Before the Independent Commissioner

Under	the Resource Management Act 1991
In the matter of	an application by Tegel Foods Limited for resource consent for the discharge of contaminants to air at 112 Carmen Road, Hornby, Christchurch

Statement of Evidence of Roger Steven Cudmore

28 July 2020

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Introduction

1 My full name is Roger Steven Cudmore. I am a Principal and director of Golder Associates (NZ) Limited (Golder). I graduated from the University of Canterbury with a degree in Chemical Engineering awarded with honours in 1986.

2 I have worked as a consultant in air quality management for 28 years, working for Industry, Regional Councils and the Ministry for the Environment (MfE). Over this time, I have had significant involvement in the development of national guideline documents for air quality management including the MfE ambient air quality guidelines (AAQGs) for New Zealand. This process commenced during the mid-1990s and led to our current MfE AAQGs (MfE, May 2002). I took part in MfE run workshops from 2000 to 2004 for developing various good practice guidelines and for establishing the Resource Management (National Environmental Standards for Air Quality) Regulations (NESAQ) (MfE, 2004). In 2008, I co-authored a review of the World Health Organisation (WHO) guideline for sulfur dioxide (SO2) (Kelly & Cudmore, 2008) and I have co-authored reports (MfE, August 2002) that were the basis for the current MfE Odour Management Guideline (MfE, 2003).

3 I have designed and commissioned of biofilters for New Zealand industry since 1997. Examples include:

(a) AFFCO Wanganui: new bed for rendering sources

(b) Bush Road, Mosgiel: new raised bed for onion cooking odour

(c) Hawkes Bay Protein: two new bed for rendering sources

(d) Alliance Group, Levin: new bed for rendering and wastewater sources

(e) Taranaki By-Products, Hawera: new rending biofilters

(f) Lowe Corp, Hawera: new bed for rendering sources

(g) Fonterra Clandeboye: new bed for wastewater tanks

(h) Tuakau Proteins: two new beds for rendering sources

(i) Silver Fern Farms, Fairton & Belfast: two new beds for fellmongery and rendering sources.

(j) PGG Wrightson, Tuakau: new bed for wastewater tank.

4 In addition to the above, I have undertaken numerous reviews of industrial/municipal biofilters throughout New Zealand and advised on upgrades (similar to the work described below for Tegel) over the last two decades and I am still very active in this field.

5 I co-authored a chapter on rendering industry biofilters in the publication: *Biotechnology for Odor and Air Pollution Control* (2005): Shareefdeen, Zarook and Ajay Singh., Springer.

6 In preparing this statement of evidence I have considered the following documents:

(a) The Assessment of Environmental Effects (**AEE**) accompanying the resource consent application;

(b) The section 42A report;

(c) Evidence of Tony Atkinson; and

(d) Evidence of Jason Pene.

7 I was previously engaged by Tegel to visit the Hornby site in May 2019 and advised on their draft rendering plant biofilter conditions and operation. I have since liaised with Tegel's Hornby based plant engineer (Mr Jason Lane), provided formal advice on biofilter design matters, as well as having reviewed the new biofilter during installation (site visit of 1 May 2020) and post commissioning (2 July 2020). Subsequent to these visits, I have prepared Golder letter reports including:

(a) Existing biofilter review, 31 May 2019.

(b) Biofilter review, 18 May 2018.

(c) Review of new biofilter, 14 July 2020.

Code of Conduct for Expert Witnesses

8 While this is not a hearing before the Environment Court, I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2014. I have complied with it in preparing this evidence and I agree to comply with it in presenting evidence at this hearing. The evidence that I give is within my area of expertise except where I state that my evidence is given in reliance on another person's evidence. I have considered all material facts that are known to me that might alter or detract from the opinions that I express in this evidence.

Scope of Evidence

9 This evidence addresses:

(a) Bio-filter design and operation

(b) Response to matters raised in the s42A report relating to the bio-filter

(c) Proposed conditions of consent relating to the bio-filter

Biofilter Design & Operation

10 Biofilters are probably the most commonly used technology for removing odorous compounds from rendering process air streams. Process air streams containing odorous organic compounds are fed through biofilter media (typically bark that supports a film of bacteria and soil substrate), which absorbs the compounds onto the media, allowing microbes the opportunity to metabolise and respire mainly water vapour and CO_2, and generate other by-products including ammonia (forming some dissolved ammonium ions) and sulphates. The overall result is the removal of unpleasant processing odours and the discharge of an air stream from the biofilter bed with a low-level bark/musty type odour. This latter odour character usually dissipates to a non-detectable level with 10 to 20 metres of the bed.

11 Therefore, the successful operation of a biofilter for treating odours, requires the maintenance of an even porous media structure, which enables effective absorption of odorous compounds and supports a healthy population of aerobic bacteria, which can metabolise these compounds. As a minimum, this requires an appropriate size range and quantify of bark, or other media, a supply of nutrients (from the odour itself for rendering plant emissions), maintenance of sufficient moisture and pH control (to avoid excessive acidic build up).

12 Biofilter bed structures are highly variable, as they can be successfully operated within an enclosed tank, within the ground, or within an above ground (raised garden type) structure. They all have one thing in common, that is the raw air to be treated is supplied underneath the bed and flows up through the bed media (which absorbs and breaks down odours) and then exits the biofilter via its upper surface.

13 Whilst the concept of biofilters and their design can appear straightforward, I am well aware that in both New Zealand and overseas, there has been actions against bed designers, mainly as a result of excessive water inundation, or bed structural failures. This reinforces the need for sound design and operational practice for biofilters based on science and proven field experience. These days, operational and design aspects are well accounted for in resource consent conditions.

Design features of the Tegel Biofilter

14 The new biofilter servicing the protein recovery plant (**PRP**) and wastewater tank, which was recently installed by Tegel, is an above ground raised-bed type structure, including a concrete base, timber walls and an open plenum system (underneath and supporting the bed) for distributing inlet raw air under the 1.5 m deep layer of soil-bark media. This design is a significant improvement upon the in-ground soil-bark biofilter previously operated at the site. The former bed design was more prone to water inundation, air channelling and excessive air pressure drop across the media. Whilst it had a much high empty bed residence time

(EBRT) than the new biofilter, the reality is that the actual air residence time in this older bed would have been vastly lower than the new bed is achieving.

15 A photograph of the new Tegel biofilter is shown below – this shows the timber wall, bark media surface, overhead watering system and outer wall of the nearby rendering plant building.

Figure 1: Photograph of Tegel Biofilter (7 July 2020).

16 Key design features associated with the new Tegel biofilter (shown above) are summarised as follows:

(a) Bed area and depth: 25 m x 37 m x 1.5 m (media volume of 1388 m^3);

(b) Design flow and associated air loading rate are respectively, 12.6 m^3/s and 33 $m^3_{air}/hr/m^3_{media}$ (equivalent to 110 seconds empty bed residence time);

(c) Inlet air is approximately a 70:30 mix of building air to warm/humid process air;

(d) Bark pre-mixed with 5 vol % top-soil and ~0.6 kg lime/m^3_{bark};

(e) Air distribution system: under bed air plenum;

(f) Sloping concrete floor and drainage system; and

(g) Over-head water misting system.

17 The raw air loading rate value of 33 $m^3_{air}/hr/m^3_{media}$ is within the criteria I have recommended for many other rendering plant biofilters when treating 100% concentrated source air streams derived from hot rendering process equipment (including highly odorous dryer exhaust non condensable gases). The Tegel biofilter is receiving an air stream that is largely made up of PRP building air, which has a much lower odour load, as well as a lower loading of non-odorous fatty volatile compounds. As such the new bed is capable of treating the air stream at higher loads of up to 45 $m^3_{air}/hr/m^3_{media}$**.** At this maximum loading rate, the bed containing 1388 m^3 of media, is capable of treating up to 17 m^3/s of rendering/wastewater plant air (nb: the bed currently receives 12.6 m^3/s), while efficiently removing all rendering type odours from the raw inlet stream.

18 The 5 vol.% top-soil (i.e. the volume of mixed in soil is 5 % of the bark volume) is within the maximum of 10 vol.% I have recommended for a number of rendering plant biofilters that have work successfully. Around 20 years ago it was more common to see much higher levels of soil added to the raw bark mix, but from experience this led to significant backpressure problems. These days, I recommend only 5 vol.% of top-soil to be pre-mixed into the raw bark and in combination with calcined lime (hydrated lime) at 0.5 – 0.6 kg/m^3 bark. The Tegel biofilter has lime pre-mixed at the higher end of this range.

19 All of the above guidelines for air loading rates, soil and lime pre-mixing per unit volume of bark, are related to the initial pre-mixed bark size distribution. There are no accepted standards in this regard, except that bark particles cannot be too small (to avoid rapid mineralisation and high pressures), or too large (to avoid poor treatment efficiency). From experience, a graded bark blend is ideal where the majority of individual bark pieces are within 10mm to 30 mm size. Having some bark which is finer < 10 mm, or coarse > 30 mm, is effective, as long as these fractions are in the order of few percent of the total bark blend volume. Having long stringy pieces of bark is also acceptable, but it these pieces break down and mineralise/compost relatively quickly. This causes the pore spaces to fill in between bark and increases the back pressure the media creates for a specific air loading rate.

20 The bark blend employed for the new Tegel bed consists mostly of 20mm to 40mm nuggets (I observed the final mixture at the site in early July 2020), with a minor portion of a more flatter shaped bark blend with a similar size range, which includes a minor portion of 50 mm or greater stringy pieces of bark. I expect this blend (with added topsoil and lime) will achieve very good rendering odour reduction, and a stable media structure for a number of years.

21 Another key design feature of the new Tegel biofilter is the air distribution plenum. This is enabled by installing the bed on a reinforced concrete floor and allows air to distribute into a 100 mm headspace below the biofilter media. Such systems

avoid the problems of hole blockages, or water inundation that can sometimes lead to uneven air flow distribution through the bed, when using drainage pipe, or drilled PVC laterals for air distribution.

22 The concrete floor design is also sloped to ensure effective drainage of bed leachate, rainwater and condensed water associated with inlet air humidification. The floor slopes to corner and drains into an external corner sump via a water head within the sump.

23 The installation of an over-head high pressure water misting system for applying water to the biofilter bed surface is also an important design feature. This will ensure a more even distribution of irrigation water to the bed, which is important, as lower pressure watering systems are one of the causes of irreversible air channelling within some biofilter beds.

24 Another design feature is the use of an inlet air humidification system in addition the misting irrigation system. This is planned for installation prior to the 2020/2021 summer. I have provided Tegel with advice on droplet size of around 10 microns (µm) and estimated maximum water demands for a fogging system (in the order of 1000 kg/hr). In practice, a high pressure drop water fogging system could be used to humidify the biofilter inlet air stream on hot northwest days to levels in the order of 80% relatively humidity. This will take watering load off the surface misting system for maintenance of bed moisture levels.

Operating parameters

25 In addition to the key design features I have discussed, there is also key operational parameters which are summarised in Table 1 attached to this evidence. I can discuss these further as requested.

26 The minimum media temperature is not common, but for airflows dominated by building air, this limit is useful to impose during the more extreme cold weather, when building air extraction rates would ideally be reduced to avoid the biofilter bed becoming too cold for efficient odour removal.

Response to matters raised in Canterbury Regional Council's s42A reports

27 I have reviewed relevant sections of the s42A reports which relate specifically to the Tegel biofilter (provided by Mr McCauley and Mr Irvine). Mr Irvine’s report raises some concerns (paragraphs 16 to 23) regarding the maximum design air loading rate for the new biofilter (or in other words, the empty bed residence time), the coarseness of the media, and the level of fines within the media to compensate the higher loading rate.

28 It is true the new biofilter has a much lower empty bed residence time (or in other terms, a much higher air loading rate) than the pre-existing bed. But the pre-existing bed would have had, without any doubt, a much lower actual air residence time and vastly lower odour removal performance than the new biofilter. This is because the old design was prone to excessive air channelling, a less effective air distribution system and had an excessive fines content within its media.

29 I have discussed the design air loading rate for the new bed in paragraph 17 and confirm it is well within the loading rate at which the bed can effectively eliminate rendering odours from the inlet air stream.

30 The new bed media is coarser than the old bed media and this is an important change. This new biofilter media is not too coarse, but rather it could be more coarse in my view, and have no bark fines at all.

31 I should clarify that when I refer to fines, I am only referring the level of bark fines within new bark media, when this is being considered for a new biofilter bed (or replenishing a spent existing bed). In this respect, I specify how much barks fines (> 2 mm) can be tolerated in the new media, but there is no need to transfer this into a condition for an operational bed. Instead the state of the gradually composting biofilter media (and gradual production of fines over time) is monitored via the media pressure drop.

32 Also, to be clear, it is common to specify the maximum level of topsoil to be added to new bark, before replacing biofilter media (i.e. < 10 % of the raw bark volume). Once added to the bed, this top-soil fraction would form part of the > 2 mm size fraction, but again there is little use in specifying this as limit within an operation bed. So, it is important to distinguish between topsoil (as well as lime) which is added to new bark, and "bark fines" which are the unwanted size fraction within new graded bark (prior to mixing). It is important to restrict the latter via a maximum specified limit, for which bark supply needs to meet.

33 Bark fines within the bark supply create more problems than benefits to long term odour treatment performance – they mineralise and tend to block voids between the larger nuggets/pieces of bark. It is not cost effective to completely remove all these fines from the raw bark, and from experience, up to a few percent of fines can be tolerated. The ideal is to have zero fines and graded bark mostly within the 10 mm to 30 mm size range and up to 40 mm (and a mean diameter of around 20 to 30 mm).

34 Fines are also not important for moisture management of media, the bark nuggets themselves are the key to maintaining a supply of moisture to the outer biofilm, which they support and the damp bark pieces provide inertia against rapid drying out of these films. By comparison, the fines in the bed are prone to dry out quickly, or otherwise plug up the porous structure of the media, decreasing the actual bed

residence times, reducing the odour treatment efficiency and increasing back pressure on the fan.

35 In paragraphs 25 to 27 of Mr Irvine's report, various biofilter operational conditions are recommended with respect to temperature, pH, pressure drops and moisture management. I recommend similar parameters to these, but different ranges in most cases. I will explain these differences when discussing proposed conditions below.

Proposed conditions of consent

36 The applicant has proposed the conditions in relation to the biofilter, which are listed below. I have advised on the wording of these conditions and limits. These conditions are a revision of those proposed as Condition 19, that are attached to Mr Irvine's report.

Proposed Condition 19 (CRC194459)

The biofilter shall be operated and maintained such that the following parameters are complied with:

a. A minimum media volume of 1,388 cubic metres;

b. A maximum air loading rate of 45 m^3_{air}/hr/m^3_{media};

c. The addition of top-soil to fresh bark media shall be a maximum of 10 vol. percent;

d. Inlet air to the Biofilter shall be:

i. ≤35 °C for more than 95 % time;

ii. ≤40 °C for more than 99 % time; and

iii. A maximum inlet temperature of 45 degrees Celsius;

e. A maximum pressure drop across the biofilter media and air supply plenum of 150 millimetres water gauge (except during several days following high precipitation events, when a maximum pressure drop of 200 millimetres water gauge applies);

f. The media pH shall be;

i. pH 5 or higher at <600 mm from the top of the media surface; and

ii. pH 3.5 or higher at >600 mm from the top of the media surface;

g. A moisture content between 50 percent and 65 percent by weight, except during and following periods of high precipitation (several days).

37 For condition 19 (a) I have reduced the specified volume of bark, so this value corresponds with the bed dimensions (i.e. 25 m x 37 m x 1.5 m depth of soil-bark media)

38 Condition 19 (b) reflects the upper limit to bed loading of 45 $m^3_{air}/hr/m^3_{media}$, as discussed in Paragraph 17 of this evidence. This equates to an empty bed residence time of 80 seconds. This limit could be specified as either an EBRT (s), or bed loading rate ($m^3_{air}/hr/m^3_{media}$). Both effectively dedicate the volume of soil-bark media needed per unit flow of air to be treated.

39 Condition 19 (c) is set to ensure that excessive soil is not mixed with new bark prior to installation. The upper limit of 10 vol.% is a significant reduction from the 20% and higher values used in past decades, but limiting to 10 vol.% ensures the bark is coated adequately with soil, while not causing some of the interstitial cavities to be filled in and blocked.

40 Condition 19 (d) has been a standard condition applied to rendering plant biofilters for the last decade or more. It will be relatively easy to meet compliance for Tegel's biofilter to achieve in this instance. This is because of the high portion of building air that makes up the raw air stream (~70%). However, in Attachment A, I provide a guideline for the management plan regarding minimum media temperature to achieve during cold ambient conditions. The building air extraction rate can be trimmed downwards during extreme cold conditions to help maintain the bed at 15 °C, or higher. These rare occasions and response can be effectively managed via a management plan and use of variable speed drive on the biofilter fan motor.

41 Condition 19 (e) above increases the bed pressure drop maximum limit recommended by Mr Irvine from 100 mm water gauge to 150 mm water gauge and 200 mm water gauge for high rainfall/snowfall events. Following heavy rainfall events, back pressures across the media can rise above normal levels for several days. I expect both the 100 mm water gauge, or the alternative higher limit of 150 mm water gauge could be readily met when measured from the plenum chamber head space. However, I have not assessed the specific pressure drop that is likely to occur across the plenum itself, so have recommended the higher value of 150 mm water gauge for pressure drop across the plenum and the soil-bark as a maximum limit.

42 Condition 19 (f) has become a more common condition applied to rendering plant biofilters in recent years. The conditions for pH proposed by Mr Irvine, or similar were once more common, but have been revised due the tendency for the soil-bark media to become more acidic in the bottom layers and for rendering odours to still be eliminated despite moderately acidic pH values (down to 3.5) within the lower layers of the bed. Lime addition to an operating bed can help achieve the limits I have proposed, but typically this measure struggles to allow the entire bed to routinely operate above pH 5.

43 Condition 19 (f) is another common condition, but the limits specified within consents are variable and include those recommended by Mr Irvine. I recommend

the tighter moisture content range, as the limits of 30 wt% and 70 wt% are respectively too close (in my view) to conditions of excessive dryness (resulting in minimal biological activity), or excessive moisture leading to high back pressures and rapid degradation of the bed media. That said, moisture levels specified within consent conditions should allow for values above 65 wt.% whilst a bed dries out following heavy rainfall or snow events. It is impractical for beds to operate within 65 wt.% moisture during and immediately after such events.

44 I again refer the Commissioners to the Table 1 contained within Attachment A to this evidence. This provides recommended operational guidelines for soil-bed biofilters. Not all of these guidelines need to be listed as a condition of consent in my view, but they could be adopted as guidelines within a management plan.

45 Table 1 in Attachment A also lists methods on monitoring and frequency. These are generally similar to the recommendations made within Mr Irvine's report (his paragraph 20). There are however some material differences between Table 1 and Mr Irvine's paragraph 20. Firstly, I recommend continuous instrumental monitoring and logging of the bed pressure drop, and the biofilter inlet air humidity and temperature.

46 I also consider that manual sampling/testing of the media for moisture and pH can be less frequent – that is 2-month and 3-month intervals, respectively. The latter changes very slowly over time, whereas the former is best monitored every week and via qualitative inspections. It is relatively easy to assess bark media dampness and determine if it is too dry, or is excessive (i.e. exhibiting free moisture). Monthly gravimetric tests for moisture content monitoring is recommended by Mr Irvine. I consider this frequency can be reduced to bi-monthly sampling/moisture testing and including a comparison of results to the continuous moisture probe data. This would enable effective bed moisture management and demonstrating compliance.

Conclusion

47 I conclude that the new Tegel biofilter should be able to effectively eliminate rendering type odours from an inlet airstream up to 17 m^3/s, given the new bed is operated within limits recommended in paragraph 36 of this evidence.

Roger Cudmore
28 July 2020

Table 1: Biofilter operating parameters and monitoring.

Component	Guideline values	Method & frequency	Location
Inlet air stream			
Pressure	< 150 mm water gauge	Instrumental gauge ***Continuous and logged***	Head space of inlet air plenum chamber
Temperature & Relative Humidity (%)	Monitor trends and set values in management plan	Instrumental ***Continuous and logged***	Biofilter fan discharge duct
Maximum Air loading rate	35 to 45 m^3_{air}/hr per m^3_{media}	Pitot tube* ***Annual***	As above
Media			

Component	Guideline values	Method & frequency	Location
Moisture content	50 wt. % to 65 wt. % normal range > 65% wt.% following heavy rainfall/snow events	Oven drying at 100°C ***2-Monthly*** *(use results to calibrate continuous probes)*	Anywhere within two quadrants of the bed and at two depths including >200 mm and >600 mm (4 samples)
Moisture content	Bark looks and feels damp but neither dry nor sodden	*Qualitative* ***Weekly***	Any where on the bed surface
Media temperature	> 15 °C	Instrumental ***Continuous and logged***	Media > 200 mm

Component	Guideline values	Method & frequency	Location
pH	pH 5‡ or higher (<600 mm deep) pH 3.5‡or higher (>600 mm deep)	Soil pH ## ***3-Monthly***	As above
Organic carbon:nitrogen ratio	< 50:1	*Combustion elemental analyser: Thermal conductivity detection.* ***Biannually (2 Years)***	As above

**IS0 10780 Measurement of Velocity and Flow Rate, or equivalent method. NB: 2 access ports to be installed for sampling at 90º (side and top of ducts).*

Sub-sample 10 grams of media and add 50 ml de-ionised water. Stir for 60 seconds and allow solids to settle. Measure pH of clarified water after 3 hours of settling time)