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Evaluation of CO and NO_x Distributions from Point (Industry) Sources in Körfez District of Kocaeli Province with ISCST3 Model

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ABSTRACT

This study was performed for the modelling of the distributions of CO and NO_x emissions emitted to the atmosphere from point sources in Körfez District of Kocaeli Province. ISCST3 (Industrial Source Complex Short Term) dispersion model approved by the EPA (US Environmental Protection Agency) was used for the study. The model uses steady state Gaussian plume flow equation for high point sources. Due to the nature of the steady-state condition, the model is able to predict distribution of emissions from point, area and volume sources within 50 km in a successful manner; therefore it is defined as a suitable model for estimating air quality. Accuracy of the estimates depends on the correct measurement of meteorological parameters in the study area, as well as the detailed and accurate emission inventory for all resources.

Körfez district has a number of pollutant sources including many industrial plants, ports and docks, railway and busy traffic arteries together with a high density of urbanisation. It is one of the most polluted sites in Kocaeli region and determination and monitoring of air quality here has a great importance. For this purpose, CO emissions emitted from 20 factory chimneys and NO_x emissions emitted from 15 factory chimneys were modelled and the daily and annual distribution maps were obtained.

The modelling study showed that the maximum ground-level CO concentrations were calculated as 335.24 $\mu g/m^3$ and 70.02 $\mu g/m^3$ in daily and annual basis respectively. On the other hand, for NO_x concentrations, daily and annual maximum values were calculated as 372.05 $\mu g/m^3$ and 26.29 $\mu g/m^3$ respectively.

Keywords: Air quality modeling, CO, ISCST-3, industry sources, Kocaeli Körfez District, NO_x

1. INTRODUCTION

Air pollutants spread from many anthropogenic sources such as industrial facilities (especially in plants using fossil fuels), power plants, waste incineration plants, motor vehicles and many natural sources such as open land fires, soil organic decay and lightning. These pollutants have negative effects on human health, vegetation, water bodies, fauna, and buildings [1]. Air pollution typically grows and differentiates as a result of human impacts. Factors giving rise to pollution are usually substances that have different structures compared to natural components of atmosphere. As a result, air pollution negatively affects the health of living things and their natural life in the biosphere [2].

In generally, air pollution is divided into several categories depending on type of source, distribution area, and amount of pollution and characteristics of emissions. According to the most common form of classification of air pollution sources, air pollution sources are classified into two types: Anthropogenic (human- induced) and natural sources. Air pollution caused by human activities is resulted from many different sources. These sources can be analyzed as point, spatial, volumetric and linear sources. Point sources are the sources from where pollutants are released to the atmosphere from one point, such as stack. Especially, pollutants emitted from industrial facilities have a great importance due to their variety. Furnaces, chimneys and vents can be considered as point sources [3,4].

CO, which is one of the modelled pollutants, is a colourless, odourless, tasteless and toxic air pollutant. CO pollution in the atmosphere is resulted from the uncompleted combustion conditions when the fuels, such as gas oil, natural gas, oil, coal and wood including carbon, are burned [5].

Another pollutant, NO_x, which represent the total concentrations of NO and NO_2, can be found in high concentrations in urban and industrial areas ($NO+NO_2=NO_x$). Initially, NO_2 constitutes less than 5% of the total. However, NO is converted into NO_2 rapidly in flue gas channels and in the atmosphere. Therefore, NO_x can be recognized as NO_2. NO is a colourless, odourless gas and has low water solubility. NO_2 is a reddish- brown colour and sharp smelling gas [6].

NO_x is usually formed in two different ways. In the first way, nitrogen and oxygen in the air react to form NO depending on the temperature. This reaction is referred to as Zeldovich mechanism as follows:

$N_2 + O \rightarrow NO + N$
$N + O_2 \rightarrow NO + O$

This reaction occurs in high temperature of burning ovens due to the reaction heat.

The second way includes combustion of fossil fuels and their derivates containing nitrogen molecule in. The amount of nitrogen is between 0.5 to 1.5 % in fossil fuels [7]. In this regard, motor vehicles are important NO_x source, and rate of NO_x emissions depends on the traffic density. In addition, NO_x is formed by oxidation of atmospheric nitrogen or nitrogen in the fuel during the combustion of fossil fuels used for heating purposes [6].

Air quality modelling systems aims at providing the necessary information for air quality and these modelling systems are based on the information about atmospheric processes leading to elimination of the pollutants by transportation and chemical transformation. Concentrations of pollutants in the atmosphere are reduced due to the current weather and atmospheric turbulence. This process is referred as atmospheric dispersion. Some factors affect the convection, distribution and dilution of pollutants in the atmosphere such as emissions or resource properties, the nature of pollutants, meteorological characteristics, the effect of terrain and man-made structures. Many industrial gaseous pollutants are released into the atmosphere vertically from a chimney or through a channel [8].

2. MATERIAL AND METHODS

In this study, CO and NO_x emissions emitted from point sources in the district of Korfez of Kocaeli Province are modelled by using ISCST-3 distribution model and the distribution maps are obtained.

2.1. Study Area

Körfez district is located on the western coast of Izmit and its distance to Izmit is 17 km. The area of the district is 398 km^2. Satellite image of the study area is given in Figure 1.

Figure 1. Study area-Korfez District

Körfez district is one of most intense counties of Kocaeli in terms of industry. The reason for high industrial densities in this district are transport networks that serve as a passage between the continents of Europe and Asia and Middle East such as railway, the road called as D-100 and the highway called as TEM. . The main industrial branch in the region is petrochemical industry and other sectors in the district are food, chemical, metal and textile.

2.2. ISCST-3

For the Modelling of the study area, ISCST-3 model (version "AERMOD View 6.5.0", developed and recommended by the EPA) was used. This model program uses the steady- state equation of Gaussian plume for high-point sources [9]. The concept of steady – state refers to experiencing the same situation for meteorological conditions in the same time and the whole of the modelled area. The model can estimate the distributions of emissions from point, area and volume resources to a distance of 50 km in the best way due to the nature of the steady-state condition [10]. Gaussian plume is a mathematical term that describes the distribution of air pollution. Gaussian distribution, essentially, estimates the vertical and horizontal distribution of pollutants [11].

Accuracy of the estimates depends on the reliability of the meteorological parameters in study area as well as detailed and accurate inventory of emissions. Predictions of the model can be further improved by the acquisition of actual data for the input parameters.

The most important advantage of this model in comparison to other dispersion models is easiness for using and accuracy of estimates. Meteorological data file necessary for the model is relatively small. The disadvantages of this model are that it does not include the structure of atmospheric boundary layer and the estimates of turbulent dispersion processes [6].

The model requires several input data such as emissions rate of pollutants, stack height (for point sources), outlet temperatures and output speeds of gases, chimney diameters, character of the land surrounding the source and the hourly meteorological data.

2.3. Model Input Data

Study area: In the model calculations, it was accepted that 40% of the study area is rural settlement area and 60 % of the study area is urban area. 50 % of the rural areas were accepted to be cultivated land and 50% was accepted to be pasture area.

Receptors: The receptors were determined based on all the study area and 1250 uniform Cartesian receptor points were designed in the area.

Meteorological data: ISCST-3 model uses annual data on an hourly basis as the meteorological data. In the model, the hourly surface meteorological data obtained for the period between 2005-2009 by "Lakes Environmental Software" were used. These data include the hourly temperature, wind speed, pressure and direction, daily cloud heights and rainfall measurements. The meteorological data was processed by RAMMET View Program which was a pre-Processor of ISCST-3 modelling program. The wind rose obtained for the study area by WRLPLOT (a pre-processor of RAMMET View program) is given in Figure 2.

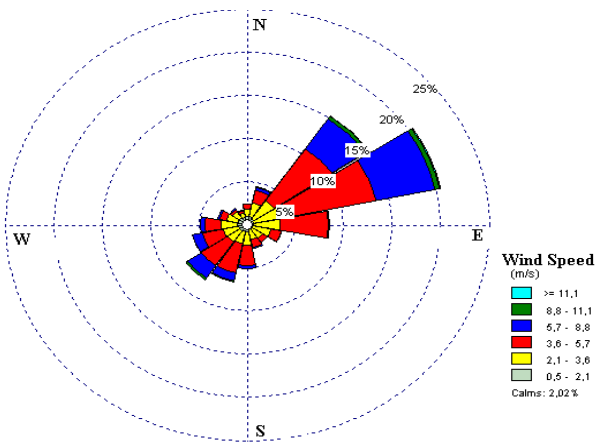

Figure 2. Wind Rose for the Study Area

Local climatic parameters: AERMIX in the PCRAMMET program, the processor of calculation of mixing heights, requires the site-specific parameters for the study area in addition to climate data. These parameters are generally related to the land use and they are a measure of the effect of land use and climate on the distribution of the pollutants in the atmosphere. Local climate parameters are given in Table-1.

Table 1. Local climate parameters entered to the program.

Parameter	Value
Surface roughness length (m)	0.62
Albedo at noon	0.21
Bowen ratio	1.89

Distribution coefficient: Population density in Korfez District is about 1266.16 persons/per km^2. In this study, urban distribution coefficient was used due to the fact that more than 50% of the modelling area was industrial and residential area.

Terrain options: Simple + complex terrain option was used in the model.

Average time options: Concentration and deposition values can be given on the basis of 1,2,3,4,6,8,12 and 24 hours, monthly and annual averages. In this study, the time options of daily (short term) average and annual (long term) averages were chosen for a general assessment.

Point source data: Within the scope of point source, 20 industrial plants for CO emissions and 15 industrial plants for NO_x emissions were taken into account in the Körfez District. The data used in the model are number of stacks (units), stack height (m), flue gas velocity (m/s) and temperature (in Kelvin), the flue inside diameter (m) and pollutant concentration (g/s).

3. RESULTS AND DISCUSSION

CO and NO_x emissions emitted from the facilities located in the Körfez district were modelled by ISCST-3 program and the daily distribution maps for the assessment of short term concentrations, and the annual distribution maps for a general assessment were obtained.

3.1. Point Source CO Distributions

20 industrial facilities in the district cause to CO emissions. The emission rates obtained from these facilities in g/s were entered ISCST-3 program and the daily and annual distribution maps were obtained. These maps are shown in figures 3 and 4. In addition, calculated concentrations and the coordinates of locations where the maximum concentrations are estimated are listed in Table 2.

Table 2. The highest calculated daily and annual concentrations of CO emission from industrial sources and the coordinates of maximum concentrations in Körfez district.

	Concentration($\mu g/m^3$)	Receptor Point Geographic Coordinates
Daily	335.24	40^o 47' 48.26" N 29^o 36' 42.46" E
Annual	70.02	40^o 47' 48.26" N 29^o 36' 42.46" E

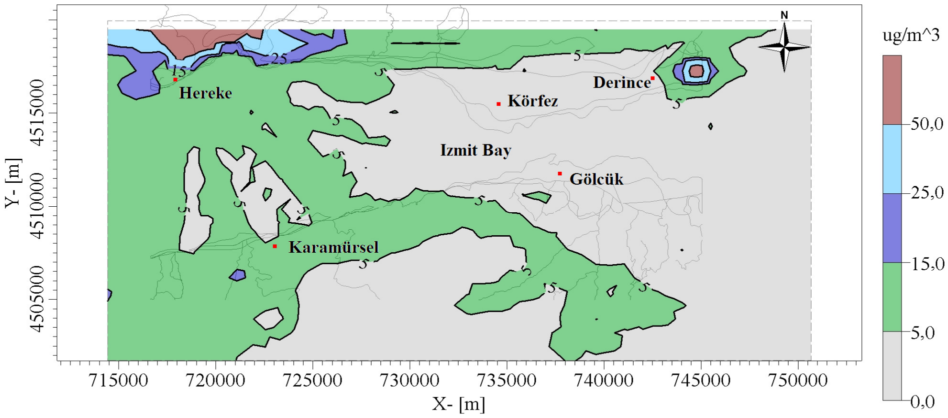

Figure 3. Estimated daily distributions of CO emissions from point sources.

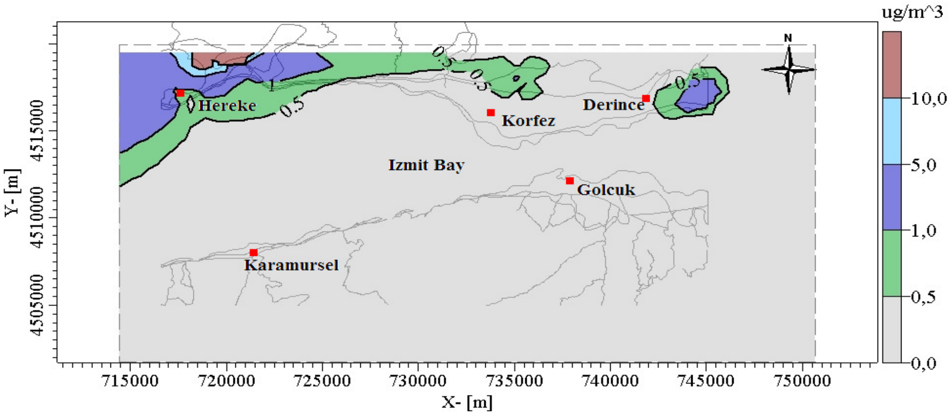

Figure 4. Estimated annual distributions of CO emissions from point sources.

It could be seen that the ground-level concentrations are estimated to be in high levels around the town of Hereke. In addition, it is thought that three plants with high CO emissions in the region affect these concentrations. Also, some high concentrations are located within the boundaries of Derince District also, which can be attributed to the dominant wind patterns blowing towards the northeast (see the wind rose in Fig. 2). The highest daily concentration in the region was calculated as 335.25 $\mu g/m^3$, for a receptor point in the inner parts of Hereke. The highest concentration on annual average was estimated as 70.02 $\mu g/m^3$ in the same place with the other receptor point where the highest concentration was calculated on a daily basis.

3.2. Point Source NO_x Distributions

15 industrial facilities in the district were modelled for NO_x emissions. The emission rates of these facilities in g/s entered ISCST-3 program and the daily and annual distribution maps were obtained. These maps are shown in figure 5 and 6. In addition, maximum concentrations and the coordinates of their locations are listed in Table 3.

Tablo 3. The highest calculated daily and annual concentrations of NO_x emission from industrial sources and coordinates of maximum concentrations in Körfez district.

	Concentration(µg/m³)	**Receptor Point Geographic Coordinates**
Daily	372.05	40° 47' 2.44" N 29° 35' 5.96" E
Annual	26.29	40° 47' 1.73" N 29° 35' 37.5" E

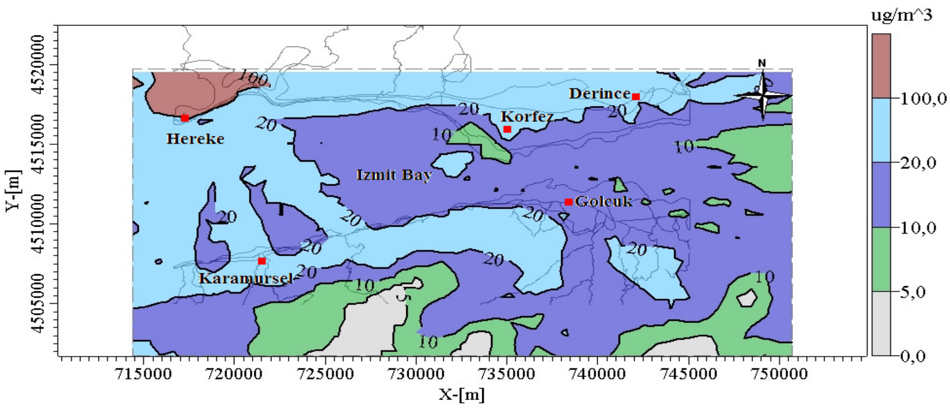

Figure 5. Estimated daily distributions of NO emissions from point sources.

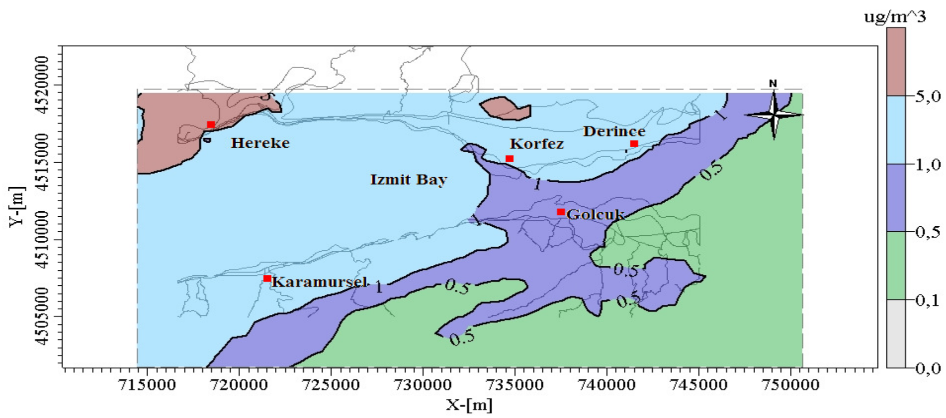

Figure 6. Estimated annual distributions of CO emissions from point sources.

When the daily and annual distribution maps are examined it could be seen that the highest concentrations are placed around the north of Hereke and the vicinity of petrochemical plants located in Körfez district. The results indicate that a plant with high NO_x emission in Hereke affects these concentrations. In addition, there are some high ground-level concentrations in Derince District as a result of the transfer of pollutant by winds. The highest concentration was estimated as 372.05 µg/m³ in daily average in the vicinity of an industrial facility in Hereke, while maximum annual average was 26.29 µg/m³ observed in-same place.

4. CONCLUSION

CO and NO_x emissions released into the atmosphere from point sources in Körfez district of Kocaeli Province were modelled by ISCTST-3 model. 20 sources of CO, 15 sources of NO_x located in the district were particularly entered to the model. As a result, daily and annual distribution maps were obtained.

- In the modelling study of CO daily and annual concentrations were estimated at 335.24 $\mu g/m^3$ and 70.02 $\mu g/m^3$ respectively. The concentrations were high around the town of Hereke according to obtained concentration maps. It is thought that three plants with high CO emission in the region affect these concentrations.

- In the modelling study of NO_x daily and annual maximum concentrations were calculated as 372.05 $\mu g/m^3$ and 26.29 $\mu g/m^3$ respectively. When the distribution maps obtained with the help of ISCST-3 program are examined it is seen that the highest concentrations were placed around the north of Hereke and the vicinity of petrochemical plants located in Körfez district. Especially, it is thought that a plant with high NO_x emission in Hereke affects these concentrations.

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