Fresenius Envir Bull 1:700-705 (1992)

1018-4619/92/110700-06 $ 1.50+0.20/0

AN ANALYSIS OF THE SO_2, NO_2 AND PARTICULATES CONCENTRATION LEVELS UNDER INVERSION BREAK-UP FUMIGATIONS IN THE PTOLEMAIS-KOZANI VALLEY, GREECE

N.M. Zoumakis, A.G. Kelessis, G. Kallos[1],
A. Triantafyllou[2], B. Charalampidou, Th. I. Kozyraki,
F.K. Vosniakos and M. Manolopoulou[3]

Laboratory of Atmospheric Physics, Technological Education Institute (T.E.I.), P.O.Box 14561, Thessaloniki 54101, Greece.

[1]Department of Applied Physics, University of Athens, Athens 10680, Greece.

[2]Department of Applied Physics, Technological Education Institute (T.E.I.) of Kozani, Kozani, Greece.

[3]Nuclear Physics Department, University of Thessaloniki, Thessaloniki 54006, Greece.

Summary. The aim of the present study is to analyse emissions of SO_2, NO_2, particulates and radionuclides from the lignite fired power stations in the Ptolemais-Kozani valley in the northern part of Greece. A thermodynamic model is proposed to calculate ground-level concentrations under inversion break-up fumigations.

Key Words: Air pollution, diffusion equation, complex terrain, inversion break-up fumigation.

Introduction

In Greece a number of coal power stations were installed using local lignite. The largest concentration of these lignite fired boilers is in the Ptolemais-Kozani valley (Figure 1), in the northern part of the country. The emissions[1] arising from combustion of lignite and from mining of the lignite coal as well as transport of lignite ash are particulates (flyash, fugitive dust, etc.), SO_2, NO_x, and the uranium series radionuclides[2].

Figure 1 The modeling region. Locations of monitoring stations (●) and point sources (▲) in the Ptolemais-Kozani valley. Elevations in m.

Formulation of the Model

The lignite mining operation and the lignite fired power stations in the valley create a situation which may eventually cause serious local pollution problems[3]. The diffusion function $D(x,y,z,H) = uC/Q$ may be written as : $D(x,y,z,H) = Y(x,y)F(x,z,H,u_d,w)$ where $Y(x,y)=[1/(2\pi\sigma_y\sigma_z)]\exp[-0.5(y/\sigma_y)^2]$, C is the downwind air concentration due to a continuous source of constant strength Q, u is the wind speed, H is the effective stack height, σ_z is the vertical and σ_y is the crosswind standard deviation of the plume concentration profile, $w=\varrho g d^2/18n$ is the terminal gravitational settling velocity from Stokes law, g is the gravitational acceleration, ϱ is the particle density, d is the effective particle diameter, n is the atmospheric dynamic viscosity, u_d is the deposition velocity, and the functional forms for $F(x,z,H,u_d,w)$ may be taken from Ermak[4] and Rao[5]. Furthermore, deflection of the plume and long term estimate of C(x,y,z) were obtained by solving the diffusion equation[6].

To estimate ground-level concentrations under inversion break-up fumigations[7,8], one assumes that the plume was initially emitted into a stable layer. An equation for the diffusion function $D_F(x,y,H)$ when the inversion has been eliminated to a height h_i is[9]: $D_F(x,y,H) = Y_F(x,y)R_F(x,H)$, where $p = (h_i-H)/\sigma_z$, $\sigma_{yF} = \sigma_y+H/8$, $Y_F(x,y) = \{1/[(2\pi)^{0.5}\sigma_{yF}h_i]\}\exp[-0.5(y/\sigma_{yF})^2]$, and the parameter $R_F(x,H)$ accounts for the portion of the plume that is mixed downward by the thermal eddies :

$$R_F(x,H) = \int_{-\infty}^{p} (1/2\pi)^{0.5} \exp(-0.5p^2)dp \qquad (1)$$

Whiteman and McKee[8] developed a thermodynamic model to simulate the evolution of vertical temperature structure during the breakup of nocturnal temperature inversions in mountain valleys:

$$dL_i/dt = W_{Li}(A_o,F,L_i,l,a_1,a_2), dZ_i/dt = W_{Zi}(A_o,F,L_i,Z_i,l,a_1,a_2) \qquad (2)$$

where A_o is the fraction of solar irradiance F coming across the area of the top (Z_i) of the inversion, L_i is the height of the convective boundary layer (CBL), l is the valley floor width, a_1, a_2 are the sidewall inclination angles, and the functional forms for $W_{Li}(A_o,F,L_i,l,a_1,a_2)$ and $W_{Zi}(A_o,F,L_i,Z_i,l,a_1,a_2)$ are taken from Whiteman and McKee[8]. An integration of Equations (1) and (2) allows the simulation of the time-dependent behavior of the heights of the CBL and inversion top, and the estimation of the ground-level concentrations under inversion break-up fumigations in the valley.

Results and Discussion

To validate the model, the input data consists of source emission inventory[1,10,11], as well as the meteorological variables[12,13,14] and topographical data currently available. It was found that a total amount 70.3kt of SO_2, 64.7kt of NO_2 and 61.5kt of particulates are emitted from point sources in the valley per year. Figure 2 shows the predicted contours of equal 24-hr averaged ground-level SO_2 concentrations (Cμ) for winter and summer period. Figures 3(a), 3(b) and 3(c) present respectively monthly mean values[12] of SO_2, particulates,and NO_2 concentrations at the Public Power Company (PPC) village, the Centre of Seed Production (CSP), Komanos, and Kozani monitoring stations (points 5,4,7 and 10, respectively, in Figure 1). The peaks in summertime SO_2 concentrations (mainly due to low winds, and fumigating and trapping plumes associated with nonuniform temperature gradients) and particulates (due to large quantities of fugitive dust during the summer period) are clearly seen in Figures 3(a) and 3(b) respectively. On the contrary, the monthly mean observations[12,13] of ground-level SO_2 at Kozani (Figure 3a) can be explained by the monthly consumption of heating fuel[13] (heavy residual oil) in the city, and the variation of height of mixing layer[14]. On the other hand, the expected minimum in summertime NO_2 is clearly seen in Figure 3(c). The annual variations of ground-level concentrations of SO_2,NO_2 and particulates, at PPC village, are shown in Figures 4(a) and 4(b). The observed[14] and predicted average diurnal variation of particles at Kozani and Komanos are presented in Figures 5(a) and 5(b). The observed and predicted diurnal variation of hourly mean departures, $C_* = 100[(C-C_\mu)/C_\mu]$, of SO_2 and NO_2, at the PPC village monitoring station, are shown in Figures 6(a) and 6(b). Also, the expected peak during the late morning hours (mainly due to inversion break-up fumigations in the valley) is clearly seen in Figures 5 and 6. Finally, Figure 7 presents the predicted contours of equal mean ^{226}Ra (in μBqm^{-3}) concentrations in the atmosphere. It is shown that the observational results compare reasonably well with the theoretical predictions[11].

As can be seen, the ground-level concentrations of particles are much higher than the recommended limits by the World Health Organization (WHO). In Figure 5(a) the plot indicate that the model underestimate the ground-level concentrations of particles. However, the model predicts the concentrations of dust emitted from the stacks. Consequently, the model only predicts a

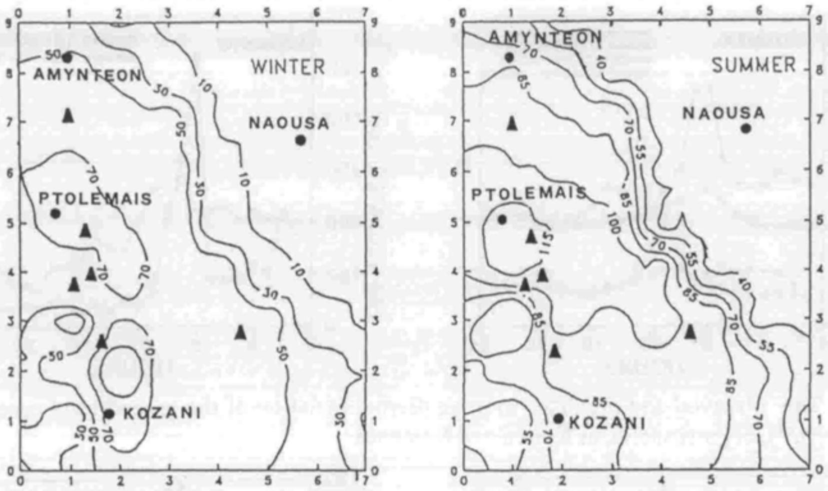

Figure 2 Predicted contours of equal 24-hr averaged ground-level SO_2 concentrations (in μgm^{-3}),for winter and summer period.

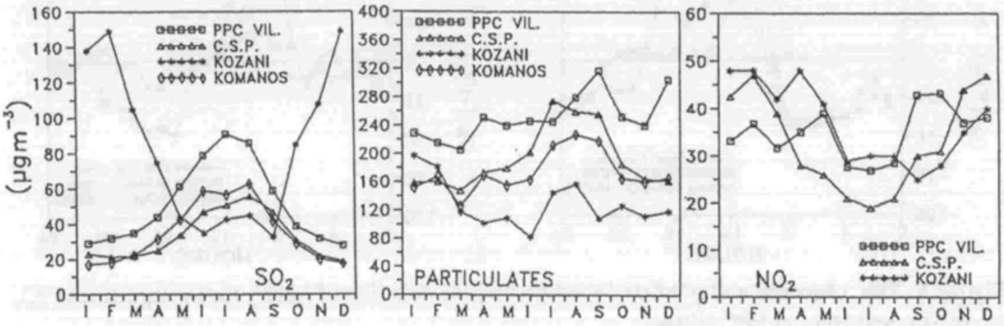

Figure 3 Monthly mean observations of ground-level SO_2, particulates and NO_2 concentrations (in μgm^{-3}), at several locations in the Ptolemais-Kozani valley.

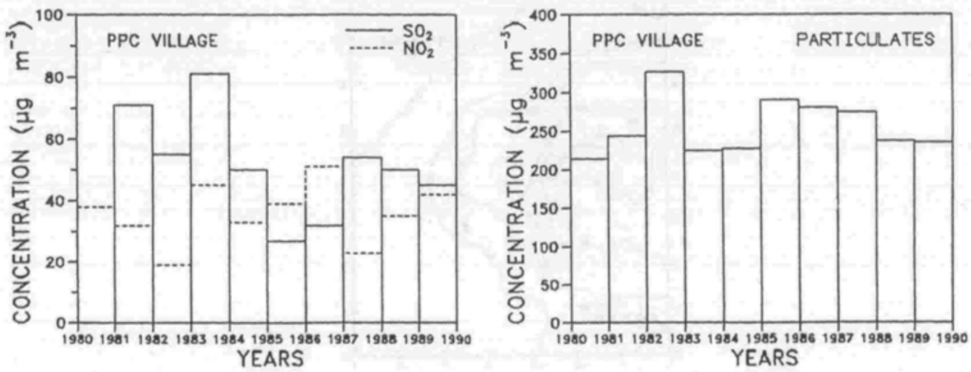

Figure 4 The annual variation of ground-level concentrations (in μgm^{-3}), of SO_2, NO_2 and particulates at PPC village.

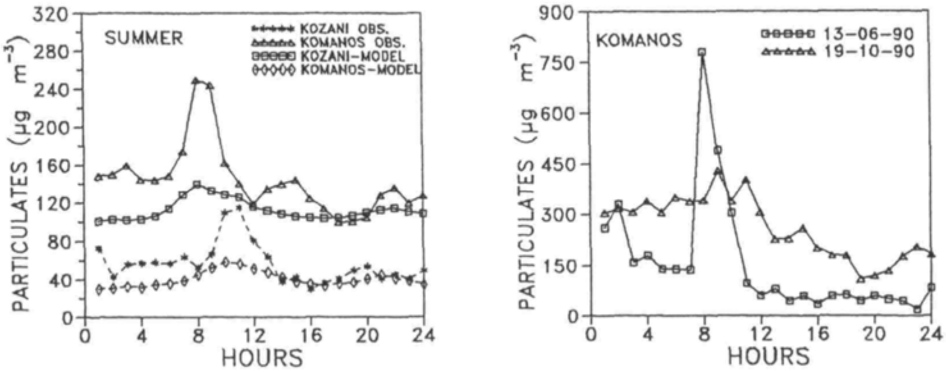

Figure 5 The observed and predicted average diurnal variation of the ground-level concentrations (in μgm^{-3}), of particulates, at Kozani and Komanos.

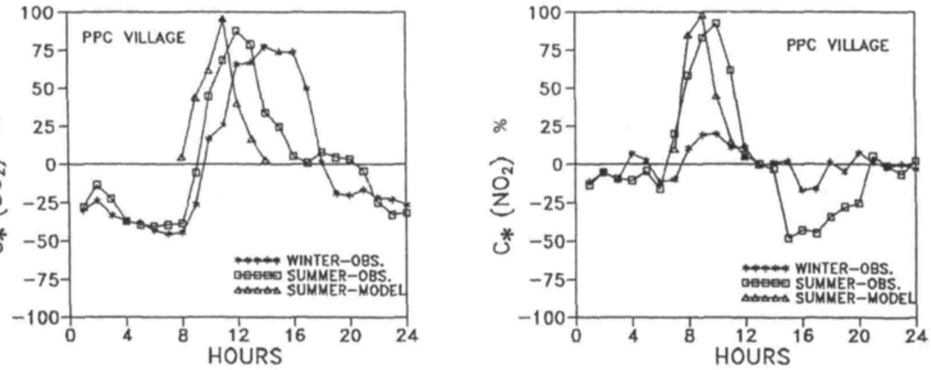

Figure 6 The observed and predicted average diurnal variation of hourly mean departures (%), C_*, of SO_2 and NO_2, at PPC village.

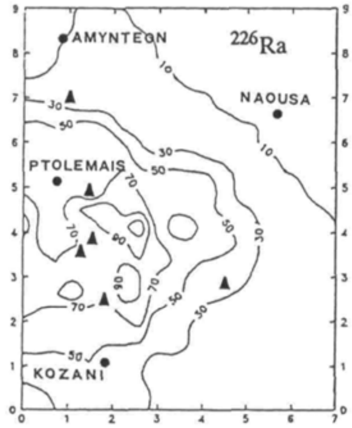

Figure 7 The predicted contours of equal mean ^{226}Ra concentrations (in μBqm^{-3}) in the atmosphere.

fraction of the dust actually measured, mainly due to local contribution fugitive dust from trucks traffic, local central heating, lignite transport and piling, as well as other fugitive sources[1]. In conclusion, the high dust emissions result in unacceptable[1,3] high ambient concentrations of particulates in whole Ptolemais-Kozani valley.

References

1. Felsvang, K., (1987), Control of emissions from lignite fired power stations, in Greece, World Health Organization, UNDP/ GRE/83/004.
2. Papastefanou, C. and Charalambous, S., (1984),On the escaping radioactivity from coal power plants, Health Physics, 46:293-302.
3. Tsiotsios, I.,(1986), Chronic Bronchitis in workers of a factory producing fertilizer (AEBAL) in Ptolemaida, Ph.D. thesis, Medical School, Univercity of Thessaloniki.
4. Ermak, D.L., (1977), An analytical model for air pollutant transport and deposition from a point source, Atmos. Environ., 11: 231-237.
5. Rao, K.S.,(1981), Analytical solutions of a gradient-transfer model for plume deposition and sedimentation, NOAA Report ERL ARL-109, NOAA, Washington D.C.
6. Burt,E.W.,(1977),Valley model user's guide,EPA-450/2-77-018, U.S.Department of Commerce.
7. Whiteman, C.D. , (1982), Breakup of temperature inversions in deep mountain valleys: Part I. Observations, J. Appl. Meteor., 21: 270-289.
8. Whiteman, C.D. and McKee, T.B.,(1982), Breakup of temperature inversions in deep mountain valleys: Part II.Thermodynamic model, J. Appl. Meteor., 21: 290-302.
9. Turner, D.B., (1970), Workbook of atmospheric dispersion estimates, Office of Air Programs Publ. No AP-26, EPA.
10. Lalas, D.P., Petrakis, M., Asimakopoulos, D.N.,Helmis C., and Barbagiannis, M., (1982), Air pollution in the Ptolemais-Kozani valley, Public Power Company, Athens.
11. Manolopoulou, M.N., (1990), Radioecological study in the coal power plant environment, Ph.D. thesis, University of Thessaloniki, Greece.
12. Public Power Company, (1990), Air pollution measurements in the Ptolemais Kozani valley, Reports : 1980-1990, Athens.
13. Prefecture of Kozani, (1989),Air pollution measurements in the Ptolemais Kozani valley, Kozani, Greece.
14. Triantafyllou, A., Stamnas, N., Ganatsios, S.and Nittis, A., (1990), Air pollution study in the area of Komanos-Ptolemais, Report-T.E.I. of Kozani, Greece.

Accepted 20 May 1992