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Environmental Evaluation of Emissions from Thermal Power Plants in Jordan: Aqaba Thermal Power Plant Case Study

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Abstract

Jordan faces a wide variety of environmental problems, most of which are attributable to the inherent of air pollution roused in the last decade, and the cost of ignoring such problem could be exorbitant and the results could be very harmful as well. As thermal power plants are considered the main pollutants emitters, Aqaba city thermal power plant, one of the major thermal power plants in Jordan, is considered as a case study to indicate the impact of main pollutants emitted to surrounding environment. This study is an attempt to generate a correlation that relates amount of emitted pollutants to the amount of the electricity generated of the considered plant. The considered pollutants are carbon dioxide, carbon monoxide, sulphur oxides, and nitrogen oxides. Actual measured data for the amount of fuel used and emission factors for each of these pollutants were provided by Aqaba thermal power station. Amounts of emitted pollutant, electricity generated, and the efficiency for the power was calculated on monthly basis. Correlation was successfully generated that relates the amount of pollutant emitted from the power station to the electrical power generated over the last four years. Using this obtained correlation, it is expected to help in the estimation of future emitted pollutants, and hence to control these amounts in an attempt to establish regulatory frame work for power pollution reduction.

Keywords: *Pollutants Activity Data, Emission factor, Pollutant Intensity*

1. Introduction

As the world population is growing over the years the demand on energy particularly fossil fuels is growing as well, this led to energy scarcity and other serious issues related to human unaccountable consumption of fossil fuel. The major portion of greenhouse gases (GHG), mainly CO_2 additional to NO_x, SO_x and CH_4) is produced by the combustion of fossil fuel in the power plants which require an additional cost to capture and storage [1]. One of the main concerns that becoming human obsession of this era is pollution. It is life threatening and could upset the whole earth living system. A significant amount of research work was conducted in attempts to cut down the emitted pollutants from combustion systems. Zhao el-al [2], investigated environmental laws and regulations impacts on power plant efficiency and CO_2 reduction. It was found that market-based regulations and government subsidies both would have positive influence on the improvement of efficiency and CO_2 reduction.

Chakraborty et al [3], studied the effect of measured emissions on emission coefficient basis of how much coal per kg burned to generate electricity per kWh, to calculate the total possible emission from Indian thermal power plants. As a result the emission coefficients were calculated for CO_2, CO, SO_2, NO and were compared closely with their corresponding values as obtained in the studies conducted by other groups

Kansal et al [4], investigated how the ambient air quality of Delhi would be improved if the World Bank emission guidelines were adopted. To accomplish this, emission contributions to ambient air quality had to be estimated. As a conclusion the ISCST3 model predictions for TSP (Total Suspended Particulates) and NO_2 were satisfactory at all receptor locations. Mittal [5], estimated the emissions of CO_2, SO_2, and NO from thermal power plants in India over the period from 2001 to 2009. Mass emission factors were calculated using basic principles of combustion. Future emissions up to 2020 were predicted based on the estimates of the nine years study and analysis. Bearing in mind those power plants in India use different resources of coal and deploy different technologies while also running under

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dissimilar operating conditions, as a result, different efficiencies were achieved by each power station (Amount of electricity generated). Rubin et al [6], generalized a tool to estimate and compare emissions displacement, efficiencies, and current costs of fossil fuel used in power plants. The results showed that power plant operation and capital costs are higher than previous studies due to recent escalations in both costs. While reduction of power plant emissions of CO_2 can be achieved up to 85–90%, the effects of energy requirements on power plant also are found to be high as well. In order to characterize such effects, another definition of the "energy penalty" was proposed.

Ghenai and Janajreh [7] compared the resources intensities and operational parameters of conventional fuel (oil, coal and gas) with renewable (wind, solar, and geothermal) and nuclear power systems. In their work not only have considered CO_2 emission but also the required capital, energy, construction materials, land use, efficiency and capacity factor. In their energy triagle they placed Middle East at the fossil fuel corner at near 100% dependency on fossil (i.e. zero renewable and nuclear). Furthermore, they indicated the CO_2 emission during the power plant construction of nearly 150 kg/kw for natural gas compared to 200 kg/kw for geothermal or nuclar plants while 400kg/kw for coal and reaching as high as 1,000 kg/kw for solar PV and 2,500kg/kw for hydro power plant.

Sarkar et-al [8], developed an estimation tool of CO_2 emission utilization by several linear equations for coking and non-coking coals. Those equations are also proving their validity against different sets of data for different Indian coals types. Nevertheless, the application of these equations towards the estimation of CO_2 emission from power plant and the uncertainty CO_2 estimation were revealed and determined. As a result the developed equations can be applied to get a realistic estimation of CO_2 emission. Emissions of greenhouse and other air pollutants are increasing in Jordan since the demand on electricity is increasing due to rapid economic growth leading to accelerated industrialization coupled with equaled urbanization. Air pollution control is one of the main public concerns, because of its destructive effects either on the environment or human health.

Song et al [9] performed a Life Cycle Assessment (LCA) process for three kinds of local electricity generation (heavy oil, natural gas, and MSW incineration) to estimate the greenhouse gas (GHG) emissions under the operating practices used from 2010 to 2014. Their Results indicated that the mean GHG emissions of electricity production from heavy oil, natural gas, and MSW incineration were 0.71, 0.42, 0.95 kg CO_2eq per kW h, respectively. Based on this, the development of natural gas-fired electricity would be more effective for GHG emission reduction target.

In this study, it was planned to conduct a similar study presented by Song et al, using two scenarios; heavy oil and natural gas as power plant fuels. However and due to the fact that no available data was available, this study was aimed to generate a correlation that relates the amount of the main emitted pollutants and the amount of the electricity generated by the power station. This is accomplished through the estimation of the emitted amounts of most common pollutants and the estimation of the quantity of the electrical generated by the power plant. Once these quantities are estimated a correlation was generated that relates both quantities. Actual data of the emitted amounts of CO_2, SOx, NOx, and CO quantities in ton for each MWh were obtained from Central Electricity Generating Company.

2. Methodology and Data Analysis

In this work, the analysis technique used to estimate the amount of emitted pollutants is that of the EEA (European Environment Agency). Which states the methods used to estimate the emission of a species is estimated using equation (1) as:

$$\textbf{Emissions} = \textbf{AD x EFi} \quad (1)$$

Where AD is the activity data and (fuel consumption), EFi is the emission factor (mass of species emitted per unit of fuel consumed). Using the data provided by Aqaba power plant (the fuel consumption) together with the values of EFi and by using equation (1) the amount of emitted pollutant of each pollutant can be calculated. The total amount of electrical power produced by the power plant was calculated using equation (2) as:

$$\textbf{Efficiency } \eta = (E_{out} / E_{in}) \quad (2)$$

Where η is the power plant efficiency (supplied by the power plant), E_{out} is the energy generated by the power plant in MWh and E_{in} is the energy consumed by the power plant in MWh, which is given by the product of the calorific vale of the fuel and its rate of consumption. Introducing the pollutant intensity (I_{pi}) which is defined as the ration between the amounts of the emitted species. E in kg and the electrical power generated E by the plant in kWh, and is written per equation (3) as:

$$I_{pi} = E_i / E_{gen} \quad (3)$$

3. Results and Discussion

3.1. The Amount of emitted pollutants

In this study amount of emitted pollutants were calculated for Aqaba thermal power plant over the period (2011 - 2014). Using equation (1) the obtained yearly emitted pollutants are presented in figures 1 through 4.

As shown in figure 1, the quantity of CO_2 emitted drops sharply during 2012, is due to the fact that in 2011 natural gas was imported from Egypt and hence power plant was powered by both natural gas and heavy fuel oil, the deployment of natural gas in the power plant leads to drop in the emission of CO_2. Unfortunately and due to frequent disturbance in the supply of natural gas from Egypt to Jordan since February 2011, the power plant had to switch to heavy fuel oil. Consequently the formation of CO_2 increases due to the fact that natural gas is a very clean fuel compared with heavy fuel oil. It also noted from figure 1 the amounts of emitted CO_2 increases continuously during the following years, this is due to increase in the power production to meet the demand of electricity.

Figure 2 through 4 show the emitted quantities of SOx, NOx and CO, respectively. As indicated in these figures, the emitted amounts of these species decrease during 2012, beyond which these amounts start to increase due to the cut down of the Egyptian natural gas supply as mentioned above.

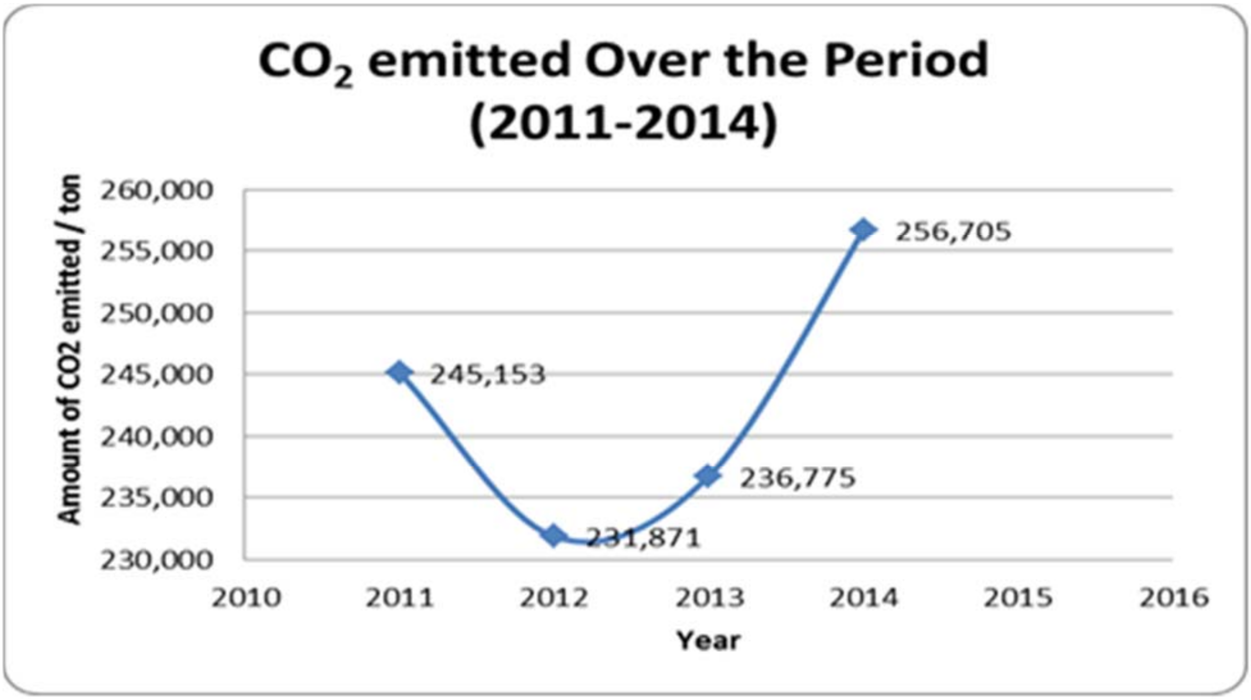

Fig. 1. Calculated amount of CO_2 emitted over the period (2011-2014)

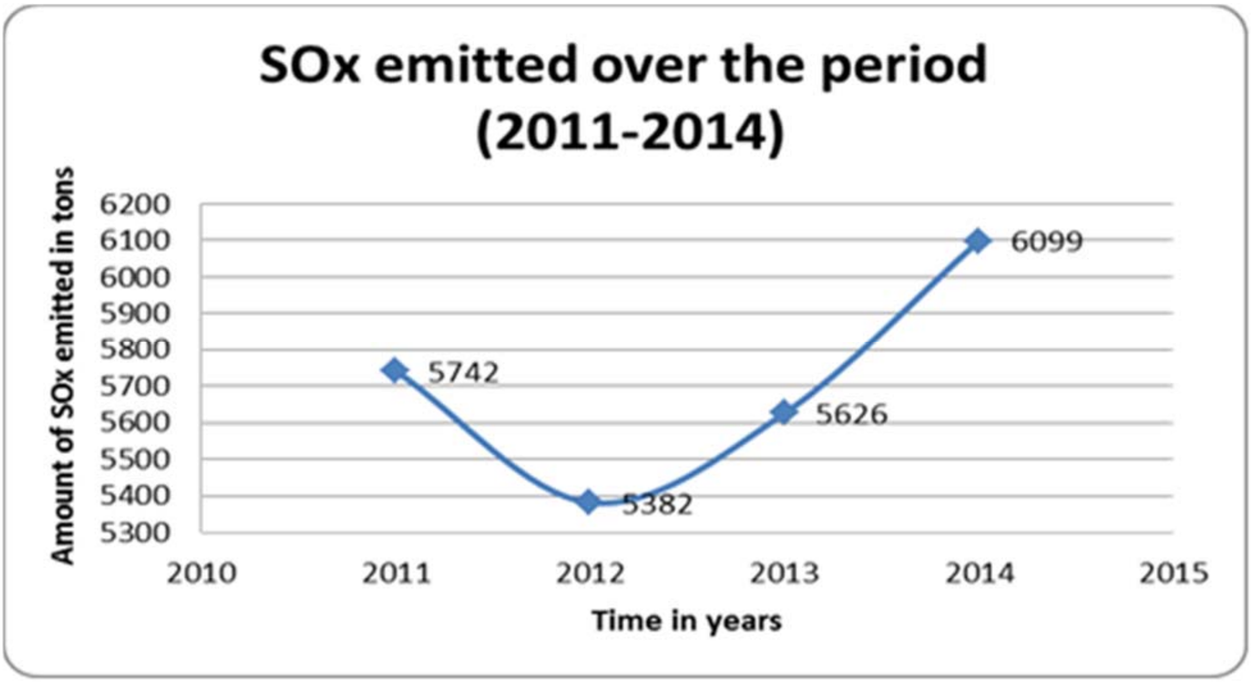

Fig. 2. Calculated amount of SOX over the period (2011-2014)

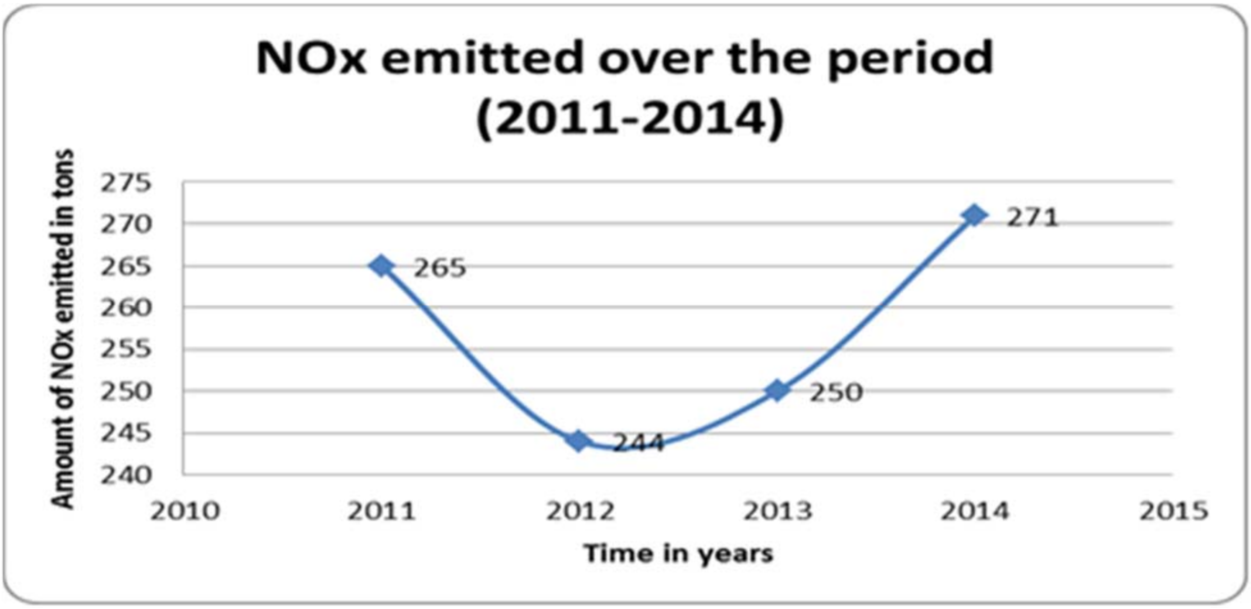

Fig. 3. Calculated amount of NOX over the period (2011-2014)

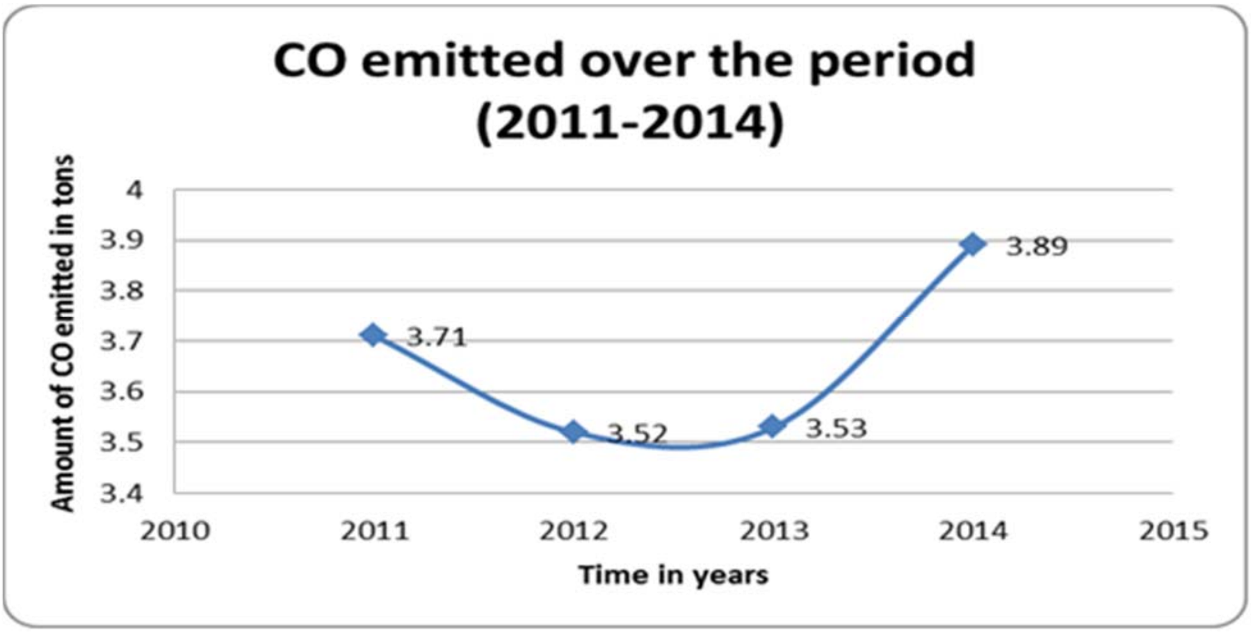

Fig. 4. Calculated amount of CO over the period (2011-2014)

3.2. Pollutant intensity calculations

Pollutants intensities defined by equation (3), were calculated and presented in figures 5 through 8.The intensity of CO_2 over four years are presented in figure 5. As shown, this intensity is almost constant over the study period with the exception that during the year 2011 some serious fluctuations may be noticed, due to the interruption in the supply of natural gas from Egypt as discussed previously.

The intensity of SOx over four years are presented in figure 6. As shown, this intensity is almost constant over the study period with small variations in this intensity, this is due to fact that the fuel used to run the power station is imported from several locations and hence it has different amount of contaminants.
The intensity NOx over four years are presented in figure 7 as shown, this intensity is almost linear over the study period with the exception that during the year 2012, during which some fluctuations may be noticed. This is due Nitrogen impurities percentage changes upon origin of the imported heavy fuel oil. This argument us valid for the intensities of SOx and CO which are shown in figures 7 and 8, respectively.

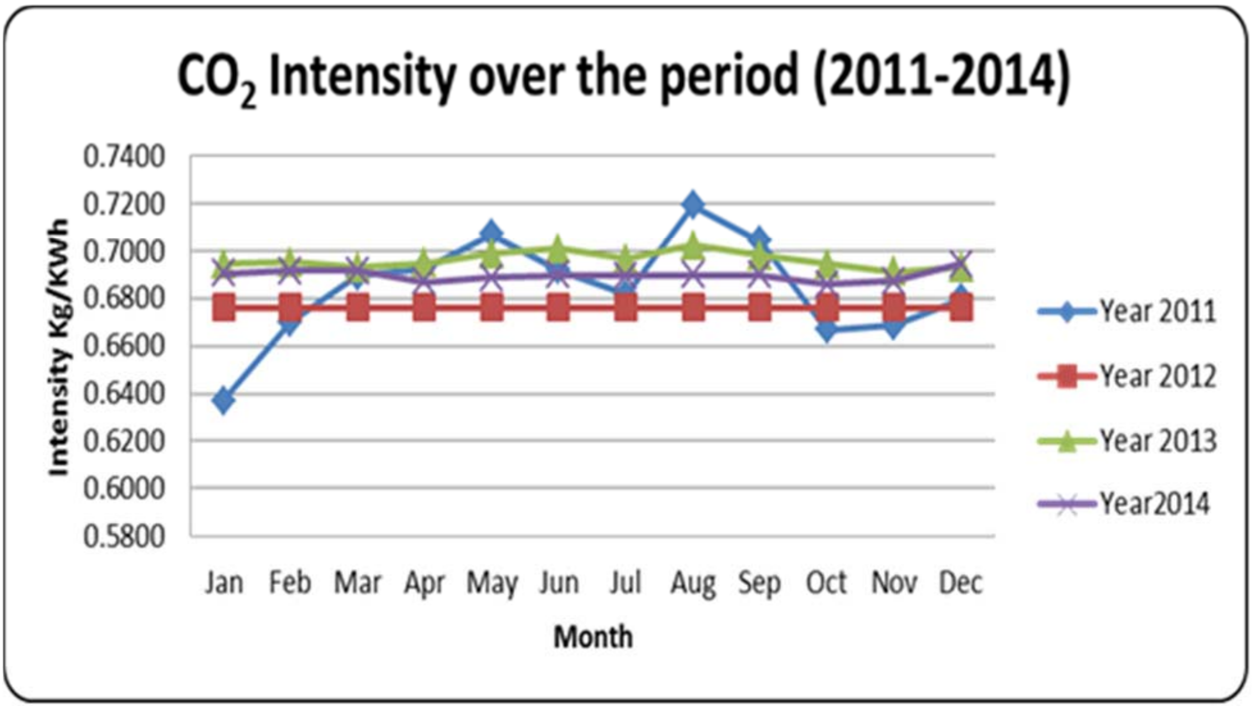

Fig. 5. Calculated Intensity for CO_2 over the period (2011-2014)

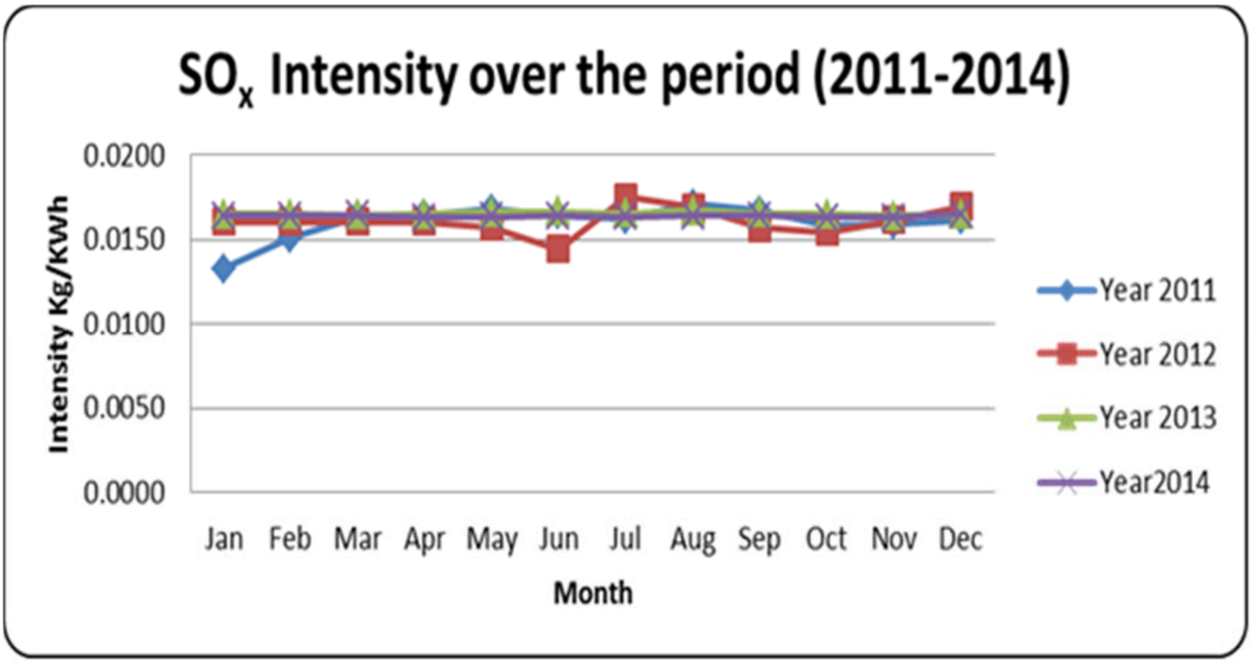

Fig. 6. Calculated Intensity for SOX over the period (2011-2014)

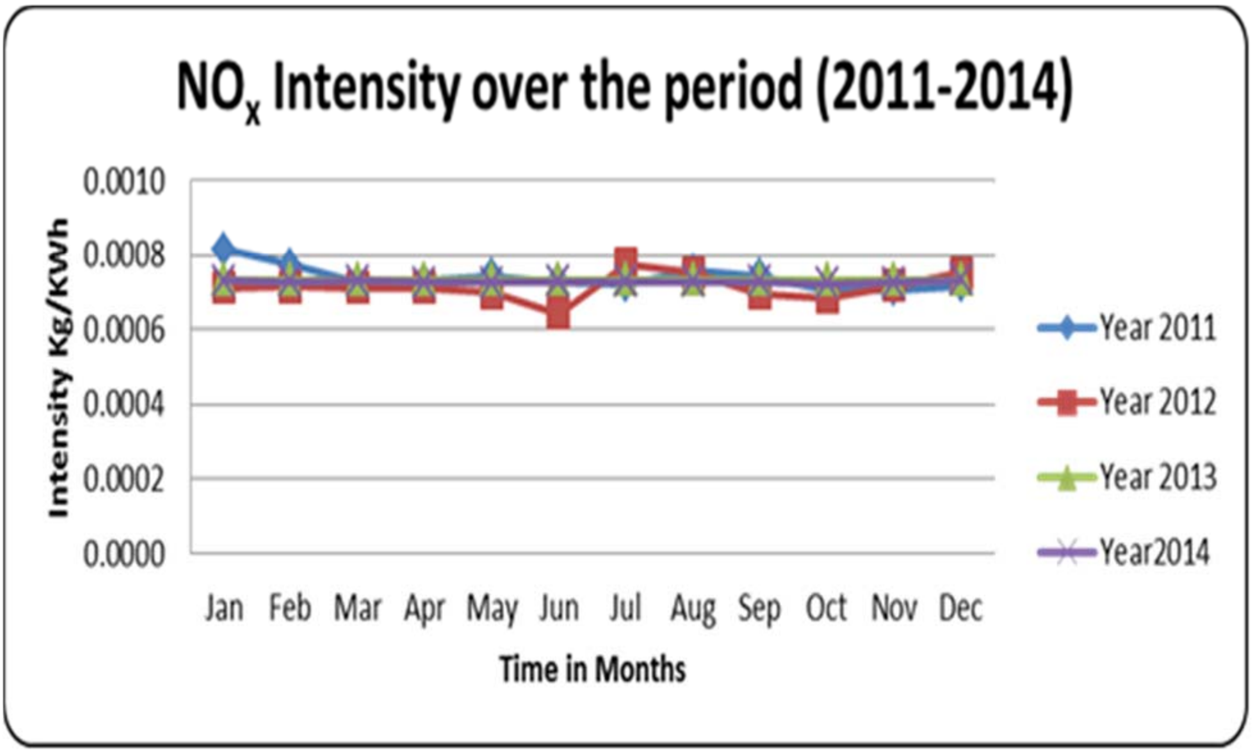

Fig.7. Calculated Intensity for NOx Over the period (2011-2014)

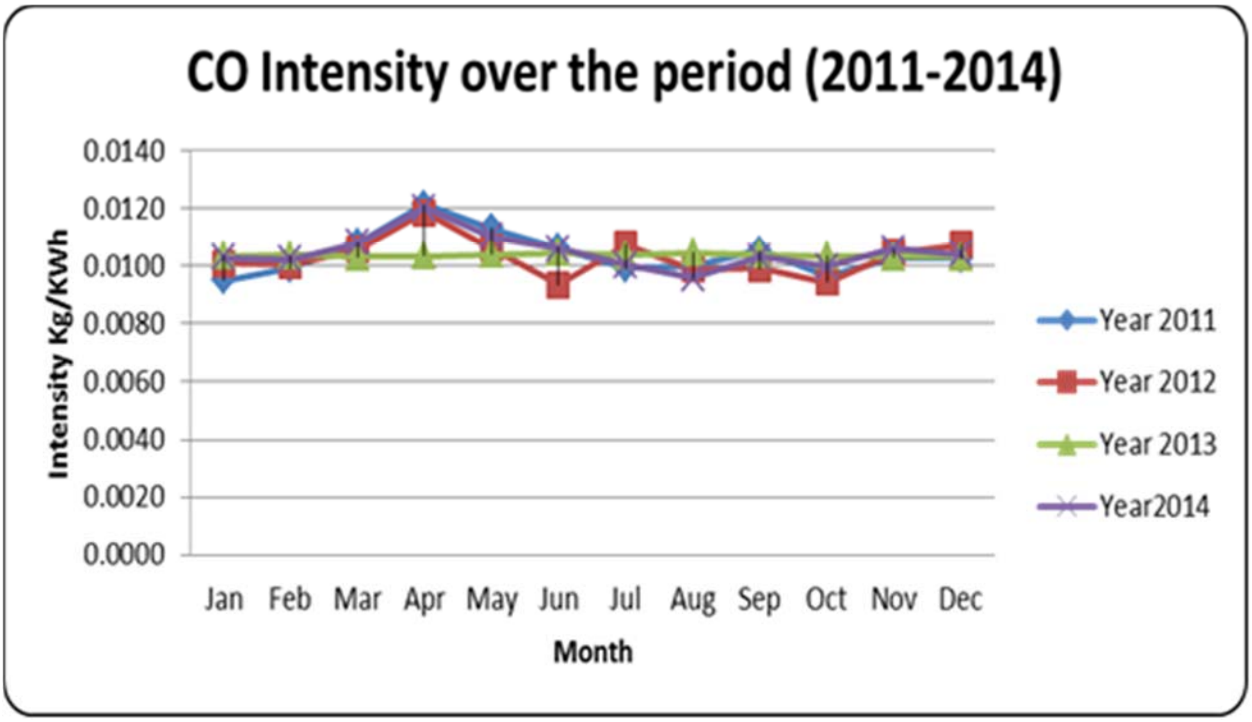

Fig. 8. Calculated Intensity for CO over the period (2011-2014)

4. Conclusion

As a conclusion a correlation that relates the amount of quantity of each emitted pollutants with the type and power generated was successfully generated, from this equation the following may be concluded

- The electrical power generated is directly proportional to the amount of fuel consumed.
- Pollutant intensity is directly proportional to amount of electricity generated and inversely proportional to the amount of pollutant emitted.
- Efficiency is directly proportional to the amount of electricity generated by the power plant.

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