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AIR POLLUTION MODELING R & D IN ITALY AND KUWAIT

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Introduction

This paper summarizes the recent air quality modeling and consulting experience of the author in Kuwait and Italy. During the period January 1982 - January 1984, the author managed a large air pollution modeling study for the Kuwait Institute for Scientific Research (KISR). This work analyzed the industrial emissions originated from the Shuaiba Industrial Area (SIA). In Italy, during the period March 1984 - October 1984, the author was an air quality modeling consultant for the Center for Thermal and Nuclear Research (CRTN) of the National Electric Power Industry (ENEL).

These modeling studies are indicative of growing worldwide interest in air pollution problems, and particularly in the development of numerical simulation techniques for planning and control of industrial activities.

Kuwait

Kuwait (see Figure 1) is an Arab country located in the northern section of the Persian (or Arabian) Gulf, near the southern Iran-Iraq border. Urban development has occurred primarily in the city of Kuwait, while major industrial development is concentrated 30-40 km south in the Shuaiba area.

A few decades ago, before industrialization, the air quality of Kuwait was adversely affected only by "natural" pollution, occurring in the form of frequent dust episodes and sand storms. However, staggering urban and industrial development in recent years has led to traffic and industrial activities that discharge a large quantity of atmospheric pollutants. As one of the largest industrial regions in the Gulf, the SIA's recent intense growth has caused increasing environmental concern. The major industrial activities in the SIA are:

- petroleum refineries
- cement factory
- petrochemical industries producing urea and ammonia
- power stations producing electric power and desalinated water
- lime factory
- asbestos factory

Atmospheric discharges from industrial stacks are mainly composed of the following pollutants:

1. sulfur dioxide; about 407 metric tons per day
2. nitrogen oxides; about 201 metric tons per day
3. cement dust; about 24 metric tons per day
4. urea; about 7 metric tons per day
5. ammonium sulfate; about 0.2 metric ton per day

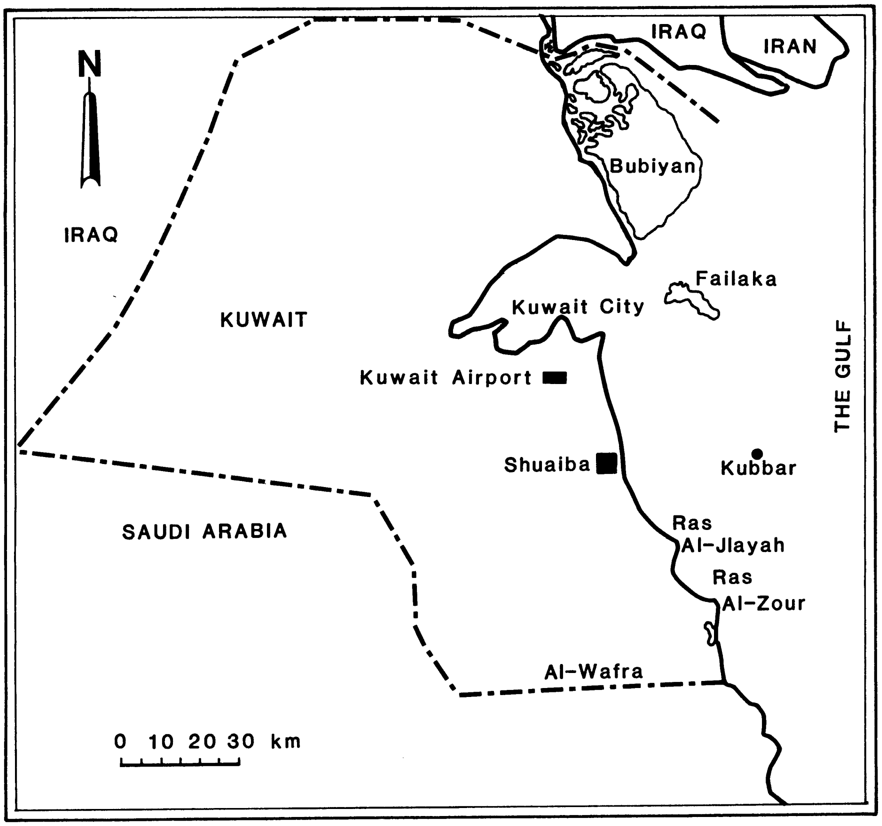

Figure 1. The Kuwait region and the Shuaiba industrial area.

6. lime dust; about 0.6 metric ton per day

7. reentrained emissions of particulate matter from motor vehicle traffic in the SIA; about 13 metric tons per day

The Air Quality Study

Shuaiba Area Authority (SAA), the organization overseeing SIA activities, recognized the need for proper environmental planning of industrial development in the SIA. As a result, it sponsored the air pollution modeling study conducted by KISR from December 1981 through May 1983, the study was established as a preliminary step, to be followed by goal-oriented activities. Twenty-four scientists and technicians contributed, operating on a $0.5 million budget.

Several important activities were performed during this study, mainly:

- Computerization of existing data, especially the meteorological data monitored at the Kuwait International Airport (KWI) during the six-year period 1977-82. Both hourly ground-level measurements and twice daily radiosonde vertical profile data were stored and analyzed.
- Performance of special monitoring activities, including:
    1) a three-month intensive monitoring field activity, using tethersonde balloon instrumentation to collect vertical profiles of wind, temperature, pressure and humidity, and
    2) source sampling of some major SO_2 sources (power plants) in the area
- Selection of five UNAMAP dispersion models (PTMAX, PTMTP, ISCST, ISCLT, and CDM) and their implementation on KISR computer facilities. A particle dispersion model[1,2], the MC-LAGPAR prototype, was also implemented for simulations of special dispersion situations in the region.
- Statistical data analysis of the collected measurements and their organization into a relational data base to facilitate future analysis.

A full description of project activities and results is presented in the project's final report[3]. The major achievements were:

- Computerized organization of all meteorological and emission data
- Meteorological characterization and evaluation through the following four studies:
    1. plotting of annual and seasonal wind and stability roses
    2. identification of daily and seasonal cycles of major meteorological variables and the meteorological effects of the desert-type features of Kuwait's environment

3. analysis of land and sea breezes in Kuwait, using the data from two meteorological stations (KWI, inland, and Mena Al-Ahmadi, on the coastline)

4. analysis of ground level and elevated inversions in Kuwait, which showed an unexpected high degree of horizontal homogeneity in Kuwait's atmospheric structure, at least during the winter period

Wind roses showed that the most frequent wind direction is from the northwest, especially during summertime (April to October) when wind speeds are higher. In winter (November to March) the south-southeast wind direction also occurs quite frequently. In general, southerly winds are more associated with stable conditions, while northerly and, especially, westerly winds are more unstable. In summer, unstable conditions are naturally more frequent, and breeze phenomena are more pronounced. The summer weather is very hot and dry (the average daily maximum in June is nearly 45^{o}C) and summer dust episodes are very frequent. In winter, the air is comfortably cool and the average daily minimum and maximum temperatures are 8-9^{o}C and 18-21^{o}C, respectively. Precipitation is rare and limited to the period between October and May. The mean seasonal rainfall is about 120 mm.

- Actual dispersion simulations for short-term (mainly using the ISCST model), and long-term (mainly using the ISCLT model). In particular, the ISCLT model was used to simulate the multi-source long-term ground-level impact of the following SIA pollutant emissions:

  1. SO_2 (78 sources)
  2. NO_x (76 sources)
  3. NH_3 (5 sources)
  4. cement dust (18 sources)
  5. urea (8 sources)

  Concentrations were calculated on a 61 x 61 ground-level receptor grid, with a resolution of 500 m in an area 30 km x 30 km surrounding the SIA. KWI meteorological data, processed by our modified version of the CRSTER pre-processor, were used to provide the required meteorological frequency summary for the ISCLT runs. Concentration outputs allowed the computation of annual and seasonal concentration isopleths for each of the five analyzed pollutants.

- The training of local scientists and technicians, especially in using computer techniques and simulation modeling tools for environmental problems.

The primary difficulty encountered in the project development was the impossibility, at that time, of performing continuous, satisfactory air quality monitoring in the region. Weather adversity (heat, dust storms, etc.) was a major problem. Instrument maintenance, shortage of spare parts and instrument calibration also presented problems. However, the overall project results were satisfactory and are expected to be used by the SAA in

- planning future industrial development
- simulating possible accidental releases
- defining least-cost emission reduction strategies, and
- identifying the major contributors to present pollution levels

Italy

The New Legislation

The new air quality law (May 1983) in Italy has drastically changed the SO_2 ambient air quality standards. Maximum allowable concentrations were previously a 30-minute average of 650 $\mu g/m^3$ and daily average of 260 $\mu g/m^3$. The new standards are the median daily average concentration during a one-calendar-year period (80 $\mu g/m^3$) and the 98th percentile of the daily average concentration in a one-calendar-year period (250 $\mu g/m^3$). The latter is particularly critical and is changing the entire perspective of air quality modeling applications in the country.

Models are no longer required to simulate worst-case 30-minute scenarios. Emphasis is now placed on the identification of the seven or eight worst days in a year and the simulation of daily SO_2 average concentrations during those days. Moreover, real-time short-term air quality forecasting is becoming a very important tool, especially for the electric power industry. In fact, appropriate fuel switching can now be used in power plants, as a function of current air quality measurements and model forecasts, in order to avoid exceedance of the daily average standard (or to limit these exceedances to a maximum of seven per year).

The Air Quality Study

The Center for Thermal and Nuclear Research of the National Electric Power Industry (CRTN-ENEL) recognized the need for new model development activities, especially to meet the requirements of the new national law. The author, working as a consultant for CRTN-ENEL, coordinated these activities. In collaboration with local CRTN scientists, the following major results were achieved:

- Implementation, on the local computer facilities, of
    1. UNAMAP diffusion codes, such as PTMTP, PTMAX, ISCST, ISCLT, CDM, CRSTER pre-processor
    2. the AVACTA II code, a segment/puff Gaussian model[4]
    3. the MC-LAGPAR code, a Monte-Carlo Lagrangian particle model[1,2]
- Recommendations for an optimal application strategy, in accordance with the new air quality legislation, of both deterministic and statistical modeling techniques. These recommendations were developed for power plant dispersion simulations in both simple and complex terrain.

- Development and improvement of the AVACTA II code[4], which we determined to be the most cost-effective modeling tool for complex dispersion simulations, while maintaining the simplicity of the basic Gaussian formulation. Several computational options were added to the code, which now allows fully three-dimensional dispersion/deposition computations in flat/complex terrain for two (primary/secondary) pollutants in short-range/long-range dispersion cases. For correct simulation of time-varying emission and meteorological input in transport conditions the Gaussian plume is broken up into segments; in calm conditions, into puffs. Several different plume rise and plume sigma equations can be optionally selected by the program's user.

- Development and improvement of the MC-LAGPAR model for special dispersion computations. The present version of the code is written in APL language and allows plume or puff simulations using a few thousand particles. Results are graphically displayed in the form of particle clouds, grid concentration values, and plume sigma growth.

- Development and test of statistical models, based on time-series analysis, for real-time short-term forecasting of air quality levels. This allows evaluation of the probability of exceeding the daily average concentration standard and recommendation of suitable short-term emission reduction strategies.

Conclusions and Final Remarks

Research and development activities in air pollution modeling are currently a subject of great interest throughout the world. Several third-world countries have begun experiencing severe adverse effects of pollution. Some of these countries, like Kuwait, possess large research institutes and facilities and have started interesting R&D and engineering studies.

Air pollution legislation seems to be a major stimulus for the development of simulation modeling techniques. In fact, requirements of various environmental laws are encouraging the development and application of different numerical techniques. Typical examples are short-term emission control strategies or supplementary control system. In the United States, these strategies have been given limited attention. However, in countries such as Italy, the different environmental laws may make these supplementary control systems the most important air quality control tools for local industries.

Geographical differences are important. Countries like Kuwait, whose air quality is adversely affected by natural causes, may be less willing to pay the cost of decreasing their anthropogenic emissions.

Length-scale considerations are also significant. The same air pollution phenomena that remain within national boundaries in the United States become international cases in Europe, due to the relatively small extent of each country. Despite progress in the last two decades toward economic and political unity in Europe, uniform environmental legislation is lacking. A recent trend toward increasing the average height of industrial stacks, especially in power plants, is improving the near-field air quality. However, it is increasing the extent of long-range transport and acid deposition throughout Europe. Lacking uniform legislation, European countries may be tempted in the near future to continue increasing emission rates and release heights, thereby increasing the pollution of neighboring nations. Joint European R&D modeling efforts are required for the immediate future in order to provide legislators with suggestions and recommendations for a unified set of European environmental regulations.

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