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Estimation of the impact in the air quality by the use of clean fuels (fuel oil versus natural gas)

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Abstract

The extended use of fuels with high sulfur content (fuel oil) in the electric power industry represents one of the biggest concerns on air quality currently in Mexico. The organic sulfur compounds in the fuel oil are oxidized as SO_x during combustion, causing high concentration at the surface level near the releasing point. Shifting towards cleaner energy is crucial, however natural gas (NG) production is currently scarce and substantial investment is required to assure the NG supply to replace the fuel oil. Large investments should be made by the public and private sectors to replace heavy fuel oil use by NG. In order to support decision takers, this work assess the air quality impact due to cleaner energy use and determine the optimal NG and fuel oil mixture required to reduce substantially the SO_2 concentration. The dispersion model was applied to compare, against a base case, a set of artificial emissions scenarios with different fuel oil and NG mixtures. The model was previously validated against SO_2 field measurements performed at an Industrial Corridor, Mexico. The results show that increasing 40% the NG consumption, the SO_2, concentration in the air is reduced in 90%, therefore not further NG increasing is needed.

Keywords: Air quality; Model dispersion; Stack emission; Power generation

1. Introduction

The politics of energy in Mexico should contribute in the use of cleanest fuels, otherwise puts risk in the adequate industrial development that needs the country to improve in matter economic and social (Comisión Reguladora de Energía [2]). The volume of fuels increase with the grade industrial development, unfortunately, in Mexico is employed way extensive the heavy fuels that contains a high concentration of sulfur (heavy fuel oil), around the 3.8% in volume (Evans et al. [3]). This aspect impacts in a negative way in the air quality, due that is emitted in large quantities of SO_2 and particles, with its consequent impacts already acquaintances of way generalized (Goddin et al. [4]; Schwede et al. [8]). The alternative is to utilize cleaner fuels, as the NG, unfortunately in the country exists a deficit, as for what is required with regard to what is produced of NG, for which great part gas natural is imported or fuels are employed less clean (Gas Research Institute [5]). Besides this deficit, the economic aspect exists in the change of fuel is too high, this change of fuel involves the execution of large investments so much publish as private (Guidelines for National Greenhouse Gas Inventories [6]). The associated costs to employment of the NG should be estimate and taken into account to evaluate the viability of the cleanest use of fuels. By it should do an analysis cost–benefit to evaluate the consequences. In this work it wants to contribute in the estimation of the effect that has the use of cleaner fuels in the quality of the air. For this, campaign experimental of measurements of the air quality were carried out (measurements of the concentration of SO_2), measurements of meteorology, development of inventory of emissions and a dispersion model is employed to evaluate in a theoretical way the effect in the quality of the air and correlating it with the effect by the use of the NG.

2. Methodology

Its design and carried out a campaign of quality of the air in the industrial region of Mexico, employing three mobile

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laboratories to carry out the measurements of simultaneous way, which include monitoring of sulfur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), ozone (O_3) and total suspended particles (TSP). The measurements were carried out according to the specific methods approved and suggested by the Agency of Protection al U.S. Environment (US EPA) in matter of monitoring of the quality of the air. Besides measurements were carried out of meteorology (direction and velocity of the wind, temperature, relative humidity, atmospheric pressure and solar radiation) (Holtslag and van Ulden [7]). Tests of calibration were carried out so much to the analyzers of employed contaminants in the study of the air quality as to the meteorological sensors, also the mobile laboratories of air quality present their tests certificates, as well as the personal accredited by the Mexican Company of Accreditation (EMA). The selection of the sites for the air quality monitoring was carried out in agreement to the historic analysis of the winds field predominant in the region during the epoch in study and by means of preliminary simulations of the dispersion of pollutants were defined the areas and distances more representative. Also a collection of the information of the emissions contaminants (stack emissions) was carried out, the environmental authority shows it. The information covered the years of 1997–2003. In this manner a dependable inventory of emissions can be obtained (USEPA [10]), which will be utilized in the study of the dispersion of contaminants and the estimations with it were compared measurements in an experimental way. Subsequently, it was carried out simulations of the dispersion of pollutants utilizing synthetic scenarios of emission, which include the use generalized and intense of the NG as main energy (Allwine and Whiteman [1]).

3. Results

In the analysis of the emissions pollutants, the information of the consumption of fuel was included also (so much NG as heavy fuel oil) and the corresponding productive capacity, in this manner can develop a base of data that serve to correlate the emissions–energy–production. In Fig. 1 the behavior of the rate of emission is presented for the SO_2 with

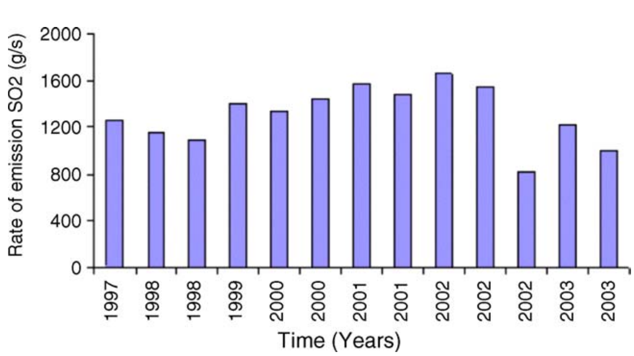

Fig. 1. Evolution of the rate emission SO_2 (g/s) (1997–2003).

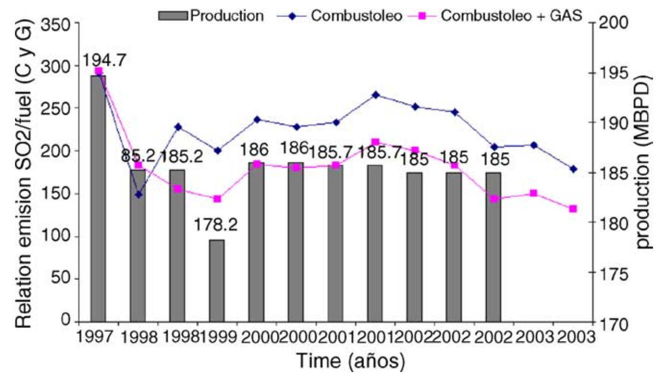

Fig. 2. Evolution of the relation between the fuel's consumption (gas and heavy fuel oil) and the SO_2 emission, and the production (1997–2003).

respect at the time. The more recent information shows a decrease in the rate of emission.

This fact is due to the decrease in the consumption of heavy fuels (heavy fuel oil), which were substituted for NG (to see Fig. 2) as well as more efficient conditions of operation, since the annual production has been maintained (to see Fig. 3).

In Fig. 2, the production is compared with the fuel consumption relation and emission of SO_2, this indicate that exist less pollutants emission by consumption of energy, even when the production of the Refinery not change. This is due to the replacement of the heavy fuel oil by NG and to the application of better custom of operation.

With the meteorology information, obtained in the experimental campaigns; and the inventory of pollutants emissions were carried out the simulations of the dispersion of pollutants to estimate the spatial distribution of the concentration of SO_2, covering an extension of 24 km $\times$ 24 km. To carry out the simulation of the dispersion of the SO_2, its employment the AERMOD model, which is developed and promoted by the Agency of Protection Environment of the United States (US EPA) and that the

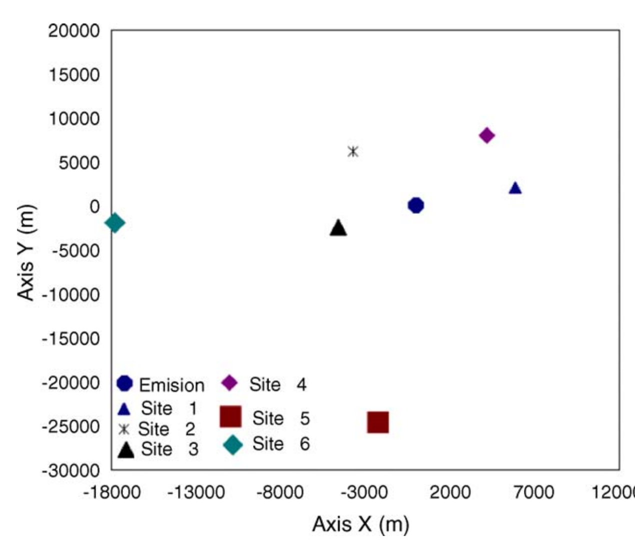

Fig. 3. Spatial distribution of the monitoring air quality sites.

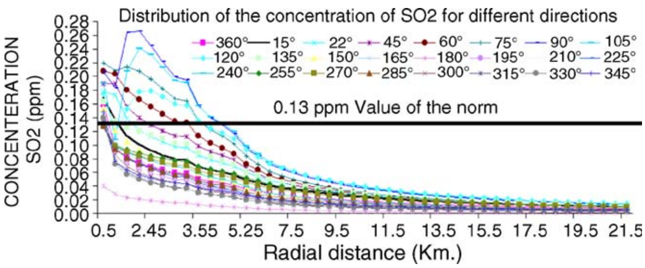

Fig. 4. Spatial distribution of the concentration of SO_2 calculated during the period of the 22–27 February of 2003 in the region.

Instituto Mexicano del Petroleo has applied in diverse regions with very encouraging results. The AERMOD employs in its algorithm information of the atmospheric turbulence, which is calculated from the meteorological information measured in surface. The simulation covers a micro region, for which is considered that the topographical accidents are not of consideration and that not an important chemical transformation of the emissions exists. In Fig. 3 it shows the relative coordinates of the sites measurements of the monitoring of air quality located in the region, as well as also the position of the source of emission.

The information of the emissions contain data of the locating of the source of emission, height and diameter of the source of emission, temperature and velocity of the gases at the outset and the flow mass of SO_2. The sources of emission that considered in this study were 58. It utilized the meteorology information registered per minute in the three places of monitoring of air quality by a period of 7 days, they were utilized a total of 21,592 meteorology scenario of data for the study of the simulation of the dispersion of SO_2. Fig. 4 shows the estimations of the spatial concentration of SO_2 resultant of the simulation for different distances and

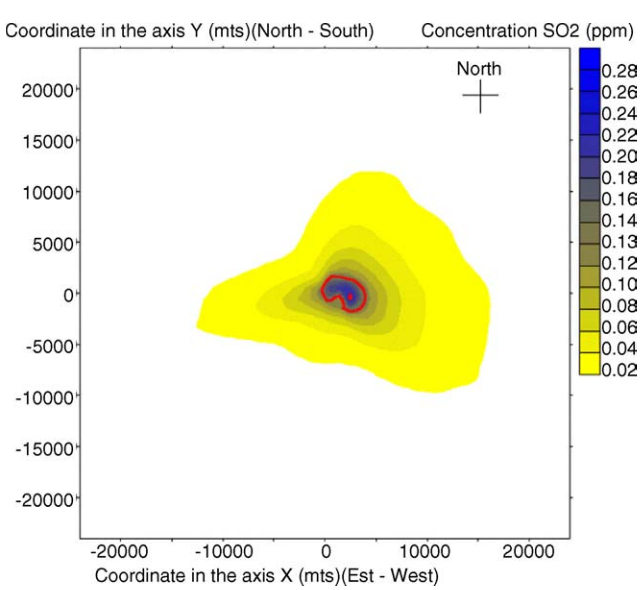

Fig. 5. Representation of the spatial distribution of the concentration of SO_2 calculated for the period of the 22–27 February of 2003 in the region.

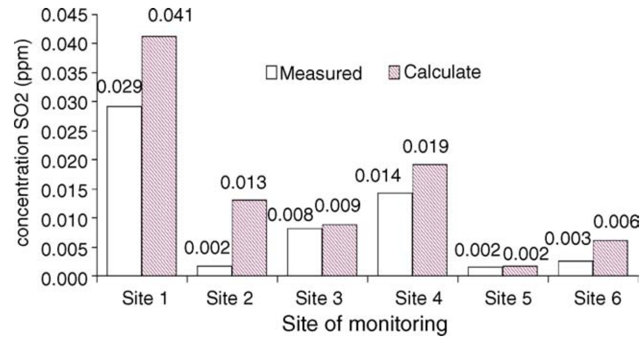

Fig. 6. Comparison between the concentration of SO_2 measured in the campaign of air quality and it estimate by the AERMOD model during the period of the 22–27 February of 2003 in the region.

directions with reference to the source of emission. High values of concentration of SO_2 exist that exceed the value indicated by the Mexican norm of quality to a distance of 5.25 km, after this distance the values comply with the value of the norm, having a radiusf influence of 17.5 km.

In Fig. 5, represented the spatial distribution of the concentration calculated of SO_2, it was obtained with the simulation of the pollutants dispersion, in figure is possible to identify the zones in which a greater impact exists and the magnitude of the extension of the emission.

Figs. 6 and 7 show the comparison between the concentration of SO_2 measured experimentally and it calculated with the simulation, being this satisfactory and obtaining a good correlation factor value ($r_2 = 0.87$), this offers a greater degree of confidence in the results obtained. The factor correlation is good for the modelling dispersion.

In Figs. 8 and 9 the results obtained of the utilization of synthetic scenarios of emission of pollutants and the dispersion simulations are showed, with the objective to know that would happen with the air quality if the use of the

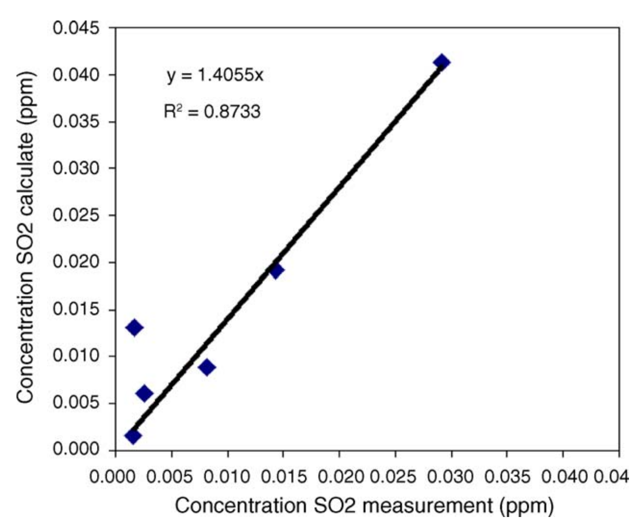

Fig. 7. Correlation factor between the concentration of SO_2 measured in the campaign of quality of the air and calculated by the model one AERMOD during the period of the 22–27 February of 2003 in the region.

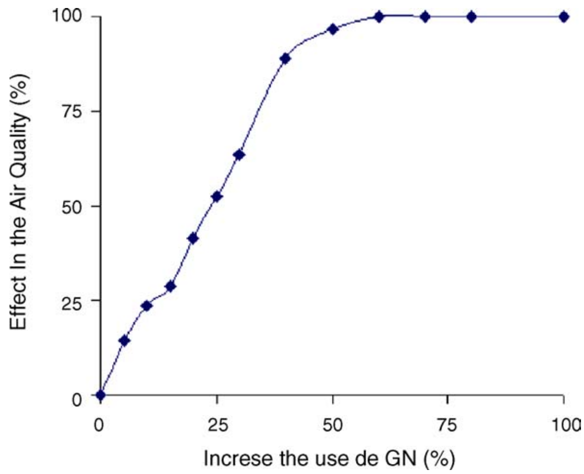

Fig. 8. Effect of the increment in the use of NG in the air quality.

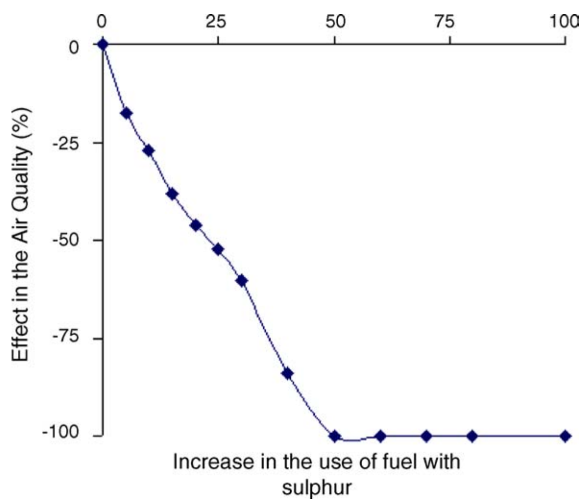

Fig. 9. Effect of the increment in the use of the heavy fuel oil in the air quality.

NG will be increased or of the heavy fuel oil. It is taken like case base the obtained with the experimental data and the effect in each one of the scenarios is evaluated. It uses different grades of consumption of NG and heavy fuels (heavy fuel oil). Fig. 8, shows that the increase in the use of NG, impact positively in the air quality until 50%. For otherwise the incremental in the use of heavy fuel oil, affect negative the air quality seriously.

4. Conclusions

The results obtained in this work indicate that the use of the simulation of the dispersion of contaminants with the model AERMOD presents a good correlation between the experimental measurements of the concentration of the sulfur dioxide in different sites. Besides that the inventory of emissions for the sulfur dioxide is well calculated. For which it concerns to the simulation of the air quality under different scenarios in the use of gas natural or fuel heavy oil, is observed that with a light increment in the use of the NG a greater positive effect in the quality of the air exists. On the contrary, small increments of the heavy fuel oil cause greater negative effects in the environment. With the results obtained in this work, can be quantified the positive effects in the air quality by the use of the NG for different levels of employment in the industry. Also it is shown the environmental risks that potentially has the employment of the heavy fuel oil. With this information and combined to the associated costs can be done to calculate exact in the convenience in the use of this clean fuel.

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