ASSESSING THE ODOUR IMPACT OF DISCHARGES TO AIR FROM THE TAUHARA STAGE TWO GEOTHERMAL POWER STATION

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ABSTRACT

The Tauhara Stage Two project is a large geothermal power station to be located approximately 4.5km to the east of Taupo. Air discharges from the plant include water vapour discharged from the three wet mechanical draft cooling towers and non-condensable gases (NCG), which are vented above the above the cooling towers.

From an air quality perspective, the primary concern is the potential odour nuisance effects associated with the discharge of hydrogen sulphide (H_2S). However, unlike health impact assessments where there are usually clear air quality concentration criteria limits, the assessment of odour is complicated due to its subjective nature. Defining appropriate H_2S odour criteria limits in geothermal area also need to account for existing H_2S background levels.

For this assessment, the relative effect of the plant was evaluated by comparing changes to the predicted frequency of an offensive or objectionable 'odour event' occurring at the nearby sensitive receptors with and without the project. Hourly average H_2S concentrations for the area surrounding the plant were predicted using the CALPUFF atmospheric dispersion model and a time-varying three dimensional meteorological grid.

The results of the dispersion modelling indicate that discharges from the proposed power station would be unlikely to result in a significant increase in the frequency or intensity of odour events at nearby sensitive receptors. The modelling also indicated that discharges of H_2S and other contaminant were unlikely to have a significant health risk to surrounding community.

1. INTRODUCTION

The proposed Contact Energy's Tauhara Stage II (Tau II) Geothermal Development Project is located approximately 4.5km to the east of Taupo, New Zealand. The power station will use a dual pressure steam condensing turbine technology to generate electricity. When fully developed, the power station will have a generation capacity of approximately 250MWe.

From an air quality perspective the primary concern is the associated with the discharge of hydrogen sulphide (H_2S) due to the potential odour nuisance effect. Observed adverse health effects associated with H_2S occur at concentrations which are many magnitudes higher than the pollutant's odour detection level (IPCS, 2003).

The power station is located in an area where emissions from natural geothermal features and existing geothermal power stations influence ambient H_2S levels. It is to be expected that ambient pollutant levels will increase when additional power stations are commissioned. As a consequence, the sensitivity of the receiving environment to H_2S odour nuisance effects varies from non-geothermal areas and odour guidelines levels developed for non-geothermal areas cannot be applied as assessment criteria.

Atmospheric dispersion models are routinely used to assess the effect of discharges to air from new emission sources. The advanced CALPUFF dispersion model was used to predict ground level H_2S concentrations at sensitive receptors located in the vicinity of the Tau II plant. The odour effect of discharges from the proposed power station was assessed in a relative manner by comparing predicted H_2S level for baseline emission scenario incorporating existing and planned power station discharges against a projected future emission scenario assuming the additional operation of the Tau II power station

Discharges were modelled for a 1-year simulation period using a time- and space- varying three-dimensional meteorological input file representative of local dispersion conditions.

1.2 Description of the receiving environment

The area surrounding the development is predominantly rural in character, although nearby land-use also includes the Taupo Motorsport Park, and an industrial area to the north-west. The most sensitive receptors are lifestyle blocks where people could potentially be exposed to discharges from the Tau II plant over extended periods of time. The closest of these dwelling is located approximately 1.5km to the west of the power station, on Centennial Drive. The locations of nearby dwelling are shown red dots in Figure 1.

Mt Tauhara is the most prominent landscape feature near the development. The mountain channels wind flows near the station in westerly and easterly direction.

A number of other geothermal power stations are also located in the area near the Tau II development. These power stations are also significant point sources of H_2S. The closest, the Tauhara Stage I binary plant, is located approach 3km to the west of the Tau II site. The Wairakei, Rotoakawa I and Ia, and Rotokawa II (Nga Awa Purua) power stations are located within 6.7km of the site.

During certain meteorological conditions discharges from these power stations contribute to H_2S levels at sensitive receptors located near the Tau II plant. The Rotokawa II power station, a 140MW power station, was under construction at time of the modelling assessment. Therefore the effect of discharges from the power station on existing H_2S levels could not be directly measured through ambient air monitoring. Dispersion modelling allows for effect of future discharge on background pollutant levels evaluated.

Other large power stations, either operating or granted resource consents, are located in Taupo district, but further away from the Tau II site. Previous dispersion modeling indicated that discharges from these plants would not be expected to have a significant effect on H_2S levels near the Tau II site (AES, 2007).

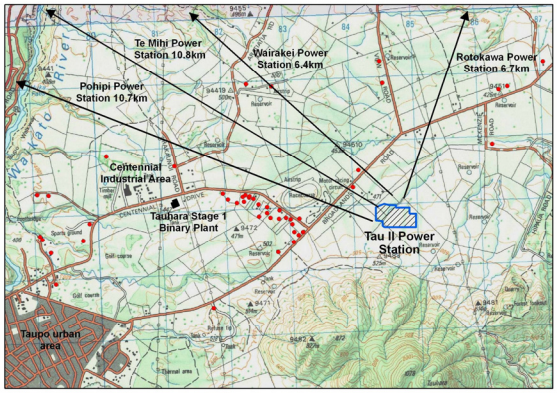

Figure 1. Location of Tau II power station and nearby sensitive receptors

2. ODOUR ASSESSMENT CRITERIA

Due to the subjective nature of odour, identifying a concentration limit at which a pollutant has an odour nuisance effect is often complicated. The Ministry for the Environment odour modelling guidelines defines both a 1-hour average guideline concentration limit (in odour units) and a level of compliance (MfE, 2003).[1] Dispersion modelling odour guideline concentration limits are usually derived from measured odour detection thresholds under laboratory test conditions and therefore take no account of existing background levels.

The application of such modelling guidelines to geothermal areas is often problematic as H_2S is commonly present in the air. People living in a geothermal area can often be desensitised to H_2S and therefore do not detect an odour at a level at which people who have not been desensitised may experience a definite or strong odour.

Also, the perception of H_2S odours can vary depending on the emission source. People who commonly experience H_2S odours in geothermal areas may not be offended by them as readily as people experiencing the same odour at the same intensity elsewhere, where it may be associated with clearly offensive odour sources, such as emissions from waste water treatment plants.

The Ministry for the Environment's Ambient Air Quality Guidelines (AAQG) defines a 1-hour average guideline limit of 7µg/m^3 for H_2S for the prevention of an odour annoyance effects (MfE, 2002). However, the AAQG notes that the guideline limit may not be suitable in geothermal areas where natural background concentration of H_2S may already be above the limit due to emissions from natural geothermal activities.

Ambient air H_2S monitoring was conducted by Contact Energy at seven monitoring sites within approximately 5km of the Tau II power station site. Maximum 1-hour concentrations recorded at sites located near the Centennial Drive life-style blocks ranged between 32 -103µg/m^3, or 4.6 – 14.7 times higher than AAQG (AES, 2009). The monitoring also show existing H_2S levels varied within a relatively small area. By comparison Rotorua 1-hour concentrations can be in excess of 4000µg/m^3 (Bay of Plenty Regional Council, 2012).

Within New Zealand a 1-hour odour guideline of 70µg/m^3 has been used as a guideline value for the assessing of discharges from geothermal power station projects (AES, 2009; Endpoint, 2007; Endpoint, 2009). However, for recent assessment this guideline limit has not been used an absolute threshold, but rather a level above which there is the potential for odour nuisance issues to arise and further assessment. Since the guideline is not applied as a stringent limit the variability of existing background levels and environmental sensitivity is able to be factored into assessments.

The flexible application of the guidelines to predicted concentrations also helps to accounts for the relative insensitivity of odour intensity (i.e. strength of the odour perceived) to changes in odour concentration. A noticeable change in odour intensity usually only occurs when there is a significant increase odour concentration. The relationship is commonly modeled using a power law expression (e.g. Stevens Law).

A practicable approach to dispersion modeling assessment of odour discharges is determine whether discharges are likely to increase the intensity of odour level experience or the frequency they are likely to occur.

3. ASSESSMENT METHODOLOGY

3.1 Dispersion modelling

Ground level concentrations were predicted using the CALPUFF (v6.262) dispersion model. The model is considered to be an advanced dispersion model. The primary advantage of using CALPUFF over simpler models is the channeling effects that terrain has on local wind flows and influence of that changes land-use have on dispersion parameters can be simulated using a three dimensional meteorological grid. The model is therefore suitable for simulating the dispersion of pollutant in large modelling domains, and near complex terrain features.

For the assessment a meteorological input file was constructed using the associated meteorological model CALMET (v6.326). Meteorological model grid points were defined every 250m in a 21km x 23km modelling domain. Surface meteorological input requirements where derived from four meteorological monitoring stations. The closest located approximately 2.4km from the site which was established for the air quality assessment. The model's upper air requirements were derived from the outputs of a second meteorological model, TAPM (v4).

[1] The MfE (2003) recommends the use of the 99.5 percentile 1-hour average concentration as the 'baseline' percentile to assess compliance (i.e. the 44th highest concentration predicted at a receptor over a standard year), although also using the more conservative 99.9 percentile concentration (9th highest concentration over a standard year) to assist in the evaluation of model results.

3.2 Modelled Discharges

3.2.1 Tau II power station discharges

The main discharge of H_2S and other non-condensable gases (NCGs) will be from vents located above the three wet mechanical-draft cooling towers. Once emitted the NCGs become entrained in the large volume of warm moist cooling air discharged through the fan units and disperse downwind with the cooling tower emission plume. The buoyancy of the cooling tower's discharge improving the pollutant disperse rate.

Due to the proximity of each of the cooling tower fan units, the combined heat release from all of the cooling fan discharges enhance the buoyancy of the emitted emission plume as the plumes merge. The effect is to improve the dispersion when compared to discharges from a single fan unit in isolation.

Due to the merging effect, the cooling tower fan units cannot be accurately represented as series of individual point emission sources. Buoyant line sources were considered to be a more appropriate representation of discharge. The source type is capable of simulating the effect that merging emission plumes of multiple emission sources in lines have on plume rise. Plume rise predictions varying with respect to the incident wind direction and wind speed.

Another advantage of using buoyant line sources are that plume rise predictions also take into consideration the merging of emission plumes from different cooling towers, and therefore the effect that different plant configurations have on pollutant dispersion.

Modelled cooling tower discharge temperature and velocity were calculated on an hourly basis taking account of changes in inlet air temperature and relative humidity. An iterative solver was used to calculate discharges parameters assuming a constant heat rejection rate and air intake rate for the simulation period.

When fully developed, the power station's maximum H_2S emission rate is estimated to be 389kg/hr, although higher emissions may occur during an initial transient period after commissioning due to effects of pressure draw down in the Tauhara geothermal reservoir. At the Wairakei power station H_2S levels were observed to increase by a factor of 1.4 -2.3 from pre-production levels over an initial 10 year period. For a similar increase at the Tauhara Stage II power station, the maximum emission rate would be 893kg/hr. However such as increase in emission rates was considered to be unlikely as the Tauhara geothermal reservoir had already been affected by substantial pressure draw-down as a result of Wairakei production (AES, 2009).

Both the effect associated with the expected discharge rate of 389kg/hr and the worst case transient discharge rate of 893kg/hr were assessed.

Smaller discharges of steam and NCGs will also occur from other source at the power station and in steam field. However, these discharges would be negligible in comparison to those discharged from the cooling towers.

3.2.2 Discharges from other geothermal power stations

Discharges from four other geothermal power stations were also incorporated into the model. Estimates of maximum H_2S emission rates for each of them are shown in Table 1. The dispersion modelling assessment assumed that maximum discharge rates occurred continuously throughout the simulation period.

The discharges of H_2S from vents over mechanical draft cooling tower and air condenser unit where modelled as buoyant line sources in a similar manner to the Tau II power station. Discharges from the Wairakei power station, where cooling is provided with river water and there are no cooling towers, were represented as stack emission sources.

Table 1: Summary of modelled H2S emission rates

Power Station	H2S Emission Rates (kg/hr)
Tauhara Stage II	389*
Tauhara Stage I	60
Rorokawa I and Ia	148
Rotokawa II	580
Wairakei	34

* Transient emission rates of up to 893 kg/hr

3.0 RESULTS

Predicted 99.9 percentile[2] 1-hour average H_2S concentrations contour are shown in shown Figure 2. The figure shows both the predicted H_2S concentrations associated with discharges from existing and consented geothermal power stations (i.e. the baseline scenario) and cumulative concentration associated with discharges from Tau II and the geothermal power stations included in the baseline scenario. Predicted cumulative concentrations assume a Tau II power station discharge rate of 389kg/hr. The green concentration contour line in the figure corresponds to the odour guideline concentration of 70µg/m^3 for geothermal areas.

The baseline scenario shows areas near the Tau II development where peak concentration would be expected to exceed the 70µg/m^3 odour guidelines prior to the commissioning of the Tau II power station. At the life-style blocks located on the Centennial Drive 99.9 percentile 1-hour average concentration are predicted to range between 50-70µg/m^3.

The areas of high concentrations predicted to the north-west of Tau II and on the northern face of Mt Tauhara are primarily due to the power station's emission plumes impinging on the high ground level elevations in these locations. Peak concentrations are predicted to occur during stable nighttime atmospheric conditions. The relative difference in ground level elevations of the terrain (at the base of Mt Tauhara the terrain elevations are approximately 480-500m above sea-level) and the Rotokawa and Wairakei power station (between approximately 330-340m above sea level) a contributing factor.

[2] Dispersion modelling conventions treats the 99.9 percentile concentration as being representative of the likely maximum 1-hour concentration to occur (MfE, 2004).

A comparison of the baseline scenario concentration predictions against the cumulative concentrations incorporating discharges from the Tau II plant shows only small increases in predicted concentration levels. The contribution from Tau II station is most clearly observed in the immediate vicinity of the plant's cooling towers. The higher ground level elevation of the Tau II site (approximately 460m above sea level) assists in the dispersion of the pollutants.

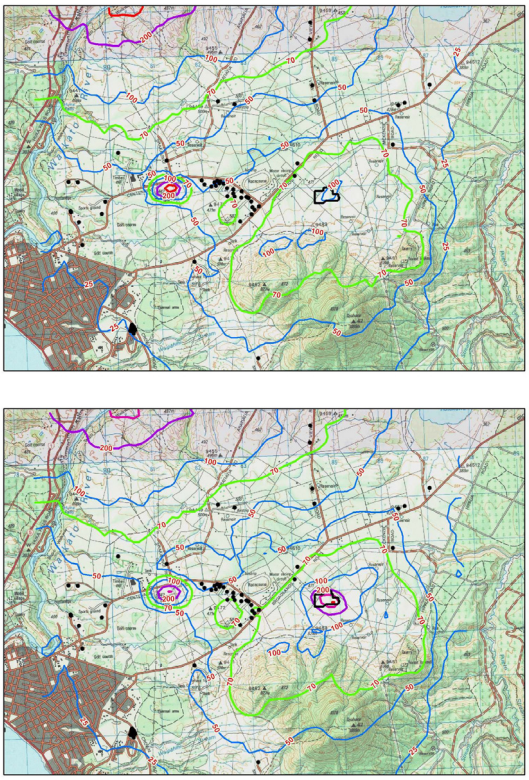

Figure 2. Predicted 99.9 percentile 1-hour average H_2S concentrations ($\mu g/m^3$) associated with discharges from other geothermal power stations (top), and cumulative discharges from all future emission sources including Tau II (bottom)

The relative effect of the discharges from the Tau II on the frequency distribution of predicted 1-hour average H_2S at the most affected life-style block is shown in Figure 3. The figure shows the cumulative effect of discharges from the Tau II would not have a significant effect on baseline H_2S levels. Predicted 99.9 percentile 1-hour concentration are predicted to increase slightly from $66\mu g/m^3$ to $74\mu g/m^3$, and the number of exceedances of the $70\mu g/m^3$ odour guideline concentration increasing from 8 hours per year to 10 per year. The results of the modelling indicate there would be little increase in perceived intensity or frequency of odour events.

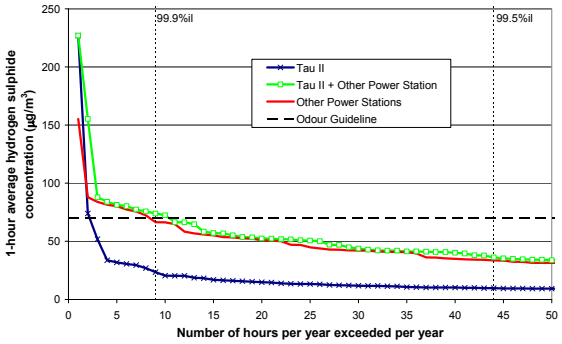

Figure 3. Predicted frequency distribution of 1-hour H_2S concentrations at Centennial Drive life-style block

The potential contribution from Tau II to ambient pollutant level is more evident when discharge rates are assumed to be equivalent to the estimated transient emission rate of 893kg/hr. Figure 4 shows the predicted frequency distribution of 1-hour H_2S concentration for the transient emission scenario at the most affected life-style block. The 99.9 percentile 1-hour average concentration is predicted to increase to $80\mu g/m^3$ from $66\mu g/m^3$. However, the 21% increase in H_2S concentration is representative of only a slight increase in odour intensity. The frequency the $70\mu g/m^3$ odour guideline is predicted to be exceeded increase from 8 hours per year for the baseline to 14 hours, a 75% increase. The results represent an extra 1-hour exceedance of the guideline every 2 months.

The results similarly suggest even if emission rates were equivalent to the estimated transient limit the relative odour nuisance effect would not be substantially different from that associated with consent emission sources.

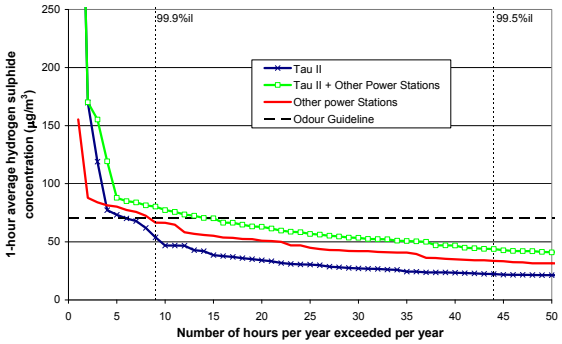

Figure 3. Predicted frequency distribution of 1-hour H_2S concentrations at Centennial Drive life-style block based on transient emission rates

4. CONCLUSION

Charactering the effect of H_2S discharges in geothermal area is complicated by the presence of background H_2S associated with either natural geothermal features or other anthropogenic emission sources. Identifying a guideline limit at which odour has an adverse effect is complex due to the variability of the H_2S levels and the sensitivity of the receiving environment.

Dispersion modelling can provide a useful tool in assessing the effect of odour particularly when the effect of the pre and post development discharges can be simulated and a comparative assessment of the frequency distribution of predicted concentrations can be undertaken. The assessment of Tau II power station indicated that emission from the plant were unlikely to have a significant additional odour nuisance effect compared to existing and consented discharges.

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