live export

Investigation into reducing odour emissions from partly loaded sheep vessels whilst in port

Project LIVE.213 A
Final Report prepared for MLA and Livecorp by:

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FREMANTLE PORTS

MEAT & LIVESTOCK AUSTRALIA

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Acknowledgements

The project has been undertaken using a collaborative and co-operative approach. The assistance of many product proprietors was required to identify possible odour management procedures and design appropriate experimentation.

Odour management is a relatively new science and many of the products and procedures may require further development to apply them to the many and varied situations that exist within the livestock industry. Many of the products were selected because proprietors had demonstrated an interest in solving industry problems. It is hoped that this collaborative and co-operative approach is sustained.

Even where products have been found to be ineffective under the experimental circumstances, it is proposed that product proprietors revisit their products and procedures to assess whether products may have application after further development.

Four **bedding additives** were evaluated in the experimentation.

- Nathan Dowell and Ken McGiven of Environmental Products (Australia) Pty Ltd. provided the "McZyme" product. This was taken from the "Ecogreen" range of products.
- Brain Maher and Chris McLaughlin of World Waste Solutions Pty Ltd. provided "Grease and Odour Eliminator" (GOE).
- Mr. George Bodnaros of Environmental Process Solutions Australia provided the Sentry 2000 product.
- Mike Kuzich of Insight Environmental Pty Ltd provided the "Qweller" product.

Three **feed additives** were evaluated in the experimentation.

- Warren Potts of Glen Forrest Stockfeeders obtained the gypsum and formulated the pellets for experimental use.
- Dr Tony Parry and Chris Brampton of Supersorb Minerals NL provided the zeolite product.
- Brian Grigson and Ian Fowler of Integra Management Pty Ltd. supplied the Yucca product.

Others who contributed were Peter Beecham of Odour Technologies, Hawkan Wihlborg of Econord Pty Ltd (Anotec range of products) and Ray King of ECOLO W.A. (Odour Control Systems Pty Ltd). These people provided "wharf based" solutions. Douglas McNaught and Johan Fourie presented the "attapulgite clay" as an option. The assistance of all these people was greatly appreciated.

Thanks go to Dr Soressa Kitessa and Andrew Williams of CSIRO who completed the experimental evaluation of the products and invested significantly more time in the project than was originally envisaged.

Rebecca Woods from Fremantle Ports provided valuable guidance throughout the project. The financial contribution that Fremantle Ports made to the project is also acknowledged.

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1.0 Introduction

Complaints about odour from livestock vessels have led to concern over potential adverse impacts on the residents of Fremantle and surrounding suburbs. Complaints have increased in association with an increase in the number of partly loaded sheep vessels visiting the port. The concern has attracted attention from the Department of Environmental Protection, which has indicated that it may be forced to use its coercive powers unless the livestock export industry can demonstrate an improvement in the way it deals with odour management.

Fremantle Ports has taken a responsible approach to the management of odour by implementing several initiatives aimed at reducing the frequency and duration of odour events. These have been successful up to a point, but additional measures may be required to demonstrate further improvement.

This project (and attached report) provides another step toward the responsible management of odour from livestock vessels within the port. It recommends a number of ways in which odour emissions may be reduced and provides a context from which to address the problem. It provides a benchmark for future improvements. It also discusses the ways in which the FIDOL factors (frequency, intensity, duration, offensiveness and location) can be best utilised to minimise complaint.

2.0 Abstract

Odour management revolves around the FIDOL factors. These are **frequency, intensity, duration, offensiveness and location.** Reducing odour emission is therefore only one of the possible measures to address odour issues and should not be viewed in isolation.

Fremantle Ports has implemented measures to address odour problems**. These revolve around berth selection and the timing of visits.** Further efforts to address odour will require measures aimed at reducing odour emissions.

Dietary manipulation is considered the “best bet” odour reduction measure. Dietary manipulation aims to reduce the level of rumen degradable protein and include more digestible ingredients in the feed. Protein levels have already been reduced in shipping pellets and there may be little scope to reduce protein any further. The use of more digestible roughage is being explored by feedmillers.

A number of feed and bedding additives were evaluated under experimental conditions (see LIVE.213B). **The bedding additives proved ineffective under the conditions of the trial** ($p>0.05$). These products may require further development to apply them to the livestock export situation.

The results of the feed additives were more encouraging. The journey from the eastern state ports provides the opportunity to use the feed to address the odour problem. **Gypsum was the most effective feed additive.** This was a statistically significant result ($p<0.05$). It can be used to partially replace lime as a binder in the manufacturing process. The inclusion of acid salts to reduce the pH of the manure is also being explored by feedmillers.

The benchmarking activities undertaken in this project suggested a strong linkage between pad moisture and odour emission rates. It is recommended that exporters identify areas on the vessel that achieve lower pad moisture and stow sheep in these areas on the voyage across the Bight. The identification of these areas may require the use of a hand held moisture-measuring instrument.

3.0 Executive Summary

- The objectives of the project were to:

    - Review literature and existing research to identify practical and cost effective, non-mechanical measures to reduce odour from partly loaded sheep vessels whilst in port
    - Evaluate proposed measures under both experimental and commercial conditions
    - Make suitable recommendations on measures to reduce odour from partly loaded sheep vessels whilst in port.

- To meet these objectives the project was undertaken in three parts. The first was a comprehensive literature review (see LIVE.213A – literature review) (McCarthy, 2003). The second was a benchmarking exercise aimed at establishing baseline emission rates and determining the characteristics of the sheep pad. The third involved the experimental evaluation of a number of odour reduction measures (see LIVE.213B) (Kitessa, 2003). The findings indicated that the evaluation of odour reduction measures under commercial conditions was not indicated at this point in time, (under instruction from MLA).

- Odour is produced by the biological degradation of the organic material within the pad. Odour is a composite of a large number of volatile organic compounds produced by the degradation process. The odour we recognise is the result of these compounds acting together.

- It can be assumed that the sheep pad is the major source of odour. The sheep pad is a mixture of faeces and urine. Odour from the established sheep pad (associated with partly loaded vessels) is considered to be more offensive than the odour from freshly loaded sheep.

- Increased complaint has been linked to the greater number of partly loaded vessels visiting the port. This has heightened concern about the adverse impact of odour on the residents of Fremantle and its surrounds. It has also attracted the attention of the Department of Environmental Protection who wish to see improvements in odour management within the port.

- Odour emission from a livestock vessel is affected by the following factors:

    - The number of livestock
    - The moisture content of the pad
    - Stocking density
    - Ventilation
    - Vessel orientation
    - The pH of the pad
    - Diet
    - Pad temperature
    - Being partially loaded
    - Wet sheep

- The likelihood that odour reaches a sensitive area is dictated by prevailing weather conditions and can be predicted using dispersion modelling. This assesses the likelihood of complaint due to an odour event in the port and surrounds based on the frequency and duration of the event.

- Odour intensity (the perceived strength of odour) is measured by the use of trained panellists in a process known as dynamic olfactometry. Each odour has a detection threshold. Dynamic olfactometry allows odour to be measured as a concentration above this threshold.

- Odour intensity is measured on a scale of 0-6. The concentration at which the odour intensity becomes distinct is used as the critical level in any subsequent dispersion modelling. This also provides the basis for separation distances. Many residential areas fall well within separation distances determined by the dispersion model (based on “distinct” odour intensity or 2.8 ou above threshold in the case of the odour from sheep vessels).

- Odour concentration is measured in odour units (ou). It can also be converted to an odour emission rate (either ou/sheep/sec or ou/m^2/sec). **In this study, the odour emission rate from the sheep pad varied from 0.2 – 1.1 ou/sheep/sec in the vessels surveyed**.

- A rate of 1.1 ou/sheep/sec can therefore be considered as the “worst case” emission rate. This is consistent with the emission rate has been used in dispersion modelling undertaken by both VIPAC (VIPAC, 2000) and Environmental Risk Solutions (E.R.S., 2001)

- Several odour reduction measures were identified in the literature review. Measures that claim to reduce odour emission include:

  - Dietary manipulation
  - Bedding additives
  - Feed additives
  - Adsorbents
  - Basic management procedures

- **Dietary manipulation** was considered the “best bet” odour reduction measure in the reviewed literature. Dietary manipulation aims to reduce the level of rumen degradable protein and include more digestible ingredients in the feed. Protein levels have been reduced in shipping pellets and there may be little scope to reduce protein any further. The use of more digestible roughage is being explored by feedmillers.

- A number of feed and bedding additives were evaluated under experimental conditions by CSIRO (see LIVE.213B), (Kitessa, 2003). **The bedding additives proved ineffective under the conditions of the trial** ($p<0.05$). These products may require further development to apply them to the livestock export situation. A practical method of application also needs to be found.

- **Gypsum was the most effective feed additive.** This was a statistically significant result ($p<0.05$). It can be used to partially replace lime as a binder. Concurrent research in another project (LIVE.202) has indicated that acid salts may be equally as effective. This may allow lime to remain in the formulation and assist in the pellet manufacturing process (Acciolly, 2003). This is being explored by feedmillers.

- Both zeolite and yucca were found to be effective, however, the wide variation in response resulted in these differences being not significantly significant. The ammonia binding capability of zeolite is relatively well documented, however, the mode of action for yucca is less understood. Both products have the potential to demonstrate productivity gains and this would help justify the $6-$10 per tonne cost of inclusion.

- Vessels with high pen air turnovers and single tiers are likely to achieve much lower pad moisture than vessels with low ventilation rates and dual tiers.

- It is recommended that the industry develop performance criteria to suit the many and varied circumstances that surround the port and the odour problem. The criteria should consider the FIDOL factors and not rely on emission rates alone.

- In the interim, the livestock export industry and product proprietors should continue to work together to develop and implement the practical and cost-effective odour reduction measures described.

4.0 Background

The Australian livestock export industry utilises Fremantle harbour to export large numbers of sheep and cattle to destinations in the Middle East and South East Asia. For some years, the Fremantle Port Authority (Fremantle Ports) has received complaints from local residents about odour from livestock export operations within the port. More recently, complaints have risen significantly. This has been linked to an increase in the number of partly loaded vessels visiting the port to complete the loading of livestock, fodder and water.

Fremantle Ports, with the co-operation of ship owners has managed the problem by minimising the time that partly loaded vessels spend along side at berthing facilities. It has also adopted a berth selection policy that has positioned vessels strategically to cater for the prevailing weather conditions and the proximity to sensitive areas around the port.

This has been partly successful, however, environmental regulators have warned that more effective odour reduction measures need to be identified and that odour levels are considered “unreasonable”. Fremantle Ports has commissioned (and completed) work that uses an odour dispersion model to identify peak odour conditions in the most likely sensitive areas. Odour emission from a representative vessel has also been measured.

Due to the concerns expressed, the livestock industry, in conjunction with Fremantle Ports has sought to build on this work and investigate odour abatement measures. This project addresses these concerns.

- The objectives of this project were to:
  - Review literature and existing research to identify practical and cost effective, non-mechanical measures to reduce odour from partly loaded sheep vessels whilst in port.
  - Evaluate proposed measures under both experimental and commercial conditions.
  - Make suitable recommendations on how best to reduce odour from partly loaded sheep vessels whilst in port.

The first part of the project involved a literature review (McCarthy, 2003). This has been completed and is available from Meat and Livestock Australia. The second part of the project involved benchmarking activities that established the odour emission rate associated with current practice. It also determined the basic characteristics of the sheep pad. Finally, possible odour abatement measures were evaluated.

The experimental evaluation of a range of odour management products was conducted by CSIRO at the Floreat campus in Western Australia. This included the evaluation of both feed and bedding additives. The results are discussed in a separate report relating to the results of this experimentation (LIVE.213B) (Kitessa, 2003). A feature of odour work is inherent variability combined with the high cost of testing.

This report places the research findings into an industry context and makes recommendations as to how best approach the odour problem. Several practical and cost effective measures have been identified.

All approaches to odour management should be considered in the context of the **FIDOL** factors. This includes the **frequency, intensity, duration, offensiveness and location** of the odour event. These factors will influence the likelihood of complaint and no one factor should be considered in isolation. Reducing the frequency and duration of an odour event may be just as effective as reducing the odour emission.

5.0 The Source of Odour

5.1 Introduction

Although animals produce some odour, manure is considered to be the main source of odour (McCrory and Hobbs, 2000). In this case it is the sheep pad. The sheep pad consists totally of manure (a mixture of urine and faeces). It has a relatively low moisture content and is well suited for use as bedding. It is used extensively as bedding onboard sheep carrying vessels.

The odour from an established sheep pad is mainly the result of the biological decomposition of the organic matter within the manure. This is different to the odour produced during loading, which is characterised by ammonia generated by the action of urine falling on bare flooring. The odour from the established sheep pad is considered more offensive and this is the reason that odour from partly loaded sheep vessels has attracted more complaint. Odour from freshly loaded vessel is considered to be less offensive than the odour of the established sheep pad. Odour associated with freshly loaded vessels will increase as loading continues and is directly proportional to the number of livestock loaded.

Unlike other livestock facilities where odour emission is continuous, odour emission from livestock vessels is intermittent and is only of concern when the vessels are in port. Odour emission within the port is therefore related to the pattern of livestock shipping activity. This is important and should be considered from the point of view of the FIDOL factors discussed previously. In particular this relates to the **frequency** of visits (by livestock vessels) and the **duration** of their stay.

The Fremantle port handles large numbers of livestock of both sheep and cattle. In general vessels visit the port in an orderly manner, however, just as it is common for there to be no livestock vessels to be in the port, it is also common for several vessels to be in port at any one time. This tends to conflict with the berthing policy of Fremantle Ports, which encourages the use of specific berths. Where multiple vessels are in port, less favoured berths are utilised with a greater chance of prevailing weather conditions causing complaint from nearby residents. Multiple vessels will also lead to a greater overall odour emission within the port region.

5.2 Shipping Frequency and Duration of Stay

Over 4 million sheep and 100,000 cattle are exported from the Fremantle port each year. Industry estimates that about 2.5 million sheep have been loaded at either Portland or Port Adelaide (Norris, R., 2003, pers. comm.). This determines the number of partly loaded vessels that visit the port. There were 25 voyages from Adelaide and 25 voyages from Portland. The majority of these would have completed loading at Fremantle.

The number of vessels involved in partly loaded shipments is much smaller, and probably involves only 6-8 vessels. These tend to operate on a continuous basis and achieve up to 8 visits per year. The vessels involved tend to be the larger sheep carriers owned and operated by the integrated companies servicing mainly the Middle East destinations. They would typically carry around 100,000 sheep in a mixture of both open and enclosed decks. Only two of the vessels involved are fully enclosed.

Vessels are loaded relatively quickly when in port and the average duration of stay is estimated at 24 hours. The actual loading of livestock can be achieved in as little as 8 hours, however, the time alongside will often be accompanied by the loading of fodder and may include periods without loading activity.

There has been a trend toward the use of vessels with a larger carrying capacity. These carry large numbers of livestock and take longer to load, however, many efficiencies exist including the use of dual loading facilities and improved loading systems. Consequently the time alongside, when related to the number of sheep loaded (minutes per sheep) has been reduced considerably. This results in either fewer visits of similar duration or the same number of visits with shorter duration. In either case the frequency and/or duration of odour events is reduced. This has implication in regards to the FIDOL factors mentioned in the introduction. Other features of the newer vessels are discussed later.

There is a seasonal pattern of vessel visits. The traditional turnoff period from the south-west agricultural regions occurs from September through to about February. Shipping activity increases during this period. Restrictions on the movement of livestock into the Middle East during the Northern Hemisphere also impact on shipping activity. The timing of the Haj Festival is also a factor, and livestock numbers being shipped to the Middle East just prior to this festival tend to escalate dramatically. Activity during the rest of the year tends to subside as the supply of livestock tightens. This generally coincides with an increase in the number of partly loaded vessels visiting the port. Seasonal weather patterns will influence how much this activity affects the local residents.

Shipping activity also fluctuates with the fortunes of the industry. The recent unrest in the Middle East, a strong Australian dollar and a tight supply of suitable sheep has dramatically reduced activity in the months preceding this report (January - May 2003). This has reduced the number of complaints from local residents.

5.3 Source Characteristics and Dispersion

The sheep pad has been identified as the major source of odour. The next issue is to determine how the odour is dispersed. Odour mixes with the air above the pad and is removed by the movement of air through the decks. The way in which this air is exhausted will vary. Air exhausted from the sides of a vessel would be considered a volume source. A volume source is characterised by low volume and low velocity.

An exhaust stack from an enclosed vessel would be considered a point source. Point sources are characterised by a high volume and high velocity. Air from an exhaust stack is thrown into the surrounding air at high speed resulting in a high degree of mixing and relatively immediate dilution. Apart from the dilution effects of a higher wind velocity, dispersion is achieved more readily due to the effects of turbulence. Where the wind velocity exceeds 6 m/sec, turbulence allows much greater dispersion. This is explained in more detail in the literature review (McCarthy, 2003). Enclosed vessels typically have between 20-30 exhaust stacks each representing a point source. The velocity of air leaving the stacks varies from 7 m/s to 25 m/s. Point sources (exhaust stacks) tend to be fixed at a higher elevation than volume sources. This elevation encourages both horizontal and vertical dispersion and allows for quicker dilution of air components. Point sources tend to be governed by mechanical ventilation and are therefore more consistent and predictable.

Volume sources tend to be governed by the prevailing weather conditions. Mixing in this instance is limited to the edges of the plume and is constrained by the angle of divergence of the air as it leaves the vessel. Dispersion from a volume source is achieved by mixing at the periphery of the odour plume. As a rule of thumb, where air is being emitted from a volume source into a “free space”, the angle of divergence will be between 20-24 degrees (Jiang and Sands, 2000). This dispersion will adopt a conical shape around the source as the air disperses both laterally and horizontally. This will occur until it reaches a barrier (such as the ground) or another jet of air from a nearby point (or volume) source. Other physical barriers such as sheds and embankments can also restrict dispersion. Lateral dispersion is generally unrestricted unless affected by physical barriers such as sheds or embankments. Upward dispersion is also unrestricted unless influenced by an inversion layer. An inversion layer can play an important part in the circumstances surrounding an odour event.

The dispersion of odour is an important factor and affects the frequency and intensity of odour events in the vicinity of the port. The pattern of dispersion will vary depending on the initial volume and concentration of the odour. When there are several vessels in port at one time, the dispersion pattern may be complex due to the combination of point and volume sources occurring at different positions throughout the harbour.

Models are used to predict the dispersion of odour. The models mathematically simulate the odour dispersion process (Jiang and Sands, 2000). Ausplume is the most commonly used dispersion model. It is a Gaussian plume model that describes the distribution of odour within the plume. The model requires a large number of inputs including odour emission rates, source characteristics, receptor locations, terrain effects and a complete set of meteorological data.

The model then calculates hourly odour concentrations (based on the assumptions). This is then plotted to produce the odour contour lines surrounding the point of emission. The Ausplume model has the capacity to consider varying emission rates based on ambient temperature, time of day, season, and wind speed. Odour associated with livestock shipping will include times when there is no emission (i.e. the emission is intermittent). It may also be possible to vary emission rates as a result of successful odour reduction measures.

Dispersion modelling can be used to predict the likelihood of complaint. It is useful to make informed decisions about planning, environmental management and regulation. There are differences between the states in the way that the modelling has been used. These differences relate to the critical odour concentration (in odour units), probability (e.g. 99.5 percentile), averaging time (usually one hour) and receptor location (or type, residential etc). This has been standardised by the EPA Draft No. 47, (EPA Draft No. 47, 2000), which recommends a “distinct” odour concentration, 99.9 percentile probability, and a one hour averaging time. This is varied in some instances to cater for different receptors (e.g. domestic dwelling, restaurant area, small town etc).

The work undertaken by VIPAC (VIPAC, 2000) utilised the Ausplume model to determine odour contours based on a $C_{99.9}$ probability and a one hour averaging time. It also plotted peak concentrations. Meteorological data from the local Hope Valley weather station (about 20 km south east of the Fremantle port) was used for the modelling. A description of the typical weather over a one-year period is contained in the VIPAC report.

Environmental Risk Solutions (ERS, 2001) also conducted modelling using the Ausplume model. Other available models include Auspuff, Calpuff, the Austrian Odour Dispersion Model (AODM). More details in regards to these are outlined in the literature review (McCarthy, 2003).

5.4 Characteristics of the Sheep Pad

5.4.1 Background

Given that the sheep pad is considered to be the major source of odour from loaded sheep vessels, further measurements were taken to better describe the pad characteristics. This was undertaken in the benchmarking stage of the project. The thickness, moisture and pH of the pad were measured.

Depending on feed and water intake, sheep in the onboard environment will produce about 2 kg of manure per day. This is a combination of faeces and urine results in manure of solid consistency with approximately 50-60% moisture. At this moisture content, the manure pad forms a highly suitable bedding for sheep throughout the voyage. Feed intake and the digestibility of the feed affect the amount of faeces produced by the sheep.

The moisture content of the pad will be affected by the amount that the animals urinate. If water consumption increases (as is the case when the animals are subjected to heat stress), the moisture content may rise and this may affect the suitability of the pad as bedding.

The ventilation rate (or pen air turnover) will also affect the pad moisture. Air moving through the sheep decks will lift moisture from the pad surface and have a drying effect. This will balance the effect of additional urine and faeces. Vessels that have a high ventilation rate relative to the pen surface area will have a much lower moisture content in the pad than those that have lower ventilation rates.

The more recently commissioned vessels that are carrying sheep in pens designed for both sheep and cattle have a high deck height and pen air turnover, relative to the mass of the sheep in the pens. This leads to a drying effect and a pad with low moisture content. At the other extreme, vessels with low ventilation rates and dual tiers will have a pad with the highest moisture content.

The continuous addition of manure to the bedding is an important feature of the sheep pad. Any bedding treatment applied to the surface of the bedding may be quickly overwhelmed by the addition of new faeces and urine. Furthermore, the action of the sheep hooves acts to compress the manure, but also disrupts the manure surface. This allows a greater amount of manure being exposed to air than if the surface was allowed to remain intact. A greater amount of aerobic activity will therefore take place. The action of the sheep hooves may also foil the activity of any bedding additives that act by sealing the surface of the manure.

At a normal stocking rate, approximately 6 kg of manure (wet weight), consisting of both faeces and urine, will be added to each square metre of pen area per day. This adds approximately 0.6 cm of height to the bedding per day. If the voyage from Portland (or Port Adelaide) to Fremantle takes 4-5 days, this would result in a pad thickness of 2.5 – 3.0 cm. After loading and completion of the final leg of the voyage to a middle East destination, the pad thickness may have risen to 15 cm, and in some places higher if the pad is uneven.

The way in which the action of the sheep’s hooves affects biological activity on the manure surface is unclear. Presumably the disturbance of the manure surface encourages aerobic activity and provides fresh substrate for the aerobic biological activity to take place. It may also allow the release of gases produced by anaerobic activity in the pad itself. The packing nature of the feet action however may retard anaerobic biological activity within the pad itself.

5.4.2 Method

The method used to determine the characteristics of the sheep pad was simple. Three sites were selected on each of the vessels. These sites were selected to represent a cross section of conditions onboard. They were not designed to be representative of the vessel overall. Once a site was selected, an odour sample was taken using an isolation flux hood. The characteristics of the pad (at the site) were determined by taking a "core sample" and measuring the depth of the pad. The core sample was forwarded to the Animal Health Laboratories at Agriculture W.A. in South Perth where the moisture level and pH was determined.

Initially it was hoped that a minimum of six vessels would be surveyed, however, a slowdown in the throughput of suitable vessels restricted the survey to four vessels. The odour analysis was conducted to Australian Standard AS/NZS 4323.3.2001. The four vessels represented a good cross section of sheep carriers and included both enclosed and open deck vessels as well as a semi-enclosed vessel with a high pen air turnover.

5.4.3 Results

The measured pad depth ranged from 2.6 - 2.8 cm. This was within the range anticipated. Moisture varied from 41% to 58% (see Table 1.). These are average values for each vessel. Individual values showed greater variation (see Table 4.). Note that the collection of pad material on the first vessel did not utilise a core sample and resulted in a disproportionate amount of surface material. The moisture on the pad surface is lower than at the most dependent point.

The pH of the sheep pad was also measured. It was less variable than moisture and ranged from 8.4 - 8.8 (see Table 1.).

Table 1. The moisture, pH and thickness of the sheep pad at the time of sampling.

	Vessel 1. (ex Portland)	Vessel 2. (ex Portland)	Vessel 3. (ex Portland)	Vessel 4. (ex Pt Adelaide)
Ave. Moisture *	40.3%***	58.0%	58.3%	54.0%
Ave. pH*	8.43	8.47	8.67	8.78
Ave. Thickness **	2.7 cm	2.75 cm	2.6 cm	2.8 cm

* Measured by the Animal Health Laboratories at Agriculture W.A. in South Perth.

** Thickness at the time of odour sampling.

*** Note the technique for measuring moisture in samples from the first vessel was slightly different to the technique used in the subsequent samples and included more surface material. This may explain the lower average moisture content.

6.0 Odour Characteristics

6.1 Intensity

5.1.1 Background

Odour **intensity** has a precise interpretation. Odour intensity is the perceived strength of an odour. Generally, the higher the concentration of an odour the greater the intensity. The interpretation, however, is not that simple since different odours will display different relationships between intensity and concentration. Small increases in concentration of some odours will dramatically increase the odour intensity, whereas other odours may require much greater increases in concentration to achieve the same increase in intensity.

Intensity is one of the FIDOL factors and will influence the likelihood of complaint. Intensity is measured on a scale of 0-6, with 0 being neutral (or not perceptible) and 6 being considered extremely strong. A key measure within this scale is 3, which coincides to the odour intensity being considered “distinct”. The determination of a “distinct” level for a particular odour requires determination of an odour intensity graph that plots the perceived odour intensity over a range of odour concentrations. This will establish the Weber-Fechner constant, which reflects the slope of the relationship between the concentration and intensity. As mentioned, the key point is the concentration at which the odour intensity becomes distinct (odour intensity score 3). This concentration is then used as the critical odour contour line in any subsequent odour dispersion modelling. The odour contour lines determined by dispersion modelling provide the basis for the determination of separation distances and can be used to predict the likelihood of complaint.

Intensity measurement (and the determination of the intensity relationship) is conducted under laboratory conditions by the use of dynamic olfactometry and is measured in odour units (ou) above the threshold. The threshold is the lowest concentration at which the odour can be confidently detected.

An odour intensity assessment (completed as part of this project) determined that an odour concentration of 2.8 ou (above the threshold), coincided with “distinct” odour intensity for partly loaded sheep vessels. This concentration is relatively low and represents an odour that is distinct at a relatively low concentration (see Table 2.). Note that where odour intensity relationship has not been determined, the Environmental Protection Authority recommends that a critical odour concentration of 2 ou (above threshold) be used (EPA Draft No. 47, 2000).

The establishment of an odour intensity relationship is a key part of the benchmarking exercise. Odour intensity does not take into account the character, offensiveness or hedonic tone of an odour. Consequently, odour intensity does not distinguish between “good” and “bad” odours. Some highly offensive odours (such as hydrogen sulphide) may have a low Weber-Fechner constant.

The “distinct” odour intensity concentrations of odours from other industrial sources are compared below in Table 2. This use of odour intensity as a criterion for odour regulation is relatively recent. Apart from poultry, intensity relationships for odour produced by other animal species was not evident in the literature reviewed. The EPA Draft No. 47 quotes an odour concentration of 7 ou being equivalent to an odour intensity score of 3 (distinct) for odour produced by intensive poultry farming. It should be noted, however, that Jiang (2000) subsequently indicated that the “distinct” intensity odour concentration (in terms of ou greater than threshold) for odour from broiler farms may actually be between 2 and 5 ou. This difference needs to be reconciled.

6.1.2 Method

The intensity measurement was undertaken on one of the air samples taken for odour analysis. It was conducted in the laboratory at "The Odour Unit Pty Ltd" in Myaree, using dynamic olfactometry and experienced panel members. The sample is initially presented to the panellists at a concentration that is below their threshold and is therefore not perceptible. The concentration is then diluted with odour free air and the panellists rate the odour intensity on the scale of 0-6. The intensity of the odour was then plotted against the concentration. The concentration at which the odour was considered distinct was then determined.

6.1.3 Results

It can be seen in the table below that there is a large variation between odours in regard to the concentration that coincides with "distinct" odour intensity. Odour from a municipal landfill (2.0 ou) and wool scouring plant (2.5 ou) for example would appear to be similar to the odour produced by sheep vessels. Odour from an oil extraction process (7.0 ou) and poultry farming (7.0 ou) would appear to require higher concentrations above threshold to achieve the same level of intensity. Odour from an alumina refinery (23 ou) and hydrogen sulphide (11 ou) require an even higher concentration.

Odour from the partly loaded sheep vessel required a concentration of 2.8 ou above threshold to coincide with "distinct" odour intensity. This has implications with regards to determining separation distances based on dispersion modelling.

Table 2. Odour concentrations coinciding with "distinct" odour intensity.

	Odour Concentration (above threshold), that coincides with a distinct intensity level. (Intensity Level 3) (ou)
Hydrogen Sulphide ***	11
Odour from the Manure Pad on Sheep Vessels **	2.8
Municipal Landfill *	2.0
Steam Stripper Outlet (Wool Scour) *	2.5
Alumina Refinery Liquor Burning TO Outlet *	23.0
Oil Extraction Plant Stack *	7.0
n-butanol Reference Gas *	20.0
Intensive Poultry Farming ***	7.0

* Shultz et al (2003)
** As measured by The Odour Unit W.A. (May 2003).
*** See Table 8. (Appendix 1.) and Table 9. (Appendix 2.) in the EPA Draft No 47. (2000).

6.2 Offensiveness

Odour intensity is not an indicator of **offensiveness**. Different odours at the same intensity may be perceived differently. Some odours are considered to be quite pleasant and may not attract complaint even at high intensity levels. Association is an important factor in regards to the perceived offensiveness. The smell of silage is not greatly different to the smell of sewerage and has many similar odour components. The smell of sewerage however, is perceived quite differently to that of silage. It is therefore difficult to determine the offensiveness of the odour from partly loaded livestock vessels.

The offensiveness of the odour from sheep vessels may vary with diet. This could warrant further research. It may also be influenced by the presence of disease such as salmonellosis. Salmonellosis has been a feature of many recent voyages where sheep have been prepared in feedlots at Portland. The diarrhoea also contributes to the moisture level of the sheep pad.

It is likely that not all people find the odour from sheep vessels offensive, and that most would adhere to the FIDOL factors indicating that it is not offensive until it exceeds acceptable levels of frequency, duration and intensity. There are a few particularly sensitive areas such as the South Terrace café strip where residents would place more stringent conditions on the presence of the odour in question.

7.0 Odour Emission

7.1 Factors Affecting Emission

Despite there being little actual emission data in the literature, there is considerable discussion of the factors that are likely to influence odour emission rates. Many of these factors are discussed in the context of dispersion modelling, whereby inputs relating to odour emission may be modified due to different management strategies. These are discussed below.

7.1.1 Total Livestock

Total livestock mass is a key element of odour production since the animal (and/or manure from the animal) represents the odour source. The total odour production from a livestock vessel will be directly proportional to the number of livestock it carries. There is a recent tendency for vessels to carry larger numbers of livestock resulting in the overall emission from a single vessel being greater, although for the same number of livestock exported the odour event will be less frequent.

It should be noted however, that the loading time required to load the larger vessel tends to be less (on a per sheep basis) due to a number of efficiencies, particularly where multiple loading ramps are being utilised. There are also efficiencies associated with fodder loading that will in some cases shorten the berth time of moored vessels. Consequently, if the emission is considered in the context of the FIDOL factors, the larger vessels may be favoured when considering odour management.

Despite these efficiencies, the more efficient smaller vessels will be alongside for a much shorter period, and although they may require several voyages to move the same number of sheep, a lower but more frequent odour emission may attract less complaint than a larger but less frequent emission. The sensitivity of the general public to this could be determined.

7.1.2 Stocking Density

Stocking density influences odour production in a number of ways. Firstly, a higher stocking density will result in a larger mass of manure per unit pen area. It is unclear as to whether the odour production from the manure surface is influenced by manure depth or more simply related to the pen surface area. Any odour production from the sheep themselves will increase if more sheep are loaded in the same pen area. It is likely that a higher stocking density will increase odour production.

Constant addition of urine and faeces will provide new substrate from which odours can be produced. If odour production from the manure does become exhausted, or if there is a pattern of production that occurs over time, then the constant addition will affect the overall odour production pattern. Stocking density is a factor in regards to the addition of new faeces and urine.

The other way in which stocking density will affect odour is due to moisture. Since bedding moisture is a balance between evaporation from the surface and the constant addition of moisture from urine and faeces, pens with higher stocking density tend to have higher moisture content. Odour production will be greater from a similar pen area due to higher moisture content.

Stocking density is noted as a factor in odour production in the model proposed in the MRC Project DAQ.079 for cattle feedlots. Typically stocking densities are much lower in cattle feedlots (when measured as kg per m^2) than seen in the onboard situation. Stocking densities in the feedlots surveyed as part of the study varied from 34-54 kg/m^2. "Pugging" (whereby the hooves disturb the entire pad) can be a problem at these densities in cattle feedlots, especially after rain. The disturbance to the manure pad adds to odour production.

Densities involving sheep in the onboard situation range from 120-150 kg/m^2. Despite this, the relatively low moisture content of sheep manure results in a solid pad with little or no "pugging" and minimal disturbance, (under normal ambient weather conditions). Hot and humid weather with little or no air movement can lead to deterioration (or melting) of the sheep pad and "pugging" can occur at the stocking densities described.

Since the pad consists largely of material that has yet to decompose, a sudden weather change (involving high levels of temperature an humidity) can result in a moistening of the pad and and acceleration of the decomposition process. This may be associated with the sudden release of gases and odour. This is a very rare occurrence and does not occur in ports in Australia.

7.1.3 Moisture

Moisture is a key factor in odour emission rates. This is particularly the case in the feedlot industry where odour emission is closely linked to rainfall events and the acceleration of anaerobic biological activity within the pad (Holmes, 1999). In keeping with this, Holmes used a model developed by Lunney and Smith (1994) incorporating the key factors affecting odour emission from the cattle manure pad.

The model is not yet publicly available for use in dispersion modelling. However it is important in that it links emission rates to meteorological events and/or management activities and is a step away from using "worst-case" emission rates under all scenarios. The model inputs include stocking density, pad and ambient temperature and is related to a time after rainfall events. The model was used to predict odour emissions in a number of feedlots. The predicted emission rates for a number of feedlots, based on this formula are shown in Table 3. Moisture is the key factor and is expressed in the formula as follows:

$$E_1 = \alpha\delta^{1.8}\theta^{.77Tp0.13} F(\theta,T_a)$$

Where: E_1 = emission rate (ou/m^2/sec)
α = a constant
δ = weight in kg/m^2 of beast
θ = a measure of moisture content (in %age)
F = function based on time after a rainfall event
T_p = pad temperature
T_a = ambient temperature

Table 3. Predicted emission rates for a number of feedlots based on the above formula (Holmes, 1999).

Feedlot	Odour Emission (ou/m^2/sec)
Feedlot A with low stocking density and low rainfall	2.5 –13.8
Feedlot B with medium stocking density and slightly higher rainfall	3.6 – 19.7
Feedlot C with higher stocking density and higher rainfall	5.4 – 32.0
Feedlot D with low stocking density and low rainfall	2.3 –8.1
Feedlot E with medium stocking density and high rainfall	4.8 – 19.0

The same linkage between odour emission and moisture content would seem to apply to the sheep pad, although the moisture content levels are much lower. The results shown in Table 4 suggest that there is a critical level of about 57% above which anaerobic decomposition of organic material is accelerated with a corresponding increase in odour emission (See also Graph 1).

This has important implications when it comes to the stowage of sheep loaded at Portland and/or Adelaide. If moisture levels are related to ventilation, then it may be that a better knowledge of the pen air turnover within the sheep decks could allow sheep to be stowed in areas where moisture content can be maintained below 57%.

Slight reductions in stocking densities for the journey to Fremantle could also play a part in minimising moisture levels. Sheep could be given additional space for this segment of the voyage and "tightened up" prior to arrival. A deck survey using hand held moisture meters in a fully loaded vessel could also be used to identify areas where pad moisture levels can be held below a critical level. This would also identify the better-ventilated areas on the vessel.

The samples were taken adjacent to where the isolation flux hood was sited to measure odour emission. Thickness, moisture and pH of the pad were also measured. It should be noted that the technique used to obtain samples of the pad on the first vessel differed from the method undertaken on the subsequent three vessels.

As previously mentioned, the sample obtained from the first vessel included a greater amount of surface material, hence the lower moisture (*). The moisture pattern across the pad section is uneven with the moisture level higher at the lowest point. Moisture levels in the lower section of the pad are probably very close to 100% as moisture settles to the lowest point.

Table 4. The linkage between odour emission and moisture content in the manure pad of partly loaded sheep vessels.

	Moisture (%)	Specific Odour Emission Rate ($ou/m^2/s$)	Specific Odour Emission Rate (ou/sheep/sec)
Vessel 1. – Sample 1.	38%*	3.96	1.50
Vessel 1. – Sample 2.	41%*	2.16	0.82
Vessel 1. - Sample 3.	42%*	2.36	0.90
Vessel 2. – Sample 1.	55%	0.76	0.29
Vessel 2. – Sample 2.	58%	2.34	0.89
Vessel 2. - Sample 3.	61%	5.63	2.14
Vessel 3. – Sample 1.	54%	0.32	0.12
Vessel 3. – Sample 2.	57%	0.42	0.16
Vessel 3. - Sample 3.	64%	2.58	0.98
Vessel 4. – Sample 1.	52%	0.41	0.16
Vessel 4. – Sample 2.	54%	0.44	0.17
Vessel 4. - Sample 3.	56%	0.69	0.26

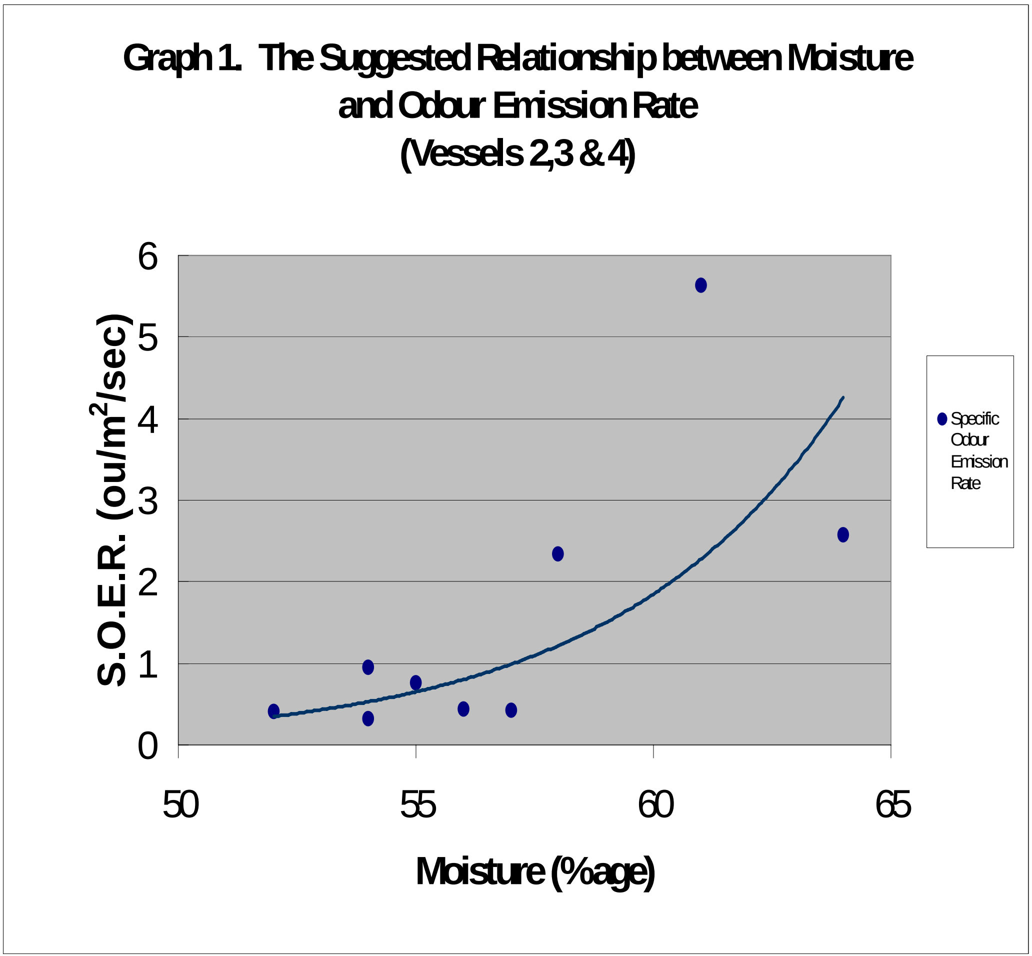
The pad temperature and local conditions were also monitored. Pad temperatures were very similar on each vessel (in the 20-22*C dry bulb). Local ammonia levels varied, especially in the open decks where they are influenced by the prevailing weather conditions. It is not considered that this had any bearing on the emission rates measured.

Both enclosed and open decks were sampled. As mentioned, sites were chosen to provide a range of measurements within each vessel. They do not necessarily represent the overall emission rate from the vessel.

Note that on vessels 2, 3 and 4, emission rates were closely linked to moisture levels, with odour levels being much higher from the moist pads.

Note also that there would appear to be critical moisture of 57% below which odour production is very low. This would appear to be the level below which there is little biological activity. This could provide a significant strategic measure in the management of odour from sheep carriers (see Graph 1.).

Note that this assumption is based on a very small number of sample points.



7.1.4 Ventilation

There are two types of ventilation systems utilised within the livestock export industry. The first is an enclosed deck system and the other an open deck system. Enclosed decks rely on mechanical ventilation to move air through the deck and remove gases and heat. Open deck systems rely on the prevailing weather conditions to achieve the same. Most vessels utilise a combination of both open and closed decks.

Most of the more modern vessels will supplement open decks with some mechanical ventilation however, older vessels rely on the ship speed to provide adequate ventilation to the open deck areas. Nil wind situations such as can occur with a following breeze equal to the ship's speed, will also occur in port when there is little or no wind. Airflow through the open decks under these conditions can be minimal.

Enclosed decks rely on mechanical ventilation. This is fixed and is usually achieved by the use of supply fans and in some cases a combination of fixed supply and exhaust fans. Airflow is measured as cubic metres hour (m^3/hr) or as the number of air exchanges per hour. More recently, the term pen air turnover has been introduced, reflecting the airflow as a function of the pen area.

It should be noted that although the ventilation rate has a direct influence on the odour concentration of the exhausted air, it might not directly influence the odour emission rate. Higher ventilation rates may, however, reduce the moisture content of the sheep pad and consequently reduce odour emission. In some instances the ventilation rate may influence the tension of gases on the pad surface and this may influence the rate of some gas producing pathways and effect overall odour production.

The ventilation rate can be a key factor in the **calculation** of the odour emission rate. The odour emission rate is a function of the ventilation rate and the odour concentration.

The relationship can be written as follows (Jiang and Sands, 2000):

The **O.E.R.** = **V** x **O.C.**

Where: **O.E.R.** = the odour emission rate in ou/sec
V = the ventilation rate in m^3/sec
O.C. = the odour concentration in ou/m^3

Conversely the odour concentration (**OC**) can be calculated as:

O.C = **O.E.R** / **V**

Calculation of ventilation rates in enclosed systems is relatively straightforward but can involve a large number of calculations due to the large number inlets and outlets involved. Measurement of the ventilation rate through open decks can be much more complex and will be continually changing with the prevailing weather conditions.

Overall airflow through enclosed decks can be calculated by adding the individual airflow through either the supply or exhaust fan system. Most fans (both exhaust and supply) have specifications relating to airflow and power (kW). In most instances these will be fairly accurate, but differences will exist where fans become fatigued. Ventilation rates can be confirmed by multiplying the area by the velocity. A velocity profile may be required to properly determine the airflow (in m^3/hr). In some cases ventilated areas will be discrete and require separate calculations. In many other cases the areas within the hold will communicate and the overall ventilation rate will require the calculation of the total airflow.

Generally, odour concentration (and other gases such as ammonia and carbon dioxide) will be similar in the exhaust outlets. Fan configuration is designed to provide a fairly even air distribution throughout the holds. However circumstances will exist where differences occur. This can occur where a hold has a greater ramp area as a proportion of deck space leading to a higher overall pen air turnover. This needs to be considered when calculating odour emissions.

Odour concentrations measured in air being expressed through exhaust outlets will lead to odour being measured as ou/m^3. Where possible odour emission should be related back to pen area and/or sheep numbers and expressed either as ou/m^2 or ou/sheep and should relate to the pen area serviced by the measured airflow.

7.1.5 Vessel Orientation

As for ventilation, vessel orientation does not directly affect odour emission, but does have a direct affect on the concentration of odour leaving the vessel. As mentioned, open decks rely on prevailing winds to ventilate the deck space and remove heat, gases and odour. The resistance created by the infrastructure of the vessel restricts the movement of the air through the deck. Only a portion of the air reaching an open deck will actually pass through it, with the majority of the air passing either around or over the vessel. Airflow through open decks can often be quite low and will move at only a fraction of the speed of the air flowing around or over the vessel.

Jiang (2000) indicated that this relationship is not fixed and that the proportion of air moving through the deck becomes smaller as the wind speed increases. Other sources have indicated that this resistance factor is in fact fixed and the same proportion of air will pass through the open deck regardless of the wind speed (C.Stacey, pers. comm.).

In either case the reduction in airflow is due to a resistance factor that is related to the nature of the infrastructure involved. The more substantial the infrastructure the greater the resistance. Dual sheep flights within a deck with little deck height will have a higher resistance than single flights with a greater deck height above the animals. A loaded deck will obviously create greater resistance than an empty deck. Stocking density will also have an impact.

Air that is required to pass through the entire length of the deck may encounter more resistance than air passing through the width of the deck. Vessel orientation therefore becomes a key factor in the ventilation of open decks (and subsequently the odour concentration of the air leaving the vessel).

Odour concentration will be directly proportional to the airflow moving through the open deck space. If the airflow is doubled then the concentration of odour will be halved. It is related to the amount of time that the air “resides” in the sheep house. Air will take longer to pass through the full length of the vessel than it will to pass across the vessel. This will have a direct bearing on the odour concentration of the air leaving the vessel even though the overall emission from the vessel may be unchanged. This has major implications when it comes to the dispersion of the odour in the exhaust plume. The odour concentration in air that has moved through the length of the vessel will be several multiples of the odour concentration of the air moving across the vessel.

7.1.6 pH

Many of the odour producing pathways are pH dependent. Ammonia production is very pH sensitive and a pH of 6 will almost completely stop ammonia production (McCarthy, 2003). The normal manure pad is between 8.4 - 8.8 pH (see Table 4.). Many of the proposed odour reduction measures act by reducing the pH of the manure. The use of gypsum (as a replacement for lime) and/or the use of acid salts in the manufacturing process would appear promising (Accioly, 2003)

7.1.7 Diet

Diet is proven to affect odour production from manure and the animal. Diets that are high in crude protein (especially nitrogen) are known to produce higher ammonia levels in faeces and urine. Commercial shipping pellets are relatively low in energy and are aimed at maintaining the weight of an animal rather than achieving a weight gain. Protein levels vary considerably between feedmillers.

There has been trend to utilise diets with lower protein. Protein levels in existing diets may already be quite low (as low as 11%). Since there is no requirement for growth, even lower levels may be possible although this may affect palatability.

Substituting nitrogen proteins with synthetic amino acids may be a future option but is unlikely to be a cost-effective option if odour is the only consideration. The use of more highly digestible roughage in the diet (hay versus straw) may also reduce odour production from urine and faeces.

It has been shown that sorghum based rations in cattle feedlots lead to a greater odour production than rations based on other cereal grains. Many cereal grains are now being ranked on digestibility with some strains of triticale demonstrating very high digestibility. The greater digestibility will result in less manure and less biological activity required to breakdown the waste organic matter. This may prove to be effective in reducing odour from sheep onboard, although it is unlikely, that sufficient grain of this nature can be obtained to service the entire export industry.

The formulation of shipping pellets is governed by the LEAP standards that require them to be within strict limits of energy, protein and fibre. Information about pellet ingredients is sometimes difficult to obtain due to the commercial interests involved. Producing pellets for the large quantities of livestock involved is a specialised business. Most pellet manufacturers are reluctant to tamper with ration formulations.

Differences between pellets will occur, and it will be important to consider this when attempting to correlate odour production with the different factors involved.

Diets, and in particular the use of different pellet binders, may also influence both the pH and moisture content of the manure. This can also have a marked affect on odour production. The use of "attapulgite" clays (and alike) that may act by reducing the moisture content of the manure has not been researched. Other feed additives have been included in the trial work at CSIRO.

7.1.8 Pad Temperature

Pad temperature will generally approximate the temperature of the deck and infrastructure. As mentioned previously, deck temperature tends to be between 2-4^{o}C (wet bulb) warmer than the ambient temperature due to the heat produced by the livestock. Temperature is a big factor in the rate of decomposition and will affect odour production. Higher temperatures will result in greater odour production.

Differences in the range of 2-4^{o}C dry bulb (to ambient temperature) have been measured within the manure pad during the investigation into ventilation efficacy. This is unusual and is thought to be the result of the fermentation process. This may occur due to the rapid decomposition of manure, but is sometimes due to decomposition of spilt feed. The fermentation of spilt feed has a distinctive odour.

Dry manure that becomes suddenly moist (such as can occur in hot and humid ports overseas) may undergo very rapid decomposition when it becomes moist and this may generate considerable heat.

The odour (and other gas production) can be quite extreme under these circumstances. Under normal circumstances, the heat contribution due to the biological decomposition of organic matter in the sheep pad is not considered to be a big factor.

Ambient temperature, especially in port, will demonstrate considerable diurnal variation. This is particularly the case where a land and/or sea breeze prevails. Although humidity will have an effect on odour production, it is the dry bulb temperature that is considered to be the most important factor. Jiang and Sands (2000) note the diurnal variation of ammonia and odour production associated with poultry sheds. Some of this is associated with ventilation as vents are opened or closed depending on the outdoor temperature. Diurnal temperature variation is likely to influence overall emission rate. If ventilation rates are lowered during cooler periods, the changes to pad moisture may influence odour emission.

7.1.9 Manure Handling and Pad Disturbance

The reviewed literature notes that manure handling activities radically increase odour production. This applies also to the action of hooves. Constant disturbance from the hooves of sheep will increase odour production. This effect will be greater in cattle than sheep. General cleanliness of the ship decks and other associated management factors will affect overall odour production. This has been discussed.

7.1.10 Wet Sheep

Wet sheep are reputedly more odorous than dry sheep. Animals themselves can act as odour sink and later emit odour. Wool length is also reputed to be a factor.

There has been considerable discussion regarding the suggestion of wash down prior to arrival. This is not a practical option. Unlike cattle, which can tolerate becoming damp in the washing process, the wetting of sheep creates health problems and the wetting adds to the subsequent odour production.

Another suggestion has been to move sheep into fresh areas and wash away the existing sheep pad. This is also an impractical option onboard. It is not possible to wash each deck as a discrete area. It is difficult to stop water from the uppermost deck from contaminating other decks. This would add to the odour problem and create additional welfare issues in regards to wet sheep. Even if the movement of livestock was able to circumvent this, the movement is a labour intensive exercise at a time when the impending ship berthing has its own labour requirements. If it were practical, the movement would have to occur well out from port and by the time the vessel berthed, the beginnings of a new pad would have been formed, with its own odour production.

Existing measurements (VIPAC, 2000) would indicate that the odour emission rate from a new pad would be similar to that of an established pad although the odour characteristics may be different.

7.1.11 Partial Loading

Partly loaded vessels are reported to be more odorous than freshly loaded vessels. This is partly because the odour from an established sheep pad is considered more offensive than from a freshly loaded vessel, however, because the vessels are already loaded with livestock they produce odour continuously whilst loading fodder and finally more livestock. It is also likely to be related to the number of livestock. This has been discussed. A fast turnaround of partly loaded vessels would reduce overall odour emission.

7.2 Odour Emission Rates

7.2.1 Background

To make meaningful comparisons about odour emission, it must be expressed as a rate. In the case of livestock exports the most relevant rate is ou/sheep/sec or ou/m^2 /sec (where m^2 refers to pen space). Since the odour emission from livestock vessels is intermittent, it is also necessary to consider time. This enables the total odour emission to be calculated and considers the duration of emission period. Dynamic olfactometry measures the concentration of odour, (usually as odour units or ou/m^3). This concentration must be related back to the pen area (and/or number of sheep) involved.

The reviewed literature makes several references to odour emission rates in cattle feedlots (McCarthy, 2003). These are outlined in Table 6.

Ross (1989) and Carson and Round (1990), found odour emission rates to be in a range of 0.1 to 2 ou/m^2/sec in cattle feedlots. These are contained in the paper written by Holmes (1999). Cattle feedlots are sited outdoors and the moisture content of the cattle manure pad is much higher and more variable than that measured in the sheep pad on livestock vessels. Moisture contents between 70-100% moisture are quoted (Holmes, 1999). It can be presumed that lower moisture content can occur during prolonged dry spells. It may also become fully saturated where consistent rain may result in water runoff. Stocking density is likely to be an important factor in all of these circumstances. Freeman (1992) stated that 5 ou/m^2/sec was a usable average emission rate for cattle feedlots. This is higher than the levels quoted by Ross (1989) and Carson and Round (1990). Variability in the figures quoted depended on moisture and/or recent rainfall events presumably due to a peak of anaerobic biological activity.

Holmes (1999) also noted that odour measurements using wind tunnels gives rise to measurement that are in the order of magnitude of two times greater than when using the isolation flux hood. This is important and emphasises the importance of sampling technique and may explain some of the differences quoted in the reviewed literature.

Actual measurements of odour emissions from livestock vessels have been undertaken by VIPAC (2000) prior to this study. Four measurements of odour concentration from the exhaust stacks of a fully enclosed sheep carrier were taken during and towards the end of loading. They represent the odour emission rate from a freshly loaded vessel (see Table 5.).

Table 5. The odour concentration in air exhausted from stacks of an enclosed vessel. (VIPAC 2000)

Sample	Measured Odour Concentration (ou)	Standardised Odour Concentration (ou) *
Stack 1. – Initial Sample 1.	87	98
Stack 2. – Initial Sample 2.	51	57
Stack 1. – Subsequent Sample 3.	170	190
Stack 2. – Subsequent Sample 4.	160	180

* Adjusted to the n-butanol standard

Table 6. Specific odour emission rates from different literature sources.

	Odour Concentration (Average ou)	Specific Odour Emission Rate (pen area) ($ou/m^2/s$)	Specific Odour Emission Rate (livestock unit) (ou/sheep/sec)
VIPAC (Oct 2000). (fully enclosed sheep vessel based on sample from exhaust stack)	185	2.90	1.10
Environmental Risk Solutions (ERS, 2000) (emission rate extrapolated from the literature)			1.0
Ross (1989) (pen surface of cattle feedlot using IFH)		.11	
Carson and Round (1990) (pen surface of cattle feedlot using IFH)		0.5 –2.0	
Freeman (1992) (pen surface of cattle feedlot using wind tunnel)		5 –21	

Neither the total airflow for the vessel, nor its carrying capacity (or pen area) is mentioned in the VIPAC report. Vessels such as the one used for the above measurements typically have ventilation that delivers over 2,000,000 m^3 of air per hour through the vessel, have a pen area in excess of 30,000 square metres and carry over 100,000 sheep. When these are considered, the odour emission rate from the vessel is calculated at 1.1 ou/sheep/sec or 2.90 $ou/m^2/sec$ (when related to pen area).

It should be noted also that not all the exhaust stacks service the same pen area within the vessel's hold. Where the airflow services an area with a greater proportional area of ramps or deck space without pens, the odour readings may be significantly lower. Despite this, the two stacks measured have quite similar values, and it can be assumed that the measurements obtained are representative of the odour emission from the other stacks on the vessel.

These measurements were taken in October 2000. The emission rate of 1.1 ou/sheep/sec was used in a dispersion model. The emission rate from the other 30 stacks was approximated (based on this data). The airflow through each stack was known and the total emission was calculated using the highest (or worst case) emission rate. The dispersion model assumed each stack to be a point odour source, (although a small number of volume sources were also included in the input data). It should be noted that the initial samples are much lower than the subsequent samples that were taken towards the end of loading. The initial readings would have been taken when the vessel was only partly loaded and would not reflect the same pen area as when the vessel was fully loaded. From this it can be concluded that the emission rate from a vessel is directly proportional to the number of livestock loaded and increases steadily over the loading period.

Other related work includes a Public Environmental Review conducted by Environmental Risk Solutions (ERS, 2001). This concludes that no information regarding odour emission rates from sheep existed in the literature. Odour emission rates were extrapolated from figures quoted for pigs (ERS, 2001). A method of back calculation was used to validate this figure. A figure of 1.0 ou/sheep/sec was utilised in the dispersion modelling subsequently undertaken.

7.2.2 Method

The benchmarking of odour emission rates in this study was undertaken using emission rates from the bedding surface rather than exhaust stacks. Samples were obtained using an isolation flux hood (IFH) and 3 samples were obtained from each vessel surveyed. Moisture levels, pH, pad temperature and local ammonia levels were all measured at the time of sampling.

7.2.3 Results and Discussion

The results stated below are an average of three samples taken from each vessel. Individual measurements showed a greater variation but demonstrated a consistent linkage to pad moisture in each case.

These results are consistent with rates stated in the reviewed literature. Both vessels 1 and 2 had emission rates between 2.8 and 2.9 ou/m^2/sec. This equates to 1.07 and 1.11 ou/sheep/sec and is comparable to the 1.0 –1.1 ou/sheep/sec used in both the VIPAC modelling (VIPAC, 2000) as well as by Environmental Risk Solutions in their Public Environmental Review (ERS, 2000). The emission rates from vessels 3 and 4 are much lower and are associated with much lower moisture levels.

These results indicate that the figure of 1.1 ou/sheep/sec is probably the worst case and is suitable to use in any modelling. (The use of worst case emission rates is recommended by the Environmental Protection Authority (EPA Draft No. 47, 2000)).

The results also suggest that much lower emission rates are achievable on some vessels. As mentioned previously, sites were selected to demonstrate the range of likely surface emission rates and not to reflect the likely overall emission rate from the vessel.

Table 7. Specific odour emission rates from partly loaded sheep vessels.

	Odour Concentration (Average ou)	Specific Odour Emission Rate (pen area) (ou/m^2/s)	Specific Odour Emission Rate (livestock unit) (ou/sheep/sec)
Vessel 1.	3,476	2.82	1.07
Vessel 2.	3.280	2.91	1.11
Vessel 3.	1,244	1.11	0.42
Vessel 4.	590	0.51	0.20

* These were measured in May 2003, by The Odour Unit Pty Ltd to the Australian Standard AS/NZS 4323.3:2001.

It is of note that the lowest emission rate was less than 20% of the worst case emission. Vessels that can demonstrate lower moisture levels may be better suited to utilise the less favoured berths when two or more vessels are in port.

It is also likely that a re-run of the dispersion model using the lower emission rate would put most of the residential areas outside any newly calculated separation distance. The extent of testing associated with this project does not allow an indication of how many vessels may achieve these lower emission rates. There is scope to run a number of “what if” scenarios to determine the effect of achieving lower emission rates and/or variations to shipping activity, duration alongside, berthing policies etc.

8.0 Evaluation of Odour Reduction Measures

8.1 Odour Reduction Measures

The primary aims of odour management are threefold. They are to:

- Reduce odour emissions
- Maximise dispersion
- Avoid sensitive areas and minimise complaint

This is best achieved in the context of the FIDOL factors discussed previously.

Only one of the four dispersion models discussed in the literature review allowed for odour reduction measures to be recognised as part of the odour modelling. This is important since it identifies and acknowledges odour management measures and rewards better odour management. Blanket recommendations that work on “worst case” scenarios (particularly when it comes to minimum separation distances) bring most operators back to the lowest common denominator. In fact in many cases, managers that do little or nothing about odour may in fact find themselves at a commercial advantage. This is obviously undesirable and an approach that rewards both good management and the investment of capital is required to provide incentive to owners of livestock facilities (in this case vessel).

Odour management measures used in the livestock industry to reduce odour emissions include:

1. **Dietary manipulation;**
2. **Feed additives;**
3. **Bedding additives;**
4. **Adsorbents and manure management;**
5. **Bio-filters and scrubbers and**
6. **Basic management procedures.**

8.1.1 Dietary Manipulation

Dietary manipulation is considered a “best bet” odour reduction measure (McCrory and Hobbs, 2001). It aims to be effective by utilising more digestible feed, reducing the protein content and/or feeding animals more closely to their requirements. The use of more highly digestible roughage in the diet (hay versus straw) is an example of the use of more digestible feed. As mentioned previously, there has also been a recent trend to utilise diets with lower protein (mainly due to the cost of lupins that were a traditional energy and protein source). Commercial shipping pellets are relatively low in energy and are aimed to maintain the weight of an animal rather than achieve any specific weight gain. Diets with lower protein levels can therefore be contemplated since protein is not required for growth.

As previously mentioned, many cereal grains are now being ranked on digestibility with some strains of triticale demonstrating very high digestibility. The greater digestibility of feed will result in less manure and less biological activity required to breakdown the waste organic matter. This may prove to be effective in reducing odour from sheep onboard, although it is unlikely, that sufficient grain of this nature can be obtained to service the entire export industry. Pre-cooking and/or flaking may allow greater digestion of feed ingredients. This practice is more common in feedlot rations.

The formulation of shipping pellets is governed by the LEAP standards that require them to be within strict limits of energy protein and fibre. It is not recommended that energy levels be reduced below recommended levels.

8.1.2 Feed Additives

Feed additives aim to be effective by either lowering the pH of digesta, faeces and urine, binding ammonia or by increasing the digestion of feed by adding suitable enzymes or other additives. They may also seek to modify the predominant fermentation and breakdown pathways.

Additives that modify the pH of faeces and urine are likely to be the ”best bet” feed additives. As previously discussed the pH of the normal sheep pad ranges between 8.4 and 8.8. This allows considerable scope for reduction. Both gypsum and acid salts aim to lower the pH of faeces and urine.

Other feed additives claim to act as ammonia binders. Typically these are members of the silicates that have crystalline structures with strong ionic attractions within the complex structure. Zeolite is one of these products.

Some additives seek to modify fermentation and breakdown pathways. These include products such as virginiamycin and bentonite. These are generally included to combat acidosis related to animals exposed to high-energy rations. Any affects on odour are likely to be secondary to this use.

There is a range of feed additives that may potentially reduce odour. There was scope to evaluate only some of these within this project. Feed additives are attractive because they directly affect the manure. They require a period of feeding that allows ingesta to pass through the entire digestive tract. This is appealing within the scope of this project in that sheep can be fed a suitable ration on the voyage across the Great Australian Bight. They are appealing in that they overcome the problem of constant addition of faeces and urine and the action of hooves on the sheep pad. Many feed additives can also be used as bedding additives.

8.1.3 Bedding Additives

Bedding additives aim to be effective by lowering the pH of the manure pad and/or binding ammonia. They may also seek to block the activity of key enzymatic pathways (e.g. urease inhibitors). Others may introduce (or stimulate) desirable bacteria that modify many of the normal odour producing biochemical pathways. Others may attempt to modify bacterial activity and either accelerate or retard the biological degradation of bedding material. They may also seek to mask odours with a more desirable masking agent and/or effectively block key odour producing pathways by the use of chemical agents.

The main problem with bedding additives in the onboard situation is the constant addition of faeces and urine. The addition of new faeces and urine may quickly overwhelm additives. The effectiveness of most bedding additives is therefore likely to be short-lived. It is also difficult to conceive a practical method of administrating the product. The product would need to be highly effective to warrant the considerable management impost that a backpack spray (or suitable automated system) would require.

Furthermore since moisture is a key factor in odour production, and the sheep pad moisture is generally low, the addition of any spray that actually moistened the pad may actually increase odour production, particularly if the moisture content is sufficiently low to be retarding biological activity. For the same reason, products that aim to accelerate biological activity are probably at odds with the characteristics of the pad. This is not to say that bedding additives have no application in addressing odour problems within the live sheep industry, however, many products may need further development before they can be considered practical and cost-effective.

8.1.4 Adsorbents

Adsorbents aim to lower the moisture content of the manure. These are usually members of the clay family such as “attapulgite”, but sawdust can be used in the same way. Sawdust is used routinely in the management of cattle bedding onboard vessels. The effects of sawdust on the sheep pad have not been explored. Adsorbents may also be useful as a host for other odour reducing agents. It has been suggested that impregnating sawdust with citric acid may be effective in reducing odour.

8.1.5 Biofilters and Bioscrubbers

Biofilters and Bioscrubbers aim to pass odorous air through damp porous medium such as soil, peat or wood chips. They also pass air through a film or mist of water that contains odour-removing compounds. Whereas the use of biofilters and bioscrubbers was seen as being outside the scope of this project, there is some scope to explore the scope for “scrubbing” air being exhausted from the exhaust stacks of fully enclosed vessels.

An odour reduction measure that has not been discussed in this report is the use of “wharf based” solutions utilizing misting and an odour-reducing product. Several discussions were held with product proprietors in regards to this method. Although the initial reaction to an “outdoors” solution is somewhat sceptical, further investigation may reveal that it may not be so far fetched. Misting is known to be effective. Furthermore the conditions where misting may be required are quite specific and relatively infrequent. Consequently the machinery could be set up to deal with a specific situation, involving a specific wind direction and sensitive receivers. The “wharf-based” solution has been considered to be outside the scope of this project, however, product proprietors have indicated that they would be willing to develop a detailed proposal if requested. It remains an option with some potential.

8.1.6 Basic Management Procedures

Attention to basic management procedures can be effective in reducing odour. This begins with the cleanliness and tidiness of the facility. Trees to act as odour “sinks” have also been suggested (McCarthy, 2003). Avoiding spillage from leaking water troughs is an obvious consideration. The possibility of modifying load plans to take advantage of the drier areas onboard has also been discussed.

8.2 CSIRO Experimentation

8.2.1 Background

This part of the project involved the experimental evaluation of odour reduction measures. Possible reduction measures were identified in the literature review. The project then looked at what was commercially available and a number of products were identified. Product proprietors were then contacted. An interview process was undertaken to determine the features and benefits of the products and determine their suitability to address the scope of the project. Each product (and proprietor) was assessed against a number of criteria including such things as their ability to service the industry, the suitability of the product, interest shown in solving industry problems and any testimonials regarding efficacy. Willingness to divulge product components and explain the mode of action was also noted. Commercial confidentiality was respected. From this a number of products were selected for evaluation. Experimental evaluation was conducted by CSIRO at the Floreat Park Campus.

8.2.2 Method

Full details of the methods used are contained in the LIVE.213B report. In summary, a 4 X 4 Latin Square design was used to evaluate three dietary treatments (plus a control) and four bedding additives (plus a control). Sheep were prepared and isolated in an animal house and fed through four feeding periods, each of 10 days. At the end of each feeding period, faeces and urine were collected. This was placed in a petri dish within a bucket. A nominal air exchange was passed through each bucket to maintain aerobic conditions. Bedding additives were then added to the collected sample under the instructions from the product proprietors. Full details of the products evaluated are outlined in the aforementioned report. Ammonia levels were then taken over a 48 hour time period. Having determined the emission pattern, odour was then measured at the end of one of the four feeding periods.

8.2.3 Result

Again, full details of the methodology are contained in the LIVE.213B report. In summary, the bedding additives were found to be ineffective in reducing both ammonia and odour under the conditions of the trial. The feed additives were more encouraging with gypsum proving the most effective in reducing both ammonia and odour. This was a statistically significant result. Both zeolite and yucca were also found to be effective but not to the same level of significance. The LIVE.213B report describes the method and includes discussion of the nutrient composition of the feed, the experimental design, feeding procedures, sample collection, feed intake, live weight change, nitrogen balance and results.

8.2.4 Discussion

Although the results relating to the bedding additives were disappointing, it does not necessarily indicate that they have no future application to the industry. It does suggest, however, that further product development is required and/or a rethink about a suitable treatment regime. It should be noted that even had the bedding additives proven to be effective, it is difficult to envisage a practical and cost effective method of application that would be readily adopted by exporters and ship owners. Unless the product was extremely effective (over a long period), it is difficult to imagine the ship crew administering the products with backpack sprays. An automated process could cost up to $100,000 on a larger vessel and has the hazard of wetting both sheep and bedding that would be counterproductive on both counts.

It is suggested that a major impediment to the effectiveness of bedding additives is the low moisture content of the sheep manure. For bedding additives to be effective they may need to fully permeate the pad and this may require much higher levels of moisture. Furthermore, if products are applied in a liquid form they may actually increase the moisture content and increase odour emission. Products that depend on biological activity may find that at the levels of moisture involved (50-60%), very little biological activity is actually occurring. This is very different to the pond or lagoon situation where the same products have reputedly been more effective.

The continuous addition of the faeces and urine also represents a problem to products that rely on either biological or chemical activity to reduce emissions. Bedding additives have been used in the onboard situation. Anecdotal experience indicates that their effect is short lived (up to 4 hours). Further investigation is required to determine whether a “fast knock down” product is cost effective and useful.

The results of the feed additives were more encouraging, particularly in regards to the scope of the project (reducing odour emission from partly loaded sheep vessels whilst in port). The journey between Fremantle and Portland and/or Adelaide provides an opportunity to utilise a dietary approach to odour reduction. As mentioned, gypsum proved to be the most effective feed additive. Its mode of action is well understood and it acts to reduce the pH of both faeces and urine. Work undertaken in separate study (Live.202) also supports the effectiveness of gypsum but suggests that the use of acid salts may be more practical.

Gypsum can replace lime as a binder in the pellet formulation but high levels may cause problem with pellet making dies and other parts of the pellet making process. A workshop that included major feedmillers has been held and options to include either gypsum or acid salts are being explored. Obviously it is necessary to have the pellets available at either Portland or Adelaide and it will be necessary to include eastern state pellet manufacturers in discussions. Some exporters will load pellets in Fremantle for the journey from the Eastern States.

Zeolite was also effective although this was not statistically significant ($P<0.05$). The ammonia binding capabilities of zeolite are well documented, as is the mode of action. The high cost of zeolite (up to $10/ tonne of feed) and the relatively high inclusion rate may discourage industry adoption unless significant productivity gains within the export process can also be demonstrated. (Increased productivity has been demonstrated in lot fed lambs (Brampton C., 2003, pers. comm.). Independent trial work is required.

Yucca was also effective, particularly in regards to odour, but showed the most variation in response. This was not a significant result ($P<0.05$). The mode of action is unclear. This (and its lack of predictability) makes it difficult to recommend commercially. The estimated cost ($6 per tonne of feed) could be justified if the product was highly effective.

The CSIRO experimentation demonstrates that ammonia proved to be a reasonable surrogate for odour measurements and was similar in trend to odour but not in magnitude. On the other hand it may prove to be misleading if odour reduction measures specifically target ammonia. There is some evidence, however, to suggest that other odour producing pathways are affected similarly by some measures (such as reduced pH).

9.0 Complaints

9.1 Location of Sensitive Receivers

The VIPAC study (VIPAC 2000) identified those locations within the Port area most prone to odour problems. Most of the port to the north is surrounded by commercial and industrial activity. The wharves used by livestock export vessels are surrounded by these activities. Residential areas, however, are situated only a few hundred metres from berth numbers 11 and 12 and also H berth, which is used occasionally for livestock export activities. There are no residential areas located directly to the west, however, near residences exist to the north, north east, east and south east of these berths (11 and 12). The distances and directions are shown in Table 8. These distances are well within the recommended separation distances published in the literature.

As mentioned, the **location** where an odour is experienced can influence whether an odour is considered acceptable or not. Clearly high odour levels reaching the South Terrace Café strip and other recreational areas are likely to attract stronger complaint than other less populated areas.

Timing is another important factor and this is being addressed by Fremantle Port's berthing policy. These areas become very busy during weekends and public holidays and an odour event during these times would be considered far less acceptable than an event mid week. The **timing** (time of day etc) of odour events would also appear to be linked to complaint in residential areas. Odour events occurring as people return from work would appear to trigger complaint especially towards the weekends when residents are planning to entertain.

Table 8. Details of sensitive receivers near to the relevant berths (VIPAC, 2000).

Receiver Address	**Direction from berth to receiver**			**Distance to berth (m)**		
	11	12	H	11	12	H
Tuckfield St	South east	South east	South east	770	685	480
Cnr Tydeman and Pearse	North east	North	North	460	340	900
Cnr East and George	South east	South east	East	900	740	770

9.2 Other Linkages

9.2.1 Prevailing Weather Conditions

The most common set of conditions that produce complaint appears to be a light north westerly/westerly breeze and vessels loading at berths 11 and 12. These condition tend to precede a stronger south westerly, either as a daily pattern during summer or preceding the regular “frontal” patterns during winter.

The stronger south westerly breezes also move odorous air over residential areas, but the higher wind velocity would appear to dilute the odour and encourage better mixing due to greater turbulence. There is little or no complaint associated with southerly or easterly wind direction. Complaint is also associated with nil wind conditions and two or three vessels in port at the same time.

Complaints by residents in far away locations such as Dalkeith are most likely linked to air caught under inversion layers that breaks up and descends (sometimes days later). The VIPAC report outlines the typical seasonal weather patterns associated with the port.

9.2.2 Berth Selection

As previously mentioned, berth selection is a major factor with regards to complaint. Clearly the majority of complaints relate to vessels berthing at berths 11 and 12. These berths are situated close to sensitive receivers and in the path of the prevailing wind patterns. These berths are generally only utilised when the more favoured berths are already being used. Consequently multiple berthing not only results in a greater overall odour emission within the port but also results in odour emission from the berths closest to known sensitive receivers.

The infrequent use of these berths is probably acceptable to the residents involved (in keeping with the FIDOL factors previously discussed). Many complainants ask why the closer berths continue to be used despite a policy that favours the berths at the western end of the port. In response to this, Fremantle Ports keeps a record of the reason that these berths are utilised. This provides a useful reference, not only to counter complaint, but also to address the issue and seek operational solutions that reduce the frequency that these berths need to be utilised. This has identified that operational constraints do exist, (such as the need for 100 tonne cranes). Action to address these constraints may be helpful.

As mentioned previously, shipping activity will fluctuate. The recent troubles in the Middle East, a strong Australian dollar and a tight supply of suitable sheep has dramatically reduced activity in the months preceding months this report (January - May 2003). This has allowed the favoured berths to be utilised when vessels visit the port, and reduced the number of times that multiple berthing has required the use of berths 11 or 12. Complaints during this period have reduced dramatically.

9.2.3 Duration of Stay

Without subjecting the complaints to formal analysis it is of note that many of the complaints are associated with the prolonged stay of a particular vessel. This was more evident when the vessel was moored at one of the less preferred berths. Clearly the fast turnaround of vessels and a minimisation of the time spent alongside is an important factor in minimising complaint. This is a win/win situation for both the community and the industry since the time alongside is costly and is generally avoided. It is also consistent with FIDOL factors mentioned previously.

Any efficiency that allows vessels to be loaded more quickly would be beneficial in this regard. This applies to loading ramps and access but an organised and uninterrupted loading will also reduce loading time. Where possible fodder should be loaded within the timeframe of the livestock loading and commence before loading where it is anticipated that it will take longer than the livestock loading process. Some of the newer, larger vessels have multiple loading ramps and can load livestock very quickly. This is a positive in regards to the management of odour.

10.0 Criteria

10.1 Acceptable Criteria

One of the difficulties involved in determining performance criteria is that it is not necessarily the odour emission that dictates the likelihood of complaint. Furthermore monitoring of odour levels is meaningless since it reflects the prevailing weather conditions at the time rather than problems with emission levels. Odour events (at least when they are within the EPA guidelines) are rare. They occur only 0.1% of the time when considered on the basis of one hour intervals. Routine monitoring, therefore, is unlikely to detect these events and is not a good indicator of successful odour management.

The Environmental Protection Authority (EPA) may, when assessing new proposals, request that there be routine odour monitoring activities be undertaken on a regular basis. This can be expensive and needs to be properly considered before becoming an integral part of any ongoing odour management planning.

There is a method of “back calculation” that enables an odour emission to be determined based on the prevailing weather conditions. This emission rate can then be estimated and used in a dispersion model that has a full set of meteorological data. The likelihood of an odour event occurring can then be predicted using conventional dispersion modelling.

The use of surface emission rates is a better approach. This allows individual operators a way of comparing their performance against others and can provide the basis for an incentive to reduce odour emissions. This approach, however, overlooks initiatives such as berth selection and the timing of visits. It also ignores the problems associated with two or more vessels being in port at any one time.

The measurement of surface odour emissions is expensive and it may be more practical to focus on pad moisture levels rather than emission rates. The linkage between moisture levels and emission rates would need to be better established (at least to a level of statistical significance) before this could be fully embraced. This approach also ignores any gains that may have been made through dietary manipulation or other odour reduction measures.

The more traditional method of addressing odour problems is to utilise dispersion modelling to determine separation distances. The EPA guidelines suggests the use of the “distinct” odour contour line based on a 99.9 percentile probability and one hour intervals. This is consistent with the FIDOL factors and considers both the frequency and duration of an odour event as well as intensity based on the likely dispersion. It does not factor offensiveness and uses “worst case” emission rates. It is also possible to modify the percentile and time interval to cater for more sensitive receivers at different locations.

The modelling undertaken by VIPAC (VIPAC, 2000) determined odour contour lines using the appropriate time interval and prediction. Many of the residential areas surrounding berths 11 and 12 fall well within a critical contour line of 2.8 ou above threshold (“distinct” intensity). The actual distances are outlined in Table 8. (Note that this assumes the worst case emission rate and that many vessels would appear to achieve much lower emission rates). Fremantle is a “working” port and the loading and shipping of livestock is a long established business. This affords it some concessions in regards to its activities. Many of the new residents in the surrounding areas have acknowledged the existence of these and other activities as part of their purchasing or rental agreements.

The other indicator of performance is simply complaint. Fremantle Ports have a well-kept complaints register that records important information relating to each complaint. This helps identify legitimate complaint and provides a level of objectivity to what may otherwise be considered a subjective measure. Fluctuating sentiments within the community can influence complaint. It can also be open to agenda.

Current shipping levels are at an all time low. This has lessened complaint due to significantly lower number of vessels arriving at the port. If shipping levels return to previous levels then the industry would be well served in taken a pro-active response to the odour management problem. It will need to either reduce odour levels or find an alternative port to lessen the dependency on the favoured berths.

Options to reduce odour levels are discussed in this report. Onboard and/or commercial experimentation has yet to be undertaken and more work is required to pave the way for the practical adoption of these options.

The Department of Environmental Protection (DEP) (who administers this act on behalf of the State of Western Australia) has concerns about the impact of odour and noise and has threatened to use coercive powers if the port cannot demonstrate a responsible approach to the management and control of odour. Just what this might entail is unclear.

Odour issues fall under Section 49 of the Environmental Act 1986, which states that:

49. (1) In this section –

> **“unreasonable emission” means an emission of noise, odour or electromagnetic radiation which unreasonably interferes with the health, welfare, convenience, comfort or amenity of any person.**

(4). A person who intentionally or with criminal negligence –

> **a) emits an unreasonable emission from any premises: or**
> **b) causes an unreasonable emission to be emitted from any premises,**
>
> **commits an offence.**

(5.) A person who –

> **(a) emits an unreasonable emission from any premises; or**
> **(b) causes and unreasonable emission to be emitted from any premise,**
>
> **commits an offence.**

(7) A person charged with committing an offence against subsection (4) may be convicted of an offence against subsection (5) which is established by the evidence.

The DEP has taken particular interest in this issue and has warned of action unless the industry can demonstrate continuous improvement. It also has the power to impose a “Pollution Abatement Notice” under Section 65 of the Act. These are prescriptive and lessen the ability of the “occupier” to manage issues in their own way.

An ongoing odour management plan is required that extracts benefit from all the factors discussed. The plan would need a high level of flexibility to address the range of weather, vessels, management and timing of visits.

10.2 Concurrent Industry Research

MLA has recently commissioned several other projects investigating odour-related issues. These include a study into the effects of ammonia on livestock (LIVE.218) and another study investigating ways to reduce ammonia levels in cattle onboard livestock carriers (LIVE.202). An investigation into heat stress at Murdoch University (LIVE.209) also looked at acid base balance in the animal and provides a useful reference point to ensure that any initiatives to reduce odour do not create problems in other areas. MLA has also commissioned a large project aimed at establishing performance criteria for the cattle feedlot industry. These investigations will contribute to our understanding of odour and odour related issues within the livestock industry.

11.0 Current Practice

11.1 Berth Selection

The Fremantle Ports has a berthing policy aimed specifically at minimising complaint from both noise and odour. The policy seeks to utilise berths that are farthest from sensitive receivers and avoid possible noise and odour events at highly sensitive times such as weekends and public holidays.

Berths 1and 2 are the most favoured being farthest from known areas of sensitive receivers. They are also furthermost west during the summer easterly weather pattern. Rough weather can cause bigger vessels to be unstable when alongside these berths. New bollards have been established to allow better wharf-side stability during rough weather. Berth selection also has some operational factors (such as the requirement for heavy lift cranes) that preclude the use of the favoured berths. The arrival of more than one vessel may also force the use of less desirable berths. Noisy vessels are considered under the same policy.

Commercial and industrial areas surround Berths 1 and 2 to the north and east. The maritime museum and the South Terrace café district are situated to the south of these berths and can be affected by the presence of a vessel and a light northerly breeze.

As discussed below, the greatest complaint occurs when one or more vessels are pulled up at Berth 11 and 12. These berths are very close to residential areas in both North and East Fremantle and these residential areas are in the path of the predominant south westerly breeze that is a feature of the local weather conditions.

11.2 Timing of Visits

More recently, Fremantle Ports has introduced a policy that discourages livestock vessels from berthing during public holidays and weekends. This acknowledges that the timing of visits influences the likelihood of complaint. This represents a significant impost on the industry. In the interests of the livestock, this may require loading to be delayed so that arrival coincides with designated times. Demurrage is expensive and ship owners and exporters have resisted this initiative. Furthermore the voyage time from the eastern ports is unpredictable due to varying headwinds and arrival times are constantly revised. Consideration of the timing of visits is a sound policy.

12.0 Recommendations

The following research or future actions are recommended based on the findings of this study:

- Assist feedmillers to determine the scope to substitute gypsum for lime, use acid salts, more digestible ingredients and/or use other feed additives in pellet formulation.
- Trial feed additives in an onboard situation.
- Undertake further research to confirm the relationship between moisture and odour emission rate.
- Complete onboard moisture mapping (using a hand held instrument) to demonstrate variations in the moisture content of the sheep pad.
- Demonstrate the gains from modifying load plans to stow sheep in areas with lower moisture content by undertaking "before" and "after" odour measurements in a fully enclosed vessel.
- Explore the productivity gains associated with the use of zeolite and yucca.
- Encourage further research into bedding additives to assist in product development through a collaborative and co-operative approach with industry.
- Investigate (in the onboard situation) whether the use of sawdust has any influence over pad moisture (as it does in cattle bedding).
- Assess the use of citric acid as a short term, "fast knock-down" odour reduction measure in the onboard situation. Assess what would be required for the product to meet occupational health and safety requirements. Assess whether sawdust could be impregnated with citric acid, and whether this may be effective in controlling odour.
- Ask proprietors of "wharf based solutions" to fully cost a solution proposal as a first step. Proving the efficacy of the product and process would be required before this could be considered a real option.
- Assess the use of "attapulgite" or other clays to reduce the moisture content of the sheep pad.
- Establish an industry consultative committee (perhaps through the auspices of WALEA), to assist the port authority to further develop its odour management plan.
- Insist that all exporters and/or ship owners using the port develop an odour management plan as part of their quality assurance approach.
- Better identify the seasonal and daily weather factors to assess whether specific measures can apply to the highest risk situations.

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