A STUDY OF THE HEALTH EFFECTS OF COMBUSTION PROCESSES

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INTRODUCTION

The assessment of air quality is most commonly by the application of air quality standards, which should not be exceeded, those laid down for the EC and UK can be seen in Environment Agency(2007). It is presumed that significant harm does not occur at levels below these. In more recent years there has been a trend to quantify the effects of air pollution more precisely, in proportion to the degree of exposure, based on epidemiological studies of correlated statistics of additional identifiable health effects resulting from specific levels of air pollution. In the UK they were based on quantifiable health outcomes, earlier deaths ('deaths brought forward', dbf) and additional hospital admissions for respiratory and cardiovascular problems ('respiratory hospital admissions', rha, and 'cardiovascular hospital admissions', cha). These health effects estimates assumed no lower level of acceptable exposure. The availability of these predictions of pollution-related health effects makes it possible to estimate, in more direct terms than through air quality standards, the additional health effects of ambient pollution, not only on an overall basis but also for individual polluting discharges. Quantification of health effects in this way has been carried out by COMEAP in the UK, who have issued a number of reports, commencing with COMEAP(1998), giving health effects estimates for the UK. Those from this first COMEAP report, of most interest here, are given in Table 1. All but ozone are primary or (partly) secondary sources of combustion processes.

The UK Environment Agency has a direct interest in this methodology and the relationship between the present approach to pollution control, based on air quality standards and emission limits, and the direct prediction of consequent dbf, rha and cha that might be attributable to individual sources. Since the estimated exposure coefficients were generally linear with concentration, the additional local increase in air pollutants from a specific source could be directly associated with specific increases in health effects. The study described briefly here (*Spanton et al*(2007)) was initiated by the UK Environment Agency to examine the health effects that might be expected in representative urban areas due to emissions of SO_2, NO_2 and PM_{10} from typical large combustion plant. It used emissions from four types of combustion plant under Agency regulation: a large (1 GW) coal fired generating station with and without Flue Gas Desulphurisation (FGD), an oil refinery, cement works with different fuel mixes and operating conditions and two types of waste incinerator (large municipal and, smaller, merchant chemical waste, with about 25t h^{-1} and 2t h^{-1} respective capacity). Only the results from generating stations are described here.

The study required the calculation of annual ambient concentration distribution patterns of the emitted pollutants and representative urban population distributions. These could then be overlaid and, using GIS software, the overall additional health effects for the urban area could be calculated.

Table 1. Pollutant exposure-response coefficients (from DEFRA (2001)).

Pollutant	Health Outcome*	Dose-Response Relationship**	Annual Baseline Health Rate (per100,000)
PM_{10}	Deaths brought forward (Excl. external causes)	+0.75% per 10 µg m^{-3} (24 hour mean)	1026
	Respiratory hospital admissions	+0.80% per 10 µg m^{-3} (24 hour mean)	942
	Cardiovascular hospital admissions***	+0.80% per 10 µg m^{-3} (24 hour mean)	734
SO_2	Deaths brought forward (Excl. external causes)	+0.6% per 10 µg m^{-3} (24 hour mean)	1026
	Respiratory hospital admissions	+0.5% per 10 µg m^{-3} (24 hour mean)	942
NO_2	Respiratory hospital admissions	+2.5% per 50 µg m^{-3} (24 hour mean)	942
O_3	Deaths brought forward (Excl. external causes)	+3% per 50 µg m^{-3} (8 hour mean)	1026
	Respiratory Hospital Admissions	+3.5% per 50 µg m^{-3} (8 hour mean)	942

* As 'Deaths Brought Forward' (dbf), additional emergency Respiratory Hospital Admissions (rha) or additional emergency Cardiovascular Hospital Admissions (cha).
** As a percentage increment, due to the pollutant concentration given, over the existing baseline health rate of deaths, rha or cha.
*** From *COMEAP* (2001).

EMISSION DATA AND DISPERSION MODELLING

Emission data were obtained from Environment Agency regulatory data. The characteristics of the generating stations with and without FGD were obtained from real examples but scaled to a representative common plant of 1GW capacity with a 200m discharge stack.. Overall assumed load factors were 60% with FGD and 40% without. Different, realistic, load patterns were assumed, based on typical rates for the two station types. These were incorporated into the dispersion calculations.

Dispersion modelling used the ADMS model in a conventional regulatory calculation, which determines the annual average concentration distribution at the ground from hourly averaged plume calculations utilising hourly meteorological data. In the present case the diurnal and seasonal variation in the generating station outputs, on an hourly basis, was also incorporated.

REPRESENTATIVE URBAN AREAS

Urban areas are generally quite heterogeneous and it was not clear at the outset of the study that they had much commonality of population density distributions. However, after some investigation of real urban areas it appeared that if the urban areas were assumed to be nominally circular in form, the population densities were averaged circumferentially around circular segments and normalised with respect to the size of the urban area and its total population, then most urban areas had a similar form of radial population density distribution. This form was used in the study. The urban areas investigated were divided into small (Pop.<200,000) medium-sized (Pop 200,000 to 1,000,000) and large (Pop.>1,000,000). Figure 1 shows an example of a real urban area, Leicester, with its normalised, circumferentially averaged form. Figure 2 shows plots of circumferentially averaged and normalised population distributions for all the urban areas investigated, split into small, medium-sized and large populations. Mean fits for the normalised population distributions are shown in these plots, with all three mean distributions shown in the lower plot. These were used in the subsequent health effects calculations.

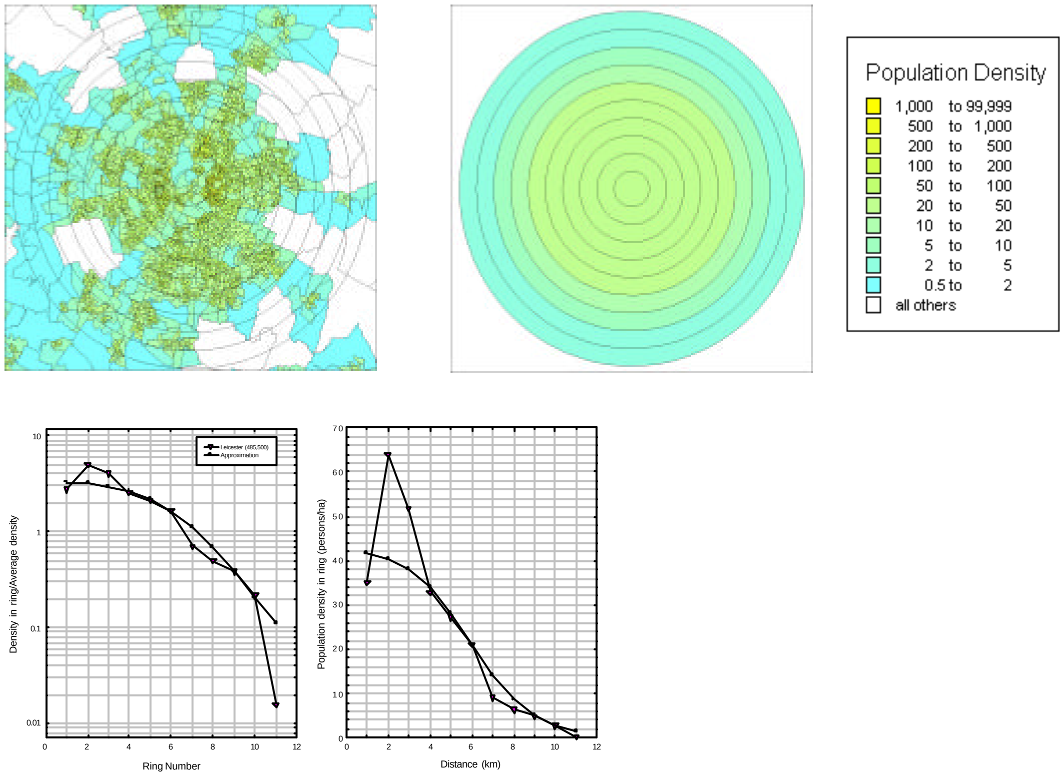

Fig. 1; Real and normalised averaged population densities for a medium-sized town, Leicester (Pop 485,000, diameter 10km).

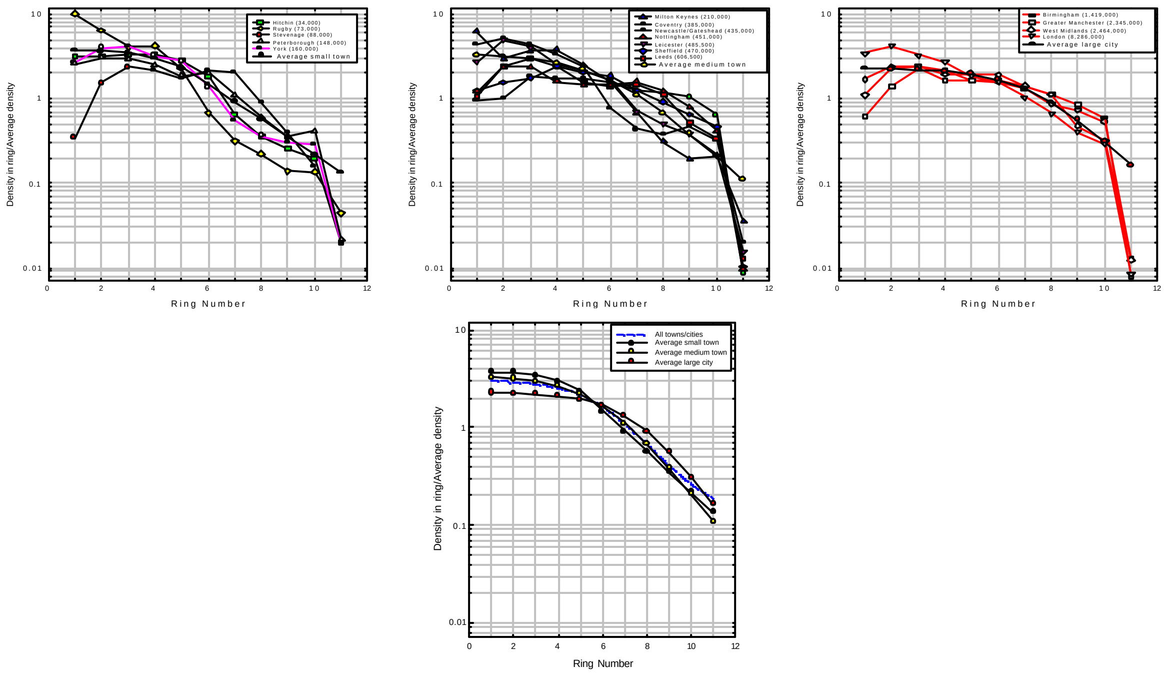

Fig. 2; Upper. Normalised population densities for small, medium and large towns respectively.

Lower. Averaged urban density distributions used in study.

HEALTH EFFECTS CALCULATIONS

Figure 3 shows a typical example of an urban population distribution overlaying an annual average concentration distribution, from which the health effects were calculated.

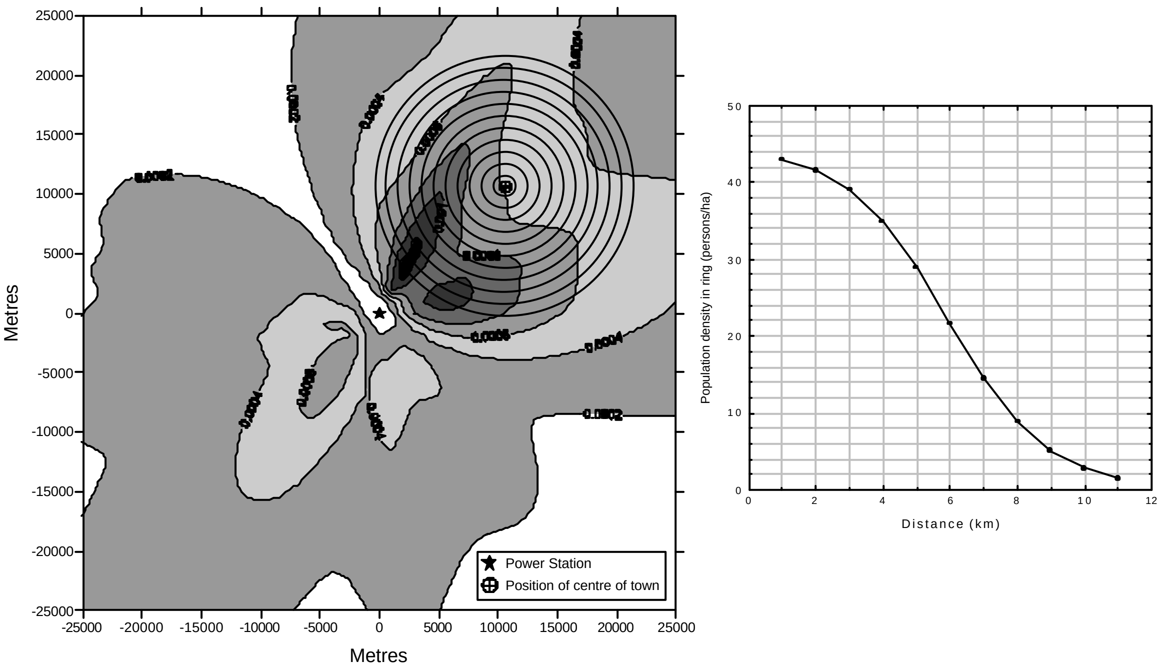

Fig. 3; Example of health effects calculation for a generating station (with no FGD), with urban density distribution (for a medium-sized town) overlaid on annual average dispersion calculation. Concentration contours are of µg m^{-3} for a unit emission of 1g s^{-1}.

Figure 4 shows calculated health effects the total dbf, rha and cha from all pollutants calculated for generating station emissions, with the discharge stacks at varying distances from the centre of the urban area. The highest additional admissions were due to SO_2 for the generating station without FGD, but due to NO_2 for the generating station with FGD. The contribution of primary PM_{10} was quite small by comparison, more than an order of magnitude less than for the acid gases. In a city of population 2M the study predicted about 9 additional dbf and 9.4 additional rha (both about 0.5 per 100,000) from all pollutants for the station without FGD and about 3.6 additional dbf and 6.6 additional rha for the station with FGD (about 0.18 and 0.33 per 100,000 respectively). This is relative to dbf and rha from all causes of order 1000 per 100,000, so represents a quite small addition in all cases.

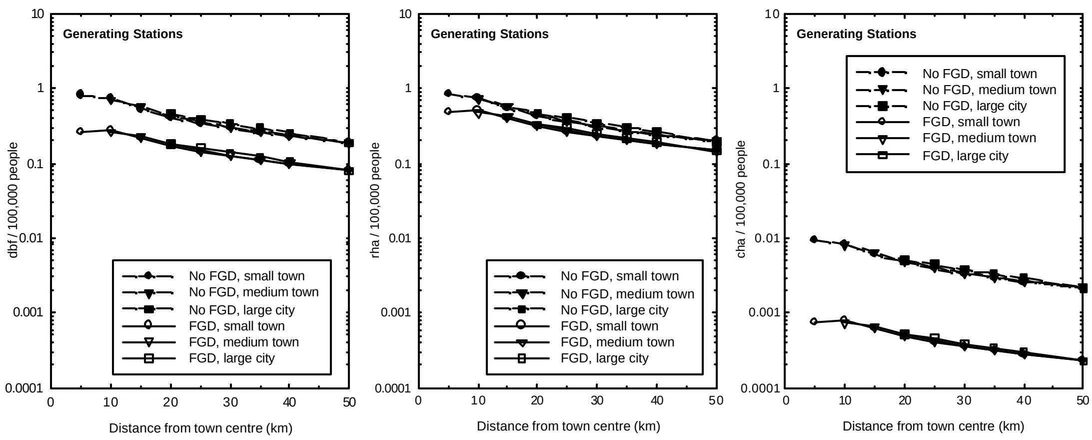

Fig. 4; Calculated health effects due to a 1GW generating station situated at varying distances from urban areas.

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