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Characteristics and Volume of Effluent Produced by Livestock Vessels

Final Report prepared for MLA and LiveCorp by:

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Table of Contents

1.0 Abstract

Meat and Livestock Australia commissioned *Landline Consulting* to determine the characteristics and volume of effluent produced by livestock vessels and make comparisons with effluent from passenger ships. This basic information is required for the International Maritime Organisation's (IMO's) Marine Protection Committee meeting in March/April 2004.

Effluent from livestock vessels, depending on number of stock carried, contains considerably greater amounts of organic matter (BOD_5), nitrogen (N), phosphorus (P) and potassium (K) than passenger ships. This is particularly the case for large vessels carrying in the order of 10,000 cattle and 50,000 sheep or goats. However, for a standardised ship with 1,000 head the following daily effluent production is predicted:

- Cattle, 500-700 kg BOD_5, 30-45 kg N, 35-40 kg P and 60-90 kg K;
- Sheep, 36-54 kg BOD_5, 6.5-9.5 kg N, 2.6-3.9 kg P and 9.6-14.4 kg K;
- Goats, 30-48 kg BOD_5, 5.5-10.0 N, 2.8-4.4 kg P and 7.8-12.4 kg K; and
- Humans, 50-75 kg BOD_5, 9-14 kg N, 1.8-2.7 kg P and 2.8-4.2 kg K.

Currently the effluent from livestock ships discharges raw into the sea, though the discharge practices vary between cattle ships (continuous discharge on the outward voyage) and sheep/goat ships (continuous discharge during part or all of the return journey). For passenger ships there is a significant trend towards short-term storage of effluent, treatment and discharge.

An understanding of the nature and composition of effluent from livestock and passenger vessels will allow an informed debate on the impacts of effluent disposal from livestock vessels. However, it is strongly recommended that the impact of effluent discharge on marine water quality should be assessed within the mixing zone behind the vessel, and not simply on the composition of the effluent.

2.0 Executive Summary

Landline Consulting conducted a desktop review for *Meat and Livestock Australia* to determine the characteristics and volume of effluent produced by livestock vessels and to make comparisons with effluent from passenger ships. This information may be used to support a case at the IMO's Marine Protection Committee meeting in March/April 2004 for the continued disposal, or some modification of livestock effluent disposal practices from vessels carrying livestock from Australia.

The review found that significant quantities of solids, nitrogen, phosphorus and potassium are produced from cattle, sheep or goats on larger capacity livestock vessels, far in excess of those quantities produced from passenger ships. For passenger cruise ships there is a movement to limited storage (2 to 3 day capacity) and treatment of black and grey water prior to discharge. For livestock ships there is storage in the form of accumulated manure on the floor of the livestock pens, and discharge of untreated effluent into the sea. The impact of discharge from livestock ships on seawater quality needs to be quantified. It is recommended that discharge strategies be assessed in terms of the impact on marine water quality, using guidelines developed by the Australian and New Zealand Environment and Conservation Council, and taking into consideration the mixing zone created behind the vessel during discharge operations.

An informed understanding of the composition and quantity of livestock effluent and the impacts of effluent disposal from livestock vessels on marine water quality is crucial for the development of sustainable effluent disposal practices within the Australian maritime industry, with long-term benefits to Australian livestock producers and exporters.

3.0 Main Research Report

3.1 Background

In September 2003, the International Convention for the Prevention of Pollution from Ships came into force internationally, with recommended practices for the storage and disposal of effluent from ships, irrespective of their cargo, whether it is livestock or human. The new requirement is "*the discharge of sewage into the sea is prohibited, except when the ship is discharging comminuted and disinfected sewage using a system approved by the (flag State) Administration…..at a distance of more than 3 nautical miles from the nearest land, or sewage which is not comminuted or disinfected at a distance of more than 12 nautical miles from the nearest land, provided that in any case, the sewage that has been stored in holding tanks shall not be discharged instantaneously but at a moderate rate when the ship is en route and proceeding at not less than 4 knots; the rate of discharge shall be approved by the Administration based on standards developed by the International Maritime Organization.*".

Unless the characteristics of effluent from vessels carrying cattle, sheep or goats is adequately defined, and appropriate disposal strategies developed, the Marine Protection Committee of the *International Maritime Organization* will impose the above standards, which appear to be designed for effluent storage and disposal for passenger ships. It is understood that the current project report will assist in the development of a case for specific effluent handling and disposal practices for livestock carriers at the meeting of the Committee in March/April 2004.

3.2 Objectives

Meat and Livestock Australia engaged *Landline Consulting* to conduct the desktop review of the characteristics and volume of effluent produced by livestock vessels. Under the agreement, Landline Consulting will report, by 15 December 2003, on the following:

- The nature and composition of effluent produced by vessels that carry sheep, goats or cattle;
- The volume of effluent produced from vessels that carry sheep, goats or cattle; and
- Compare the nature and volume of effluent from livestock vessels with effluent originating from passenger ships.

3.3 Method

A literature review and Internet search were undertaken, along with discussions with livestock and passenger ship owners. The review found a dearth of critical information on the characteristics of effluent from livestock carriers. Therefore use was made of effluent data derived from feedlots and from theoretical calculations of feed intake and utilisation.

Because volume of wash-down water on livestock vessels cannot be specified, we have based our calculations on manure disposal alone, since the wash-down water will contain no solids, nutrients or organisms of concern.

4.0 Results and Discussion

4.1 Effluent Generated on Livestock Vessels

4.1.1 Nature

Sheep and goats produce a dry faecal pellet compared with sloppy cattle faeces, reducing the need for wash-down of sheep and goat pens. Generally, sheep and goat pellets have a moisture content of 50-60% compared with 75-80% for cattle faeces (ASEA 1999; Church 1980; DPI 2003).

4.1.2 Quantity

Ruminants eat 2 to 3% of body weight daily, on a dry matter basis, and water intake is 10-20% of body live weight (DPI 2003; SCA 1990). The result is a large output of excrement (Table1). For cattle of typical live-export body weight, the volume of manure (faeces and urine combined) is in the range of 20 to 30 L per head (5 to 6% of body weight) per day (DPI 2003); and for typical live-export sheep and goats it is 1.2 to 1.8 L per head (4% of body weight) per day (ASAE 1999). For humans, published figures (Fleming and Ford 2001; Magidy and Henze 2000) usually include unmeasured dilution water, making estimates of total mass and urine volume less accurate than for ruminants.

Table 1. Daily production of manure (faeces and urine) and its components by 1000 head of cattle sheep, goats and humans, at each of two live weights.

	Animal LW (kg)	**Total manure** (kg)	**Dry matter** (kg)	**Organic dry matter** (kg)	**Urine** (L)
Cattle	300	17,400	2,600	2,200	5,400
	450	26,100	3,800	3,200	8,100
Sheep	30	1,200	330	280	450
	45	1,800	500	410	680
Goat	25	1,000	320	230	375
	40	1,600	520	370	600
Human	60	1,000	160	140	800
	90	1,000	240	190	1,200

The effluent produced by small and large ships for each animal type and weight are presented in Table 2.

Table 2. Daily production of manure (faeces and urine) (tonnes) by cattle, sheep, goats and humans, at each of two liveweights and two typical ship sizes.

	Cattle		**Sheep and goats**		**Humans**	
	1,000	10,000	1,000	50,000	500	3000
Lower LW	17	174	1.2	60	0.5	3
Higher LW	26	261	1.8	90	0.5	3

4.1.3 Composition

Total solids in cattle manure comprise 10 to 15% on a dry weight basis, or 0.5 to 0.9% of body weight, or about 40% of dry matter intake (ASEA 1999; DPI 2003; Gardener *et al*. 1993). For sheep and goats, total solids in manure comprise, 28 to 32% on a dry weight basis, 1.1% to 1.3% of body weight, or 35% of dry matter intake (ASEA 1999).

Nutrient content is somewhat dependent on feed quality but there are obligatory losses that set minimum concentrations of nutrients in faeces and urine. The typical manure compositions for feedlot animals are shown in Table 3 (ASAE 1999; DPI 2003).

Table 3. Typical manure (faeces and urine) composition, on wet basis.

	Dry matter	BOD*	Nitrogen	Phosphorus	Potassium
	%	%	%	%	%
Cattle	15	2.7	0.58	0.17	0.36
Sheep	28	3.0	1.05	0.22	0.80
Goats	32	3.4	1.10	0.27	0.75

**BOD = biological oxygen demand, a measure of the capacity for organic matter to consume oxygen during decomposition.*

The daily production of manure components, standardised for 1,000 of livestock or humans varies markedly between livestock and humans (Table 4).

Volatilisation of nitrogen occurs in fresh manure and in manure built up in a pad. For cattle, discounting the volatilisation of fresh and padded manure of 92% given by Environment Australia (2001) to 70% to account for only short duration in pads leads to large reductions in nitrogen discharge (Table 4). In the absence of volatilisation data for sheep and goats, we have arbitrarily discounted the figures of Environment Australia (2001) from 92% to 50%.

Table 4. Daily production of manure components by 1000 head of cattle sheep, goats and humans, at each of two liveweights.

	Animal LW kg	**BOD*** kg	**Nitrogen as excreted** kg	**Nitrogen after volatilisation** kg	**Phosphorus** kg	**Potassium** kg
Cattle	300	500	100	30	30	60
	450	700	150	45	40	90
Sheep	30	36	13	6.5	2.6	9.6
	45	54	19	9.5	3.9	14.4
Goat	25	30	11	5.5	2.8	7.8
	40	48	20	10.0	4.4	12.4
Human**	60	50	9.1	9.1	1.8	2.8
	90	75	13.6	13.6	2.7	4.2

**BOD = biological oxygen demand, a measure of the capacity for organic matter to consume oxygen during decomposition.*
** Fleming and Ford 2001; Magidy and Henze 2000.

Calcium, magnesium, sodium and trace element concentrations are not considered since the high background levels in the ocean mask any contribution from livestock shipping. The typical composition of seawater is calcium 1.16%, sodium 30.6%, magnesium 3.69%, potassium 1.10% and sulphur (as sulphate) 2.56%.

All animals excrete bacteria, protozoa and virus. The important enteric pathogens excreted by ruminants (as well as humans) are: *Salmonella spp., Escherichia coli O157:H7, Campylobacter jejuni, Yersinia enterocolitica, Giardia lamblia, and Cryptospiridium spp.* (Olson 2000). A common index of bacterial (and protozoan and viral) contamination is faecal coliforms, although there is a trend now to list levels of specific organisms. Some typical levels of enteric organisms are shown in Table 5 (Fleming and Ford 2001).

Table 5. Enteric organisms excreted by ruminants and humans.

	Faecal coliforms	*E. coli*
	number/head/day	number/head/day
Cattle	1.0E+11	4.0E+09
Sheep	1.7E+10	N/a
Goats	N/a	6.3E+09
Humans	2.75E+05	1.30E+09

N/a – Data unavailable

Total numbers discharged from ships are much less important than the numbers per unit volume of water after dilution and mixing. The impact of these organisms in the ocean is extremely brief owing to dilution and the combined sterilization effects of seawater and ultraviolet light. Time for 90% mortality of *E. coli* in the sea varies from 4 hours to 4 days depending on water temperature; mortality is faster in warmer conditions (Olson 2000).

4.2 Wash-down Practices

4.2.1 Livestock vessels

Effluent from ships currently operating in the Australian livestock market is disposed of in an unregulated manner directly into the sea, with unspecified precautions against disposal close to land. There is no storage of the manure in holding tanks.

Effluent disposal strategy varies with the shipping operator and the type of livestock carried. Cattle effluent is washed overboard from the pens on a continuous basis depending on the size of the ship and number of cattle carried. For large ships this means that each pen might be washed down every three to four days, or longer, as the attendants work their way around the cattle pens and between decks. The net effect is that effluent from the ship equates closely to manure production, except for volatilised nitrogen. Volatile losses of ammonia-nitrogen from accumulated manure on the pen floor may be greater than 90% particularly in hot tropical conditions (Environment Australia 2001), and this mechanism can markedly reduce the quantity of nitrogen discharged into the sea.

For smaller animals such as sheep and goats, which have dry faeces, a pad is allowed to develop on the pen floor, and assists in absorbing urine. Generally, wash-down of the pens does not occur at all, on the delivery voyage because wetting and disturbance of sheep, and particularly goats, can be stressful. Wash-down of pens and effluent disposal occurs after the ship has discharged the animals and during the return journey. If wash-down occupies much of the return voyage, the effect is the same as if wash-down had occurred on the outward voyage. The daily effluent discharge will depend on the duration of the wash-down as:

Daily discharge = daily manure production x duration of outward voyage/duration of wash-down

The volume of wash-down water is unregulated, and it will determine the concentration of constituents disposed off in the sea. Number, age and type of livestock as well as wash-down frequency will determine the quantity of solids and nutrients discharged at any particular location. Within 15 minutes of discharge, the concentrations of solids, nutrients or organisms in the mixing zone behind the ship will depend on rate of discharge, ship speed and the concentration of components in the effluent. These parameters need to be critically assessed as they determine the impact of effluent discharge on the marine water quality, and any possible response by environmental regulators.

4.2.2 Passenger ships

Human effluent from passenger ships is generally treated in some form prior to disposal; modern cruise ships have sophisticated maceration, aeration, filtration and disinfection systems for sewage treatment, which results in relatively clean water for disposal. One large passenger ship company operating in Australia and internationally has tertiary systems (HamworthyKSE sewage treatment system) installed in its new cruise ships, and is steadily retrofitting those systems to older ships. The Hamworthy system is a stand-alone plant, which operates as an activated sludge/suspended aeration system, combined with disinfection. The manufacturer claims that effluent discharge quality meets IMO certification issued by the U.K. Maritime Safety Authority, by reducing BOD_5 to 2.6 mg/L and coliforms to 106 counts /L.

Common practice on smaller passenger/cargo ships is to treat effluent by maceration and aeration, and discharge on a continuous basis. Although in environmentally sensitive areas such as the Alaskan coast and the Great Barrier Reef waters, shipping operators have modified effluent disposal practices. For example, one small cargo/passenger shipping company operating in the Barrier Reef area has installed a Hamworthy system for sewage treatment.

On the larger ships there is normally an on-board effluent storage capacity for 2-3 days, which is used in port.

It should be noted that the sewage treatment systems used on many passenger ships focus on the reduction of solids and microbes rather than potentially contaminating nutrients such as phosphorus and nitrogen.

5.0 Success in Achieving Objectives

A review of the literature and discussion with ship owners concludes that effluent from livestock carriers is disposed off untreated into the sea. Depending on livestock numbers carried these vessels have the potential to accumulate and discharge large quantities of solids as well as nitrogen, phosphorus and potassium into the sea. However, the impact of the effluent constituents on the marine environment will be determined by a number of factors including the effluent load, the ship speed, the mixing zone and the sensitivity of the receiving waters.

Whilst passenger ships generally do not exceed 3,500 passengers, livestock ships can carry in excess of 50,000 sheep and goats or 10,000 head of cattle. Large livestock ships have the capacity to exceed the effluent discharge levels of passenger ships, due largely to the numbers involved, and composition of the manure.

6.0 Impact on Meat and Livestock Industry

The review shows that large livestock vessels have the capacity to generate significantly greater quantities of solids, nitrogen, phosphorus and potassium than passenger ships. If similar disposal restrictions were to be imposed on livestock vessels and passenger vessels alike, major modifications to livestock vessels would be required to treat effluent and, in some instances, hold that effluent until the required distance from the nearest land.

7.0 Conclusions and Recommendations

Livestock ships generate large quantities of solids, BOD_5, nitrogen, phosphorus and potassium, which often accumulate on ship and are finally discharged untreated into the sea. Pathological organisms (coliforms and *E. coli*) appear to be at least as abundant in cattle effluent as in human effluent. Effluent from passenger ships has less potential to generate these waste products simply due to the limited numbers of passengers. Nevertheless, cruise ship companies are bringing new ships into service with sophisticated sewage treatment systems, and steadily retrofitting older vessels with those systems so that they comply with anticipated stringent discharge standards.

It is strongly recommended that the livestock shipping industry critically assess the impact of effluent disposal on marine water quality, taking into account the role of key factors such as ship speed, discharge rate and mixing zone, on the dilution of effluent solids and potential contaminants. The ANZECC (2000) guidelines clearly indicate trigger levels and contaminant limits for the range of parameters contained in effluent discharge.

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