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BULLETIN

IRRIGATION OF MEAT PROCESSING EFFLUENTS

Irrigation is an excellent disposal and treatment option for meat processing wastewater. Wastewater irrigation applies plant nutrients and water to the land, enhancing plant growth. This Bulletin discusses the advantages and disadvantages of such irrigation and also management strategies to avoid adverse effects.

The amount and properties of the wastewater produced by a meat processing plant each day present a challenging disposal problem. Typical water use is 250-500 litres per animal for sheep processing and 1500-3000 litres for beef processing. These volumes translate to equivalent volumes of wastewater.

Untreated meat processing wastewater contains blood, fat and other animal tissues, as well as digestive system contents and faecal matter. Where treatment is concerned, what matters most are the amounts of organic matter, nutrients, and faecal microorganisms.

If discharged to waterways without appropriate treatment, the organic matter in the effluent can cause oxygen depletion and contribute to colour and turbidity. The nutrients in the effluent can cause unwanted biological growth in receiving waters, and ammonia and hydrogen sulphide in the effluent can be toxic to aquatic life. Faecal microorganisms in the wastewater can affect the suitability of the receiving waters for recreation and other uses.

Where suitable land is available, irrigation is often the preferred method of treating and disposing of meat processing effluent as it avoids a point source discharge into waterways. Irrigation also meets a Maori cultural preference that wastewater containing faecal material be "purified" by passage through the earth.

Irrigation of meat processing wastewater is not without risks. Irrigation systems must be designed and managed to avoid potential problems, including groundwater contamination, nuisance odours, aerosol drift, surface runoff into waterways, and degradation of soil structure and quality.

Fourteen New Zealand meat processing plants currently irrigate some or all of their wastewater to pasture or plantations of trees: the oldest schemes have been operating for nearly 100 years.

NUTRIENT VALUE OF WASTEWATER

Meat processing effluents are essentially a liquid fertilizer containing a natural balance of plant nutrients. Typically, 1 m^3 (1000 litres) of settled or screened raw effluent contains 100-250 g of nitrogen, 10-30 g of phosphorus and 20-150 g of potassium, as well as several other plant nutrients. If the effluent is treated in conventional anaerobic and aerobic lagoons, the concentrations of these nutrients change very little.

Pasture yields greater than 10,000 kg dry matter per hectare per year can be expected at New Zealand sites receiving regular applications of effluent during the growing season.

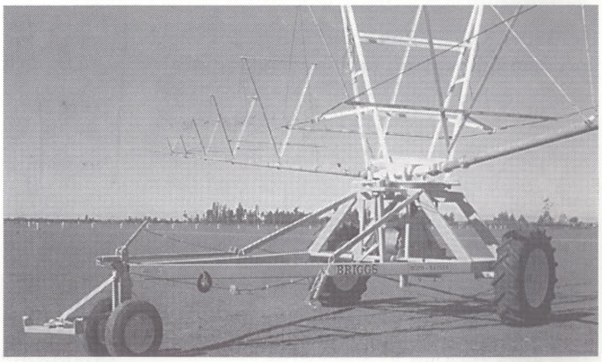
The wastewater stimulates plant growth by both a moisture effect and a nutrient effect.

MIRINZ studies have found that pasture plants growing in areas irrigated with meat processing effluent have significantly increased concentrations of nitrogen, phosphorus, potassium and sodium, so irrigation can affect plant composition as well as plant growth.

HOW MUCH WASTEWATER TO APPLY

The effluent application rate is important, because the amount of effluent that can be safely applied to an area of land determines the capital and operating costs of an irrigation system. The effluent application rate can be expressed in terms of the depth of water applied (the hydraulic loading rate, e.g. mm y^{-1}), or as the mass loading rate of a particular nutrient, usually nitrogen, in the wastewater (for example, kg N ha^{-1} y^{-1}).

When irrigating meat processing wastewater, the annual application rate is typically governed by the nitrogen loading allowed rather than by how much water can be applied



A travelling irrigator. (Photo courtesy of Briggs Irrigation)

to the site. This is because meat processing wastewater contains relatively high concentrations of nitrogen (other nutrients in the wastewater are usually not of environmental concern at the levels applied). Applying too much nitrogen can cause problems. For example excessive nitrogen can leach to groundwater, or plants at the site can contain excessive levels of nitrate due to "luxury uptake" (the plants take up more nitrate than they need for growth). This can be a problem if animals will be eating these plants.

Any nitrogen (and any other nutrient) applied to the soil that is not taken up by plants, stored in the soil or removed by microbial processes will eventually leach to the groundwater.

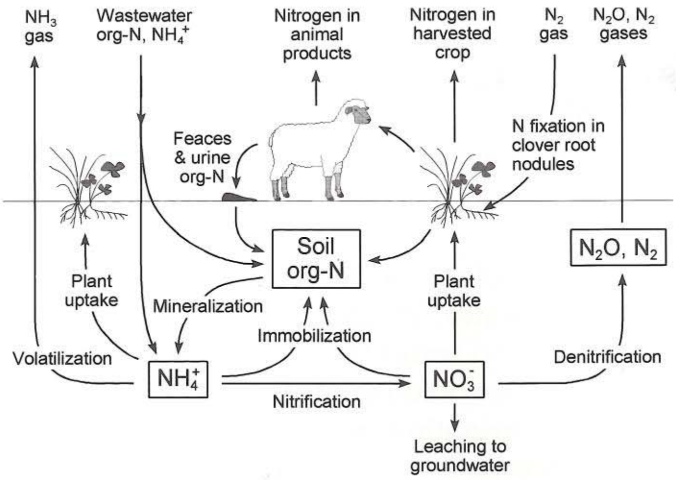
One way to avoid nutrient leaching is to match the amount of nutrient applied to plant needs. In this case, the rate of application must be frequently adjusted to take into account seasonal variations in plant need, and a large land area and large wastewater storage capacity are needed, making this option expensive.

A more practical approach is to apply more nutrients than plants need, and take advantage of natural removal processes other than just plant growth. These include adsorption to soil particles, and for nitrogen, microbial removal through denitrification. Meat processing plants taking this approach must ensure that their irrigation scheme has no adverse effects on crops, soil, groundwater or grazing animals. Compared with the first option, this approach requires less land area and wastewater storage capacity, and because excess nutrients can stimulate plant growth, there can also be an economic benefit.

Whichever application strategy is chosen, cumulative effects need to be considered as well as immediate short-term ones.

NITROGEN - THE KEY NUTRIENT

Although meat processing wastewater contains substantial quantities of various nutrients, most do not cause problems at irrigation sites. For example, phosphorus is not very mobile in soils and potassium is not considered harmful. In contrast, nitrogen, which can be mobile in soils, is a considerable environmental concern.



Schematic diagram showing the main nitrogen inputs, transformations and outputs that occur at a wastewater irrigation site.

Most of the nitrogen in primary-treated (settled and/or screened) wastewater is in the form of organic nitrogen (mainly protein), and some is present as ammonia.

The irrigated proteins are absorbed by the top layer of soils, where microorganisms mineralize the organic nitrogen to ammonia, and then rapidly oxidize the ammonia to nitrate (the process of nitrification) (see Figure). Both ammonia and nitrate can be taken up by plants. Ammonia is generally immobile in soils but nitrate can be leached rapidly into groundwater.

The World Health Organization recommends a maximum nitrate concentration of 50 g m^{-3} (11.3 g nitrate-nitrogen m^{-3}) in drinking water.

There have been reports overseas that animals eating plants containing 0.2-0.3% (dry weight) nitrate have died due to effects on the blood (methaemoglobinaemia). In contrast, New Zealand animals free-range grazing on pasture containing this amount of nitrate are apparently unharmed.

Some of the nitrogen applied at irrigation sites is lost to the atmosphere through denitrification. Denitrifying bacteria in the soil convert nitrate to dinitrogen (N_2) and nitrous oxide (N_2O) gases. Although this process is desirable in terms of groundwater and plant nitrate levels, it may have environmental consequences of its own. For example, nitrous oxide absorbs infra-red radiation and so is thought to contribute to global warming.

The proportion of N_2O produced by denitrification tends to decrease with increasing soil pH, and is usually minor above a pH of 6.5. Thus, above this pH, most of the gas formed will be the desirable N_2 rather than N_2O.

The wastewater is the main source of nitrogen at meat-waste irrigation sites. The excess nitrogen in the soil at an effluent irrigation site probably suppresses the nitrogen fixing capacity of any legumes, like clover, present.

STRATEGIES TO REDUCE NITRATE LEACHING

In practice, the wastewater application rate is usually limited by the amount of nitrate entering the groundwater. This in turn depends on the nitrogen loading rate (and the form of nitrogen), and the soil type, plant cover, land use and denitrification rates at the site. Therefore optimal application rates are site and wastewater specific.

Reduce Nitrogen Application Rate

Reducing the nitrogen application rate is an obvious method of reducing the risk of nitrate leaching. This can be achieved by either increasing the irrigated land area or reducing the wastewater nitrogen content.

The nitrogen content of the effluent can be reduced by improving waste minimization practices in the plant, and/or by treating the

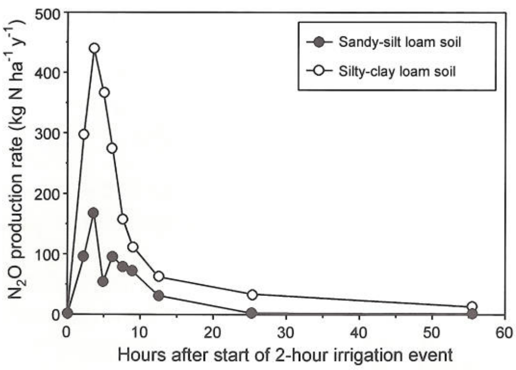
effluent to remove some of the nitrogen before it is irrigated. A recent MIRINZ study found that, in some situations, removing a proportion of the effluent nitrogen using a biological nitrogen removal system is more cost effective than extending the irrigation system.

Retain Nutrients in the Topsoil
Denitrification and plant uptake occur mainly in the topsoil. To maximize nitrogen removal by these mechanisms, the effluent application should be managed such that the irrigated wastewater and its nutrients are retained in the topsoil for as long as possible.

The effluent should be distributed evenly, and it is better to frequently apply small volumes of wastewater to an area of land than to apply large volumes infrequently.

When effluent is irrigated onto grazed pasture, the grazing rotation rate and the need to withhold grazing for a period after irrigation will impact on the application frequency. Nevertheless, the volume of effluent applied during each irrigation should be less than the water-holding capacity of the topsoil, to avoid washing too much effluent through the topsoil.

Irrigate Primary Effluent
The denitrification rate, which is highest soon after an irrigation event (see figure), depends on both the amount of organic carbon and the form of nitrogen in the applied wastewater. Most meat processing plants that irrigate their effluent apply the effluent after primary treatment, which often consists of screening followed by a saveall or dissolved air flotation unit.



Nitrous oxide emission following an irrigation event.

Primary treated effluent is a good type of effluent to irrigate from a nitrogen-removal point of view, as most of the nitrogen in this effluent is in an organic form, whereas secondary biological treatment (e.g. lagoons) converts most of the nitrogen into ammonia or nitrate.

When applied in an organic form, the effluent nitrogen is more likely to be incorporated into plant or soil organic matter, than if applied in the form of ammonia or nitrate.

Primary treated effluent also contains high concentrations of readily biodegradable organic carbon. This carbon is a food source for the denitrifying bacteria, and its presence in the effluent can enhance the rate of denitrification. In contrast, secondary-treated effluents usually contain low concentrations of organic carbon, so denitrification rates tend to be lower.

Effluents that have been biologically treated in storage lagoons can contain significant concentrations of nitrate. A MIRINZ study has found that irrigating such effluent together with high-carbon primary effluent produces much higher rates of denitrification and lower rates of nitrate leaching than when the nitrate-rich effluent is irrigated alone. Again, this is because the primary effluent provides the organic carbon required by denitrifying bacteria.

Harvest a Crop
At most meat processing effluent irrigation sites in New Zealand, the effluent is irrigated onto grazed pasture. Grazing animals recycle about 90% of their nitrogen intake back to pasture, and thus only about 10% of the nitrogen taken up by plants is eventually removed from the site in the form of animal products.

A much higher proportion of the plant nitrogen can be removed in a "cut and carry" system, in which the pasture is harvested and taken off-site in the form of hay or silage. Sites can be managed for both grazing and harvesting. Harvesting allows higher nitrogen application rates and is increasingly practised to control nitrogen at irrigation sites.

TYPES OF IRRIGATION SYSTEM

Many different types of irrigation system are suitable for meat processing wastewater. Which type is best for any given irrigation system will depend on various factors, including terrain and soil characteristics, crop type, capital cost, operating cost, and precision of application.

Nitrogen loading rates are determined by consent conditions, and the rates allowed mean that relatively large land areas must be used for irrigation. These large land areas mean that capital and operating costs of whatever irrigation system is chosen will be high. Meat processing plants wanting to irrigate their effluent should carefully analyse the technical and economic aspects of the various irrigation systems they could use.

Most meat processing plants use some form of spray irrigation. Spray systems can consist of a permanent sprinkler network or an irrigator that moves from place to place. Commonly used irrigators are described in the following sections.

Permanent Sprinkler Network
Permanent systems have all of the necessary pipes and sprinklers set in place to cover the entire irrigation area. These systems are sometimes referred to as solid set systems. Valves control the flow of water to different areas so each area is irrigated in turn.

Permanent sprinkler networks have a comparatively high capital cost due to the large pipework and sprinkler inventory, but the operating labour cost can be very low, especially if the valves are remote controlled.

Manually Moved Irrigator
These systems consist of a permanent buried mains network, with hydrants at regular intervals, to which a rain gun or rotating boom irrigator can be connected by a length of flexible hose. The irrigator is moved manually at regular intervals so that the entire irrigation

A manually moved rain gun.

area is covered, and the hose is long enough to allow the irrigator to be moved to a number of positions while connected to the same hydrant.

The capital cost of such systems is lower than for the permanent network, but the operating labour requirements are higher. Also, there is a higher potential for poor uniformity of coverage if the system is not managed properly.

Travelling Irrigator

These systems consist of either a large rotating boom irrigator, a lateral boom irrigator, or a rain gun, which is moved across the field by a winch arrangement driven by a water turbine. The turbine obtains its power from the flow of water on its way to the irrigator.

The capital cost of travelling irrigator systems is slightly higher than for the manually moved systems. However, compared with manually moved systems, travelling systems can cover larger areas per shift due to the continuous movement of the irrigator, and the application rate can be adjusted by changing the travel speed. Travelling irrigators need fairly flat terrain on which to operate.

HYDRAULIC LOADING

The rate of effluent application during an irrigation event must be considered in addition to the depth of effluent applied. If the effluent is applied too quickly, the soil may not be able to absorb all of the effluent, resulting in ponding of liquid on the soil surface, and runoff. The effluent application rate should therefore not exceed the infiltration rate, which is largely determined by the hydraulic conductivity or permeability of the soil.

The effluent application itself can affect the permeability of the soil. The organic matter in untreated effluents can block the pores in the surface soil, reducing the infiltration rate. This occurs to a much lesser extent when treated effluents are applied.

Also, wastewaters that contain high concentrations of sodium relative to calcium and magnesium can affect the soil structure and reduce infiltration rates. Meat processing effluents generally have salt ratios that are suitable for irrigation. However, some processes (e.g. salting of casings) produce effluents with high concentrations of sodium, and where such effluent is irrigated, the affect on soil structure should be closely monitored.

Soils with a low permeability may not be able to accept effluent applications during periods of wet weather without causing some runoff. For such soils the rate of effluent application should be kept to a minimum, and it may be necessary to avoid effluent application during wet weather by using lagoon storage. The lagoon treatment will also help to reduce the pore-blockage affect.

OTHER CONSIDERATIONS

Regardless of whether irrigated pasture is grazed or harvested and fed to animals off-site, luxury nitrate uptake by the plants needs to be considered. Animals seem able to adapt to high nitrate in pasture if the intake is slow and steady, whereas gorging on high nitrate feed can cause fatal methaemoglobinaemia.

Irrigation has the potential to spread infectious disease, by aerosols being inhaled or by effluent liquid or aerosols being deposited on plants that are then eaten. Thus, if the irrigated site is grazed, a suitable withholding period after irrigation must be established, and irrigation schemes must take aerosols and spray drift into account, in terms of any potential impact on animals, workers or neighbouring properties.

CONCLUSIONS

With proper management, meat processing wastewater can be safely irrigated onto land.

The land area required is usually determined by the allowable nitrogen loading rate. An acceptable nitrogen loading rate is site-specific, and is governed by the rate at which plants and soil can sustainably assimilate the applied nitrogen, and how much of the assimilated nitrogen is removed from the site, whether in plant or animal form.

FURTHER READING

Meat Research Corporation (1995) Effluent irrigation manual for meat processing plants. Meat Research Corporation, Australia.

Russell, J.M. and Cooper, R.N. (1992) The use of meat processing effluents for irrigation of pasture. Proc. Workshop: The Use of Wastes and Byproducts as Fertilizers and Soil Amendments for Pastures and Crops. Massey University. pp. 208-213.

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