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A Nitrogen Management Strategy for Meat Processing Plants

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Executive Summary

In October 2001, Australia Meat Holdings (AMH) Dinmore abattoir commissioned an entirely new byproducts processing facility. It incorporated a number of new features designed to reduce nutrient emissions and improve value-added products. Of special importance were:

- new blood drying technology, which reduced blood stickwater generation;
- the elimination of the pneumatic raw material conveying system with a “dry” pumping technology.

Prior assessment of these changes in the design stages by Dr. Mike Johns (Johns Environmental Pty. Ltd). predicted significant reductions in COD and nutrient emissions to the wastewater treatment plant. Such a reduction is of major benefit to the Dinmore facility, which incurs significant capital and operating cost in treating COD and nutrient concentrations in the wastewater prior to disposal.

In early 2001, Meat & Livestock Australia (MLA) commissioned UniQuest Limited [UniQuest] to perform a benchmarking exercise to measure the reductions in nutrients and other contaminants achieved by AMH by implementing the above improvements to their plant. The methodology used involved two approaches to estimating the contaminant loads released from the abattoir:

- Approach 1 required benchmarking nutrient loads emitted to the primary treatment system before and after the commissioning of the new Byproducts facility. This was achieved by measuring wastewater flow and contaminant concentrations post the primary treatment facility.
- Approach 2 required a more complex process of closing contaminant mass balances over the abattoir using flow measurements and individual stream sampling to estimate actual released loads for approximately 20 waste streams. A spreadsheet model previously developed by Dr. Johns was used for this approach. This identified the “dirtiest” waste streams.

From these two approaches the spreadsheet model could be refined and the dirtiest streams identified. This permits further waste reduction strategies to be considered.

It was found that the installation and commissioning of the new Byproducts facility at Dinmore abattoir achieved the following reductions in loads of contaminants discharged to the primary treatment system:

Chemical Oxygen Demand:	11%
Total Suspended Solids:	13%
Total Nitrogen:	21%
Total Phosphorus:	11%

The flow actually increased a little. These reductions were achieved despite the processing of raw material that had previously been sent out for rendering (the data were not adjusted to take this into account). Therefore, the reductions in load discharged are almost certainly larger than shown.

Studies of the discharged contaminant loads prior to the modifications, showed that the raw material bin drainage from the old byproducts plant was the worst contributor to COD (22% of total) and nitrogen (32% of total) of any waste stream. This was due largely to its significant volume (3.4% of total flow) and high strength. It was found that large quantities of water had to be added to prevent blockage of the blow lines during raw material transport and that this captured large quantities of nutrients and COD.

Elimination of the blow system by a dry pumping system resulted in the very significant reductions in COD and TN discharge seen above. The reduction in COD load alone is equivalent to a city of 40,000 persons!

The old byproducts plant (including the LTR plant and the raw material bin drainage) contributed to contaminant loads out of all proportion to its effluent flow (only 10% of total). COD, TN and TP loads

discharged prior to the new facility amounted to 36%, 50% and 24%, respectively. The new byproducts facility is much cleaner at 25% COD, 40% TN and 13% TP (with addition throughput).

The spreadsheet model could be used to estimate loads discharged by any of 20 waste streams in the abattoir using estimated and measured flows of each stream and measured compositions with very reasonable accuracy, when validated against the total discharge of each contaminant at the wastewater treatment plant inlet.

Individual waste streams were found to fall into three categories according to composition:

1. Very high strength streams characterised by very high COD (> 50,000 mg/L), very high TSS (>20,000 mg/l), typically high O&G (> 7,000 mg/l) and very high nitrogen (>3,000 mg/l) and phosphorus (> 200 mg/l), although there is significant variability. These included:

   - raw material bin drainage
   - tallow stickwater from the polishers
   - tallow stickwater from the low temperature rendering plant (gel bone).

   Of these the raw material bin drainage dominated contaminant load discharge.

2. A second group of waste streams is characterised as medium strength and is characterised by high COD (14 – 20,000 mg/L), high TSS (> 7,000 mg/l), and high nitrogen (>340 mg/l) and phosphorus (> 150 mg/l). These streams comprise a significant number of the worst streams due to their high flow, including:

   - cattle yard wash streams
   - tripe processing effluent;
   - dry dump stream (especially for phosphorus)

3. The remaining waste streams comprise relatively weak contaminant levels with COD typically < 6,000 mg/l, TSS < 2,000 mg/l and nutrients generally low (TN < 250 mg/l; TP < 25 mg/l), although again there is significant variability. These streams pose significant loads only at high flows. The only stream of significance from this group was:

- red offal wash stream (trommel), especially for oil & grease loads (almost half the total discharge load).

Following the commissioning of the new byproducts facility, the AMH Dinmore processing plant in total is now at world best practice performance in terms of contaminant discharge in the raw wastewater (prior to treatment). Contaminant loads (with world best practice data in brackets) comprise:

- 5.4 kL wastewater/tonne HSCW (WBP: 5.5)
- 39.2 kg TCOD/tonne HSCW (WBP: 30)
- 1.58 kg TN/tonne HSCW (WBP: 1.5)
- 0.25 kg TP/tonne HSCW (WBP: 0.25).

The project appears to have been successful. It is hoped these data will provide further incentive for developing and implementing new strategies to further reduce resource consumption and waste generation during meat processing.

Contents

1. Scope

1.1 Project Setting

Meat processing generates a raw wastewater that contains:

- medium levels of organic pollution (COD, BOD),
- large amounts of Total Suspended Solids (TSS) and Oil & Grease (O&G)
- and high concentrations of the nutrients nitrogen and phosphorus – normally defined as Total Nitrogen (TN) and Total Phosphorus (TP) by Environmental Agencies in Australia.

Although traditional forms of wastewater treatment, such as screens, savealls, Dissolved Air Flotation (DAF) units and pond systems, have provided a reasonable degree of treatment for the first two of the above contaminant groups, they achieve only very limited reduction in the levels of nitrogen and phosphorus.

Nutrients have become a troublesome issue for meat processing plants, whether effluent disposal is to sewer, surface waters or land irrigation. In all three final disposal options, nitrogen and phosphorus tend to be present in excessive amount. The removal of nutrients from wastewater is possible, but requires expensive and relatively sophisticated technology and must be associated with more routine monitoring than traditional pond systems. Key technology options for nutrient removal, which are generally suitable for meat processing plants include:

- Biological nutrient removal systems – especially Sequencing Batch Reactor (SBR) activated sludge systems. There are currently about 6 SBR systems constructed for meat plants in Australia. While these systems can be configured to remove both nitrogen and phosphorus from domestic sewage, current systems generally achieve only very limited phosphorus removal, but excellent nitrogen reduction (> 92%) in meat processing facilities.

- Chemical precipitation of phosphorus. Where biological removal of phosphorus is limited, additional removal of orthophosphate can be achieved by precipitation with metal salts – especially aluminium of iron. However, very large amounts of chemical sludge are generated, if low levels of phosphorus in the final effluent are required.

Further details of these technologies are provided in MLA publications (MLA, 1999).

The installation of more eco-efficient processing technology offers the meat-processing sector an alternative and complementary approach for reducing the load of nutrients emitted from process plants. If less nutrients are sent to the wastewater treatment plant, significant capital and operating expenditure is reduced, since the nutrient removal technology and/or irrigation areas required are smaller. The Australian industry has begun to aggressively adopt this approach for greenfield sites and during upgrades of existing facilities. However, there are few if any demonstrated examples of success.

This project sought to benchmark the reduction of contaminant – and especially nutrient - loads generated when new, cleaner processing technology was installed during an upgrade to the Australia Meat Holdings meat processing plant at Dinmore. It presents a simple “before” and “after” case study of the nutrient reductions possible when superior technology is installed.

1.2 Objectives

The objectives of the project were:

1. To benchmark nitrogen & phosphorus wastewater emissions in the current Dinmore abattoir facility – the “Before” case;

2. Use the information to define the impact of process changes on the existing effluent treatment system (in terms of nitrogen & phosphorus loads) & identify source reduction wins; and

3. Monitor the reduction of nutrient loads after implementation of nitrogen reduction strategies (new Byproducts facility) at AMH Dinmore.

2. Background

2.1 Previous Work

In Australia during the early 1990s the attention of Environmental Regulatory Authorities was focused on nutrient issues by:

- the massive blue-green outbreak in the Murray-Darling river system during 1991-1992, due to elevated nutrient levels;
- continuous blue-green algal blooms in the Swan and Canning rivers in Perth;
- concern about eutrophication of Port Phillip Bay near Melbourne and the Hawkesbury-Nepean river system near Sydney;
- demonstrated nutrient pollution of groundwater in both WA and south-eastern SA;
- concerns of over-application of nutrients to land through irrigation of effluent and biosolids.

This eventuated in the publication of a suite of EPA regulations to control nutrient discharges. In most States, discharge to rivers was strongly discouraged in preference to land application. In NSW, draft effluent irrigation guidelines were published in 1995, followed by Load-based regulation of effluent application to the environment – including land application – in 1997/98.

Prior to 1995, very little was known about the emission of nutrients in wastewater from Australian meat processing plants. Typically only BOD, TSS and O&G were measured in the final effluent before disposal and many licences contained no reference to nutrients. Publications from the early 1990s (Greenfield & Johns, 1992) indicated poor nutrient removal in existing meat processing wastewater treatment systems.

Some detailed work on nutrient emissions in various waste streams had been published for German abattoirs (Tritt & Schuchardt, 1992), but it was not easy to decipher. A review by Johns (1995) summarised existing knowledge at the time.

In 1994, the precursor to MLA – the Meat Research Corporation – conducted a project, which measured nutrient generation in individual waste streams at five Australian abattoirs. This complemented a PhD study (Harrison, 2000) of the AMH Dinmore abattoir being performed by M. Harrison under supervision of Mike Johns and Phil Hutchison (AMH Group Engineer). The combined work was published as "Identification of Nutrient Source Reduction Opportunities and Treatment Options for Australian Abattoirs and Rendering Plants" [Nutrient Audit] in November 1995. The Nutrient Audit identified the following waste streams as significant nutrient generators:

For phosphorus:

- Manure & paunch
- Rendering plant, especially raw material bin drainage & blood processing;
- Recycled effluent
- Stockyard washdown
- Offal processing.

For nitrogen:

- Rendering plant, especially raw material bin drainage & blood processing;
- Slaughter & evisceration
- Manure & paunch
- Offal processing.
- Casing processing.

Dr. Johns later presented these data on a Hot Standard Carcass Weight (HSCW) basis for the industry (Figure 1). The data from the Nutrient Audit study provided seminal information to the industry and permitted various nutrient reduction strategies to be considered for implementation.

Further studies followed including:

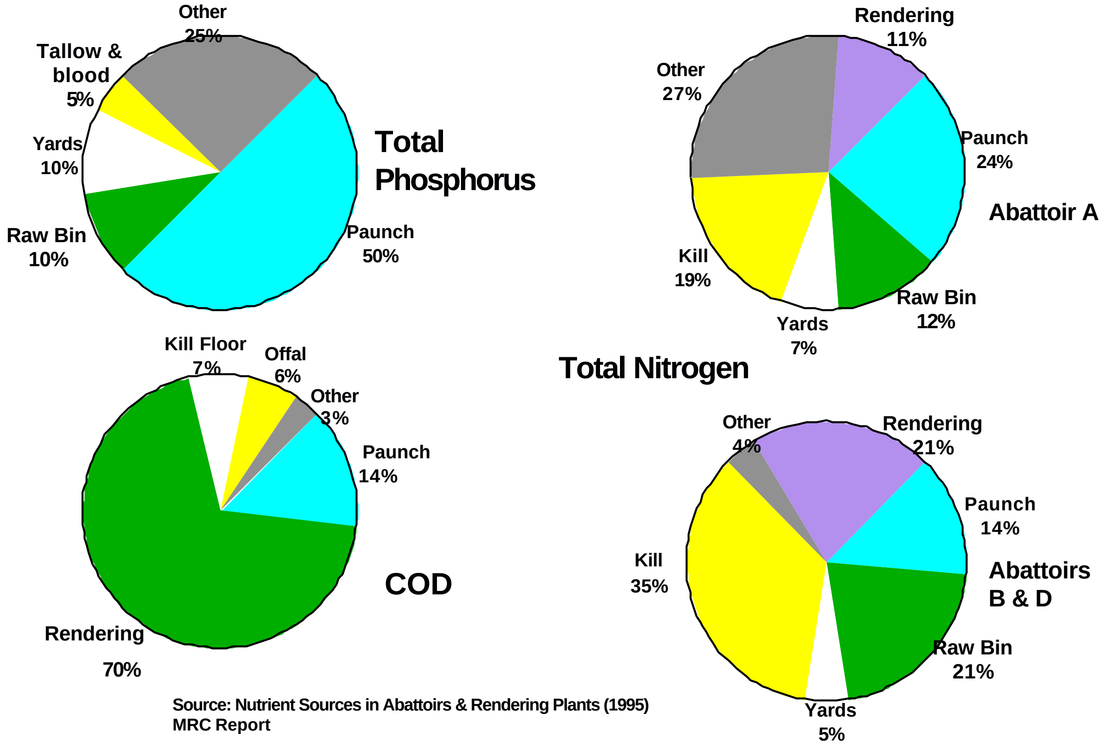
- Assessment of Dry Paunch Dumping in red meat processing plants (MLA, 2001 as PRENV.008). This work identified that up to 20% of the phosphorus emitted by an integrated, modern abattoir was generated through paunch dumping. Dry dumping led to this load being captured in a low volume, highly concentrated stream, also containing large COD and TSS levels.

- Stickwater Evaporation. This work was undertaken at a Queensland abattoir, to evaluate the benefit of this technology for reducing nutrients from the rendering process (MLA, 1996 as M.734).

Much of this information has been recently incorporated into the MLA Eco-Efficiency Manual (2002).

This current report now provides a clear case study illustrating the immense benefit of incorporating clean technology into meat processing facilities.

Figure 1: Percentage contribution of COD, Total Nitrogen and Phosphorus contributed by each part of abattoirs participating in the Nutrient Audit Project (M.445) in 1994/95 (MRC, 1995).



2.2 Dinmore Abattoir

2.2.1 General Description

The Dinmore abattoir of Australia Meat Holdings Pty. Limited (AMH) is a modern, fully integrated plant, which processes only cattle. The kill floor, offal floor and edible blood processing operations form part of the new abattoir constructed in 1998. Dry dump technology for paunch contents was installed at that time. The boning room, freezing and chilling areas and a low temperature rendering plant (gel bone) are housed in the adjacent older buildings, but have been upgraded over the years.

The wastewater treatment system is extensive, since a large part of the treated effluent is discharged to the Bremer River, close to the junction of the Brisbane River. The discharge is highly regulated by an innovative load-based license and covers nutrients, organic carbon, and many other contaminants. The treatment system consists of:

- screening through fine aperture wedgewire rotary screens;
- savealls to reduce TSS and O&G;
- anaerobic pond treatment to reduce BOD and COD;
- twin SBRs to reduce BOD, COD, TSS and nitrogen to required levels. Some phosphorus reduction also occurs.

2.2.2 The “Before” Technologies (Pre-Modification)

The processing changes which were the focus of this project concerned the byproducts plant – a source of COD and nutrient emissions out of all proportion to the wastewater flow. The technology existing at the start of this project included:

- a continuous high temperature rendering system;
- an edible blood collection, processing and plasma drying system. Edible haemoglobin fraction was sent to the inedible blood system;
- a traditional steam coagulation inedible blood processing plant.
- a large pneumatic (blow bowl) system to transport raw material from the kill floor to the byproducts plant.

Due to capacity constraints, a large quantity of raw material was exported for off-site rendering.

2.2.3 The “After” Technologies (Post-Modification)

In October 2001, the new byproducts facility was commissioned. This state-of-the-art facility involved a complete rebuild of the existing byproducts plant and incorporation of new processing technologies. Key processing changes included:

- a new continuous high temperature rendering system;
- retaining of the edible blood collection, processing and plasma drying system.

- installation of new drying capacity for the edible haemoglobin fraction;
- retention of the traditional steam coagulation process for inedible blood only.
- elimination of the large pneumatic (blow bowl) system with a hydraulic (V Ram) system to transport raw material from the kill floor to the new byproducts plant. The hydraulic system requires no water addition for transport – a major Achilles heel of blow systems.

The new byproducts plant processed all raw material generated by the abattoir.

3. Methodology

A four-stage approach was developed for the work. This involved:

Stage 1: Conducting sampling and analysis of the most critical waste streams within the abattoir under the "Before" scenario. Special attention was focussed on waste streams from the old byproducts plant, which was to be demolished during the reconstruction.

An extensive sampling protocol was developed for the abattoir. Personnel from UniQuest Limited conducted sampling in October 2001. This involved composite sampling of waste streams to obtain samples as typically representative as possible. These were analysed for a wide range of contaminants by the analytical laboratory operated by Wastewater Futures Pty. Ltd. at the University of Queensland. The full range of analyses conducted and the test methods performed are listed in Appendix 1. The results were evaluated by Dr. Mike Johns.

Stage 2: A spreadsheet mass balance model previously developed by Johns Environmental Pty. Ltd. to describe integrated abattoir operations was used to evaluate the overall abattoir and individual stream contaminant loads for each of the 18 – 20 waste streams generated by the abattoir. There are many more individual waste streams that could be sampled further back in the process, but the increasing error associated with both flow and composition measurement make it improbable that the increased cost of doing so would improve the accuracy of the model outputs.

The model results were validated against the actual contaminant loads emitted to the primary wastewater treatment system.

Stage 3: The worst waste streams were identified for the "Before" case.

Stage 4: Subsequent to the commissioning of the new byproducts facility at Dinmore in October 2001, flowmeters were installed by AMH on major water distribution pipes to determine water flows to key processing sections with more accuracy. A further, more extensive round of sampling of the waste streams – incorporating those from the new byproducts plant – was conducted in April 2002 by which time the byproducts plant had settled down to normal operation.

The data were evaluated using the spreadsheet model adapted to the processing facility in Stage 2.

The abattoir operates 7 days/week using a mix of single and double shift days. This study considers only the "double-shift" operation.

4. Emissions before the Modifications

The first Stage of the project was to benchmark emissions of contaminants from the Dinmore abattoir prior to the planned modifications to the Byproducts Section of the plant. This would provide the comparison for judging how effective the modifications were in reducing emissions. This study was completed in October 2001.

4.1 Approach

In order to assess the impact of potential nitrogen management strategies on reductions in nitrogen emissions from the abattoir, it is first necessary to develop a mass balance model for each contaminant (COD, TSS, TN, etc) of interest. The mass balance model can be summarised mathematically as:

$$L_N = C_{N,w} \cdot Q_w = \sum_{i=0}^{i=n} C_{N,i} \cdot Q_i \qquad \textit{equation 1}$$

where:

L_N = Load of contaminant, N (kg/day)

$C_{n,w}$ = Concentration (mg/l) of contaminant N in the total wastewater discharged to the primary treatment system;

Q_w = Estimated flow of the total wastewater discharged to the primary treatment system (ML/day);

$C_{n,i}$ = Concentration (mg/l) of contaminant N in the i*th* waste stream.

Q_i = Estimated flow (ML/day) of the i*th* waste stream.

n = Number of waste streams

Essentially equation 1 permits estimation of the load of a contaminant released in the wastewater from the plant by two methods:

1. ***Overall Mass Balance***: This approach determines the concentration of the contaminant in the total wastewater discharged and multiplies it by the total flow of wastewater to give the total load of contaminant generated in the abattoir (see equation 2 below). This is the first term of the above equation. This is the most accurate method, since it involves only one set of analysis and measurement of one flow. Further, the inherent variability in contaminant load is likely to be much less than in individual waste streams, due to the equalising effect of larger volumes.

$$L_N = C_{N,w} \cdot Q_w \qquad \textit{equation 2}$$

Unfortunately, this method does not provide any knowledge about the contribution of the individual waste streams to the load. Consequently, an assessment of cleaner production strategies is impossible with only this information.

However, for the purposes of this report, this approach will be used to provide a reality check - the best estimate of total load of contaminant released from the abattoir. The mass balance model (approach 2) will only be considered to be useful (validated) if its estimate of load are within reasonable agreement with that determined by this first method.

2. ***"Sum of Waste Streams" Mass Balance***: The second approach works on the basis that if we add all the load contributions of each waste stream which make up the total effluent, we should get the same answer as approach 1. This is the second term of equation 1 above and is given below as equation 3.

   In this study, we identified up to 19 individual waste streams (n = 19) that might provide significant loads of the 8 contaminants to the final raw wastewater. This approach requires that each stream is sampled and tested for each contaminant and that its flow is known. This is the greatest difficulty with this approach – it requires huge effort and expense to derive 19 sets of representative contaminant concentrations and 19 estimates of stream flows, when in most plants, some of these flows are either highly inaccessible or highly variable or periodic in nature, or both!

$$L_N = \sum_{i=0}^{i=n} C_{N,i} \cdot Q_i \qquad \textit{equation 3}$$

   Furthermore, all the sampling and measurement error implicit in each measurement adds to the total uncertainty of the right hand side of equation 3. Hence, the estimates of L_N by this method are more rubbery. This is acceptable, if this is understood and if the final value has a reality check. In our case our reality check is the answer from Approach 1.

   The primary benefit of Approach 2, however, is that the contribution of the individual waste streams to the load of any contaminant can be identified and an excellent assessment of cleaner production strategies is possible. In fact, even the predicted improvement can be estimated (within some degree of error).

4.2 The Reality Check: Overall Mass Balance

The Benchmarking study of primary-treated wastewater was performed on 10th April 2001. As discussed above, two pieces of information are necessary to determine the loads of pollutant :

- an estimate of average daily flow;
- a measurement of the "typical" pollutant concentration.

4.2.1 Wastewater Flow

During 2001, an ultrasonic measurement device (using a weir in the effluent channel) measured the primary-treated wastewater flow at Dinmore. A separate flow meter measured wastewater flow, which bypassed the weir. The sum of these two measurements gives the total flow from the facility. These devices record continuously with the daily flow calculated by integration of the readings.

To estimate the daily flow for the purposes of the benchmarking study:

- Only double-shift day flows were used. There were 4 double-shift days per week. Analysis of flows found that the flow on the first of the four double shift days was significantly lower (> 2 std. deviation variation) than that of the other three days. Consequently, only data from the three "full-flow" days was used to calculate average double-shift day flow.

- A full 6 months of flow data comprising April – September 2001 inclusive was used to estimate the 50-percentile flow (as the best estimate), since abattoir operations were steady during this period and no significant process technology was commissioned that affected waste streams.

- The median daily double-shift flow for the period was 5.0 ML/day.

4.2.2 Contaminant Concentrations

To obtain as accurate a measurement of the contaminant concentrations in the raw wastewater as possible, the following were performed:

- The on-site AMH laboratory analysed the samples from the primary-treated effluent on a daily basis. Samples were tested for total COD, TSS, ammonia-nitrogen, phosphate and pH. Data from a six month period (Apr-Sept 2001 inclusive) were obtained and analysed to develop 50-percentile concentration values.

- Since total nutrient concentrations were required and AMH measures soluble inorganic nutrients only, composite samples were taken from the primary-treated wastewater over a processing day and tested for total nitrogen (Total Kjeldahl Nitrogen, TKN) and Total Phosphorus (TP) to obtain concentrations of both inorganic and organic nutrients.

- Both soluble and total COD, TKN and TP tests were performed.

4.2.3 Contaminant Loads Discharged

Table 1 provides the median concentrations and loads of contaminants in the primary-treated wastewater discharged from Dinmore abattoir prior to the plant modifications. Almost 2 tonne/day of nitrogen and 270 kg/day of phosphorus were discharged to the wastewater treatment plant. For comparison purposes, the nitrogen load is equivalent to a city of 150,000 persons!

Table 1. Wastewater flow & contaminant loads discharged to the primary treatment system pre-modifications.

Source	Units	Value	TCOD	TSS	TKN	NH_3-N	TP
Wastewater flow	ML/d	5.0					
Median concentration	mg/l		8,500	2,710	386	53	54
Median load discharged	kg/d		42,500	13,550	1,930	265	270

4.3 Developing the Model: Mass Balance from Individual Waste Streams

A mass balance model of the Dinmore abattoir was now generated using the following pieces of information:

- an estimate of daily flow for each of 19 individual waste streams
- measurements of the concentrations of each of the 8 contaminants in each waste stream to determine representative and "typical" contaminant concentrations.

4.3.1 Individual Waste streams Flows

The estimated individual stream flows from the Dinmore processing facility are provided in Table 2 and graphically in Figure 2. There is significant uncertainty associated with these values, since:

- there is a normal daily variability in flow
- in many cases, only the inflows to these parts of the plant are known from flowmeter measurements, rather than effluent flows;
- in some instances, actual measurements of waste streams could not be performed due to the inaccessibility of the waste stream;

Table 2 provides the closest possible estimation of flows for each waste stream. A summary of the methods used to estimate the flows is provided in Appendix 2. Note that the "Red Offal Wash" is not included in the total flow in Table 2, since waste streams from the kill floor and tripe processing were used to wash offal at Dinmore and so including it would be "double-counting".

A fuller discussion of these stream flows is presented in Section 5.1.2. However some salient observations include:

1. The estimated flow agrees within error with the 5.0 ML/day measured into the wastewater treatment plant (Overall Mass Balance Approach – See Table 1). This overall flow closure is as good as may be expected.
2. The waste streams contributing the greatest flows are (in order of volume):

   - Kill floor red flows;
   - Ante-mortem yard flow
   - Tripe processing flow
   - Cleaning flows from the kill floor & boning room;
   - Boning room flow.

   What is interesting is that these streams generally do not rank as the biggest load contributors, except for the ante-mortem yard and tripe processing flows.

3. The old (pre-modification) Byproducts Department generates only a small percentage of the total flow from the abattoir (10.6%). Yet, as demonstrated in Figure 3, it contributes some of the richest contaminant load to the raw wastewater from the abattoir.

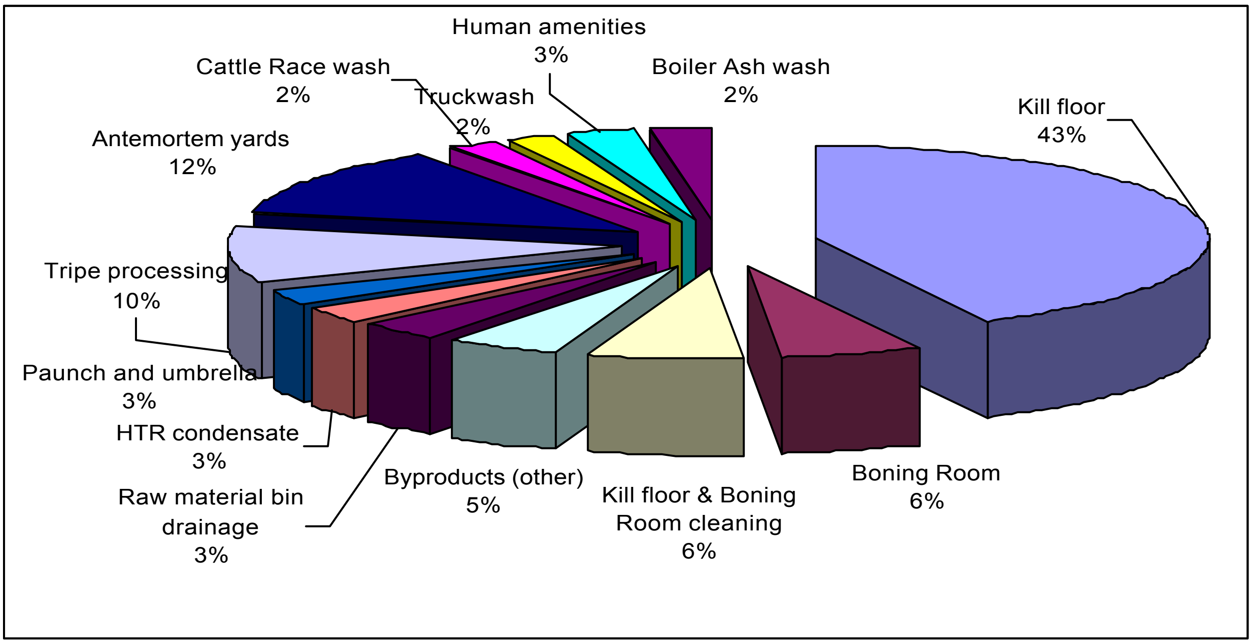
Table 2. Estimate of Individual waste stream flows in the pre-modification plant

Waste stream	**Flow** kL/day	**% of total flow**	**Stream Rank**
Red flows			
Kill floor	2,150	42.7	1
Red Offal wash (trommel screen)	2,650		
Boning Room	300	6.0	5
Kill floor & Boning Room cleaning	320	6.4	4
		(55.1)	
Byproducts			
Raw material bin drainage	170	3.4	
HTR condensate	133	2.6	
HTR Stickwater	40	0.8	
Blood processing stickwater	40	0.8	
Blood drier scrubber	86	1.7	
Miscellaneous (incl. washdown)	45	0.9	
Gel bone LTR plant	30	0.6	
		(10.6)	
Green flows			
Paunch dry dump	70	1.4	
Umbrella wash	64	1.3	
Tripe processing	500	9.9	3
Antemortem yards	620	12.3	2
Cattle Race wash	100	2.0	
Truckwash	100	2.0	
		(28.9)	
Miscellaneous flows			
Human amenities	150	3.0	
Boiler Ash wash	120	2.4	
Sink (virtual flow)	0	0.0	
Total	**5,038**	**100.0**	

Notes:

1. Sub-total percentages for each of the plant sections may not accurately equal the sum of the individual waste streams due to rounding error.
2. The red offal wash flow is not included in the Total Flow (since it reuses kill floor & tripe flows)

Figure 2: Contribution of waste stream flows, expressed as % of total flow.



4.3.2 Contaminant Concentrations in Individual Waste Streams

Sampling of the individual waste streams at AMH Dinmore was performed over two campaigns – one in October 2001 (pre-modification) and one in April 2002 (post-modification). In total, 19 different waste streams were sampled and analysed for 8 chemical parameters. These were:

- Total Chemical Oxygen Demand (TCOD);
- Soluble Chemical Oxygen Demand (SCOD);
- Total Suspended Solids (TSS);
- Oil & Grease (O&G);
- Total Kjeldahl Nitrogen (TKN) – equivalent to Total Nitrogen in raw abattoir streams.
- Ammonia nitrogen (NH_3-N)
- Total Phosphorus (TP)
- Ortho-phosphate phosphorus (PO_4-P)

In addition, temperature and pH were recorded for most streams. The raw data are presented in Appendix 3. Results for some streams showed reasonable consistency between composited samples taken at different intervals during normal processing. For other streams, it proved extremely difficult to obtain consistent data, despite the use of composite sampling techniques. Troublesome streams included:

- High temperature tallow stickwater
- Blood stickwater
- Red offal wash (trommel effluent)

For these streams some degree of interpretation was required to eliminate dodgy sample results. Previous results from the MRC (1995) Nutrient Audit Report, and from data measured by Johns Environmental for similar waste streams at other Australian abattoir sites were used to assist in this screening process.

- The average values for contaminant concentrations in each waste stream (pre-modification) are presented in Table 3.

Table 3. Average contaminant concentrations in waste streams at Dinmore abattoir pre-modification.

Waste stream	**Note**	**Contaminant concentration (mg/L)**							
		TCOD	**SCOD**	**TSS**	**O&G**	**TN**	**NH_3-N**	**TP**	**PO_4P**
Kill Floor streams									
Kill floor red 1		1,400	560	500	320	80	9	3	1
Kill floor red 2		1,700	810	520	65	110	2	2	1
Red Offal wash (screen)	1	1,650	210	1,230	2,610	36	1	12	8
Boning Room	2	300		50	100	10		1	
Cleandown		6,500	1,840	4,400	670	265	10	25	15
Byproducts streams									
Raw material bin drainage		57,150	19,350	23,470	7,300	3,500	250	280	130
HTR condensate		730	615	30	60	245	230	1	0
HT stickwater		55,000	780	21,000	18,500	240	5	190	12
Blood stickwater		15,000	6,500	7,700	10	2,050	100	150	65
Blood drier scrubber		700	40	460	3	100	20	22	20
Miscellaneous, washdown	3	5,000	2,167	2,567	3	683	33	50	22
LTR plant		96,000		50,200	17,300	4,350		300	
Offal Processing streams									
Paunch dump	4	20,000	2,500	11,000	2,080	650	50	600	335
Umbrella wash	4	3,300	440	2,100		90	7	65	40
Tripe processing		14,500	1,000	8,500	7,325	340	10	45	24
Miscellaneous									
Ante-mortem yards		14,000	1,200	18,000	750	500	180	143	33
Cattle Race wash	5	800		340		22	6	3	
Truckwash	5	1,300		1,100	190	140		7	
Human sewage	6	450		200	5	50		12	
Chillers				5		2		0	
Boiler ash wash		700		730	0	2	1	1	1

Notes to table 3:

1. Concentrations for the Red offal wash are treated differently to those of other streams. The offal is washed in a large contrashear prior to being transported to the byproducts plant. The offal is washed with two streams originating from the kill floor and also the tripe-processing stream. The effluent from the screen, therefore contains the pollutant load present in the original 3 streams plus that washed from the offal in the screen.

   To allow input into the spreadsheet model, the net increase in pollutant concentrations during washing was calculated as the difference between inlet and outlet pollutant loads over the screen allowing for the fact that there were two outlets. Each outlet was measured for pollutant concentrations and the results used in the above calculation. The red offal stream result represents the incremental concentration of pollutants resulting from the wash step in the screen and neglecting those originally present in the reused streams.

1. The boning room flow was inaccessible to sampling. These data are sourced from the MRC (1995) report.

2. Estimated as 1/3rd the concentration of the blood stickwater as a first approach.

3. The LTR plant was used for gel-bone production.

4. Data for these streams is sourced from the MLA (2001) report on Dry Paunch Dumping (conducted at AMH Dinmore).

5. These data were sourced from Johns Environmental files for similar facilities.

6. This waste stream was inaccessible. Standard values for Australian sewage are used as a first approximation.

Key points include:

1. There are some very strong waste streams generated at Dinmore. These include:

   - Raw material bin drainage
   - High temperature stickwater from the tallow polishers;
   - Tallow stickwater from the low temperature rendering unit for gel bone production;

   In general, each stream is characterised by very high COD (> 50,000 mg/L), TSS (> 20,000 mg/l), typically high O&G (> 7,000 mg/l) and very high nitrogen (> 3,000 mg/l) and phosphorus (> 200 mg/l), although there is significant variability. It is fortunate that the flow of some of these streams is relatively low.

2. A second group of waste streams can be characterised as medium strength. These include:

   - Dry dumped paunch stream
   - Tripe processing effluent.
   - Blood processing stickwater
   - Ante-mortem yard washdown;

   These streams are characterized by high COD (14 – 20,000 mg/L), high TSS (> 7,000 mg/l), and high nitrogen (> 340 mg/l) and phosphorus (> 150 mg/l), with the exception of the tripe processing stream which has a relatively low TP concentration.

3. The remaining waste streams comprise relatively weak contaminant levels with COD typically in the range 1,500 – 6,000 mg/l, TSS < 2,000 mg/l and nutrients generally low (TN < 250 mg/l; TP < 25 mg/l), although again there is significant variability. These streams contain significant loads only at high flows.

4. The characteristics of each stream will not be discussed in this report. They are well described in the MRC (1995) Nutrient Audit report.

4.4 Dirty Waste Streams: Ranking by Contaminant Loads

From the individual stream flows and contaminant concentrations, it is now possible to estimate contaminant loads generated by each waste stream using a spreadsheet mass balance model.

The contaminant load (kg of contaminant generated per day) is given as the product of concentration and flow:

Load (kg/day) = concentration (mg/l or ppm) x stream flow (kL/day/1,000)

The contaminant load, rather than the concentration, is the most critical issue for wastewater – whether for the design of the wastewater treatment plant, or for release of the effluent to the receiving environment.

4.4.1 Suitability of the Mass Balance Model Approach

Table 4 presents the percentage contribution of each waste stream to the total load of contaminant emitted from the abattoir. At the base of the table a comparison is made of the total load of key contaminants predicted from the mass balance model (Approach 2) and that measured using the overall mass balance (Approach 1).

Table 4. Percentage contribution to total load from individual waste streams discharged to the primary treatment system pre-modification.

Loads	TCOD	SCOD	TSS	O&G	TN	NH_3-N	TP	PO_4P
Kill Floor streams								
Kill floor	7.7	18.8	3.7	2.9	11.2	5.4	1.6	1.4
Red Offal wash (screen)	10.0	7.1	11.2	48.1	5.2	1.2	11.4	18.6
Boning Room	0.2	0.0	0.1	0.2	0.2	0.0	0.1	0.0
Kill/Boning clean	4.8	7.5	4.8	1.5	4.6	1.5	2.9	4.2
Byproducts streams								
Raw material bin drainage	22.3	42.0	13.7	8.6	32.5	19.4	17.1	19.4
HTR condensate	0.2	1.0	0.0	0.1	1.8	13.9	0.0	0.0
HT stickwater	5.1	0.4	2.9	5.1	0.5	0.1	2.7	0.4
Blood stickwater	1.4	3.3	1.1	0.0	4.5	1.8	2.1	2.3
Blood drier scrubber	0.1	0.0	0.1	0.0	0.5	0.8	0.7	1.5
Miscellaneous washdown	0.5	1.2	0.4	0.0	1.7	0.7	0.8	0.9
LTR plant (gel bone)	6.6	0.0	5.2	3.6	7.1	0.0	3.2	0.0
Offal Processing streams								
Paunch dry dump	3.2	2.2	2.6	1.0	2.5	1.6	15.0	20.6
Umbrella wash	0.5	0.4	0.5	0.0	0.3	0.2	1.5	2.2
Tripe processing	16.	6.4	14.6	25.5	9.3	2.3	8.1	10.5
Miscellaneous streams	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ante-mortem yards	19.9	9.5	38.3	3.2	16.9	50.9	31.8	18.0
Truckwash	0.3	0.0	0.4	0.1	0.8	0.0	0.3	0.0
Human sewage	0.2	0.0	0.1	0.0	0.4	0.0	0.6	0.0
Total (%)	99.6	100.0	99.6	100.0	99.9	99.7	99.8	99.9
Contaminant loads total								
Total from model (kg/d)	43,555	7,829	29,158	14,376	1,832	219	279	114
Approach 1 load (kg/d)	42,500		13,550		1,930	265	270	
Model variance	2.5%		115.2%		-5.1%	-17.2%	3.4%	

Notes to table 4:

1. Red Offal wash is called trommel wash in the charts.
2. The Total for some contaminants does not sum to 100% since some very minor streams are omitted from the Table.

Comments include:

- The total emitted loads for COD, total nitrogen and total phosphorus – as estimated by the 2 approaches - agree to within 5%, which is very acceptable given the sampling and analytical error implicit in measuring these highly variable streams.

- The load of TSS predicted by the model is more than double (115%) that measured after primary treatment at the weir using Approach 1. This would seem to suggest that the "Sum of Streams" model (Approach 2) over-predicts the emission of TSS relative to the reality check. However, it should be noted that the model estimates loads generated prior to primary treatment. Whereas relatively little COD and nutrients are removed by screens and savealls at Dinmore, typical removal of TSS is of the order of 40 – 50%, which would give reasonably good agreement between the two methods. Therefore, the model is probably correct.

Consequently, the model appears to give a reasonable estimation of the contribution of different waste streams to contaminant loads.

4.4.2 Waste Streams of Little Significance

Of the 19 waste streams assessed, 7 are of little consequence in terms of contaminant loads but are included in Table 4 for the sake of completeness. These include:

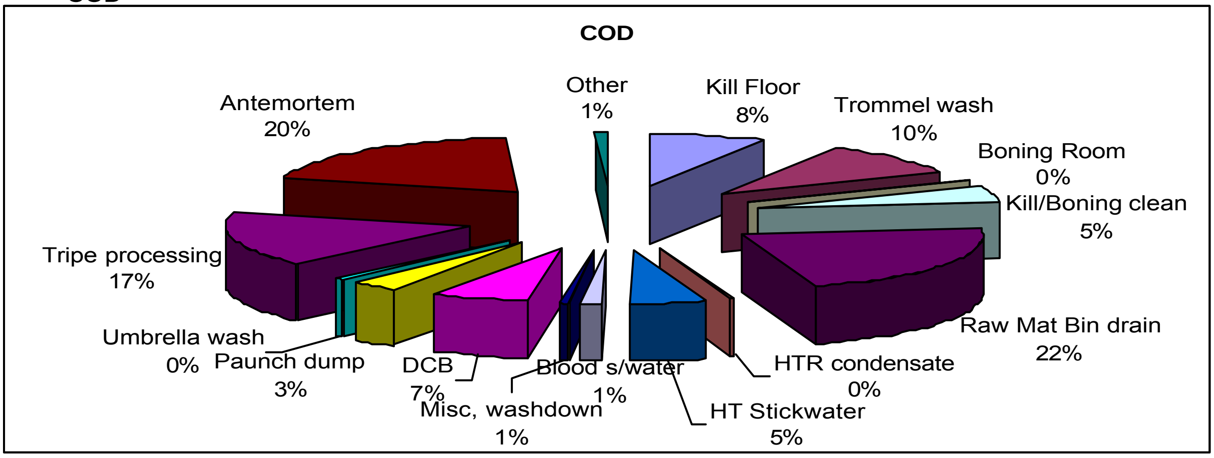
- Effluent from the boning room (less than 0.3% of any contaminant)
- Miscellaneous byproducts washdowns (less than 2% of any contaminant);
- Paunch umbrella wash (less than 3% of any contaminant);
- Truckwash (less than 1% of any contaminant);
- Human amenities (less than 1% of any contaminant);

These flows comprise approximately 18% of the total effluent flow.

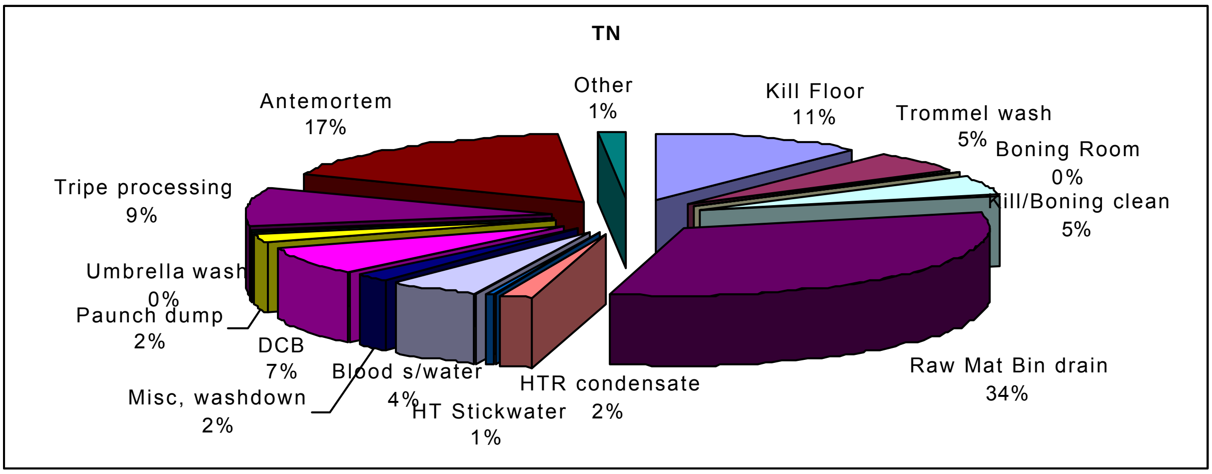
4.4.3 *Waste Streams of Major Significance*

Figure 3 illustrates emission of the major pollutant loads, COD, TN and TP from each of the major contributing waste streams.

Figure 3. Percentage contribution of COD, TN and TP from each waste stream.
COD



Total Nitrogen



Total Phosphorus

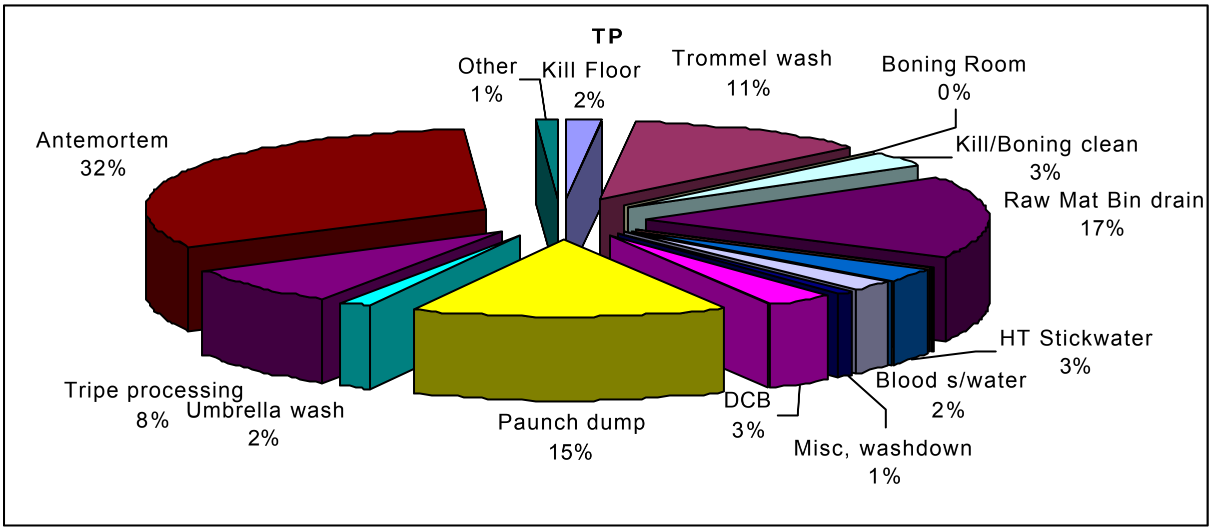


Table 5 ranks the individual process waste streams according to load emission of each of the major 5 contaminants. The percentage figure in brackets represents the percentage of the total load emitted by the abattoir and byproducts plant. The worst 4 streams are clearly:

- ante-mortem yard (Cattle yard wash in the Figures).
- raw material bin drainage (RM Bin)
- red offal wash
- tripe processing

The four worst streams in each category accounted for more than 65% of the total load emitted for any contaminant.

Table 5. Ranking of waste streams according to their contribution to total load discharged to the primary treatment system pre-modification.

Ranking	TCOD	TSS	O&G	TN	TP
1 (worst)	RM Bin (22%)	Cattle yard wash (38%)	Red offal wash (48%)	RM Bin (32%)	Cattle yard wash (32%)
2	Cattle yard wash (20%)	Tripe process (15%)	Tripe process (26%)	Cattle yard wash (17%)	RM Bin (17%)
3	Tripe process (17%)	RM Bin (14%)	RM Bin (8.6%)	Tripe process (9%)	Dry dump (15%)
4	Red offal wash (10%)	Red offal wash (11%)	HT stickwater (5%)	DCB process (7%)	Red offal wash (11%)
Proportion of total emission	69%	78%	87.6%	65%	75%

4.5 Summary – Pre-Modification.

Key outcomes for the abattoir prior to the commissioning of the New Byproducts Facility include:

- The 4 worst waste streams in each contaminant category emit 65% or more of the total load of contaminants. These streams represent good targets for source reduction.

- These streams individually represent much less than 15% of the total flow and in some cases less.

- There is some probability that the Cattle yard wash loads of COD and TSS are over-stated. Additional work may be needed to check the measured concentrations of these parameters. If this is the case, the order of the remaining streams remains valid.

- The Old Byproducts Department (including the LTR gel bone plant and Raw material bin drainage) generated 36% of the COD, 50% of the Total Nitrogen and 26% of the Total Phosphorus from the abattoir, despite comprising only 10% of the total flow. This finding agrees with that from the Nutrient Audit project (MRC, 1995), although the percentage of COD is low. This makes these streams good targets for reducing nitrogen loads to the wastewater treatment plant.

- Offal processing streams generated 25% of the total phosphorus emitted by the plant.

5. Emissions after the Modifications

5.1 Predicted Reductions in Contaminant Load Output.

The construction of the new Byproducts plant at AMH Dinmore was predicted to achieve the following reductions in contaminant loads:

Contaminant	Expected reduction
COD	17%
O & G	5%
TN	24%
TP	17%

These reductions are based on a number of assumptions. The key target streams in this analysis were:

- Elimination of the pneumatic conveying system for raw material. This was seen as a key to reducing drainage from the raw material bin to a minimum. This stream was identified as the worst emitter of nitrogen in the abattoir, in addition to other contaminants.

- Blood stickwater was targeted for reduction through further drying of the edible fraction of blood collected at the abattoir, although this leads to only a small decrease in nitrogen emission.

Against these reductions was balanced the fact that all the raw material formerly processed off-site would be processed once more entirely at Dinmore, resulting in increased Byproducts effluent.

This Section benchmarks the improvements in contaminant emission from the abattoir subsequent to the modifications made to the plant as outlined in Section 2.2.3 of this report. The benchmarking was performed using the twin approach method discussed in the previous Section of the report.

5.2 Water Balance

This Section is broken into the overall water balance for the abattoir and the individual waste stream balances. The analysis is worked out for a double-shift 24-hour period, which is the preferred mode of plant operation at this facility.

5.2.1 Overall Plant Water Balance

An overall water balance for the AMH Dinmore abattoir is presented in Table 6. This is a reasonably rigorous balance, in that the following forms of water entering the plant are included:

- Water supplied by utilities;

- Water present in the beef animals, which is liberated through processing and enters the wastewater treatment system.

Of the 5.57 ML/day entering the plant, 5.2 ML/day emerged as wastewater entering the wastewater treatment plant. This flow was accurately monitored by 4 electronic mag flowmeters with data recorded continuously to the plant's SCADA system.

It is more usual to neglect animal-derived moisture inputs when assessing water flows in abattoirs, since they are usually only a small part of the total (only 6.6% from Table 6).

Of the water entering the plant, 4.8 ML/day was sourced from town water supply (metered), with a further 400 kL/day recycled as polished final effluent for low grade use external to the buildings. The recycled flow was estimated from water balances performed over April 2003, since this flow is not metered.

For the purposes of this report, the total wastewater flow to the plant of 5.2 ML/day was used for calculations.

Table 6. Overall water balance over Dinmore Abattoir

Source	**Flow** kL/day	**Comments**
Water In		
Town water	4,800	metered into plant during Apr 2003
Recycled water	400	estimated.
Blood liquid in cattle	19	estimated at approx 6 litres inedible/head @ 3,200 hd/day
Paunch contents	128	estimated as 40 litres/paunch @ 3,200 hd/day
HTR condensate	185	from mass balance over rendering plant.
Raw material bin drainage	35	measured.
Total In	5,567	Total liquid entering the plant in all forms.
Water Out		
To Wastewater system	5,200	Measured by magnetic flowmeters
Water unaccounted for	367	

5.2.2 Individual Waste Stream Flows

The estimated individual stream flows from the Dinmore processing facility are provided in Table 7. There is significant uncertainty associated with these values as discussed in Section 4.3.1.

Table 7 therefore provides the closest possible estimation of flows for each waste stream. A summary of the methods used to estimate the flows is provided in Appendix 2. Note that the “Red Offal Wash” is not included in the total in Table 7, since waste streams from the kill floor and tripe processing were used for this purpose at Dinmore.

In most cases the flows from the kill floor and offal processing section waste streams did not vary significantly from the previous study and the same values have been maintained. The biggest changes to flows are in the new Byproducts section of the plant.

Table 7. Flow breakdown in the post-modification plant

Waste stream	Flow kL/day	% of total flow	Stream Rank
Red flows			
Kill floor	2,870	55.2	1
Red Offal wash (trommel screen)	2,650		
Boning Room	300	5.8	5
Kill floor & Boning Room cleaning	420	8.1	4
		(69.1)	
Byproducts			
Raw material bin drainage	34	0.7	
HTR condensate	185	3.6	
HTR Stickwater	53	1.0	
Blood processing stickwater	19	0.4	
Miscellaneous (incl. washdown)	45	0.9	
Gel bone (DCB) LTR plant	30	0.6	
		(7.2)	
Green flows			
Paunch dry dump	70	1.3	
Umbrella wash	64	1.2	
Tripe processing	500	9.6	3
Antemortem yards	620	11.9	2
Cattle Race wash	100	1.9	
Truckwash	100	1.9	
		(27.8)	
Miscellaneous flows			
Human amenities	150	2.9	
Chillers	100	1.9	
Boiler Ash wash	120	2.3	
Sink (virtual flow)	140	2.7	
Total	**5,200**	**100.0**	
Red Stream	3,236		
Green stream	1,454		
Total	4,690		

Notes:
1. Sub-total percentages for each of the plant sections may not accurately equal the sum of the individual waste streams due to rounding error.
2. The red offal wash flow is not included in the Total Flow (since it reuses kill floor & tripe flows).
3. The "Sink" is a "virtual flow" and accounts for discrepancies in flow between the 2 approaches used in this study.

Primary conclusions from Table 7 include:

1. The estimated flows are equivalent to the 5.2 ML/day measured into the wastewater treatment plant to within 3%. An amount of 140 kL/day is unaccounted for ("Sink or virtual flow") in Table 7. This overall flow closure is reasonable.

2. The Red flow from the kill floor and boning room areas contribute the lion's share of the overall waste flow generated. It amounts to almost 70% of total flow, with approximately 55% from the kill floor operations alone. These values continue to show good agreement with previous data (MRC, 1995).

3. Analysis of the results of flowmeters positioned on the water distribution network into the plant suggests that supply to the kill floor comprises approximately 60% cold water and 40% hot water, although this analysis contains substantial uncertainties and should be treated with care.

4. Analysis of the cleaning flows suggest that overall cleaning flows for double shift operation amount to only 12% of total emissions. This is substantially less than the 25% of total flow measured at Dinmore for the cleaning shift during single shift operation only. Experience has shown that the incremental gain in water usage in going to double shift is only 35-50% of the cattle throughput increase. Substantial water efficiency gains are therefore realised by double-shift operation.

   Traditional allowances for cleaning flows in Australian abattoirs are typically 20 – 30% of total flow. This figure assumes single shift operation – which was normal practice 10 years ago for almost all abattoirs.

5. Wastewater flow from the new byproducts plant represented only 7.2% of the total wastewater generated. This is towards the low end for byproducts facilities and is due to:

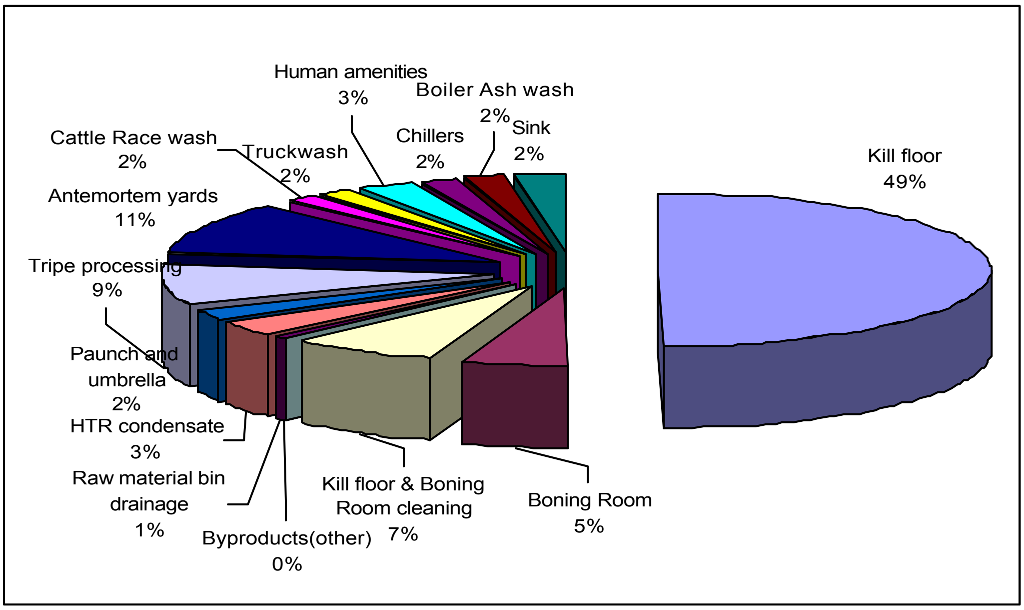
   - greatly diminished raw material bin drainage compared to pre-modification (34 kL/day vs 170 kL/day). This is a direct benefit from the elimination of the pneumatic blow system for conveying raw material from the kill floor and its replacement with a positive displacement pump system. This requires the addition of no water for lubrication – the Achilles heel of every pneumatic system.

   - Diminished flow of blood stickwater due to the installation of blood drying process for the edible haemoglobin fraction. Some stickwater still arises from inedible blood processing.

6. Green flows constitute just over a quarter of all wastewater flow from the plant, mainly due to extensive offal processing activities performed on-site and to ante-mortem yard discharge.

7. Miscellaneous flows comprise less than 7% of the total flow from the abattoir and a negligible contaminant load.

Figure 4. Contribution of waste streams to flow post-modification plant



5.3 Contaminant Concentrations in Waste Streams

The changes to the Dinmore abattoir mainly affected the Byproducts Department, which was completely rebuilt. Consequently, only waste streams, which were generated entirely by the modified processes are included in Table 8. Other streams were assumed to have the same composition as shown in Table 3.

Further sampling of the cleaning flows was performed, however, to attempt to get a superior representation of the typical cleaning stream values during the highest cleaning flows. These data are shown in Table 8. Comparison with Table 3 values for cleaning flows suggest that they are generally weaker.

The waste streams from the new Byproducts plant had similar composition to those from the old Byproducts plant, although in some cases they were stronger than before, especially the blood processing stickwater stream. All remain very strong waste streams.

Table 8. Average contaminant concentrations in waste streams at Dinmore abattoir post-modification.

Waste stream	Note	Contaminant concentration (mg/L)							
		TCOD	SCOD	SS	O&G	TN	NH_3-N	TP	PO_4P
Kill Floor streams									
Cleandown		3,200	950	1,420	840	140	10	13	5
Byproducts streams									
Raw Mat Bin drain new		73,620	24,100	21,250	1,670	5,900	270	430	180
HTR condensate		850	820	25	35	480	420	0	0
HT Stickwater		54,700	610	24,770	21,550	155	1	110	10
Blood stickwater		34,200	9,600	40,100	350	8,400	35	130	40
Misc, washdown		3,200	950	1,420	840	140	10	13	5

5.4 Dirty Waste Streams

5.4.1 Agreement Between the Two Approaches

A total of 19 individual waste streams were considered as part of the post-modification sampling. Once more, the “Sums of Streams” model approach gave reasonable closure with the Overall Mass balance (Approach 1). The closure is indicated in Table 9. These data are compared to the pre-modification situation in Section 6.

Table 9. Comparison of contaminant loads measured by the two approaches used for waste streams at Dinmore abattoir post-modification.

Contaminant loads total	TCOD	TSS	TN	TP
Total from model (kg/d)	36,270	25,910	1,510	235
Approach 1 load (kg/d)	37,650	11,740	1,515	240
Model variance	-3.7	120%	-0.4%	-2.0

5.4.2 Waste Streams of Little Consequence

Of the 19 streams assessed, only 8 streams contribute significantly to any of the contaminant loads, with a further 2 of marginal interest. Streams of little consequence in terms of contaminant loads were largely the same as those identified in earlier sampling (See Section 4.4.2). They include:

- Effluent from the boning room (less than 0.3% of any contaminant)
- Cleaning flows from the kill floor and boning room (less than 5% of any contaminant);
- Miscellaneous byproducts washdowns (less than 1% of any contaminant);
- Paunch umbrella wash (less than 5% of any contaminant);
- Truckwash (less than 5% of any contaminant);
- Cattle race final wash
- Human amenities (less than 1% of any contaminant);
- Chiller defrost;
- Boiler ash wash flow.

These flows comprise approximately 27% of the total effluent flow subsequent to the commissioning of the new Byproducts Plant. This not significantly increased on the pre-modification case, since cleaning flows were included in the above list in contrast to the before.

5.4.3 "Dirtiest" Waste Streams

Contaminant loads from both the dirtiest waste streams and two of marginal impact are summarised in Table 10. These are discussed in further detail in Section 5.5.

However, some observations that may be valuable include:

1. These 10 individual waste streams accounted for more than 90% of the load discharged for each contaminant, and in most cases accounted for more than 94% of the load. They remain good targets for further clean production.

2. For each contaminant, the three dirtiest streams generated more than 60% of the total load, except for Total COD (56%) and total nitrogen (47%). The identity of the worst three streams varied with the contaminant.

3. The worst streams (in order of worst at top) in the post-modification abattoir are:
   - ante-mortem yard (highest ranking for all contaminants except O&G);
   - tripe processing effluent (2nd worst for TCOD, TSS, O&G);
   - trommel wash (red offal wash)
   - kill floor stream
   - paunch dry dump

4. The raw material bin drainage has been largely eliminated as a significant stream.

5. Other streams provided lesser loads and tended to be sourced from the new byproducts facility.

Table 10.. The dirtiest waste streams discharged to the primary treatment system post-modification.

Loads	TCOD	SCOD	TSS	O&G	TN	AN	TP	PO_4-P
Kill Floor streams								
Kill floor	**9.1%**	**28.9%**	4.3%	3.0%	**13.5%**	5.1%	1.8%	1.6%
Red Offal wash	**12.1%**	**10.9%**	**12.6%**	**50.2%**	6.3%	1.2%	**13.6%**	**23.3%**
Byproducts streams								
Raw Mat Bin drain	6.9%	**16.1%**	2.8%	0.4%	**13.3%**	4.0%	6.2%	6.7%
HTR condensate	0.4%	3.0%	0.0%	0.0%	5.9%	**34.1%**	0.0%	0.0%
HT Stickwater	8.0%	0.6%	5.1%	**8.3%**	0.5%	0.0%	2.5%	0.6%
Blood stickwater	1.8%	3.6%	2.9%	0.0%	10.5%	0.3%	1.0%	0.8%
LTR plant	7.9%	0.0%	5.8%	3.8%	8.6%	0.0%	3.8%	0.0%
Offal Processing								
Paunch dump dry	3.9%	3.4%	3.0%	1.1%	3.0%	1.5%	**17.9%**	**25.8%**
Tripe processing	**20.0%**	9.8%	**16.4%**	**26.6%**	**11.3%**	2.2%	9.6%	13.2%
Miscellaneous								
Antemortem yards	**23.9%**	**14.6%**	**43.1%**	3.4%	**20.5%**	**49.0%**	**37.8%**	**22.5%**
Total from dirty streams	94.0%	90.8%	95.9%	96.8%	93.5%	97.4%	94.2%	94.4%
Total from top 3 streams	56.0%	59.5%	72.1%	85.1%	47.3%	83.1%	69.3%	71.5%

Notes:

1. Figures in bold represent the worst 3 – 4 streams for each contaminant.
2. "Total from Dirty streams" represents the share of the total contaminant load released in the raw wastewater comprised by the dirty streams. The red offal wash flow is not included in the Total Flow (since it reuses kill floor & tripe flows).
3. "Total from top 3 streams" represents the share of the total contaminant load released into the raw wastewater comprised by the three streams contributing the greatest loads.

5.5 Sources of Contaminants

The following Section examines generation of contaminants from abattoir operations post-modification.

5.5.1 Waste streams contributing COD

The generation of TCOD from the Dinmore abattoir is illustrated in Figures 5 (% distribution) and 6 (as grams COD per tonne HSCW).

Figure 5: % distribution of COD in waste streams

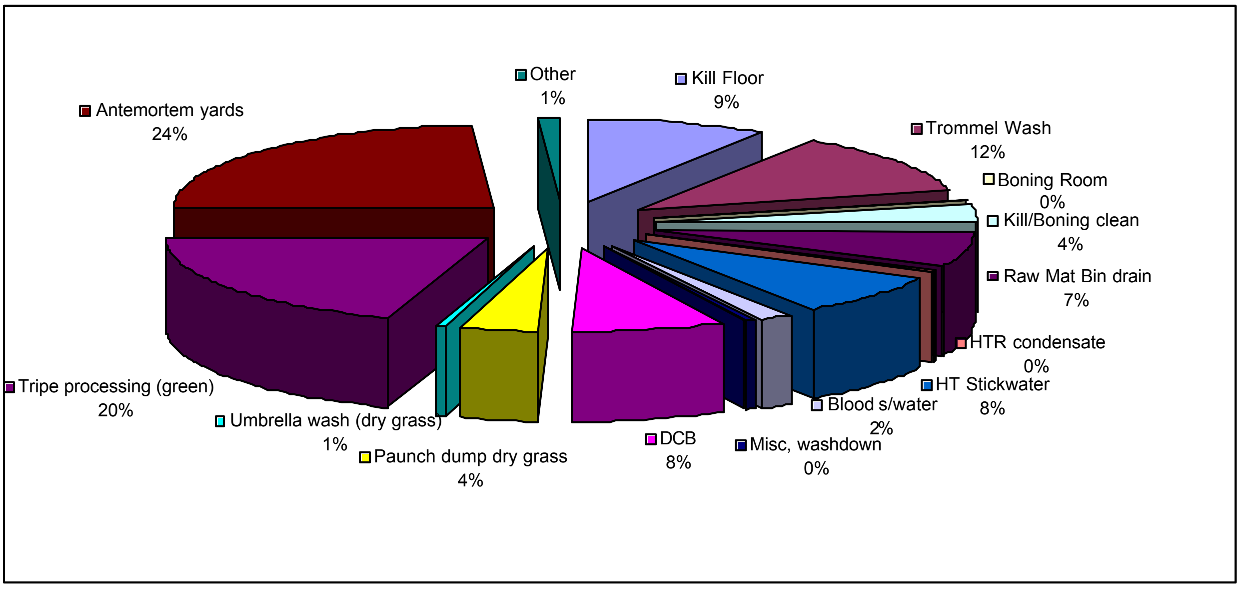
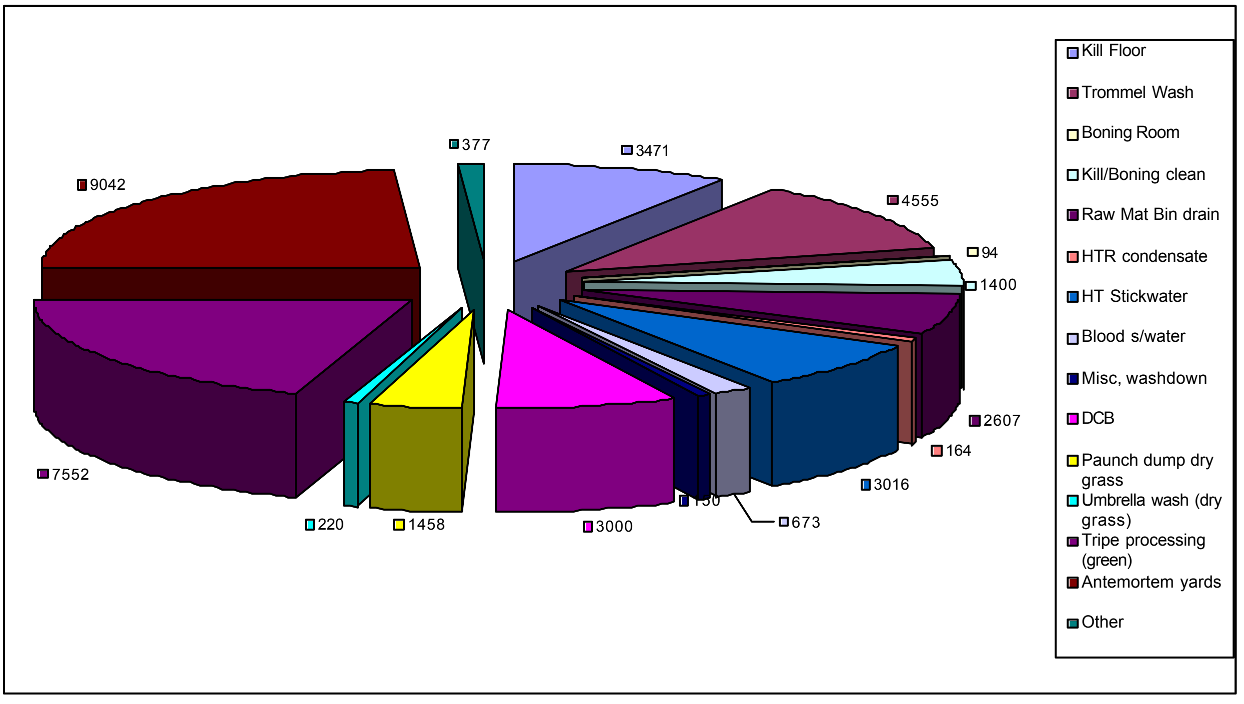


Figure 6: grams COD/tonne HSCW



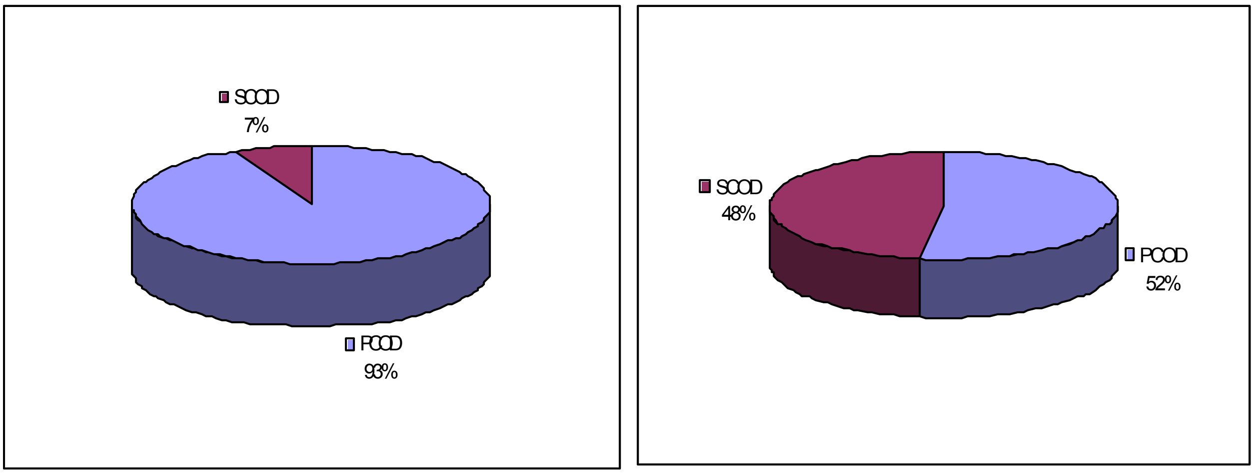
The most notable feature is that only 4 waste streams generate COD loads in excess of 8% of the plant total, which makes further reductions in COD emissions challenging. This is especially so in view of the fact that each of the 4 streams has a daily flow in excess of 500 kL/day, making any equipment or process installed to reduce COD expensive.

Individual streams varied considerably with respect to the nature of the COD. Some streams contain a very high fraction of soluble COD – for example the High Temperature Rendering Condensate stream (96% SCOD) and the kill floor streams (> 40% SCOD). Others contained mainly particulate COD – especially the Tripe Processing stream (PCOD > 93%) and the trommel wash stream (> 85%). This may be due to the high fat content.

Table 11: Ratio of soluble COD to particulate COD (PCOD) for key waste streams

Stream	%SCOD	%PCOD
Kill floor red 1	40	60
Kill floor red 2	48	52
Red offal wash (Trommel wash)	13	87
Raw Material Bin drainage	33	67
HT Stickwater	1	99
Blood stickwater	28	72
Paunch dump dry grass	13	87
Tripe processing	7	93
Ante-mortem yards	9	91

Figure 7: COD composition from Tripe Processing (LHS) and Kill Floor effluent (RHS).



5.5.2 Waste Streams contributing Nitrogen

With the virtual elimination of the nitrogen-rich raw material bin drainage from the Old Byproducts facility, the remaining abattoir nitrogen discharge is fractured across several streams, most emitting a fairly low 11 – 14% of total nitrogen (Figures 8, 9). Less than 50% of the nitrogen is present in top 3 richest nitrogen streams, which is low compared to other contaminants. This suggests that low hanging fruit have been well and truly picked for further nitrogen reductions.

Figure 8: Percentage distribution of TN in waste streams post-modifications.

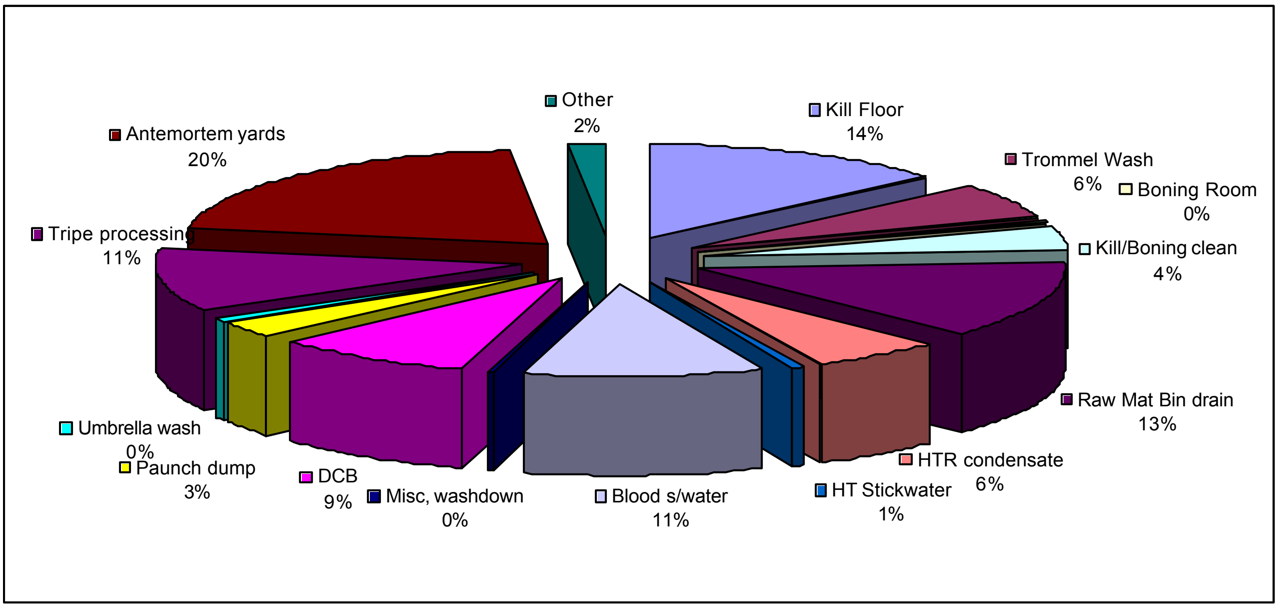
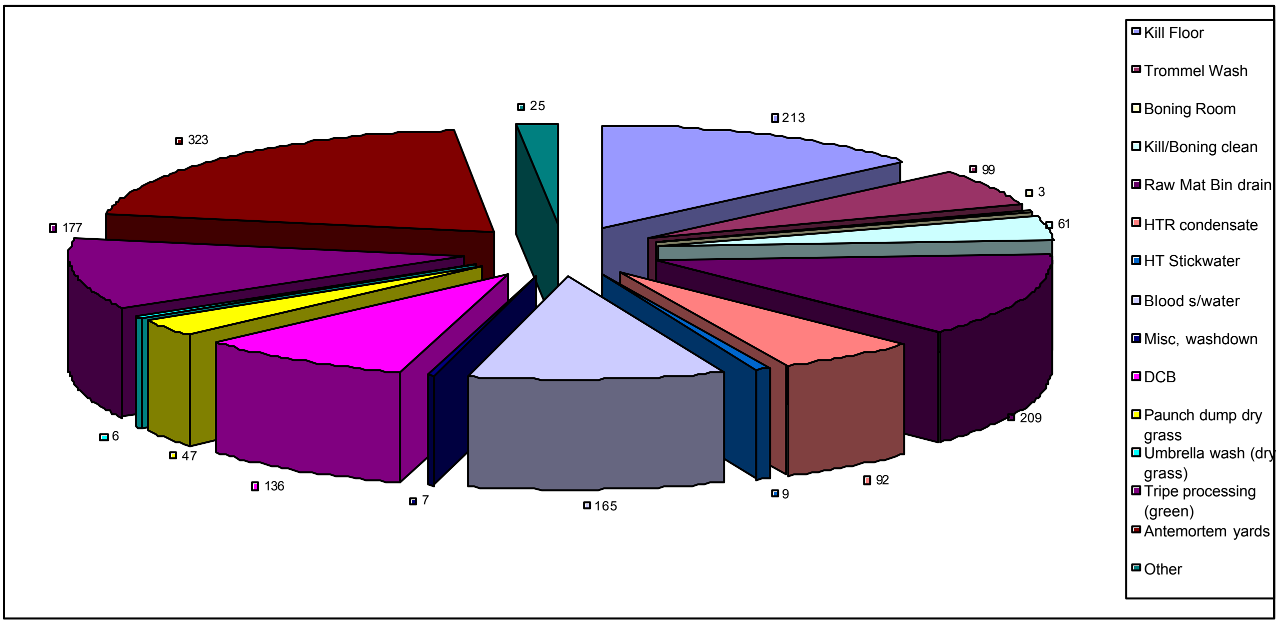


Figure 9: Emission of TN in waste streams (post-modifications) expressed as grams TN/tonne HSCW



Nitrogen exists almost entirely in the organic form in all waste streams except the High Temperature Rendering condensate, where volatile ammonia is the predominant form.

5.5.3 Waste Streams contributing Phosphorus

The primary contributors of phosphorus remain the ante-mortem yard wash and the dry dump liquor. Figure 10 indicates the general percentage contribution of streams, while Figure 11 provides the same data on a g TP per tonne HSCW basis.

Figure 10: Percentage distribution of TP in waste streams post-modifications

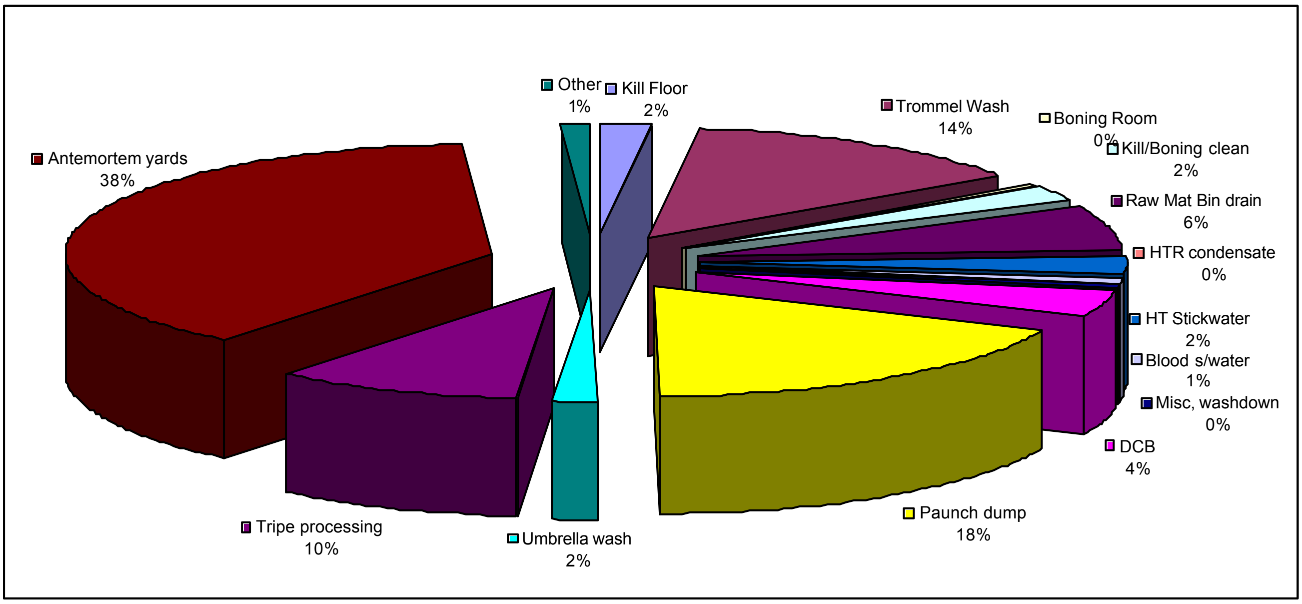
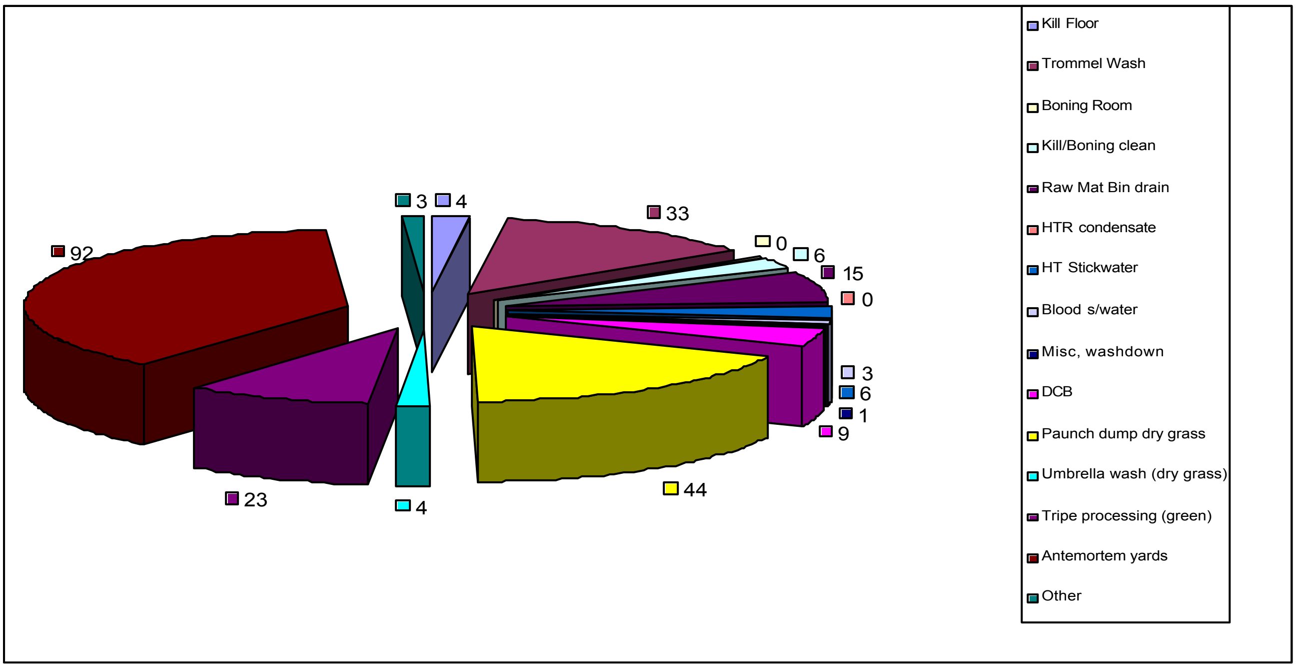


Figure 11: Emission of TP in waste streams (post-modifications) expressed as grams TP/tonne HSCW



The most notable feature is that 3 waste streams generate almost 70% of the TP of the plant total. Typically they are also associated with large TSS levels, which makes treatment difficult. The three streams are:

- Ante-mortem yards
- Dry paunch dumping
- Tripe processing.

Individual streams varied considerably with respect to the nature of the phosphorus. Some streams contain a high fraction of soluble inorganic phosphorus (orthophosphate) – for example the dry paunch dump and tripe processing streams (PO_4-P > 50%). Others contained mainly organic phosphorus – especially the High Temperature stickwater stream (>90% Org P), the ante-mortem stream (Org P > 79%) and the kill floor 1 stream (> 75%). This is illustrated in Figures 13-15 below.

Table 12. Ratio of organic phosphate to orthophosphate for key waste streams

Stream	%Org-P	%PO_4-P
Kill floor red 1	76	24
Kill floor red 2	47	53
Trommel wash	33	67
Raw Material Bin	58	42
HT Stickwater	91	9
Blood stickwater	69	31
Paunch dump dry grass	44	56
Tripe processing	47	53
Antemortem yards	79	21

Figure 13: TP composition in paunch dumping (dry grass)

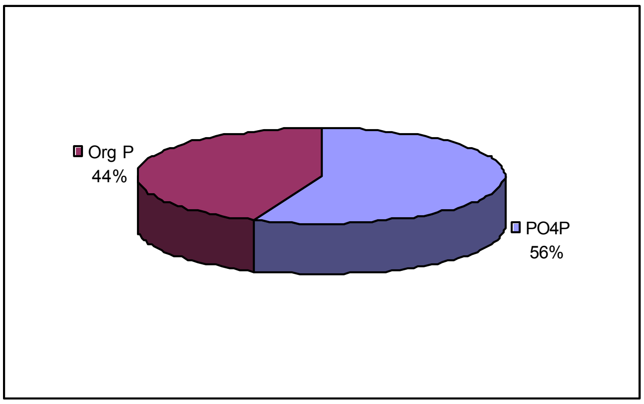


Figure 14: TP composition in raw material bin drainage

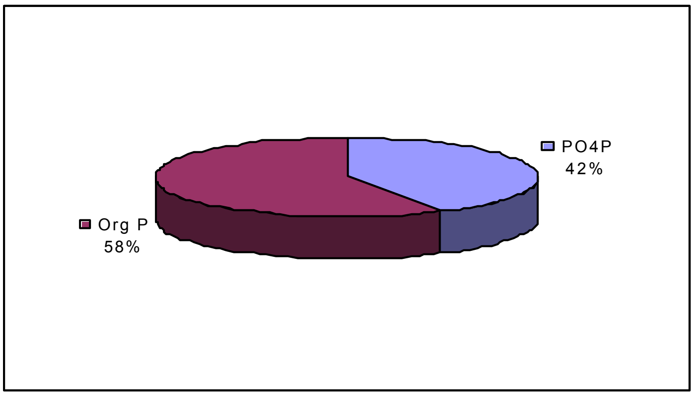
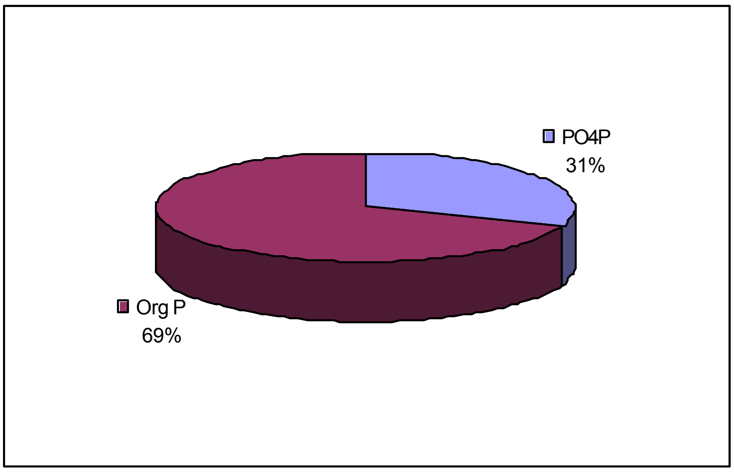


Figure 15: TP composition in blood processing stickwater



5.5.4 Waste Streams contributing Suspended Solids

The primary contributors of TSS remain the ante-mortem yard wash and the tripe processing. Figures 16 & 17 indicate the general contribution of streams.

Figure 16: Percentage distribution of TSS in waste streams post-modifications

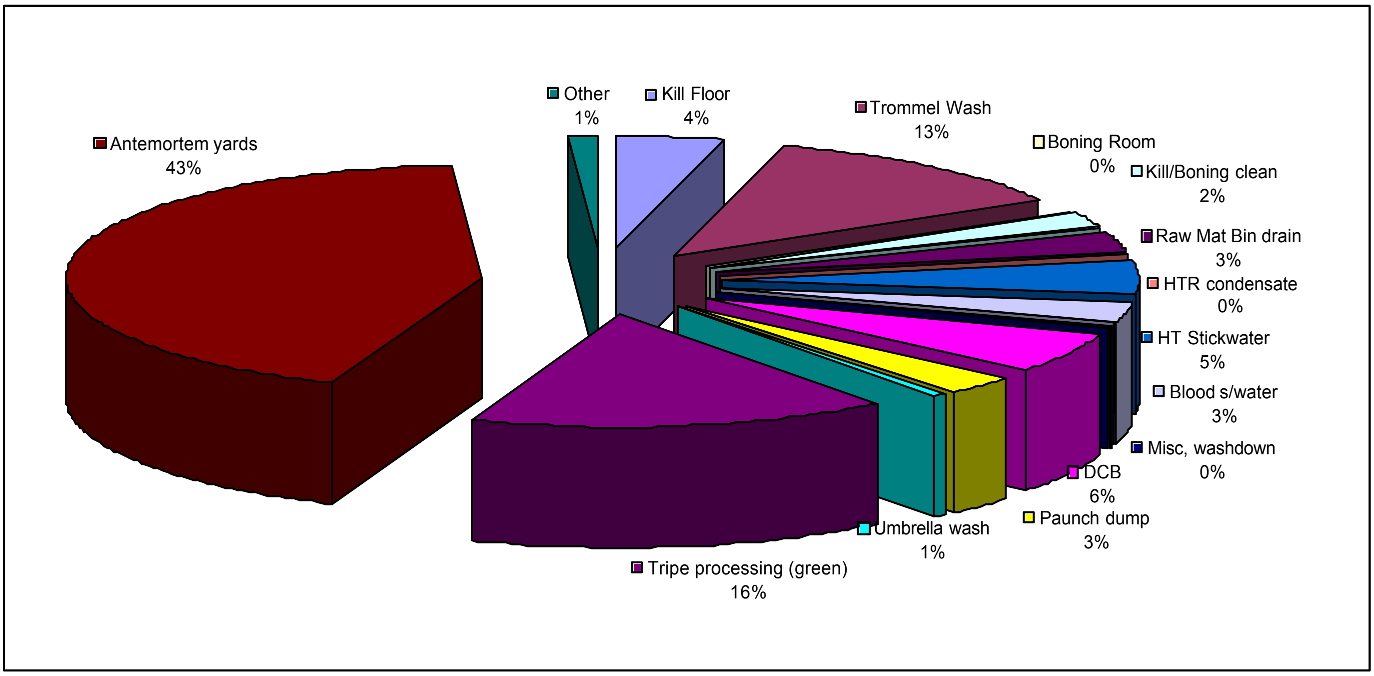
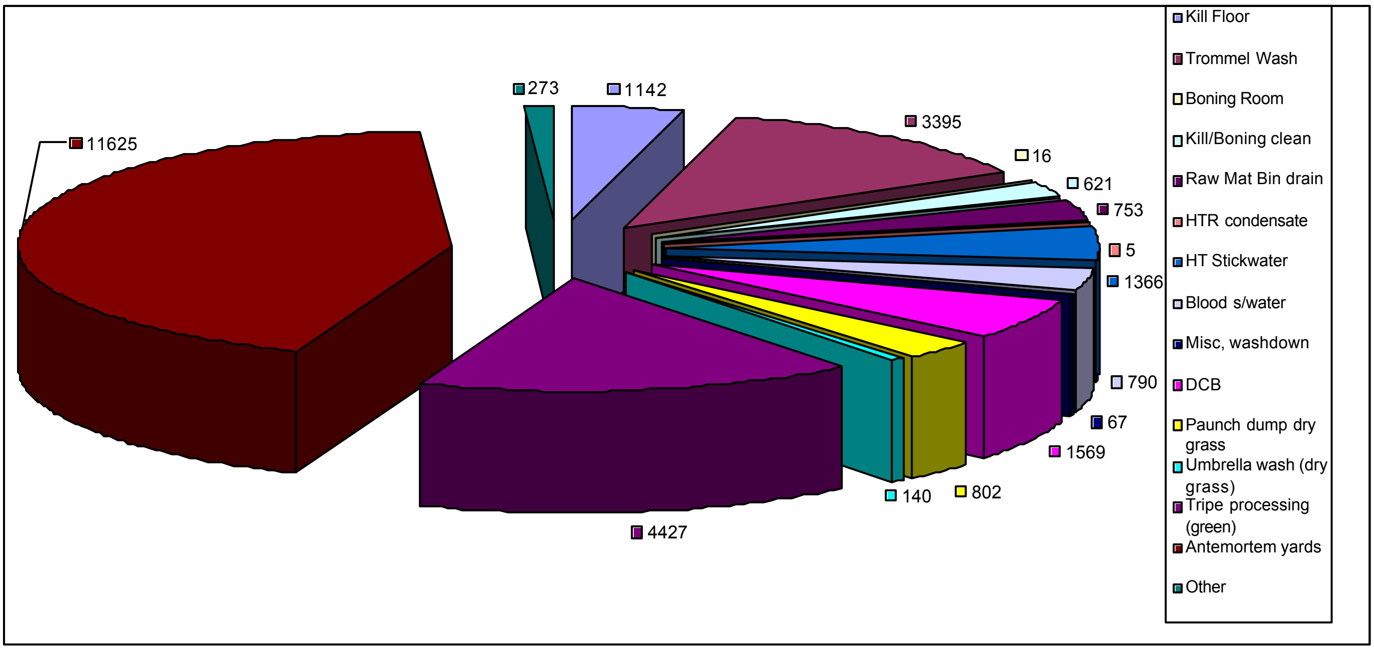


Figure 17. Emission of TSS in waste streams (post-modifications) expressed as grams TSS/tonne HSCW



5.5.5 *Waste Streams contributing Oil & Grease*

The trommel wash dominates the contribution of O&G to the wastewater with the tripe processing process a close second. These two streams account for more than 75% of emissions. Figure 18 indicates the general contribution of streams. As is the case with COD-rich streams, both of these streams are characterised by very high flows and large TSS concentrations. This provides a challenge for O&G recovery.

Figure 18. Percentage distribution of O&G in waste streams post-modifications

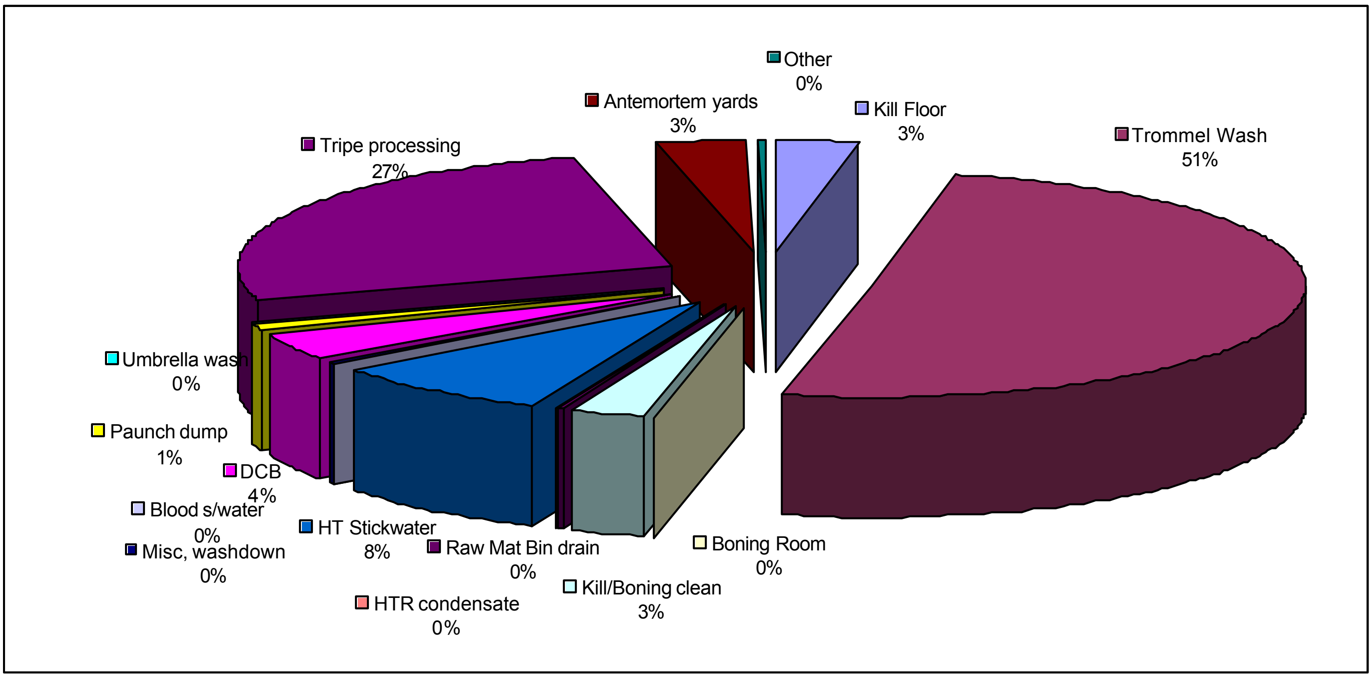
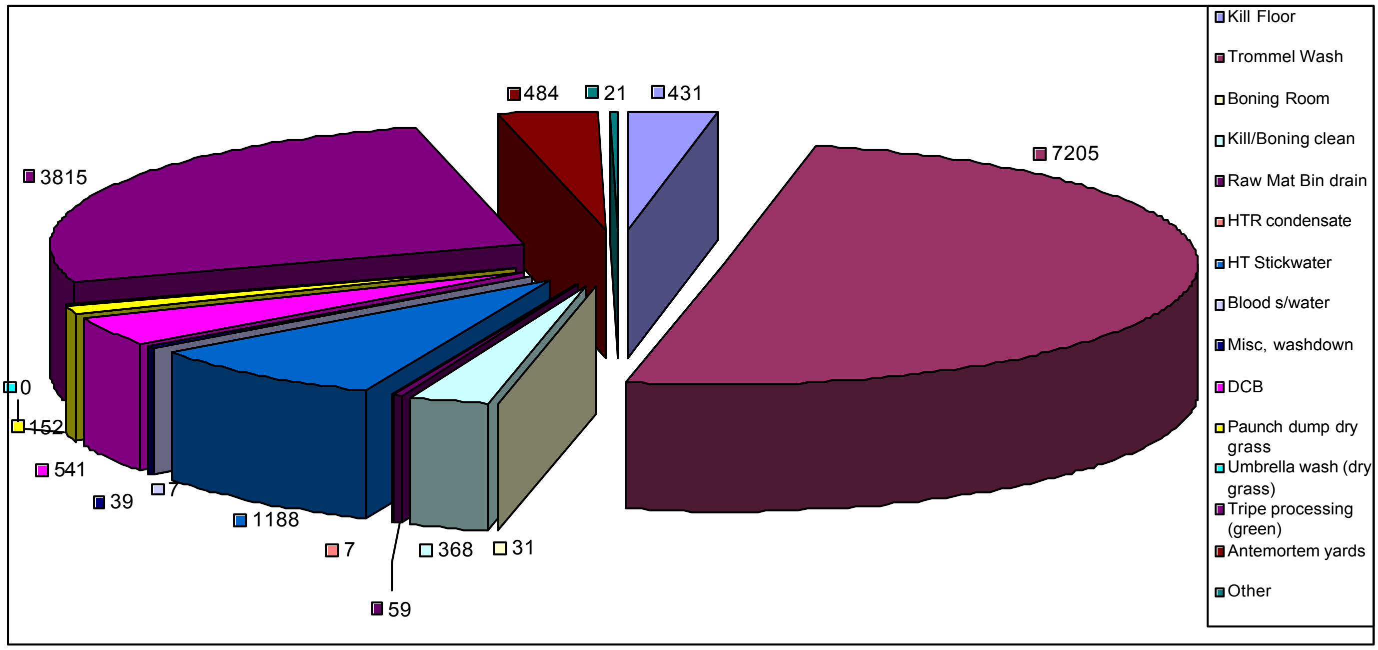


Figure 19. Emission of O&G in waste streams (post-modifications) expressed as grams/tonne HSCW



6. Impact of the Process Modifications

6.1 Reduced Nutrient Loads

The implementation of the process modifications had a significant and measurable impact on the loads of contaminants discharged from the factory to the wastewater treatment system, especially nitrogen. This is significant, since nitrogen is particularly challenging and expensive to reduce to the required discharge limits.

Table 13 identifies the flow and contaminant loads discharged post-modifications (the "After" case). These can be directly compared to those for the pre-modification period (the "Before" case) presented in Table 14. It should be remembered that although the throughput was largely identical in both cases, approximately 100 tonne/day of raw material was being processed externally during the pre-modification period. This represents a sizeable pollutant load, which is not included in Table 14 data. Consequently, the comparison is highly conservative in the beneficial impact of the changes.

Table 13. Wastewater flow & contaminant loads discharged to the primary treatment system post-modifications.

Source	Units	Value	TCOD	TSS	TKN	NH_3-N	TP
Wastewater flow	ML/d	5.2					
Concentration	mg/l		7,310	2,280	295	90	47
Load discharged	kg/d		37,647	11,742	1,517	462	239
Flow per head	litres/head	1,609					
Load per head	kg/head		11.76	3.67	0.47	0.14	0.07
Flow per tonne HSCW	kL/t HSCW	5.4					
Load per tonne HSCW	kg/t HSCW		39.2	12.2	1.58	0.48	0.25

Table 14. Wastewater flow & contaminant loads discharged to the primary treatment system pre-modifications.

Source	Units	Value	TCOD	TSS	TKN	NH_3-N	TP
Wastewater flow	ML/d	5.0					
Concentration	mg/l		8,500	2,710	386	53	54
Load discharged	kg/d		42,500	13,550	1,930	265	270
Flow per head	l/hd	1,563					
Load per head	kg/hd		13.28	4.23	0.60	0.08	0.08
Flow per tonne HSCW	kL/t HSCW	5.2					
Load per tonne HSCW	kg/t HSCW		44.3	14.1	2.01	0.28	0.28

Table 15 presents the actual reduction in contaminant load due to the process modifications. The results are impressive.

- The COD load emitted fell by 11.4%, or almost 5 tonne/day. This is equivalent to a city of 40,000 EP.
- TSS emissions fell by 13.3% or 1.8 tonne/day.
- Nitrogen emissions, measured as Total Kjeldahl Nitrogen, fell by 21%, or 410 kg/day. This is an exciting reduction. Typical oxygen requirements for nitrification of this amount of nitrogen would amount to 1.9 tonne/day. This is equivalent to an 80 kW aerator operating 24 hrs/day at an annual electrical cost ($0.08/kWh, 350 days/yr) of $53,800. No allowance is made for denitrification benefits, which would reduce this consumption.

- Phosphorus reduction amounted to 11.3%, or 30 kg/day. This corresponds to a fall in effluent concentration from 50 mg P/l to about 45 mg P/l. Precipitation of 30 kg P/day would roughly produce 180 kg/day dry solids of chemical sludge (or 1.8 tonne/day at 10% solids). At a landfill cost of $25/wet tonne, this amounts to $15,750 p.a. saved (ignoring dewatering and transport costs).

- Table 14 appears to suggest that the form of nitrogen emitted from the abattoir changed with significantly more ammonia generated than prior to the modifications. Ammonia is produced principally from the ante-mortem yards and the high temperature rendering condensate. The latter stream not only increased in quantity post modification, but also increased substantially in ammonia concentration. This is probably the cause of the observed ammonia increase. Nevertheless, total nitrogen load from the plant fell substantially.

The process technologies have produced a clear improvement in reducing nutrient emissions to the environment and the wastewater treatment plant. Further, these quantities are presumably contributing to improved product yields in the byproducts plant.

Table 15. Reduction in Contaminant Emissions to Wastewater Treatment System post modifications.

Source		Flow	TCOD	TSS	TKN	NH_3-N	TP
Reduction	%	-3.0%	11.4%	13.3%	21.4%	-74.5%	11.3%
Load reduction	kg/day		4,854	1,808	413	-197	30.5

6.2 Comparison of Performance with Best Practice

Table 16 contrasts the performance of the AMH Dinmore abattoir (after commissioning the new Byproducts plant) with a current estimate of World Best Practice (WBP) performance. The latter data were derived from work performed by Dr. Mike Johns during a partnership project between MLA and Australian Country Choice in 2001/02 to establish such Key Performance Indicators (KPI).

It is immediately clear that the Dinmore facility is a highly eco-efficient plant and stands clearly at the leading edge of current World Best Practice Environmental performance in terms of wastewater production.

Table 16. Comparison of Dinmore abattoir (post-modification) performance with World Best Practice.

KPI	Units	WBP	Dinmore
Wastewater generation	kL/tonne HSCW	5.5	5.4
COD load	kg/tonne HSCW	30	39.2
TN load	kg/tonne HSCW	1.50	1.58
TP load	kg/tonne HSCW	0.25	0.25

7. Conclusions

- The nitrogen management strategy selected by AMH at Dinmore complemented their construction of a new Byproducts Facility at Dinmore abattoir to replace the existing ageing plant. The strategy was to reduce nitrogen emissions by decreasing raw material bin drainage (through retiring the existing large pneumatic (blow) system and replacing it with a hydraulic pumping system) and to dry the haemoglobin fraction of the edible blood, in addition to generally improving rendering processing technology.

- On completion, this strategy had achieved the following measured reductions in contaminant loads discharged to the primary treatment system:
  Chemical Oxygen Demand: 11%
  Total Suspended Solids: 13%
  Total Nitrogen: 21%
  Total Phosphorus: 11%
  The flow actually increased a little.

  These reductions were achieved despite the processing of a significant amount of raw material that had previously been sent out for rendering (the data were not adjusted to take this into account). Therefore, the reductions in load discharged are almost certainly larger than shown.

- Studies of the discharged loads of contaminants prior to the modifications, showed that the raw material bin drainage from the old byproducts plant was the worst contributor to COD (22% of total discharge) and nitrogen (32% of total) of any waste stream. This was due largely to its significant volume (3.4% of total flow) and high strength. It was found that large quantities of water had to be added to prevent blockage of the blow lines during raw material transport and that this captured large quantities of nutrients and COD.

  Elimination of the blow system by a dry pumping system resulted in the very significant reductions in COD and TN discharge seen above. The reduction in COD load alone is equivalent to a city of 40,000 persons!

- The old byproducts plant (including the LTR plant and the raw material bin drainage) contributed to contaminant loads out of all proportion to its effluent flow (only 10% of total). COD, TN and TP loads discharged prior to the new facility amounted to 36%, 50% and 24%, respectively. The new byproducts facility is much cleaner at 25% COD, 40% TN and 13% TP (with additional throughput).

- The spreadsheet model could be used to estimate loads discharged by any of 20 waste streams in the abattoir using estimated and measured flows of each stream and measured compositions with very reasonable accuracy, when validated against the total discharge of each contaminant at the wastewater treatment plant inlet.

- Individual waste streams were found to fall into three categories according to composition:
  1. Very high strength streams characterised by very high COD (> 50,000 mg/L), TSS (>20,000 mg/l), and nitrogen (>3,000 mg/l) with phosphorus of > 200 mg/l. Of these streams, the raw material bin drainage dominated contaminant load discharge from the abattoir.

  2. A second group of waste streams is characterised as medium strength and is characterised by high COD (14 – 20,000 mg/L), TSS (> 7,000 mg/l), and high nitrogen (>340 mg/l) and phosphorus (> 150 mg/l). These streams comprise a significant number of the worst streams due to their high flow, including cattle yard wash stream, tripe processing effluent and the dry dump stream (especially for phosphorus).

3. The remaining waste streams comprise relatively weak contaminant levels with COD typically < 6,000 mg/l, TSS < 2,000 mg/l and nutrients generally low (TN < 250 mg/l; TP < 25 mg/l), although again there is significant variability. These streams pose significant loads only at high flows. The only stream of significance from this group was the red offal wash stream (trommel), especially for oil & grease loads (almost half the total discharge load).

- Following the commissioning of the new byproducts facility, the AMH Dinmore processing plant in total is now at world best practice performance in terms of contaminant discharge in the raw wastewater (prior to treatment).

The project appears to have been successful. It is hoped these data will provide further incentive for developing and implementing new strategies to further reduce resource consumption and waste generation during meat processing.

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Abbreviations

AMH	=	Australia Meat Holdings Pty. Limited
AN	=	Ammonia Nitrogen (mg/l)
BOD_5	=	Biochemical Oxygen Demand (measured in 5 days at 20°C) (mg/l).
COD	=	Chemical Oxygen Demand (mg/l)
DAF	=	Dissolved Air Flotation
DCB	=	Degreased Cattle Bones (Gel bone)
EPA	=	Environmental Protection Agency
HSCW	=	Hot Standard Carcase Weight
HTR	=	high temperature rendering
LTR	=	low temperature rendering
ML	=	Megalitre
MLA	=	Meat and Livestock Australia
MRC	=	Meat Research Council
NH_3-N	=	Ammonia-Nitrogen concentration (mg/l)
O&G	=	Oil and Grease (mg/l)
Org N	=	Organic Nitrogen (mg/l)
PCOD	=	Particulate COD
PO_4-P	=	ortho-phosphate concentration (mg/l)
RM	=	raw materials
SBR	=	Sequencing Batch Reactor
SCOD	=	Soluble Chemical Oxygen Demand (mg/l)
TCOD	=	Total Chemical Oxygen Demand (mg/l)
TKN	=	Total Kjeldahl nitrogen (mg/l)
TN	=	Total Nitrogen concentration (mg/l)
TP	=	Total Phosphorus concentration (mg/l)
TSS	=	Total Suspended Solids (mg/l)
WBP	=	World Best Practice.

Appendix 1: Test Methodology.

Wastewater characteristics for each waste stream were determined by sampling and subsequent analysis off-site. Composite sampling was performed for all waste streams except:

- Discharge from the blood drier scrubber (Round 1);
- Boiler ash wash.

Both streams exhibit a high degree of consistency in contaminant levels and flow.

Composite sampling method: To obtain a composite sample, four grab samples (at least 3-5 litres each) were taken of the effluent stream over 5 - 10 minutes of normal operation and mixed together. After mixing this total volume thoroughly, samples were withdrawn for analysis and cooled immediately on ice to prevent bacterial action altering the sample during holding and transport to the lab. The sample was required to get to the lab within 6 hours. Both laboratories were within 30 mins travel time of the site.

Analysis of samples was performed as shown in Table A1. Testing was performed off-site for individual waste streams. Total Kjeldahl Nitrogen (TKN) was considered to be equivalent to Total Nitrogen. Experience has shown that oxidised nitrogen forms do not exist in raw abattoir wastewater streams.

Table A1. Analytical Analysis Methods.

Test	Method	Laboratory
Total & Soluble COD	Digestion APHA 5770C	WWF
TSS		WWF
O&G	Gravimetric	FALA
TKN	Semi-micro digestion	WWF
Ammonia nitrogen	FIA	WWF
TP	Digestion & FIA	WWF
Orthophosphate	FIA	WWF

Notes: WWF – Wastewater Futures Laboratory, The University of Queensland;
FALA – Food & Agriculture Laboratories, Australia, Archerfield.

Appendix 2: Wastewater Stream Flow Estimation

As part of the project, 14 flowmeters were installed within the water distribution system of the Dinmore plant to assist water balance estimation. The meters were placed as follows:

- 9 on cold water streams;
- 5 on hot water flows.

Table A2 below identifies how individual waste stream flows were estimated.

Table A2. Flow Analysis Methods.

Waste stream	Flow Method
Kill floor flow	Flowmeters
Red Offal wash	estimated from sum of kill floor & tripe process flows
Boning room	Flowmeters
Cleaning	Flowmeters
Raw material bin drainage	Tank fill/time to fill method
HT Condensate	Estimated from water balance on byproducts
HT Stickwater	Estimated from water balance on byproducts
Blood process stickwater	Estimated from water balance on byproducts
DCB plant	Estimated from plant settings
Paunch dumping	Bucket/stopwatch
Umbrella wash	Bucket/stopwatch
Tripe processing	Flowmeters
Antemortem yards	Estimated from water balance
Cattle race wash	Flowmeters
Truckwash	Estimated
Human amenities	Estimated
Chillers	Flowmeters
Boiler ash wash	Bucket/stopwatch
Town water	Flowmeters
Raw wastewater effluent	Flowmeters

Appendix 3: Raw Analytical Data from Abattoir Wastewater

This Appendix contains the results of analytical testing of samples of the various waste streams conducted during the project.

Table 1. Old Byproducts Streams

Location	Date	Time	pH	Temp	TCOD mg / L	SCOD mg / L	TSS mg / L	O&G mg / L	TKN mg / L	NH4-N mg / L	TKP mg / L	PO4-P mg / L
Raw Material Bin	8/10/01	11.15 am	6.18	37	53,310	17,900	22,700	7833	3402	255	268	144
Raw Material Bin	8/10/01	12.15 pm	_	34	57,810	19,720	22,100	8260	3170	266	254	161
Raw Material Bin	8/10/01	12.55 pm	6.31	36	60,310	20,460	25,600	5867	4086	240	328	164
Cooker Condensate	8/10/01	11.05 am	7.72	24	671	610	0	56.6	214	194.7	<2	0
Cooker Condensate	8/10/01	12.00 noon	8.50	24	781	619	62.5	63	274	266.31	<2	0
Tallow Stickwater	8/10/01	11.40 am	6.86	80	159,620	4532	121,300	10.25% w/v	284	4.29	204	16.5
Tallow Stickwater	8/10/01	12.45 pm	6.91	78	54,000	776	21,100	18,500	242	1.32	170	8.25
Blood Stickwater	8/10/01	11.30 am	7.81	76	14,596	6464	7,700	12	2036	98	153	65
Blood Stickwater	8/10/01	12.30 pm	7.90	68	1515	165	660	5.8	124	13	22.3	20
Blood Drier Discharge	8/10/01	11.15 am	6.96	42	667	45	400	<5	98.2	20.46	22.4	20.46
Blood Drier Discharge	8/10/01	12.20 pm	7.34	41	708	40	560	<5	83.4	18.81	21.4	20.13
Blood Drier Discharge	8/10/01	1.00 pm	7.71	41	709	27	420	<5	91.2	22.11	21.8	20.46

Appendix 3 (cont)

Table 2. New Byproducts Streams													
Location	**Date**	**Time**	**pH**	**Temp**	**TCOD**	**SCOD**	**TSS**	**VSS**	**O&G**	**TKN**	**NH4-N**	**TKP**	**PO4-P**
					mg / L	mg / L	mg / L	mg/l	mg / L	mg / L	mg / L	mg / L	mg / L
DCB plant effluent	16/4/02	12.50pm		70+	98,067	NC	45,275	39,875	11,500	3,983	N/A	278	N/A
DCB plant effluent	16/4/02	1.05pm		70+	93,975	NC	51,000	45,799	11,600	4,436	N/A	298	N/A
DCB plant effluent	16/4/02	1.15pm		70+	96,323	NC	54,275	47,875	28,800	4,632	N/A	308	N/A
Raw material bin	22/3/02	4.00pm	6.5	35	82,460	44,040	32,350	30,350	123,700	6,090	252	542	223
Raw material bin	22/3/02	5.35pm	6.5	35	64,782	4,182	10,149	9,500	1,120	5,665	285	314	131
Raw material bin	22/3/02	6.40pm	6.9	30	5,606	2,693	1,900	1,799	1,670	397	39	24	14
Cooker condensate	22/3/02	3.50pm	8.2	27	639	730	10	10	30	433	379.8	<0.6	0.0
Cooker condensate	22/3/02	5.10pm	8.1	28	906	815	20	20	33	483	439.5	<0.6	1.3
Cooker condensate	22/3/02	6.30pm	8.3	28	996	909	39	39	37	517	443.1	<0.6	0.0
Tallow stickwater	22/3/02	3.20pm	6.4	70+	25,137	323	17,500	17,125	18,255	120	0.9	77	5.7
Tallow stickwater	22/3/02	5.10pm	6.7	70+	44,593	1,036	18,775	18,325	13,080	124	1.4	104	7.4
Tallow stickwater	22/3/02	6.30pm	6.6	70+	94,323	458	38,025	37,375	33,320	222	1.3	144	13.3
Blood stickwater	22/3/02	3.40pm	6.9	70+	34,220	9,596	40,100	39,225	346	8,387	34.4	131	41.2
Blood stickwater	22/3/02	5.25pm	7.1	68	4,768	3,545	1,090	1,050	72	247	12.4	34	14.0

Appendix 3 (cont)

Table 3. Offal Processing Streams

Location	Date	Time	Temp	TCOD	SCOD	TSS	VSS	O&G	TKN	NH4-N	TKP	PO4-P
				mg / L	mg / L	mg / L	mg / L	mg / L	mg / L	mg / L	mg / L	mg / L
Tripe process effluent	16/4/02	1.30pm	51	29,683	2,103	18,600	18,400	49,300	796	27.3	104	56.8
Tripe process effluent	16/4/02	2.10pm	65	13,513	819	4,966	4,941	23,110	196	5.7	25	14.4
Tripe process effluent	16/4/02	2.50pm	54	225	44	1,865	1,865	345	8	0.7	1	0.7
Cattle yard wash	23/04/02	6.45 pm		16,190	1,008	21,200		700	425	125	138	38.7
Cattle yard wash	23/04/02	6.45 pm		11,905	1,437	15,000		800	557	232	147	27.5

Table 4. Kill Floor Streams

Location	Date	Time	Temp	TCOD	SCOD	TSS	VSS	O&G	TKN	NH4-N	TKP	PO4-P
				mg / L	mg / L	mg / L	mg / L	mg / L	mg / L	mg / L	mg / L	mg / L
Kill floor effluent 1	16/4/02	1.30pm	46	1,591	579	550	545	250	83	9.0	2.8	0.9
Kill floor effluent 1	16/4/02	2.05pm	34	1,443	559	475	475	555	81	6.0	2.6	0.6
Kill floor effluent 1	16/4/02	2.45pm	38	1,227	538	460	460	163	83	1.2	1.6	0.4
Kill floor effluent 2	16/4/02	1.30pm	48	2,342	635	1,155	1,130	52	106	2.1	6.9	1.9
Kill floor effluent 2	16/4/02	2.15pm	35	702	479	180	180	77	68	1.7	1.2	0.6
Kill floor effluent 2	16/4/02	2.55pm	39	1,998	1,315	220	215	73	158	3.0	1.4	1.0
Gut wash effluent 1	16/4/02	12.30pm	36	2,266	295	1,100	1,065	1,465	57	1	3.7	2
Gut wash effluent 1	16/4/02	1.50pm	38	11,437	836	7,580	6,639	6,380	193	15.7	46	30.7
Gut wash effluent 1	16/4/02	2.30pm	38	8,209	3,206	1,785	1,719	8,440	464		24	
Gut wash effluent 2	16/4/02	12.30pm	37	997	353	630	504	126	66	0.9	1.4	<0.2
Gut wash effluent 2	16/4/02	1.55pm	38	4,057	443	3,254	3,004	1,485	113	6.5	20	8.5
Gut wash effluent 2	16/4/02	2.35pm	38	4,966	884	3,029	2,909	3,060	228	9	20	11.4

Appendix 3 (cont)

Table 5. Miscellaneous Streams													
Location	**Date**	**Time**	**pH**	**Temp**	**TCOD**	**SCOD**	**TSS**	**VSS**	**O&G**	**TKN**	**NH4-N**	**TKP**	**PO4-P**
					mg / L	mg / L	mg / L	mg / L	mg / L	mg / L	mg / L	mg / L	mg / L
Boiler ash wash	22/3/02	4.15pm	7.51	27	560	<20	1,145	155	< 5	2.8	0.8	2.6	1.5
Boiler ash wash	22/3/02	5.45pm	7.47	27	560	<20	495	130	< 5	1.4	0.4	0.3	1.5
Boiler ash wash	22/3/02	6.50pm	7.20	25	982	<20	560	100	< 5	1.8	0.4	0.5	1.5
Cleaning Flow	11/10/01	3.55 pm	6.41	42	10,790	1985	8,900		1378	292	14	50.8	35
Cleaning Flow	11/10/01	4.15 pm	5.74	42	5060	2111	3,000		506	308	8	12.38	7
Cleaning Flow	11/10/01	5.00 pm	5.56	42	3600	1410	1,400		121	192	8	7.22	4
Cleaning flow	22/3/02	4.30pm	6.30	38	3,817	906	2,560	2,330	1,090	188	11.4	11.0	5.9
Cleaning flow	22/3/02	4.40pm	6.31	39	2,999	1,147	1,570	1,489	780	173	11.7	7.0	3.4
Cleaning flow	22/3/02	5.50pm	9.31	36	2,664	965	1,040	960	730	73	6.8	15.0	4.5
Cleaning flow	22/3/02	6.00pm	8.63	40	3,468	945	1,270	1,170	900	110	9.0	18.0	7.3
Cleaning flow	22/3/02	7.10pm	8.15	38	1,119	1,087	580	549	173	48	8.7	5.0	7.3
Cleaning flow	22/3/02	7.20pm	8.21	38	971	686	429	409	166	33	5.9	4.0	7.0