant during the study period for the year July 2011- June 2014 (Fig.7,8,9).

Obviously, it is clearly that the amount of NO_x, SO and CO formed, are around 11%, 86% and 3%, respectively, in the four natural gas/ heavy oil fueled units of Abu Sultan power plant for the year July 2011-June 2012. The amount of NO_x, SO and CO formed, are around 10%, 87% and 3%, respectively, in the four natural gas/ heavy oil fueled units of Abu Sultan power plant for the year July 2012- June 2013. The amount of NO_x, SO and CO formed, are around 12%, 84% and 4%, respectively, in the four natural gas/ heavy oil fueled units of Abu Sultan power plant for the year July 2013- June 2014 (Fig 10,11,12).

The emissions from power generation not only affect Local air quality but also transport over long distance and cause regional/global environmental issues **(Huang *et al.*, 2016).** Studies related to emission measurement and estimations from thermal power plants conducted by different researchers **(Mittal and Sharma, 2003b; Gurjar *et al.*, 2004; Blottnitz, 2006; Nazari *et al.*, 2010, Tsilingiridis *et al.*, 2011; Liu *et al.*, 2013, Huang *et al.*, 2016**) have confirmed the pollution potential of the measured gases particularly with respect to the increasing trend in temperature or in other words global warming and therein lies the importance of carrying out this project work to determine the amount of emissions of these gases particularly for a very fast developing economy like.

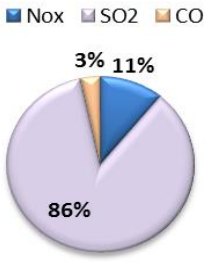

Fig.7: Average Emission Gases (NOx, SO_2 and CO) as $\mu g/m^3$ in Abu Sultan Power Plant in Year 2011/12.

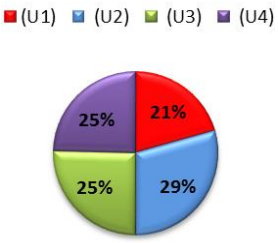

Fig.4: Average Emission of Nitrogen Oxides (NOx) as µg/m^3 in The Four Units of Abu Sultan Power Plant (U; 1, 2, 3 and 4) in Years 2011/12, 2012/13 and 2013/14

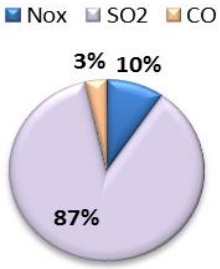

Fig.8: Average Emission Gases (NOx, SO2 and CO) as µg/m3 in Abu Sultan Power Plant in Year 2012/13

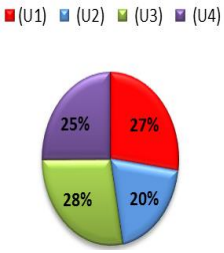

Fig.5: Average Emission of Sulfur Dioxide (SO_2) as µg/m^3 in The Four Units of Abu Sultan Power Plant (U; 1, 2, 3 and 4) in Years 2011/12, 2012/13 and 2013/14

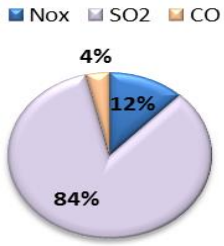

Fig.9: Average Emission Gases (NOx, SO2 and CO) as µg/m3 in Abu Sultan Power Plant in Year 2013/14.

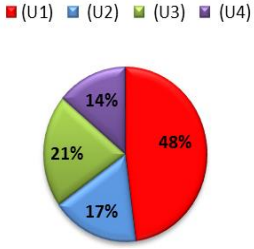

Fig.6: Average Emission of Carbon Monoxide(CO)as µg/m^3 in The Four Units of Abu Sultan Power Plant (U; 1, 2, 3 and 4) in Years 2011/12, 2012/13 and 2013/14

Conclusions

The calculations for the emission have been shown that thermal power plants emissions can be affected by many factors as; that regard to the power plant' operation characteristics including fuel type, power plants' efficiency, the age of the generating units and a capacity of power plants and vertical stack height from ground level.
Obviously, it is clearly that experimental values obtained over thermal power plants of reference, are closer to the values given in this paper, so this study has been revealed as a very good study for measuring the environmental impact of these plants.

Recommendations

The environmental situation has become increasingly worrisome, even as great progress has been made in social and economic development. There has been very serious air pollution, acid rain and solid waste pollution in recent years and the ecological environment has deteriorated generally. Therefore, great attention must be paid to environmental protection in planning future social and economic development, especially power system expansion.
The following recommendations suggested improving the air quality related to thermal power plants emissions:

- Replacement of internal combustion engine with low pollution engines
- Replacing thermal cycles for combined cycles.
- Development of alternative fuels that may produce low concentration of pollutants upon combustion.
- Replacing the progressive substitution of fuel oil for natural gas, reducing sensitively both CO_2 and SO_2.
- Reduction of air pollutant emissions using renewable energy sources for power generation.
- As a result, the power plant is designed to meet high environmental standards and comply with the emission limits of the Arab Republic of Egypt and the World Bank.

- Supercritical power plants are highly efficient plants with best available pollution control technology, reducing existing pollution levels by burning less fuel per megawatt-hour produced and capturing the vast majority of the pollutants. This technology increases the kWh produced with fewer emissions.

References

Alavijeh H. S., Kiyoumarsioskouei A., Asheri M.H., Naemi S., Alavije H. S., Tabrizi H. B.,(2013), Greenhouse Gas Emission Measurement and Economic Analysis of Iran Natural Gas Fired Power Plants, Energy Policy 60 (2013) 20 0 –207

Beer J. M., 2007, High efficiency electric power generation: The environmental role, Progress in Energy and Combustion Science Volume 33, Issue 2, Pages 107–134

Blanco J.M. , Mendía F. , Peña F. ,2006, Comparative analysis of CO2 and SO2 emissions between combined and conventional cycles with natural gas and fuel oil consumption over the Spanish thermal power plants, Volume 85, Issue 9, Pages 1280–1285.

Blottnitz H. V., 2006, A comparison of air emissions of thermal power plants in South Africa and 15 European countries, Journal of Energy in Southern Africa • Vol 17 No 1 • February 2006

Dockery DW, Brunekreef B (1996). Longitudinal studies of air pollution effects on lung function. Am. J. Respir. Crit. Care Med. 154:5250- 256.

Environmental Protection Agency (EPA). Emission factors & AP42. Washington, DC: Environmental Protection Agency. See also http://www.epa.gov/ttn/chief/ap42/index.html .

Ghiasseddin M. (2004). Comparison of Iran Power Plants Air Pollutants before

and After Shifting to Natural Gas , Iranian J Env Health Sci Eng, Vol.1, no. 1, pp.39-41, 2004.

Gujar, B.R., Aardenne van, J.A., Lelieveld, J., Mohan, M., 2004. Emission Estimates and Trends (1990-200) for megacity Delhi and implications. Atmospheric Environment 38, 5663-5681

Huang, L., Hu, J., Chen, M., Zhang, H. (2016) Impacts of power generation on air quality in China—part I: An overview. Resources, Conservation and Recycling, p. 12, article in press

(IPCC) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. http://www.ipcc-ggip.iges.or.jp/public/gp/gpgaum.

Liu C. H., Lin S. J., Lewis C., (2013) Evaluation of NOx, SOx and CO2 Emissions of Taiwan's Thermal Power Plants by Data Envelopment Analysis , Aerosol and Air Quality Research, 13: 1815–1823.

Mahlia T., 2002, Emissions from electricity generation in Malaysia, Renewable Energy 27 . (293–300).

Ministry of Egyptian electricity annual report 2012. See also http://www.moee.gov.eg/english_new/EEHC_Rep/2011-2012.pdf

Miller P. J, Atten C. V, (2004) North American Power Plant Air Emissions. Commission for Environmental Cooperation of North America. (23-83)

Mittal, M.L., Sharma, C., 2003a. Anthropogenic Emissions from Energy Activities in India: Generation and Source characterization (Part—I. Emissions from thermal power generation in India). URL: http://www.osc.edu/research/ pcrm/emissions/India.pdf.

Nazari N. S. , Shahhoseini O., Sohrabi-Kashani A., Davari S., Paydar R., Delavar-Moghadam Z. (2010) Experimental determination and analysis of CO 2 ,SO2 and NO x emission factors in Iran' s thermal power plants, iran, Energy 35 (2010) 2992 - 2998

Palmer K , Burtraw D, Shih J. (2006). The benefits and costs of reducing emissions from the electricity sector. Journal of Environmental Management 83, 115–130

Silveira J.L. ,Carvalho J. A. Jr., Villela I. D. A.D.C, (2007) , Combined cycle versus one thousand diesel power plants: pollutant emissions, ecological efficiency and economic analysis, Renewable and Sustainable Energy Reviews 11 (2007) 524–535

Stackelberg K.V.,(2011) Power Generation and Human Health , Encyclopedia of Environmental Health 2011, Pages 640–647

Tsilingiridis G., Sidiropoulos C. , Pentaliotis A., 2011, Reduction of air pollutant emissions using renewable energy sources for power generation in Cyprus, Renewable Energy 36 , 3292-3296.

Weisser D., (2007), A guide to life-cycle greenhouse gas (GHG) emissions from

electric supply technologies, Wagramer Strasse 5 1400 – Vienna Austria.

WHO (2003) Health aspects of air pollution with particulate matter, ozone and nitrogen dioxide. WHO Regional Office for Europe, Copenhagen. Available at http://www.euro.who.int/document/e79097.pdf.

.

الملخص العربي

عنوان البحث: تقييم انبعاثات غازات اكاسيد النيتروجين والكبريت واول اكسيد الكربون والغازات الدفيئة، للوحدات الحرارية لتوليد الطاقة المستخدمه للغاز والمازوت

مي إبراهيم الجمال[1]، امنية عبد السلام البطراوى[1]، ساره محمد عنان [2]

[1] قسم علوم البيئة، كلية العلوم ، جامعة دمياط ، مصر
[2] شركة شرق الدلتا لانتاج الكهرباء- جهاز شئون البيئة

اصبحت حالة البيئة تزداد سوءا مع الزيادة السريعة فى الطلب على الكهرباء وتوسيع شبكة الامداد مقيدة بشدة من نقص الاموال. ولذلك تهدف هذه الدراسة الى قياس الانبعاثات الجوية (ثاني أوكسيد النيتروجين ، ثاني أوكسيد الكبريت ، أول أوكسيد الكاربون و انبعاثات ثاني أوكسيد الكاربون الكلية) من محطات توليد الطاقة الحرارية .تقارن هذة الورقة البحثية الانبعاثات الغازية في محطات الطاقة الحرارية اثناء استخدام الغاز الطبيعي والمازوت كوقود. تم قياس انبعاثات العادم لمحطة ابو سلطان الحرارية ذات قدرة 600 ميجاوات خلال الفترة من 2011 إلى 2014 مع الأخذ بالاعتبار خصائص تشغيل المحطة متضمنة قدرة التوليد و نوع الوقود.
وقد اتضح من خلال هذه الدراسة ان نتائج انبعاثات ثاني أوكسيد النيتروجين ، ثاني أوكسيد الكبريت ، أول أوكسيد الكاربون و انبعاثات ثاني أوكسيد الكاربون الكلية كانت 357,55 مجم/م3 ، 2854,92 مجم/م3، 122,56 مجم/م3 و 432036,4 طن ثاني اكسيد الكربون مكافئ على التوالى.
كذلك تشير هذه الدراسة إن الانبعاثات الغازية من المحطات قد يتناقص اذا تم استخدام الغاز الطبيعي بدلًا من المازوت ، وكذلك ستزيد كفاءة المحطة عند تشغيل نظام مراقبة الانبعاثات المستمر و نظم تقليل التلوث في المحطة . ولذلك، ينبغى ايلاء اهتمام خاص لحماية البيئة فى التخطيط لمستقبل التنمية الاجتماعية والاقتصادية، ولا سيما نظام الطاقة . تيسير وضع استراتيجيات مستدامة وتحسين نوعية الحياة فى الوقت الذى تقلل فيه الى ادنى حد من الاثار السلبية الصحية والبيئية من مخزون الطاقة واستخدامها.