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Salinity reduction in tannery effluents in India and Australia

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Salinity reduction in tannery effluents in India and Australia

Hayden Fisher and David Pearce
Centre for International Economics

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2009

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Published by the Australian Centre for International Agricultural Research (ACIAR)

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Fisher H. and Pearce D. 2009. *Salinity reduction in tannery effluents in India and Australia*. ACIAR Impact Assessment Series Report No. 61. Australian Centre for International Agricultural Research: Canberra. 53 pp.

ISSN 1832-1879
ISBN 978 1 921615 02 3 (print)
ISBN 978 1 921615 03 0 (online)

Editing and design by Clarus Design
Printing by Elect Printing

Cover: Conventional salted hides, KKSK Tannery, Erode, India. The ACIAR-funded project developed a chilling system to replace salting. Photo: Mark Hickey, CSIRO.

Foreword

The Australian Centre for International Agricultural Research (ACIAR) has for many years assessed the realised and potential impacts of its substantial investments in discrete areas of research. In this study, it examines the research undertaken in India, where communities are suffering economically and socially from the salt pollution from tanneries. The effect of salinity on land and water is also a political issue in both India and Australia and, since 1995, there have been tannery closures in India due to pollution.

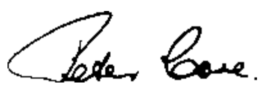
Tannery wastes with high levels of salt and other dissolved solids have led to high levels of pollution in groundwater and rivers in both India and Australia. Thus, ACIAR commissioned CSIRO Textile and Fibre Technology to undertake a project in collaboration with the Central Leather Research Institute in India that would develop technologies to reduce inputs of salt. The research took place between July 2002 and June 2008.

The project focused on reduction of effluent pollution in both India and Australia. Although the research delivered some outputs relevant to Australia, the Australian tanneries involved in the project subsequently closed due to their inability to compete with lower-cost producers. Since these project outputs are therefore unlikely to deliver any benefits to Australia, this impact assessment has focused on the outputs that are relevant to India.

This study found that the project had developed technologies that lower the salinity of tannery effluent by reducing the quantity of salt used for skin and hide preservation, and by recycling various liquors used in the tanning process.

In recent times, tanneries in Tamil Nadu state have been forced to comply with new government regulations covering their discharge. The authors of the study contend that the technologies developed under the ACIAR-funded project will substantially reduce leather production costs, mainly by lowering the cost of effluent treatment and waste-salt disposal. They highlight the value of developing technologies that reduce the level of pollutants rather than dealing with the pollution further down the line.

The estimated net benefits to Indian tanneries of A$47.3 million in present-value terms (using a 5% discount rate), of which $22.4 million can be attributed to ACIAR on a cost-share basis, are very gratifying. They represent an impressive 32.4% internal rate of return. Although acknowledging that these benefits hinge on uptake of the research, there are likely to be many converts once players in the industry realise the rewards of investing in the new technologies. Adoption by just 10–20% of the tanneries across the country (mostly in Tamil Nadu) would be a resounding justification for the research investment.



Peter Core
Chief Executive Officer
ACIAR

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
CEMCOT	Chennai Environmental Management Company of Tanners
CETP	common effluent treatment plant
CLRI	Central Leather Research Institute (India)
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DCLR	direct chrome liquor recycling
FAO	Food and Agriculture Organization of the United Nations
PLR	pickle liquor recycling
ppm	parts per million
RO	reverse osmosis
Rs	rupees (Indian monetary unit)
TDS	total dissolved solids

Acknowledgments

The authors would like to thank the Central Leather Research Institute for its cooperation and assistance in preparing this impact assessment. In particular, we thank:

- Professor Dr Asit Baran Mandal
- Dr A. Amudeswari
- Dr C. Muralidharan
- Dr N.K. Chandra Babu
- Dr J. Raghava Rao
- Mr P. Saravanan
- Mr D. Chandramouli
- Mr V. John Sundar.

We also thank the tanners and other tanning industry stakeholders, who were all generous with their time. From the Chennai Environmental Management Company of Tanners, we thank:

- Mr A. Sahasranaman
- Mr K.V. Emmanuel.

From S.A. Abdul Azeez & Co. tannery in Erode, we thank:

- Mr S.A.M. Yousoofeen
- Mr Nisarahmad
- Mr Cranston.

From KKSK Tannery in Erode, we thank:

- Mr Rafiq.

From TAW Tannery in Ambur, we thank:

- Mr T. Rafeeq Ahmed
- Mr A. Naveed Ahmed
- Mr Williams
- Mr Jawaad.

We thank the following members of the All India Skin and Hide Merchants and Tanners Association:

- Mr S. Mohammed Hassan
- Mr N. Abdur Rahman
- Mr S.M. Faiyaz Ahmed
- Mr Mohamed Nazeeb
- Mr M. Fayaz Ahmed
- Mr R. Ramesh Prasad
- Mr S. Gopalakrishnan
- Mr C.M. Zafarullah
- Mr C.N.S. Ahmed
- Mr Y. Ayoob Khan.

From the Madras School of Economics, we thank:

- Professor U. Sankar.

We also thank Dr Catherine Money (formerly of CSIRO) from Catherine Money Consulting.

Finally, we thank Ms Simrat Labana of ACIAR and Dr A. Amudeswari of the Central Leather Research Institute for organising the meeting program in India from 16–20 March 2009.

Summary

The tanning industry is an important contributor to economic output in India, particularly in the state of Tamil Nadu, the source of around 60% of India's total leather production.[1] However, high salinity of effluent from tanneries has caused significant environmental damage. In particular, tannery effluent has increased the salinity of groundwater and river systems, which has had an adverse impact on the productivity of agricultural land and the quality of drinking water surrounding tannery clusters. Consequently, norms on the discharge of various pollutants were imposed on tanneries in Tamil Nadu. Following improvements to effluent treatment practices, most of these norms were met. One exception was the total dissolved solid norm of 2,100 parts per million.

Reducing the salinity of effluent was a common challenge for both Indian and Australian tanners. The Australian Centre for International Agricultural Research (ACIAR) therefore provided funding for a project (AS1/2001/005: *Salinity reduction in tannery effluents in India and Australia*) that aimed to reduce the salinity of tannery effluent by developing technologies that reduced salt inputs. The project was undertaken by CSIRO Textile and Fibre Technology in partnership with the Central Leather Research Institute (CLRI) in India and ran from July 2002 to June 2008 (including two extensions). During this period, ACIAR contributed A$0.8 million (in nominal terms) of a total budget of A$1.9 million.

Outputs and adoption

The project delivered a package of four technologies that have been shown to be effective in Indian conditions:

- low-salt preservation of goat skins
- preservation of hides and skins through chilling
- direct chrome liquor recycling
- pickle liquor recycling for vegetable tanning (tanning using compounds from plants).

The first two outputs focus on reducing the salt used for skin and hide preservation, the others on recycling liquors used in tanning processes.

As a result of some significant barriers, few tanneries have so far adopted the new technologies. First, many tanneries have been focusing on 'end-of-pipe' treatment of effluent, in line with the Tamil Nadu Pollution Control Board's zero-liquid-discharge requirements, rather than reducing salt inputs. This has required effluent to be treated using reverse osmosis (RO) technology. Second, the end users of the preservation technologies are the slaughterhouses, village butchers, flayers, and skin and hide dealers, rather than the tanneries. Many tanners argued they do not have sufficient control over their skin and hide suppliers to enforce the required changes. Third, there appears to be some reluctance to change entrenched practices without either government assistance or regulation compelling adoption of these technologies.

However, it seems that the technologies developed under the ACIAR-funded project will be part of the solution to reducing salt pollution. Even without regulation or government assistance, it is in tanners' own interests to adopt them. This has not yet been fully appreciated by tanners. It is likely that it will as the costs associated with RO treatment become better understood.

CLRI is confident that the technologies will be adopted by 10–20% of tanners across the country, mostly in Tamil Nadu.

[1] Project final report (Money 2008, p. 1)

Outcomes

Adoption of the technologies developed through the ACIAR-funded project will significantly reduce the salt used in tanning processes and therefore the salinity of effluent. Largely because of lower costs of effluent treatment and waste-salt disposal, adopting the low-salt technologies is estimated to significantly reduce the cost of leather production. This is despite the significant investment required to implement most of the technologies. Some technologies are also estimated to reduce the costs of salt and other chemical inputs, and transport.

Impacts

Rather than reducing the costs associated with high salinity imposed on local farmers and households, lower salt inputs will reduce costs for tanners. The zero-liquid-discharge requirements will reduce the salinity of rivers and groundwater sources. Adoption of the reduced-salt technologies will decrease the cost of complying with zero-liquid-discharge requirements.

Lower costs will directly benefit tanners and result in a higher level of output than would otherwise have been the case.

Estimated net benefits

It is estimated that, in constant 2008–09 dollars, the project will deliver benefits to Indian tanners of around A$49.4 million in present-value terms, using a discount rate of 5%. Of these total benefits, A$22.4 million can be attributed to ACIAR on a cost-share basis. These estimated benefits significantly exceed the cost of the project, which was A$2.1 million when expressed in comparable terms. This is a net benefit of A$47.3 million and a benefit of A$23.60 for every A$1.00 spent. The internal rate of return on the project is estimated to be 32.4%. All four technologies are expected to deliver benefits to those tanneries that adopt them, with the largest benefits coming from direct chrome liquor recycling and chilling.

These estimates are subject to significant uncertainty, since most of the benefits will occur in the future, which cannot be known with any certainty. The key risk is that the new technologies are not adopted, or adoption is much lower than expected. The estimates are also sensitive to some of the key assumptions used. Nevertheless, the broad conclusion that the project is likely to deliver benefits to Indian tanneries that significantly exceed the costs is robust to variations of these assumptions within a plausible range.

Conclusions

A number of broad lessons that may be relevant to future projects can be drawn from this impact assessment:

- The project has demonstrated that research aimed at finding technological solutions to pollution problems can deliver significant benefits to developing countries.
- To find a technological solution to pollution problems, this project has also shown it can be beneficial to look for technologies that reduce the use of pollutants, as well as technologies that treat the pollution.
- The project has also demonstrated that developing a package of technologies reduces the risk of the project delivering no benefits due to non-adoption.
- The difficulties tanners foresee in getting their skin and hide suppliers to adopt reduced-salt preservation technologies demonstrate that the end users of new technologies must have an incentive to adopt.
- Finally, the project has shown that changes to the regulatory environment can affect the impacts of research and development projects. The project was initially expected to reduce the level of pollution and therefore benefit the farmers and households surrounding tannery clusters. But since zero-liquid-discharge requirements mean that river and groundwater salinity would have been reduced even without the project, all the benefits instead flow to the tanneries by reducing the cost of achieving zero liquid discharge.

The pathways to benefits from the project are summarised in Figure 1.

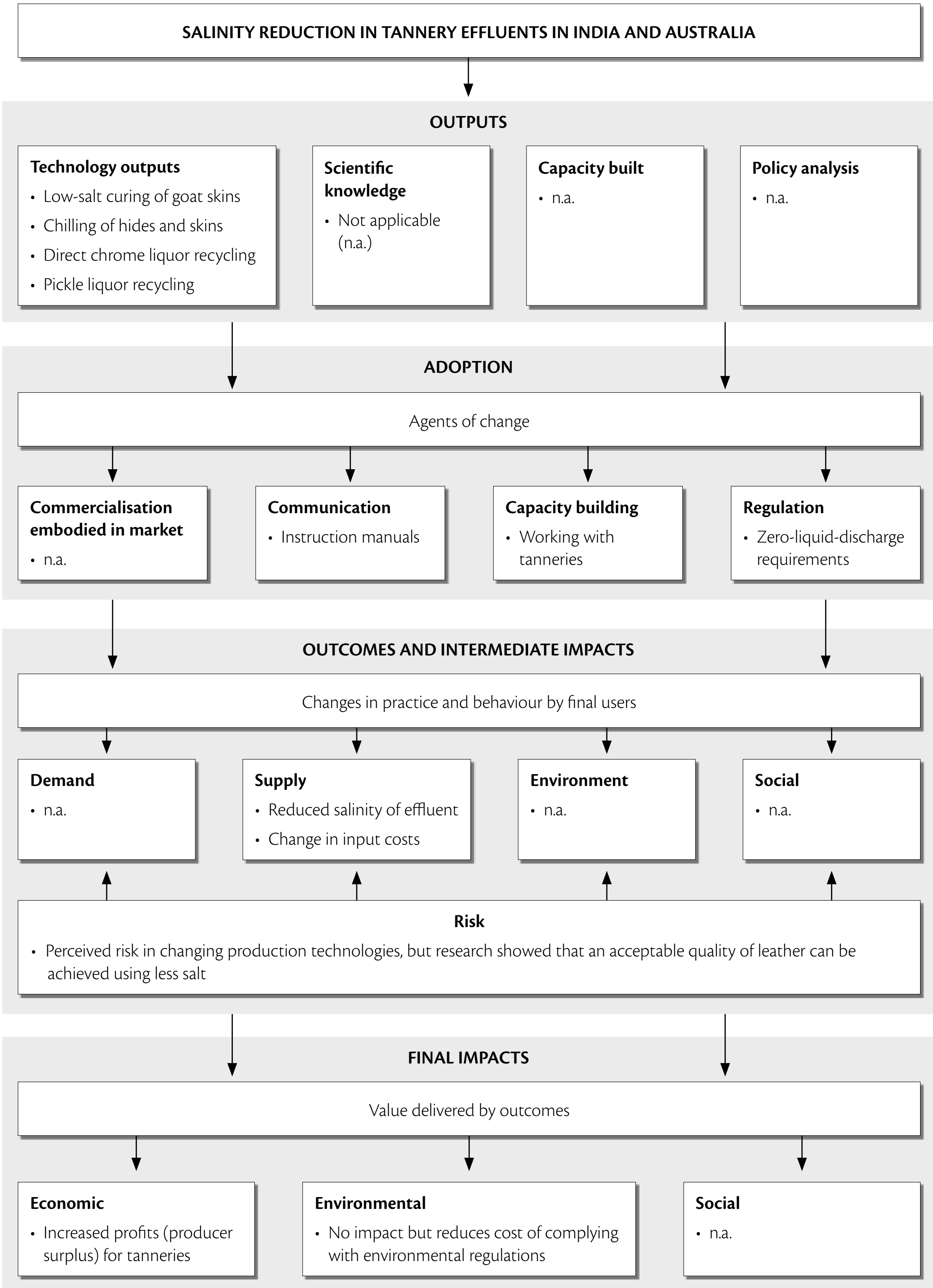

Figure 1. Pathways to benefits from ACIAR project AS1/2001/005. Sources: Davis et al. (2008); Centre for International Economics

1 Introduction and overview

The leather industry in India

India is one of the world's largest leather producers. The leather industry is therefore a significant contributor to economic activity and employment, particularly in the state of Tamil Nadu, where around 60% of tanning occurs.[2] Leather and leather products are also an important source of export earnings. India's leather industry includes all stages in the supply chain, from the recovery of skins and hides from slaughtered and fallen animals, through to the tanning process to produce semi-finished and finished leather, and the manufacture of final leather products such as shoes and other apparel.

Cattle, goats and sheep are the most common sources of raw skins and hides for the tanneries in India. The slaughter of most animals throughout India takes place in small butcheries in villages and small towns throughout the country. There are some larger slaughter-houses that operate like a service centre for farmers. However, even these slaughterhouses are relatively small-scale operations. It is illegal to slaughter cattle in India, except in the states of Kerala and West Bengal and the north-eastern states. However, the hides and carcasses of animals that have died can be recovered for further use.[3]

After the hides or skins are removed from animals in the village butcheries and slaughterhouses, salt is applied immediately to preserve the skin or hide until it is tanned. Salt is the preferred option for curing because it is cheap and readily available. Typically, a small trader or the agent of a large hide and skin dealer then collects the skins and hides, and takes them to weekly markets held in many important centres of the country. The hides and skins of some animals that are slaughtered close to major markets are brought to the dealers in green form and are salted by the dealer. Anywhere between 1 and 6 weeks can elapse from the time an animal is slaughtered to when the hide or skin is processed in a tannery.[4]

The level of processing varies across tanneries. Many tanneries process all the way from raw hides and skins to finished leather. Others process only to the semi-finished, 'wet–blue' or 'EI' stage, and then either sell the semi-finished leather to another tannery that processes from semi-finished to finished leather, or pay such a tannery to finish the leather for them for sale to leather product manufacturers. The supply chain from primary producers through to the final consumers of leather products is summarised in Figure 2.

Tanneries in India use two main tanning processes. Around 70% of leather is tanned using the 'chrome' process (so called because it uses compounds of chromium), while most of the remaining 30% is produced using a vegetable tanning process (so called because it uses tannins from plants).[5] The finished leather from these tanning processes has different characteristics, but sells at around the same price. While vegetable tanning costs significantly more than chrome tanning, it can hide natural flaws and therefore can be cost-effective for lower quality raw material.[6]

India currently contributes around 7% of total world production of raw hides from cattle and buffalo (by wet salted weight), around 3% of total world production of raw sheep and lamb skins, and around 18% of raw goat

2 Project proposal (CSIRO 2001, p. 19)

3 Project review (Sahasranaman and Jackson 2005, pp. 31–32)

4 Project review (Sahasranaman and Jackson 2005, pp. 31–32)

5 Dr N.K. Chandra Babu (pers. comm., 16 March 2009)

6 Mr A. Naveed Ahmed (pers. comm., 19 March 2009)

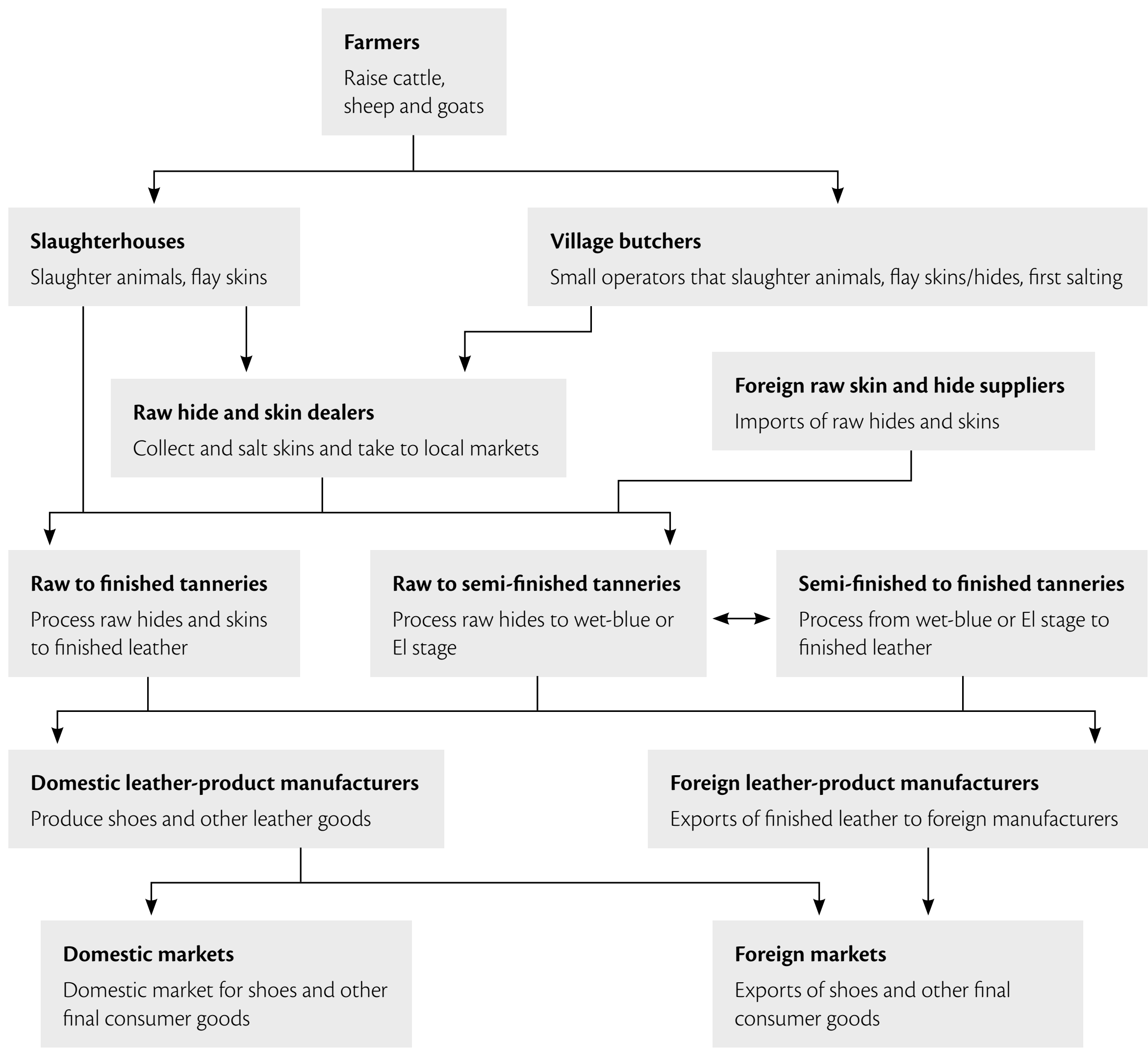

Figure 2. The leather supply chain in India

and kid skins (by dry weight). India's share of world production of sheep and, particularly, goat skins has declined since the late 1980s (Figure 3). Around 11% of world production of heavy leather from bovine animals, 5% of world production of light leather from bovine animals and 10% of world production of light leather from sheep and goats is from India. India's share of world leather production has also declined since the late 1980s.

The Government of India identified the leather industry as a potential growth industry in its Eleventh Five Year Plan,[7] despite the relatively modest growth of the industry over recent years.

[7] Planning Commission, Government of India (2008, pp. 179–181)

Environmental issues

While the tanning industry is an important contributor to economic activity, effluent from tanneries is one of the contributing factors for increasing salinity in rivers and groundwater. This has had adverse effects on local communities by reducing the productivity of agricultural land and the quality of drinking water. In the 1990s, the Vellore Citizens Forum, a non-government organisation, lodged a public-interest litigation in the Supreme Court, claiming that tanneries were not treating effluent properly. The Tamil Nadu Pollution Control Board responded by forcing all tanneries in the

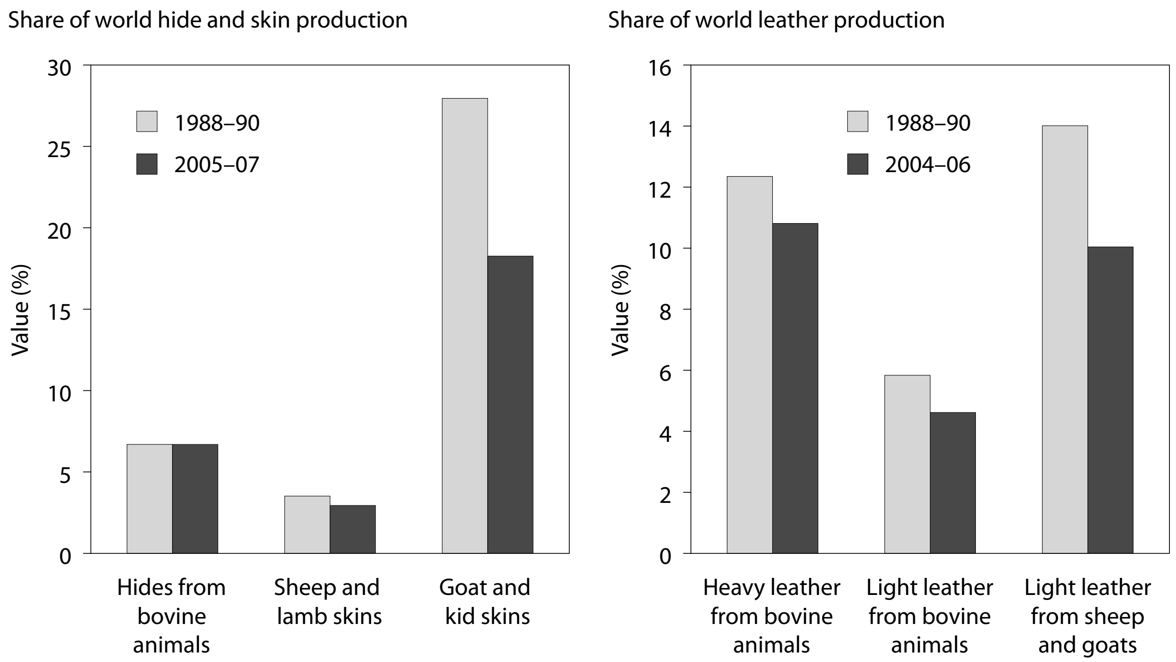

Figure 3. India's share of world production of hides, skins and leather. Data source: FAO (2008)

state that were not meeting biological oxygen demand norms of 30 mg per litre—around 400 tanneries in all—to close immediately.[8] It also became necessary for the remaining tanneries to improve their effluent-treatment practices to meet the strict pollution norms. Tanneries in India are found in clusters throughout the country and are mostly small-scale enterprises. As a result, the effluents from many tanneries are treated by common effluent treatment plants (CETPs), which service multiple tanneries within a cluster. Currently, the cost of operation of each CETP is shared among its members, based on the volume of effluent discharged.[9] Tamil Nadu has the strictest regulations and enforcement mechanisms of any state, and therefore 14 of the 18 tannery CETPs are located there.[10] All operational tanneries in Tamil Nadu are now either connected to a CETP or have their own effluent-treatment plant. By the end of the millennium, most of the discharge requirements were being met by tanneries. One major exception was the total dissolved solids (TDS) norm of 2,100 ppm, which is a measure of the salinity of tannery effluent.

8 Dr N.K. Chandra Babu (pers. comm., 17 March 2009)

9 Project review (Sahasranaman and Jackson 2005, p. 32)

10 Project review (Sahasranaman and Jackson 2005, p. 32)

Salinisation of rivers and groundwater has led to loss of agricultural production and reduced drinking water quality in Tamil Nadu.[11] It has been estimated that over 55,000 hectares of land have been contaminated by tannery wastes.[12] In addition, around 5 million people are affected by a poorer social environment and lower quality drinking water.[13] Following the public interest litigation, the Supreme Court established the Loss of Ecology Authority to determine what compensation tanners should pay farmers for the loss of agricultural production. Sixty tanneries in the Vellore district were required to pay compensation of around Rs300 million (about US$6.6 million) for the damage caused by salinisation of groundwater in the region during 1991–98.[14] The payments were determined on the basis of a detailed study that, among other things, considered soil salinity in various areas. The Loss of Ecology Authority is planning to go through a similar process to determine the damage caused between 1998 and 2008.

11 Project final report (Money 2008, p. 21)

12 Project proposal (CSIRO 2001, pp. 20–21)

13 Project review (Sahasranaman and Jackson 2005, p. 24)

14 Project proposal (CSIRO 2001, p. 8)

The ACIAR project

Since reducing salinity in tannery effluents was a common challenge faced by tanneries in both India and Australia, CSIRO Textile and Fibre Technology (hereinafter referred to as CSIRO) was commissioned to undertake the project *Salinity reduction in tannery effluents in India and Australia* (ACIAR project AS1/2001/005), which began in July 2002. The project was initially expected to be completed by June 2005. However, the external project reviewers (Sahasranaman and Jackson 2005) recommended that the project be extended for 2 years to June 2007 to further develop, consolidate and magnify the benefits of the results.[15]

The extension aimed to cover implementation of the new technologies in Indian tanneries. Subsequently, the project was further extended (unfunded) until March 2008 to allow implementation in India of chilling of hides and direct chrome liquor recycling (DCLR).

Objectives

The overall aim of the project was to develop, evaluate and apply systems to eliminate or reduce salt use in hide and skin preservation and processing, so as to significantly reduce the TDS in tannery effluent.[16]

Specific objectives

Initially, 'air drying and dry salting of skins' and 'short-term preservation with chemicals and chilling' were two of the specific objectives of the project. However, the objectives were revised in 2004 because there was some overlap between the two and it seemed unlikely that air drying or dry salting would be adopted for skin preservation. Work on drying therefore did not continue.

The revised project activities and objectives were as follows:

- Low-salt preservation for up to 21 days
  - to develop low-salt preservation systems for up to 21 days for Indian goat skins and Australian sheep skins.
- Chilling of hides and skins
  - to develop hide chilling systems suitable for India.
- DCLR, including recovery and re-use of excess liquor to reduce TDS
  - to enable development of DCLR for India to reduce TDS, determine the effect of pickle pH and temperature on chrome complexes and chrome penetration for Indian chrome powder.
- Pickle recycle systems for TDS reduction
  - to investigate systems to allow indefinite pickle re-use for Australian woolskins and Indian vegetable-tanned leathers
  - to allow production of vegetable-tanned leathers with reduced salt use and lower TDS discharge.[17]

Collaborators

The key Indian collaborator was the Central Leather Research Institute (CLRI), based in Chennai. CLRI was founded more than 60 years ago and is the world's largest leather research institute. It has direct roles in education and training, research, testing, designing, forecasting, planning and social empowerment issues relating to the leather industry. CLRI's facilities support innovation in leather processing, creative design of leather products including garments, accessories and footwear, and the development of new environmental technologies for the leather industry.[18]

Commercial trials were also conducted at a number of tanneries in India, including TAW, KKSK and AA Abdul Azeez. In Australia, the CSIRO collaborated with two tanneries—Kreglinger Australia and Black Diamond Industries—both located in Victoria.

Other relevant research

A previous ACIAR project, *Pollution of agricultural land due to waste disposal from tannery industries* (AS1/1993/022), focused on chromium compounds in tannery effluents.

15 Project review (Sahasranaman and Jackson 2005, p. 26)

16 Project final report (Money 2008, p. 7)

17 Project proposal (CSIRO 2001, p. 6)

18 CLRI website at <http://www.clri.org/>, accessed 21 January 2009

The United Nations Industrial Development Organization (UNIDO) Regional Programme for Pollution Control in the Tanning Industry in South-East Asia has also conducted research in this area, although not specifically on reducing salt inputs in the tanning process.

In line with India's Eleventh Five Year Plan, reducing the environmental impacts of tanning is currently a major focus of research at CLRI.[19]

Funding

ACIAR contributed around $0.8 million to the overall project budget of $1.9 million (Table 1). CSIRO made an in-kind contribution of $0.6 million, largely made up of personnel and infrastructure costs. CLRI contributed $0.4 million in mainly in-kind personnel costs. There were also small in-kind contributions from Kreglinger Australia and Black Diamond Industries, which included processing and evaluation of dry-salted skins, as well as equipment and storage. In addition to the contribution to the ACIAR-funded project and the extensions, CLRI estimates it needs a further A$100,000 to encourage tanners to adopt the new technologies over the next few years.[20] It is appropriate to consider these costs as a project input.

Table 1. Funding (A$'000) of ACIAR project AS1/2001/005

	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	Total
Australia											
ACIAR	208.9	206.5	203.7	15.0	17.5	17.5	–	–	–	–	669.0
CSIRO	198.7	185.6	189.8	7.8	3.9	3.9	–	–	–	–	589.7
Kreglinger Australia	8.3	23.9	15.3	–	–	–	–	–	–	–	47.5
Black Diamond	8.3	23.9	15.3	–	–	–	–	–	–	–	47.5
Total – Australia	424.2	439.8	424.1	22.8	21.4	21.4	–	–	–	–	1,353.7
India											
ACIAR	48.9	60.4	37.8	–	–	–	–	–	–	–	147.1
CLRI	52.5	54.0	52.5	48.5	24.3	24.3	25.0	25.0	25.0	25.0	356.0
Total – India	101.4	114.4	90.3	48.5	24.3	24.3	25.0	25.0	25.0	25.0	503.1
Total											
ACIAR	257.7	266.9	241.5	15.0	17.5	17.5	–	–	–	–	816.1
Other	267.8	287.4	272.9	56.3	28.2	28.2	25.0	25.0	25.0	25.0	1,040.7
Total	525.6	554.2	514.4	71.3	45.7	45.7	25.0	25.0	25.0	25.0	1,856.8

Sources: ACIAR budget; Dr A. Amudeswari (pers. comm., 20 March 2009)

Note: ACIAR = Australian Centre for International Agricultural Research; CSIRO = Commonwealth Scientific and Industrial Research Organisation (Australia); CLRI = Central Leather Research Institute (India). Due to rounding of numbers, some columns do not sum exactly.

19 Dr Mandal (pers. comm., 16 March 2009)

20 Dr A. Amudeswari (pers. comm., 20 March 2009)

2 Outputs and adoption

Project outputs

The research focused on developing, for Indian conditions, techniques that lower effluent salinity. While the project also delivered some outputs relevant to Australia, the Australian tanneries involved subsequently closed due to an inability to compete with lower cost producers.[21] These outputs are therefore unlikely to deliver any benefits, so the impact assessment focuses on the outputs relevant to India.

Around 50% of the salinity in tannery effluent in India is attributable to the salt used for hide and skin preservation.[22] One focus of the research was therefore on reducing salt inputs at the preservation stage. In this area, the project delivered two new technologies that reduce (or eliminate) the quantity of salt used for preservation:

- low-salt preservation of goat skins
- hide and skin preservation by chilling.

Various salts are also used in pickling and tanning. Another focus of the research project was therefore on reducing salt discharge at that stage of production. The project delivered two techniques for recycling tanning liquors:

- direct chrome liquor recycling (DCLR)
- pickle liquor recycling (PLR) for vegetable tanning.

An outline of each of these four outputs follows.

[21] Project final report (Money 2008, p. 24)

[22] Dr N.K. Chandra Babu (pers. comm., 17 March 2009)

Reduced salt use in skin preservation

The project delivered a low-salt system for the preservation of goat skins that is commercially viable for end users and which produces acceptable leather quality. Currently, skins are treated with salt amounting to 50–100% of the weight of the skin. Following laboratory and industry trials, it was determined that the industry preferred—over air drying and dry salting systems—a low-salt system without drying.

Larger scale commercial trials were conducted at TAW tannery in Ambur. The trials found that preservation for 21 days could be achieved using 20% salt with an appropriate additive. Various additives were tried. Magnesium oxide, for example, was found to be an unsatisfactory additive, since it resulted in skins sticking together in summer.[23] Use of sodium carbonate (soda ash), on the other hand, produced satisfactory results. To encourage adoption, an instruction manual detailing the low-salt system was produced.

Preservation by chilling

To eliminate the need to use salt in preservation, a chilling system was investigated as an alternative. A hide-chilling system that is effective under Indian conditions was developed through laboratory and industry trials in Erode and Kerala. The chilling system uses no salt, yet produces leather of an acceptable quality. The process for hide preservation by chilling is as follows:

- The hides are brought to a chiller within a few hours of slaughter, to avoid damage.
- The hides are then hung on hooks on a conveyor in the chiller and chilled to 5° C or less in 1 hour while they drain. They are then removed from the hooks

[23] Project final report (Money 2008, p. 11)

and dropped into a crate that is kept chilled. Hides quickly chilled to 5° C or less can be held for up to 1 week.

- The crates of chilled hides are transported in insulated or refrigerated trucks to the tannery, which has a chiller to store the hides.[24]

The system therefore requires:

- blast chillers with generators, and additional chilled storage areas at collection centres
- insulated and possibly air-conditioned trucks for transport
- chilled storage areas for holding hides at tanneries before processing
- quick delivery of hides to collection centres
- a number of other changes to operational processes.[25]

An acceptable chilling system for goat and sheep skins was also developed. Chilling improved the quality of goat skins, compared with those produced using existing processes. An instruction manual detailing the chilling system under Indian conditions was produced to encourage adoption.

Direct chrome liquor recycling

Tanneries in Tamil Nadu are already required to recover the chromium salts ('chrome') used in tanning. Chrome powder is relatively expensive, so the recovered chrome is re-used. Unlike the current chrome recovery system, DCLR recycles the entire chrome liquor, which also reduces the salinity of effluent. Laboratory trials established the conditions required for DCLR to be effective. It was established that when the used chrome liquor is acidified to pH 1 and aged for 12 hours before re-use, good-quality leather is produced. It was found that, with good practice, chrome liquors can be recycled continuously, more or less eliminating effluent from this particular source.[26] A manual was produced to encourage adoption.

Improved pickle recycle systems

Another source of salinity in tannery effluent is from the discharge of pickle liquors. Laboratory and industry trials in India established that it is possible to recycle pickle liquors up to 12 times without compromising skin quality.[27] It was found to be important to acidify the spent pickle liquor soon after a pickle cycle is finished. A manual was produced.

Adoption of outputs

Few tanneries have so far adopted the new technologies developed under the ACIAR-funded project. A range of factors, including government policies favouring alternative technologies, high upfront implementation costs, logistical issues arising as a result of India's highly decentralised hide and skin supply systems, and resistance to changing entrenched practices, have proven to be significant barriers to adoption. In the longer term, however, it seems likely that at least some tanneries in Tamil Nadu will adopt the low-salt technologies because ultimately it is in their own interests to do so. This is largely because of the cost savings associated with effluent treatment and disposal of waste salt. These cost savings do not yet appear to be fully appreciated by tanners. Depending on the technology, there are also savings in costs of salt and other chemical inputs, and transport.

Government policies that focus on 'end-of-pipe' mitigation measures, rather than salt-reduction technologies, have so far proven to be a barrier to adoption. The Tamil Nadu Pollution Control Board has mandated a zero-liquid-discharge regime for tanneries that are unable to meet the 2,100 ppm TDS norm—which means, in effect, all of them—even if they adopt the low-salt technologies developed under the project. This requires that all effluent be treated by reverse osmosis (RO) and an evaporation system to ensure there is no liquid discharge. RO is essentially a filtering system that recovers around 75–80% clean water from effluent. This water can be re-used in tanning processes. Evaporation to dryness of the remaining 20–25% of highly concentrated reject liquid allows recovery of the mixed salts it

24 Project final report (Money 2008, p. 16)

25 Project final report (Money 2008, pp. 15–16)

26 Project final report (Money 2008, pp. 17–18)

27 Mr P. Saravanan (pers. comm., 16 March 2009)

contains. The Indian central government subsidised 50% of the capital cost of this technology for CETPs, with the Tamil Nadu state government contributing a further 15%.[28] Tanners have therefore been focusing on the costly implementation of RO and evaporation systems, rather than reducing salt inputs. However, in the longer term, the zero-liquid-discharge regime will provide a strong incentive for tanneries to adopt reduced-salt technologies, because reducing salt inputs reduces the cost of treating effluent and disposing of waste salt (see Chapter 3 for further details). This is effectively shifting the burden of the cost of salt use from local communities to tanneries themselves.

The upfront investment in new equipment required to implement a number of the new technologies is also a significant barrier to adoption. Many tanneries are small family businesses that can have difficulty accessing cheap capital. Some tanners also perceive that there is some risk associated with new technologies, and resistance to changing entrenched practices is also evident.[29]

Nevertheless, as argued in the project final report (Money 2008), once the costs of RO treatment and disposing of waste salt are recognised by tanners, at least some tanneries in Tamil Nadu are likely to eventually adopt the low-salt technologies.[30] The Chennai Environmental Management Company of Tanners (CEMCOT) is currently helping seven CETPs in Tamil Nadu install RO and evaporation systems. These CETPs currently have a combined capacity to treat 13,000 m^3 (cubic metres) of effluent per day and service 440 tanneries. These new facilities will include impervious salt-storage sites with the capacity to store recovered salt from desalting conventionally salted hides and skins and from the evaporation of saline effluents and RO concentrates for 3 years. Importantly, these new facilities will also have the capacity to measure effluent TDS load from each connected tannery, as well as the volume of effluent. This will make it possible to charge tanneries on the basis of TDS load, which will pass on the price signal to individual tanneries.[31]

A discussion of adoption issues specific to each technology follows.

28 Project final report (Money 2008, p. 21)

29 Project final report (Money 2008, p. 15)

30 Project final report (Money 2008, p. 21)

31 Mr A. Sahasranaman (pers. comm., 16 March 2009)

Low-salt preservation of goat skins

Low-salt preservation is a relatively simple, cost-effective technology that significantly reduces the quantity of salt used in skin preservation. However, the end users of this technology are not the tanners but the butchers and skin dealers that salt the skins. Since skin suppliers in India are highly dispersed across thousands of villages, slaughterhouses and skin dealers, the logistics of disseminating this technology to end users is a key barrier to adoption. Moreover, some tanners argued that they do not have sufficient control over their skin suppliers to insist on low-salt skin preservation. TAW and some other larger tanneries operate their own collection centres and have sufficient control over some skin suppliers to insist on low-salt preservation. However, not even the largest tanners can control all of their suppliers and many are resistant to change. Some tanners argued that CLRI would be better served by marketing this technology to skin dealers. A key problem seems to be that the skin dealers do not appear to have any incentive to change. As will be discussed in Chapter 3, the benefits of reducing salt inputs accrue to tanners, in terms of lower costs of transport, effluent treatment and waste-salt disposal. Tanners nevertheless argued that it is not commercially viable to pay a premium for skins preserved with less salt and therefore provide a price incentive for skin dealers. These attitudes may change once the full benefits of reduced salt are understood by tanners.

Although CLRI has produced manuals that clearly specify the correct mix of salt and soda ash, and easy rules of thumb on how much of the mix to apply, some skin dealers have low levels of literacy. One solution proposed is for tanners to provide suppliers with a pre-mix that would be distributed to villages and slaughterhouses by local skin dealers.

While these barriers present some difficult challenges, they are unlikely to be insurmountable. TAW has implemented the system for at least some of its skin suppliers, and is satisfied with the preservation system and the quality of the leather produced. Other tanneries are expected to follow. CLRI estimates that adoption of this technology could reach around 15–20% of the industry across India, with adoption occurring over the next 2–3 years. Since zero effluent discharge applies only in Tamil Nadu, tanneries in that state are the most likely to adopt. This would equate to slightly less than 30% of goat skins processed in Tamil Nadu.[32] Adoption typically follows an S-shaped curve, with adoption occurring slowly at first, then accelerating as the technology catches on, and subsequently slowing as it reaches maximum adoption. The adoption profile estimated for this study is shown in Figure 4.

Chilling

In encouraging the adoption of chilling technology, CLRI appears to face even greater challenges than for low-salt preservation. Chilling has limited applicability in India because of the highly decentralised skin and hide collection systems. A chilling system would be applicable only where green hides can be secured by the tanneries either directly or through their dealers within around 3–4 hours of slaughter. The travel time from the source of raw material to the tannery by road transport should be no more than 12 hours.[33] Since tanneries in Tamil Nadu source skins from all over India, this is a key barrier to the widespread adoption of chilling technology. While it could be applicable when the chilled storage facility is located close to a large slaughterhouse, there are few slaughterhouses of sufficient size to achieve the scale required to make this technology viable. Chilling may become more applicable in an Indian context as slaughterhouses increase in scale with the development of meat-production systems over time.

Adoption of chilling also faces many of the same supply-chain challenges as low-salt preservation. CLRI demonstrated the technology to KKSK tannery using its mobile chilling facility. The tannery is satisfied that the technology works, but remains concerned about its practical application. Some tanners also insisted that either the skin and hide dealers or the government should be responsible for providing the blast chiller and chilled storage facilities at the collection centre. They perceived that the risks associated with a tannery investing in chilling facilities are too high, since the skin and hide dealers could choose not to deal with them and continue using salt.

Despite these challenges, it seems likely that chilling will eventually be adopted by at least some tanneries. A key advantage of chilling is that it uses no salt.

32 This is estimated on the basis that Tamil Nadu is the source of around 60% of leather produced in India.

33 Project review (Sahasranaman and Jackson 2005, p. 16)

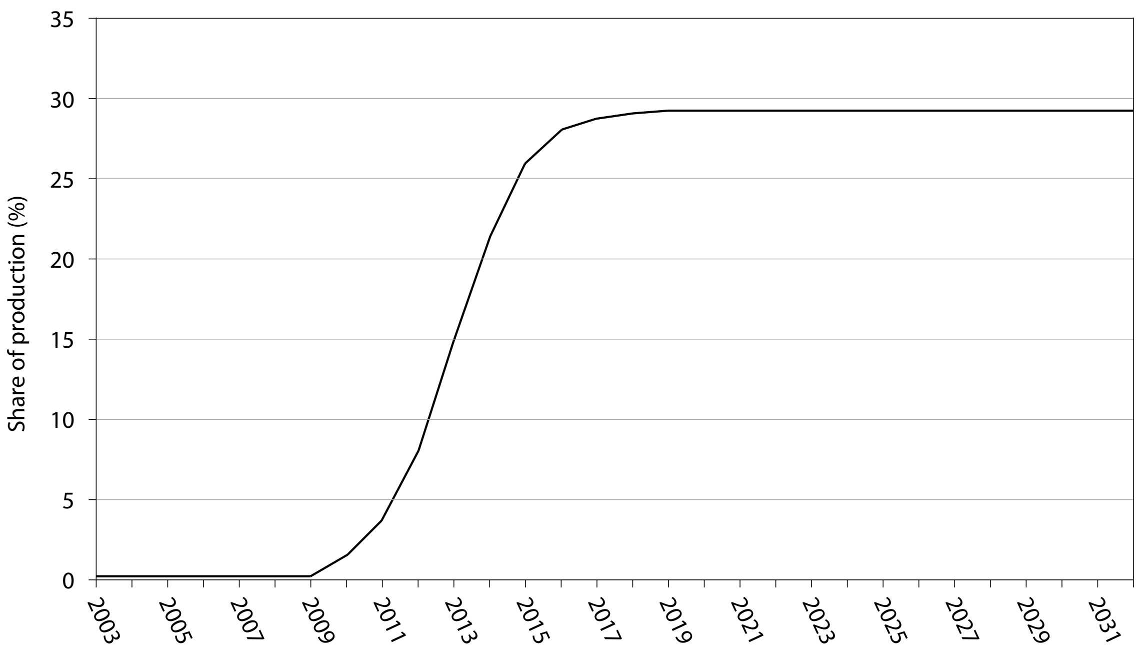

Figure 4. Estimated adoption profile for low-salt preservation of skins for tanning. Data sources: Central Leather Research Institute; Centre for International Economics

Chilling could therefore be part of a longer term, no-salt solution if the logistical and incentive problems can be solved. It was also noted that the vegetable industry is starting to use chilling technologies, which could demonstrate to tanneries that they are feasible under Indian conditions.[34]

However, the primary reason chilling is likely to be adopted is that there appear to be significant benefits for those tanneries that do so. In contrast to the project final report (Money 2008), which argued that chilling would not currently provide a rate of return on the investment, our estimates indicate that there would be significant cost savings to tanneries in Tamil Nadu from adopting this technology once the effluent treatment and waste-salt disposal costs are taken into account (see Chapter 3). It is, nevertheless, critical for skin and hide dealers to be provided with an incentive to participate in a chilling system. Some of the benefits flowing to the tanneries will therefore need to be passed on.

34 Dr N.K. Chandra Babu (pers. comm., 17 March 2009)

The external reviewers estimated that potentially about 10% of hides and skins produced in the country could be covered by this technology.[35] This is equivalent to around 16% of the skins and hides processed in Tamil Nadu. CLRI researchers felt this was an optimistic, but achievable, target.[36] They suggested that, at best, this could be achieved in around 2–3 years. Since the barriers to adoption for this technology seem to be even more challenging than for low-salt preservation, some tanneries suggested a time frame of 5–6 years might be more realistic. The adoption profile used in this study is shown in Figure 5.

Direct chrome liquor recycling

There are fewer barriers to adoption of the recycling technologies developed under the ACIAR-funded project, since the end users of these technologies—the tanneries—are also the beneficiaries. However, tanning is as much an art as a science and there is some reluctance to change tanning processes in case this reduces the quality of leather.

35 Project review (Sahasranaman and Jackson 2005, p. 17)

36 Dr N.K. Chandra Babu (pers. comm., 16 March 2009)

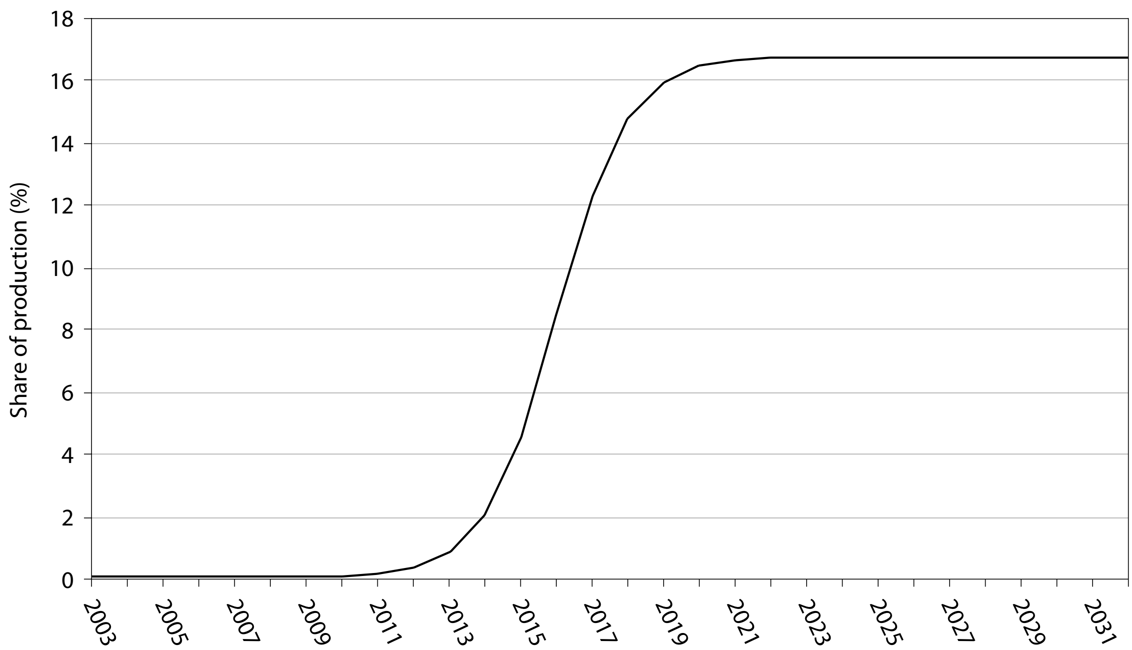

Figure 5. Estimated adoption profile for chilling technology for skins and hides for tanning. Data sources: Central Leather Research Institute; Centre for International Economics

The tanneries that have adopted DCLR are pleased with the new system, yet the project final report (Money 2008) suggests that adoption of DCLR is expected to be gradual unless the government provides financial assistance for implementation.[37] However, in Tamil Nadu where zero-liquid-discharge requirements apply, the cost savings associated with better RO-system efficiency and smaller quantities of waste salt to be disposed of mean there is a strong commercial incentive to adopt DCLR, even without government assistance.[38] These incentives depend on CETPs charging tanneries on the basis of TDS load, rather than effluent throughput. This seems likely, since all the CETPs in which CEMCOT is helping to install DCLR must be able to measure TDS load as well as volume of effluent.[39]

The CLRI researchers suggest that 20% adoption could be achieved in 2–3 years.[40] This is equivalent to around one-third of the leather produced in Tamil Nadu. The estimated adoption profile for DCLR is shown in Figure 6.

37 Project final report (Money 2008, p. 18)

38 Project review (Sahasranaman and Jackson 2005, p. 12)

39 Mr A. Sahasranaman (pers. comm., 16 March 2009)

40 Dr J. Raghava Rao (pers. comm., 16 March 2009)

Pickle liquor recycling for vegetable tanning

This technology is most likely to be implemented in the tanning centre of Dindigul, a vegetable tanning centre with major salinity issues.[41] The project final report (Money 2008) argues that there is little incentive to adopt the new technology in this region because they have made significant investment to upgrade the CETP to achieve zero liquid discharge. However, once effluent treatment and waste-salt disposal are taken into account, cost savings can be achieved by adopting this technology, albeit smaller than those for the other technologies. If the CETPs charge member tanneries based on TDS load rather than effluent volume, there is likely to be a commercial incentive to invest in this technology.

The external reviewers estimated that approximately 20% of relevant tanneries are likely to take up the technology.[42] This is equivalent to around one-third of production in Tamil Nadu. However, because vegetable tanning is used to produce only around 30% of the leather in Tamil Nadu, there is a smaller potential market for this technology. The estimated adoption profile is shown in Figure 7.

41 Project final report (Money 2008, p. 19)

42 Project review (Sahasranaman and Jackson 2005, p. 22)

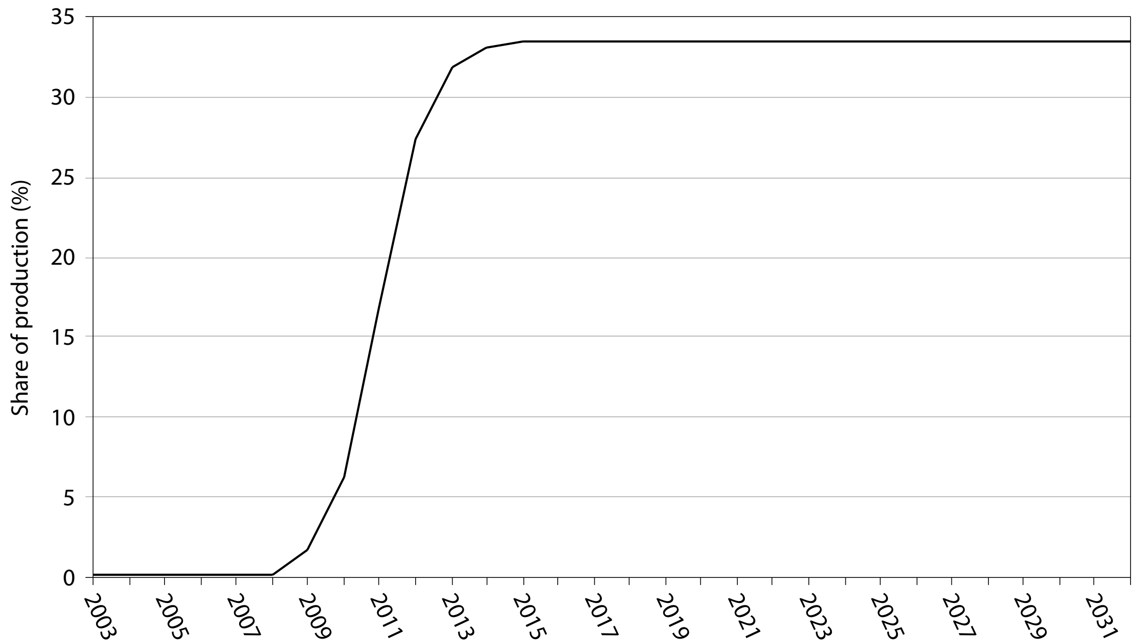

Figure 6. Estimated adoption profile for direct chrome liquor recycling in tanning. Data sources: Central Leather Research Institute; Centre for International Economics

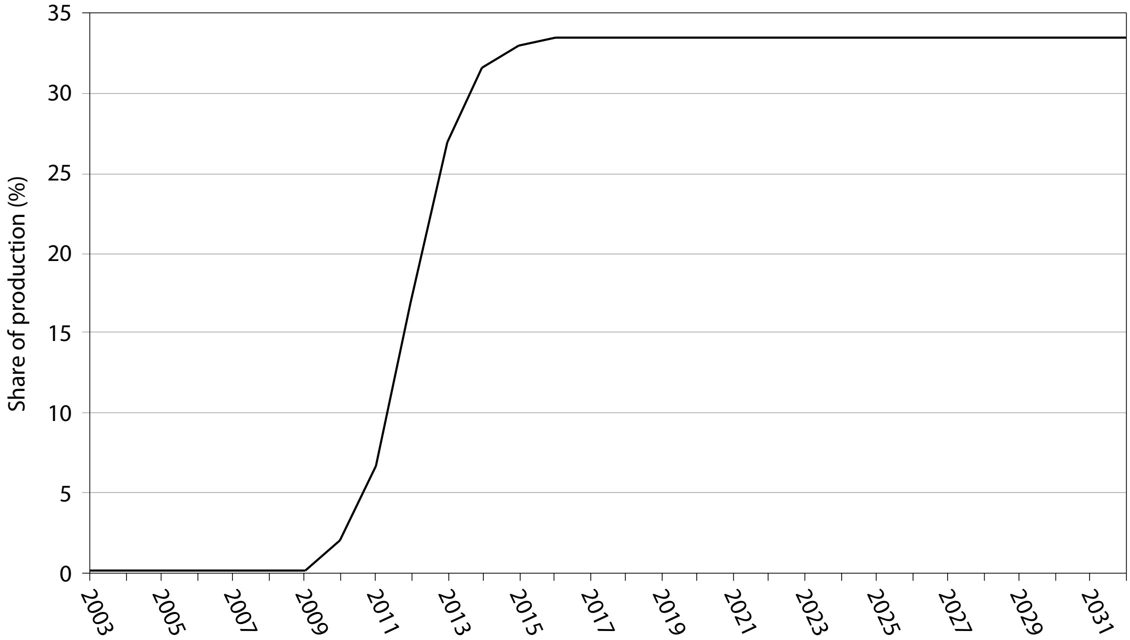

Figure 7. Estimated adoption profile for pickle liquor recycling in tanning. Data sources: Central Leather Research Institute; Centre for International Economics

3 Outcomes

The adoption of the low-salt technologies developed under the ACIAR-funded project leads to two main outcomes:

- a substantial reduction in the quantity of salt used in tanning processes and therefore significantly lower effluent salinity
- a change in production costs, arising from the cost of equipment to implement some of the new technologies, changes in input costs and a reduction in the cost of treating effluent and disposing of waste salts.

These outcomes are quantified and discussed below.

Salinity reduction

Various salts are used in a number of stages of leather production, each of them contributing to the salinity of tannery effluent. The estimated contribution of each stage of production to TDS load is shown in Table 2.

The estimated salinity reduction achieved by adopting each of the four outputs is discussed below.

Low-salt preservation

To reduce TDS, first handlers of Indian goat skins can salt unopened skins as usual with salt equivalent to only 20% of skin weight, compared with the 50–100% currently used. Adoption of low-salt preservation for goat skins therefore reduces salt use by between 300 kg and 800 kg per tonne of skin. Using the midpoint of this range (550 kg) suggests that the low-salt treatment reduces the quantity of salt used in the preservation stage by 73.3% (Table 3). It can be difficult to track the quantity of salt used in each stage of production through to the TDS in the effluent because not all of the salt used ends up there; for example, skins are put through a desalting machine before they are soaked. However, it is reasonable to assume that the percentage reduction in salt use will result in a proportional reduction in the salinity of effluent. Since the salt used in preservation is estimated to contribute around 50% to the total TDS load in effluent, this implies that low-salt preservation can reduce the TDS load by around 36.7%. The TDS load in effluent from most tanneries in Tamil Nadu is currently estimated at between 7,000 and 15,000 ppm.[43] Assuming the average TDS load in tannery effluent is currently 11,000 ppm (the midpoint of the estimated range), a 36.7% reduction from the adoption of low-salt preservation would reduce the TDS load by 4,033 ppm.

Chilling

Under the chilling system developed by the project team, no salt is used in the preservation of hides and skins. Since preservation is estimated to contribute 50% of the TDS load in tannery effluent, for skins this implies a 50%, or 5,500 ppm, reduction in TDS load (Table 4). Since less salt is typically used to preserve hides, the counterfactual TDS load must also be adjusted downwards. Between 400 kg and 500 kg of salt per tonne of raw hide is typically used for preservation.[44] Using the midpoint of 450 kg, this is 40% lower than the estimate of salt used to cure skins. It is therefore reasonable to assume that the preservation contribution to the TDS load for hides is around 20% lower than for skins.[45] This implies an

43 Project review (Sahasranaman and Jackson 2005, p. 5)

44 Project final report (Money 2008, p. 6)

45 In practice, effluent from all tanning processes is mixed before treatment.

effluent TDS load of around 8,800 ppm for producing finished leather from hides. Using chilling rather than salting for preservation would reduce the TDS load to 5,500 ppm, as for skins, since the same quantity of salts is used post-preservation. This is a TDS reduction of 3,300 ppm.

Table 2. Estimated contributions (%) of different production stages to total dissolved solids (TDS) in tannery effluent

Preservation	Pickling and tanning processes	Finishing
50	35	15

Source: Dr N.K. Chandra Babu (pers. comm., 16 March 2009)

Table 3. Estimated reduction in tannery effluent salinity from using low-salt preservation of skins and hides

	Quantity of salt used per tonne of raw material	Total dissolved solids (TDS) in effluent
	kg	ppm
Current practice	750.0	11,000
Low-salt preservation	200.0	6,967
Change	−550.0	−4,033
Percentage change	−73.3	−36.7[a]

[a] This is estimated as the percentage change in salt used adjusted for the 50% contribution that preservation makes to TDS load.

Sources: project final report (Money 2008); Centre for International Economics

Table 4. Estimated reduction in tannery effluent salinity from using chilling for preservation of skins and hides

	Quantity of salt used per tonne of raw material	Total dissolved solids (TDS) in effluent
	kg	ppm
Skins		
Current	750.0	11,000
Chilling	–	5,500
Change	−750.0	−5,500
Percentage change	−100.0	−50.0[a]
Hides		
Current	450.0	8,800
Chilling	–	5,500
Change	−450.0	−3,300
Percentage change	−100.0	−37.5

[a] This is estimated as the percentage change in salt used adjusted for the 50% contribution that preservation makes to TDS load.

Sources: project final report (Money 2008); Centre for International Economics

Direct chrome liquor recycling

Good practice allows indefinite re-use of the chrome liquor used by tanneries. The chrome-tanning process contributes around 20% of the TDS load.[46] Since continuous DCLR eliminates TDS discharge from this source, the TDS load is reduced by 20%. This is equivalent of a reduction of 2,200 ppm in the TDS load of effluent (Table 5).

Pickle liquor recycling for vegetable tanning

Commercial trials suggested that recycling pickle liquors for more than around 12 cycles may compromise the quality of leather. Therefore, the pickle liquors cannot be recycled continuously, as is the case with DCLR. It is estimated that recycling pickle liquors for up to 12 cycles can reduce the TDS load in effluent by 22–27%.[47] Using the midpoint of this range and assuming that the pickling and tanning stage of production contributes around 35% to TDS, implies a reduction of around 8.6%, or 943 ppm (Table 6).

Change in production costs

Adoption of the technologies developed as part of the ACIAR-funded project will also change production costs. First, most of the technologies require investment in new equipment, involving some upfront costs. Second, adoption of the new technologies reduces salt inputs and therefore costs to producers. Some other input costs also change for some of the technologies.

Adopting reduced-salt technologies will also reduce the cost of treating tannery effluent and disposal of waste salt. RO is essentially a filtering system whereby the effluent is forced through a membrane. This recovers 75–80% of effluent volume as clean water that can be re-used in tanning processes. The remaining 20–25% reject liquid has very high salinity and is placed in large evaporation pans to recover the solid waste. Effluent containing higher TDS loads is more costly to treat for the following reasons:

- More energy is required to force the effluent through the membrane. TAW tannery estimated that the energy required to operate the RO facility increases by around 15–20% when higher TDS effluent is being treated.
- The membrane, which is expensive, does not last as long.
- The membrane must be cleaned more frequently. TAW tannery estimated that the membrane must be cleaned every 6 hours with high TDS effluent. This compares to approximately every 12 hours with lower TDS effluent.[48]

46 Dr Raghava Rao (pers. comm., 16 March 2009)

47 Mr P. Saravanan (pers. comm., 16 March 2009)

48 Mr Williams (pers. comm., 19 March 2009)

Table 5. Estimated reduction in tannery effluent salinity from using direct chrome liquor recycling (DCLR)

	Total dissolved solids in effluent
	ppm
Current	11,000
DCLR	8,800
Change	−2,200
Percentage change	−20.0

Sources: Dr J. Raghava Rao (pers. comm., 16 March 2009); Centre for International Economics

Table 6. Estimated reduction in tannery effluent salinity from using pickle liquor recycling (PLR) for vegetable tanning

	Total dissolved solids (TDS) in effluent
	ppm
Current	11,000
PLR	10,057
Change	−943
Percentage change	−8.6[a]

[a] PLR is estimated to reduce effluent salinity by between 22% and 27% in the raw to tanning stage. Using the midpoint of this range, and assuming the raw to tanning stage contributes on around 35% to TDS, implies a reduction of total effluent salinity of around 8.6%.

Sources: Mr P. Saravanan (pers. comm., 16 March 2009); Centre for International Economics

CEMCOT estimates that reducing the TDS load of effluent from around 12,000–15,000 ppm to around 7,000–9,000 ppm would reduce treatment costs from around US$3 to US$2 per m^3 (including the cost of capital, energy and maintenance).[49] This estimate appears broadly consistent with the information provided by TAW. Furthermore, the solid waste salt must be disposed of correctly to prevent it from dispersing into the environment. A CEMCOT study found that disposing of waste salt in impervious storage facilities will cost between Rs2,600 and Rs3,000 per tonne, depending on the size of the disposal facility.[50]

Since tanneries typically produce around 30 m^3 of effluent for every tonne of raw material processed, this information implies that reducing the TDS load from around 13,500 ppm to around 8,000 ppm reduces the cost of effluent treatment by around Rs1,403 for every tonne of raw material processed (Table 7).[51] Likewise, the cost of waste-salt disposal is reduced by around Rs462.[52] This implies that, for every tonne of raw material processed, production costs fall by around Rs339 for every 1,000 ppm reduction in the salinity of effluent.

The changes in the costs accruing to end users (tanneries) associated with adopting each of the new technologies are estimated below.

Low-salt preservation

The CLRI researchers estimate that adopting low-salt preservation of goat skins will result in a modest input-cost saving.[53] Salt costs around Rs2 per kg. A reduction in salt use of around 550 kg per tonne of skin therefore results in a cost saving of Rs1,100. However, this is partly offset by the cost of soda ash, estimated at around Rs400 per tonne of raw material. In addition, there are costs associated with preparing the mix in the right proportions, distributing the pre-mix to skin suppliers and measuring the quantity used in salting, which have not been considered. Tannery staff suggested that adopting the technology is broadly cost neutral.

However, this analysis ignores the reduced costs of transport, effluent treatment and waste-salt disposal. While skins are purchased per piece, so that the quantity of salt used has no impact on the cost of the raw material itself, transport from the collection centre to the tannery is based on weight. Therefore, the more salt is used for preservation, the higher the transport costs per skin. Obviously, transport costs depend on the distance between the collection centre and the tannery. As an indicator, transporting 10 tonnes from Delhi to Ambur costs around Rs60,000.[54] While tanneries in Tamil Nadu source skins from all over India, the average distance skins are transported is likely to be significantly shorter than that. We use one-quarter of the distance from Delhi to Ambur to make our estimate of average transport costs.

Reducing the salt used in preservation from 75% of weight to 20% increases the quantity of skin received per 10 tonne delivery from 5.7 tonnes to 8.3 tonnes. Assuming an average delivery costs Rs15,000, this is equivalent to a cost saving of Rs825 per tonne of raw skin (Table 8).

We previously estimated that low-salt preservation of goat skins will reduce effluent salinity by 4,033 ppm. This implies a saving in effluent treatments costs of Rs1,029 per tonne of raw material, and a saving of Rs339 in waste-salt disposal costs. Even if adopting the technology is cost neutral in terms of chemical inputs, adopting low-salt preservation is estimated to produce savings of Rs2,192 per tonne of raw material. In India, around 4–4.5 square feet (0.37–0.42 m^2) of finished leather are produced per kilogram of raw goat skins.[55] This implies a cost saving of around Rs0.5 per square foot of finished leather (Table 9).

Preservation by chilling

Unlike the low-salt preservation system, adopting a chilling system for skin and hide preservation requires investment in new capital equipment. To be of a viable scale, a tanner would need to be able to process at

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49 Mr A. Sahasranaman (pers. comm., 16 March 2009)

50 Mr K.V. Emmanuel (pers. comm., 20 March 2009)

51 This estimate is based on the midpoints of the ranges estimated by CEMCOT and is converted to rupees using the average exchange rate over the year to 24 March 2009 of Rs46.7 per US dollar obtained from the OzForex website at <http://www.ozforex.com.au/>.

52 Based on the midpoint of the estimated range provided by CEMCOT (Mr K.V. Emmanuel, pers. comm., 20 March 2009)

53 Dr C. Muralidharan (pers. comm., 16 March 2009)

54 Mr T. Rafeeq Ahmed (pers. comm., 19 March 2009)

55 Dr C. Muralidharan (pers. comm., 19 March 2009)

Table 7. Changes in costs of tannery effluent treatment and waste-salt disposal from lowering the total dissolved solids (TDS) load (see text for explanation)

	13,500 ppm TDS[a]	8,000 ppm TDS[b]	Change	Change per 1,000 ppm[c] TDS
Effluent treatment				
Cost per m^3 (Rs)[d]	140.3	93.5	−46.8	
Cost per tonne of raw material (Rs)[e]	4,208	2,805	−1,403	−255
Wast salt disposal				
Waste salt per tonne of raw material (kg)	405	240	−165	
Cost of disposal (Rs)[f]	1,134	672	−462	−84
Total cost per tonne of raw material (Rs)	**5,342**	**3,477**	**−1,865**	**−339**

a Midpoint of 12,000–15,000 ppm range

b Midpoint of 7,000–9,000 ppm range

c Estimated change in costs divided by the 5,500 ppm reduction in TDS

d Treatment costs for various TDS loads are based on estimates from the Chennai Environmental Management Company of Tanners (CEMCOT) that reducing TDS load from 12,000–15,000 ppm to 7,000–9,000 ppm would reduce effluent treatment costs from US$3 to US$2 per m^3 (Mr A. Sahasranaman, pers. comm., 16 March 2009); converted from US dollars using the average daily exchange rates quoted at <http://www.ozforex.com.au/> over the year to 24 March 2009.

e On average, tanneries produce 30 m^3 of effluent per tonne of raw material (Sahasranaman, pers. comm., 16 March 2009).

f Assuming waste-salt disposal costs of Rs2,800 per tonne, this is the midpoint of the estimated range of Rs2,600 and Rs3,000 provided by CEMCOT (Mr K.V. Emmanuel pers. comm., 20 March 2009).

Sources: Mr A. Sahasranaman (pers. comm., 16 March 2009); Mr K.V. Emmanuel (pers. comm., 20 March 2009); Centre for International Economics

Table 8. Average transport costs for skins for tanning, with conventional and low-salt preservation

	75% salt	20% salt	Change
Weight of skins per 10-tonne delivery (tonnes)	5.7	8.3	2.6
Average cost per 10-tonne delivery (Rs)[a]	15,000	15,000	–
Average cost per tonne skin (Rs)	2,625	1,800	−825

a Based on one-quarter of the distance from Delhi to Ambur

Sources: Mr T. Rafeeq Ahmed (pers. comm., 19 March 2009); Centre for International Economics

Table 9. Change in production costs from adopting low-salt preservation of skins for tanning

	Change in costs per tonne	Change in costs per square foot
	Rs per tonne	Rs per square foot
Transport costs	−825	−0.19
Effluent treatment costs	−1,029	−0.24
Waste-salt disposal	−339	−0.08
Total (excluding input costs)	−2,192	−0.52

Sources: Dr C. Muralidharan (pers. comm., 16 March 2009); Dr C. Muralidharan (pers. comm., 19 March 2009); Mr A. Sahasranaman (pers. comm., 16 March 2009); Mr T. Rafeeq Ahmed (pers. comm., 19 March 2009); Mr K.V. Emmanuel (pers. comm., 20 March 2009); Centre for International Economics least 5 tonnes of raw material per day. The cost of the capital equipment required to operate such a system is estimated to be around Rs3.5 million (Table 10).[56]

Table 10. Estimated cost of equipment required for a 5 tonne per day chilling system for preservation of skins and hides for tanning

	Cost
	Rs
Blast chiller plus chilled storage at collection centre (5 tonnes per day capacity)	2,045,000
Tannery chilled storage (10 tonnes capacity)	1,500,000
Total equipment costs	3,545,000

Source: Dr N.K. Chandra Babu (pers. comm., 16 March 2009)

Based on information provided by CLRI, we estimate that a 5 tonne per day chilling system could result in annual savings of around Rs4.7 million for skins and Rs2.2 million for hides (Table 11). [57] The savings in the cost of salt more than offset the costs associated with the chilling equipment (including interest, depreciation and maintenance costs), power to operate the facility and an increase in labour costs. In addition, the reduction in the TDS of effluent of 5,500 ppm for skins and 3,300 ppm for hides results in savings in costs of treatment and waste-salt disposal of a further Rs3.4 million and Rs2.0 million for skins and hides, respectively. The total cost savings are equivalent to around Rs2,565 per tonne of skins and Rs1,219 per tonne of hides. In India, 1 kg of hide is estimated to produce 1–1.5 square feet (c. 0.1 m^2) of finished leather.[58] Therefore, the chilling system is estimated to reduce production costs by Rs1.0 per square foot of finished leather from cattle and Rs0.6 per square foot of leather from goats or sheep.

Direct chrome liquor recycling

CLRI estimates that to implement a DCLR system with a capacity to tan 5 tonnes of raw material per day would require a capital investment of US$6,000.[59]

[56] Dr N.K. Chandra Babu (pers. comm., 16 March 2009)

[57] Dr N.K. Chandra Babu (pers. comm., 16 March 2009)

[58] Dr C. Muralidharan (pers. comm., 19 March 2009)

[59] Dr J. Raghava Rao (pers. comm., 16 March 2009)

Table 11. Change in production costs (in rupees) from adopting chilling technology for preservation of skins and hides for tanning

	Skins	Hides
Annual costs (5 tonnes of raw material per day)		
Capital costs:		
– cost of capital (@ 15%)	531,750	531,750
– depreciation (@ 5%)	177,250	177,250
– maintenance costs	35,450	35,450
Labour costs	219,000	219,000
Salt cost	–2,737,500	–1,642,500
Power costs		
– blast chiller	204,400	204,400
– cold storage	292,000	292,000
Treatment costs	–2,559,832	–1,535,899
Waste-salt disposal costs	–843,150	–505,890
Total change in annual costs	–4,680,632	–2,224,439
Unit costs		
Change in costs per tonne	–2,565	–1,219
Change in costs per square foot[a]	–0.60	–0.98

[a] The estimates are based on 1 kg of raw hides producing 1.25 square feet of finished leather, and 1 kg of raw skin producing 4.25 square feet of finished leather.

Sources: Dr N.K. Chandra Babu (pers. comm., 16 March 2009); Mr A. Sahasranaman (pers. comm., 16 March 2009); Mr K.V. Emmanuel (pers. comm., 20 March 2009); Centre for International Economics

The cost of the additional energy required to operate the pump is estimated at US$2 per day. However, as chemicals are recycled in a continuous DCLR system, savings in chemical costs are estimated at US$48 per day. This implies a cost reduction of around US$15,600, or Rs623,000, per year. When the reduction in costs of effluent treatment and waste-salt disposal associated with the 2,200 ppm reduction in the salinity of effluent are taken into account, the estimated cost saving increases to around Rs1.8 million per year. This is around Rs1,005 per tonne of raw material, or Rs0.8 per square foot of finished bovine leather or Rs0.24 per square foot of finished sheep or goat leather (Table 12).

Table 12. Change in production costs from adopting direct chrome liquor recycling (DCLR) in leather tanning

	Change in costs	Change in costs[a]
	(US$)	(Rs)
Annual costs (5 tonnes of raw material per day)		
Capital costs:[b]		
– return on capital (@15%)	900	35,955
– depreciation (@ 5%)	300	11,985
Energy[c]	730	29,164
Chemicals	–17,520	–699,924
Effluent treatment costs[d]	–21,900	–874,905
Waste-salt disposal costs[e]	–7,213	–337,260
Total change in costs	–44,703	–1,834,986
Unit costs		
Change in costs per tonne of raw material	–24.490	–1,005.00
Change in costs per square foot finished leather (cattle)[f]	–0.020	–0.80
Change in costs per square foot finished leather (sheep and goat)[g]	–0.006	–0.24

a This is converted from US dollars using the average daily exchange rates quoted on <http://www.ozforex.com.au/> over the year to 24 March 2009.

b The cost of capital equipment to implement a DCLR system is estimated at US$6,000 (Dr J. Raghava Rao).

c The energy required to operate the pump is estimated to cost US$2 per day.

d This is based on a 2,200 ppm reduction in TDS (Table 5) at a cost saving of Rs255 per 1,000 ppm (Table 7).

e This is based on a 2,200 ppm reduction in TDS (Table 5) at a cost saving of Rs84 per 1,000 ppm (Table 7).

f This is based on an estimated 1.25 square feet of finished leather per kilogram of raw hide (Dr C. Muralidharan).

g This is based on an estimated 4.25 square feet of finished leather per kilogram of raw skin (Dr C. Muralidharan).

Sources: Dr J. Raghava Rao; <http://www.ozforex.com.au/>; Mr A. Sahasranaman (pers. comm., 16 March 2009); Mr K.V. Emmanuel (pers. comm., 20 March 2009); Dr C. Muralidharan; Centre for International Economics

Pickle liquor recycling

CLRI estimates that the additional capital equipment required to operate a PLR system with a capacity to process 5 tonnes of raw material per day would cost Rs280,000. This implies annual capital costs of Rs56,000, including the return on capital and depreciation. The additional energy required to operate the pump is estimated to be 15 kWh per day. However, a PLR system would also reduce energy consumption in other areas by around 10 kWh per day.[60] With energy costing around Rs5 per kWh, this is an overall increase of Rs25 per day in energy costs. In annual terms, the cost of capital and the net increase in energy costs is estimated at Rs65,125.

However, these cost increases are likely to be more than offset by the cost savings associated with lower effluent salinity. Based on the effluent salinity reduction of 943 ppm estimated previously, effluent treatment costs are estimated to decline by around Rs439,000, and salt disposal costs by Rs145,000 per year. The overall cost saving is estimated at around Rs284 per tonne of raw material. This is equivalent to Rs0.23 per square foot of finished leather from cattle, and Rs0.07 per square foot of finished leather from sheep and goats (Table 13).

60 Mr P. Saravanan (pers. comm., 16 March 2009)

Table 13. Change in production costs (in rupees) from adopting pickle liquor recycling (PLR) for vegetable tanning of leather

	Change in costs
Annual costs (5 tonnes of raw material per day)	
Capital costs:[a]	
– return on capital (@15%)	42,000
– depreciation (@5%)	14,000
Energy costs:	
– pumping[b]	27,375
– other[c]	−18,250
Effluent treatment costs[d]	−439,011
Waste-salt disposal costs[e]	−144,600
Total	– 518,486
Unit costs	
Total per tonne of raw material	−284
Total per square foot of finished leather (cattle)[f]	−0.23
Total per square foot of finished leather (sheep and goat)[g]	−0.07

[a] The cost of capital equipment to implement a PLR system is estimated at Rs280,000 (Mr P. Saravanan).

[b] The energy required to operate the pump is estimated at 15 kWh per day at a cost of Rs5 per kWh (Mr P. Saravanan).

[c] Other energy savings are estimated at 10 kWh per day at a cost of Rs5 per kWh (Mr P. Saravanan).

[d] This is based on a 943 ppm reduction in TDS (Table 6) at a cost saving of Rs255.0 per 1,000 ppm (Table 7).

[e] This is based on a 943 ppm reduction in TDS (Table 6) at a cost saving of Rs84 per 1,000 ppm (Table 7).

[f] This is based on an estimated 1.25 square feet of finished leather per kilogram of raw hide (Dr C. Muralidharan).

[g] This is based on an estimated 4.25 square feet of finished leather per kilogram of raw skin (Dr C. Muralidharan).

Sources: Mr P. Saravanan; Mr A. Sahasranaman (pers. comm., 16 March 2009); Mr K.V. Emmanuel (pers. comm., 20 March 2009); Dr C. Muralidharan; Centre for International Economics

4 Impacts

To understand the impacts of adopting low-salt technologies, it is important to understand how relevant markets are affected. Markets are shaped by a range of factors, including government policies and regulations such as trade policy and pollution regulations, the technology used in production, and demand from both domestic and international markets. The interaction of these factors determines the benefits associated with adopting the new technology. The impacts of adopting each of the four technologies are therefore analysed and subsequently estimated using a partial equilibrium, economic surplus framework.

The markets for raw skins and hides, and finished leather

The main markets directly affected by the adoption of the reduced-salt technologies developed under the ACIAR-funded project are raw skin and hide markets and finished leather markets. There are also markets for semi-finished leather, as some tanneries process from raw skins and hides up to the semi-finished stage, before the leather is finished elsewhere. The reduced-salt technologies developed during the ACIAR-funded project focus on the pre-tanning and raw to semi-finished leather stages of production and not the salt used in finishing. However, there are punitive export restrictions on the export of semi-finished leather that result in all semi-finished leather produced in India also proceeding to finishing there. Therefore, the Indian domestic market for finished leather is affected by the adoption of low-salt technologies in the same way, regardless of whether tanning and finishing operations are separated or vertically integrated.

The price received for finished leather is determined by a number of factors, including quality and the type of finishing. This means there is not a single market for generic finished leather. Rather, there are many different markets for each level of quality and different finishes. It is impractical, however, to analyse each market separately. It is also unnecessary, since the technologies developed under the ACIAR-funded project focus on the pre-tanning and tanning stages of production, and therefore affect all finished leather markets in the same way. For practical reasons, the market analyses below therefore treat the market for leather as a generic market.

Trade policy plays a major role in shaping goods markets. Currently, raw skins and hides can be imported into India duty free. Indian producers therefore operate in a competitive global market. Exports of hides, skins and semi-finished wet–blue leather, however, attract an export duty of 60%. Semi-finished, vegetable-tanned leather attracts an export duty of 15%. As a result, a negligible quantity of raw material is exported. Most of the skins and hides tanned in India are sourced domestically, although a relatively small quantity of raw hides and skins is currently imported. In recent years, less than 5% of the raw hides and goat skins tanned in India were imported. However, typically 10–15% of sheepskins are imported. Production of raw hides and skins in India has grown at a modest pace over the past two decades. Since the mid 1990s, production of raw bovine hides has grown at an average annual rate of around 0.8%, and goat and kid skins by around 0.5%, while production of raw sheep and lamb skins has fallen by an average annual rate of around 0.7% (Figure 8).

By contrast, finished leather producers are protected by a 15% tariff. Moreover, there are significant incentives to export, such as duty drawbacks and exemption from local taxes and tariffs on intermediate inputs. India is consequently currently a net exporter of finished leather,

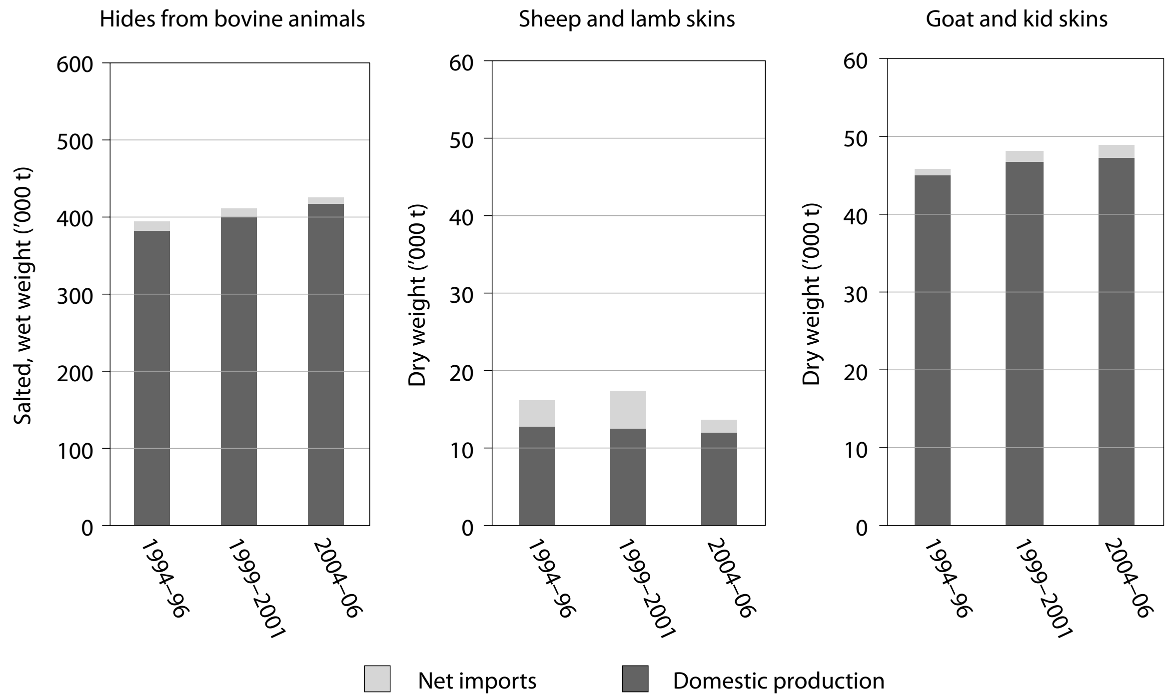

Figure 8. Raw hides and skins processed in India, 1994–96 to 2004–06. Data source: FAO (2008)

although in volume terms most of the finished leather produced in India is manufactured domestically into final consumer goods, such as shoes and other apparel. Since the mid 1990s, production of light leather from bovine animals has grown at an average annual rate of 1.5%, while production of light leather from sheep and goats has grown at an average annual rate of 0.1% (Figure 9). India also produces some heavy leather from bovine animals, although little is produced in Tamil Nadu.

The pollution problem in an economic framework

While India produces around 5% of the world's light leather from bovine animals and around 10% of light leather from sheep and goats, changes in India's domestic leather market are unlikely to have a significant impact on world prices. It is therefore considered appropriate to model India as a small economy operating in the global markets for raw hide and skin and finished leather products. Before the imposition of environmental regulations, the salt used by raw hide and skin dealers and tanneries, and subsequently discharged by tanneries, imposed a cost on local communities in terms of lost agricultural production and reduced drinking water quality. Since these costs were borne by local farmers and householders and not the users of the salt, they were not taken into account by those users. In the left panel of Figure 10, the private marginal cost of producing raw skins and hides is depicted by the supply curve *S*. The marginal social cost of skin and hide production, which includes the external costs of TDS pollution on communities surrounding tanneries, is represented by *MSC*. At the world price p^w, Indian tanneries demand q_d units, while q_s units are produced domestically. M represents imports. The benefit to Indian skin and hide suppliers (producer surplus) is depicted as the lighter shaded area, while the benefit flowing to Indian tanneries (consumer surplus) is depicted as the darker shaded area. However, these benefits are at least partly offset by the costs imposed on farmers and households surrounding tannery clusters—depicted as the checked shaded area. This area includes the costs imposed by the salt used by foreign as well as domestic skin and hide suppliers, since the salt applied by foreign skin suppliers also imposes costs on the communities surrounding Indian tanneries.

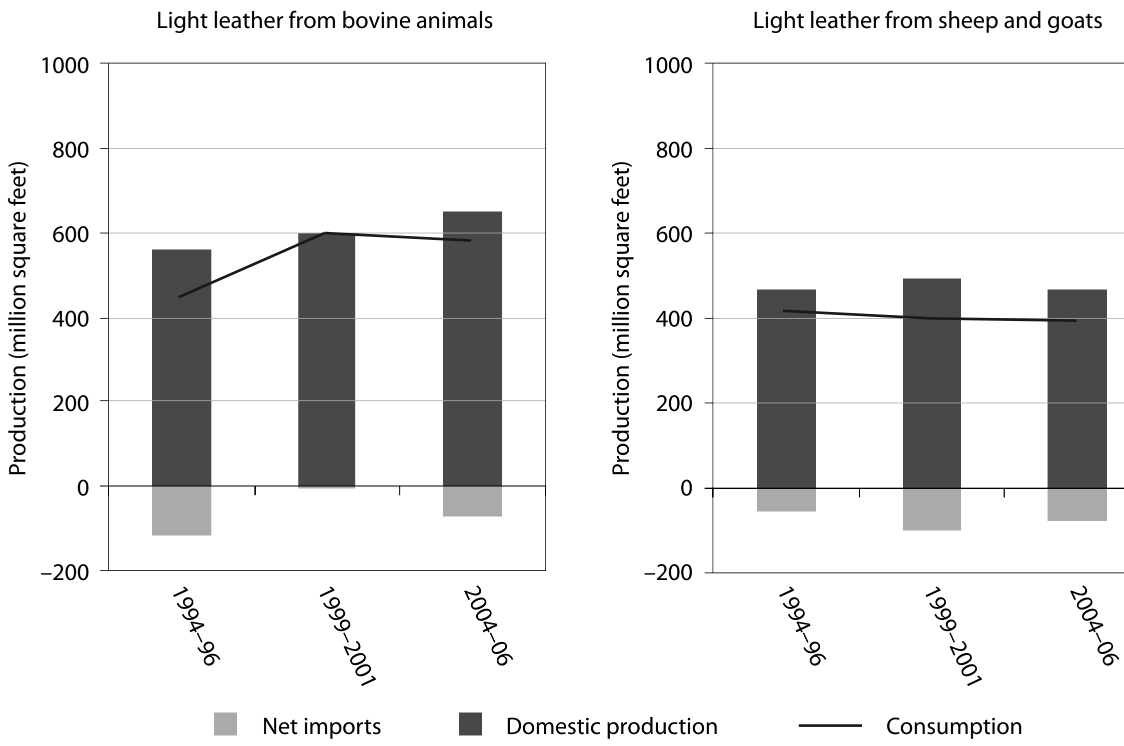

Figure 9. Light leather produced in India, 1994–96 to 2004–06. Data source: FAO (2008)

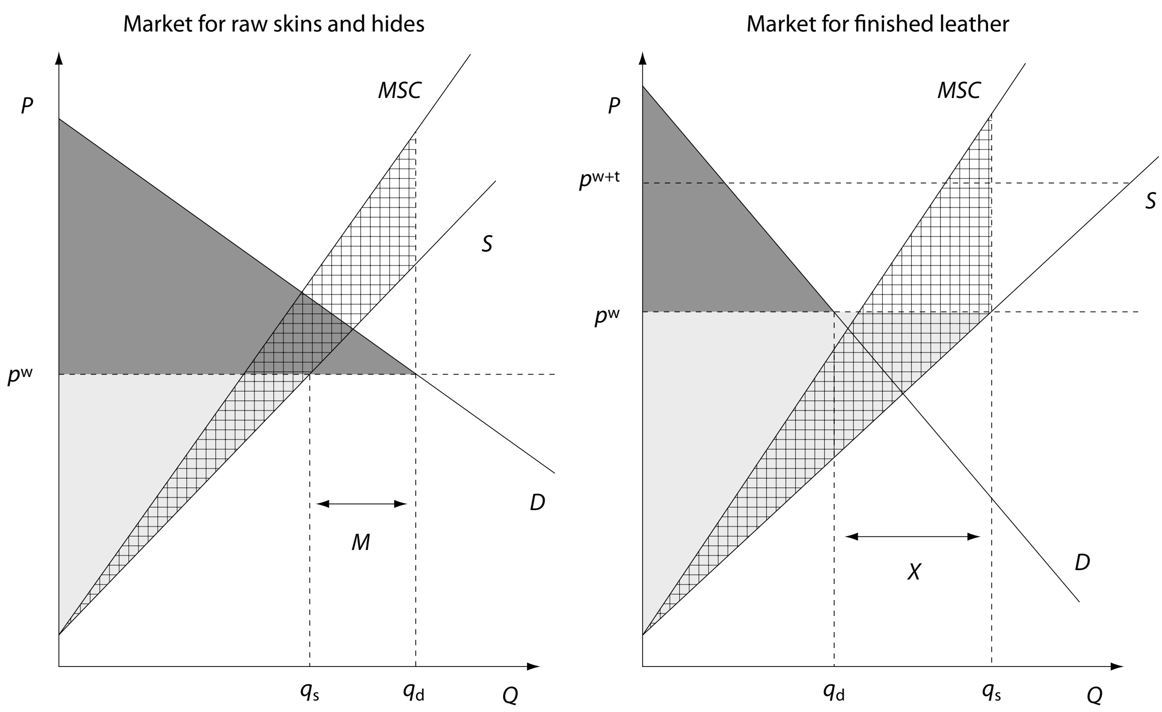

Figure 10. The markets for raw skins and hides and finished leather in India without environmental regulations (see text for explanation). Source: Centre for International Economics

The market for finished leather (Figure 10, right panel) is broadly similar, although tanners are protected by a tariff. The tariff appears to have had little effect since Indian tanners are net exporters of finished leather. At the world price for finished leather p^w, Indian tanners ignore the external costs imposed on local farmers and communities and produce q_s units of finished leather, of which q_d is purchased by domestic manufacturers of leather consumer goods, with the remainder exported (X). The benefit to Indian manufacturers (consumer surplus) is depicted as the vertical shaded area and the benefit to Indian tanners (producer surplus) as the horizontal shaded area, while the external cost imposed on local farmers and households is depicted as the checked shaded area. It is important to note that the external costs depicted in the right-hand panel include the external costs depicted in the left-hand panel because, ultimately, the salt used by skin and hide suppliers is discharged by the tanneries.

Impact of zero liquid discharge

In more recent years, a range of environmental regulations has had major impacts on the tanning industry in Tamil Nadu. This includes various effluent norms. Of particular relevance is the recently mandated zero liquid discharge. This has required effluent treatment plants (both common and individual) to install reverse osmosis and evaporation facilities. Since these regulations apply only to producers in Tamil Nadu, the diagrams analyse the market for leather produced in only that state.

When fully implemented, these requirements will have two important effects on the market for finished leather. First, they will eliminate the external cost imposed on the farmers and households surrounding tannery clusters. The project final report (Money 2008) expressed concern that some salts recovered through RO and evaporation are not being disposed of correctly and will continue to disperse into the environment during monsoonal rains. However, if properly enforced, zero liquid discharge will ensure that there is no further environmental damage caused by TDS. Indeed, it is estimated that much of the environmental damage will be reversed within 5 years once zero liquid discharge has been achieved.[61] In the right-hand panel of Figure 11, the marginal social cost (*MSC*) is the same as the marginal private cost, since the external costs have been eliminated. The marginal social cost therefore becomes the same as the supply curve.

Zero liquid discharge will also substantially increase the cost of leather production in Tamil Nadu. As this requirement applies only in Tamil Nadu, some tanners expressed concern that this will result in a loss of competitiveness against tanneries in other states and countries. However, tanners also recognised the importance of reducing pollution to the sustainability of the industry in Tamil Nadu. Ultimately, they see that cleaner production technology could be a competitive advantage for Tamil Nadu tanneries. Buyers are increasingly demanding more 'environmentally friendly' leather, and tanners see a commercial opportunity in marketing Tamil Nadu leather as being such. It is also likely that tanneries located in other states and countries will eventually be subjected to similar environmental standards. However, these changes are highly uncertain and have not been taken into account in the analysis.

CEMCOT estimates that RO treatment will increase the cost of effluent treatment from around US$0.70 per m^3 to US$2.00–3.00 per m^3, with tanneries typically discharging around 30 m^3 of effluent for every tonne of raw material processed.[62] This includes the capital cost of installation, and operational costs such as energy and maintenance. Disposal of recovered mixed salts also adds to costs, as they cannot be re-used in tanning processes. Some tanneries have found a niche market for the recovered mixed salts as fertiliser for coconut trees in Kerala,[63] but this is a restricted solution. The RO systems that CEMCOT is helping the CETPs to install include facilities to dispose of around 3 years' worth of salt. However, beyond that, disposing of salt will continue to be a problem. CEMCOT estimates that disposing of waste salt in impervious storage facilities will cost between Rs2,600 and Rs3,000 per tonne, depending on the size of the storage facility.[64] Zero-liquid-discharge requirements have therefore added significantly to leather production costs in Tamil Nadu.

61 Mr A. Sahasranaman (pers. comm., 16 March 2009)

62 Mr A. Sahasranaman (pers. comm., 16 March 2009)

63 Project final report (Money 2008)

64 Mr K.V. Emmanuel (pers. comm., 20 March 2009)

The increase in production costs represents an upward shift in the supply curve in the market for finished leather. However, this upward shift is partly offset by a government subsidy. India's central government has subsidised 50% of the capital cost of RO installation, and the Tamil Nadu state government has contributed a further 15%. However, tanners pointed out that operating costs have not been subsidised, so the actual subsidy on RO treatment is actually much lower. The net increase in the cost of leather production results in a reduction in the quantity of leather produced, and therefore of exports (ΔX). The lower costs imposed on the communities surrounding the tannery clusters are thus at least partly offset by a reduction in the producer surplus of tanners. There would also be flow-on effects on the demand for raw skins and hides, resulting in fewer imports (ΔM).

Zero-liquid-discharge requirements have no direct impacts on the market for raw skins and hides (left-hand panel of Figure 11). Since transport, effluent treatment and waste-salt disposal costs borne by tanneries are higher the more salt is used for preservation, zero-liquid-discharge requirements result in the external cost burden imposed by excessive salt use by flayers, butchers and raw skin and hide dealers being transferred from farmers and households surrounding tanneries to the tanners. Unless the skin and hide dealers have an incentive to reduce the quantity used, they are likely to continue using excessive quantities of salt.

The impact of adopting low-salt technologies

The impacts of adopting the new technologies must be assessed against a plausible counterfactual scenario; that is, the scenario that is likely to have occurred in the absence of the ACIAR-funded project. In developing the counterfactual scenario, it is important to consider the broader context and directions in which the tanning industry in Tamil Nadu is heading. Reducing salt pollution has been a concern of various authorities in Tamil Nadu over the past decade or more. This is demonstrated by a range of actions, including:

- mandating a maximum allowable TDS discharge of 2,100 ppm
- requiring tanneries in Tamil Nadu to compensate farmers for the loss of agricultural production due to TDS
- implementing zero-effluent-discharge systems and funding part of the capital cost of these.

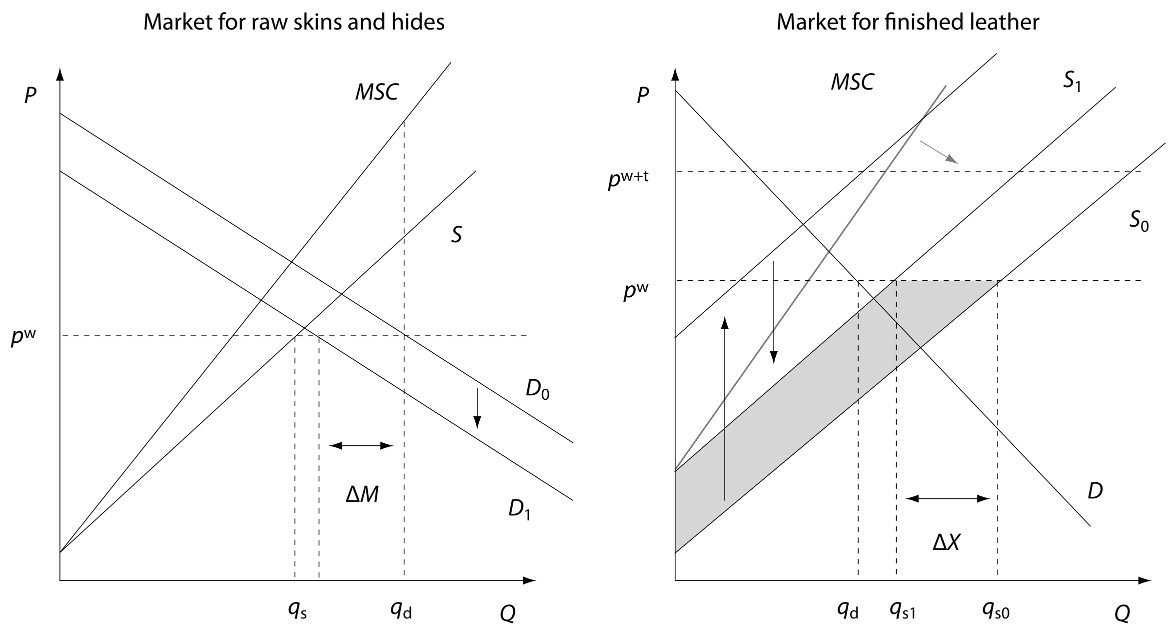

Figure 11. Impact of the requirement for zero liquid discharge from tanneries on markets for raw skins and hides and finished leather (see text for explanation). Source: Centre for International Economics

While some of the decision-making authorities, such as the Tamil Nadu Pollution Control Board, are aware of the ACIAR-funded project, this did not influence these actions. Therefore, the measures taken by various government authorities would have occurred even in the absence of the project. The impact of adopting the low-salt technologies developed under the ACIAR project must therefore be assessed in the context of zero-liquid-discharge requirements.

Assuming waste salts recovered through RO and evaporation are disposed of correctly, the low-salt technologies have no impact on the level of pollution. Tanners would have been required to meet zero liquid discharge regardless of the ACIAR-funded project. Rather, the low-salt technologies reduce the cost of meeting these zero-liquid-discharge requirements.

Preservation technologies

Salting of hides and skins occurs before they reach the tannery. The end users of the reduced-salt preservation technologies developed under the ACIAR-funded project are therefore the butchers, skin and hide dealers, and others that apply salt to preserve the raw skins and hides. These technologies therefore affect both the market for raw hides and skins and the market for finished leather.

Adoption of the new technologies is estimated to be broadly cost neutral for skin and hide dealers. However, they significantly reduce the costs of transport, effluent treatment and waste-salt disposal, which are borne by tanners. As discussed previously, if there are no benefits to end users, a technology is less likely to be adopted. It seems likely that for these technologies to be adopted by end users, some of the benefits flowing to tanneries from their adoption will need to be passed onto skin and hide dealers in the form of a price premium on skins and hides preserved with less salt. While tanners argued that this is not commercially viable, it seems likely that there will be some scope to pass on some of the cost savings once they are fully appreciated by tanners. Figure 12 shows all the benefits accruing to tanners. This assumes that tanners are able to encourage skin and hide dealers to adopt the new technology without offering a price incentive, which seems unlikely. If some of the benefits of the low-salt technologies are passed onto skin and hide dealers, this will affect the distribution of benefits, but not their magnitude.

Referring to Figure 12, adoption of the new technologies is broadly cost neutral for skin and hide dealers, so there is no shift in the supply curve. Adopting low-salt technologies reduces the external cost on tanners. Similarly,

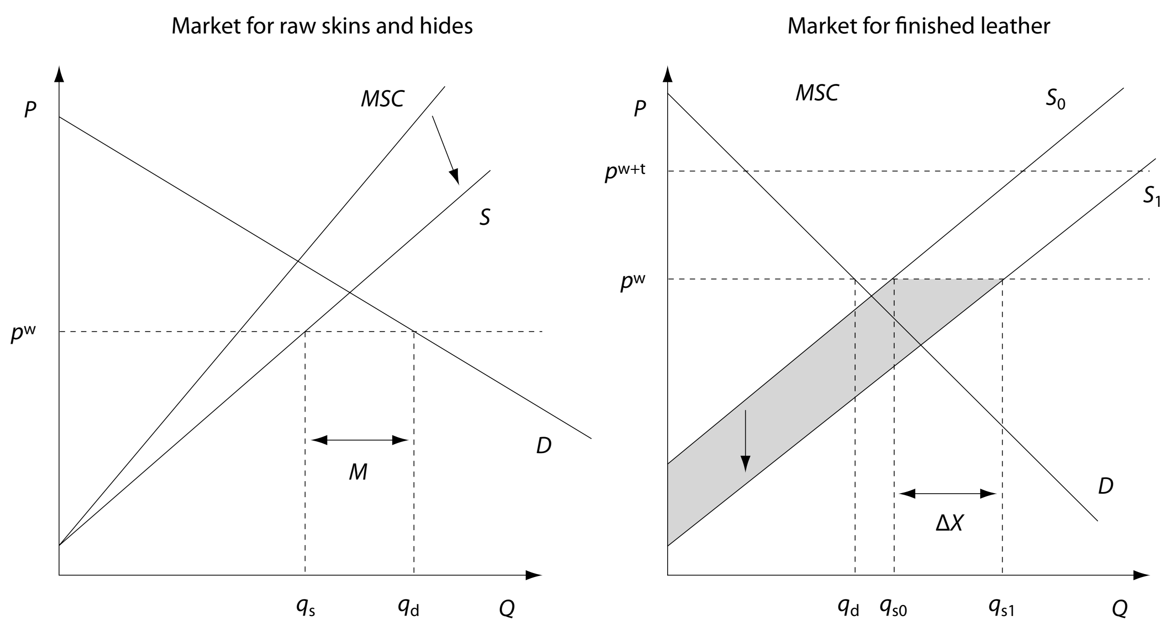

Figure 12. Impact of adopting low-salt preservation technologies on markets for raw skins and hides and finished leather (see text for explanation). Data source: Centre for International Economics

adopting the chilling technology is likely to be broadly cost neutral for skin and hide dealers. However, even including the costs associated with capital investment, chilling results in cost savings for tanners, mostly due to reduced costs of effluent treatment and salt disposal. This results in higher production and therefore of exports (ΔX). When estimating the benefits of adopting these technologies, it is important not to double count. In Figure 12, the reduction in the external costs in the market for raw skins and hides is the same cost reduction in the market for finished leather.

Liquor-recycling technologies

Unlike the preservation technologies, the end users of the recycling technologies are the tanneries. The markets for raw hides and skins are therefore not affected in any way by the adoption of these technologies. The adoption of the liquor-recycling technologies reduces the cost of production for tanneries. This is depicted as a vertical downward shift in the supply curve for those tanneries that adopt the technology (Figure 13). This results in a small increase in production and a corresponding increase in exports.

Estimating the impacts

The change in economic surplus from adopting each of the low-salt technologies is represented by the shaded area in Figures 12 and 13. This can be estimated as:

$$\Delta PS_i = K_i q_{s0} + 0.5 K_i \Delta q_i \qquad (1)$$

where

- ΔPS_i is the change in producer surplus associated with adopting technology i
- K_i is the shift in supply approximated by the change in per unit production costs from adopting technology i (see Chapter 3)
- q_{s0} is the quantity of leather produced under the counterfactual scenario
- Δq is the change in the quantity of leather produced by those tanneries in Tamil Nadu that adopt the reduced-salt technologies.

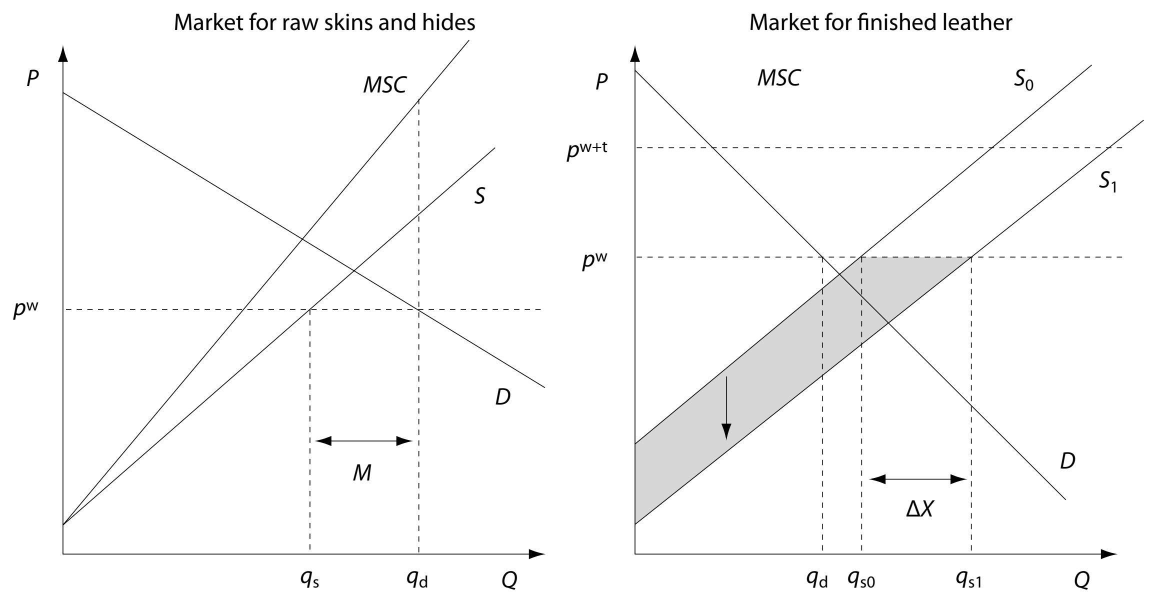

Figure 13. Impact of adopting liquor-recycling technologies on markets for raw skins and hides and finished leather (see text for explanation). Data source: Centre for International Economics

The counterfactual quantity produced

Counterfactual quantities in each market can be derived from estimates of production in India published by the Food and Agriculture Organization of the United Nations (FAO 2008). Since only tanneries in Tamil Nadu are likely to adopt the reduced-salt technologies, it is the quantity of leather produced in Tamil Nadu that is relevant (around 60% of the total). Furthermore, not all of the technologies developed under the project are relevant to all types of leather.

Table 14 shows the estimated production of light leather from bovine animals, sheep and goats in India and Tamil Nadu. We disaggregate the FAO's estimate of the quantity of light leather produced from sheep and goats using the ratio of raw sheep and lamb skins to goat and kid skins produced in India. Production in Tamil Nadu is estimated as 60% of total production in India. Around 70% of the leather produced in India is estimated to be chrome tanned, with the remaining 30% vegetable tanned. The lower half of Table 14 shows which type of leather is relevant to each technology.

Change in quantity produced

To estimate the change in the quantity of finished leather produced, we assume a linear supply curve of the form:

$$P = a + bQ \qquad (2)$$

where P is price, Q is the quantity produced, and a and b are the intercept and slope terms, respectively. Given that we have assumed that developments in India's domestic market do not have a significant effect on the world price, the change in the quantity produced for a given vertical shift in the supply curve is given by:

$$\Delta Q = \frac{-\Delta a}{b} \qquad (3)$$

We assume an elasticity of supply of 0.8 at the initial equilibrium. There have been no previous, data-based studies to estimate the elasticity of supply and such a study would likely be difficult. In the absence of empirical estimates, an elasticity of 1 is a reasonable

Table 14. Estimated 2007 production (million square feet) of light leather in India and Tamil Nadu state

	From bovine animals	From sheep[a]	From goats[a]	Total
Leather production				
India	647.2	138.9	332.8	1118.9
Tamil Nadu[b]	388.3	83.3	199.7	671.3
Chrome tanned[c]	271.8	58.3	139.8	469.9
Vegetable tanned[d]	116.5	25.0	59.9	201.4
Relevant production for each project output				
Low-salt preservation	–	–	199.7	199.7
Chilling	388.3	83.3	199.7	671.3
Direct chrome liquor recycling	271.8	58.3	139.8	469.9
Pickle liquor recycling	116.5	25.0	59.9	201.4

[a] FAO combines the production of leather produced from sheep and goats. Leathers made from sheep and goats are disaggregated on the basis of the ratio of raw sheep and lamb skins to raw goat and kid skins produced in India.

[b] Tanneries in Tamil Nadu are estimated to produce 60% of India's total leather production.

[c] This is estimated as 70% of the leather produced in Tamil Nadu.

[d] This is estimated as 30% of the leather produced in Tamil Nadu.

Source: FAO (2008)

starting point. However, our intuition is that this may be too high for the leather industry in Tamil Nadu.[65] The elasticity of supply (ε) can be represented as:

$$\varepsilon = \frac{\Delta Q}{\Delta P} \times \frac{p^w}{q_0} \quad (4)$$

where p^w is the world price of around US$1.10 per square foot of finished leather and q_0 is the most recent estimate of production published by FAO. The slope of the aggregate supply curve is therefore:

$$b = \frac{1}{\varepsilon} \times \frac{p^w}{q_0} \quad (5)$$

The intercept of the aggregate supply curve in the counterfactual scenario thus becomes:

$$a_0 = p^w - \left(\frac{1}{\varepsilon} \times \frac{p^w}{q_0} \right) q_0 = p^w \left(1 - \frac{1}{\varepsilon} \right) \quad (6)$$

Since the aggregate supply curve is the horizontal sum of many linear individual supply curves, the slope of the supply curve ($b_{i,t}$) of those tanneries that adopt technology *i* at time *t* is:

$$b_{i,t} = \frac{p^w - a_0}{q_{i,t0}} \quad (7)$$

where $q_{i,t0}$ is the quantity produced by the adopters of technology *i* at time *t* in the counterfactual scenario. This depends on the adoption rate of the technology ($r_{i,t}$) as follows:

$$q_{i,t0} = r_{i,t} \times q_0 \quad (8)$$

Substituting equations (6) and (8) into equation (7) gives:

$$b_{i,t} = \frac{p^w - p^w \left(1 - \frac{1}{\varepsilon}\right)}{r_{i,t} q_0} = \frac{p^w \frac{1}{\varepsilon}}{r_{i,t} q_0} \quad (9)$$

We previously defined the shift in the supply curve from adopting technology *i* as K_i. Therefore, substituting equation (9) into equation (3), the change in the quantity produced by adopters, as a result of adopting technology *i* at time *t*, is given by:

$$\Delta q_{i,t} = \frac{K_i}{b_{i,t}} = \frac{K_i r_{i,t} q_0}{p^w \frac{1}{\varepsilon}} \quad (10)$$

[65] U. Sankar (pers. comm., 20 March 2009)

5 Net benefits

This chapter brings together the estimated benefits and costs associated with the project in a benefit–cost analysis framework. We also discuss the risks surrounding the estimates and test how robust the conclusions drawn from them are to varying some key assumptions within a plausible range.

Benefits

The estimated benefits of adopting each of the low-salt technologies over a 30-year period from 2002–03 to 2031–32 are shown in Table 15. The benefits are estimated in Indian rupees and are converted to Australian dollars using historical annual average exchange rates up to 2007–08. For the 2008–09 average, actual exchange rates are used from July to February. The exchange rate for March 2009 is estimated as the average of actual daily exchange rates up to 24 March, with the rate then assumed to remain constant for the rest of the month. For future periods, the exchange rate is assumed to remain constant at estimated March levels.

Once maximum adoption has been reached, the project is estimated to deliver benefits of around $6.5 million per year. All four technologies are expected to produce benefits in the long term. This highlights the advantages of developing a package of technologies that are applicable in a wide range of circumstances, rather than a single technology that may have limited applicability.

Chilling is expected to deliver the largest annual benefits in the longer term, at around 42% of the total. However, the risk that chilling will not be adopted and therefore not deliver any benefits is probably the highest of the four technologies, given that there are more barriers to adoption. Chilling uses no salt and therefore has the most significant impact on effluent salinity. However, some of its benefits are partly offset by relatively high capital costs. Adoption is also expected to be lower, since this technology is not as widely applicable in India, given the dispersion of meat production and therefore of skin and hide collection systems. Chilling is applicable to both hides and skins.

Around 40% of the total annual benefits are estimated to be delivered by DCLR. This technology is widely applicable in India, since 70% of the leather produced uses chrome tanning and it is relevant to skins from sheep and goats as well as hides. It is also adopted within the tannery, and there are consequently fewer logistical problems in encouraging adoption.

Low-salt preservation of goat skins is estimated to deliver around 14% of the total annual benefits. Adoption of this technology results in a significant reduction in effluent salinity, and the cost of adoption is low because no new capital equipment is required to adopt it (although the cost to the tanners of training skin suppliers has not been considered). However, the benefits are estimated to be smaller than chilling and DCLR because low-salt preservation is applicable only to goat skins and there are challenges in encouraging skin suppliers to adopt the technology.

PLR for vegetable tanning is expected to produce around 5% of the total annual benefits. This technology is less widely applicable because only 30% of the leather produced in India is vegetable tanned. Also, the salinity reduction is less for this technology, for two main reasons. First, the raw to semi-finished stage of production contributes less to effluent salinity than does the preservation stage. Second, unlike DCLR, the pickle liquor must be replaced after around 12 cycles. This means that there is still some effluent produced. Largely as a result of the lower impact on effluent salinity,

Table 15. Estimated benefits of adopting low-salt technologies in leather tanning in India

	Low-salt	Chilling	DCLR	PLR	Exchange rate	Low-salt	Chilling	DCLR	PLR
	Rs m	Rs m	Rs m	Rs m	Rs/$A	A$m	A$m	A$m	A$m
2002–03	–	–	–	–	28.0	–	–	–	–
2003–04	–	–	–	–	32.4	–	–	–	–
2004–05	–	–	–	–	33.5	–	–	–	–
2005–06	–	–	–	–	33.4	–	–	–	–
2006–07	–	–	–	–	34.7	–	–	–	–
2007–08	–	–	–	–	36.2	–	–	–	–
2008–09	–	–	4.2	–	35.0	–	–	0.1	–
2009–10	1.4	–	16.2	0.6	34.1	0.0	–	0.5	0.0
2010–11	3.6	0.6	44.5	2.1	34.1	0.1	0.0	1.3	0.1
2011–12	8.1	1.7	72.8	5.4	34.1	0.2	0.0	2.1	0.2
2012–13	15.1	4.4	84.8	8.6	34.1	0.4	0.1	2.5	0.3
2013–14	22.1	11.0	88.0	10.1	34.1	0.6	0.3	2.6	0.3
2014–15	26.6	24.8	88.8	10.6	34.1	0.8	0.7	2.6	0.3
2015–16	28.7	46.1	88.9	10.7	34.1	0.8	1.4	2.6	0.3
2016–17	29.6	67.4	89.0	10.7	34.1	0.9	2.0	2.6	0.3
2017–18	30.0	81.2	89.0	10.7	34.1	0.9	2.4	2.6	0.3
2018–19	30.1	87.8	89.0	10.7	34.1	0.9	2.6	2.6	0.3
2019–20	30.1	90.5	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2020–21	30.2	91.6	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2021–22	30.2	92.0	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2022–23	30.2	92.1	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2023–24	30.2	92.2	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2024–25	30.2	92.2	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2025–26	30.2	92.2	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2026–27	30.2	92.2	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2027–28	30.2	92.2	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2028–29	30.2	92.2	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2029–30	30.2	92.2	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2030–31	30.2	92.2	89.0	10.7	34.1	0.9	2.7	2.6	0.3
2031–32	30.2	92.2	89.0	10.7	34.1	0.9	2.7	2.6	0.3

Note: DCLR = direct chrome liquor recycling; PLR = pickle liquor recycling

Sources: OzForex website at <http://www.ozforex.com.au/>; Centre for International Economics the cost reduction associated with this technology is therefore expected to be smaller than the others. Nevertheless, PLR is still expected to deliver some benefits to vegetable tanneries in India.

Since we have assumed that changes in production costs in Tamil Nadu will have no significant impact on world prices, all of the benefits flow to the tanneries that adopt the low-salt technologies. There is no external benefit to local farmers and households through lower salinity of rivers and groundwater because we have assumed that the zero-liquid-discharge requirements will eventually mean that salinity would have been reduced, even without adoption of low-salt technologies. The lack of impact on the price of finished leather in either world or Indian markets also means that:

- there is no benefit to Indian (or foreign) leather product manufacturers or consumers since they continue to pay the same price for finished leather and therefore leather consumer goods
- tanneries in Tamil Nadu that do not adopt the lower cost technologies are also not disadvantaged by their competitors adopting.

Adoption of the new technologies could have an impact on the price of finished leather in India's domestic market if the cost of complying with zero-liquid-discharge requirements were to push the price of finished leather in India's domestic market above the world price, but below the world price plus the tariff. At these prices, India's domestic market would be in balance. It is unlikely that this will be the case since tanneries in Tamil Nadu that have installed their own RO facilities and are therefore complying with zero-liquid-discharge requirements continue to export finished leather.

Costs

The nominal research costs, which include all cash and in-kind contributions as well as the expected cost to CLRI of facilitating adoption, are converted to real 2008–09 dollars using the Australian GDP deflator published by the Australian Bureau of Statistics. For future periods, an annual increase of 3.0% is assumed in line with the upper end of the Reserve Bank of Australia's inflation target. Nominal and real (in 2008–09 dollars) project costs to ACIAR and from other sources are shown in Table 16.

Table 16. ACIAR project AS1/2001/05 costs

	ACIAR	**Other sources**	**Total inputs**	**Deflator**	**ACIAR**	**Other sources**	**Total inputs**
	Current A$'000	Current A$'000	Current A$'000	Index, 2008–09 =100	2008–09 A$'000	2008–09 A$'000	2008–09 A$'000
2002–03	257.7	267.8	525.5	78.3	329.1	342.0	671.1
2003–04	266.9	287.4	554.3	81.0	329.3	354.6	684.0
2004–05	241.5	272.9	514.4	84.1	287.1	324.5	611.7
2005–06	15.0	56.3	71.3	88.0	17.0	64.0	81.0
2006–07	17.5	28.2	45.7	92.1	19.0	30.6	49.6
2007–08	17.5	28.2	45.7	96.2	18.2	29.3	47.5
2008–09	–	25.0	25.0	100.0	–	25.0	25.0
2009–10	–	25.0	25.0	103.0	–	24.3	24.3
2010–11	–	25.0	25.0	106.1	–	23.6	23.6
2011–12	–	25.0	25.0	109.3	–	22.9	22.9

Sources: ACIAR project budget; Australian Bureau of Statistics Catalogue No. 6204.0; Dr A. Amudeswari (pers. comm., 20 March 2009); Centre for International Economics

Summary measures

Over the 30-year period from 2002–03 to 2031–32, it is estimated that the project will deliver benefits to Indian tanneries of A$49.4 million (Table 17), expressed in 2008–09 dollars (in present-value terms using a discount rate of 5%). The estimated benefits significantly exceed the cost of the project, which was A$2.1 million, expressed in comparable terms. The project is therefore expected to produce net benefits of A$47.3 million, equivalent to around A$23.60 for every A$1.00 spent. The internal rate of return on the investment in research into low-salt technologies is estimated at 32.4%. While the net benefits are obviously lower, even using a discount rate of 10%, the broad conclusion that the project will deliver significant net benefits holds.

Attribution of benefits

It is reasonable to attribute benefits among the project contributors on a cost-share basis. Using a discount rate of 5%, ACIAR contributed 0.9 million, or 45% of the total cost of the project. Benefits of around A$22.4 million can therefore be attributed to ACIAR (Table 18).

Robustness of estimates

While the benefits of the ACIAR-funded project are expected to accrue in the future, here, as with all such projects, there is significant uncertainty and risk associated with such an expectation. We discuss this below. The estimated benefits are also critically dependent on

Table 17. Summary measures of ACIAR project AS1/2001/005 benefits and costs

Discount rate	1%	5%	10%
Present value of benefits (A$m)	102.2	49.4	22.1
– low-salt preservation	14.2	6.9	3.1
– chilling	36.1	16.3	6.6
– direct chrome liquor recycling	46.6	23.5	11.2
– pickle liquor recycling	5.3	2.6	1.2
Present value of costs (A$m)	2.21	2.10	1.97
Net present value (A$m)	100.0	47.3	20.1
Benefit:cost ratio	46.3	23.6	11.2
Internal rate of return (%)	32.4	32.4	32.4

Source: Centre for International Economics

Table 18. Attribution of benefits of project AS1/2001/005 to ACIAR

Discount rate	1%	5%	10%
Present value of ACIAR costs (A$m)	1.0	0.9	0.9
Share of total costs (%)	44.8	45.3	45.8
Present value of benefits attributable to ACIAR (A$m)	45.8	22.4	10.1

Source: Centre for International Economics a number of key parameters and assumptions provided by the researchers and other project stakeholders. We also test how robust the conclusions drawn from the estimates are to varying those assumptions.

Risks

The estimated benefits presented in this impact assessment are based on a reasonable assessment of the future. However, the future can never be predicted with certainty. A key risk is the level of adoption. Clearly, the project can deliver benefits only if the outputs are adopted and there is some risk that tanners will not adopt the low-salt technologies, due to the barriers discussed in Chapter 2.

The question is: How low would adoption have to be before the project delivers no net benefits? This is a difficult question to answer since there are four technologies and the risk of no adoption is different for each. For example, there are more barriers to adopting chilling than DCLR. To simplify the analysis, we assume that adoption rates are reduced proportionately. To produce a project net present value of 0 (or benefit:cost ratio of 1), the maximum adoption rate for each technology would have to fall to less than 1.5% of the leather produced in Tamil Nadu (using a discount rate of 5%), which seems unlikely (Figure 14).[66] We can therefore be confident that the project will deliver some net benefits, even if there is significantly lower adoption than expected.

As the benefits are distributed across four technologies, the risk of the project failing to deliver any net benefits due to non-adoption is reduced. Even if there is no adoption of some of the outputs, the project is still likely to deliver some net benefits in total. Indeed, the estimated benefits of each of the four technologies exceed the total cost of the project. This demonstrates the advantage, over a single technology that might have limited applicability, of a package of technologies applicable in a variety of situations. Table 19 shows, for each technology, the maximum adoption rate (in Tamil Nadu) required to recover the project costs, assuming zero adoption of the other technologies. Only a modest rate of adoption of one of the technologies is required for the project to recover its costs.

66 This assumes a proportionately similar path to reach the maximum adoption rate. The timing of adoption also influences the benefits, but this is not examined here.

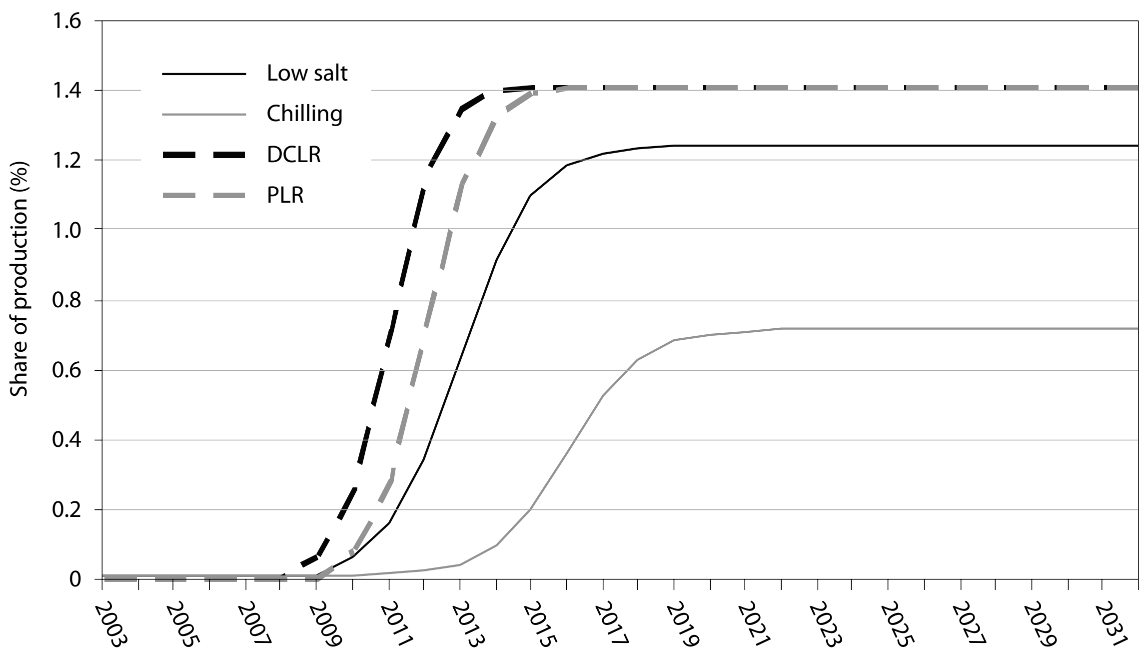

Figure 14. Adoption profiles that deliver zero net benefits from project AS1/2001/005 technologies. Data source: Centre for International Economics

Table 19. Maximum adoption rate (%) required to recover ACIAR project AS1/2001/005 costs[a]

	Low-salt preservation	Chilling	Direct chrome liquor recycling	Pickle liquor recycling
Maximum adoption rate	8.9	2.1	3.0	26.5

[a] Assuming zero adoption of all other technologies
Source: Centre for International Economics

Another risk to the project delivering benefits as large as has been estimated is that the outputs will be usurped by newer and better technology. That would imply that the outputs are adopted by end users, then subsequently disadopted as better technology becomes available. For example, CLRI continues to research technologies that use no salt, and other research is investigating techniques to recover individual salts from the mixed waste salts recovered from RO. However, even significant developments in these areas are unlikely to significantly reduce the benefits attributable to the ACIAR-funded project. Often, new technology builds on old technology, so some of the benefits of the new technology can be attributed to the research undertaken to develop the old technology. It is therefore inappropriate to treat this as disadoption of the old technology.

Furthermore, if new technology to recover individual salts from the mixed waste salts becomes available, reduced-salt technologies are still likely to be relevant. Such a process is likely to involve some costs, which would be lower for lower quantities of recovered mixed salts. This is analogous to the cost of RO being lower for effluent with lower TDS loads. Therefore, new technology in this area is likely to complement rather than replace low-salt technologies.

Sensitivity analysis

The results presented are also critically dependent on a number of parameter estimates provided by project stakeholders, as well as various other assumptions. In many cases, these parameters cannot be estimated with any precision at this stage, and researchers and other project stakeholders typically gave a range rather than a point estimate. In this impact assessment, we have typically based our analysis on the midpoint of the range provided by researchers. In this section, we test the robustness of our estimates and the conclusions drawn from them to varying these assumptions. In particular, we vary our assumptions relating to the following factors:

- *Elasticity of supply*. As there have been no empirical studies estimating the elasticity of supply, we assumed it is around 0.8. We test the sensitivity of the estimated benefits to this assumption by varying the elasticity in a relatively wide range, between 0.1 and 1.5.
- *Price of finished leather*. Tanneries estimated that, on average, the price of finished leather is between US\$1.00 and US\$1.20 per square foot.
- *Cost of capital*. The costings for implementing the low-salt technologies are based on a cost of capital of 15%, as estimated by CLRI.[67] However, many tanneries in Tamil Nadu are very small, family-operated businesses. This type of business can often have trouble accessing cheap capital in India.[68] We therefore test the sensitivities of the estimated benefits by varying the assumed cost of capital within a range of 5–25%.
- *Cost of effluent treatment*. CEMCOT estimated that reducing the TDS in effluent from 12,000–15,000 ppm to 7,000–9,000 ppm reduces treatment costs from US\$3 per m^3 to US\$2 per m^3.[69] Based on the mid-point of these ranges, we estimated that effluent treatment costs for 1 tonne of leather could be Rs255 lower for every 1,000 ppm reduction in TDS. A low alternative assumption would a US\$1 per m^3 cost reduction for reducing TDS from 15,000 ppm to 7,000 ppm. This equates to a Rs175 reduction in the cost of treating the effluent from 1 tonne of leather. A high alternative assumption would be a US\$1 per m^3 cost reduction from reducing TDS from 12,000 ppm to 9,000 ppm. This translates to a reduction in effluent treatment costs of Rs468 per tonne of leather.

67 Dr N.K. Chandra Babu (pers. comm., 16 March 2009)
68 Professor U. Sankar (pers. comm., 20 March 2009)
69 Mr A. Sahasranaman (pers. comm., 16 March 2009)

- *Waste-salt disposal costs*. A CEMCOT study estimated that the cost of disposal of a tonne of waste salt was between Rs2,600 and Rs3,000, depending on the size of the storage facility.[70]
- *Counterfactual TDS*. The TDS load from tanneries in Tamil Nadu is estimated at between 7,000 ppm and 15,000 ppm.[71]

[70] Mr K.V. Emmanuel (pers. comm., 20 March 2009)

[71] Project review (Sahasranaman and Jackson 2005, p. 5)

Table 20 shows these ranges for the key parameters and the effect each of these alternative assumptions has on the estimated net present value and the benefit:cost ratio (holding all other parameters constant). Variations in the elasticity of supply and the price of finished leather have little impact on the overall estimates. The estimates are somewhat more sensitive to the other assumptions, particularly the cost of effluent treatment and the assumed effluent TDS in the counterfactual scenario. However, the broad conclusion that the project will deliver significant net benefits to India holds when these assumptions are varied within a plausible range. We can therefore be confident that the conclusions drawn from our estimates are robust.

Table 20. Sensitivity analysis of ACIAR project AS1/2001/005 benefits

	Low scenario	Central case	High scenario
Variables			
Elasticity of supply	0.1	0.8	1.5
Price of finished leather (US$ per square foot)	1.0	1.1	1.2
Effluent treatment costs (Rs per '000 ppm)[a]	175	255	468
Waste-salt disposal costs (Rs per tonne)	2,600	2,800	3,000
Counterfactual total dissolved solids (TDS) (ppm)	7,000	11,000	15,000
Cost of capital (%)	5.0	10.0	25.0
Net present value (A$m)			
Elasticity of supply	47.0	47.3	47.5
Price of finished leather	47.3	47.3	47.2
Effluent treatment costs	38.7	47.3	70.1
Waste-salt disposal costs	46.6	47.3	48.0
Counterfactual TDS	37.6	47.3	57.0
Cost of capital	49.9	47.3	44.6
Benefit:cost ratio			
Elasticity of supply	23.5	23.6	23.7
Price of finished leather	23.6	23.6	23.6
Effluent treatment costs	19.5	23.6	34.5
Waste-salt disposal costs	23.3	23.6	23.9
Counterfactual TDS	19.0	23.6	28.2
Cost of capital	24.9	23.6	22.3

[a] Based on producing 1 tonne of raw material

Source: Centre for International Economics

6 Conclusions

While widespread benefits are yet to be realised, we estimate that the ACIAR-funded project *Salinity reduction in tannery effluents in India and Australia* will eventually deliver significant benefits to Indian tanneries. As the Australian tanneries involved in the project subsequently closed due to competitive pressures from lower cost producers, it is unlikely that the project will deliver any benefits to Australia. These conclusions are robust to varying key assumption within a plausible range. The key risk to the benefit estimates is that the technologies developed under the project are not adopted.

Adoption has so far been slow due to a range of barriers, including the following, that have discouraged tanners from adopting the new technologies.

- Zero-liquid-discharge requirements have meant that tanners have focused on installing RO treatment facilities, rather than reducing salt inputs.
- The dispersed nature of Indian skin and hide collection systems means that tanneries tend to have many small-scale skin and hide suppliers. This makes it more difficult for tanners to train the dealers and insist that skins and hides are preserved using less salt.
- The tanneries and not the end users (skin and hide suppliers) are the ultimate beneficiaries of using less salt for preservation. This means there is little incentive for the end users to adopt the reduced-salt preservation technologies developed under the project.
- There is a reluctance and perceived risk in changing entrenched practices without government assistance, or unless compelled to do so by regulation.

Nevertheless, we think it is likely that low-salt technologies will eventually be adopted, even without regulation or government assistance, for one primary reason: it is to the tanneries' own benefit to do so. The benefits of adopting the technologies in terms of reduced effluent treatment and waste-salt disposal costs do not yet appear to be fully appreciated. However, as RO facilities are installed at CETPs over the next few years, the costs associated with treating high TDS effluent and disposing of waste salt will be recognised, so long as CETPs charge member tanneries on the basis of TDS load rather than volume of effluent. The new RO facilities that are being installed at CETPs have the capacity to measure TDS load as well as effluent volumes. Rather than discouraging adoption of low-salt technologies, the zero-liquid-discharge requirements will actually encourage adoption, as they force tanners to internalise the costs of excessive salt use.

However, zero-liquid-discharge requirements do not provide an incentive for skin and hide suppliers to reduce the quantity of salt used for preservation. The cost burden from their excessive salt use is simply shifted from the local communities surrounding tannery clusters to the tanneries. But as tanneries are active participants in the market for raw skins and hides, a market solution is more likely to be found. Tanneries argued that it is not commercially viable to pay a premium for skins and hides cured with less salt. However, there appears to be some scope to pass on the benefits associated with lower costs of effluent treatment and waste-salt disposal, to provide an incentive for raw skin and hide suppliers to adopt the low-salt technologies. It therefore seems likely that all of the reduced-salt technologies will make some contribution to a sustainable solution to reducing the environmental damage caused by tannery effluent.

This impact assessment has highlighted the following broader lessons that may be relevant to future projects:

- The project has demonstrated that research aimed at finding technological solutions to pollution problems can deliver significant benefits to developing countries. As pollution issues in rapidly developing countries become more pressing, development projects aimed at reducing pollution are likely to become increasingly important. Firms, such as the tanneries in Tamil Nadu, need practical solutions to help them to meet low-pollution standards.
- This project has also shown that it can be beneficial to look for technologies that reduce the use of pollutants, as well as technologies that treat the pollution to reduce its negative impacts. In this case, a combination of technologies that reduce the use of pollutants and treat the pollution has been necessary to achieve a satisfactory outcome. More broadly, this shows there may be no 'silver bullet' technological solution to pollution problems, but rather a number of technologies can progressively contribute to a sustainable solution.
- The project has also demonstrated that developing a package of technologies reduces the risk of the project delivering no benefits due to non-adoption. For example, chilling is estimated to deliver the highest annual benefits of the four technologies, but the risk of its non-adoption also seems to be the highest. The project is nevertheless likely to deliver significant benefits overall, even if chilling is not adopted.
- The difficulties tanners foresee in getting their skin and hide suppliers to adopt reduced-salt preservation technologies demonstrate that the end users of new technologies must have an incentive to adopt.
- Finally, the project has shown that changes to the regulatory environment can affect the impacts of research and development projects. In this case, the final impacts seem to be quite different from what was initially intended. The project was initially expected to reduce the level of pollution and therefore benefit the farmers and households surrounding tannery clusters. However, zero-liquid-discharge requirements mean that river and groundwater salinity would have been reduced, even without the project. Instead, the project is likely to directly benefit tanneries by reducing the cost of achieving zero liquid discharge.

References

CSIRO 2001. Salinity reduction in tannery effluents in India and Australia. Project proposal to ACIAR by CSIRO Textile and Fibre Technology, Leather Research Centre.

Davis J., Gordon J., Pearce D. and Templeton D. 2008. Guidelines for assessing the impacts of ACIAR's research activities. Impact Assessment Series Report No. 58. ACIAR: Canberra.

FAO (Food and Agriculture Organization of the United Nations) 2008. World statistical compendium for raw hides and skins, leather and leather footwear, 1988–2007. Commodities and Trade Division, FAO: Rome.

Money C.A. 2008. Salinity reduction in tannery effluents in India and Australia: final report on project AS1/2001/005. ACIAR: Canberra.

Planning Commission, Government of India 2008. Eleventh five year plan (2007–2012): agriculture, rural development, industry, services and physical infrastructure, volume III. Oxford University Press: New Delhi.

Sahasranaman A. and Jackson M. 2005. Salinity reduction in tannery effluents in India and Australia: project review. ACIAR: Canberra.

IMPACT ASSESSMENT SERIES

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22	Bauer, M., Pearce, D. and Vincent, D. (2003)	Saving a staple crop: impact of biological control of the banana skipper on poverty reduction in Papua New Guinea	CS2/1988/002-C
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24	Palis, F.G., Sumalde, Z.M. and Hossain, M. (2004)	Assessment of the rodent control projects in Vietnam funded by ACIAR and AUSAID: adoption and impact	AS1/1998/036

No.	Author(s) and year of publication	Title	ACIAR project numbers
25	Brennan, J.P. and Quade, K.J. (2004)	Genetics of and breeding for rust resistance in wheat in India and Pakistan	CS1/1983/037 and CS1/1988/014
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30	van Bueren, M. (2004)	Eucalypt tree improvement in China	FST/1990/044, FST/1994/025, FST/1984/057, FST/1988/048, FST/1987/036, FST/1996/125 and FST/1997/077
31	Pearce, D. (2005)	Review of ACIAR's research on agricultural policy	
32	Tingsong Jiang and Pearce, D. (2005)	Shelf-life extension of leafy vegetables—evaluating the impacts	PHT/1994/016
33	Vere, D. (2005)	Research into conservation tillage for dryland cropping in Australia and China	LWR2/1992/009, LWR2/1996/143
34	Pearce, D. (2005)	Identifying the sex pheromone of the sugarcane borer moth	CS2/1991/680
35	Raitzer, D.A. and Lindner, R. (2005)	Review of the returns to ACIAR's bilateral R&D investments	
36	Lindner, R. (2005)	Impacts of mud crab hatchery technology in Vietnam	FIS/1992/017 and FIS/1999/076
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39	Pearce, D., Monck, M., Chadwick, K. and Corbishley, J. (2006)	Benefits to Australia from ACIAR-funded research	FST/1993/016, PHT/1990/051, CS1/1990/012, CS1/1994/968, AS2/1990/028, AS2/1994/017, AS2/1994/018 and AS2/1999/060
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41	ACIAR (2006)	ACIAR and public funding of R&D. Submission to Productivity Commission study on public support for science and innovation	
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No.	Author(s) and year of publication	Title	ACIAR project numbers
47	Fisher, H. and Gordon, J. (2007)	Improved Australian tree species for Vietnam	FST/1993/118 and FST/1998/096
48	Longmore, C., Gordon, J., and Bantilan, M.C. (2007)	Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia	CS1/1994/968
49	Fisher, H. and Gordon, J. (2007)	Minimising impacts of fungal disease of eucalypts in South-East Asia	FST/1994/041
50	Monck, M. and Pearce, D. (2007)	Improved trade in mangoes from the Philippines, Thailand and Australia	PHT/1990/051 and CS1/1990/012
51	Corbishley, J. and Pearce, D. (2007)	Growing trees on salt-affected land	FST/1993/016
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53	Monck M. and Pearce D. (2008)	The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology	AH/1997/115
54	Monck M. and Pearce D. (2008)	Impact of improved management of white grubs in peanut-cropping systems	CS2/1994/050
55	Martin G. (2008)	ACIAR fisheries projects in Indonesia: review and impact assessment	FIS/1997/022, FIS/1997/125, FIS/2000/061, FIS/2001/079, FIS/2002/074, FIS/2002/076, FIS/2005/169 and FIS/2006/144
56	Lindner, B. and McLeod, P. (2008)	A review and impact assessment of ACIAR's fruit-fly research partnerships – 1984 to 2007	CS2/1983/043, CS2/1989/019, CS2/1989/020, CS2/1994/003, CS2/1994/115, CS2/1996/225, CS2/1997/101, CS2/1998/005, CS2/2003/036, CP/2007/002, CP/2007/187, PHT/1990/051, PHT/1994/133, PHT/1993/87, CP/1997/079, CP/2001/027 and CP/2002/086
57	Montes N.D., Zapata Jr N.R., Alo A.M.P. and Mullen J.D. (2008)	Management of internal parasites in goats in the Philippines	AS1/1997/133
58	Davis J., Gordon J., Pearce D. and Templeton D. (2008)	Guidelines for assessing the impacts of ACIAR's research activities	
59	Chupungco A., Dumayas E. and Mullen J. (2008)	Two-stage grain drying in the Philippines	PHT/1983/008, PHT/1986/008, PHT/1990/008
60	Centre for International Economics (2009)	ACIAR Database for Impact Assessments (ADIA): an outline of the database structure and a guide to its operation	
61	Fisher H. and Pearce D. (2009)	Salinity reduction in tannery effluents in India and Australia	AS1/2001/005

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