Waste Not, Want Not: Managing Livestock Waste for Income and the Environment

Jock Christoe

Paper prepared for presentation at the "The Livestock Revolution: A Pathway from Poverty?" conference conducted by the Crawford Fund for International Agricultural Research, Parliament House, Canberra, Australia, August 13, 2003

Waste Not, Want Not: Managing Livestock Waste for Income and the Environment

JOCK CHRISTOE

Summary

The world-wide intensification of livestock industries poses major challenges for waste disposal. For example, the total solids wastes discharged from livestock farms in China exceeded 1.7 billion tons in 1997, with a further 20 billion tons of waste water being discharged to the environment — only 10% of these wastes were treated!

A key element of sustainable development is Cleaner Production. Cleaner Production is an approach in which wastes are handled in such a way that environmental pollution is avoided. Cleaner Production practices include waste minimisation, pollution prevention, recycling and community-based environmental approaches.

An increase in the production of livestock products means an increase in the production of livestock wastes and, consequently, an increase in the potential for environmental pollution.

DR JOCK CHRISTOE has been a research scientist with CSIRO for over 30 years. He has had extensive experience in working with woollen mills in China and India. Currently he is the project leader of an ACIAR environmental project involving mills in Australia, China and India. He has been involved in the development of environmental technologies that have been adopted at mills around the world. In 1992 he was awarded the CSIRO Medal for Research Achievement. Dr Christoe has given lectures and courses on wool scouring and effluent treatment in Australia, Argentina, New Zealand, USA, Korea, China, India, Uruguay, UK, Japan and Hong Kong.

The applications of the principles of Cleaner Production for four types of livestock waste are discussed in this paper.

With wool-scouring wastes, the process streams are segregated in order to separate the raw wool contaminants so that the dirt and wool wax can either be composted to produce either a soil conditioner or a premium potting mix, or used as a fuel. The water-soluble contaminants can then be used as a source of potassium. The treated water can be recycled to the washing process, thereby eliminating aqueous discharges completely.

The pollution propensity of the wastes produced in the leather industry can be reduced by methods such as converting waste hair into a fertiliser, recycling chrome liquor and reducing salt discharges through hide drying technologies.

In order to facilitate the adoption of Cleaner Production technologies with piggery wastes in the Pacific Island countries, participatory methods and action research are being used to encourage community involvement.

Nutrient audits of farms using farmyard manure applications to improve crop yields showed that Indian farmers under-fertilised their crops, whereas Australian farmers over-fertilised them.

Introduction

There are two types of livestock waste. These are wastes generated during livestock production, such as manures and slurries, and wastes produced in secondary industries that include abattoirs (such as offal, blood and chicken feathers), leather production and wool scouring.

Livestock production wastes

Livestock production generates considerable amounts of waste. It is claimed that in the USA livestock wastes are 130 times greater than humans. For example, a new 50 000 acre pig farm being built in Utah will generate more waste than the City of Los Angeles (Halweil and Caron 1998). In China (2002) and Europe (Gendebein *et al.* 2001) 1.7 and 1.2 billion t of waste, respectively are produced annually. In addition 20 billion t of wastewater are discharged to the environment in China with only about 10% being treated.

Animals are not particularly efficient users of nutrients. For example, pigs and cattle excrete 70% and 80–90% respectively of the protein in the feed (Steinfeld *et al.* 1997) — the remainder is discharged as waste. Based upon the degree of integration with crop production there are three types of livestock production systems: grazing, mixed farming and industrial (UNEP 2002). Industrial production is the fastest-growing form of livestock production due to population growth, increasing incomes and urbanisation.

Grazing systems are based solely on livestock production and the animal wastes are used within the system. However, resource degradation is becoming a major problem in many grazing areas in the world.

Mixed farming systems involve integrated crop and livestock production. Wastes from both activities can be recycled as farmyard manure (FYM).

Industrial systems depend on outside supplies of feed, energy and other inputs. There are claimed to be a number of environmental benefits accruing from these systems. These include better use of total feed requirements (the technologies used can be transferred to mixed farming systems), and reduced pressure for deforestation and degradation of rangelands (Steinfeld *et al.* 1997). Under these circumstances, the amounts of byproducts produced exceed the capacity of the land to utilise the nutrients. Consequently, there is a problem in disposing of these extra byproducts.

Wastes from livestock production cause basically four types of environmental problem:

- point source pollution from poor waste management practices, such as spillage and seepage from containment areas
- emissions from waste treatment plants — methane released to the atmosphere from anaerobic ponds has 21 times the effect of carbon dioxide as a greenhouse gas (Lake *et al.* 1999)
- accumulation of contaminants in soil, such as heavy metals
- an excess of nutrient, leading to soil and water pollution.

Abattoir wastes

About 21% of an animal becomes waste when processed. These wastes include blood, bones, feathers, stomach and bowel contents, manure wash liquors and sludges. Most of the wastes (80–90%) are reused or recycled into animal feedstock. Some components, such as hooves and bone, are recycled into other industries. About 5–10% of the wastes are applied to land with or without composting — these wastes are mainly gut contents that contain mainly partly-digested feed (Gendebein *et al.* 2001).

Leather production

Skins and hides that are preserved for tanning can contain up to half of their weight in salt. In all types of leather production, dirt and biological materials including grease and proteins, such as blood and hair, must be removed from the raw material. The skin collagen is then chemically stabilised with a tanning agent. Chromium III is the most widely used tannage but vegetable extracts are used for sole leathers, fish oil for chamois and syntans are used to confer specific properties to leathers. Tanneries use large volumes of water: conventional woolskin processes use 400 l per skin and wet-blue production 30 l per kg of hide. However, with improvements in both housekeeping and processes, wet-blue is now produced with 10 l of water per kg of hide.

The components in the liquid wastes that are of concern include salinity, ammonia, sulphides, sulphates, organic matter, grease, chromium and manganese. Other potential pollutants are solvent residues used during processing and solid wastes such as sludges, fleshings, hair, untanned trimmings and tanned waste.

Wool scouring

Wool is perceived to be a clean, green, natural fibre. However, raw (greasy) wool contains substantial amounts of natural pollutants (about 40% by weight) that must be washed off (scoured) before the wool can be used. The major contaminants are wool wax (solvent-extractable contaminants), suint (water-soluble contaminants) and dirt. The resulting effluent from wool scouring poses a number of environmental problems. First, the organic load is very high. Even after recovery of about 30% of the wool wax by centrifuging, the organic effluent load from a typical wool scour equals the sewerage from a town of 50 000 people. In the Geelong/Melbourne region alone this is equivalent to a population of over 500 000 people. A typical effluent would have to be diluted about 5000 times to avoid eutrophication of a receiving water. Second, wool wax is very difficult to degrade in biological effluent treatment systems because of both its chemical structure and its physical characteristics. Third, there are components of the effluent that are biorefractory. Fourth, the high levels of suspended matter hinder biological treatment. Fifth, the levels of total dissolved solids make sustainable irrigation impractical for most scouring locations (Bateup *et al.* 1996).

Wastes as resources

In this paper, I want to consider a more proactive approach to environmental issues in which we focus on the opportunities that emerge from treating livestock wastes as a resource. For a number of years I have been on a campaign to redefine wool grease as wool wax. Not only is the latter the correct chemical term but also it creates a positive value to the material. I believe that same approach should be applied to livestock wastes. ‘The reference to livestock manure as livestock ‘waste’ has helped lead to the undervaluation of manure as a source of nutrients, the loss of manure nutrients through mishandling and misapplication, and the over application of manure to the land. Understanding that term’s use implies a value; the agricultural sector can replace the use of the word ‘waste’ with ‘manure’, ‘residuals’, or ‘byproducts’’ (USDA/NRCS 1995).

I am going to show how the principles of Cleaner Production can be applied to reduce the negative environmental impacts of four types of livestock byproducts. These wastes are: wool processing effluents, leather production byproducts and two examples of animal production byproducts: piggeries in Pacific Island Countries and farmyard manure use on farms in India and Australia. The work reported is taken from four current or recently-completed ACIAR projects.

Cleaner production

Environmental practice can be considered as a staircase of concepts (Hamner 1996). The different concepts form the steps, with each step including those concepts below as well as additional elements of scope and complexity. At the top of the staircase is sustainable development that is defined as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (WCED 1987).

Cleaner Production is a subset of sustainable development. Cleaner Production is ‘the continuous application of an integrated preventative environmental strategy to processes, products and services to increase overall efficiency, and reduce risks to humans and the environment’ (UNEP 2001). Cleaner Production is seen as a ‘win-win’ system as it aims to protect the environment while improving productivity and competitiveness (UNEP 2001). It is a broad term that covers subjects such as eco-efficiency, waste minimisation and pollution prevention. It also refers to an approach in which goods are produced with minimum environmental impact under present technological and economic limits. In this context, waste is considered as a ‘product’ having negative economic value. The difference between pollution control and Cleaner Production is that the former is a react-and-treat approach whereas the latter is proactive and preventative.

In applying Cleaner Production, the first step is to carry out an environmental audit in order to identify inputs, wastes and products (Fig. 1). To do this we need to define a boundary for operations of the process, be it a farm, a feedlot, a tannery or a wool scouring plant. This can be either an administrative or a physical boundary. We then need to consider all inputs and outputs that cross that operations boundary and develop a complete mass balance for the process under consideration. Only then can we make an inventory of the waste production. In some ways we are carrying out an element of a life cycle assessment.

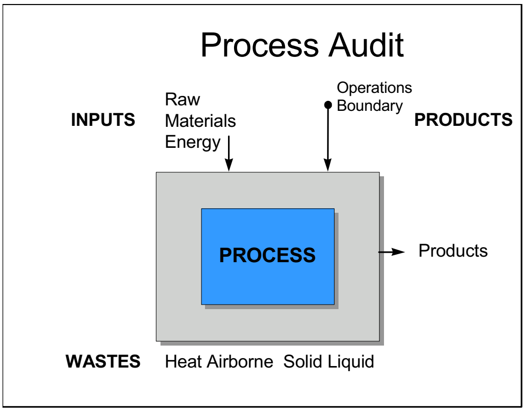

Figure 1. Environmental/process audit

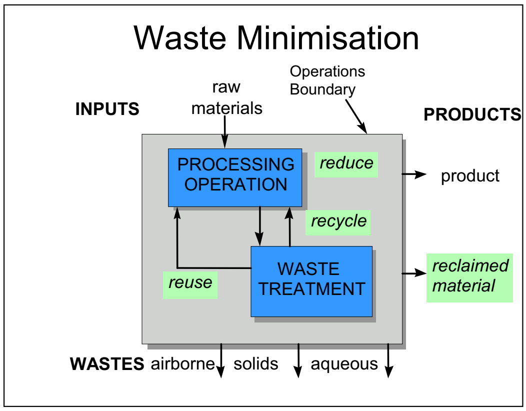

Figure 2. Waste minimisation

Waste minimisation is any action that reduces the toxicity and quantity of waste. The least desirable form involves transferring the waste from one state to another. For example, passing a wool scouring effluent through a decanter centrifuge transfers some of the particulate matter from the effluent into a sludge which is then discharged to landfill. Waste minimisation involves (Fig. 2):

- reducing the generation of waste
- reusing any waste if possible
- reclaiming any waste that cannot be reused
- recycling as much unused, reclaimed material as possible

In the context of livestock wastes, waste minimisation is the more important than changing inputs because, in general, one cannot readily reduce the amount of waste an animal produces daily or the amounts of contamination on greasy wool. However, preserving hides and skins without using salt is an example of point source reduction.

Waste minimisation and livestock by-products

Wool Scouring (ACIAR Project AS1/97/069)

CSIRO has made significant contributions to scouring and effluent treatment (Bateup and Christoe 1996; Christoe and Bateup 1987). Underlying these technologies is a large body of basic scientific research into the nature of the raw wool contaminants and their mechanisms of removal during scouring, as well as parametric studies into wool scouring and effluent treatment. From these investigations CSIRO has developed an integrated approach to treating scouring effluents.

The CSIRO integrated waste management approach has the following important features:

1. The principles of waste minimisation have been used specifically to achieve a paradigm shift in the attitude of the scouring industry to waste management by treating scouring wastes as a resource (Bateup *et al.* 2000, 2001).
2. Rather than treating the combined scouring effluent, the three main liquid waste streams are treated separately as they have different characteristics and, consequently, require different technologies for optimal treatment.
3. The operation of the effluent treatments is closely integrated with the operation of the scouring line. The performance of the contaminant recovery loops that are used to remove wool wax and dirt continuously are optimised to produce concentrates containing as much of the contaminants as possible in the smallest possible volume. The possibility of recycling the treated waste waters to the scouring operation is an important feature of the system.

The cornerstone of CSIRO's approach is Sirolan CF (Bateup *et al.* 1996). It is a chemical flocculation process that has been specifically developed to treat the strong flow effluent. In contrast to the conventional chemical treatments, Sirolan CF is an in-line process, where the only chemicals used are an acid for pH adjustment and a polymeric flocculant. Sirolan CF plants have been installed in Australia, England, New Zealand and Portugal. The technology has been demonstrated successfully in India at the pilot plant level as part of the ACIAR project. It is currently on its way to China.

The sludge from Sirolan CF has a solids content of 60–70% and contains no free water. It can be either composted to produce a soil conditioner or a premium potting mix, or used as a fuel. The trials with the pilot plant in India have shown that the preferred mode of use would be as a fuel because the energy value is about double that of lignite.

The centrate from Sirolan CF contains the water-soluble suint salts. Sheep differ from humans in the composition of their sweat. Human sweat contains predominantly sodium, whereas sheep sweat (suint) contains predominantly potassium. The proportion of potassium in suint is about 27–30%. Sheep take about 10 000 t of potassium from the land annually. Nearly all of the potassium used as fertiliser in Australia is imported as potassium chloride (muriate of potash), about 150 000 t y^{-1}. Agriculture Victoria showed that the recovered suint was as good as if not a better fertiliser than the imported fertiliser (Maheswaran *et al.* 1999).

Leather Production (ACIAR Project AS1/2001/005)

The image of tanneries has been markedly improved through both the introduction of new technologies that minimise waste, and segregating waste streams and treating them with appropriate technologies. Examples include lime recycling (Money and Adminis 1974), short-term preservation of hides and skins (Money 1974; Adminis and Money 1998), carbon dioxide deliming (White *et al.* 1993), direct recycling of chrome liquors (Davis and Scoggie 1980; Cranston *et al.* 1997; Money 1998) and utilisation of hair (White *et al.* 1991). As a consequence of these developments salinity remains the main problem facing the leather industry. For example, tanneries in India are able to meet the stringent regulations for the discharge of wastewaters to land apart from the level of total dissolved solids.

At present salt cannot be eliminated from tannery processes and there is no viable technique to decrease the levels in effluents to satisfy discharge regulations. However, there are several process improvements that should reduce salt use. These are improved pickle liquor recycling and Direct Chrome Liquor Recycling. The elimination of salt for skin preservation through the development of appropriate air-drying technologies will have the largest effect on salinity. These approaches are the subject of the recently-begun ACIAR project.

Piggeries in Pacific Island Countries (ACIAR Project LWR/2001/038)

In the Pacific Islands, livestock management evolved using imported animals (principally pigs). It made use of limited physical resources and developed within the constraints imposed by society. Most of the livestock are owned by small-scale farmers. Due to increased animal numbers (pig densities are as high as 500 km^{-2}) livestock wastes are neither collected nor managed. Consequently, surface and underground water supplies are contaminated, leading to risks to human health.

Attempts in the past to make greater use of animal manure as a resource for biogas production, and crop and garden fertilisers, have not been successful due to a lack of community involvement.

The new ACIAR project is trying to overcome this problem by getting community involvement and ownership. This would be a win-win result because the environmental impact of the wastes would be eliminated concomitant with increased crop and garden production. The project is using a team capable of examining the social and physical environments, and the relationships between livestock waste and crop production in association with the local communities.

Farmyard Manure Disposal (ACIAR Project LWR/1998/136)

In order to optimise the production of crops one needs to balance their nutrient needs with what is available. Too little nutrient leads to low yields. Too much nutrient is wasteful and could lead to environmental problems. This issue was examined in this recently-completed ACIAR project. This project assessed the nutrient balances of cattle farms in India and Australia, and the impact of livestock manure on the nutrient balance.

In India the cattle manure is composted to farmyard manure (FYM) by mixing cattle dung (50–60%) with crop residues (30–35%) and household and other wastes (5–20%) and keeping covered for a year before being applied to the land. In Australia, the cattle manure is stock-piled before being spread on the land.

Nutrient audits were carried out in both countries to assess the cropping potential. The researchers found that the Indian farmers under-fertilised their land whereas the Australian farmers, who were operating small feedlots, over-fertilised the land, leading to potential pollution of dams and water-ways. Neither group of farmers knew the plant nutrient value of the applied manures. A major constraint to using more FYM in India is the competitive use of dried dung as a fuel source. About 50% of the dung is used in this way. Access to sufficient cash flows seems to limit a shift to alternative fuels. This means that marginal farmers (operating on an area of less than 1 ha) are less likely than medium to large farmers to want to shift to other fuels.

Conclusion

Livestock generate vast amounts of waste. Because of the increasing complexity of the external environment, the livestock and associated industries need a more sophisticated approach to waste than just waste treatment. This paper has shown how this is possible, through the principles of Cleaner Production, and through an understanding of how these wastes can be avoided either by changing practices to limit their production or by using the wastes as resources. In developing countries the concepts of Cleaner Production are no less important than in developed countries. For every livestock producer (primary or secondary) it is important to know the inputs and outputs to the place of production so that rational decisions can be made that prevent environmental pollution and maximise profits. The possibilities that arise from generating income from the sale of livestock by-products are very relevant to reducing poverty in developing countries.

The principles of Cleaner Production and quality management are essential tools in making the industry more effective, more economic and more environmentally responsible.

Acknowledgements

I would like to thank Bob Clements, Catherine Money, Ram Dalal, Gavin Ramsay, Alan Skerman and Mathew Redding for sending me lots of information and helping me in preparing this paper.

References

Adminis, U. and Money, C.A. (1998) Short-term preservation of hides and skins. *Meat Technology Update, AMT,* No. 98/3.

Bateup, B.O. and Christoe, J.R. (1996) Siroscour — a study of technical innovation. *Proceedings of Top Tech'96*, Geelong, Australia, November 1996, 419–431.

Bateup, B.O., Christoe, J.R., Jones, F.W., Poole, A.J., Skourtis, C. and Westmoreland, D.J. (1996). Effluent management. *Proceedings of Top Tech'96,* Geelong, Australia, November 1996, 408–418.

Bateup, B.O., Christoe, J.R., Jones, F.W., Poole, A.J., Skourtis, C. and Westmoreland, D.J. (2000). Where there is muck there is brass – turning an effluent problem into an opportunity. *Enviro 2000*, Sydney.

Bateup, B.O., Christoe, J.R., Jones, F.W., Poole, A.J., Skourtis, C. and Westmoreland, D.J. (2001) From filth to tilth — wool scouring in an environmentally sustainable world. *80th Textile Institute Conference*, Melbourne, 2001.

Christoe, J.R. and Bateup, B.O. (1987) Developments in wool scouring — an Australian perspective. *Wool Science Review* **64,** 25–43.

Cranston, R.W., Gleisner, R.W., Macoun, R.G., Simpson, C.M., Cowey, S.G. and Money, C.A. (1997) The total recycling of chromium and salts in tanning liquors. In: *Proceedings of IULTCS Centenary Congress*, London.

Davis, M.H. and Scroggie, J.G. (1980) *Das Leder* **31,** 1.

Gendebein, A., Ferguson, J., Brink, H., Horth, H., Sullivan, M., Davis, R., Brunet, H., Dalimier, F., Landrea, B., Krack, D., Perot, J. and Orsi, C. (2001) *European Commission-Directorate-General for Environment, Survey of Wastes Spread on Land — Final Report.* WRc Ref: CO4953-2.

Halweil, B. and Caron, M. (1998) United States leads world meat stampede. Worldwatch Press Briefing on the Global Trends in Meat Consumption, July 2, 1998.
http://www.worldwatch.org/alerts/pr980704.html

Hamner, B. (1996) What is the relationship between Cleaner Production, pollution prevention, waste minimisation and ISO 14000? Paper to *The 1st Asian Conference on Cleaner Production in the Chemical Industry.* Taipei, Taiwan.
http://www.cleanerproduction.com/misc/Pubs/CP%20Concepts.html

Lake, M., Pullar, S., Pagan, R. and Chiotto, N. (1999) Energy recovery from wet wastes — a viable Cleaner Production option. In: *Proceedings of the 2nd Asia Pacific Cleaner Production Roundtable*, Brisbane, Australia, 21–23 April 1999, 505 pp. http://www.acpa.org.au/General%20Industry/Lake.PDF

Maheswaran, J., Cody, J., Meehan, B., Baxter, F., Phung, K. and Dziedzic, A.-M. (1999) Conversion opportunities for agri-industry wastes. In: *Proceedings of Contaminated Wastes Industry Future Directions Conference*, Melbourne, November 1999.

Money, C.A. (1974) Short-term preservation of hides. *Journal American Leather Chemists Association* **69,** 112.

Money, C.A. (1998) Advanced chrome tanning methods. In: *UNIDO Workshop on Cleaner Technologies for Tanners*, Chennai, September 1998.

Money, C.A. and Adminis, U. (1974) Recycling of lime-sulphide unhairing liquors. *Journal of Society Leather Technology Chemistry* **58,** 35.

OPET (Organisation for the Promotion of Energy Technologies, Sweden) (2002) Web page: http://www.ecd.dk/bulletin/biogas-china.htm

Steinfeld, H., de Hann, C. and Blackburn, H. (1997) Industrial livestock systems and the environment. *Livestock and the Environment — Finding a Balance.* Chapter 4. http://www.fao.org/WAICENT/FAOINFO/AGRICULT/aga/lspa/LXEHTML/tech

UNEP (United Nations Environment Programme) (2001) Cleaner Production. Web page http://www.uneptie.org/pc/cp/understanding_cp/home.htm

UNEP (United Nations Environment Programme) (2002) Good practices — sectors. Livestock farms. *Sustainable Agri-Food Production and Consumption Forum.* 31 July 2002. http://www.agrifood-forum.net/practices/sector/livestock/21systems.asp

USDA/NRCS (United States Department of Agriculture / Natural Resources Conservation Service) (1995) *Animal Manure Management*. NRCS RCA Issue Brief 7, December 1995. http://www.nrcs.usda.gov/technical/land/pubs/ib7text.html

White, H.F., Cranston, R.W. and Money, C.A. (1991) Utilisation of hair from the Sirolime Unhairing Process. In: *Proceedings XXI IULTCS Congress,* Barcelona.

White, H.F., Money, C.A., Poole, J.M. and Karamoshos, D. (1993) Carbon dioxide deliming of thick hides. In: *Proceedings XXII IULTCS Congress,* Porto Alegre.

WCED (World Commission on Environment and Development) (1987). *Our Common Future.* Oxford: Oxford University Press, p. 43. http://sdgateway.net/introsd/definitions.htm