REAL DISPERSION MODELLING FOR REAL REGULATORS
Case Studies from Industry

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1.0 Introduction

Over the past ten years, there has been a steady convergence of the technical basis behind state-of-the-art atmospheric dispersion models used by regulators and industry. However over the same period, relatively little attention has been given to the different ways in which these models are used by experienced dispersion modellers and regulators for assessing even the simplest practical applications. In this paper, three hypothetical examples are shown to represent real difficulties faced by industrial practitioners.

2.0 The design of a chimney stack for a combined heat and power plant

With the methods for power generation switching from large coal fired power stations to smaller gas fired plant, combined heat and power (CHP) systems have been installed on many industrial sites. These systems not only generate power but they efficiently utilise the waste heat from gas or steam turbines to generate steam, which in the chemical industry is then used to heat process vessels, chemical reactors etc.

The design of a stack for a new CHP system to be located on a chemical plant, by chance, highlighted the difference in approach taken by two experienced dispersion modellers, one from the power generating industry and myself from the chemical industry:-

(a) In the power generating industry, the emission rates of pollutants, often NOx and sulphur dioxide, can be estimated with a reasonable degree of accuracy. Sulphur dioxide discharge rates can be quantified by measuring the sulphur content in the fuel and boiler suppliers, by measurement, will guarantee maximum emission rates of NOx for a new application.

Thus, dispersion modellers in the power generating industry often specify a stack height so that the maximum predicted ground level concentrations (including the background concentration) are as high as 60 - 80% of the air quality standard. However, regulators usually accept these relatively high concentrations because of the confidence with which emission rates can be predicted.

(b) For chemical industry applications, it is far more difficult to estimate emission rates accurately. For example, the rates at which gases are vented from chemical reactions are far from uniform. The highest discharge rates usually occur in the initial phases of a chemical reaction or when vapours are displaced to atmosphere during the filling of vessels. Evaporative losses from storage tanks; fugitive emissions from pipe joints, or discharge from poorly seated relief valves often cannot be accurately assessed within a factor of five.

Consequently, a more cautious approach has to be taken in assessing such emissions. It is usual for design to ensure that concentrations do not exceed 10% of the air quality standard (or 10% of the Environmental Assessment Level for chemicals not covered by the UK Air Quality Strategy Objectives).

2.1 CHP stack example

For a new CHP scheme, a stack has to be designed to safely discharge 6 g/s of nitrogen dioxide. The exit temperature is 70 deg C and the stack diameter has been selected to give an exit velocity of 15 m/s. (For this example, it is assumed that all of the NOx is discharged as nitrogen dioxide). In the UK, the air quality standard for nitrogen dioxide is 105ppb by volume expressed as a 99.8th percentile of concentration (i.e. 18 hourly exceedences in one year are allowed). The background concentration at this hypothetical site is around 15ppb. The dispersion model ADMS v3.0 has been used for the following calculations.

A dispersion modeller working in the power generating industry would probably recommend a stack height around 25m. Fig 1.1 shows that a 25m stack would give a maximum 99.8th percentile of concentration of around 60ppb, when statistical weather data recorded at Boulmer in North East England. Adding the background of 15ppb would give a maximum 99.8th percentile of concentration of 75ppb.

The approach of modellers more familiar with chemical industry applications is likely to be more conservative. Many practitioners would select a stack height so that the maximum ground level concentration due to emissions from the stack would be equal to around 10% of the air quality standard (before adding the background). The implications on stack design are severe. A 90m rather than a 25m stack would be required. (Fig 2)

The difference in cost between a 25m stack and 90m stack would be at least £500,000. A dispersion specialist who recommends a 90m stack when a 25m stack would meet the requirements of regulators would rapidly lose his credibility.

Fig 1 - Generating industry approach
99.8th percentile of hourly concentrations
Boulmer weather data
6 g/s NO2 - 25m stack
Concs in ppb by volume

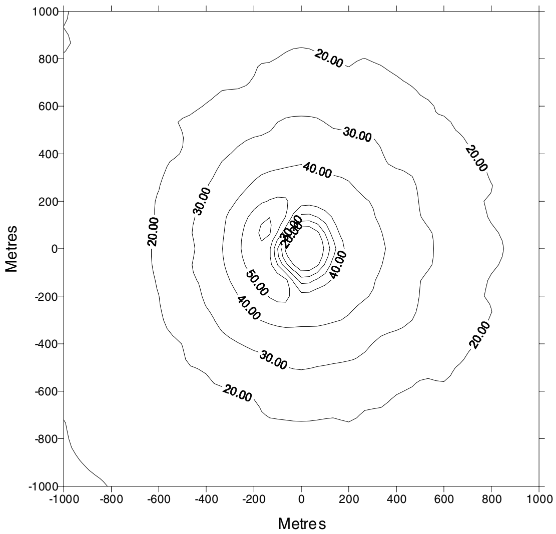
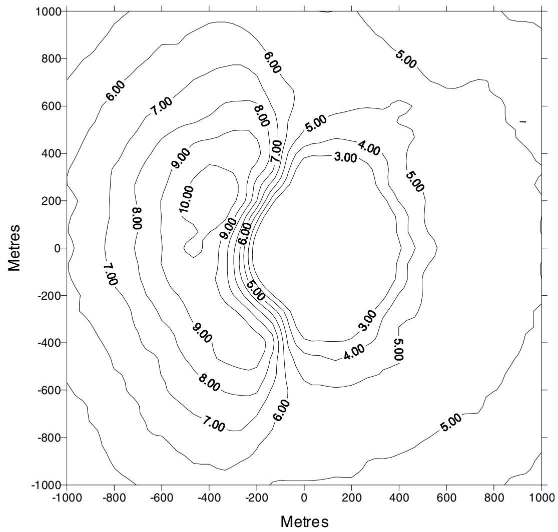


Fig 2 - Chemical industry approach
99.8th percentile of hourly concentrations
Boulmer weather data
6 g/s NO2 - 90m stack
Concentrations in ppb by volume



In practice, the stack height chosen for such applications is almost entirely dependent on the fraction of the Air Quality Standard acceptable to the regulator assessing the design. This in turn may be dependent on whether he comes from a chemical industry, power generating or urban pollution background. For routine applications such as this, better guidance for stack designers is required, if a harmonised approach is to be achieved.

3.0 Differences in Air Quality Standards Worldwide

Many large multinational companies wish to apply the same standards across all of their plants world-wide. As an example, if a manufacturing process is carried out in factories in a number of different countries, ICI plc strives to maintain the same environmental standards are applied in each of these factories . Thus the most stringent standard existing in any of the countries in which it operates a particular process applies to all of its processes throughout the world.

For air pollution modelling, this can be difficult since there is no uniformity in air quality standards across the world.

As an example, the following table details some of the air pollution standards which apply to sulphur dioxide. The range of standards is almost bewildering, with averaging times from 10 minutes up to one year and different allowable number of exceedences. Applying these standards can be difficult, especially for those inexperienced in the subject.

Country	Annual average (microgrammes/m3)	Maximum 24 hr average (microgrammes/m3)	Maximum hourly average (microgrammes/m3)	Other
Australia	50	210	530 *(24 exceedences)*	
China	60	150	500	
EU		125 *(3 exceedences)*	350 *(24 exceedences)*	
Holland	75	500	830	
Malaysia		105	350	500 *(ten minutes)*
Poland	32	200	600	
Sweden		100	200 *(maximum)*	
Thailand	100			
UK		125 *(3 exceedences)*	350 *(24 exceedences)*	266 *(15min av. 35 exceedences*
USA	80	365		
WHO	50	125		500 *(10 min av)*

A series of dispersion calculations predicting ground level concentrations was carried out using ADMS v3 and Kilnsea (UK) sequential weather data. The representative example chosen was a 50m high stack discharging 1 g/s of sulphur dioxide in a bulk flow with an exit velocity of 15 m/s and an exit temperature of 70 deg C. The maximum ground level concentrations are summarised in the following table:-

Criterion	Concentration (microgrammes/m^3)
Annual average	0.26
99th percentile of 24 hour averages	1.8
Maximum 24hour average	2.95
99.7th percentile of hourly averages	9.0
99.9th percentile based upon an averaging time of 15 minutes	14
Maximum hourly average	18

The following graphs show the maximum allowable emission rate from the stack in order to give a maximum ground level concentration less than 10% of the air quality standards for a number of different countries throughout the world.

Fig 3.1 - The maximum annual average discharge rate of sulphur dioxide from a 50m stack to ensure that ground level concentrations remain below 10% of the daily average air quality standard

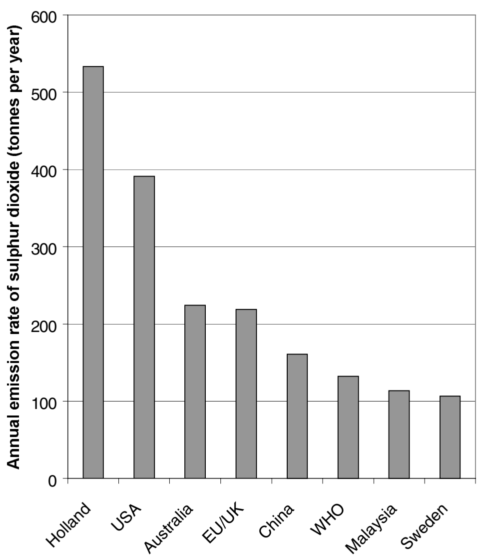
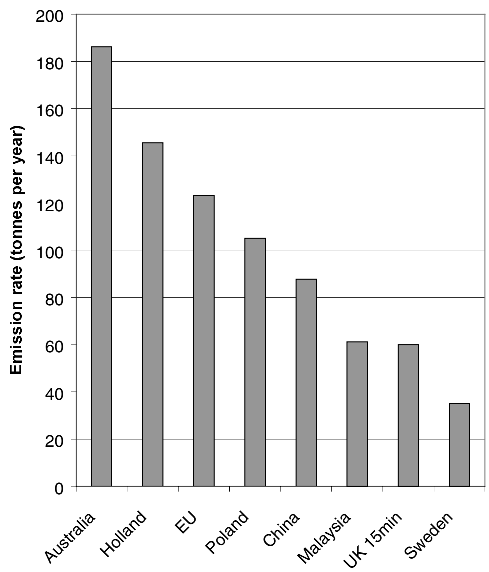


Fig 3.2 The maximum annual average discharge rate of sulphur dioxide to ensure that ground level concentrations remain below 10% of the hourly/15min average air quality standard



It should be noted that by basing the above calculations on the same wind and weather data, the above comparisons may not be entirely appropriate. Also, regulators in different countries may apply air quality standards in different ways. However, for chemical processes which discharge large quantities of sulphur dioxide, such as sulphuric acid recovery plants, it may be significantly easier, from an emission viewpoint, to operate in countries such as Holland and USA than in the UK and Sweden.

It is difficult for a multinational company to meet the most stringent air pollution regulations applying to their plants world-wide because of the difficulty in assessing which standard to aim for!

4.0 Difficulties caused by the sparse network of weather stations in the UK

Whilst many larger industrial sites will continuously monitor wind speed and direction (to give emergency services some indication of the area over which an accidental release would spread) the quality of the data is rarely sufficient to enable a detailed annual average or long term percentile calculation to be made.

Industry is therefore reliant on data supplied by nearby meteorological stations. The UK Meteorological Office is part of the Ministry of Defence and consequently most weather stations are located at military airports, often well distant from the industrial locations. There is only one weather station in the whole of Northern Ireland that produces sufficient data for dispersion modelling!

Teesside is another area lacking in weather stations – there used to be a station at the airport at Middleton St George but this closed in the 1980s. Dispersion calculations for chemical industry applications have to use data from the two nearest sites, Boulmer (located 100 km to the north) or at Leeming (40km to the South West).

A small chemical plant in the area was discharging a volatile organic compound at a relatively low rate. In assessing the environmental impact of this chemical, the use of Leeming data resulted in the maximum predicted annual average concentrations over the nearest residential area over two times greater than if Boulmer data was used. Small companies often do not have the resources to set up their own meteorological stations. There is a need for more meteorological stations in industrial areas.

Fig 4.1
Annual average xylene concentration in ppb by vol
Leeming data; 10g/s - 35m high stack

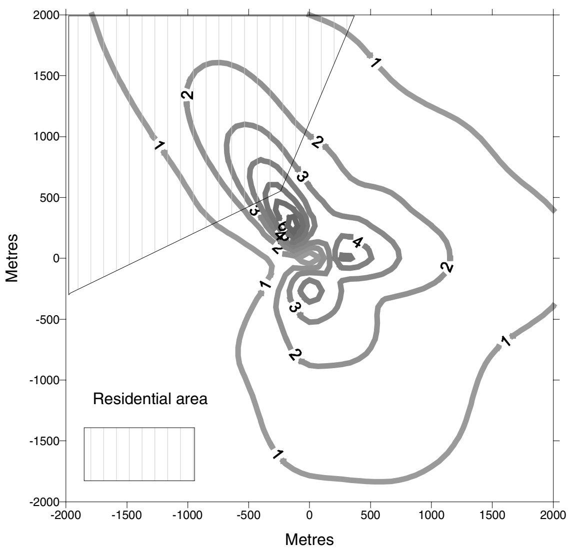
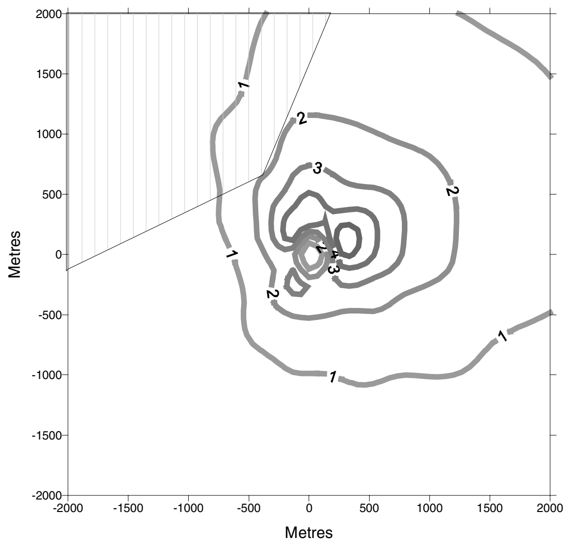


Fig 4.2
Annual average xylene concentration in ppb by vol
Boulmer data; 10 g/s, 35m high stack



5.0 Summary

Hopefully, this short paper indicates that to achieve harmonisation in gas dispersion modelling across Europe, there is a need to harmonise not only the models, but the also the way they are used. Having the same air quality standards world wide would make the dispersion modelling so much easier for those involved in regulatory work.