STUDIES ON ODOUR EMISSIONS AND THEIR IMPACTS

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THE PROBLEM

Odour impacts from broiler farms are an ongoing issue. Not all farms are responsible for causing impacts but environmental regulators continue to receive enough complaints that the whole industry is placed under close scrutiny. Urban encroachment is frequently touted as a primary cause for odour impacts, but there are some relatively new farms that also cause impacts, and these farms have been built in agricultural areas, have undergone rigorous odour assessment (including dispersion modelling), and have relatively large separation distances between the farm and neighbours. So why do some farms cause odour impacts while many others do not?

Detailed information about odour emissions and control strategies for meat chicken farms has previously been presented at PIX (Dunlop *et al.*, 2008a; McGahan *et al.*, 2002). Information in these papers is still correct and current for the most part, but in recent years, additional research has been conducted on some of the topics discussed in those papers. In general, the best way to prevent odour impacts is still with good farm management practices and maintaining appropriate buffer distances (McGahan and Tucker, 2003).

All broiler sheds smell, but these smells do not necessarily cause odour impacts. *Odour impacts* occur when the smell from a broiler shed affects the quality of life of a receptor leading to psychological stress and possibly physical symptoms such as insomnia and loss of appetite (Belgiorno *et al.*, 2013; Radon *et al.*, 2004).

Odour impacts require consideration of more than just odour emissions from the sheds. They require consideration of how the odour is being transported to the receptor and how they perceive the odour. Of these, the most effective way to reduce impacts is to prevent odours being produced or leaving the shed.

From a research perspective, developing odour impact mitigation strategies is extremely challenging because the causes for the impacts are frequently very specific. Odour impacts may be the result of excess odour resulting from a feature or management practice within a shed or poor odour dispersion caused by specific terrain features or wind patterns that only exists at the farm in question. There are no 'one-size-fits-all' solutions for odour impacts, and trying to apply general solutions will only result in disappointment.

The process for applying an odour impact mitigation strategy is to:

1. identify the specific cause for the odour impacts that are occurring;
2. understand the fundamental principles of why the things you identify are causing odour impacts;
3. develop a strategy, timeframe for application and operating protocols;
4. apply the strategy;

   (note: the only way to test the effectiveness of an odour mitigation strategy is to apply it at full scale and monitor odour complaints….a lower risk option that might be useful is to test the strategy by applying it to one or two sheds first. If you can't tell the difference then there probably isn't any.)
5. Monitor the results – have complaints reduced or ceased? If not, look for another cause and develop another strategy accordingly.

You may wish to seek some professional guidance during several stages of this process.

Regardless of the strategy, there will be costs associated with reducing odour impacts—capital, operating, energy, labour, consultants, reduced production costs—because broiler sheds are designed and managed for production and energy efficiency, not minimal odour.

This paper can't possibly cover all the specifics associated with odour mitigation strategies. Only some fundamental concepts relating to the causes of odour impacts are discussed. If you find yourself needing to mitigate odour impacts, consider seeking help from other growers, processor staff, researchers or consultants.

SOME COMPLEX SCIENTIFIC STUFF

HOW ODOUR EMISSIONS FROM BROILER SHEDS CONTRIBUTE TO ODOUR IMPACTS

The majority of odour from a broiler shed is produced in the litter, but some will also be from the birds. Odours are released from freshly deposited manure and also from decomposition within the litter. Table 1 lists a selection of the dozens of odorous compounds which have been identified in broiler shed air. It also provides a description of how the individual odorant may smell and the odour threshold. In very general terms, the odour threshold is the concentration at which people will begin to smell it…odorants with a low odour threshold will typically have a stronger smell at lower concentrations than compounds with a higher odour threshold. It can also be seen that very few of these odorants have a 'pleasant' odour character.

Table 1. List of selected odorants in broiler odour, odour character and detection threshold

Odorant	Odour Character	Odour Threshold Range (ppb)
methyl mercaptan	Rotten cabbage	0.00015 – 19.3
2,3-butanedione	Butter, rancid, fat, chlorine, sickly	0.002 – 1.42
dimethyl trisulphide	Metallic, sulphur, pungent, garlicky, onion	0.012 – 1.7
dimethyl sulphide	Rotten eggs, rotten vegetable (cabbage, canned corn)	0.12 – 63.0
hydrogen sulphide	Decaying vegetation rotten eggs	0.15 – 194
dimethyl disulphide	Purification, putrid, rotten garlic, smoke, burning, rubber, rotten cabbage	0.29 – 20.2
3-methyl-butanal	Malt, rancid	0.45 – 2.3
Methylamine	Fishy	0.945 – 4802
Heptanal	Rancid, citrus	1.3 – 55.7
Octanal	Green, citrus	1.5
acetaldehyde	Fruity, sweet fruity	1.5 – 555
acetic acid	Vinegar	10.2 – 4071
3-methyl-1-butanol	Alcoholic, banana, green, malt, sweet	22.2 – 42
ammonia	Ammonia, pungent	38 – 54,300
1-butanol	Solvent, alcohol	52.1 – 13,854
2-butanone	Sweet, minty	250 – 84,000
α-pinene	Pine	377 – 4130
3-hydroxy-2-butanone	Mushroom, earth;	Not available

Conditions within the litter will affect the amount of odour that is produced and also the way it smells. Temperature, pH, water content and aeration are some of the physical conditions know to influence odour emissions. Of these, water content is the main one to focus on because it will influence the other conditions and is something that can be managed during a broiler grow-out cycle.

Wet litter will increase microbial activity. Microbial activity takes a few days to increase depending on how wet the litter becomes and the litter temperature (Watts *et al.*, 1994). Once the microbes are active, odour and heat production within the litter will increase (Bessei, 2006). This heat will not only further accelerate the microbial activity but will make the shed warmer and require more ventilation air to remove it.

Wet litter will have less porosity, leading to anaerobic conditions (low or no oxygen in the litter). When litter becomes anaerobic, pH will drop (makes the litter more acidic). Low pH will reduce the gaseous emission of ammonia and some odorants, but will promote the release of sulphides (Barth *et al.*, 1984). Looking at the list of odorants in Table 1, five of the top six odorants with low odour threshold are sulphides. With such low odour threshold and unpleasant character, these odorants are more capable of being smelt further from the farm and causing offence (assuming atmospheric and wind conditions transport the odour plume towards a receptor).

Manure cake is another matter altogether. Cake is dense, compacted material with low porosity, high manure content and generally starts with high moisture content. It therefore leads to anaerobic conditions with low pH, which results in the emission of low threshold, unpleasant odours. Another property of cake, relating to low porosity, is that diffusion of gases through cake is slower compared to friable litter. While this lower diffusion rate may slow the emission of odorants (including ammonia (Miles *et al.*, 2008)), it also slows drying (Yusheng and Poulsen, 1988). This means that cake will take much longer to dry than friable litter…..so it either won't dry (because evaporation rate is less than the rate of water added by the birds) or will require substantially more air speed and ventilation to enable it to dry.

Dry litter also smells but less than wet litter due to limiting moisture microbial activity. Dry litter will also be more aerobic (due to more air-filled pores) and pH will be higher (neutral or slightly alkaline). These conditions favour the emission of ammonia and other odorants with higher odour thresholds. In general, this means that they will dilute more rapidly once exhausted from the shed and receptors will be less able to smell them compared to the low odour threshold odorants like the sulphides.

In practice, wet anaerobic litter makes an odour plumes smell different, especially as you move away from the sheds. With only dry litter in a shed, the odour plume will smell like 'a broiler shed' or may even have more of a 'dry feed' smell. With wet litter, an odour plume may smell more like 'cabbage', 'wet socks', 'yoghurt', 'garlic/onion'. This may not be noticeable during the day because odour plumes will tend to disperse vertically within a short distance from the shed, but will be more pronounced at night when odour plumes stick to the ground.

HOW ODOUR TRANSPORT CONTRIBUTES TO ODOUR IMPACTS

Odour needs to travel 'on the wind' to a receptor for them to smell it…and then they need to smell it often enough and strong enough for it to become an impact. The exact strength and frequency will be different for each receptor and situation.

The journey that an odour takes from a broiler shed to a receptor is very complex. Environmental conditions will control the direction that a plume travels and amount that the odour is diluted. Environmental conditions change frequently and this can strongly influence the potential for odour impacts.

Maximum dilution and vertical plume movement will usually occur during the day, minimising the potential for odour impacts. The reverse situation occurs at night, when odour plumes are more likely to stay close to the ground and calm winds will reduce turbulence and dilution. Potential for odour impacts is therefore usually greater at night and early in the morning (until an hour after sunrise).

During the planning stages for new or expanding farms, odour consultants may be employed to simulate and predict this complex journey so the farm can be positioned and surrounded with sufficient buffer zone so that receptors (that exist at the time of modelling) will hopefully not be impacted by odours.

Strategies to reduce odour impacts by controlling odour transport need to redirect odour plumes away from receptors or significantly increase turbulence to reduce how much it smells before reaching a receptor.

RECEPTOR CHARACTERISTICS RELEVANT TO ODOUR IMPACTS

There are physiological and psychological factors that influence a person's perception of a smell, and if it will impact on their quality of life. Every person has a different sense of smell, and may be more or less sensitive to individual odorants (Klarenbeek *et al.*, 2014; Lehtinen *et al.*, 2012). To further complicate matters, receptors who have previously experienced an odour may become more sensitive to it in the future (Feddes and Edeogu, 2001). Also, a person experiencing increased anxiety or distress will find smells less pleasant because this emotion is neurologically linked with a person's sense of smell (Krusemark *et al.*, 2013). A person's age, gender, social status, past experiences and health status will all contribute to their perception, and tolerance of odours (Lebrero *et al.*, 2011; Lehtinen *et al.*, 2012).

A broiler farmer cannot alter a receptor's sensitivity to odours, but reducing the *frequency, intensity, duration and offensiveness* (FIDO factors) of their exposure to the smell may help to reduce the potential for odour impacts to occur in the first place (Feddes and Edeogu, 2001).

RESULTS FROM ODOUR RESEARCH

The most effective way to prevent odour impacts is to build new farms in suitable locations with appropriate buffer distances to minimise the amount of odour reaching receptors. Therefore, the majority of research has focussed on measuring odour emission rates and improving understanding of what happens after odour leaves the shed. Other research has focussed on technologies and shed management to reduce odour impacts.

ODOUR EMISSIONS FROM BROILER SHEDS

We measured odour emission rates from broiler farms in Queensland and Victoria (Dunlop *et al.*, 2011). At three farms, we measured odour emission rates weekly and at a further nine farms, we measured odour emission rates on the day before the first pickup (Figure 1).

What we found was that odour emission rates were highly variable—they varied within the same day at each shed, each sampling day and between farms. Overall, there was a lot of variability that couldn't be explained by the parameters that we could measure (bird age, bird density, shed average litter moisture content, ventilation rate temperature).

What we derived from the data was a general trend for daily peak emissions rates to increase during the batch with total live weight and then reduce following each pickup. Daily minimum odour emission rates were frequently much lower than the daily maximum, and these usually occurred early in the morning when ventilation rates were lower.

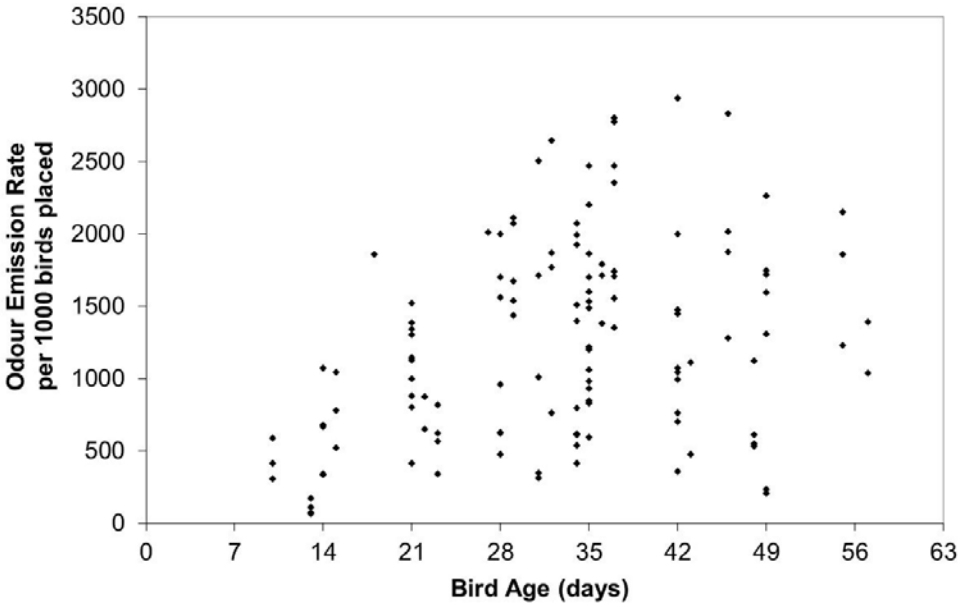


Figure 1. Odour emission rates measured at broiler sheds

Odour impacts are known to occur at night and early morning when stable conditions reduce the amount that odour plumes disperse. This means that odour impacts may actually correspond to daily minimum odour emission rates, not just the maximum odour emission rates. This highlights the important contribution of the environment (i.e. terrain) and weather in dispersing odour, or reducing the dispersion of an odour, before reaching a receptor.

EFFECT OF LITTER MOISTURE CONTENT ON ODOUR EMISSIONS

It is recommended that litter moisture content be maintained between 15–30% moisture content to minimise both odour and dust emissions (McGahan and Tucker, 2003). We measured litter moisture content on the same day as odour measurements. What we found was that maximum odour emission rates often corresponded with shed-average litter moisture content lower than 30%. Similar relationships between litter moisture content and odour emission rates have been found by other researchers (Simons, 2010). Care must be taken in interpreting this data because higher odour emission rates usually corresponded with high ventilation rates. It may be coincidental that lower odour emission rates corresponded with wet litter on days when ventilation rates were low (e.g. winter, in the first part of a batch, or when total live weight was low), and were high on days when ventilation rate was high (e.g. summer or when total live weight was high).

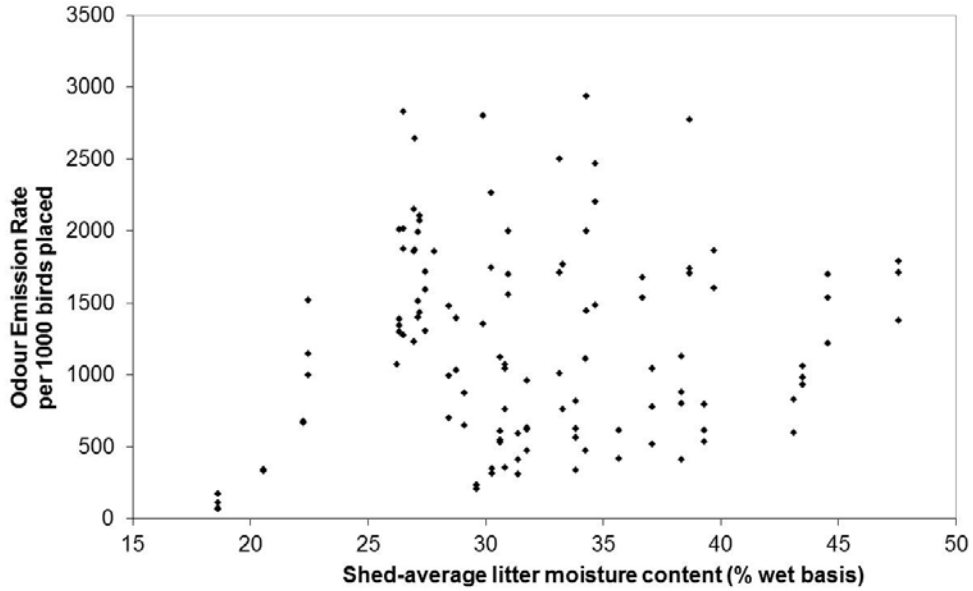


Figure 2. Odour emission rate from broiler sheds compared to shed average litter moisture content

In practice, shed average moisture content of 30% may actually mean litter moisture content ranging from 10–60% throughout the shed. It is therefore very difficult to draw conclusions about the effect of wet litter when only measuring 'average' odour emission rates at the exhaust fans. Additionally, measurement of odour emission rates does not consider the character of the odour. Based on the information provided above, odour released from wet litter is likely to contain pungent, unpleasant smelling sulphides.

WINDBREAK WALLS, SHORT STACKS AND VEGETATIVE BUFFERS

Windbreak walls, short stacks and vegetative buffers are designed to improve the dispersion and dilution of odours by increasing turbulence and mixing with fresh air or by redirecting plumes away from receptors. Permeable windbreak walls and vegetative buffers have the additional ability to capture dust and odorants as well. Vegetative buffers, once grown, will also screen the sheds from view. Research has suggested that they could be a cost-effective and useful technology for reducing odour impacts (Bottcher *et al.*, 2001; Hernandez *et al.*, 2012; Ismael and Benbow, 2010; Parker *et al.*, 2011; Patterson and Adrizal, 2005; Tyndall and Colletti, 2007).

We investigated windbreak walls and short stacks using CFD modelling and smoke releases and concluded that odour reducing benefits were negligible beyond a fairly short distance of approximately 150m from the sheds. This was especially the case during stable atmospheric and weather condition, which commonly occur at night and early morning. Our findings have been supported by other researchers (e.g. (Hernandez *et al.*, 2012; Parker *et al.*, 2011)), while there is also research suggesting that the benefits of vegetative buffers can last much further downwind.

Inconsistency in the performance of windbreak walls, short stacks and vegetative buffers is likely due to differences in their design and specific environmental conditions at the time of testing. The latter reason is why we concluded that windbreak walls should not be considered a reliable technology for reducing odour impacts (Dunlop *et al.*, 2008b); however, it is likely that in certain circumstances they could be beneficial. Regarding vegetative buffers, it is critical that they be strategically and specifically designed otherwise it's likely that they won't be effective.

STRATEGIES TO REDUCE ODOUR IMPACTS

The first challenge in strategically mitigating odour impacts is identifying the causes. Impacts may be due to something happening on the farm, how the environment is transporting odours towards the receptor, or related to the receptor's physiological sensitivity to odour (which can vary with time and emotion) or their expectations. Specific causes for impacts are likely to be different in every situation and may even change over time. A strategy that works at one farm may not work at another. Without understanding the specific causes for odour impacts, it's likely that significant investment will be made in strategies that have limited chance for success.

It's very difficult for researchers to develop odour mitigation strategies due to the many factors that affect odour impacts. Research has typically focussed on developing technologies that can be added to existing sheds to reduce odour emission rates, usually without requiring any changes to shed management or husbandry practices. McGahan *et al.* (2002) and Dunlop (2009) have previously reported on technologies that may reduce odour emissions from broiler sheds. These included ozone treatment, biofilters, wet/chemical scrubbers, incinerators, active oxygen treatment, odour neutralising agents, litter aeration, electrostatic ionisation and dry dust filtration. In general, these technologies are expensive, unsuited to high ventilation rates or may not consistently reduce odour concentration. Consequently, adoption of these technologies in broiler sheds has been limited, even in a global context.

Vegetative buffers with strategically planted grasses, shrubs and trees are expected to make an incremental, yet likely beneficial, improvement to odour impacts (Tyndall and Colletti, 2007). They do this by intercepting some odour laden dust and by accelerating dilution of odours by increasing turbulent mixing. They also improve the appearance of the landscape by hiding the sheds from view, making them 'out-of-sight and out-of-mind'. It can be challenging to get the plants established and growing, and it will take some time for them to reach maturity. Also, the full potential benefit and planting design won't be fully known until several years after planting. While the plants are growing, temporary screens may be beneficial for protecting young plants and also getting the buffer 'working' straight away. It is CRITICAL that the vegetative buffer be designed with consideration of how odorous air is exhausted from the sheds and how the environment is transporting odour plumes towards receptors. Any gaps in a vegetative buffer (including driveways), could potentially concentrate and funnel odours towards a receptor and undo all of the hard work and investment that was put into establishing the vegetation buffer in the first place.

FOCUS OF FUTURE ODOUR RESERACH

The focus of future odour research is how litter conditions affect the types and quantity of odorants that are being released. Litter moisture content is a primary focus because it has a strong effect on other litter conditions, and is something that can be managed by the grower. The first stages of this research has been on collecting data about the moisture holding capacity and drying rate for litter, and measuring how moisture content influences pH and porosity.

Early indications are that having dry litter is a good way to minimise the formation of strong, unpleasant odours, especially sulphide compounds. By dry, this means very dry, friable litter with no damp spots and no cake. Of course the consequence of having such dry litter is there may be more dust, which can create problems of its own. We acknowledge that managing litter conditions to be this dry may be difficult to achieve due to practical and environmental considerations such as weather conditions, but may be worthwhile for some producers.

Managing conditions in a shed for dry, friable litter to control odour is not something that all farms would need to do, but may prove to be an effective solution for odour impacts at some farms where the emission of certain odorants is the main contributor to odour impact. Managing a shed and ventilation system for dry litter will have additional costs, but will likely be achievable using the equipment already installed in the shed.

CONCLUSIONS

Odour impacts can be difficult to understand and mitigate. Commercially available technologies to capture and treat odour emissions are expensive, ineffective or may be incompatible with very high ventilation rates. Strategically designed vegetative buffers are expected to provide an incremental improvement to odour impacts, but on their own may not be enough to prevent odour impacts in all circumstances.

If the primary cause for odour impacts is the formation of unpleasant odours in damp litter then actively managing a shed for dry litter could be a useful solution. Overall, moisture is a key condition that can be controlled within the shed during the grow-out period. Higher moisture content in the litter will increase microbial activity, form anaerobic zones and reduce pH. These changes will increase the formation and release of unpleasant, low threshold odorants that have greater potential to be smelt by receptors. Dry litter will still have odour, but is likely to contain more ammonia and other odorants with lower detection thresholds, which are less likely to be smelt by receptors surrounding the farm.

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