Air pollution at schools from the proposed Gloucestershire incinerator

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We use AERMOD to model emissions from the proposed Gloucestershire incinerator and predict the additional air pollution levels, caused by the incinerator, at primary schools in the area. One reason for focusing on schools is that young children are the most susceptible to air pollution. Another reason is that there have been suggestions to monitor ambient air at schools when the incinerator is operational. Finally, each school is surrounded by housing, so these pollution levels are also representative of those to be endured by nearby residents.

1. Introduction

Table 1 lists the schools that we consider, and Figure 1 shows their location and the incinerator's location. These are intended to be all primary schools located in the vicinity of the incinerator. Locations (grid coordinates) were obtained from a map, except for Hunts Grove School, which does not yet exist. The location of Hunts Grove School was obtained from a map in [10]. Table 1 does not necessarily show the formal name of each school.

Table 1. Schools and their locations.

School name	Easting	Northing	Latitude	Longitude
Kingsway School	381670	213700	51.82162	-2.26734
Waterwells School	381830	213200	51.81713	-2.26500
Haresfield School	381490	210280	51.79086	-2.26977
Beech Green School	380670	214330	51.82724	-2.28189
Meadowside School	380850	214930	51.83265	-2.27931
Hardwicke School	380040	213000	51.81527	-2.29095
Whitminster School	377270	208350	51.77336	-2.33083
Field Court Junior School	380620	213780	51.82230	-2.28258
Hunts Grove School	381100	212240	51.80847	-2.27553

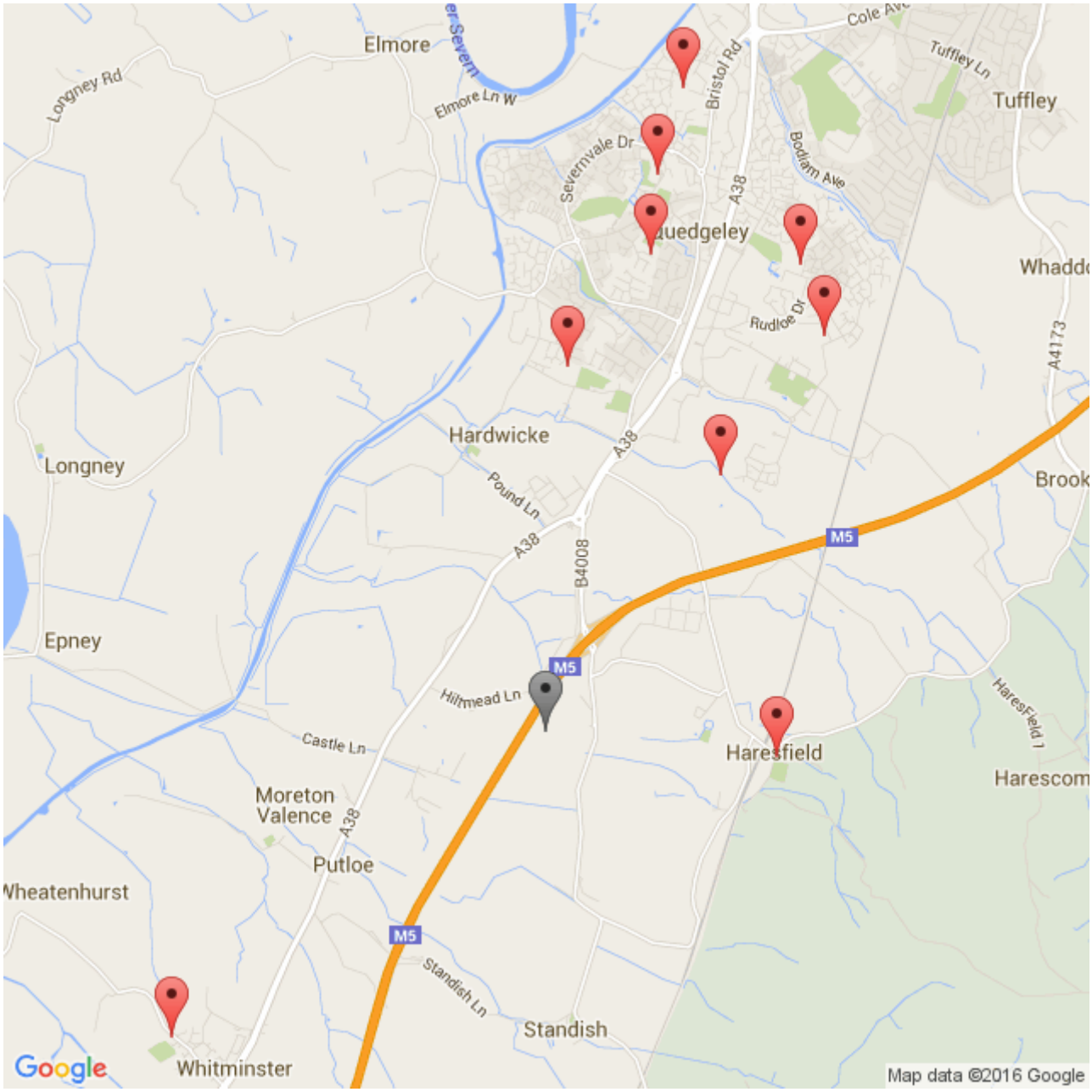

Figure 2. Location of schools (red) and incinerator (black).

2. Methods

We aim to predict air pollution from the proposed incinerator in the same way as [1] but in much more detail. The similarities and differences between our methods are explained here.

2.1 Software and parameters

The main difference from [1] is that we do not use the ADMS software, because of its prohibitive cost. Instead we use AERMOD [2], with its companion software, AERMET, which preprocesses meteorological data. In the remainder of this paper we refer to the AERMOD/AERMET combination as simply “AERMOD”. We use the latest versions of AERMOD and AERMET, dated August 2015.

AERMOD calculates the predicted concentration of a specified pollutant at each location at ground level. We use a "pollutant ID" of "other", which means that AERMOD will not perform any chemical simulations (e.g., converting nitric oxide to nitrogen dioxide). Like [1], we assume that the incinerator emits pollutants at a constant emission rate all year.

AERMOD is provided with several parameters of the emissions source, all taken from [1]:

- Stack location (379882, 210464) = (51.7925, -2.2931).
- Stack height (70m).
- Stack diameter (1.81m).
- Stack gas exit velocity (19.91m/s).
- Stack gas temperature (130ºC).
- Emission rate of pollutant (9.08g/s oxides of nitrogen, as nitrogen dioxide).

AERMOD also requires a few parameters of the area near the emissions source:

- Albedo. We use 0.2, based on guidance in the AERMOD [2] User's Guide; this is not mentioned in [1].
- Bowen ratio. We use 1.0, based on guidance in the AERMOD [2] User's Guide; this is not mentioned in [1].
- Roughness length. We use 0.3m, as specified in [1].

Finally, AERMOD has various options that control how the model works. We use the standard "regulatory default" options.

The following components (and versions) of the AERMOD system were used:

- AERMOD (v15181).
- AERMET (v15181).
- AERMAP (v11103).
- BPIP (v04274).

2.2 Weather data

AERMOD was supplied with hourly weather observations for the following:

- Wind direction.
- Wind speed.
- Temperature.
- Pressure.
- Solar radiation.
- Cloud cover.

Most of these were obtained from Weather Underground [3], a free source of weather data. Wind speed, direction, temperature, and pressure were obtained hourly from the Quedgeley weather station [4] at (51.824, -2.284) = (380523, 213969), which is very close to the emissions source. Solar radiation is not recorded at Quedgeley, so it was obtained from the Lansdown weather station [5] at (51.895, -2.089) = (393972, 221832). Both of these weather stations are very reliable. In the very few hours when Quedgeley observations were missing, Lansdown observations were used. In the very few hours when Lansdown observations were missing, solar radiation readings from the Horfield/Filton weather station [6] were used instead.

Cloud cover data was obtained from the ERA Interim dataset [7, 8] for the location (51.75, -2.25) = (382838, 205730). This location (in Stroud) is the nearest available.

Since we use an "onsite" file for weather observations, AERMOD treats observations with calm winds as missing observations. We therefore replaced calm winds (those with speed 0 and direction 0 degrees) by very light winds from a random direction. AERMOD replaces these and all other light winds (with speed below 0.28m/s) by increasing the speed to 0.28m/s without changing the direction.

AERMOD also requires upper air observations from the previous midnight (GMT) sounding, for:

- Wind direction.
- Wind speed.
- Temperature.
- Pressure.
- Dewpoint.
- Height.

for various heights in the atmosphere. We use the observations from Camborne, obtained from meteocentre.com.

For the experiments in this paper we have used the period from 1/1/2015 to 31/12/2015, inclusive. This period was chosen because it is the most recent year for which data was available at the time of performing the experiments. We have also used repeated the experiments on the period from 1/1/2014 to 31/12/2014, for comparison.

2.3 Terrain

In order to model dispersion correctly for the terrain, we obtained the OS Terrain 50 dataset [9] from Ordnance Survey. This was converted to DEM format and preprocessed by AERMAP, AERMOD's terrain preprocessor, to be used by AERMOD.

2.4 Building downwash

We also needed to handle *building downwash*. We measured the building from the plans in the planning applications, and fed the description into AERMOD's BPIP preprocessor. BPIP generated information for AERMOD to correctly model building downwash. The highest part of the incinerator building has a sloping roof whose height varies from 41.75m to 48.195m. It is not clear how to specify a sloping roof in BPIP, so we experimented with roof heights between 41.75m and 48.195m, and chose 48.195m because it gave results most similar to those of [1].

It is worth noting that *stack tip downwash* is also modelled, but this is just one of AERMOD's regulatory default options.

3. Results

In this paper we predict the ground-level concentration of nitrogen dioxide, because it is the most commonly predicted pollutant and because incinerators tend to emit high levels of oxides of nitrogen, close to the emission rate limits which we use for modelling.

One complication is that, although the emission rate of oxides of nitrogen is known, we do not know how much reaches the ground in the form of nitrogen dioxide. We do not use AERMOD to model the conversion of nitric oxide to nitrogen dioxide. Instead we multiply the predicted concentrations of oxides of nitrogen by a factor to arrive at predicted nitrogen dioxide concentrations. The factor used is 0.7 for annual means and 0.35 for short-term values, as recommended by the Environment Agency and used in [1] and similar documents.

Using this method to predict the annual mean nitrogen dioxide concentrations for 2015, the results are shown in Figure 2, for a 7.5x7.5 km square centred on the incinerator.

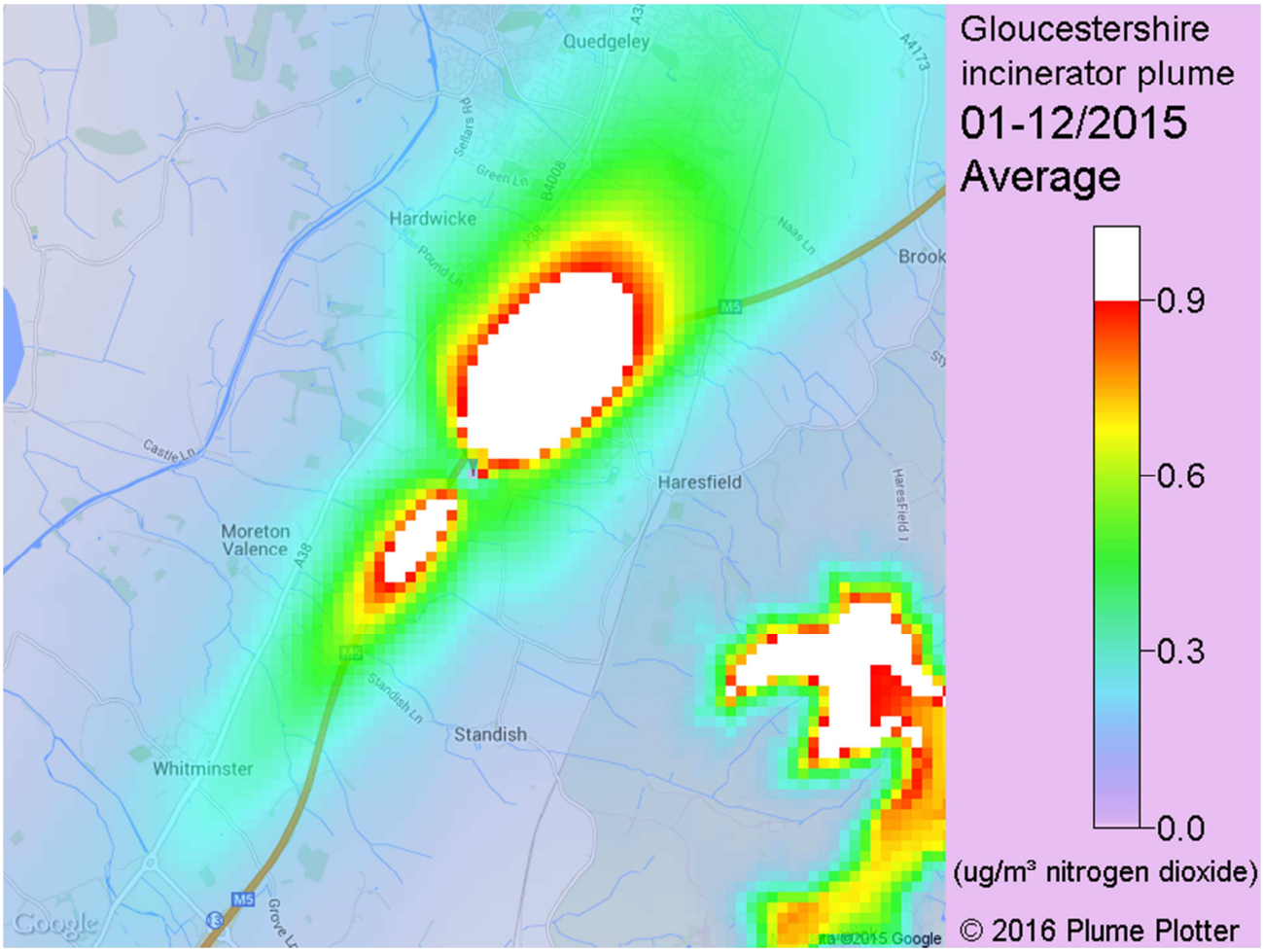

Figure 2. Annual mean ground-level concentration of nitrogen dioxide (1/1/2015-31/12/2015). This assumes that 70% of the nitrogen oxides are in the form of nitrogen dioxide.

Figure 2 is very similar to Figure C.2 of [1], which uses weather data from Filton for the year 2008. However, their plot shows the most-polluted area (north-east of the incinerator) rotated slightly clockwise; we believe this to be due to the (well-known) difference in the prevailing wind direction between Bristol and Gloucester. Another difference is that we often predict higher pollution on hills (for example, in the south-east corner of the map) because of a difference between AERMOD and ADMS, but this difference is not relevant for this paper.

Table 2 shows the results of modelling the incinerator emissions for the whole of 2015. For each school, we give the predicted annual mean concentration of nitrogen dioxide as well as the 99.79th percentile (the hourly concentration which was exceeded exactly 18 times in the year) and the maximum value of the hourly concentration. The last two were calculated as 35% of the corresponding predicted levels of oxides of nitrogen. The final column shows the time and date of the maximum observation. This is for illustration only, because it could change dramatically if the parameters or weather conditions were varied slightly, while the other results are more robust.

Table 3 shows the same results as Table 2, but for 2014. Both tables are ordered by annual mean concentration, and the order is the same in both years.

Table 2. Predicted nitrogen dioxide concentrations at each school in 2015. Concentrations are in $\mu g/m^3$. Times are in GMT or BST as appropriate.

School name	Annual mean	99.79th percentile	Maximum	Date and time of maximum
Hunts Grove School	0.74	6.73	8.04	27/06 00:00
Waterwells School	0.38	4.82	6.17	05/06 22:00
Kingsway School	0.34	4.37	5.22	15/04 01:00
Hardwicke School	0.26	7.42	12.54	22/08 03:00
Field Court Junior School	0.23	6.50	8.44	09/12 07:00
Beech Green School	0.18	4.93	7.07	27/02 19:00
Meadowside School	0.16	4.28	5.91	18/02 07:00
Whitminster School	0.15	6.08	9.84	22/04 00:00
Haresfield School	0.15	2.58	5.82	26/02 19:00

Table 3. Predicted nitrogen dioxide concentrations at each school in 2014. Concentrations are in $\mu g/m^3$. Times are in GMT or BST as appropriate.

School name	Annual mean	99.79th percentile	Maximum	Date and time of maximum
Hunts Grove School	0.64	6.88	8.54	15/03 23:00
Waterwells School	0.32	5.03	6.97	15/03 23:00
Kingsway School	0.30	4.61	5.22	07/12 21:00
Hardwicke School	0.29	9.19	11.68	13/02 03:00
Field Court Junior School	0.27	7.60	9.56	02/02 19:00
Beech Green School	0.21	6.09	8.04	10/10 03:00
Meadowside School	0.18	5.16	6.82	10/10 03:00
Whitminster School	0.14	5.59	10.27	27/08 01:00
Haresfield School	0.12	2.28	5.92	20/12 08:00

In Figure 3 we show the cumulative frequency distribution for each school for the whole two-year period 2014-15. The horizontal axis shows the concentration of nitrogen dioxide and the vertical axis shows the fraction of hours when this concentration would have been exceeded.

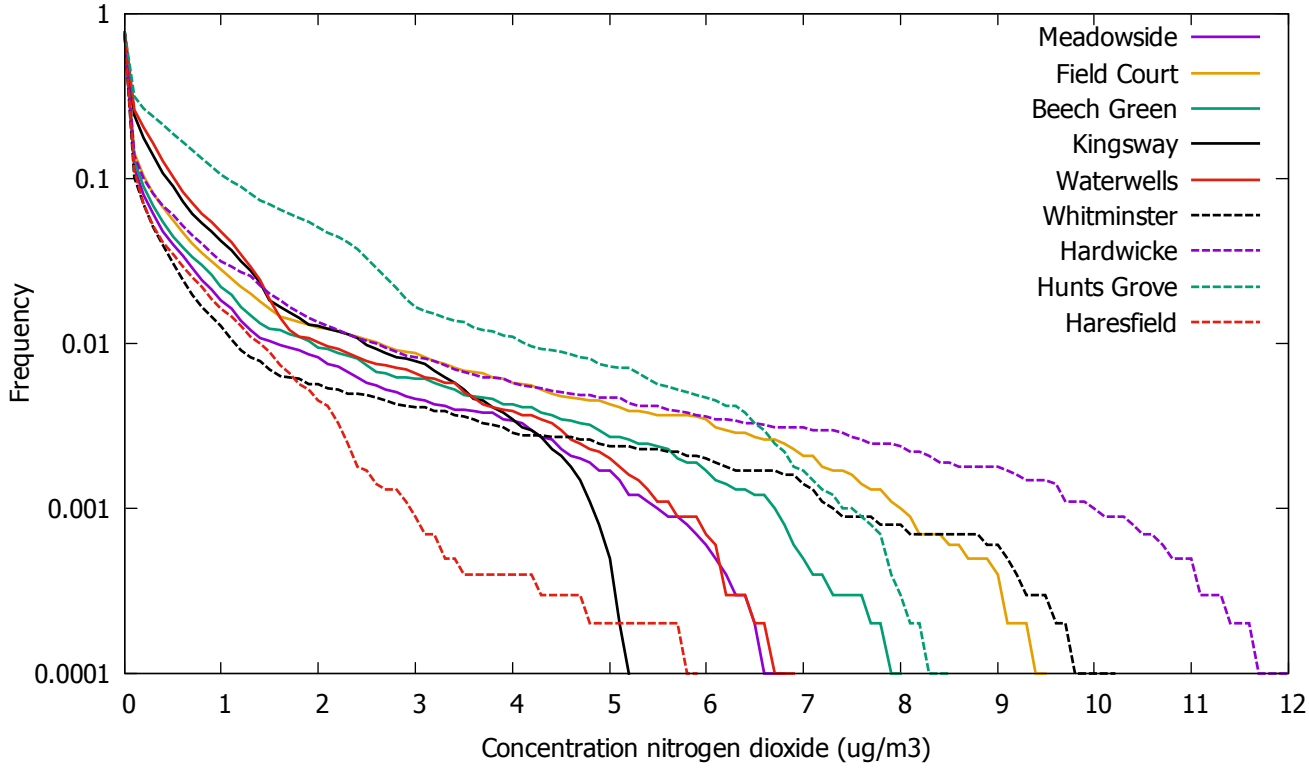

Figure 3. Distribution of predicted pollution levels at each school in 2014-15.

4. Conclusions

Our results show that the worst average pollution is predicted in the triangle between the A38 and the railway. The highest increase in average concentrations occurs at the planned school in Hunts Grove, and this is double the level predicted at the two schools in Kingsway. Schools to the west of the A38, in Quedgeley and Hardwicke, have only slightly less pollution. Haresfield School, although closest to the incinerator, has the lowest average pollution of all.

Considering instead the relatively rare events with high pollution levels, Hunts Grove School is still badly affected, but so are Field Court and Whitminster schools, with Hardwicke being the worst affected. Haresfield School again escapes, having the least frequent occurrence of high concentrations.

Unlike the authors of [1], we want to ensure that our experiments are reproducible. To this end, all command and data files will be made available online at `plumeplotter.com/news/schools`.

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