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Effluent treatment in the Australian meat industry M.050

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SUMMARY

The meat industry in Australia will have to operate in a climate of increased environmental awareness, with tougher regulations and harsher penalties controlling its operations and discharges. Industry will have to move away from the "end of pipe" treatment philosophy and explore opportunities to reduce those emissions requiring treatment through waste minimisation and recycling technologies.

In order to audit the range of effluent treatment technologies used by the Australian meat industry and identify the environmental issues facing the industry, a total of 45 meat processing plants were visited in New South Wales, Western Australia, Queensland, Victoria and South Australia. The appropriate Regulatory Authorities in these States were also visited.

In addition, the opportunity was taken to review those processes, such as blood processing, gut cutting and rendering operations, that can have a significant impact on the characteristics of the effluent produced by a meat processing plant. Air pollution problems relating to the operation of rendering plants have been identified as an issue that concerns all Regulatory Authorities spoken with.

Key findings were as follows:

- Primary effluent treatment at many plants can be improved. At many plants, increases in plant throughput have not been matched by an upgrading of these treatment facilities.

- The most common secondary treatment systems employed in the Australian meat industry are anaerobic/aerobic lagoons with final treatment being by irrigation. Problems were identified with the operation of anaerobic lagoons and these were attributed in part to overloading of the lagoons due to poor primary treatment. Many aerobic lagoons were either not properly designed or were overloaded, a situation that contributed to air pollution problems.

- A number of irrigation systems were visited, some of which were operating outside State Regulatory Authority guidelines. This is an area that will require attention in the near future as protection of groundwater resources and the concepts of sustainable operation are implemented by the Regulatory Authorities.

- Air pollution issues relating to rendering plant emissions will receive increasing attention from the Regulatory Authorities.

- Meat processing company operations will be subjected to considerable scrutiny from the Regulatory Authorities through environmental and process audits.

This report discusses the major processes that contribute to effluent loads and individual treatment processes under separate headings. In each section existing technology is discussed, problems are identified, Regulatory Authority concerns are highlighted, Research and Development needs and technology transfer requirements are listed and a list of background reading is given.

CONTENTS

1. INTRODUCTION

The Environmental Management Section of the Meat Industry Research Institute of New Zealand (Inc.) was contracted by the Australian Meat and Livestock Research and Development Corporation (AMLRDC) (now The Meat Research Corporation) to investigate the environmental issues facing the Australian meat industry. The detailed project specification required that a review report be produced which:

1. Audits the range of technologies used in the treatment of liquid and solid wastes produced by the Australian meat industry.
2. Identifies industry and regulatory concerns in respect of environmental management.
3. Identifies environmental issues that will impact on the operation of the industry.
4. Defines anticipated future requirements for effluent treatment and solid waste disposal or utilization to ensure compliance with changing requirements for environmental management.
5. Makes appropriate recommendations for R&D into waste disposal technologies needed by the meat industry.

In order to determine the effluent treatment status of the Australian meat industry, and its future requirements, four separate visits were made to Australia between May and December of 1990. Each visit concentrated on a separate geographical area of Australia and during each trip, visits were made to a number of meat processing plants and the appropriate State Regulatory Authorities. Contacts and introductions to the processing plants were made using the resident CSIRO Extension Officers in each State. The Extension Officer's local knowledge also ensured that the meat processing plants visited represented a cross-section of the types of environmental problems faced by the Australian meat industry as well as being representative of the types of effluent treatment technologies employed.

In New South Wales, ten meat processing plants were visited and discussions held with officers of the State Pollution Control Commission both in Sydney and at two regional offices.

In Western Australia, thirteen meat processing plants were visited and discussions held with officers of the Water Authority of Western Australia (WAWA), the

Environmental Protection Authority of Western Australia, the Waterways Commission and the Western Australian Department of Agriculture.

In Queensland, twelve meat processing plants were visited and discussions held with officers of the Water Resources Commission and at the head office and a regional office of the Queensland Department of Environment and Heritage.

In Victoria and South Australia a total of ten meat plants were visited and discussions held with officers of the Melbourne Metropolitan Board of Works, the Victorian Environmental Protection Authority and in South Australia officers of the Engineering and Water Supply Department at the Department of Environment and Planning.

The wide range of meat processing plants visited in different geographic and climatic locations enabled a picture to be built up of the range of effluent treatment technologies currently employed by the Australian meat industry.

The discussions held with the various State Regulatory Authorities allowed a clear picture of the changing regulatory climate to be formed.

The above objectives have been met and findings from the survey are discussed in the following sections of this report. The scope of the report is, however, wider than was envisaged when the listed objectives were established and includes a detailed discussion of some major processing operations that contribute to the total effluent load produced by a meat processing plant.

The principal reason for this change in emphasis is a recognition of the direction that environmental legislation is taking in Australia. Legislation currently coming into force and being enacted in many States in Australia is focusing on the principles of waste minimisation, re-use and recycling prior to accepting 'end of pipe' solutions. A report that concentrated only on end of pipe treatment technologies would therefore have ignored the underlying philosophy of emerging Australian environmental legislation.

In addition, air pollution issues as they relate to the operation of rendering plants, as well as to other meat plant activities, are discussed in this report. Many of the Regulatory Authorities identify air pollution issues associated with rendering plants as one of their major areas of concern.

Treatment technologies are discussed under unit operation headings, such as 'Solid Wastes, Anaerobic Treatment', etc. Proprietary systems manufactured, marketed or promoted by commercial organisations are not discussed. This is because in most cases there is not enough objective scientific information on these technologies.

A selected bibliography of references for further reading is given at the end of each major section.

2. THE REGULATORY CLIMATE

2.1 Introduction

Environmental issues, in Australia as well as elsewhere in the world, are the subject of intense public interest. Environmental issues have become mainstreamed and are politically acceptable both at State and Federal level.

One of the key issues in the environmental debate is the concept of satisfactory and sustainable development. This concept is likely to form the philosophical base on which environmental policies, both at State and National level, are founded.

The Federal Government in 1990 produced a draft discussion paper that included the following definition of sustainable development:

> 'Ecologically, sustainable development means using conserving and enhancing the community's resources so that ecological processes, on which life depends are maintained and the total quality of life now and in the future can be increased'.

Adoption of such an approach clearly signals that economic development can occur only when environmental protection issues have been discussed and the appropriate safeguards implemented.

The Federal Government has stated that its commitment to the concept of sustainability and sustainable development and will achieve these goals by targeting air and water quality through the setting of strict pollution standards.

As part of this process a draft set of National Water and Air Quality Goals was published for discussion by the Australia and New Zealand Environmental Council

(ANZEC). These goals will become standards when given legal status by the various State Governments. Such developments are likely to be overseen by a Federal Environmental Protection Authority.

Sustainable development does not mean no development, it simply means that the priorities have changed. For example, it is no longer acceptable to expect urban residents to have to tolerate airborne emissions from meat processing plants, despite the fact that the plant may have been there for 60 years and the complainants live in new suburbs, built near the plant as a result of urban sprawl. This new climate of environmental awareness and responsibility may result in the closure of meat plants that are inappropriately located from an environmental management perspective.

2.2 State Regulations

The environmental management regulations that license discharges and impose conditions are under review or have recently been reviewed in all States. New South Wales and Victoria are the most advanced in this regard with both State Parliaments enacting substantial amendments or additional Acts in 1989. The meat industry will only now be beginning to appreciate the new regulatory climate as existing licences are renewed.

The philosophy behind the regulatory changes is and will be one of self regulation with strict accountability for compliance with licence conditions and greater public participation in the licensing and approval procedures. As a consequence, many meat processing plants will be forced to undergo a significant change in philosophy. They will have to invest more resources in recording, monitoring and auditing those aspects of their operations that have an environmental impact.

Licence conditions will not remain unchanged and the annual licence renewal will no longer be a 'roll over' of existing conditions. Regulatory requirements will change and become more stringent and restrictive as industry is forced to adopt a 'more responsible' attitude towards the environment.

Recent regulatory changes in Victoria and New South Wales will ensure this happens, and the regulatory changes in other States will have similar goals.

In New South Wales the Environmental Offences and Penalties Act (1989) provides for new licence renewal requirements as well providing harsh penalties for breach of licence conditions. The philosophy of self regulation, additional monitoring and auditing resources applies to not only to the waste treatment facilities but also to those processing operations that generate waste.

The Act also recognizes that environmental improvement will not happen overnight and that industry needs time to make decisions and commit resources to achieve agreed environmental emission targets. Licence conditions will change and will reflect an 'immediately achievable reality'. In many cases this will be a transient holding point where existing licence conditions are 'inadequate to ensure environmental protection'. The Regulatory Authority, to ensure environmental protection, will then move to implement a pollution reduction programme that will require that specified environmental discharge requirements be met by an agreed date. To ensure that industry responds to these environmental improvement programmes, bonds of greater than $60,000 will have to be posted. Failure to meet targets will mean that the bond will be forfeit, no licence will be issued, and the processing plant could not therefore operate legally.

In addition, in New South Wales there will be a move away from the 'Best Practicable Option' (BOP) approach to one of 'Best Available Technology Economically Achievable', (BATEA). This is a significant change and one with far-reaching implications.

The situation in Victoria is similar, although the end result will be achieved by slightly different means.

The Victoria EPA can declare entire industries subject to an 'Environmental Improvement Plan' (EIP) which is defined as:

> 'A plan developed by industry in consultation with the Regulatory Authorities and community specifying a series of performance objectives and the means of achieving them.'

Once an industry has been declared as subject to an EIP, that industry has a choice. It can either co-operate with the EPA in devising an EIP that will include adopting waste minimisation strategies and using Best Available Technology (BAT) to deal with all waste discharges, or it can chose not to co-operate.

If an industry as a whole, or individual companies, elect not to co-operate with the EPA, then the EPA can amend licence conditions to require that an audit be undertaken of that industry's or company's activities. The EPA would appoint the auditors and would also define the scope of the audit. The industry or company would, of course, pay all costs and would have no control over how the audit report was used or where it was published.

The EIP is regarded as an important tool in achieving the goal of improved environmental quality and will incorporate the principle of adopting waste minimisation and recycling technologies as well as employing Best Available Technology to treat residual emissions in an environmentally responsible manner.

2.3 Conclusions

The meat industry in Australia will have to operate in a climate of increased environmental awareness, with tougher regulations and harsher penalties controlling its operations and discharges. Industry will have to move away from the 'end of pipe' treatment philosophy and explore through waste minimisation and recycling technologies, opportunities to reduce those emissions requiring treatment.

Meeting the challenges that this new climate presents should be seen positively as an opportunity to protect existing investment in plant and facilities and ensure that the industry continues to operate into the twenty-first century.

It can do this by being proactive, and by assuming that its operations will be subject to audit and commissioning such audits before it is required to do so by the Regulatory Authorities. The Regulatory Authorities should be involved at this stage to assist in defining audit objectives.

3. CHARACTERISTICS OF MEAT PROCESSING EFFLUENT

Meat processing effluents are organic in nature and are characterised by the high concentrations of organic nitrogen and fat they contain. The principal sources of these organic components are listed below:

- Paunch contents from gut cutting and washing operations.
- Faecal material from stock and sheep yards and casings operations.
- Blood losses from sticking areas and blood processing operations.
- Fat from rendering and gut processing operations.
- Emulsified fat, soluble protein and suspended solids from washdown, conveying water and general processing operations.

The characteristics of meat processing effluent vary widely between processing plants. This variation is due to differences in the types and numbers of stock processed and the various types of processing operations employed.

For example, the type of rendering process used can significantly affect the concentrations of nitrogen and fat in the plant effluent, and differences in gut cutting and washing procedures influence the amount of flotable fat discharged for recovery to primary treatment systems.

The nature of the untreated effluent produced by meat processing operations makes it difficult to characterise, and meaningful comparison of the effluent produced by different plants can be made only after primary treatment. The characteristics of meat processing effluent after primary treatment are given in Table 1.

Table 1. Characteristics of meat processing effluent after primary treatment.

	Range (g/m^3)
Biochemical Oxygen Demand, BOD_5	700-4000
Chemical Oxygen Demand, COD	1300-7500
Total Kjeldahl Nitrogen, TKN	100-250
Ammonia Nitrogen, NH_3-N	20-60
Total Suspended Solids, TSS	200-1200
Total Fat	100-1000

The chemical oxygen demand (COD) of primary treated meat processing effluent can be estimated using the following relationship:

$$COD = (\text{Organic nitrogen}) \times 9 + (\text{Fat}) \times 3 \quad (1)$$

Where all units are g/m^3 and organic nitrogen is defined as [TKN - (NH_3-N)].

The relationship in Eq.(1) applies only to primary treated meat processing effluent and cannot be used for anaerobically or aerobically treated effluent.

The relationship can be used to predict the effect of changes in processing operations or improvements to primary treatment facilities on effluent characteristics. For example, if improved primary treatment reduces the fat concentration by 100 g/m^3, then the effluent COD would be expected to reduce by 300 g/m^3. Similarly, if improvements to blood collection and processing operations reduce the organic nitrogen by 30 g/m^3, the effluent COD would reduce by 270 g/m^3.

The wide range of values for characteristics of primary treated meat processing effluent shown in Table 1 can be attributed to many factors, the principal ones being as follows:

- Water use influences effluent concentration. As well, the use of large volumes of water for conveying and washing raw material increases losses to emulsification, leaching of soluble components and comminution in turbulent drains.

- Good management and process control in blood collection and processing area and in rendering departments will reduce the total nitrogen and fat concentrations in the effluent.

- The type of rendering process employed influences the amount of potential product lost to the effluent system.

- Gut cutting and washing systems influence the amount of fat lost to the effluent system.

- Dry cleaning of processing areas to recover solids reduces the load on primary treatment systems and improves their efficiency.

- The type of primary treatment plant used influences effluent characteristics. Pre-screening in combination with gravity separation is more efficient than screening or sedimentation alone. The use of dissolved air flotation (daf) will effect a further improvement.

Only a proportion of the fat in meat processing effluents will be removed by primary treatment. The rest is emulsified and represents both product loss and a load on secondary treatment plants.

The major proportion of the nitrogen discharged to primary treatment systems is soluble and cannot be removed by physical means. It is this nitrogen component of meat processing effluent that is of particular concern with respect to the design and operation of secondary treatment plants, including irrigation systems.

Effluent nitrogen loadings can be significantly reduced by, for example, improved blood collection and processing procedures, and these reductions will further influence the design of effluent treatment systems. For example, irrigation systems should be designed on a nitrogen loading basis, and a reduction in the amount of nitrogen in an effluent will result in a smaller irrigation area being required.

In-plant processes therefore have to be considered in any discussion of meat plant processing effluent treatment.

4. BLOOD COLLECTION AND PROCESSING

4.1 Introduction

Blood is the single most identifiable source of nitrogen that is discharged from a meat plant to an effluent treatment system. Once blood is discharged to an effluent system it is not recoverable and a valuable by-product becomes a soluble oxygen demand and nutrient problem.

The oxygen demand and nutrient load from blood can be treated only in biological treatment systems where the protein nitrogen is converted sequentially to ammonia and then nitrate. Nitrogen is then lost only by denitrification processes, and the extent to which these occur will be a function of treatment plant design. Chemical treatment systems do not generally remove blood proteins unless specific protein precipitants are added, as blood proteins will not precipitate under acid conditions alone.

4.2 Blood Oxygen Demand and Nitrogen Loadings

The significant contribution that blood can make to the oxygen demand and nitrogen concentration in meat processing effluents is often not appreciated.

The effect of discharging all the 'collectable' blood to an effluent system, in terms of nitrogen and chemical oxygen demand (COD) is summarised in Table 2. These figures are based on New Zealand data and will represent the situation in Australian meat processing plants.

Table 2. COD and nitrogen loadings associated with the discharge of whole blood to an effluent treatment system.

	Nitrogen (g/carcass)	COD (g/carcass)
Lamb	22-29	190-250
Prime beef	330-470	2850-4100

With blood collection (but not taking into account fellmongery and skin processing), the total nitrogen loading from processing one lamb to meat and by-products is approximately 60 g. Therefore, if blood is not collected, nitrogen loading is increased by 35-50% (Table 2).

4.3 Blood Recovery

Beef and mutton sticking areas were inspected at a number of plants and the following observations recorded:

- At some plants, every effort was made to maximize the collection of blood by providing collection troughs as well as minimising the ingress of water from knife and apron wash operations.

- At some beef plants, blood collection troughs had been extended to include some of the carcass dressing stations, where significant blood drip was observed to be occurring.

- At many plants the bleeding times and rails were too short, with insufficient time for complete bleed-out to occur.

- Dry-cleaning of blood collection areas was carried out fastidiously at some plants and less enthusiastically at others.

- Segregation of the blood collection ramps and troughs to prevent the ingress of added water could be improved in many plants.

- Many rendering supervisors reported periodic problems with excess water in the blood transported to the rendering plant for processing.

4.4 Blood Processing

Blood processing was generally accomplished using live stream injection to coagulate blood solids, followed by centrifugal separation and drying of the centrifuge solids (the crumb) in either a direct-fired ring drier or a modified batch rendering cooker.

Significant product losses can occur during processing if incorrect coagulation temperatures are used, because coagulable blood solids are lost in the centrate. At a number of plants, control of coagulation temperature was poor and no indication of the temperature was available to the operator.

Added water can significantly reduce the efficiency of the coagulation process. Undiluted blood is typically 19% total solids. Whilst some addition of water is unavoidable during collection, this can be kept to a minimum by attention to the design of blood collection areas and clean-down procedures.

If fresh blood is diluted to 10% total solids by the addition of water at collection, then approximately only 65% of the total solids in the blood will be recovered. By contrast, if the amount of added water is reduced such that the blood total solids is 15%, then recovery increases to approximately 80%. Therefore, adding water increases losses of blood solids, and also increases processing time, energy usage and effluent loading.

4.5 Blood Aging

Current practice in Australia is to process fresh blood, and only a limited number of plants age the blood before processing. Aging involves holding the blood overnight and then processing it the following day. The advantages of aging are that solids losses are reduced due to improved coagulation and the solids recovery is less dependent on coagulation temperature or initial blood total solids concentration; therefore, overall solids recovery is generally higher.

This can be illustrated with reference to the previous example but now considering the coagulation of aged blood at 10 and 15% total solids. In this case the total solids recoveries would increase to approximately 87 and 90% respectively.

Aging blood has one disadvantage in that odours can be produced during storage. These odours, if not controlled, will be present in the flash steam at the decanter as well as in combustion air discharged from the driers. Adding sodium metabisulphite to the blood holding tanks has been found to be effective in preventing odours and does not affect the advantages that can be obtained by aging. Indeed blood can be held over a weekend without offence, provided the correct amount of sodium metabisulphite has been added.

4.6 Checking Dried Blood Yields

For a plant to assess the overall efficiency of its blood collection and processing system, blood yield data are required. These data, which should be in the form of achievable dried blood production figures per unit of different types of stock throughput, would enable a company to compare its actual dried blood production with that achievable. Investigative action could then be undertaken to determine if blood was being lost from the system due to poor collection procedures, excessive water addition or incorrect coagulation procedures. Remedial action to correct the problem would then be undertaken.

Many companies did not have blood yield data available and therefore could not implement quality management procedures in this area. Plants also did not monitor process performance in any quantifiable manner with no samples being taken from the various process streams.

The process streams that should be monitored are:

- Raw blood in the rendering department holding tank. This stream should be analysed for total solids to determine the amount of added water.

- The centrate and solids phase from the decanter. These streams should be analysed for total solids to calculate the percentage of incoming blood solids that are lost to the effluent.

The approximate percentage of the total solids lost can be estimated using the following formula.

$$\text{Approximate \% total solids lost} = \frac{100\,C}{B} \times \frac{1.15 - B}{S - C} \qquad (2)$$

where

B = % total solids in raw blood

S = % total solids in coagulum

C = % total solids in the centrate

Simple process quality control techniques such as these will ensure that blood recovery and production of dried blood are maximized and that the effluent loadings from the blood collection and processing areas are minimised. Blood that is not collected or is lost during processing cannot be recovered and represents an incremental increase in both the capital and operating costs of effluent treatment systems, as well as increasing the potential environmental impact of a plant's operations.

4.7 Transport of Blood for Processing

A number of smaller meat processing plants discharged all the blood from the slaughtering operations to their effluent treatment system. This may be because the processing capacity of these plants is so small that it is uneconomic to establish a blood processing facility, or because there is no meat processing plant within an economic transport distance able or willing to accept the blood for processing. One company did collect and coagulate the blood, but then buried the coagulated solids. This approach converts a liquid waste problem into a solid wastes problem and is not a solution.

Plants that import blood for processing are facing tighter restrictions from the Air Pollution Control Authorities on the nature and age of the raw material being processed. The air pollution problems associated with the processing of blood more than 12 hours old are well known, and the imposition of licence conditions requiring that blood be processed on the day of collection would have serious implications for the operators of small meat processing plants as well as those that operate a service rendering facility. The addition of sodium metabisulphite to preserve the blood may help to alleviate problems in such circumstances.

4.8 R&D Needs and Technology Transfer

- Develop a code of practice specifying minimum bleeding times, to maximize blood collection.

- Incorporate in this code of practice recommendations on the design and layout of sticking areas to minimize blood loss and the minimize addition of water during collection. An emphasis on dry cleaning procedures and effective supervision will be an important component.

- Develop and promote the use of blood yield figures that are achievable by plants using good blood collection and processing procedures.

- Promote the concept of regular monitoring of blood processing as an integral part of Quality Management.
- Promote the use of blood aging as a means of increasing blood yields, and in particular provide evidence to convince the Regulatory Authorities of the efficiency of the process.
- Develop a protocol for the storage and processing of raw blood for transport from remote locations.
- Examine the economics of processes such as ultrafiltration for concentrating dilute blood-containing effluents, as a potential means of recovery.
- Investigate alternative blood processing techniques suitable for use at small abattoirs where on-site or central processing facilities are not available.

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5. RENDERING OPERATIONS

5.1 Introduction

Rendering plants are an integral part of meat processing, converting by-products from other processing operations into the valuable commodities of meal, tallow and dried blood. Rendering plants, in general, produce low effluent volumes, but these effluents can contain significant quantities of soluble and insoluble organic material, as well as tallow. In addition, rendering plants are a potential source of air pollution problems.

5.2 Sources of Effluent

The sources of effluent in a rendering plant are:

- Losses from raw material storage bins and screw conveyors.
- Leakage from processing equipment such as pump and cooker shaft glands.
- Discharge of condensables from heat recovery units.

- Wash water and de-sludging discharges from centrifugal tallow separators and decanters.
- Stickwater from low temperature rendering (LTR) processes.
- Centrate from blood processing operations.
- Tallow spills during tallow handling or load-out operations.

5.3 Reduction of Effluent Loading

One of the most common causes of high effluent loading in rendering plants is losses from raw material storage bins and conveyors. These losses usually arise during transfer of inadequately dewatered raw material to the rendering plant. Some compressive dewatering of raw material is inevitable during transfer and storage, but in the worst cases drain holes have to be drilled in the troughs of screw conveyors to ensure that the material can be conveyed. The drainage water from this type of installation will contain substantial quantities of fat.

The source of the problem is usually gut washing screens that do not dewater the cut gut material adequately prior to discharge to a screw conveyor or blow pot. Modification of the gut cutting and washing system and/or the provision of a dewatering system prior to the raw material bin will reduce losses from this area.

All drainage water from raw material holding bins and conveyors, together with general washdown water, should be treated in a separate departmental save-all, where flotable material can be recovered.

Losses from pump glands and cooker shafts in particular can be largely prevented by maintenance programmes. Leaks can be contained by the provision of trays under the leaking glands, to prevent tallow being lost to the drain.

When a tallow spill occurs, the tallow should be allowed to set and then shovelled up by scraping for recycle to the raw materials bin.

Material losses from cookers due to priming can largely be avoided by not over-filling the cookers. Solid material entrained in the cooker vent gases and removed in intercept vessels should be either recycled or disposed of as solids waste.

Where centrifugal separators are used for washing and refining of tallow, tallow losses should be minimal provided the equipment is properly maintained and is operated under the correct conditions. Areas where tallow spills can occur, due to line breakage or tank overflow, should be drained to a departmental save-all where recovery can take place. This will minimise the losses that occur if recovery is delayed until the effluent is mixed with all other processing effluents for treatment in a primary save-all unit.

Low temperature rendering (LTR) plants produce less odour than conventional batch dry rendering plants because most of the raw material water is removed by mechanical separation. These plants have not been widely adopted in Australia because of difficulties in treating the stickwater, which contains high concentrations of chemical oxygen demand and nitrogen. These difficulties are resolved if the stickwater treatment is regarded as a product recovery issue rather than one of effluent treatment. Stickwater can be recovered by concentration using either evaporation or ultrafiltration. The concentrated stickwater may then be dried or alternatively it can be sold as a liquid pig feed supplement. The unconcentrated stickwater can also be used as a pig food, but the high water content (95%) seriously affects the economics of such an operation.

Four plants were visited that had installed LTR plants of various configurations. Of these four, one was not operational because of effluent treatment problems associated with stickwater discharges.

5.4 Rendering Plant Environmental Issues

The unanimous principal concern of the Regulatory Authorities in all States in relation to meat processing plants related to odour nuisance problems associated with rendering plants.

The vast majority of plants visited had heat recovery systems, but a substantial number had no odour control on either the building ambient air or on specific process streams such as exhaust gases from blood driers and heat recovery systems.

Some Regulatory Authorities identified specific processing practices as contributing to the air pollution problem and at the same time acknowledged that incorrectly operated or undersized afterburner units also contributed.

The processing practices that are of concern relate to the age of raw material at the time of processing (both soft offal and blood) and conditions to control this are likely to be incorporated into air pollution licences in the future.

Acid stabilisation of soft offal to prevent spoilage and prevent tallow quality degradation was not widely practised. Acid stabilisation of soft offals will also minimise any odour problems that result from the processing of stored material.

A particular issue that was raised in both Victoria and South Australia is the importing of raw material from satellite meat processing plants for processing at a central facility. Experience has shown that if paunches are emptied at the original processing plant, then odour problems during subsequent processing are minimised or eliminated. Air pollution licence conditions for rendering operations are likely to reflect this observation. This requirement relocates an effluent and solids disposal issue back to small abattoirs without rendering facilities.

Attention is also focusing on other aspects of the rendering process and in particular on odours and emissions from meal presses. Many plants have installed hoods over meal presses and other operations where odorous vapours are produced. The collected vapours are conveyed to air pollution control equipment. Where plants are located in an urban environment, total enclosure of the rendering plant with treatment of all ventilation air is likely to be a future requirement. This will present problems for those plants located in older buildings not designed with controlled ventilation in mind, as well as for the type of odour control that can be economically used to treat a building ventilation requirement of 10 air charges per hour. The most likely scenario is one where point source odours such as those from cooker vents, blood driers and meal presses are collected for treatment in air pollution control equipment whilst the diffuse background odours are controlled by dispersion through vent stacks.

5.5 Control of Air Pollution

Some of the air pollution issues regularly raised by the Regulatory Authorities could be substantially reduced, if not eliminated, by the proper operation of existing equipment and by up-grading existing equipment to handle the process load generated. At a number of plants staff acknowledged that it was common for the capacity of the heat recovery unit to be exceeded by too many batch cookers venting at the same time. As a result, a proportion of the vent gases would be discharged directly to atmosphere. Under these conditions the specified time temperature relationship in the odour control afterburner, typically 3 sec at 760°C, may not be satisfied. Improved supervision and logic control of cooker operations could prevent this happening.

Many blood driers vented directly to atmosphere with no odour control equipment installed. Water scrubbers on the drier cyclone exhaust would help.

The costs of operating afterburners and chemical scrubbing systems are high, and there is a need to develop design protocols for alternative systems such as soil or compost filters, particularly for high volumes of ventilation air.

5.6 R&D Needs and Technology Transfer

- Promote the use of acid stabilisation of raw material as a means of preventing raw material and product degradation as well as minimising odour problems from the processing of stored material.

- Demonstrate the use of evaporation and/or ultrafiltration for the concentration of LTR plant stickwater and report on the economics of these processes. With stickwater concentration for product recovery, the total effluent nutrient load from a plant with an LTR system could be reduced by up to 25% with respect to oxygen demand and nitrogen.

- Undertake pig feeding trials using both unconcentrated and concentrated stickwater to determine the economics of its use as a pig feed supplement. Particular emphasis should be given to microbiological aspects of the material and its stability under storage.

- Quantify the level of odour emissions from modern low temperature rendering plants to determine if they should be subject to less stringent control than conventional dry rendering processes, particularly with respect to the age of material at processing.

- Develop design criteria for biofilters for the treatment of odorous process gas streams produced by rendering plants. Consideration will have to be given to the wide range of climatic conditions prevailing in continental Australia.

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6. SOLID WASTES TREATMENT

6.1 Sources of Solid Wastes

The most common sources of solid wastes in the meat industry are:

- paunch opening operations.
- gut cutting and washing operations.
- sheep and beef yard effluent streams.
- casings processing.
- general processing wastes, including rendering.
- de-sludging of effluent treatment lagoons.

6.2 Treatment of Solid Wastes

Solid wastes are generally removed from the liquid effluent streams at the primary treatment stage. The sophistication and degree of complexity of the primary treatment plant influences the nature and composition of the solids removed. Primary treatment systems vary in complexity from a single screen, primary-sedimentation tank (save-all) or dissolved air flotation unit, to segregation and individual treatment of separate effluent streams by screening or sedimentation.

6.3 Segregation of Effluent Streams for Solids Removal

The effluent streams most commonly segregated for solids removal are:

- sheep and beef yard effluents.
- paunch opening effluents.
- gut cutting and washing effluents (to a lesser extent).

The segregation of paunch opening and sheep and cattle yard effluents has a number of advantages.

- The effluents are generally relatively easy to isolate for separate treatment.

- The solids in the effluent streams are easily removed by either static or rotating wedge-wire screens.

- The solids are faecal in origin, have no immediate commercial value and if separately removed will not down-grade fat recovered in other primary treatment systems.

- The segregated and screened effluent streams may in some cases by-pass downstream primary treatment units, thereby reducing the hydraulic loading on these units and improving their performance.

- Removal of solids from an effluent stream close to the point of generation can reduce downstream effluent loadings because the comminution of solids that occurs due to pumping and conveyance is minimised, as are the solubilization and leaching of soluble material from the solids that occur in the effluent stream.

In general the use of large volumes of water for conveying solids or mixing solids with other effluents to convey them to a treatment plant for solids removal should be discouraged.

6.4 Dry Dumping of Paunch Content

Dry dumping of beef paunch content can be done as a part of beef tripe processing operations. It involves opening the beef paunch with a single cut and allowing the gross paunch contents to drain into a separate hopper. The paunch solids are then removed from the hopper by an auger or suitable pump. This process has the advantage that most of the paunch solids are collected with the addition of minimal water, thereby reducing both water use and the solids loading on effluent treatment plants downstream.

Dry dumping of beef paunches was not observed in many plants, although the beef tripe rooms in some plants would be amenable to modification to incorporate the practice.

Where practised, dry dumping was used only for those paunches to be further processed for tripe. This leaves often a substantial number of condemned paunches or all paunches when tripes are not being saved that require separate treatment using gut cutters and washers before transport to the rendering department.

In some cases condemned and un-opened beef paunches were conveyed unopened to soft offal bins for processing in the rendering department. This practice avoids the need for gut cutting and washing systems and will reduce both product loss and water use.

6.5 Gut Cutting and Washing

Mutton paunches are usually transported using water to a mechanical gut cutting and washing system. Various types of cutter are used, including the hammer mill type, pre-breakers, rotating saw-blades and MIRINZ gut cutters.

In a few plants, all paunches, both beef and mutton, were slashed and emptied prior to transport to a cutter-washer system, and the paunch contents were flushed directly to a screen, solids pit or anaerobic lagoon.

6.5.1 Type of gut cutter

The objective of gut cutting is to reduce the size of gut material and allow the material to be washed. Any size reduction process will increase product loss, and in general cutters that tear and shred will generate higher product losses than those with a less aggressive cutting action. Of the types generally employed, the MIRINZ gut cutter produces the least pea fat. These cutters are quite widely used in the Australian meat industry, although the hammer mill and saw-blade types are still relatively common.

6.5.2 Gut washing screens

Gut washing screens are generally of two types. The basic cylindrical trommel type screen varies in diameter from about 800 to 1000 mm and in length from 3 to 5 metres. These screens are formed from rolled perforated sheet with holes 5 to 10 mm in diameter and are fitted with both internal and external wash sprays along their length.

Alternatively, wedge-wire type rotating type screens are used, sometimes built with two different aperture sizes. In this case, a coarser aperture is used at the feed end of the screen, to allow a certain amount of paunch content to be washed from the raw material, and a finer aperture (1 mm) at the discharge end, where product dewatering takes place, to minimise fat loss.

The degree and type of washing undertaken varied from plant to plant, with some plants using large quantities of water to wash the cut material in an attempt to remove as much paunch content as possible. Whilst this practice results in clean material and probably allows the production of high-grade meals and tallows, the resultant high fat losses and downstream implications on effluent treatment should not be overlooked.

Screening of any fat-containing material will result in blinding of screens; this blinding can be controlled by using hot water. Hot water is usually used on the outside of screens to control fat build up. Hot water need be used only intermittently, a few minutes every hour being sufficient to prevent screen blinding. In some plants, hot water was used continuously, a practice that will result in high non-recoverable fat losses due to emulsification.

6.5.3 Pre-treatment of gut screen wash water

At many plants visited, gut screen wash water was discharged directly to the primary treatment system. This will result in additional fat losses due to emulsification and break-up of material in pumps and drains. In addition the fat recovered in primary treatment systems is often downgraded and therefore used to produce a lower grade tallow or in the worst situation is dumped.

A number of companies treated the gut cutter and wash effluent in a small gravity save-all, immediately adjacent to the gut processing area. This allowed the recovery of flotable fat and its incorporation in the main rendering raw-material product stream, thereby maximizing by-product yield and value. The underflow from such systems, including settled solids, was discharged to the primary effluent treatment system.

Gut cutting and washing operations can be a significant source of both tallow loss and tallow degradation. These operations produce an effluent characterised by the presence of flotable and emulsified fat, high soluble nitrogen and settleable and suspended solids. The amount of product lost in the form of flotable and emulsified fat is a function of:

- the type of cutter employed.
- the type of washing and screening system used downstream of the cutter.

6.6 Present Solid Wastes Disposal Practices

6.6.1 Regulations

The disposal of solid wastes is currently not the subject of much control by the various State Regulatory Authorities. The Authorities are, however, aware of the potential for groundwater pollution, and of nuisance odour problems from some current practices. Solid wastes disposal, therefore, is an area that can be expected to receive increasing attention in the future and be subject to licence conditions.

A number of disposal practices were observed, the most common being:

- dumping to land fill either on or off-site.
- stockpiling on site and land spreading.
- disposal to lagoons.
- removal by contractors for land spreading.

6.6.2 Dumping

Dumping or burying of solid wastes has been a common practice for many years. A number of companies are running out of land suitable for disposal of solids in burial trenches and are finding that when old areas are re-excavated after 20 years, old buried material has not substantially decomposed.

6.6.3 Land spreading

Land spreading is a satisfactory method of disposal/utilisation for screened paunch content and yards solids, provided a number of safeguards are observed and the practice is properly managed.

- The area used should be large enough to ensure that excess nutrients are not applied and that run-off is minimised.

- An appropriate spreading technique should be used, with the material being applied to the pasture in a number of light applications as opposed to gross spreading.

- A properly designed stockpiling area should be provided where material can be accumulated during wet weather, when machinery should be kept off pasture to avoid soil compaction. Run-off collection may also need to be provided.

- A management plan is needed to ensure that material is spread in the correct rotation so that some areas are not overloaded. The management plan will derive from a statement defining the annual nutrient application to be achieved.

- Where material is taken off-site by contractors and spread or dumped, the company should be aware of the practices employed by the contractor, to ensure that remote environmental impacts due to the company's operations do not occur.

6.6.4 Lagoon treatment

The lagoon treatment of solid wastes is quite a common practice and usually consists of a number of lagoons in parallel into which unscreened paunch or yard effluent is discharged. The lagoons gradually fill with sedimented solids and the liquid effluent overflow is discharged for subsequent treatment.

Once a particular lagoon is full, it is allowed to dry out prior to emptying by mechanical excavator for land spreading. These solids will be anaerobic and malodorous and could cause an air pollution problem during both the lagoon emptying and land spreading operations. The solids will still contain significant quantities of nutrients and be only partially stabilized.

A management plan detailing application rates and spreading practices as well as lagoon management practices is essential. Whilst lagoons containing high amounts of solids might be expected to seal readily, there is opportunity for direct loss of nutrients to ground water in sensitive areas.

Lagoon treatment of solids can be regarded as delaying the issue of the ultimate disposal of solid wastes until the time a lagoon requires desludging.

6.7 Alternative Solids Disposal Practices

6.7.1 Composting

The only solids disposal practice that warrants serious discussion is the stabilisation of these wastes by aerobic composting.

Composting has the advantages of:

- Producing a stable, odour-free, solid compost material with potential for use in agricultural and horticulture.

- Because the compost has a commercial value, returns from its sale will off-set to some degree its costs of production. This contrasts with the disposal of fresh solids directly to pasture and the costs of desludging and spreading the solids from solids waste lagoons, where the economic value of the nutrients in the solids is not realised.

- Composting can be used to stabilise other solid wastes such as those from primary treatment systems that may contain fat and meat scraps.

- Composting under Australian conditions has been demonstrated by the CSIRO with MIRINZ support.

- Weed seeds are not a problem in properly composted and stabilised material.

6.7.2 Anaerobic solids digestion

Anaerobic digestion of paunch solids and other solid wastes is a possible treatment technology. The solids would be treated in a closed digester either operating at ambient temperature or at 30-35°C if a proportion of the methane produced is used to heat the digester contents. The by-products of digestion are biogas, containing carbon dioxide and methane, which can be used for a fuel, together with a sludge and a liquid effluent containing high concentrations of nitrogen. The liquid phase will require biological treatment prior to discharge and will represent a significant additional nitrogen load to an effluent irrigation system. The sludge will require separate disposal.

Anaerobic digestion of meat solids containing high concentrations of lipid material has not been successfully reported. In experiments undertaken at MIRINZ, stable operation could not be achieved. Reactor failure was characterised by declining gas yield, foaming and an increase in volatile fatty acids. These phenomena indicate inhibition of the methanogenesis stage of the anaerobic reaction sequence. Clearly, more work is required in this area. As well, consideration must be given to the utilisation of the liquid phase overflow from such a system. This overflow will contain ammonia nitrogen concentrations of several thousand grams per cubic metre.

This technology is therefore not regarded as viable at this stage of its development.

6.8 R & D Needs and Technology Transfer

- Actively promoted the adoption of the MIRINZ aerated static-pile composting technology for the treatment/utilisation of solid wastes.

- Develop protocols for the collection, dewatering and storage of solid wastes prior to land application.

- Define nutrient loading rates and evaluate land spreading techniques for fresh solid wastes to ensure sustainability of the practice in terms of environmental impact, soil nutrient status and groundwater where appropriate.

- Evaluate product losses (flotable and emulsified fat) associated with the various combinations of gut cutting and screening technologies currently available.

- Define a recommended industry standard for gut cutting and washing with respect to management practice including water use, and frequency and type of washing (including hot water).

- Evaluate the design and performance of flotable fat recovery units on gut cutting and wash effluent.

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7. PRIMARY TREATMENT

7.1 Introduction

Primary treatment, in the context of this report, is defined as the treatment of liquid effluents to remove settleable solids and flotable material. It is the first of the 'end of pipe' processes and does not refer to any waste-minimisation or recovery systems used in the plant itself.

Primary treatment is most often achieved using screens, save-alls (sedimentation tanks) or dissolved air flotation, either alone or in combination.

7.2 Effluent Stream Segregation

Two distinctly different effluent streams can be identified as being discharged from meat processing operations. These are:

- A manure effluent stream, originating from the drainage and stock washing operations in cattle and sheep holding yards. This effluent stream may also contain the effluents from paunch emptying and washing. The solids that can be recovered from this waste stream have no immediate commercial value, do not represent product loss and cannot therefore be recycled.

- A processing effluent stream containing all the other effluents that are produced as a live animal is converted into meat and by-products. The major proportion of this effluent arises from product and equipment washing requirements, together with product conveying water and liquid effluent streams from blood processing operations.

These two waste streams are clearly different in character, and from a product-recovery point of view are best segregated to avoid recoverable, saleable fat being downgraded through contamination with faecal material.

7.3 Screens

Screens are widely used in the Australian meat processing industry both for the screening of paunch and yard wastes and of effluent streams containing flotable fat.

Most of the screens being used are of the modern wedge-wire type, either stationary or of the rotating drum type. A number of vibrating mesh type screens are also in use, but these are being progressively replaced with wedge-wire types due to high maintenance costs and screen blinding problems with the former. For screens to work effectively, they must be appropriately sized with respect to both screen aperture size and hydraulic capacity. The hydraulic capacity of a screen has to be determined based on peak flow conditions, rather than average daily flow, and the anticipated solids loading. A screen that is inadequately sized in this regard will be unable to handle the solids load at peak flows, resulting in some of the effluent being discharged to the solids receiving area or bin. This produces wet solids, which are more difficult to recover in a rendering plant. Consequently additional dewatering equipment may have to be installed, which treats a symptom rather than a cause. Where faecal-type solids are being utilised in a composting process, excessively wet solids will lead to leachate problems and a need for additional bulking agent, and will increase the volume of material being handled. This will increase costs as well as cause operational problems.

Any type of screening device requires washing to control blinding, and most screens are fitted with proprietary washing systems supplied by the manufacturer.

Screens handling paunch and faecal waste effluent streams generally do not present any particular screening difficulties, and timer control of screen washers is generally sufficient to ensure trouble-free operation.

The screening of effluents containing solid fat particles can and does create operational difficulties. Any fat-containing waste steam will quickly blind a screen. How quickly a screen blinds will depend on the gross amount of fat in the waste stream and the screen aperture size, a finer screen blinding more quickly than a coarser screen. Cold water is of some use in controlling fat build-up on screens, but screens can be kept clean only through the use of hot water.

The amounts and type (hot or cold) of wash water used varied widely between plants. Some plants used continuous hot water on both the internal and external wash sprays of rotating type wedge-wire screens. Other plants used hot water on the external wash spray only and cold on the internal.

The excessive use of hot water on screens is to be avoided as it will increase the loss of fat material to the screened effluent through emulsification.

Timer controlled hot water sprays were installed on a number of screens. This type of screen wash system uses both hot and cold water, with the cold water being replaced by hot water for a short period at set intervals. Properly adjusted and maintained, this type of system keeps screens clean and ensures trouble free operation.

Screen washing can use large quantities of water. Installations were noted where the screen wash nozzles had been removed from the screen spray pipe, resulting in excessive water use for screen washing.

The use of high pressure water in low quantities may be one way of reducing screen wash water use.

7.4 Gravity Separation Systems

Two types of gravity separation primary treatment systems are in common use in the Australian meat industry: save-alls and dissolved air flotation (daf) units. These systems are increasingly being preceded by wedge-wire screens to remove gross solids. Screens will remove only a proportion of the suspended solids from an effluent and additional flotable fat recovery will be achieved in both save-alls and daf units. Screening prior to gravity separation has the additional advantage that the amount of settleable material recovered from save-alls and daf units is reduced.

7.4.1 Save-alls

A save-all is basically a sedimentation tank, where, with sufficient retention time, flotable and settleable material are separated by gravity due to specific gravity differences.

The material that floats generally contains a high proportion of flotable fat. This material is removed by top scrapers and discharged to a holding tank for recycling to the rendering plant. The amount of flotable material in the effluent is related to in-plant processing, and the principal sources are gut processing operations and losses from the rendering plant.

Some plants dumped recovered top solids to avoid downgrading normal tallow production due to an increase in free fatty acids.

Sedimented bottom solids were generally removed from save-alls by bottom scrapers, which dragged material either up a beach or to a sump at one end of the save-all where it was removed by a siphon arrangement.

The recovered bottom solids were then usually dumped, or discharged to a solids lagoon, although some plants discharged them back into the treated effluent stream. This latter practice has implication on solids accumulation in downstream anaerobic lagoons and subsequent desludging requirements.

In general, many of the save-alls seen were overloaded, with inadequate retention time and consequent poor performance. This again has implications on the operation of downstream anaerobic treatment lagoons.

The overloading has generally come about because increased plant processing throughput and expansion have taken place without parallel expansion of the primary waste treatment facilities.

7.4.2 Dissolved air flotation units

Dissolved air flotation units are widely used in the Australian meat industry and are of two types, those using recycle of a proportion of the treated effluent as the medium to dissolve air and those using the total effluent flow.

No tests have been run to demonstrate the efficiency of one system over the other, but dissolved air flotation with recycle is the preferred and most common system employed.

The recycle system has the advantage of reduced power costs because a smaller volume of liquid has to be pressurised and air dissolution efficiency should be higher. In addition, total pressurisation systems do not operate well when the influent flow is interrupted due to the stopping and starting of the feed pump operating on level-control in a sump.

Some of the dissolved air flotation units were not being operated correctly. The most common problems were as follows:

- Intermittent operation of the daf feed pump (also the pump was sometimes oversized) when controlled by level switches. This led to a hydraulic surge in the centre of the daf unit, which often completely destroyed the floating scum layer on the liquid surface. A significant proportion of the previously separated solids were then lost in the effluent flowing out of the tank.

- Incorrect operation of the recycle system, with no indication of the recycle pressure and no control or indication of the amount of air added to the recycle stream.

- Hydraulic overloading of the daf unit as a consequence of increased throughput and water use in the processing plant.

- Inadequate recycle ratio.

All these factors result in the loss of excessive amounts of flotable fat and solids to downstream effluent treatment units.

7.4.3 Dispersed air flotation

A variant of the flotation processes described above is the dispersed air flotation system. In this system fine microbubbles of air are produced by mechanical means using a unit driven by an electric motor. The unit can be fitted into existing sedimentation tanks or retrofitted into daf tanks. Such a system would appear to have advantages and should be investigated. It could overcome many of the operational and maintenance difficulties observed with daf systems.

7.5 Upgrading of Primary Treatment Systems

A number of meat processing plants in parts of Australia discharge their effluent after primary treatment to Local Authority sewers for disposal and/or treatment. There are moves, for example in Victoria, to adopt a uniform system of trade wastes charges throughout the State. It is likely in this instance that the Melbourne Metropolitan Board of Works charges will be used. Under the Board's scale of charges, plants could face trade wastes charges of the order of several hundred thousand dollars a year.

This situation provides considerable incentive for plants to upgrade effluent quality in terms of biochemical oxygen demand and suspended solids.

In addition, charges are now to be levied on effluents that have a mean total nitrogen concentration greater than 50 g/m^3. The nitrogen concentration of meat plant effluents is usually in the range of 100-250 g/m^3.

Many dissolved air flotation units can be up-graded to produce a better quality effluent through the adoption of a chemical treatment process. A wide variety of chemical treatment processes has been reported and range from the use of polyelectrolytes to improve suspended solids removal to processes designed to remove up to 50% of the effluent soluble nitrogen by coagulation and flocculation processes. The materials of construction of the original daf unit may restrict the chemical treatment process that could be used due to corrosion considerations.

The opportunities for the adoption of chemical treatment processes will increase in line with the national move to more stringent effluent discharge requirements. Companies do have the option of continuing to pay whatever trades wastes charges are levied, but it is likely that the incentives to treat on site will become very great.

Improving effluent quality through the use of chemical treatment processes always produces large quantities of additional solids in the form of an 8-12% solids sludge. Sludge utilisation strategies have to be developed at the same time as the chemical treatment options are evaluated. Failure to do so, may lead to the cost savings in better effluent quality being off-set by the difficulties in sludge disposal.

7.6 R&D Needs and Technology Transfer

- Develop a code of practice for screen washing and cleaning, including consideration of the use of high pressure water sprays to reduce the volume of wash water used.

- Produce guidelines, based on evaluations of existing facilities, for the design of save-alls and dissolved air flotation units.

- Evaluate the use of pump motor speed control as a method of minimising hydraulic surges on primary treatment units.

- Promote the adoption of waste minimisation and in-plant product recovery strategies as a means of reducing the load on primary treatment systems as well as improving product yield and quality.

- Evaluate the economics and performance of dispersed air flotation as a method of upgrading existing primary treatment systems.

8. ANAEROBIC TREATMENT

8.1 Anaerobic Lagoons

Anaerobic lagoons are widely used in the Australian meat industry as the first stage of a biological treatment system. Subsequent treatment is usually achieved in aerobic or aerated lagoons, with ultimate disposal by irrigation or discharge to surface waters.

Meat processing effluents contain high concentrations of soluble BOD_5 and soluble nitrogen, which are readily available to anaerobic microorganisms. The soluble nitrogen in meat processing effluents will have a concentration in the range 100-250 g/m^3, of which 60-80% will be organic nitrogen. This organic nitrogen is converted to ammonia nitrogen under anaerobic conditions. The resultant high ammonia concentrations in the lagoon provide considerable buffering capacity and ensure that the lagoon pH remains in the optimum range of 6.5-8.5. Therefore, anaerobic lagoons treating meat processing effluent do not require pH correction, a problem which can occur with other effluents. Anaerobic lagoons, however, are not without their problems, most of which are attributable to incorrect design, and operation.

8.2 Operation of Lagoons

A number of environmental and operational issues were identified during visits to meat processing plants that anaerobic lagoons as part of their effluent treatment system. The major environmental issue was nuisance odours and the major operational issue was de-sludging the lagoon.

8.2.1 Odour problems

The principal environmental issue of concern to the Regulatory Authorities with respect to anaerobic lagoons is odour. Anaerobic lagoons can produce odours and this odour production is most commonly associated with overloading or the absence of an intact, heavy scum layer over the entire surface of the lagoon.

Lagoons are particularly prone to produce odours during the first year of establishment, particularly if commissioning occurs during the autumn/winter period. Commissioning should therefore be scheduled for spring/summer and specific steps taken to encourage the rapid formation of a scum layer. A technique that has been successfully used in New Zealand is to attach floating baffles to wire ropes across the lagoon, to minimise the amount of wind-induced movement until a stable scum layer is formed. Wind-break fences round the perimeter of lagoons have also been used to good effect.

The formation of a scum layer can also be encouraged by discharging paunch content to lagoons, the paunch grass being buoyed to the surface of the lagoon by gas bubbles. Discharging tallow to the lagoon also serves to cement the scum layer together and ensure its integrity. Spreading straw on the surface of lagoons has also been used to encourage the formation of a scum layer.

The use of some or all of these techniques has allowed the establishment of anaerobic lagoons in New Zealand with only occasional complaints during the months following commissioning. Maintenance of the established scum layer has then ensured that lagoons can be established and operated without nuisance.

Some of the odour nuisances attributed to anaerobic lagoons in Australia are, in my opinion, more correctly attributed to the 'aerobic' lagoons in series with the anaerobic lagoon. This occurs because of incorrect design or sizing of the anaerobic and aerobic lagoons. Overloading of the anaerobic lagoon results in a deterioration in effluent quality with a consequent increase in loading on the downstream aerobic systems. These aerobic lagoons become overloaded and function as anaerobic lagoons. The loading on the lagoons, however, is such that a scum layer to contain and treat malodorous gaseous compounds does not form.

8.2.2 De-sludging lagoons

Many of the anaerobic lagoons used in the Australian meat industry are regularly de-sludged due to excessive solids accumulation. If not removed, the excessive accumulated solids reduce residence time and cause lagoon performance to deteriorate.

A number of plants were noted to operate two anaerobic lagoons in parallel, with only one being in use at any time. The other lagoon was being drained or dried out prior to de-sludging.

De-sludging of anaerobic lagoons is an expensive process. As well, problems associated with recommissioning lagoons and re-establishing scum layers, together with the associated problems of odour nuisances, must continually be addressed.

Anaerobic lagoons are de-sludged only infrequently, if at all, in the New Zealand meat industry. In general, if correctly designed and operated, anaerobic lagoons should not require desludging until at least 15 to 20 years after initial establishment. In my opinion the principal difference between the operation of anaerobic lagoons in New Zealand and Australia is in the efficiency of the effluent primary treatment system. Inefficient and overloaded primary treatment systems will discharge excess solids to the anaerobic lagoons, resulting in solids accumulation. A number of plants were also noted to discharge unscreened paunch and stockyard effluents to anaerobic lagoons. Much of this manure-type material is refractory in an anaerobic lagoon and quickly contributes to a reduction in lagoon capacity.

Upgrading of primary effluent treatment facilities will therefore lead to a reduction in operational problems with an aerobic lagoon as well as reducing solids handling and disposal problems.

8.3 Design of Anaerobic Lagoons

The influent to an anaerobic lagoon treating meat wastes contains Chemical Oxygen Demand (COD) in both soluble and particulate forms. The soluble COD consists principally of organic nitrogenous compounds and is relatively rapidly decomposed under anaerobic conditions to ammonia.

Work undertaken at MIRINZ has shown that the removal of the soluble COD can be described by the following empirical equation:

$$\% \text{ soluble COD removed} = 5.74 \times R \times (1.04)^{(T-20)} \qquad (3)$$

Where R is the hydraulic retention time (days)
T is the lagoon temperature.

The particulate fraction of the influent to an anaerobic lagoon will be removed initially by sedimentation, and anaerobic digestion of the solids will occur in an accumulating sludge layer. Emulsified lipid material is readily destabilised under anaerobic conditions and fat will tend to accumulate in a floating scum layer where decomposition will be slow.

Most anaerobic lagoons in the New Zealand meat industry have retention times of 12-16 days and achieve COD removals of 70-90%. The suspended solids concentration in anaerobic lagoon effluents generally increases with decreasing retention time. Typical performance data for anaerobic lagoons in New Zealand are summarised in Table 3. Similar results would be expected under Australian conditions.

Table 3. Anaerobic lagoon performance for meat processing effluents.

	Influent (g/m^3)	Effluent (g/m^3)
BOD_5	500-1500	70-200
COD	1500-3000	200-500
TKN	70-160	70-160
NH_3-N	5-30	60-160
TSS	300-1200	50-200

8.4 An Alternative Anaerobic Treatment Technology: the UASB

A number of high-rate anaerobic treatment technologies have been developed, none of which has yet found widespread acceptance for the treatment of meat processing effluents. One of the most common high-rate processes that is attracting attention is the upflow anaerobic sludge blanket reactor (UASB).

The UASB was developed in the Netherlands in 1970s and has to date found most application for the treatment of high-strength soluble effluent streams.

A schematic diagram of a UASB reactor is shown in Figure 1. Effluent is introduced to the reactor through a distribution system in the base and rises through a sludge blanket of anaerobic bacteria. Only those anaerobic bacteria that have a high settling velocity are retained in the reactor, other anaerobic bacteria being washed out of the system. Biogas produced in the system is collected in a gas collector system at the top of the reactor, and treated effluent is discharged via an overflow weir.

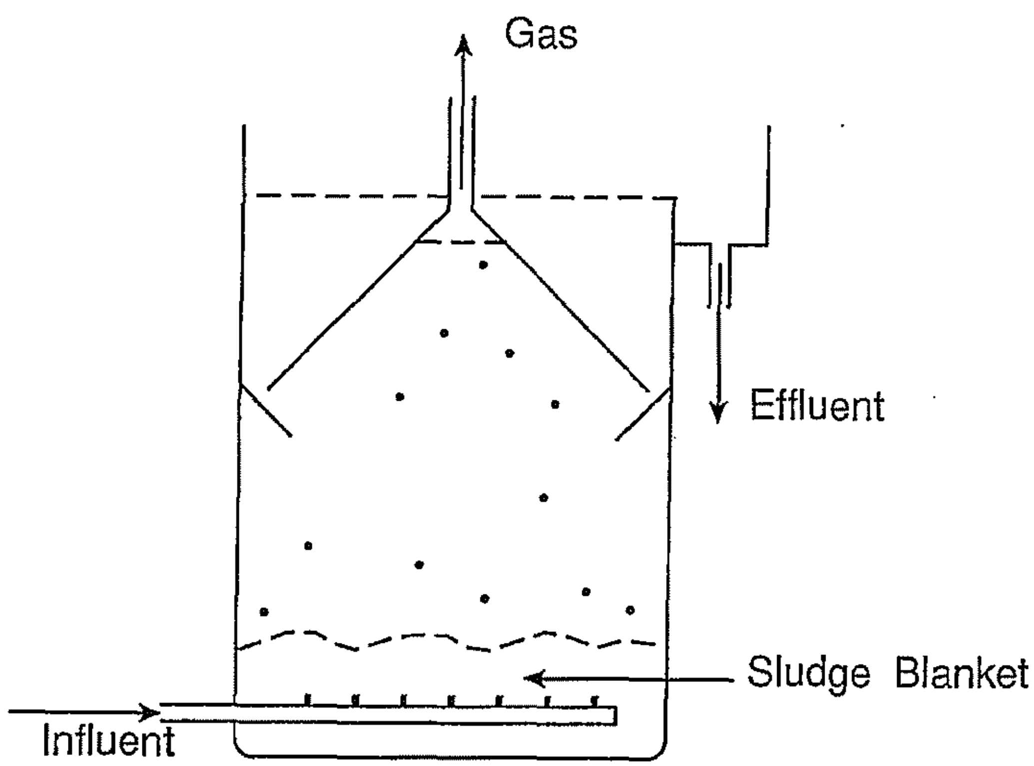

Figure 1. Schematic diagram of an upflow anaerobic sludge blanket (UASB) reactor.

Work undertaken at MIRINZ on primary treated meat processing effluent showed that soluble COD removals of 50-80% could be achieved at loading rates of 1-2 kg $COD/m^3/d$ at temperatures in the range 14 to 24°C. The reactor was loaded for only 10 hours per day, corresponding to the normal effluent production cycle at a meat plant. The instantaneous COD loading rate was therefore as high as 5 kg $COD/m^3/d$ with hydraulic retention times in the range 11 to 32 hours.

As with anaerobic lagoons, the UASB reactor was found to be very efficient in separating the lipid component of the meat processing effluent, and lipid material accumulated in a scum on the top of the reactor and under the gas separation hood. This interfered with biogas removal and resulted in a deterioration in effluent quality due to a high suspended solids concentration in the treated effluent.

Results obtained at MIRINZ showed that between 10-25% of the influent COD accumulates on the surface of the reactor as a scum layer. Provision has to be made for the regular removal of this material, together with its further treatment. The material removed is high in free fatty acids and tallow cannot be recovered. It is likely that the satisfactory treatment of this material would be expensive and difficult.

The UASB reactor does allow the recovery of biogas, which can be used as a fuel to replace part of the normal fossil fuel requirement of a processing plant. In addition, the biogas collected will contain those odours often associated with anaerobic treatment.

Measured biogas yields from the UASB reactor studied were lower than the theoretical yield of 0.35 m^3 of methane per kilogram of COD removed. This is due to storage of organic material in the sludge blanket and the physical removal of some COD in the scum layer.

8.5 R & D Needs and Technology Transfer

- Develop and standardize anaerobic lagoon design criteria.
- Develop protocols for the formation and maintenance of a scum layer on anaerobic lagoons.
- Determine the efficiency of floating aquatic plants that could be used to assist in the formation of anaerobic lagoon scum covers.

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9. AEROBIC TREATMENT PROCESSES

9.1 Introduction

Aerobic treatment is widely used in the Australian meat industry to further treat the effluent from anaerobic lagoons prior to irrigation or discharge to surface waters.

Aerobic processes are not widely used to treat primary treated effluent because of the high carbon and nitrogenous oxygen demand of these effluents, which results in a high aeration demand and very high running costs.

Only two aerobic systems that treated primary effluent were seen during the tour of Australian meats plants. One facility had an activated sludge plant, which had proved very expensive to operate and produced large quantities of sludge that was both difficult and expensive to dispose of. The other was an aerated lagoon operating without solids recycle prior to discharging the treated effluent to an oxidation pond for further treatment. This plant was expensive to operate in terms of aerator power demands and was prone to periodically producing severe odour problems due to the aeration capacity being inadequate at times. This lagoon has since been replaced by an anaerobic system.

Aerobic treatment as the first stage of a biological treatment system is unlikely to find widespread application in the meat industry due to the high capital and operating costs of these systems. The only exception will be for small plants in sensitive locations. Aerobic treatment is therefore discussed in this report only in the context of tertiary lagoons used to further treat the effluent from an anaerobic lagoon.

9.2 Tertiary Lagoons

Tertiary lagoons are defined as aerobic lagoons (usually either oxidation ponds or aerated lagoons) used to further treat the effluent from an anaerobic lagoon.

The effluent produced by anaerobic lagoons will generally have a BOD_5 in the range 200-300 g/m^3 and a high ammonia nitrogen content. Anaerobic lagoons convert all the nitrogen in meat processing effluents to ammonia and no nitrogen is lost from the system. Ammonia is toxic to fish, and if the anaerobic effluent is to be discharged to surface waters then the ammonia concentration in the effluent has to be reduced.

Tertiary lagoons can reduce effluent nitrogen concentrations through nitrification/denitrification processes. In this way nutrient loadings to irrigation systems can be reduced. In addition, irrigation of an anaerobic effluent can cause air pollution problems due to the air stripping of volatile organics and sulphur compounds during spray irrigation. Odours can be avoided by aerobic treatment prior to irrigation.

Irrigation cannot be carried out during periods of highly seasonal rainfall that occur in parts of Australia. A storage component is therefore an important part of lagoon design. Only well-treated effluent can be stored if odour nuisances during storage and subsequent irrigation are to be avoided.

Tertiary lagoons are generally of two types, oxidation ponds and aerated lagoons.

9.3 Oxidation Ponds

9.3.1 Description

Oxidation ponds are shallow lagoons, generally about 1.2 m deep, with an extensive surface area. These lagoons rely on diffusion of oxygen at the liquid-air interface to supply oxygen as well as production of oxygen from algal photosynthesis during daylight hours.

These lagoons are generally designed on a surface area loading basis expressed in terms of kilograms of BOD_5 per hectare per day. There is uncertainty as to the correct design procedures to be used for oxidation ponds treating anaerobic effluents with a high concentration of ammonia nitrogen. There is practical evidence in New Zealand that oxidation ponds with BOD_5 loadings twice that considered appropriate for oxidation ponds treating domestic sewage still perform satisfactorily. The reasons for this are unknown but may relate to the different carbon to nitrogen ratios in domestic and anaerobically treated meat processing effluent.

Ammonia concentration is reduced in an oxidation pond through oxidation to nitrate (nitrification). Nitrogen may then be lost from the system if the nitrate is reduced, producing the gases nitrous oxide and nitrogen, a process known as denitrification. Significant quantities of nitrogen are not generally lost by this mechanism in oxidation ponds.

9.3.2 Operation of ponds

A number of plants had ponds following anaerobic lagoons. These ponds were in general too small to be described as oxidation ponds and observation of the pond surface and the colour of the pond effluent indicated that these ponds were in fact anaerobic lagoons. The purification mechanisms occurring in these ponds will vary, and the ponds are probably operationally unstable. Under conditions of light loading the surface layers may be aerobic, whilst at other times the ponds are probably completely anaerobic. Odour nuisances may therefore be expected to occur.

In certain parts of Australia, where evaporation rates are high, a number of anaerobic/aerobic pond systems had no discharge. This occurs because evaporation from the surface of the aerobic pond was approximately in balance with the influent hydraulic and annual rainfall loading. Such a system, if correctly designed, has minimal environmental impact.

The characteristics of the discharge from an oxidation pond exhibit a diurnal pattern over a 24 hour period. This is due to the pond algal population moving vertically in the water column in response to changing solar radiation intensity during the day. A single grab sample of the effluent from such a lagoon may therefore give misleading information as to the pond's performance.

9.4 Aerated Lagoons

Aerated lagoons are generally 3 to 4 metres deep and fitted with a surface aerator that supplies oxygen by aerating the lagoon contents. Such lagoons are smaller in area than oxidation ponds and have additional operating costs associated with the power and maintenance costs of the aeration system. A properly designed aerated lagoon will convert a substantial proportion of the ammonia nitrogen to nitrate and nitrite nitrogen. In addition, by ensuring that the lagoon is not completely mixed, there will be some losses of nitrogen by denitrification.

Complete nitrification of the ammonia in the lagoon will not occur. The conversion of ammonia nitrogen to nitrate nitrogen in an aerated lagoon destroys alkalinity and consequently the lagoon pH drops. The amount of nitrification that can occur in an aerated lagoon is regulated by alkalinity and pH considerations. Sludge build-up in such lagoons used in the New Zealand meat industry is slow, and accumulated sludge is insignificant after 3-5 years of continuous operation.

9.5 Combined Aerated/Oxidation Ponds

A number of plants used an aerated lagoon followed by one or more naturally aerated lagoons in series to treat the effluent from an anaerobic lagoon. No data were available to assess the performance of such systems or to judge the nature and extent of the nitrogen transformations and losses that occur.

Such systems if correctly designed have the capacity to reduce initial ammonia nitrogen concentrations by 50-70% and also to achieve nitrogen losses to atmosphere in the range 30-50%.

Hybrid pond systems such as these will be required if existing and proposed nutrient discharge limits to surface waters in some parts of Australia are to be met. In addition, the treatment of effluents in this manner prior to irrigation would result in reduced irrigation nitrogen loadings.

10. IRRIGATION

10.1 Introduction

Irrigation is widely practised by meat processing plants in New South Wales Queensland, Victoria, South Australia and Western Australia. The wide climatic differences within and between these States, together with different soil types and geological structures will result in various design and performance criteria being appropriate for different locations. In certain areas, for example, effluent will have to be stored for several months of the year due to highly seasonal precipitation.

Meat processing effluent is high in nutrients, and it is this nutrient content that will determine the irrigation area size when environmental impact objectives with respect to, for example, ground water are taken into account.

Table 3 shows the fertiliser equivalent of primary treated effluent produced by processing 1000 lambs in terms of the weight of urea (N), superphosphate (P), and potassium chloride (K) equivalent to each nutrient present. In most cases it will be the nitrogen loading of the irrigation area that will be the determinant of irrigation area size, although in areas where soils have low phosphorus adsorption capacities, phosphorus may be more important.

Table 3. Fertiliser equivalent of primary treated effluent produced by the processing of 1000 lambs.

	kg
Urea (46% N)	54
Superphosphate (10% P)	38
Potassium chloride (50% K)	40

10.2 Irrigation Techniques

Irrigation techniques used in the Australian meat industry at the sites visited can be divided into four categories: spray irrigation, fixed spray systems, border dyke irrigation and contour irrigation.

10.2.1 Spray irrigation

A number of installations were visited where effluent from both primary treatment and from anaerobic/aerobic lagoons was applied using spray irrigation techniques. Several types of irrigator were used. One plant used a large, centre pivot irrigator

9.6 R&D Needs and Technology Transfer

- Determine the appropriate design criteria for oxidation ponds treating anaerobic effluent and in particular determine their potential for nitrification of ammonia and nitrogen loss by denitrification.

- Determine the design criteria for aerated lagoons treating anaerobic effluent and in particular determine the potential of aerated lagoons and oxidation ponds in series to maximize nutrient removal.

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that slowly rotated round a fixed effluent supply hydrant and irrigated a circle 100-200 m in diameter; another used self-winching single-nozzle big gun irrigators that winched themselves along a strip of land, dragging the irrigation hose along behind them. The area irrigated will depend on the spray radius of the irrigation nozzle, which will be a function of pump supply pressure and nozzle size. These types of irrigators require flat land or land with a gradual, even slope. Application rates can be varied by changing the speed with which the irrigators move. A disadvantage of these types of irrigators is that they have a high instantaneous effluent application rate. This will result in transient surface ponding occurring because the infiltration capacity of the soil (mm/hr) will be exceeded.

10.2.2 Fixed spray systems

Fixed spray irrigation systems are of two general types, both of which were seen in operation. The first is a system where a network of irrigation pipes fitted with risers and spray nozzles is laid out from a supply hydrant to the area being irrigated. Such systems have a labour and management component since they must be relocated after each irrigation event to avoid overloading of the irrigated area. These systems are also prone to leak at the pipe joints, causing localised ponding and degradation of the soil/plant system.

The second type of stationary system involves a network of buried pipes supplying fixed irrigators mounted on risers above the ground. Advantages of this type of system include the fact that it is easily controlled, as the area to be irrigated can be selected and the duration and frequency of the irrigation period are easily changed if the appropriate controls are installed. At one plant this system was used on a fairly steep contour in an attempt to spread effluent as evenly across the face of the slope as possible.

Fixed spray irrigation systems must be protected from grazing stock, either by providing protective fencing, or attaching the spray heads to fence posts.

At the plants visited, fixed spray irrigation systems were used to irrigate primary, anaerobic/aerobic and chemically treated effluents.

10.2.3 Border-dyke irrigation

In border-dyke irrigation systems the land is graded to form borders of various widths. Raised mounds about 100-150 mm high run the length of each border and separate adjacent borders. The effluent to be irrigated is supplied from a head race.

Border dike systems require constant supervision, as the time for which effluent can be applied will be influenced by previous climatic events.

Over-application will result in effluent reaching the end of the border and causing ponds. Solids drop out at the head of the border and can also cause sealing problems as well as effluent distribution problems. In addition, heavy stocking causes damage to the borders, and evidence can often be seen of effluent tracking along paths worn by stock. Finally, from a nutrient utilisation perspective, nutrient loadings will vary with distance along the border, with the area closest to the inlet end receiving the highest loading.

10.2.4 Contour irrigation

In contour irrigation, an irrigation race is constructed along the line of a contour on a hillside or slope. Breaches can be made in the side of the race to allow effluent to flow down-slope or gates can be fitted.

Contour irrigation is often used on fairly steep slopes, and a series of contour drains will be constructed down slope to capture and retain run-off. Subsequent contour drains will over-flow when full and discharge down slope. Run-off from this type of system is inevitable under certain climatic conditions.

10.3 Licensing of Irrigation Systems

A number of licences that impose conditions on meat industry effluent irrigation systems were examined. In most cases these licences are deficient from an environmental management perspective. The conditions do not impose controls on the operation of an irrigation system in a way that recognises the nutrient utilisation mechanisms that occur.

Nutrient loading rates in terms of kilograms of nitrogen per hectare per year were not specified, nor were hydraulic loading rates or irrigation return periods given.

In fact the only licence conditions commonly applied related to the quality of the run-off that is allowed to occur to adjacent water courses at times of rainfall.

A number of States produce guidelines for the disposal of effluents by land application. The design principles outlined in these documents are in general soundly based and if applied to existing effluent irrigation systems would impose restrictions on the operation of many of them. These restrictions would have the effect of requiring a processing plant to limit throughput or to invest significant capital expenditure to either increase the land area irrigated or reduce the nutrient concentration of the effluent by additional treatment prior to irrigation.

10.4 Irrigation of Alternative Crops

A cover crop is an integral part of an effluent irrigation system. The crop utilizes nutrients, thereby recovering a proportion of the nutrients in the applied effluent. If the crop, such as grass, is then grazed, however, the overall removal of nutrients from the irrigation site will be small, since ruminants such as sheep and cattle typically void about 90% of the feed nitrogen in faeces and urine.

Mechanical harvesting of a crop and making hay or silage effectively removes nitrogen from the site but may lead to a transfer of the nutrient problem to another site, for example at a feed-lot.

Microbiological and public health considerations will always limit the application of meat processing effluent to crops principally used for animal feed-stuffs. The irrigation of high-value cash crops, such as those in horticulture, cannot be contemplated. Although at one installation visited sugar cane was irrigated successfully, the seasonal growth characteristics and harvesting requirements limit the usefulness of such crops in irrigation schemes.

Selection of grass species to suit particular conditions is an avenue worth exploring. Some grasses, for example, exhibit superior winter growth characteristics or thrive under irrigation conditions. Nutrient up-take by these plants will therefore be maximized.

10.5 Forestry Irrigation

Irrigation of tree plantations as an alternative to pasture irrigation is an area of active research in many parts of the world, including Australia. Irrigation of trees with meat processing effluent has not been reported in the literature, although work is currently being undertaken by MIRINZ in New Zealand.

The tree plantations irrigated are generally planted at a density of 3000 to 5000 stems per hectare and would be managed as a source of timber for fuel. Various eucalypt species appear to be suitable for this type of system.

As part of the management of this type of system, it is envisaged that the trees would be harvested mechanically, leaving the stump to coppice and produce new growth. The tree form will then probably be such that the only way to utilize the harvested stem branches and leaves would be to chip the entire tree, the wood chips being utilized as boiler fuel.

Irrigation of other species for commercial timber production may be possible by irrigating existing forest stands. Such irrigation could maximize growth rates by overcoming seasonal moisture deficits as well as stimulate growth by supplying a source of nutrients.

The nutrient uptake of trees is less than that of pasture. This means that to achieve the same environmental management objective in terms of controlling the loss of nitrogen from the root zone, a tree irrigation area will have to be larger than an equivalent pasture irrigation site. However, in low-rainfall areas, it may be that no drainage of effluent past the root zone occurs because of the higher forest evaportranspiration when compared to similarly irrigated pasture. The use of forest plantations to prevent migration of nutrients past the root zone is presently being considered in Western Australia. There is a danger, however, that nutrients will build up in the root zone to the extent that toxicity problems occur.

Irrigation of tree plantations is an effluent treatment renovation technique that may find application in Australia. Significant management input is, however, required, particularly during establishment when young trees are in competition for light with weeds. In addition, at the outset, the effluent treatment objectives need to be defined as does the production objective for the tree crop. Considerable research is warranted to define the treatment removal capabilities and identify suitable species for tree plantation irrigation.

10.6 Nitrogen Removal Mechanisms

Nitrogen in the principal nutrient in meat processing effluent and will be present in a range of chemical species, depending upon the degree of treatment the effluent has received. Primary treated effluent has a high organic nitrogen component, whilst anaerobic effluent contains principally ammonia nitrogen. Effluent from oxidation ponds and aerated lagoons will contain ammonia nitrogen as well as oxidized nitrogen forms (nitrate and nitrite).

An understanding of the nitrogen transformations that occur in soil after irrigation of meat processing effluent is essential if nitrogen uptake, removal and loss mechanisms are to be controlled to minimize environmental impact.

The principal nitrogen removal mechanisms on irrigation sites are:

- plant uptake
- leaching of nitrate to groundwater
- denitrification

- Plant Uptake
  Pasture irrigated with nitrogen-containing effluent responds by producing an increased dry matter yield as well as producing grass with a higher than normal nitrogen concentration. In order to predict nitrogen balances, it is essential that the growth characteristics and composition of grasses under a range of irrigation conditions are determined.

- Leaching of nitrate
  Under aerobic soil conditions organic nitrogen is rapidly converted to ammonia and then nitrate. The ammonia is generally immobilized in the upper soil horizons, but the nitrate is mobile and will leach with percolating soil water to groundwater. The amount of nitrate leached will depend on three factors: the amount of nitrogen applied, the amount removed by plant uptake and the extent to which denitrification occurs.

- Denitrification
  Denitrification is the microbial transformation of nitrate under anoxic conditions to nitrous oxide and nitrogen gas. Denitrification also requires a carbon source, which will generally be supplied by the applied effluent. Effluent irrigation produces a sequential anoxic/aerobic soil environment. Denitrification will be maximal immediately following irrigation, when the conditions will be anoxic due to the applied effluent displacing the soil atmosphere. As aerobic conditions return, denitrification rates decline. Denitrification rates vary widely from site to site, being influenced by the type of effluent applied, soil characteristics and perhaps the effluent application regime. Work in New Zealand has shown that the losses of nitrogen as oxide can vary between 20 and 300 kg nitrogen per ha at different sites.

A knowledge of the denitrification losses is therefore important in predicting environmental impact.

10.7 R&D Needs and Technology Transfer

Irrigation is being promoted by State Regulatory Authorities as the preferred method of effluent disposal/utilisation. Irrigation has the advantage of recycling both the nutrient and water components of effluent. It is not, however, without its disadvantages. Irrigation of nitrogenous effluents has the potential to contaminate groundwater resources as well as impact on surface waters through run-off. A detailed knowledge of the nutrient transformation and removal mechanisms is required if irrigation systems are to be designed and operated with acceptable and sustainable environmental impact. The following general areas have been identified as requiring investigation.

- Evaluate a range of grass species and determine their suitability for use as a cover crop receiving meat plant effluent.
- Evaluate zero grazing management options to maximize nitrogen removal from irrigation areas and determine the economics of making both hay and silage for utilisation off-site.
- Determine by direct on-site measurement the amount of nitrogen lost by denitrification processes under a range of irrigation conditions, with a range of effluents applied to a number of different soil types.
- Evaluate tree irrigation as an alternative to irrigation of pasture.
- Develop in conjunction with the State Regulatory Authorities guidelines for the irrigation of meat processing effluents that utilise and apply the results from the studies outlined above.

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11. CONSTRUCTED WASTEWATER WETLANDS

11.1 Introduction

Constructed wastewater wetlands are the subject of much international research effort. Examination of the literature, however, shows that there is little reported work, apart from that in New Zealand, being undertaken on meat processing effluents. There are two principal types of wastewater wetlands, surface flow and sub-surface flow (also sometimes referred to as gravel bed or root zone wetland systems).

The two types of system are illustrated schematically in Figure 2. In the sub-surface or gravel bed system, wastewater flows through the gravel/plant root matrix. By contrast, in the surface flow type of system the wastewater flows through a matrix of growing plant material.

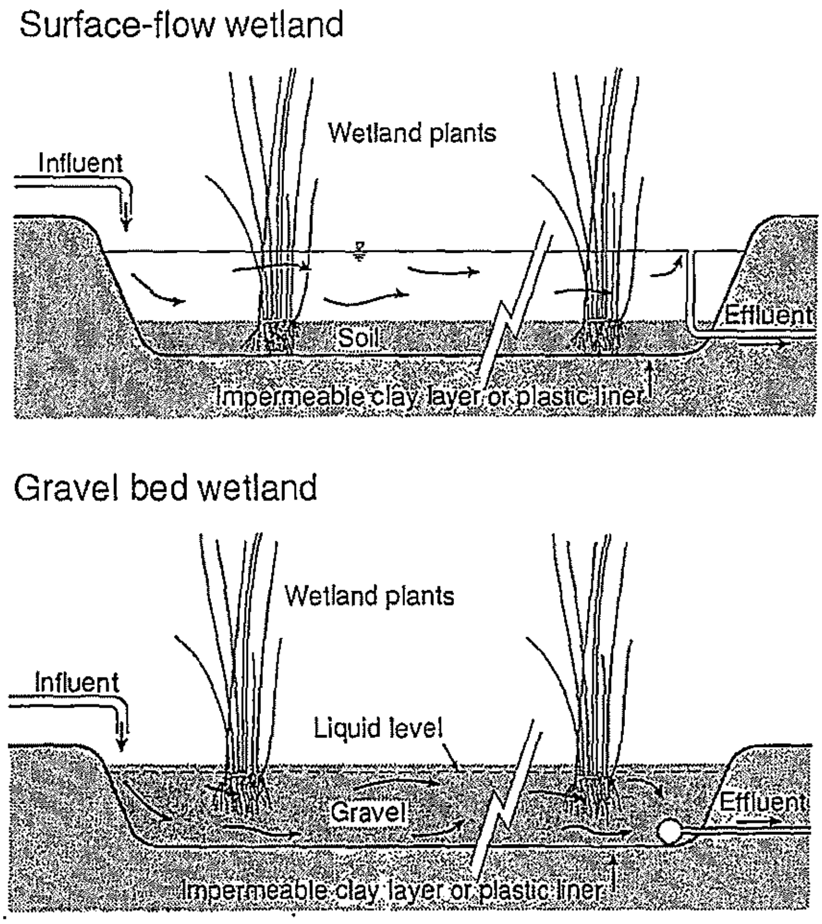

Figure 2. Schematic diagram showing the two types of constructed wastewater wetlands.

The purification mechanisms that occur in wastewater wetlands are varied and complex but will include sedimentation, filtration, adsorption and anaerobic and aerobic microbiological metabolism.

11.2 Present Knowledge

A considerable amount of work has been undertaken on the use of constructed wastewater wetlands. Unfortunately, little of the reported work has focused on the treatment of high-nitrogen wastes, which are characteristic of meat processing effluents.

Constructed wastewater wetlands have a place in the treatment of meat processing effluents and a number of MIRINZ-designed systems are either under construction and are currently being designed in New Zealand.

Work undertaken at MIRINZ has shown that constructed wastewater wetlands have a low potential for nitrogen removal unless the influent to the system has received the appropriate pre-treatment. Furthermore, the surface flow wetlands are preferred to the gravel bed type of system, which may be prone to blockage.

Constructed wastewater wetlands will find application in the Australian meat industry and a number of likely applications can be identified.

- as a run-off buffer zone along the boundaries of irrigation systems.
- as a further treatment process added on to existing lagoon systems.

11.3 R&D Needs and Technology Transfer

Research is needed on the application of constructed surface flow wetlands to further treat the effluent from existing lagoon systems. In particular:

- Determine the most suitable plants for use in these systems. A number of trials will need to be established to reflect the climatic range of continental Australia.
- Determine the nutrient removal capacity of constructed wastewater wetlands.
- Develop design criteria for the use of constructed wastewater wetlands in the various regions of Australia.
- Examine the use of constructed wastewater wetlands planted round the margin of irrigation sites to minimize nutrient transport from the site.

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12. GREENHOUSE GAS EMISSIONS

12.1 Introduction

Greenhouse gas emissions are regarded by some as one of the most pressing environmental issues facing the world today. Notwithstanding that the scientific community is far from united on the importance of the greenhouse effect and its likely impact on the global climate, many governments have adopted a greenhouse gas emission reduction policy.

In Australia, the Federal Government has announced an interim planning target of reducing greenhouse gas emissions by 20% by 2005, and a similar target figure has been announced by the New Zealand Government. The 20% figure is based on a proposal put forward at a 1988 international conference on the greenhouse effect in Toronto.

If the Government is to implement and achieve its target of reducing greenhouse gas emissions, then information on sources from human activities, particularly various industry sources, will be required. The meat processing industry should, therefore, determine its greenhouse gas emissions, firstly in order to assist the Federal Government in determining, if its target of a 20% reduction can be achieved without damaging Australia's international competitiveness, and secondly to highlight areas where reductions may most effectively and economically be achieved.

12.2 The Greenhouse Gases

Carbon dioxide, methane, nitrous oxide and chlorofluorocarbons are the principal greenhouse gases produced by human activity. Of these four, chlorofluorocarbons are most easily dealt with. The meat processing industry is unlikely to be a significant source of chlorofluorocarbons. Consequently, only the production of carbon dioxide, methane and nitrous oxide by meat industry activities will be discussed here.

12.2.1 Carbon dioxide

Carbon dioxide is produced by the combustion of fossil fuels or wood in steam-raising plant. The amount of carbon dioxide produced per unit of steam raised will vary depending on the fuel used, such as coal, oil, natural gas or wood.

A number of plants fire wood chips, and it can be argued that this practice has zero impact on the global carbon dioxide budget if the timber being used as a fuel is being replaced by replanting. Timber as a fuel can therefore be regarded as a sustainable resource.

This argument cannot be used for coal, natural gas or oil, as combustion of these fuels liberates a previously stored source of carbon. Carbon dioxide is also produced by microorganisms in effluent treatment systems. It will be liberated from anaerobic lagoons, aerobic treatment systems, solid wastes disposal sites and irrigation areas.

12.2.2 Methane

Methane is a by-product of anaerobic digestion and will be produced in anaerobic lagoons, solid wastes tips and from the anaerobic sediments in aerobic lagoons.

12.2.3 Nitrous oxide

The principal sources of nitrous oxide are combustion processes and effluent treatment systems. In effluent treatment systems, nitrous oxide is produced as a consequence of the conversion of organic nitrogen to ammonia nitrogen and then nitrate under aerobic conditions, followed by the reduction of nitrate to nitrous oxide and nitrogen gas under anerobic conditions (denitrification).

Nitrous oxide will be liberated from aerobic ponds and irrigation areas. In aerobic ponds nitrous oxides will be produced in the anoxic zones, and some systems are designed specifically to facilitate denitrification.

At irrigation sites, nitrate is produced by aerobic microbial metabolism of ammonia nitrogen. With subsequent irrigation, transient anoxic conditions are produced which favour denitrification of the nitrate already in the soil. The amount of nitrous oxide produced is influenced by a number of factors, principally soil pH.

The ratio of the amounts of nitrous oxide and nitrogen gas produced also varies. Generally the ratio of nitrous oxide to nitrogen is considerably higher in the gases liberated during irrigation than from lagoon systems. This highlights the conflicts that occur in environmental decision making. Irrigation of effluents may well protect water resources, but at the cost of an increased discharge of nitrous oxide to the atmosphere. The environmental impact equation therefore becomes more complex.

12.3 R&D Needs and Technology Transfer

The Australian meat industry should commission a study to estimate the total atmospheric greenhouse emissions that result from its operations. Such a study should include estimates of carbon dioxide, methane and nitrous oxide emissions from both fossil fuel use as well as from liquid and solid wastes treatment.

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13. ENVIRONMENTAL AUDITING

13.1 Components of an Audit

Environmental audits will become an essential management tool of the future, be they undertaken voluntarily by management or required by Regulatory Authorities. The audit process should be regarded positively and seen as an opportunity for a company to define and meet the following objectives:

- Define the level of environmental risk.
- Define corporate environmental objectives.
- Identify opportunities for resource use minimisation.
- Identify opportunities for waste minimisation.
- Increase product yields.

The environmental audit is therefore multifaceted and includes auditing at the corporate level right through to Quality Management on the slaughterfloor and effluent treatment plant. For the audit to be successful, a corporate culture that recognises that environmental issues are an integral and important part of the production equation, must be developed and driven from the top.

13.2 Environmental Risk

Defining environmental risk includes knowing:

- What licences and approvals are required for a plant's continued operation.
- Are performance criteria, where specified, being met.
- What competition exists now for land and water resources and what may develop in the future.
- What will be the impact of changing environmental legislation on the continued operation of a plant.
- What additional investment will be required to continue operating and satisfy additional constraints.

13.3 Resource Use Minimisation

The meat processing industry uses large quantities of water and it is in this area that major opportunities to minimise resource use exist. An audit should therefore define water use in all processing areas and seek to minimise water use through examining water use patterns and evaluating alternative processes that may be more efficient users of water.

13.4 Waste Minimisation and Increasing Product Yield

Waste minimisation requires that product yield data be collected and monitored. Most companies will collect and monitor information on boning room yields. The same effort should be put into monitoring blood, tallow and meal yields. This will require the establishment of laboratory facilities and the employment of Quality Management staff to monitor and advise on waste minimisation opportunities.

13.5 R&D Needs and Technology Transfer

To help to meat processing companies undertaken environmental audits, national guidelines should be produced that provide baseline information as a yardstick. This will enable individual companies to make judgements about their own operations and identify areas for improvement.

These guidelines should contain the following information:

- Rendering yields, including yields of meal, tallow and dried blood, that can be realistically achieved.
- A breakdown of water use for all major processing operations in a meat processing plant.
- Waste minimisation achievements that have been recorded by process changes such as changes to gut cutting and washing, and implementation of blood aging.

13.6 Bibliography

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14. CONCLUSIONS

The environment will become increasingly considered before jobs and economic development and it may well be that environmental pressures close meat processing plants that are inappropriately located when it comes to dealing with the issues of effluent and solid wastes disposal and treatment.

All these changes in environmental legislation are not taking place without considerable emphasis by the Federal and State Governments on the public participation process. Discussion papers are produced, inviting public comment.

The meat industry can and should participate in these debates and express its point of view and raise those issues that are relevant. A collective lobby approach is often most effective, although submissions by individual companies on specific issues should be encouraged.

Failure by the Australian meat processing industry to take the opportunity to participate in these debates will result in change being forced upon it.

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