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INVESTIGATION OF AIR POLLUTION IN THE ZEYTINBURNU COUNTY OF ISTANBUL BY USING A DISPERSION MODEL

Namık AK
Kar-Su ve Kardelen A.Ş. General Coordinator, Ümraniye/İSTANBUL

Ferruh Ertürk
Yıldız Teknik University, Dept. of Environmental Engineering, Beşiktaş 80750, ISTANBUL.

Abstract

SO_2 and Total Suspended Particules (TSP) concentration distributions were investigated in order to assess air pollution in İstanbul during the winter season (November-March) in which the concentration of these pollutants reach to the highest levels due to the consumption of low-quality fuels (mainly coal) for residential heating. Meteorological conditions are also taken into consideration in terms of severe air pollution events. Statistical modeling based on the method of Kriging by spherical interpolation was used to obtain the concentration distribution of these pollutants. The pollution map obtained by this method indicated that topographical effects, unplanned urbanization, population density and meteorological factors also play an important role besides low-quality fuels used during the winter season.

1. Introduction

İstanbul is located at about 40 °N and 29 °E and lies in two parts, Asian and European (Figure 1). The total area of these two parts is about 5712 km^2 and estimated population of the metropolitan area for 1994 is around 12,500,000. Figure 2 shows the population and human density of framed area with dashed lines in Figure 1, which is highly populated region of the city. Increased migration from less developed regions of the country at the end of 1980's, caused a rapid increase in the population and expansion of the built-up areas in the city. Population density of the framed area is increased from 3000 people/km^2 to over 6000 people/km^2. İstanbul is also the most industrialized city of the country. In addition to rich trade and commerce, the city has experienced a number of industrial activities. Almost % 70 of Turkey's industry is located in the southern coast of the city.

The average yearly temperature and yearly total precipitation is 13.7°C and 734 mm, respectively. Coldest months are January and February with an average temperature of around 5°C while the hottest are July and August.

Mean daily SO_2 and PM concentrations exceeding air quality standards have been recorded many times during the period of 1985 to 1998 at several stations of the city. These daily values have been measured by the Ministry of Health since 1985 in about 16 stations. SO_2 is determined by titrimetric method which is based on the acidity of solution of hydrogen peroxide. PM is measured by filter soiling method which is based on reflectivity measurements on filter paper.

In the period between 1985-1994, Istanbul has faced severe air pollution problems. The occurrences of high concentrations of air pollution in the city have reached to the levels of danger for habitants (1,2). Mean daily SO_2 and PM concentrations exceeding air quality standards implemented by WHO have been recorded many times. Because of the interannual variability of emission rates and meteorological conditions, and the surface roughness mainly caused by the densely built high structures, the distribution of air pollutants and their concentration may vary greatly from month to month, especially between winter months , when residential heating is started, and summer months, and also from district to district. The main cause of İstanbul's air pollution was due to from the burning of low quality lignite and other fossil fuels containing high percent of sulfur used mainly for heating purposes, especially in the period 1985-1994.

However, after 1995 the air quality in İstanbul has improved significantly due to the following reasons:

-Significant increase in the consumption of natural gas within the İstanbul Greater Municapility boundaries from 126 million m^3 in the first months of 1994, to 7 billion m^3 in 1997 ,

- In the same period, the annual coal consumption has decreased from 8 million tons to 3.5 million tons, and also the quality of coal has improved due to stringent quality control.

The aim of this study is to investigate different air pollution control scenarios in the Zeytinburnu County of İstanbul by using a dispersion model.

2. Methods

Air quality models are used for different purposes such as, establishment of regulations, e.g., determination of maximum allowable emissins, comparing different control scenarios, evaluation of source-receptor relations, and environmental impact assessment.

Ideally an air pollution model would predict the concentrations that would result from specified set of pollutant emissions, for specified meteorological conditions, at any location. These distributions could be temporal or spatial depending on the model used. However, even the best available models are far from this ideal because of the complexity of the atmospheric variables.

2.1 Box Models

In this model, it is assumed that all the flows and emissions are independent of time, atmospheri turbulance produces complete mixing of pollutants up to the mixing height H, the pollutan concentration is uniform in the whole volume, the wind blows from one direction and is constant, an that no pollutant leaves or enters through the top or sides of the box.(See Fig. 1). The resultan expression is (3):

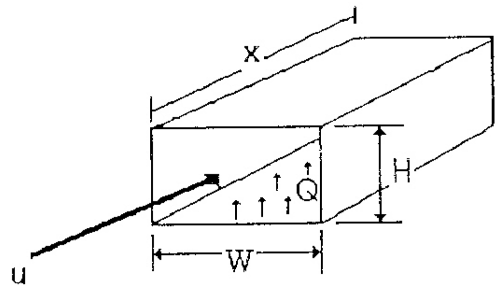


Figure 1. Box Model.

$$C_i = \frac{Q_i}{u W H} \tag{1}$$

where , C_i = steady state concentration of the pollutant i ($\mu g/m^3$)

u = average wind speed (m/sec)

W = width of the box perpendicular to the wind direction (m)

H = height of the box perpendicular to the wind direction (mixing height) (μ)

Q_i = emission rate of the pollutant i ($\mu g/sec$)

2.2 Dispersion Models

Dispersion models use the Gaussian plume concept, which is a material balance model. This model is based on the principle that the plume emitted from a point source shows a "Normal" or "Gauss" type distribution in the y-z coordinates.

Point Sources

The model can be used to compute the downwind concentration from a point source, such as a smokestack of a factory. The following assumptions are made in the derivation of the equation:

1. Steady-state, i.e., pollutant emissions does not change with time so that,

$$\frac{\delta C_i}{\delta t} = 0$$

2. Wind speed in the y and z directions is zero ,n = w = 0 , and in the x-direction u is constant.
3. The transport in the x-direction is controlled by convection (wind) and overwhelms transport by diffusion,

$$u\frac{\delta C_i}{\delta x} >> D_x\frac{\delta^2 C_i}{\delta x^2}$$

4. The pollutant does not undergo any chemical reaction

With these assumptions, the resultant equation becomes (4):

$$C(x,y,z;H) = \frac{Q}{2\pi\sigma_y\sigma_z u}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\} \quad (2)$$

In equation (1), the term (z - H) represents the "actual" source above the ground level, (z + H represents the "imaginary" source below the ground level, and the other terms are defined as follows:

C= pollutant concentration

σ_y and σ_z are the dispersion coefficients, in the y and z directions, respectively

Q = rate of pollutant emission

u = wind speed

H = "effective" stack height = h + Δh

where , h = geometric stack height

Δh = plume rise

Line Sources

In cases where a number of point sources are located along a line, such as a river, a highway or seaport, the pollution source can be assumed as a line source. In this case , if the wind direction : assumed to be perpendicular to the emission line, the steady-state ground-level concentration can t expressed as [4]:

$$C(x,0) = \frac{2q}{(2\pi)^{1/2}\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2 \right] \quad (3)$$

In this expression , q is the emission source strength per unit length (g/m-sec), and the other terr are as defined previously.

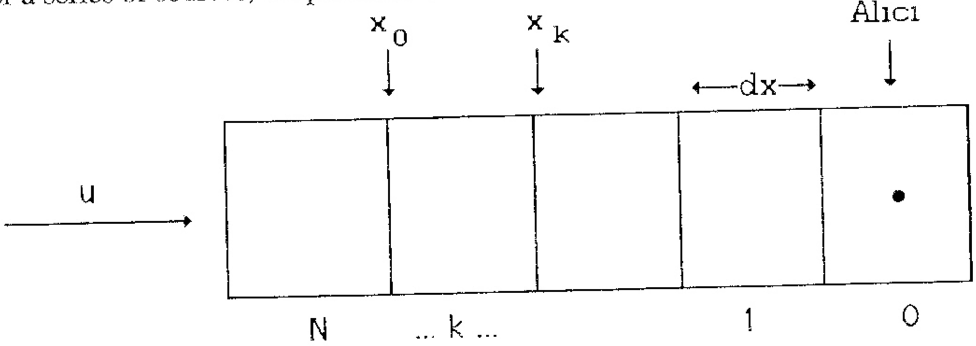
Area Sources

The expression for the steady-state ground-level concentration from area sources is based o the " narrow plume " concept developed by Gifford [5] and Hanna [6], which is given by th expression:

$$C = \frac{Q}{u\sqrt{2\pi}\,\sigma_z}\left[\exp\left\{-\frac{(z-H)^2}{2\sigma_z^2}\right\} + \exp\left\{-\frac{(z+H)^2}{2\sigma_z^2}\right\}\right] \quad (4)$$

where, $\sigma_z = ax^\beta$, and a and b are constants depending on atmospheric stability.

For a series of sources, the pollutant concentration in the receptor grid :



Alıcının (receptor) bulunduğu gridde , konsentrasyon aşağıdaki şekilde ifade edilebilir:

$X_A = X_0 + X_1 + X_2 + \ldots\ldots\ldots + X_K + X_N$

Ηερηανγι βιρ κ γριδινδεκι κονσεντρασψον ισε :

$$\text{Burada, } F = \frac{1}{\sigma_z}\left[\exp\left\{-\frac{(z-H)^2}{2\,\sigma_z^2}\right\} + \exp\left\{-\frac{(z+H)^2}{2\sigma_z^2}\right\}\right]$$

$$x_0 = \frac{(2k+1).dx}{2}, \quad x_k = \frac{(2k-1).\,dx}{2}$$

$$C_A = \frac{u}{\sqrt{2\pi}}\,(Q_0 I_0 + Q_1 I_1 + \ldots\ldots + Q_k I_k + Q_N I_N)$$

3. Results

The variation of the monthly average concentrations of SO_2 and Particulate Matter for the winter season (November-March) from the year 1985 to 1991 is shown in Figure 3. It can be seen that there is an increasing trend in the concentrations of both pollutants during this period . Also, it can be seen that there is a close interrelation (correlation) between SO_2 and PM in the trends at both monthly average and yearly average levels. Figure 4 shows the quantities of fuels used in the Greater İstanbul Metropolitan area for the years 1980-1993 (1991-92 data excluded). The data was obtained from the State Statistical Institute. It can be seen that the ratio of coal/fuel-oil increases drastically especially after 1988.

Figure 5 illustrates SO_2 distributions over the city for December 1993 and January 1994 based on Krigging technique , the detailed description of which is given in Appendix. Two major maxima are observed in the Golden Horn Valley of European side and Göztepe in the Asian side. We think that the topographical effects are the main factor for having these maxims with the meteorological conditions. Deniz et al. (1995) show that in 1993-94 winter season İstanbul had experienced less cyclonic activities than the climatological mean.

4. Summary and Conclusions

Air pollution problem in İstanbul is at alarming levels as it can be seen from SO_2 and PM measurements carried out at several stations since 1985 (Figure 4). Both monthly and yearly average concentrations exceed the limits given by WHO Air Quality Standards by several fold especially after 1987, and a definite increasing trend is observed since 1985.

The major pollution sources contributing to the high levels of SO_2 and PM is the consumption of low-quality fuels (mainly coal and high-sulfur)in the residential areas for heating purposes in the winter season.

Previous studies has indicated that majors factors that must be controlled are the sulfur content in coal and fuel-oil and particulate matter emissions from coal, and that the desired levels can be achieved by using low-sulfur fuels (coal and fuel-oil containing<1 % S) and high-quality coal (smokeless coal) in residential areas (Ertürk, 1986).

Air pollution problem in İstanbul is a multidimensional and requires a systematic approach involving all variables to reach a feasible solution. The determination of priorities is also considered a very important step to set the systematic solutions.

The major source for pollutants for the heating season comes from low quality coal and burning systems.

Severity of the air pollution in İstanbul have already reached to the levels of danger for human beings. As a conclusion we can suggest the following short and long-term precautions:

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