Peer Review of:

'*Air pollution in hills from the proposed Gloucestershire incinerator', Ashley, Plume Plotter, October 8, 2015, Revised October 21, 2015*

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1. Introduction

1.1 My name is Dr Yasmin Vawda. I am an expert in air quality assessment, having worked as a dispersion modeller for 24 years, prior to re-training as a science teacher in 2014.

1.2 I have been approached by Chris Harmer of Glosvain to peer review a study carried out by 'Ashley, Plume Plotter'[1]. This critical review is set out in Sections 2 – 5, supplemented by information on air quality assessment and monitoring methodologies which may be useful in the context of the proposed development. My peer review is an independent overview of the Ashley paper, and I have no association with Glosvain or any other group involved in opposing or promoting the Gloucestershire incinerator.

1.3 I hold a PhD in Atmospheric Chemistry which was partly undertaken at the UK Atomic Energy Authority Harwell Laboratories. Until July 2014, I held the position of Senior Consultant with a global environmental consultancy (Bureau Veritas). I also worked for ERM between 1990 – 1992. I have prepared proofs of evidence and acted as an expert witness at a number of planning inquires.

1.4 I am a member of the Royal Society of Chemistry, a Chartered Chemist and a Chartered Scientist. I am a Fellow of the Royal Meteorological Society, and until recently also a member of the Institute of Air Quality Management and a member of the Institute of Environmental Management (though my membership has lapsed since I changed career).

1.5 I have served on Defra and Environment Agency (EA) expert panels[2]. I have drafted Secretary of State's Technical Guidance Notes for local air quality management (LAQM) on behalf of Defra[3] and the UK Environment Agency (notably I am the author of Ref. 14[4] cited by Ashley), and I have also drafted Environmental Protection UK guidance on air quality issues[5]. Therefore, I am fully conversant with the dispersion modelling and air quality assessment methodologies used as the basis of Ashley's study, and also used by Fichtner (Ref.1 in the Ashley paper).

[1] Air pollution in hills from the proposed Gloucestershire incinerator', Ashley, Plume Plotter, October 8, 2015, Revised October 21, 2015
[2] APEG (1998). Source Apportionment of Airborne Particulate Matter in the United Kingdom. Airborne Particles Expert Group.
[3] https://www.gov.uk/government/publications/local-air-quality-management-technical-guidance-laqm-tg-09
[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/290980/scho0307bmkq-e-e.pdf
[5] http://laqm.defra.gov.uk/documents/SupplementaryAssistanceonStackHeight.pdf

1.6 This review considers only the Ashley paper. I am aware that air quality studies were carried out by ERM and Fichtner in support of the planning application (to Gloucestershire County Council), appeal and Environmental Permit (EP) application. Though I have not reviewed the latter documents, I have assumed any technical reference/comparison that Ashley makes to these reports to be correct. I understand that these documents were subjected to rigorous examination during the appeal.

2. Dispersion Models

2.1 There are a number of dispersion models available for predicting the dispersion and dilution of pollutants from industrial chimneys. AERMOD[6] is the US regulatory model; its on-going development, mandatory periodic reviews, testing and updates are funded by US taxpayers. AERMOD is subject to rigorous validation against monitoring data in field trials carried out in the US. The US Environmental Protection Agency (EPA) prescribes to a permit applicant which dispersion model to use. AERMOD is available free of charge on the internet[7]. More user-friendly versions are available at cost from software companies such as Trinity Consultants Inc.

2.2 In contrast, ADMS is a proprietary dispersion model developed and promoted by CERC, a commercial company[8]. In its early days of development, ADMS had some sponsorship from National Power and the Meteorological Office, though this partnership has ceased. The on-going development of ADMS relies upon profits CERC makes from selling licences to dispersion modelers. The Ashley paper comments on the 'prohibitive cost' of ADMS (para.1.1). Updates to ADMS are not subject to mandatory technical peer review.

2.3 The UK EA does not recommend or prescribe any specific dispersion model for regulatory purposes. It accepts the outputs of both AERMOD and ADMS, on a case-specific basis.

2.4 As well as comparing the results of models against real-field monitoring data (which is called validation), there are frequent studies which compare the outputs of different models[9]. These are called model inter-comparisons[10]. It is important to remember that just because two or more models give the same result, it does not mean that any of them are correct in predicting the actual outcome of a pollutant release from a chimney. The Ashley paper is a model inter-comparison, of ADMS against AERMOD for certain scenarios associated with the proposed Gloucestershire incinerator.

2.5 Ashley correctly used the AERMOD terrain pre-processor (AERMEP) and AERMOD's building wake effects pre-processor (BPIP) (paras. 1.3 and 1.4).

[6] https://en.wikipedia.org/wiki/AERMOD
[7] http://www3.epa.gov/scram001/dispersion_prefrec.htm
[8] https://en.wikipedia.org/wiki/ADMS_3
[9] http://webarchive.nationalarchives.gov.uk/20131103234051/http://www.admlc.org.uk/pdfs/workshop/bernard_fisher.pdf
[10] http://www.harmo.org/intercomparison/P362.pdf

2.6 In recognition of the uncertainties inherent in any predictive technique, best practice guidance has stated that in contentious situations, more than one dispersion model should be employed[11] to predict the impact on air quality[12]. Good practice would also expect the precautionary principle to prevail, and the more pessimistic result be used for regulatory purposes[13]. The Ashley paper shows that AERMOD gives more pessimistic results than ADMS for certain locations. However, it would appear that these results were not available during the planning or EP permit applications, and the AERMOD results were also not available at the Inquiry.

2.7 The tendency of AERMOD to give higher results than ADMS when the plume impacts on hillsides is well-known and documented[14] [15]. Therefore, it does not surprise me that Fichtner, on behalf of Urbaser the developer, chose not to use AERMOD despite the presence of hills to the east of the proposed incinerator.

2.8 Dispersion models are most reliable in simple situations e.g. flat terrain, steady-state continuous releases, and no downwash effects. Nearby tall buildings cause eddies which deflect the plume in the wake of these obstacles[16]. Most dispersion models assume that if the chimney is at least 2.5 – 3 times higher than the tallest building near the chimney, the plume will escape the downwash effects of the building. Ashley states that the proposed chimney is of height 70 m (para. 1.1), and the height of the adjacent building is 41.75 – 48.195 m (para. 1.4). Such a building would significantly affect the dispersion of the plume (i.e. cause downwash), and therefore increase predicted ground level pollutant concentrations at receptors close to the chimney.

2.9 Just as the results of dispersion models become increasingly unreliable when they attempt to include terrain in the calculations, building downwash effect algorithms introduce another layer of uncertainty[17]. However, it is good practice to carry out a 'sensitivity analysis' for building effects (which Ashley does in Table 5): this involves running the dispersion model with and without the building information. ADMS truncates all the building information into a

[11] http://www.welshairquality.co.uk/documents/seminars/328100928_7_EA_Permitting.pdf
[12] http://laqm.defra.gov.uk/laqm-faqs/faq120.html
[13] http://webarchive.nationalarchives.gov.uk/20131103234051/http://www.admlc.org.uk/model_guidelines/documents/ADMLC-2004-3.pdf
[14] Atmospheric Dispersion Modelling Liaison Committee. Annual Report 2005-2006. ADMLC-R5. Includes annex on A Review of atmospheric dispersion in complex terrain
[15] http://nepis.epa.gov/Exe/ZyNET.exe/P1009S6X.txt?ZyActionD=ZyDocument&Client=EPA&Index=2000%20Thru%202005&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C00THRU05%5CTXT%5C00000026%5CP1009S6X.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1
[16] Atmospheric Dispersion Modelling Liaison Committee. Annual Report 1998–99. Chilton, NRPB-R322. Includes annex on Review of flow and dispersion in the vicinity of groups of buildings
[17] http://www.harmo.org/Intercomparison/HARMO7Intercomp.pdf

surrogate single block. However, AERMOD allows a more detailed consideration of building downwash effects based on hourly wind direction[18].

2.10 I would be surprised if the ERM and Fichtner studies had ignored the effect of buildings close to the chimney. It is standard practice to include building downwash effects in dispersion modelling, if the building is at least 30 -40% of the height of the proposed chimney. Ashley has correctly included building downwash effects by using BPIP (para. 1.4).

2.11 The Ashley paper reports the AERMOD modeling with a very high degree of transparency. Consistency of model input parameters to allow direct comparison against previous studies is optimized. The comparisons which are made between the AERMOD results against the ADMS results of other papers are valid as far as I can ascertain without reviewing the Fichtner report/s, and the inferences Ashley makes appear to be reasonable.

2.12 The Ashley modelling using AERMOD predicts significantly higher pollutant concentrations to the east of the incinerator stack where there are hills. This is not surprising in view of different algorithms which AERMOD includes for plume dispersion over complex terrain, a feature which ADMS does not incorporate in the same way. AERMOD also treats building downwash effects differently from ADMS; however, building downwash will affect predicted pollutant concentrations close to the source, and have little effect on the predicted pollutant concentrations at Cotswold Beechwood SAC. This Ashley has shown to be the case (para. 3, Table 5).

3. Ambient Monitoring

3.1 Only once the Gloucestershire incinerator is up and running, can the ADMS and/or AERMOD modelling predictions be validated. In order to do this, measurements of airborne pollutant concentrations would need to be carried out BEFORE the incinerator is commissioned (the 'baseline' air quality) and then after commissioning (the 'do-something' scenario, as it is usually called in air quality assessments). The INCREMENT to the measured airborne pollutant concentration would need to be compared against the dispersion modelling predictions, to assess the validity of the model/s.

3.2 For this reason, it is imperative that baseline monitoring should be carried out for as long a time-period as possible prior to commissioning. Pollutant concentrations vary on an hourly basis, due to fluctuating weather conditions and temporal patterns in emissions (e.g. traffic flow variations, hours of operation of industrial plant). Air quality standards (e.g. the EU Limit Values[19], from which the UK Air Quality Strategy objectives[20] are derived) are

[18] http://www3.epa.gov/scram001/10thmodconf/presentations/3-3-EPA10thConferenceAQModeling-BuildingDownwash_SchulmanScire.pdf
[19] http://uk-air.defra.gov.uk/air-pollution/uk-eu-limits

expressed in various statistics (e.g. for NO_2, there is an annual limit of 40 µg/m^3 not to be exceeded. But there is also an hourly limit of 200 µg/m^3 which should not be exceeded on more than 18 hours in the year, which is approximately equivalent to a 99.8th percentile).

3.3 The ideal case is to have at least 1 year of baseline air quality monitoring at every location of concern (with the measurement reflecting the averaging periods in which the air quality standards and objectives are expressed e.g. hourly and annual mean for NO_2, and annual means for PM_{10}) at a number of sensitive locations in different directions from the stack.

3.4 The locations for ambient monitoring need careful consideration[21]. Areas of worst-case impact can be identified from the dispersion modelling contour maps, but locations for the monitors should also reflect 'relevant exposure' i.e. where receptors are exposed to the pollutants over the relevant time-frames of the air quality standards and objectives. So, for harm to ecosystems, annual mean NOx could be measured within a SAC; for harm to humans via inhalation, hourly mean NO_2 could be measured along a shopping street or within a school playground, and annual mean NO_2 at residential properties (e.g. care homes, traveler sites).

3.5 Ambient monitoring over short averaging periods (e.g. 24-hour means for PM_{10} and 1-hour means for NO_2) requires sophisticated, real-time instruments with data-loggers. Ambient monitoring over longer time frames (e.g. weekly, monthly) are often carried out far more cheaply using passive absorption devices (e.g. NO_2 diffusion tubes). However, the latter do not give any measurement of 1-hour peaks in NO_2 concentrations, for comparison against the hourly mean air quality objective (200 µg/m^3 as a 99.8th percentile). Care needs to be atken to conduct measurements using instruments which provide data which can interpreted against the relevant air quality standards and objectives.

4. Pollutant Emissions

4.1 Once sufficient baseline monitoring has been carried out, and compared against measured pollutant concentrations after commissioning, it is almost irrelevant what the different dispersion models had predicted. At that point in time, the questions could be:

- Are there breaches of air quality standards or objectives which were not observed during the baseline monitoring period?
- Can these breaches be attributed to the Gloucestershire incinerator?
- If these breaches were not previously predicted, is the incinerator operating within its emission limits as set out in the EP? (a responsibility of the EA to regulate).

[20] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298239/geho0410bsil-e-e.pdf
[21] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/301188/TGN_M8_Monitoring_Ambient_Air.pdf

4.2 I find it surprising that the EP states 'No limit set' for emissions of NH_3 from the main stack. The nitrogen (N) in the ammonia (NH_3) contributes to the total Nitrogen deposition[22]. Similarly, the EP states 'No limit set' for Dioxins/furans emissions. Dioxins/furans have an emission limit in the EU Waste Incineration Directive (WID)[23]. However, I have not reviewed the appeal documents and previous ERM and Fichtner air quality impact assessment reports, which may provide an explanation for this.

4.3 If breaches of statutory air quality objectives or standards were measured post-commissioning, at that point in time, the EA would need to ensure that the operation of the incinerator is modified/curtailed such that emissions are reduced (or dispersion parameters improved), to ensure that compliance with the air quality standards and objectives is restored.

4.4 The potential adverse health effects of different size fractions of fine particulate matter is a subject of much research currently[24]. Focus is changing from PM_{10} to $PM_{2.5}$, i.e. the smaller particles which can penetrate deeper into the lungs. Particle size distribution measurements of the particulate emissions from the incinerator chimney are proposed as an Improvement Condition (IC) 2 of the EP. Therefore, particle size distribution measurements of the ambient particulate matter at sensitive locations where the plume is predicted to ground, would be advisable, to allow a correlation between the particle size distribution profiles between source (the chimney) and receptor (the monitoring location/s).

5. Meteorology

5.1 The Ashley paper identified different locations of worst-case impact as compared to the predictions of Fichtner; this can be explained in terms of the different meteorological dataset employed by Ashley and Fichtner. Ashley compiled the meteorological dataset for input to AERMOD's AERMET pre-processor in the correct manner, having due regard for missing hours, calms, and the needs for solar radiation readings.

5.2 It is accepted good-practice for a sensitivity analysis to be carried out on the modelled impacts by using more than 1 meteorological dataset, and also more than one meteorological year[25]. Ashley has carried out such a sensitivity analysis (2014-2015, and also 2013-2014; Quedgeley and Lansdown) in para. 3, Table 7. Though I have not reviewed the studies which were examined at the planning application stage or the Inquiry, I would be surprised if ERM and/or Fichtner had not modelled using more than one meteorological dataset and more than 1 observational year.

[22] http://www.pollutantdeposition.defra.gov.uk/ammonia_network
[23] http://ec.europa.eu/environment/archives/air/stationary/wid/legislation.htm
[24] https://www.gov.uk/government/publications/fine-particulate-matter-pm2-5-in-the-uk
[25] http://airshed.co.uk/pdf/EA%20requirements%20for%20dispersion%20modelling.pdf

5.3 Moreover, dispersion modelers are increasingly using site-specific meteorology, which is a synthesized dataset of wind speed, direction and the other required parameters (rather than direct measurements at an observing station such as Bristol). This is called National Weather Prediction (NWP) data, which can be purchased for any OS location in the UK[26] from the Met. Office, for direct input into dispersion models. The NWP data take into account the site-specific terrain and wind flows[27]. I am surprised that in view of the contentious nature of the Gloucestershire incinerator, it appears that Fichtner did not employ NWP meteorological data, in addition to (or in preference over) observational data from the Bristol weather station.

6. Conclusion

6.1 It is likely that the impact on air quality (and therefore nitrogen deposition) at Cotswold Beechwoods SAC (an area of rising terrain to the east of the incinerator) could be worse than that which the Inspector concluded based on the information that was available to him at the time of the Inquiry.

6.2 The dispersion models have been used to predict the contribution of the stack only; other sources of pollutants from the Gloucestershire incinerator have not been taken into account. This is relevant for fine particulates (PM_{10} and $PM_{2.5}$). Some of the waste materials produced at the site will be dust, e.g. incinerator bottom ash. Dust can also potentially be released from the tipping hall. In theory, a Dust Management Plan will seek to put in place measures to minimize these releases of particles. In practice, these sources could contribute to PM_{10} and $PM_{2.5}$ ambient concentrations beyond the site boundaries, depending on weather conditions. This opens the possibility for the dispersion modelling predictions for PM_{10} and $PM_{2.5}$ at sensitive locations to be under-estimates, as the dispersion modelling did not include these 'fugitive' sources in the dispersion calculations.

6.3 The conclusion of the Fichtner report was that the contribution of the incinerator stack to ground level NOx at all relevant locations would be less than 1% of the Critical Level (for airborne concentrations) and 1% of the Critical Load (for deposition). These conclusions were based on ADMS dispersion modelling results. Ashley's results using AERMOD show that the 1% benchmark would be exceeded at Cotswold Beechwood SAC.

6.4 Dispersion models are predictive tools. It is not possible to say which model (ADMS- or AERMOD) is the more accurate for this situation i.e. this incinerator at this location, for receptors at Cotswold Beechwood SAC). Only once the incinerator is up and running, with the emission characteristics exactly as set out in the EP, would it be possible to measure

[26] http://laqm.defra.gov.uk/documents/Where_do_errors_in_dispersion_modelling_commonly_arise_and_what_can_be_done_to_minimise_themv1.pdf
[27] http://www.umad.de/infos/cleanair13/pdf/full_227.pdf

the NOx concentrations at Cotswold Beechwood (and compare against the level before emissions commence from the chimney) and validate the results of the two dispersion models.

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