ENVIRONMENTAL IMPACT OF FOSSIL FUEL UTILIZATION IN NEKA THERMAL POWER PLANT

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(Received: October 4, 2008 – Accepted in Revised Form: March 11, 2010)

Abstract Carbon dioxide causes green house effect and has been considered as a pollutant source for safe environment. Since combustion of fossil fuel may create tremendous amount of carbon dioxide, detecting any pollutant sources would be important to eliminate the origin of pollution sources. Evaluation of smoke dispersion generated by the power plant utilizing fossil fuel is the objective of this paper. The concentration of NO_x and SO_x in the soil till a distance of 15 km from Neka power plant, have been analyzed. The maximum concentrations of SO_x and NO_x in the distance of 2.5 to 4 km from the power plant were 0.13 and 0.36 ppm, respectively. Replacement of fossil fuel (fuel no. 6, Mazout) by natural gas may increase NO_x concentration in the atmosphere; however the use of natural gas was recommend by environmental protection agencies as clean fuel. Use of natural gas may not be an actual solution for prevention of NO_x pollution.

Keywords Fossil fuel, Air pollution, Power plant, Green house effect, Soil pollution

چکیده مشکلات زیست محیطی ناشی از مصرف سوخت های فسیلی و پدیده اثر گازهای گلخانه ای، در سال های اخیر توجه زیادی را به خود اختصاص داده است. در این مطالعه تجربی، ضمن براورد میزان آلاینده های سوخت فسیلی نیروگاه نکا، نسبت انتشار در اطراف آن نیز مورد ارزیابی قرار گرفت. بیشترین غلظت آلاینده های SO_x و NO_x در فاصله حدود ۲/۵ تا ۴ کیلومتری از نیروگاه و برابر ۰/۱۳ و ۰/۳۶ ppm بدست آمد که اندکی بیشتر از حد استاندارد قرار دارد. در حال حاضر، جهت تولید انرژی در ایران، استفاده از گاز طبیعی بعنوان سوخت تمیز بجای سوخت فسیلی (نفت سیاه) توصیه گردید، اما به دلیل افزایش غلظت NO_x در جو، از این روش نمی‌توان در دراز مدت استفاده کرد.

1. INTRODUCTION

There are number of problems associated with use of fossil fuel, such as pollution and green house effect [1, 2]. The issue of air pollution brought into attention in fourteen century, as combustion of coal caused air pollution [3]. Dispersion of carcinogenic chemicals reported to be as major source of pollution [4, 5]. Naturally, the ecosystem is disable to degrade all toxic chemical wastes. Nowadays, the fossil fuel still is the major source of energy. Combustion of fossil fuel with sulfur content generates carbon monoxide, carbon dioxide, sulfur oxides and nitrogen oxides [3-6]. In order to reduce global air pollution, industrial zone outside of civilization and residential area were established. Green belt of forest around the civilized area for protection of the environment and reduction of air pollution were suggested [7-9].

The most important sources of fuel for energy conversion in thermal power plant are mainly fossil fuels, coal and natural gas [10-13].

Combustion of fuel generates gaseous products such as CO, SO_x and NO_x, which are considered major air pollutants. Most power plants using fossil fuel cause tremendous amount of environmental pollution. Elimination of pollution sources by using high quality of fuel would be able to reduce air pollution and to meet the international standards for clean environment [4-6, 14-18]. In industrialized countries, demand for electrical power is rapidly developing. Along with massive power generation, tremendous amount of air pollution is also created. Therefore application of energy efficient and environmental friendly system, are recommended. In past decades, energy recoveries from industrial wastes and conversion of waste to energy as a byproduct were highly encouraged [19-21]. For instance pulp and paper industry for energy efficient system, the enriched lignin black liquor is regenerated in a furnace for chemical recovery and the heat of combustion used in steam generator, as a result, electrical energy is produced in steam turbine. Chuka Pulp and Paper Company, located in the north of Iran not only supplies its own power, but also delivers additional 50 MW power to the main electrical power transmission line, which generates more revenue [22].

The purpose of this research was to identify origin of any air pollution sources in the region of Mazandaran, North of Iran. Since the major source of air pollution for the main industrial activities in this region was suspected to be Neka Power Plant, therefore an extensive research in the radius of 15 km from Neka power plant was conducted to find out any impact of the air pollution in this region. The quality of fossil fuel and natural gas used in the power plant and analysis of numerous soil samples were conducted for the adsorbed gases caused by the polluted air. Investigations were carried out in the surrounding region of Neka power plant.

2. MATERIAL AND METHODS

2.1. Description of study area and sampling places

Neka Power Plant is located on the south of Caspian Sea, in the north of Iran with total power generation capacity of 2170 MW. The power plant capacity was enhanced and expanded in 2000s with dual gas modern gas turbines with capacity of 270 MW. Also the plant is benefited by a combined cycle unit, combination of gas and steam turbine cycles for electric power generation with highest efficiency and capacity of 140 MW. This thermal power plant consists of 4 thermal units, each has power generation capacity of 440 MW, with 4 concrete type stack gas chimney of 134 m height. The major combustion fuels are dark fuel oil (Fuel no. 6 and Mazout) and natural gas. The standard heat of combustion for the fuel oil is known as heating value of the fuel that is about 39700 Btu/kg and for natural gas 42500 Btu/m^3 [23]. Since there is shortage of natural gas in cold season, the plant may depend mostly on fossil fuel. The number 6 fuel oil is a complex blend of hydrocarbons derived from various refinery streams, usually residues, and can contain small amount of hydrogen sulfide. Typical streams include atmospheric tower bottoms, vacuum tower bottoms, catalytically cracked gas oil, slurry oil and acid soluble oil. The composition is complex and varies with the source of crude oil. This kind fuel is combustible at high temperature with auto-ignition temperature of 315.59°C (600.1°F), Flash point of higher than 60°C (140°F). The products of combustion are carbon oxides (CO, CO_2), nitrogen and sulfur oxides (NO_X, SO_X), particulate matter, VOC's [24].

The stacks are normally tall enough to carry stack gas away from the plant; the major pollutants are CO, SO_2, NO_x and SO_x. The SO_2 is colorless, choking gas, soluble in water, damage natural flora, fauna materials. The CO gas is also colorless and odorless formed during incomplete combustion of hydrocarbons, which causes green house effect and finally climatic changes. Most stack gases are discharged vertically into open air. The contaminated gases are diluted by large volume of ambient air. The dilutions of pollutants are not considered as real solution; the pollutants are eventually dispersed and adsorbed to the ground soil and natural flora. Increasing the stack gas velocity and temperature may increase the plume rise. The effective stack height is the physical stack height and in addition it boosts the plume rise.

2.2. Air Sampling

Air samples were taken from the surrounding area of the plant in three directions. Random samplings of the ambient air were taken from 1.5 to 2 m from the ground level, in distance of 100, 150, 300 and 500 meters from stack. The samples were taken by adsorption of gas from the ambient by solid adsorber. Then, the gas samples were analyzed by gas chromatograph (GC) (HP 5890, Series II, Hewlett–Packard, Palo Alto, CA). Also the titration method was developed by hydrogen peroxide solution, SO_2 was absorbed in the solution, and the acidity of solution was neutralized by a standard alkaline solution (0.002 Molar NaOH). A 50 ml of 3 percent hydrogen peroxide solution was used for the air sample. Vacuum pump (Edwards, UK) with 53 kPa vacuum capacities was used to pump flow rate of 200 ml/min.

The NO_x gas was adsorbed by a solution to develop pink to violet color. The color solution was detected by colorimetric method using spectrophotometer (Cecil instrument 1000 series, UK). This method was calibrated for NO_2 air pump and rotameter was used to determine the air flow rate. The developed color was detected at wavelength of 550 nm.

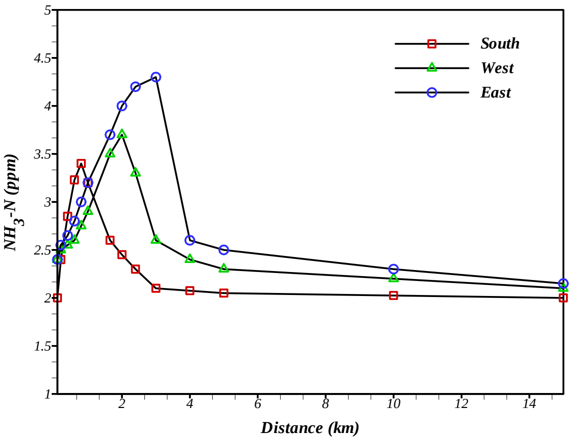

Figure 1. NH_3-N concentration in the soil at various directions.

The CO was also detected by colorimetric method. Gas sampling was carried out from the stack gas leaving the chimney.

2.3. Soil Sampling

The soil samples from inside and outside of the power plant in radius of 15 km in South, East and West directions were taken. Since in North direction there was Caspian Sea, it was impossible to take any sample. Random and zigzag sampling was conducted to take soil sample up to 20 cm depth and 10 samples were taken in each selected zone.

Nitrate was measured by Griess-Saltzman method [25], in this method, liquid solution was used to absorb NO_x; red to violet color was developed, which was detected by the spectrophotometer at 550 nm wavelength. Gas anemometer was used to project the flow rate. The NO_2 was detected by potassium permanganate, after NO was converted to NO_2 in presence of oxidizing agents, nitrate concentration was detected by bromocresol reagent using colorimetric method [25].

3. RESULTS AND DISCUSSION

The analysis of data was carried out for the surrounding area of the plant in a maximum distance of 15 km. The data were collected in winter, spring and summer in three consecutive seasons at stable and unstable weather with the average wind velocity in the range of 14-17 m/s, as the season was changing the wind speed may gradually increased. Wind velocity was measured by means of an anemometer. The cup anemometer, an instrument with four small hollow metal hemispheres set so that they catch the wind and revolve about a vertical rod; an electrical device records the revolutions of the cups and thus the wind velocity. The stable weather is defined as the movement of air is limited and the air molecules are nearly stagnant while for unstable weather the flow of air may be turbulent and the movements of air molecules are maximized with high wind speed. There was no incident to be reported or the level of pollution was not significant in the distance of 1 km from the power plant. Therefore, minimum air pollution exists in the plant environment since the plant is benefited from tall chimneys for stack gases.

Figure 1 depicts the NH_3-N concentration with respect to distance. As it is shown, the maximum concentration values of NH_3-N in three directions, East, West and South were 4.3, 3.7 and 3.45 ppm, respectively. It is shown that in the distance of more than 4 km, the values for NH_3-N were low and evidently in all cases steady states were achieved within the distance of 15 km.

Figure 2 presents the NO_3^- concentration with respect to distance. According to Gaussian model projection, the smoke may normally hit to the ground in the direction of wind from West to East. Maximum pollution of nitrate was obtained about 13.8 ppm in the East direction of the plant in the distance of about 2 km.

Figure 3 shows the SO_4^{2-} concentration in the soil at various directions. The wind velocity would accelerate the deposition of air pollutants into the soil. The smoke from the stack in the South side of the plant reached to the ground in the distance of 2.5 km; a shorter distance since the wind velocity and direction was not affected on the South direction.

Evaluation of fossil fuel from Iran and Turkmenistan is shown in Table 1; low heating values represent low quality of fuel. Unfortunately the high sulfur content of Iranian fossil fuel may cause air pollution. The main fuel considered for the power plant was natural gas; however there was limitation and short supply of the natural gas reservoir in Khorasan, Iran, and liquid fossil fuel Figure 4 presents pollution caused by fossil fuel oil and gas fuel in stable and unstable weather conditions for NO_x in maximum distance of 15 km from the chimney. As it is clearly shown, gas fuel generated more NO_x and the maximum NO_x production for gas and fuel oil (fuel no. 6) was 0.36 and 0.21 ppm, respectively. According to National Environment Protection Council (NEPC) standard of Australia 2008 and US National Ambient Air Quality Standards, the maximum concentration of SO_X and NO_x in the air reported to be 0.03 and 0.12 ppm, respectively [26, 27]. The distance which maximum pollution was occurred, in stable weather condition was more than unstable weather condition.

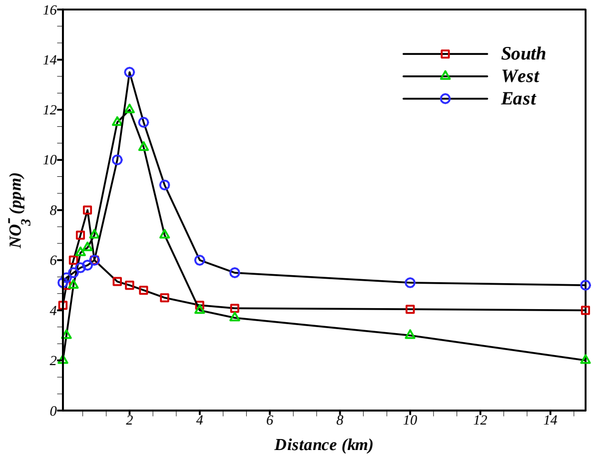

Figure 2. NO_3^- Concentration in the soil at various directions.

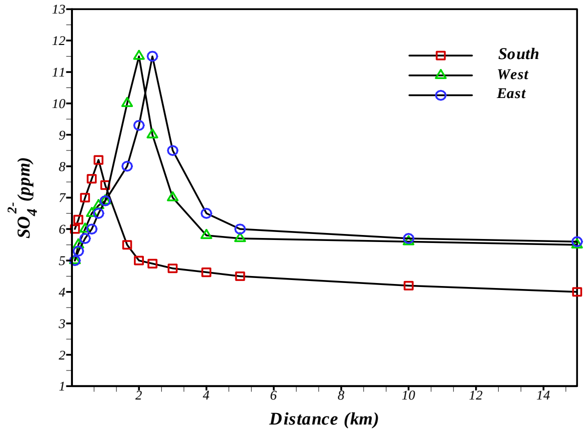

Figure 3. SO_4^{2-} Concentration in the soil at various directions.

TABLE 1. Evaluation of fossil fuel from Iran and Turkmenistan.

Fuel	Iran	Turkmenistan
Specific Gravity	0.94	0.9
Flash point, °C	74	74
Carbon residue, wt%	12.65	4.79
Ash content, wt%	trace	0.05
Sulfur, wt%	2.5	0.37
Calorific Value, Btu/lb	18849.5	15992.6

Figure 5 shows the SO_x concentration with respect to distance from the stack. Based on two standards, the concentration of SO_x concentrations stated above were 0.03 and 0.08 ppm, respectively [26, 27]. The maximum concentration of SO_x was obtained at the distance of 2.5 km from the power plant which was about 0.13 ppm; that was slightly above the international standards. The obtained data shown that, by increasing the distance of sampling point, the pollution concentration was decreased.

The CO concentration around the power plant is shown in Figure 6. The maximum concentration value of CO was 0.0075 ppm at the distance of 3 and 4.5 km for unstable weather and stable weather conditions. In the stable weather conditions, the CO value reached to near zero at 15 km distance, however in the unstable weather condition, the CO concentration value was 0.0027 ppm at the distance of 15 km from the power plant. Based on National Environment Protection Council (NEPC) Australian Standards 2008 and US Air Act the maximum concentration of CO is 9 ppm [26, 27]. Thus the CO concentration around the power plant was much lower than international standard value.

5. CONCLUSION

The results in this experimental research indicated that the high quality of fuel with low sulfur content with high heating value would have less air pollution. In order to minimize air pollution addition of high quality of fuel such as fuel no. 6 was recommended. To reduce green house effect and CO using natural gas monitoring on combustion for later stage of aeration would be recommended. Application of wet scrubber to eliminate air pollution was also recommended. The aim of Neka power plant management was to meet the demand established by the local environmental protection agency or international standard organization. This goal can be easily achieved by implementation of additional scrubbers for elimination of the remained emission gases. The rate of dispersion of SO_x and NO_x appeared in maximum amount in the distance of 2.5 to 4 km on East and West sides of the power plant.

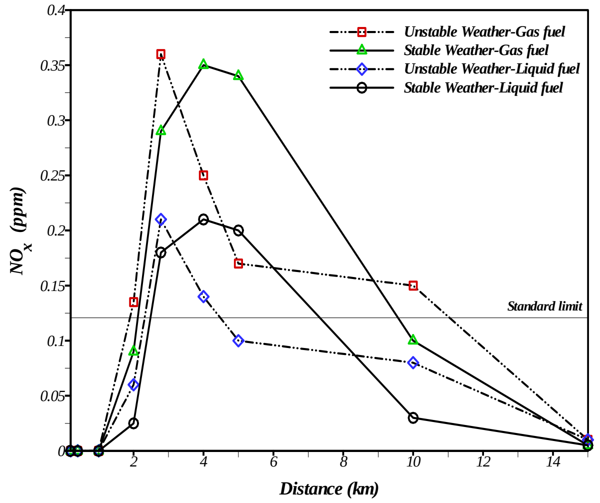

Figure 4. NO_x concentration in the soil at stable and unstable weather conditions.

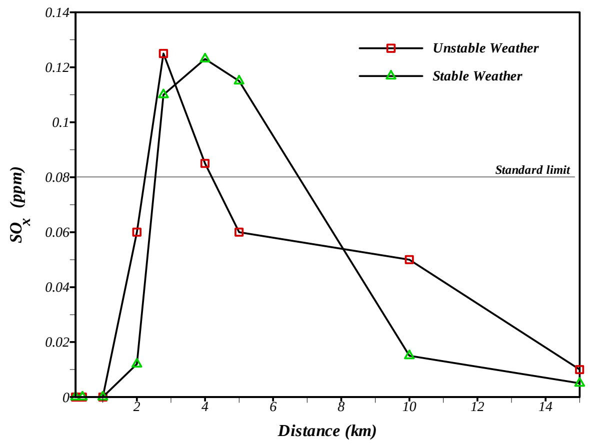

Figure 5. SO_x concentration in the soil at stable and unstable weather conditions.

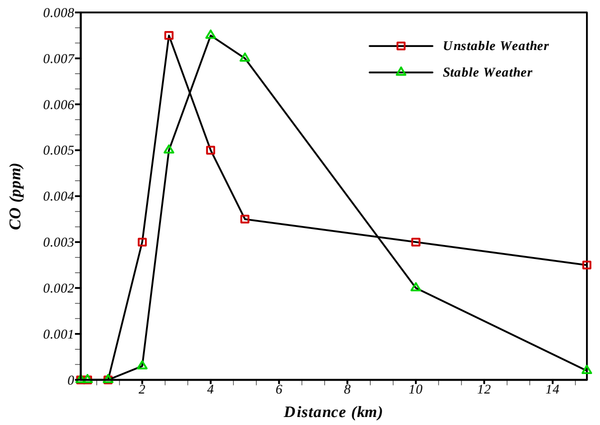

Figure 6. CO Concentration in the soil at stable and unstable weather conditions.

Acknowledgement

The present work was made possible with the full support of Neka Power Plant's administration and engineers, research and development group in the Ministry of Power, Iran. The authors wish to thank the engineering and analytical departments of the power plant for their valuable assistants throughout the experiments.

6. REFERENCES

1. Petkovsek S.A.S., Batic F. and Lasnik C.R., "Norway spruce needles as bioindicator of air pollution in the area of influence of the Sostanj Thermal Power Plant, Slovenia", ***Environmental Pollution***, Vol. 151, (2008), pp. 287-291.
2. Quadrelli R. and Peterson, S., "The energy–climate challenge: Recent trends in CO_2 emissions from fuel combustion", ***Energy Policy***, Vol. 35, (2007), pp. 5938-5952.
3. Kiely G., "Environmental Engineering", McGraw-Hill, New York (1997), pp. 334-388.
4. Davis L.M. and Cornwell D.A., "Introduction to Environmental Engineering", 4^{th} Ed., McGraw-Hill, New York, (2008), 547-646.
5. Masters G.M., "Introduction to Environmental Engineering and Science", Prentice Hall, New York, (1991), pp. 270-372.
6. Cicek A. and Koparal A.S., "Accumulation of sulfur and heavy metals in soil and tree leaves sampled from the surroundings of Tuncbilek Thermal Power Plant", ***Chemosphere***, Vol. 57, (2004), pp. 1031-1036.
7. DeMarco A. and Poncia, G., "A model of combustion chambers, including nitrogen oxide generation, in thermal power plants", ***Control Engineering Practice***, Vol. 7, (1999), pp. 483-492.
8. Dogan O. and Kobya M., "Elemental analysis of trace elements in fly ash sample of Yatagan thermal power plants using EDXRF", ***Journal of Quantitative Spectroscopy & Radiative Transfer***, Vol. 101, (2006), pp. 146-150.
9. He B. and Chen C., "Energy ecological efficiency of coal fired plant in China", ***Energy Conversion and Management,*** Vol. 43, (2002), pp. 2553-2567.
10. Lopez M.T., Zuk M., Garibay V., Tzintzun G., Iniestra R. and Fernandez A., "Health impacts from power plant emissions in Mexico", ***Atmospheric Environment***, Vol. 39, (2005), pp. 1199-1209.
11. Matthias R., Davidsdottir B. and Amato A., "Climate change policies and capital vintage effects: the cases of US pulp and paper, iron and steel, and ethylene", ***Journal of Environmental Management***, Vol. 70, (2004), pp. 235-252.
12. Mishra U.C., "Environmental impact of coal industry and thermal power plants in India", ***Journal of Environmental Radioactivity***, Vol. 72, (2004), pp. 35-40.
13. Mukhopadhyay K. and Forssell O., "An empirical investigation of air pollution from fossil fuel combustion and its impact on health in India during 1973–1974 to 1996–1997", ***Ecological Economics***, Vol. 55, (2005), pp. 235-250.
14. Muriel M.G. and Leon H.R., "Numerical and experimental study on the SO_2 pollution produced by Lerdo thermal power plant, Mexico", ***Atmospheric Environment***, Vol. 33, (1999), pp. 3723-3728.
15. Nevers N.D., "Air Pollution Control Engineering", McGraw Hill, New York, 1995.
16. Peker N.S., "Lignite-fired thermal power plants and SO2 pollution in Turkey", ***Energy Policy***, Vol. 34, (2006), pp. 2690-2701.
17. Karandinos A.N.R. and Karandinos M.G., "Assessment of air pollution from a lignite power plant in the plain of Megalopolis (Greece) using as biomonitors three species of lichens; impacts on some biochemical parameters of lichens", ***The Science of the Total Environment***, Vol. 215, (1998), 167-183.
18. Sengupta I., "Regulation of suspended particulate matter (SPM) in Indian coal-based thermal power plants: A static approach", ***Energy Economics***, Vol. 29, (2007), pp. 479-502.
19. Shekar M.R. and Venkataraman C., "Inventory of aerosol and sulphur dioxide emissions from India: I-fossil fuel combustion", ***Atmospheric Environment***, Vol. 36, (2002), pp. 677-697.
20. Vitaly A.P., "Alternative trends in development of thermal power plants", ***Applied Thermal Engineering***, Vol. 28, (2008), pp. 190-194.
21. Vitaly A.P., "Strategies for emission reduction from thermal power plants", ***Journal of Environmental Management***, Vol. 80, (2006), pp. 75-82.
22. Najafpour G.D., Mehdizadeh S.J. and Mohamed A.R., "Environmental impact of fossil fuel utilization in the thermal power plant", ***Malaysia Sci. Technol. Cong. 99, Symp.***, Kuching, Serawak, Malaysia, (Nov. 8-10, 1999).
23. Himmelblau D.M. and Riggs J.B., "Basic Principles and Calculations in Chemical Engineering" 7^{th} Ed., Prentice Hall, New Jersey (2004), pp. 780-781.
24. Jones D.S.J. and Pujadó P.R., Handbook of Petroleum Processing, 1^{st} Ed., Springer, Dordrecht (2006).
25. Lodge J.P., "Methods of Air Sampling and Analysis", 1^{st} Ed., CRC Press, New York (1989), pp. 325-385.
26. Stewart E.B. and Dibble W.E., "Air Pollution Legislation and Regulations", McKetta J.J. and Cunninghan W.A., Encyclopedia of Chemical Process and Design, Marcel Dekker, Inc., New York, (1983), Vol. 2, pp. 289-339.
27. The Ambient Air Quality Standards, National Environment Protection Council (NEPC) 2008. http://www.environment.gov.au/about/councils/nepc/, www.nepc.gov.au/nepns/air.