Chapter 4

Subsector-Specific Cleaner Production Briefings

Contents

This section offers tools that may be useful in evaluating micro- and small enterprises' (MSEs') environmental impacts and mitigation opportunities—emphasizing financially viable cleaner production (CP) opportunities.

These briefings have been prepared for (1) **business development services (BDS) providers**, which offer services such as management training or marketing support to MSEs, and (2) **intermediate credit institutions (ICIs)** and **direct lenders** that provide financial credit to MSEs. They are intended to be used in concert with other sections in Part III of the *Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Development Activities,* which is USAID Africa Bureau's principal source of sector-specific environmental guidance. Part III discusses specific problems, strategies, tools and benefits of dealing proactively with MSEs' potential negative impacts on the environment and health. Other chapters in the *Guidelines* may also be of help and are referred to as appropriate.

This section presents briefings for seven subsectors that generate significant adverse environmental impacts and/or present numerous **cleaner production** opportunities[1] for cost savings. The subsectors covered are:

a. Brick and tile manufacturing
b. Food processing
c. Leather processing
d. Metal finishing
e. Mining
f. Wet textile operations
g. Wood processing and furniture making

These are by no means the only MSE sectors in need of environmental assessment and mitigation. Nor do these briefings present all possible impacts or CP opportunities. These fact sheets should be used, rather, as a starting point for an environmental audit, and are designed for use by individuals without extensive environmental training. BDS and credit organizations may want to extend these briefings to capture institutional and field experience as suits their needs. They may also wish to create similar fact sheets for other commonly supported subsectors.

Cleaner production (CP) options with clear financial benefits will be easier to find in some firms than others. Even when they use CP methods, some businesses may need to use pollution controls or other solutions offering no financial return if regulations or community relations require it.

The fact sheets focus on CP as the preferred mitigation strategy. In addition to environmental, health and safety benefits, many cleaner production techniques provide opportunities to substantially reduce operating costs and improve product quality. MSEs can profit from cleaner production through more efficient use of inputs and machinery, higher quality, and reduced waste disposal costs. Improved safety measures can also help MSEs avoid costly accidents and worker absences.

Experience has demonstrated that, with assistance, MSEs can often identify cleaner production opportunities that produce a positive financial return, sometimes with little or no investment. Many enterprises that change to CP methods may realize substantial financial and environmental benefits, indicating that CP should be the first option considered in addressing MSEs' environmental problems.

Although this approach can offer tremendous advantages, readers should also recognize that cleaner production options showing clear financial benefit will be easier to find in some enterprises than in others. Often they may not completely mitigate environmental problems. In some cases, even when pursuing cleaner production techniques, some businesses may need to use pollution control or other solutions that offer no measurable financial return—if such solutions are required by USAID's Regulation 216, local regulations, or other reasons such as community goodwill. To some extent, these fact sheets offer pollution control suggestions that supplement or complement cleaner production suggestions.

[1] See Chapter 2 of this section (Part II of the *Environmental Guidelines)* for a background discussion of cleaner production (CP) and CP opportunities for MSEs.

Chapter 4.1
Brick and Tile Production: Cleaner Production Fact Sheet and Resource Guide

Purpose

This fact sheet offers basic information on the important adverse environmental impacts of brick and tile production, as well as associated health and safety impacts. It also discusses opportunities for mitigating those impacts, with an emphasis upon "cleaner production" strategies that may also provide financial benefits to micro- and small enterprises (MSEs). In addition, each fact sheet offers a substantial, annotated list of resources for those organizations seeking more information.[2]

This fact sheet has been prepared for (1) **business development services (BDS) providers**, which offer services such as management training or marketing support to MSEs, and (2) **intermediate credit institutions (ICIs)** and **direct lenders** that provide financial credit to MSEs. It is intended to be used in concert with other sections in Part III of the *Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Development Activities,* which is USAID Africa Bureau's principal source of sector-specific environmental guidance.

Why Focus on Cleaner Production for Mitigation?

Cleaner production (CP) is a preventive business strategy designed to conserve resources, mitigate risks to humans and the environment, and promote greater overall efficiency through improved production techniques and technologies. Cleaner production methods may include:

- substituting different materials
- modifying processes
- upgrading equipment
- redesigning products

In addition to environmental, health and safety benefits, many cleaner production techniques provide opportunities to substantially reduce operating costs and improve product quality. MSEs can profit from CP through more efficient use of inputs and machinery, higher-quality goods that command higher prices, and reduced waste disposal costs. Improved

[2] At the time of writing, USAID cleaner production fact sheets are available for the following subsectors that are likely to have substantial adverse impacts on the environment and/or workers' health: brick and tile production; leather processing; small-scale mining; food processing; metal finishing; wood processing and furniture making, and wet textile operations.

safety measures can also help MSEs avoid costly accidents and worker absences.

Experience has demonstrated that, with assistance, MSEs can frequently identify cleaner production opportunities that produce a positive financial return, sometimes with little or no investment. Many enterprises that change to CP methods may reap substantial financial and environmental benefits, indicating that CP should be the first option considered in addressing MSEs' environmental problems.

Yet, although this approach can offer tremendous advantages, readers should also recognize that cleaner production options showing clear financial benefit will only be available to varying degrees among different enterprises and often may not completely mitigate environmental problems. In some cases, even when pursuing CP techniques, some businesses may need to use solutions that offer no measurable financial return—if such solutions are required by USAID's Regulation 216 or local regulations or desired for other reasons, such as community goodwill.

Small-scale brick and tile factories, like this facility in South Africa, can benefit the environment and their finances by more efficient use of resources and inputs.

Important Environmental Issues Addressed by This Fact Sheet

- Inefficient use of fuel
- Resource extraction and depletion
- Inefficient use of non-fuel inputs
- Dust
- Chemical pollution

Adverse Environmental Impacts and Mitigation Opportunities

Several key environmental issues associated with brick and tile production are listed in the box at left and discussed below. For each impact, the fact sheet provides a list of questions to aid in the assessment of individual MSEs. These questions are followed by a number of mitigation strategies that can be considered, with an emphasis on cleaner production strategies where possible. The strategies presented typically represent a range of available options, from profitable activities that require no investment to other activities that may increase MSEs' costs.

❑ *Inefficient use of fuel*

Traditional brick and tile production requires a great deal of fuel during firing. Inefficient production technologies and techniques and excessive fuel consumption are typical. High fuel use increases air pollution, worsening respiratory illnesses. It also increases deforestation and associated environmental impacts, leaving less wood for future use. Reducing consumption reduces costs, conserves resources and lowers pollution levels.

Key questions to consider:

- What type of fuel is used in production? Where does it come from?
- What other types of fuel are available?
- Are there leaks or openings in the kiln structure?
- How close are settlements to the (proposed) kiln site?
- How much exposure to smoke and ash do workers have?
- How much bending and lifting do workers do?

Selected Mitigation Strategies:

- Use alternative fuel types. Organic wastes such as rice husks or sugar bagasse can supplement scarce fuel sources, such as wood, without sacrificing efficiency.
- Raise kiln temperature using improved firing techniques. Adding combustible material around the bricks or between clamps can increase temperatures and lower traditional fuel needs.
- Maintain kiln structure and repair cracks or leaks. Even small leaks can substantially increase fuel costs over time. Monitor structure and machinery to identify potential leaks.
- If traditional brick-making technology is used (brick clamps), ensure adequate insulation of the clamp and orient it at a 90° angle to prevailing wind direction to reduce underfiring or overfiring of bricks. See http://www.gtz.de/basin/gate/brickclamps.htm for a more extensive review of best practices.
- Increase efficiency and reduce emissions by using kiln structures that require less fuel. Ventilated-shaft brick kilns (VSBKs) or bull trench kilns (BTKs) are effective in reducing smoke and lowering the amount of fuel required for firing.

- Install filters in chimneys. One small-scale brick producer used broken brick pieces to absorb carbon dioxide (CO^2) and reduced emissions substantially.[3]

- Prepare a safety and health plan to minimize adverse respiratory effects and physical stress on kiln workers.

❑ *Resource extraction and depletion*

Brick and tile production can alter the landscape in ways that are harmful to the environment and may hamper future business plans. Production can deplete local sources of fuelwood, eventually raising the cost of labor for acquiring fuel. It can also create clay pits or "borrow" areas, which, if improperly managed, can become safety hazards. They may also accumulate rainwater and become habitat for mosquitoes. These effects, with associated soil erosion, may make land unusable for farming. For all these reasons, landowners or communities may resist further expansion.

Key questions to consider:

- How is the landscape expected to change (from tree-cutting, borrow pits, etc.) over the course of production?

Selected mitigation strategies:

- Consider planting fast-growing tree species that can be coppiced easily, such as *Leucaena* or *Albizia*, to maintain a source of fuel. Tree planting also helps to prevent soil erosion, reduce siltation of water bodies and maintain soil fertility. If trees are planted, make sure it is clear who owns them to encourage better long-term management.

Return land to a usable state. Set topsoil aside before removing clay and replace it after production ends. If topsoil has been lost or dispersed, fill the borrow pit with soil to avoid creating pools of water that attract mosquitoes.

❑ *Inefficient use of non-fuel inputs*

Inefficient production techniques reduce productivity and create excessive waste. Improper brick and tile formation and low-quality inputs result in a high number of bricks or tiles that crack or break during firing and must be discarded. This decreases output and increases waste disposal costs. Brick or tile wastes require significant amounts of space, leaving less land available for other uses. Better use of technology and training will increase productivity and efficiency while reducing costs and waste.

---

[3] For more information, see "Remediation of Airborne Polyaromatic Hydrocarbons (PAHs)" in the reference section of this document.

Key questions to consider:

- What kind of machinery is used in the production process?
- What kinds of raw materials are used in production and how are they identified?
- What quality control processes are used to evaluate raw materials?
- What waste will be left after production is finished?

Selected mitigation strategies:

- If little or no machinery is used, consider low-cost technology improvements. Decrease losses during firing by improving brick preparation: use an extruder to process clay, or form bricks with manual presses.
- Improve input quality. Bricks that crack during firing may have too much organic material in them or too much topsoil mixed in with clay. Train workers and monitor quality regularly.
- Consolidate or remove brick and tile waste once production ends. This waste may be scattered over a large area and make it hard to farm the land in the future. Investigate possible uses of broken or burnt brick for construction and other processes.

❑ *Dust*

Dust, a byproduct of brick and tile production, may cause serious health problems. Dust is most prevalent and most dangerous when clay is extracted and when finished bricks are transported following the firing process. Inhaling rock dust can lead to silicosis, a disease that affects lungs and breathing. Silicosis lowers the productivity of workers and can have long-term and even fatal effects on the health of workers, owners and people who live close by (including the families of workers and owners).

Key questions to consider:

- When is dust most prevalent in the production process?
- What safety measures are available to workers?

Selected mitigation strategies:

- Provide workers with face masks and instruct them to use masks in high-dust operations.
- Dampen bricks and tiles to keep dust down. In particular, if bricks or tiles are made and then broken for use in construction, make sure to dampen them first. However, try not to use excessive water.

❑ *Chemical pollution*

Adding pigment to bricks or glazing roofing tiles produces chemical wastes that could harm workers, pollute the air and contaminate water supplies. Glazing and enameling require materials that contain acids or metals, and improper handling or excessive contact can lead to metal poisoning, skin irritations or lung disease. Unhealthy workers can lower productivity, miss work too often and contribute to costly mistakes. Poor housekeeping practices can waste materials, raising input costs.

Key questions to consider:

- What types of glaze or enamels are used in production?
- What safety and housekeeping measures do workers practice?
- Are chemical wastes disposed of away from water sources?

Selected mitigation strategies:

- If possible, use water-based acrylic glazes to minimize environmental problems.
- Improve storage practices. Close containers containing glazing or enameling material to prevent loss of the material through evaporation, spoilage or spills, and to minimize workers' exposure to fumes.
- Require workers to wear masks when they are using glazing or enameling chemicals.
- Require workers to wash their hands after working with glazes. Many glazes have traces of metal that can cause metal poisoning when ingested. Provide gloves made of rubber, vinyl or other impermeable materials for workers who are handling glazes and glazed material.
- Ventilate kilns after firing. Dangerous gases and fumes escape during the firing process and can sicken workers removing bricks or tile.
- Prevent water contamination. Apply glazes away from water sources and dispose of chemical wastes properly. Do not clean spilled glazes with water. Sprinkle them with absorbent material such as straw, clay or dirt, and sweep up the spill into a separate container. To prevent metals from leaching out of the glazes into water supply, they should be disposed of safely (for example, in clay- or concrete-lined pits). Check with an environmental expert to confirm the chosen disposal method is safe for the chemicals used.

References and Resources

- Blackman, Allen and Geoffrey J. Bannister (1998). *Pollution Control in the Informal Sector: The Ciudad Juárez Brickmakers' Project*. Discussion Paper 98-15, Resources for the Future.

  http://www.rff.org/Documents/RFF-DP-98-15.pdf. This case study discusses the development of technology for improving polluting emissions among small-scale brickmakers in Mexico.

- *The Clay Brick Industry: Improvement of Resource Efficiency and Environmental Performance* (2000). Cleanerproduction.com, Hamner and Associates LLC.

  http://www.cleanerproduction.com/Directory/sectors/subsectors/clay.html. Direct links to online guides for cleaner production in clay brick making.

- *Clay Preparation Methods*. Wall Technical Briefs. German Federal Ministry for Economic Cooperation and Development (GTZ).

  http://sleekfreak.ath.cx:81/3wdev/GATE_DL/BUILDING/BASTB13E.PDF;
  http://sleekfreak.ath.cx:81/3wdev/GATE_DL/BUILDING/BASTB11E.PDF;
  http://sleekfreak.ath.cx:81/3wdev/GATE_DL/BUILDING/BASTB12E.PDF.

  A series of technical briefs dealing with the drying of clay for brick- and tile making, the preparation of clay, and the molding and firing of clay bricks and tiles. The brief describes basic drying processes, different drying methods, surface treatment, drying tests, choice of drying methods, economics and flexibility. A table explains drying faults, their causes and remedies.

- *Energy Efficiency Improvement in the Brick, Tile and Lime Industries on Java* (1987). World Bank Energy Sector Management Assistance Program. UNDP, World Bank.

  http://www-wds.worldbank.org/servlet/WDS_IBank_Servlet?pcont=details&eid=000009265_3960928074130 This report discusses improvements in the brick, tile and lime industry in Indonesia. Particular attention is paid to better ways to prepare clay and keep tiles from breaking in the kiln.

- "Energy Saving in Brick Industry: Brick-by-Brick Approach to Sustainable Development." (1999) *Terivision* No. 18. Tata Energy Research Institute.

  http://www.teri.res.in/teriin/news/terivsn/issue18/main.htm. A general discussion of improving energy efficiency in the brick industry. This is not a very technical document but includes useful starting strategies for dealing with energy issues.

- *Status and Development Issues of the Brick Industry in Asia* (1993). Field Document No. 35, UN Food and Agriculture Organization (FAO).

  http://www.fao.org/docrep/006/AD592E/AD592E00.HTM. A comprehensive description of brick production and alternative technologies that improve production. Specific reference to kiln types and different methods of input extraction.

- *Uganda: Energy Efficiency Improvement in the Brick and Tile Industry* (1989). World Bank Energy Sector Management Assistance Program. UNDP, World Bank.

  http://www-wds.worldbank.org/servlet/WDS_IBank_Servlet?pcont=details&eid=000009265_3960928084948. This report analyzes technical and economically feasible means for improving energy efficiency in brick and tile production in Uganda. Specific discussion of fuelwood conservation.

Other Resources

- *Bull's Trench Brick Kiln*. Wall Technical Brief. German Federal Ministry for Economic Cooperation and Development (GTZ).

  http://sleekfreak.ath.cx:81/3wdev/GATE_DL/BUILDING/BK.HTM. Description of the Bull's Trench Brick Kiln technology. Discusses advantages and disadvantages of the technology, with specific reference to lowering fuel use and improving productivity. Includes diagrams and figures.

- *Energy Conservation in the Ceramic Industry* (1994). United Nations Industrial Development Organization (UNIDO).

  http://www.unido.org/userfiles/PuffK/ceramic.pdf. This report covers the broader ceramics industry, including pottery, but contains a useful detailed discussion of how to improve energy efficiency in kilns.

- "The Environmental Colours of Microfinance Theory" and "Practice Enabling the Link between Microcredit and Environment" in *Promoting Environmentally Based Micro-Enterprises* (2000). Global Development Research Centre.

  http://www.gdrc.org/icm/environ/environ.html. This is a larger document on environmental assessment of microenterprises, but includes a case study of brickmakers in Zimbabwe.

- Maithel, Sameer, Heini Mueller and Rajinder Singh (2000). *Experiences in the Transfer and Diffusion of Efficient Technologies in the Indian Brick Industry*. CTI/Industry Joint Seminar on Technology Diffusion in Asia, 14–15 January 2000. United Nations Framework Convention on Climate Change Secretariat.

- Scott, Andrew. *The Environmental Impact of Small-Scale Industries in the Third World*. Global Environmental Change Programme Briefings No. 19.

  http://www.susx.ac.uk/Units/gec/pubs/briefing/brief-19.pdf. This technical brief includes a short discussion of the environmental impacts associated with small-scale brickmaking. *Vertical Shaft Brick Kiln Fact Sheet*. Development Alternatives Inc.

  http://www.devalt.org/da/tsb/vsbk.pdf. This fact sheet discuses vertical-shaft brick kiln (VSBK) technology and provides contact information for further inquiries and technical material.

Chapter 4.2
Food Processing: Cleaner Production Fact Sheet and Resource Guide

Purpose

This fact sheet offers basic information on the important adverse environmental impacts of food processing, as well as associated health and safety impacts. It also discusses opportunities for mitigating those impacts, with an emphasis upon “cleaner production” strategies that may also provide financial benefits to micro- and small enterprises (MSEs). In addition, each fact sheet offers a substantial, annotated list of resources for organizations seeking more information.[4]

This fact sheet has been prepared for (1) **business development services (BDS) providers**, which offer services such as management training or marketing support to MSEs, and (2) **intermediate credit institutions (ICIs) and direct lenders** that provide financial credit to MSEs. It is intended to be used in concert with other sections in Part III of the *Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Development Activities,* which is USAID Africa Bureau's principal source of sector-specific environmental guidance.

Why Focus on Cleaner Production for Mitigation?

Cleaner production (CP) is a preventive business strategy designed to conserve resources, mitigate risks to humans and the environment, and promote greater overall efficiency through improved production techniques and technologies. CP methods may include:

- substituting different materials
- modifying processes
- upgrading equipment
- redesigning products

In addition to environmental, health and safety benefits, many cleaner production techniques can substantially reduce operating costs and improve product quality. MSEs may profit from CP through more efficient use of inputs and machinery, higher-quality goods that can command higher prices,

[4] At the time of writing, USAID cleaner production fact sheets are available for the following subsectors that are likely to have substantial adverse impacts on the environment and/or workers’ health: brick and tile production; leather processing; small-scale mining; food processing; metal finishing; wood processing and furniture production, and wet textile operations.

and reduced waste disposal costs. Improved safety measures can also help MSEs avoid costly accidents and worker absences.

Experience has demonstrated that, with assistance, MSEs can frequently identify cleaner production opportunities that produce a positive financial return, sometimes with little or no investment. Many enterprises that change to CP methods may realize substantial financial and environmental benefits, indicating that CP should be the first option considered in addressing MSEs' environmental problems.

Yet, although this approach can offer tremendous advantages, readers should also recognize that cleaner production options showing clear financial benefit will only be available to varying degrees among different enterprises and often may not completely mitigate environmental problems. In some cases, even when pursuing CP techniques, some businesses may need to use solutions that offer no measurable financial return—if such solutions are required by USAID's Regulation 216 or local regulations or desired for other reasons, such as community goodwill.

Food processing is an area where many cleaner production opportunities can be found, from water usage to recycling.

Important Environmental Issues Addressed by This Fact Sheet

- Water pollution
- Working conditions
- Spoilage
- Solid waste
- Poorly maintained machinery

Adverse Environmental Impacts and Mitigation Opportunities

A wide variety of African MSEs engage in food-processing activities ranging from abbatoirs to cashew nut processing. Several key environmental issues associated with food processing are listed in the box at left and discussed below. For each environmental impact, the fact sheet provides a list of questions to aid in the assessment of individual MSEs. These questions are followed by a number of mitigation strategies that can be considered, with an emphasis on cleaner production strategies where possible. The strategies presented typically represent a range of available options, from profitable activities that require no investment to other activities that may increase MSEs' costs.

❑ *Water pollution*

Harmful wastes disposed of in pits or waterways can leach into groundwater and affect water quality for workers and the community. Contamination of water sources may not occur immediately, but can increase or accumulate over time, eventually damaging to product quality and affecting workers' health.

Key questions to consider:

- Is there any chance rain could transport elements of the firm's waste from its original site to community centers or water sources?
- How near is the waste site to the water table and/or groundwater sources, such as wells?
- How close is the waste site to streams, rivers, lakes or other surface water bodies?
- Is the enterprise mixing chemical and organic waste?

Selected mitigation strategies:

- Site small dumps or waste treatment sites far away from surface or groundwater water sources.
- Separate harmful chemical waste from organic waste, and use more care in handling chemical waste. Dispose of chemical waste in a way that prevents chemicals from leaching into ground or surface waters (such as clay- or concrete-lined pits). Check with an environmental expert to confirm the chosen disposal method is safe for the chemicals being disposed of.
- If the enterprise stores waste temporarily before transporting it to a treatment facility or landfill, make sure it is not leaking into the ground.

❑ *Working conditions*

Certain working conditions—excessive heat caused by operating machinery, lack of ventilation, skin-irritating acids from fruits—can damage workers' health. An unhealthy workforce may be unproductive, miss work too often and make costly mistakes.

Key questions to consider:

- Do workers and managers know safety measures well?
- Are there any by-products from production that cause skin, eye or breathing irritation, even occasionally?

- Is protective clothing (e.g., gloves, boots, face masks) available for workers?

- Is there enough light and air so workers do not have to strain to perform their work?

Selected mitigation strategies:

- Maintain safety equipment and reinforce safety training. Safety measures may already be in place, but workers should be reminded often; designate one person as the safety trainer and have that person train others. Check existing safety equipment regularly, and replace elements like dust filters frequently.

- Create a prevention strategy. Sometimes small changes such as buying a face mask or rubber gloves can dramatically reduce incidences of harm to workers. Find ways of preventing accidents.

- Find ways of reducing harmful byproducts. For example, clean the floors in between production cycles to get rid of excess dust, or install drip trays to catch acidic fruit juice.

❑ *Spoilage*

Certain structural features of the food-processing site may lead to spoilage or contamination of the products. Such site or building features include inadequate drainage or a lack of screens to keep out insects/rodents. Increased spoilage causes more waste and less profitability, while contamination may result in health problems for consumers.

Key questions to consider:

- Does the site experience substantial losses in raw materials during storage before production? If so, what causes these losses?

- How open are structures to the outside elements and pests? Can they be closed off more effectively while maintaining sufficient ventilation?

- What sanitation procedures are currently in place?

Selected mitigation strategies:

- Ensure that the building structure is secure not only from people but also from animals. Screens should be placed over drains and windows to keep out disease-carrying rodents and flies.

- Storage areas should be well-ventilated and large enough so that excessive heat and moisture do not spoil fruits and vegetables.

❑ *Solid Waste*

Food processing creates substantial amounts of organic and inorganic wastes. This can lead to increased costs for supplies, labor and sometimes fees for waste disposal. In addition, high volumes of burdensome waste, whether placed in a landfill or treated and disposed of, may place a serious strain on limited land resources. Minimizing waste can save on the cost of supplies and labor needed for waste disposal. Converting waste to productive uses can provide an extra source of income.

Key questions to consider:

- Are there any other uses for organic waste generated by the production process? For instance, can organic waste be turned into fodder or compost?

- What contributes most to waste?

- How can production processes be changed to reduce waste?

Selected mitigation strategies:

- Re-use organic waste. Some organic waste such as vegetable peelings can be used as animal fodder; other waste, such as the fiber from palm kernel husks, can be used as fuel.

- Modify waste disposal to facilitate faster decomposition/breakdown of organic material. Add layers of dirt and dry organic material to waste pits, or spread waste over large areas of land. This type of composting and "land spreading" can speed up decomposition and quickly lowers waste volume. Ensure, however, that this material does not attract disease-carrying vectors including birds, rodents and insects.

- Minimize wastes by improving production processes. Identify and change elements of production that may be inefficient or produce excess waste. For example, improved techniques for cutting food produce can reduce waste and yield more product.

❑ *Poorly maintained machinery*

Machinery that leaks chemicals or fuel is wasting energy, can contaminate water supplies and may threaten workers' health. Repairing leaks lowers fuel costs and can prevent costly accidents such as fire. For dairy processors, who use more machinery and refrigeration systems than other food processors, reducing leakage can save money spent on refrigerants and other chemicals.

Key questions to consider:

- How often is machinery checked?

- Are there any routines or technology in place to detect leakages?

- Do workers ever complain of nausea or dizziness on the job?

Selected mitigation strategies:

- Schedule regular machine maintenance checks and repairs. Ensure that workers have up-to-date training in operation and maintenance. Do not wait until machinery is broken before checking it; leaks can occur long before serious equipment breakdown and may be costing the business money. If possible and cost-effective, replace faulty machinery with more efficient machinery.

- If machinery is difficult to access, then monitor wastes or emissions to detect leaks. For example, check for puddles underneath machinery or chemical/fuel smells.

- Use wood shavings, drop cloths and/or oil-water separators to catch spills and leaks.

- If the business is disposing of organic and chemical wastes separately, ensure that chemical or fuel waste does not contaminate the organic waste.

- If it is not cost-effective to replace or to repair machinery, make sure that harmful effects are minimized. Increase ventilation around any machinery that has high gas or chemical emissions.

❑ *Water use*

Food processing workers sometimes use too much water, usually when they are cleaning equipment or food materials. This may not only cause others in the community to have less water, but also lessen the enterprise's own future access to water. It may also mean that water costs are unnecessarily high, even with use of a well. New wells may have to be drilled more frequently as groundwater levels drop.

Key questions to consider:

- Does the business primarily use water to clean machinery and floors?

- Is the source of water limited?

- Is water left running when it is not in use?

- How much money does the business pay for water, and how much could that cost be reduced through more careful usage?

Selected mitigation strategies:

- Decrease water usage through "dry cleanup." Dry cleanup involves an initial cleaning without water (sweeping, wiping down) before washing. This method reduces the amount of water required to dislodge solid wastes from floors or machinery.

- Regulate water flow. Using high-pressure water hoses can ease cleaning and cut water use; usually this only involves adding a new nozzle to the end of a hose.

- Reuse water. Some food processors use steam to purify or clean packaging materials; a closed-loop system can cycle hot water back into the system. This process saves money on both water and energy costs.

❑ *Liquid waste*

Meat processing creates a good deal of liquid waste—wastewater with blood or animal fats in it—that may coagulate and clog pipes, or contaminate sources of water. Liquid wastes can also gather in stagnant pools, creating breeding grounds for insects. These conditions may cause costly losses in labor and meat from the spread of disease among workers and animals.

Key questions to consider:

- How large is the volume of liquid wastes that is produced?

- Do liquid wastes gather in pools, serving as a breeding grounds for mosquitoes and other insects?

- What waste treatment systems are in place?

Selected mitigation strategies:

- Practice water reduction strategies mentioned above, including "dry cleanup," to minimize the amount of wastewater created and the amount of waste materials in the wastewater.

- Separate fats, grease and solids from wastewater. Oil separators or oil traps can be purchased or made at relatively low cost and can dramatically reduce the amount oil in wastewater. Drain stagnant pools of liquid or water away from holding pens and working areas.

- Consider constructing waste treatment ponds. Both solid and liquid waste can be treated in these ponds, which can aid decomposition and reduce disposal costs. Since they may attract mosquitoes and other insects, site such ponds away from animals and places of human activity.

❑ *Noises and odors*

Food processing may result in noises or odors that affect the quality of life surrounding the production site. Community members may be unwilling to tolerate continued production or may block plans to expand production in the future. Loud noises may also damage the ears of workers and managers.

Key questions to consider:

- Are there some aspects of the production process that are much louder than others?

- Is your waste disposal or treatment site located near human settlements?

- What smells are produced in the production process?

Selected mitigation strategies:

- Locate waste disposal sites away from housing or town centers.

- Modify waste disposal or production practices to minimize odors. For example, if treating waste in lagoons or compost pits, make sure they are large enough to accommodate the volume of waste that is produced—if they are too small, the effectiveness of the treatment decreases and smell increases.

- Provide earplugs for workers.

- Repair and maintain machinery so that excessive grinding or squeaking is minimized. This may increase the machinery's efficiency and make it last longer

Resources and References:

- *Cleaner Production Assessment in Dairy Processing*. United Nations Environment Program, Division of Technology, Industry and Economics (UNEP-TIE).

  http://www.agrifood-forum.net/publications/guide/index.htm. A guide to the application of cleaner production in the dairy industry, with a focus on the processing of milk and milk products at dairy processing plants.

- *Cleaner Production Assessment in Meat Processing*. United Nations Environment Program, Division of Technology, Industry and Economics (UNEP-TIE).

  http://www.agrifood-forum.net/publications/guide/index.htm. This document is a guide to the application of cleaner production to the meat processing industry, with a focus on the slaughtering of cattle and pigs at abattoirs. Includes case studies, sample evaluation, and assessment forms.

- Crickenberger, Roger G. and Roy E. Carawan (1996). *Using Food Processing By-Products for Animal Feed*. North Carolina Cooperative Extension Service.

  http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/cd37.html. This paper gives information to help food processors prevent pollution and save money by recovering by-products for use as animal feed. It considers some by-products suitable for animal feeding and factors to consider when selecting by-products for feed, e.g., moisture content, waste stream, volume of material, and effects on feed consumption.

- *Energy Conservation in the Food Industry* (1995). United Nations Industrial Development Organization (UNIDO).

  http://www.unido.org/userfiles/PuffK/food.pdf. This document includes a general discussion on energy conservation for food processors in the areas of steam leakage, wastewater treatment, refrigeration systems, cookers, and baking furnaces. Recommendations include insulating methods, refinishing cookers to increase radiation, and various heat recovery techniques.

- Fellows, Peter. *Guidelines for Small-Scale Fruit and Vegetable Processors* (1997). Agricultural Services Bulletin 127. UN Food and Agriculture Organization (FAO).

  http://www.fao.org/docrep/w6864e/w6864e0g.htm. (see appendix). This document generally concerns the production process, but it does also include a good overview of health and safety issues for fruit and vegetable processors. Specifically discusses methods for avoiding dangers of hot liquids/jams, fruit acids and steam. Some mention of high volumes of solid organic waste and contamination of the product from workers.

- Fellows, P., B. Axtell, and M. Dillon (1995). *Quality Assurance for Small-Scale Rural Food Industries*. Agricultural Services Bulletin No. 117. UN Food and Agriculture Organization (FAO).

  http://www.fao.org/docrep/V5380E/V5380E00.htm. A good discussion of cleaner production building design. Specific mention of how to keep rodents and insects out of building structures in addition to sanitation and hygiene in production.

- *Food Processing Fact Sheets*. Minnesota Technical Assistance Program, University of Minnesota.

  http://wrrc.p2pays.org/indsectinfo.asp?INDSECT=50. Although this site gives examples of cleaner production strategies undertaken by some Minnesota food processors, it is relevant to developing country producers. Links to the following fact sheets:

  - *Composting and Landspreading Food Processing By-Products*. http://www.mntap.umn.edu/food/78-CompLand.htm. A good discussion of how to compost commercial food processing wastes quickly through landspreading methods.

  - *Dairy Waste Reduction Tips*. http://www.mntap.umn.edu/POTW/Dairywaste.htm. A discussion of what some Minnesota dairy companies are doing to reduce wastewater and product losses. Includes 10 water conservation strategies.

  - *Feeding Food By-Products to Livestock*. http://www.p2pays.org/ref/02/01247_files/fs77-r.htm. This fact sheet explains the conditions under which non-meat uncooked food by-products can be used as animal feed.

- "Fruit and Vegetable Processing" in *Pollution Prevention Abatement Handbook* (1998). World Bank.

  http://lnweb18.worldbank.org/ESSD/envext.nsf/51ByDocName/PollutionPreventionandAbatementHandbook. General guidelines on reducing pollution, noise and effluent, with specific recommendations on the recirculation of water in production, dry cleanup, and reuse of organic wastes. Also includes technical information on requirements affecting effluent and acceptable levels of waste for specific items.

- *A Guide to Cleaner Production in the Food Industry*. The United Nations Environmental Program (UNEP) Working Group Centre for Cleaner Production in the Food Industry.

  http://www.cleanerproduction.com/Directory/sectors/subsectors/FoodProc.html. These guidelines are comprehensive and include an introduction to cleaner production as well as methods of planning, implementing, and evaluating cleaner production projects. Specific fact sheets are available, including:

  - *Fruit and Vegetable Processing.* http://www.geosp.uq.edu.au/emc/CP/Res/facts/FACT3.HTM. Discusses sources of waste and ways of reducing waste and water use. Comprehensive checklist on potential targets for cleaner production.

  - *Dairy Manufacturing*. http://www.geosp.uq.edu.au/emc/CP/Res/facts/FACT2.HTM. Discusses waste points in production process and possible waste minimization solutions from Cleaning in Place methods. Comprehensive checklist at end.

  - *Meat Processing*. http://www.geosp.uq.edu.au/emc/CP/Res/facts/FACT7.HTM. Good discussion of factors involved generating waste—types of animals and cleaning methods—and suggests better cleaning methods for pollution reduction. Comprehensive checklist at end.

  - *Food Processing Checklists*. http://www.geosp.uq.edu.au/emc/CP/Res/facts/FACT1.HTM. Very good checklist that addresses general food processing strategies for cleaner production.

- *Information Resources on Industrial Pollution Prevention* (2000). United States Agency for International Development (USAID).

  Contains guides, case studies, and articles focused on pollution prevention in food processing and other sectors.

- *International Cleaner Production Information Clearinghouse* (1999). CD Version 1.0. United Nations Environment Program, Division of Technology, Industry and Economics (UNEP-TIE)

  Contains case studies, country profiles, and cleaner production strategies for food processing.

- *Separator for Organic Grease and Oil* (1990). United Nations Industrial Development Organization (UNIDO).

  http://www.unido.org/userfiles/PembletP/Vol5_Z06.pdf. A how-to document on constructing an oil separator that removes vegetable oil, animal grease and fats from wastewater. Includes diagrams.

- "Vegetable Oils and Fats." Chapter 55 in Vol. II of *Environmental Handbook: Documentation on Monitoring and Evaluating Environmental Impacts*. German Federal Ministry for Economic Cooperation and Development (GTZ).

  http://ces.iisc.ernet.in/energy/HC270799/HDL/ENV/enven/vol238.htm. This chapter provides an overview of the techniques used to process oil from seeds, nuts and fruit, as well as the environmental hazards associated with the production process. Specific discussion of the extraction of oil from wastewater using oil traps; reuse of wastewater and organic waste; and problems in chemical refining.

Chapter 4.3
Leather Processing: Cleaner Production Fact Sheet and Resource Guide

Purpose

This fact sheet offers basic information on important adverse environmental impacts of leather processing, as well as associated health and safety impacts. It also discusses opportunities for mitigating those impacts, with an emphasis upon "cleaner production" strategies that may also provide financial benefits to micro- and small enterprises (MSEs). In addition, each fact sheet offers a substantial, annotated list of resources for those organizations seeking more information.[5]

This fact sheet has been prepared for (1) **business development services (BDS) providers,** which offer services such as management training or marketing support to MSEs, and (2) **intermediate credit institutions (ICIs) and direct lenders** that provide financial credit to MSEs. It is intended to be used in concert with other sections in Part III of the *Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Development Activities,* which is USAID Africa Bureau's principal source of sector-specific environmental guidance.

Why Focus on Cleaner Production for Mitigation?

Cleaner production (CP) is a preventive business strategy designed to conserve resources, mitigate risks to humans and the environment, and promote greater overall efficiency through improved production techniques and technologies. Cleaner production methods may include:

- substituting different materials
- modifying processes
- upgrading equipment
- redesigning products

In addition to environmental, health and safety benefits, many cleaner production techniques provide opportunities to substantially reduce operating costs and improve product quality. MSEs can profit from cleaner production through more efficient use of inputs and machinery, higher-quality goods that can command higher prices, and reduced waste disposal

---

[5] At the time of writing, USAID cleaner production fact sheets are available for the following subsectors that are likely to have substantial adverse impacts on the environment and/or workers' health: brick and tile production; leather processing; small-scale mining; food processing; metal finishing; wood processing and furniture production, and wet textile operations.

costs. Improved safety measures can also help MSEs avoid costly accidents and worker absences.

Experience has demonstrated that, with assistance, MSEs can frequently identify cleaner production opportunities that produce a positive financial return, sometimes with little or no investment. Many enterprises that change to CP methods may realize substantial financial and environmental benefits, indicating that CP should be the first option considered in addressing MSEs' environmental problems.

Yet, although this approach can offer tremendous advantages, readers should also recognize that cleaner production options showing clear financial benefit will only be available to varying degrees among different enterprises and often may not completely mitigate environmental problems. In some cases, even when pursuing CP techniques, some businesses may need to use solutions that offer no measurable financial return—if such solutions are required by USAID's Regulation 216 or local regulations or desired for other reasons, such as community goodwill.

Important Environmental Issues Addressed by This Fact Sheet

- Chemicals
- Water use
- Worker health hazards
- Odor

Leather processing uses large amount of toxic and environmentally dangerous chemicals. CP techniques can prevent these chemicals from becoming a threat to public health and save money for the micro-entrepreneur.

Adverse Environmental Impacts and Mitigation Opportunities

Several key environmental issues associated with leather processing are listed in the box at left and discussed below. For each environmental impact, the fact sheet provides a list of questions to aid in the assessment of individual MSEs. These questions are followed by a number of mitigation strategies that can be considered, with an emphasis on cleaner production strategies where possible. The strategies presented typically represent a range of available options, from profitable activities that require no investment to other activities that may increase MSEs' costs.

❑ *Chemicals*

Leather processing requires extensive use of chemicals to treat and soften hides. These chemicals are present in the firm's wastewater and can contaminate community water sources. When chemicals are improperly or inefficiently used in production, costs rise and pollution increases. More efficient chemical use can both lower production costs and reduce pollution.

Key questions to consider:

- What kind of chemicals are used?
- Which of these chemicals are the most harmful?
- Which production stages use the most chemicals? In what quantities?
- Where are chemicals stored?

Selected mitigation strategies:

- Improve production methods to increase efficiency. Using higher temperatures in chrome baths helps chrome adhere to hides and reduces the amount of chemicals left in the wastewater. Instruct workers about the correct chemical ratios to use in tanning and finishing baths. Use measuring equipment to minimize overuse.
- Improve chemical storage to reduce waste and spills. Store chemicals in sturdy, waterproof containers. Instruct employees to seal containers after use to avoid spills.
- Consider using alternative chemicals that are less hazardous. For instance, vegetable-based tanning solutions can be substituted for chrome. Take into consideration, though, that switching to low-polluting chemicals may involve a tradeoff in quality. For example, vegetable dyes may produce unpredictable colors.
- Recycle chrome and tanning bath solutions. Chrome and lime effluent can be reused in future production stages without loss of effectiveness; use filters to screen out solid wastes and then set aside the solution to use it again. Assess the cost-effectiveness of such strategies before proceeding, however. For example, some chrome-recycling strategies may not be cost-effective for smaller operations.

❑ *Water use*

Leather processing requires water in almost every stage of production, but certain production methods or machinery can lead to overuse. If well or pump water is used, excessive water use can deplete water sources for future production or community use. Energy costs for pumping, as well as environmental impacts from energy consumption, will also be higher than necessary. Excessive groundwater use may lower the water table and require frequent redrilling of wells. Also, untreated wastewater (effluent) from processing operations may contain organic wastes which can both pollute local water sources and degrade water quality for downstream communities.

Using water more efficiently guarantees less costly production and ensures against water shortages that could interrupt production. If the enterprise pays by volume for the water it uses, reducing water usage can be expected to provide substantial savings.

Key questions to consider:

- Is water left running between production stages?
- Is fresh water used in every new bath? Could some water be reused?
- Are hides pre-cleaned before they are washed?

Selected mitigation strategies:

- Reuse water from "cleaner" stages of production in "dirtier" stages of the next production cycle. For example, use rinse water from the final stage of production for the initial soaking or washing of the next batch of hides.
- Conserve water by improving production methods. Turn off water between batches or while transferring hides between baths. Install nozzles on hoses to increase the effectiveness of spraying while decreasing water use. Prevent baths from overflowing by monitoring water levels closely or installing an automatic shut-off mechanism.
- Use dry cleanup methods. Wipe down spills with dry material; use brooms or cloth to remove as much solid or semi-solid waste as possible from floors or machinery before rinsing them down with water.
- Divert organic effluent away from water bodies (see below under "Odor" for production mitigation strategies for tannery effluent).

❑ *Worker health hazards*

Certain working conditions in leather processing—such as exposure to chemicals in the air or in solution baths—can be hazardous to workers. Symptoms can include skin irritations, dizziness and breathing problems. Unhealthy workers may be less productive, miss work too often and make potentially costly mistakes.

Key questions to consider:

- What safety measures are currently in place?
- How often are workers exposed to chemicals?
- Is the tannery structure well ventilated?

Selected mitigation strategies:

- Provide safety equipment such as face masks, rubber gloves and boots for workers. Small improvements can increase worker safety dramatically and improve long-run productivity.

- Ventilate the production sites well. Organic solvents, in particular, are harmful when inhaled. Over time, even minor exposure can cause long-term damage to health.

- Train workers in the proper handling of chemicals. Minimize chemical spills and accidental exposure by educating workers about preventive safety measures. For example, sealing chemical containers when not in use can prevent both spillage and evaporation and thus reduce input costs.

❑ *Odor*

Tannery effluent often contains highly odorous waste. Strong smells can damage the quality of life around the tannery site and may reduce or destroy community support for further production or expansion. Controlling odor through improved waste treatment techniques, or even recycling, can improve community relations and may reduce costs.

Key questions to consider:

- Which wastes smell the worst?

- Can wastes or trimmings be separated before chemical treatment?

- Where are solid wastes disposed of?

Selected mitigation strategies:

- Separate and sell non-contaminated wastes to farmers. Untanned collagen wastes and fats produce odors, but they can be reused as agricultural fertilizer if not contaminated by chemical wastes.

- Implement a waste disposal or treatment system. Avoid simply dumping solid wastes; instead, use a proper landfill or dig an appropriately sized pit. (See the chapter on solid waste in the *Guidelines*.) Bury waste to minimize odors. Wherever solid waste is disposed of, make sure it is away from water sources and cannot be washed away.

- Control sludge to decrease odors. Do not let sludge stagnate in or around the tannery site. Place it in a landfill or treatment area. Standing pools of liquid smell bad and are potential breeding grounds for insects, particularly mosquitoes. Eliminate these problems by draining the pools.

❑ *Excess waste*

Inefficient or poor production methods contribute to excessive waste and costly product loss. Tanneries with low-quality production processes may have to discard or rework an unnecessarily high proportion of their products. Improving production through maintenance and training can save costly reworking, reduce product loss, and thereby save money while reducing environmental impacts.

Key questions to consider:

- How much and what kind of products are lost in the production process?
- Which production processes are most prone to mistakes and wasted product?
- Which production processes are easiest to modify in order to reduce waste?

Selected mitigation strategies:

- Ensure that regular maintenance schedules for machinery are followed. For example, to reduce spoilage or losses, workers should regularly clean filters and screens of machinery used in dehairing and hide-shaving.
- Use appropriate equipment and train workers in proper machine operation and maintenance.
- Identify opportunities to improve efficiency. For example, do not overfill or underfill tanning baths with hides. Overfilling reduces efficiency, while underfilling wastes valuable inputs.

Resources and References

- Biller, Dan and Juan David Quintero (1995). *Policy Options to Address Informal Sector Contamination in Urban Latin America: The Case of Leather Tanneries in Bogotá, Colombia*. LATEN Dissemination Note # 14.Washington, DC: World Bank.

  http://wbln0018.worldbank.org/lac/lacinfoclient.nsf/6968dd46d8c5c4d88525695d007235c8/bebb2e6b3d6030f2852567ef006dcf7b/$FILE/Dn-14.doc. This report is a case study of informal leather tanneries in the San Benito neighborhood of Bogotá, Colombia. It includes proposals and policy options for addressing the industry's pollution problems.

- Covington, Anthony D. (1999). *Innovations in Processing*. International Union of Leather Technologists and Chemists Societies (IULTCS) Congress held in Chennai, India, January 1999.

  http://leather.webindia.com/innovation.html. This paper includes a useful overview of hide processing and presents new or alternative production methods that increase efficiency and/or reduce chemical use.

- Cranston, R.W., R.W. Gleisner et al. (1997). *The Total Recycling of Chromium and Salts in Tanning Liquors.* Australia: CSIRO Leather Research Centre.

  http://www.tft.csiro.au/leather/totrecycling.html. A how-to paper on chromium recycling. Includes diagrams and cost-benefit analyses.

- *Hair-Save Unhairing Methods in Leather Processing* (2000). Regional Programme for Pollution Control in the Tanning Industry in South-East Asia, United Nations Industrial Development Organization (UNIDO).

  http://www.unido.org/userfiles/PuffK/L_hairsave_unhairing.pdf. This report discusses methods of unhairing that result in lower levels of contaminated wastewater, compared to traditional chemical unhairing procedures.

- Money, Catherine A. (1999). *Clean Technology Challenges*. International Union of Leather Technologists and Chemists Societies (IULTCS) Congress held in Chennai, India, January 1999.

  http://www.tft.csiro.au/leather/cleantech.html#tzw. A very useful overview of cleaner production strategies in leather production. Contains checklists for cleaner production technologies. Compares advantages and disadvantages of certain methods. Also includes diagrams of filtering technology.

- *Re-Use of Chromium in Leather Tanning*. United Nations Environment Program (UNEP) Cleaner Production Case Studies. http://www.p2pays.org/ref/10/09545.htm.

  EP3—Pollution Prevention Audit for a Sheep Hide Tannery. United Nations Environment Program (UNEP) Cleaner Production Case Studies. http://www.p2pays.org/ref/10/09234.htm.

  EP3—Cleaner Production Audit for a Cattle Hide Tannery. United Nations Environment Program (UNEP) Cleaner Production Case Studies. http://www.p2pays.org/ref/10/09238.htm.

  Three short case studies of cleaner production in a medium-scale sheep and cattle hide tanneries. These provide a useful overview of cleaner production opportunities. Included are

cost estimates of cleaner production methods. The studies also focus on re-use of chemical effluents.

- Sahasranaman, A. (1999) *Occupational Safety and Health in the Tanning Industry: Emerging Challenges*. International Union of Leather Technologists and Chemists Societies (IULTCS) Congress held in Chennai, India, January 1999.

  http://leather.webindia.com/safety.html. This short reports lists worker safety issues associated with tanneries and provides policy strategies for addressing these issues.

- *Sources, Detection and Avoidance of Hexavalent Chromium in Leather and Leather Products* (2000). Regional Programme for Pollution Control in the Tanning Industry in South-East Asia, United Nations Industrial Development Organization (UNIDO).

  http://www.unido.org/userfiles/PuffK/hexavalent.pdf. This document evaluates a variety of tanning production methods to see which produce dangerous levels of chromium IV, a by-product of chromium III usage. Technical in some sections, but the general discussion on which methods produce the most danger is quite accessible.

- "Tanning and Leather Finishing" (1998). In *Pollution Prevention and Abatement Handbook.* Washington, D.C.: World Bank.
  http://ifcln1.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/gui_tanning_WB/$FILE/tanning_PPAH.pdf
  This chapter from the World Bank's pollution prevention handbook provides minimum pollution standards for tanneries and leather finishers.

Other Resources:

- Davis, M.H. and J.G. Scroggie (1980). *Theory and Practice of Direct Chrome Liquor Recycling*. Australia: CSIRO Leather Research Centre.

  http://www.tft.csiro.au/leather/dclr.html. Examples and strategies for reusing chrome solution during hide processing.

- Money, Catherine A. *Curing of Hides and Skins: Alternative Methods*. Australia: CSIRO Leather Research Centre. http://www.tft.csiro.au/leather/curinghides.html.

  Money, Catherine A. *Unhairing and Dewooling—Requirements for Quality and the Environment*: Procter Memorial Lecture. Australia: CSIRO Leather Research Centre. http://www.tft.csiro.au/leather/procter.html.

  These two papers present alternative methods of hide preparation and unhairing. There is a short discussion of current methods and alternative methods that can improve quality.

- Pojer, Peter M. and Chi P. Huynh. *A Salt-Free Pickling Regime for Hides and Skins.* Australia: CSIRO Leather Research Centre.

  http://www.tft.csiro.au/leather/saltfreepickling.html. Provides information on eliminating the salt pickle method of preparing hides for tanning.

- *Tanneries and the Environment: A Technical Guide to Reducing the Environmental Impact of Tannery Operations* (1991). Technical Report Series No. 4. United Nations Environment Program (UNEP).

  http://www.ecoethics.net/bib/tl-021-a.htm. Extensive discussion of environmental issues associated with tanneries, with possible solutions. Ordered from this Web site for US $25.

- *Trainers Workbook on Cleaner Production in Leather Tanning* (1996). United Nations Environment Program (UNEP).

  http://www.uneptie.org/pc/cp/library/catalogue/cp_training.htm. Available from UNEP for around US $120.

Chapter 4.4
Metal Finishing: Cleaner Production Fact Sheet and Resource Guide

Purpose

This fact sheet offers basic information on the important adverse environmental impacts of metal finishing, as well as associated health and safety impacts. **Metal finishing** includes both **electroplating** and **coating operations,** as well as their supporting processes (polishing, cleaning, degreasing, pickling, etching, etc.). The purpose of metal finishing is to prevent corrosion and wear, change electrical properties, enhance bonding for adhesives and coatings, and provide a decorative finish for metal products.

This fact sheet also discusses opportunities for mitigating these impacts, with an emphasis upon "cleaner production" strategies that may also provide financial benefits to micro- and small enterprises (MSEs). In addition, it provides a substantial, annotated list of resources for organizations seeking more information.[6]

This fact sheet has been prepared for (1) **business development services (BDS) providers**, which offer services such as management training or marketing support to MSEs, and (2) **intermediate credit institutions (ICIs)** and **direct lenders** that provide financial credit to MSEs. It is intended to be used in concert with other sections in Part III of the *Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Development Activities,* which is USAID Africa Bureau's principal source of sector-specific environmental guidance.

Why Focus on Cleaner Production for Mitigation?

Cleaner production (CP) is a preventive business strategy designed to conserve resources, mitigate risks to humans and the environment, and

---

[6] USAID cleaner production fact sheets are available for the following subsectors that are likely to have substantial adverse impacts on the environment and/or worker health: brick and tile production; leather processing; small-scale mining; food processing; wood processing and furniture making; metal finishing; and wet textile operations.

promote greater overall efficiency through improved production techniques and technologies. Cleaner production methods may include:

- substituting different materials
- modifying processes
- upgrading equipment
- redesigning products

In addition to environmental, health and safety benefits, many CP techniques provide opportunities to substantially reduce operating costs and improve product quality. MSEs can profit from CP through more efficient use of inputs and machinery, higher-quality goods that command higher prices, and reduced waste disposal costs. Improved safety measures can also help MSEs avoid costly accidents and worker absences.

Experience has demonstrated that, with assistance, MSEs can often identify cleaner production opportunities that produce a positive financial return, sometimes with little or no investment. Many enterprises that change to CP methods may reap substantial financial and environmental benefits, indicating that CP should be the first option considered in addressing MSEs' environmental problems.

However, CP options with clear financial benefits are not equally available to all businesses. Further, such options may not completely mitigate environmental problems. In some cases, improving environmental performance may require businesses to use methods or approaches that offer no measurable financial return. Businesses typically undertake such measures if required by law or as part of a commitment to the community.

Important Environmental Issues Addressed by This Fact Sheet

- Use of hazardous chemicals
- Solid and hazardous wastes
- Air pollution
- Water use
- Wastewater

Adverse Environmental Impacts and Mitigation Opportunities

Several key environmental issues associated with metal finishing are listed in the box at left and discussed below. For each issue, the fact sheet provides a list of questions to aid in the assessment of individual MSEs.

These questions are followed by a number of mitigation strategies that can be considered. Where possible, cleaner production strategies are emphasized. The strategies presented typically represent a range of available options, from profitable activities that require no investment to other activities that may increase MSEs' costs.

❑ *Use of Hazardous Chemicals*

Metal finishing operations routinely use various hazardous chemicals, including solvents for cleaning the metal parts, acids and bases for etching them, and solutions of metal salts for plating the finish onto the desired form (substrate).

Most coating processes require the metal surface to be thoroughly cleaned beforehand, because surface contaminants greatly diminish the quality of the finished product. Both cleaning and plating processes generally occur in a “bath”—that is, a tank in which parts are dipped into a solution of chemicals. Preparing the surface of the metal for treatment involves the removal of greases, soils and oxides. Cleaning agents used for this purpose include detergents, solvents, acidic solutions and caustics.

Finished metal parts are often further coated with some combination of paint, lacquer or ceramic coating. These coatings can themselves contain toxic solvents and heavy metals.

Chemicals used may include the following:

- acids (sulfuric, hydrochloric, nitric, phosphoric)
- toxic metals (cadmium, nickel, zinc, chromium, lead, copper) and compounds which contain these metals
- solvents (1,1,1-trichloroethane, methylene chloride, tetrachloroethylene, methyl ethyl ketone [MEK], toluene, xylene)
- cyanide compounds.

These chemicals may be toxic to humans and animals, cause cancer in both humans and animals, easily catch fire, and/or persist in the environment for a long time, entering the food supply. In particular, hexavalent chromium is highly toxic to humans, causing kidney damage and increasing the risk of lung cancer in humans. It is also highly toxic to aquatic animals at very small doses. Both workers and local communities are at risk from exposure to these chemicals, particularly those that persist in ground and surface water supplies for long times.

In general, cleaner production can reduce the environmental harm caused by using hazardous chemicals and improve the financial performance of the production process. Cleaner production options in this area are simple techniques, including pre-cleaning, production/inventory planning, substituting less hazardous chemicals and/or processes, and reusing or reclaiming “dirty” chemicals. These methods are described in detail below.

Key Questions to Consider:

- What chemicals are used at the facility?
- How are your chemicals stored?
- How do you manage use of chemicals in your facility? Do you keep an up-to-date inventory? Do you limit employees’ access to chemicals?
- Which processes use chemicals? What quantities of chemicals do they require?
- Can any of the chemicals be replaced with less hazardous chemicals?

- How frequently do you have chemical spills at your facility? What do you do to protect against such spills?
- Can you reuse any chemicals?
- Can any chemicals used for specific purposes be replaced with more multi-purpose chemicals?

Selected Mitigation Strategies:

- **Avoid keeping outdated chemicals.** Chemicals may lose their effectiveness if used past their expiration date, resulting in poor-quality products and wasted bath solutions.

  Recently purchased chemicals should be used after older chemicals (a “first in, first out” policy) in order to prevent accumulation of expired stock. Creating an inventory control system will prevent waste by ensuring that all chemicals are used in order of arrival in the storeroom.

  Label all chemical containers with the name of the chemical, the date it arrived at the storeroom, the name of the manufacturer/distributor, and any appropriate hazard warnings. The manufacturer, and in some cases the distributor, may be able to provide a Material Safety Data Sheet (MSDS), which includes necessary warnings as well as details about proper safety equipment and procedures for handling the chemical. Assistance providers may also be able to find MSDSs via the Internet.

- **Conduct employee trainings** in the proper handling of chemicals, the reasons for using safer techniques, and emergency response. Trained employees will be better able to operate baths at peak efficiency, minimize spills, and improve the consistency of solutions.

  Training can also minimize the number of “bad baths” in which the entire solution must be changed out, which wastes time, materials and water, and may require workers to reprocessi of metal parts. Ensure that only trained employees are responsible for mixing bath solutions and setting flow levels.

- **Reduce the need for chemicals**.
  - Reduce the use of rust inhibitors (a toxic cleaning agent) by ordering metal parts to be delivered only at the time that they are needed, and also by storing them away from moisture if possible. This reduces the chances that they will rust.
  - Pre-clean parts (wipe them with rags, squeeze them, blow air or plastic pellets on them, vibrate them with abrasive media) before applying liquid or vapor degreasing solvents. This can reduce the amount (and cost) of solvents required and extend the life of degreasing solutions. Cold cleaning with mineral spirits can also help reduce the use of solvents by removing oil before vapor degreasing.

- **Optimize solvent-handling procedures.** There are a number of ways to reduce the amount of solvents used throughout a facility; several require little or no investment.
    - Solvents left from “upstream” (earlier) processes can be reused in “downstream” (later) machine operations. For example, solvents used for final wash during equipment cleaning can be reused as paint thinner, eliminating the need to purchase paint thinners.
    - Rotating the treated metal parts before removing them from the degreaser will allow all condensed solvent to flow back into the degreasing unit, reducing the need to refill (top off) solvents.
    - Covering degreasing baths when they are not in use will reduce evaporation of solvents; firms can spend less on solvents and lower the risk of toxic exposures to workers.
    - Alkali washes can be used instead of solvents in degreasing operations. This way, wastes from alkaline cleaners can be chemically treated to reduce toxicity and then discharged into the sewer, which minimizes cleaning costs. (See the description of wastewater treatment systems below.)
    - Extend the life of cleaning solutions and reduce costs by filtering the cleaning solutions to remove sludge buildup. Refresh the solution by topping it off with fresh solution and emulsifiers. For small operators, a single mobile filtration unit can service all caustic and acid solutions. Use cleanable polystyrene or metal filters in the filtration unit and clean the filters by blowing compressed air over them.
    - Use blast media to air-strip paint for line-of-sight stripping, instead of using solvents. Stripping paint using plastic blast media requires only low pressures and does minimal harm to the part substrate. Plastic blast media can be recycled, generate less waste than sand blasting, and can be cheaper and faster than chemical stripping methods.[7] Blast stripping should be performed only in well-ventilated spaces such as a walk-in booth or a large room. As with solvent-stripping methods, workers should wear respirators to protect themselves from airborne particulates and hazardous emissions.
    - Recycle solvents onsite. Use gravity to separate a solvent/sludge mixture and reclaim the clear solvent for equipment cleaning. If reclaimed solvent is pure enough, it can also be used for formulating primers and base coats of paint. For larger volumes of solvents, recycle by using batch distillation. This works well for recovering isopropyl acetate, xylene, and paint thinner from cleanup operations. Residue from solvent recovery processes can be blended with fuel and burned in a combustion unit. Burning is safest for

[7] Northeast Waste Management Officials' Association, 1998.

local communities as long as controls are used to capture toxic metals from the air emissions before they are released into the atmosphere. **Do not burn residue without such controls.** Residue from the burning must still be disposed of properly, as it will be toxic.

- **Use process substitution** to reduce hazards to workers, communities, and the environment.
  - Zinc alloy plating, such as zinc-nickel or zinc-cobalt, can be used to provide corrosion protection instead of cadmium plating, which is highly toxic and carcinogenic. Alkaline zinc solutions can be used with existing equipment, although zinc solutions that do not contain cyanide require more thorough parts cleaning to be as effective as cadmium cyanide solutions. If cadmium plating is necessary, use bright chloride, high-alkaline baths, as they are less toxic than cadmium cyanide solutions.
  - Because cyanide is highly toxic to humans, use cyanide-free systems for zinc plating when possible. Cyanide-free systems include zinc chloride (acid) baths and zinc alkaline systems.
  - Zinc chloride baths have higher operating efficiencies, offer energy savings through improved bath conductivity, and result in better quality of product because hydrogen embrittlement is reduced. (This is a type of metal deterioration that reduces metal strength and ductility.) Zinc chloride baths, however, require that traditional steel tanks be lined with an acid-resistant material, such as hard rubber or polypropylene.
  - Zinc alkaline systems can be used in traditional steel tanks and produce good brightness, but require tighter operational controls to ensure an efficient process.
  - Replace cyanide cleaners with trisodium phosphate or ammonia. Use non-fuming cleaners such as sulfuric acid and hydrogen peroxide instead of chromic acid cleaner.
  - Use trivalent chromium instead of hexavalent chromium, as it is less toxic to humans and aquatic animals, creates less sludge, and is less viscous, therefore causing less drag-out (see below). Trivalent chromium also uses the same equipment as hexavalent chromium, so it requires no infrastructure changes. Unfortunately, trivalent chromium can only be used for a plating thickness no greater than 0.003mm. Trivalent chrome baths may also require additives to correct color differences.
  - For the copper bright-dipping process, use a sulfuric acid/hydrogen peroxide dip instead of cyanide and chromic acid dips. This reduces the toxicity of the bath and allows recovery of copper from the solution.

- **Consider options to reduce drag-out.** Drag-out is the residual solution that adheres to a part when it is removed from a process bath. Drag-out reduces the concentrations of chemicals in the plating bath, requiring more chemical inputs to maintain operating conditions. Methods to reduce drag-out include:
  - *Drainage from baths*: Install rails above process baths to rack pieces for drainage before rinsing. Add drain holes to plated parts to prevent bath solutions from pooling in racked items. Allow 10–20 seconds of drip time before rinsing.
  - *Change bath conditions*: Operate baths at lowest possible concentration to reduce drag-out loss. Using wetting agents to decrease the surface tension of the solution will also help prevent the solution from clinging to the parts. Increasing bath temperatures to make the solution less viscous can also reduce drag-out, but be sure that the higher temperatures do not reduce the effectiveness of any brightener being used. If MSEs choose to increase bath temperatures to reduce viscosity, they should insulate the tanks to reduce heating costs.
  - *Redesign processes*: Insert a drag-out recovery tank before the rinsing stage to minimize metal concentrations in the wastewater. Keep the drag-out that has been recovered from different process steps segregated so it can be used to top off plating tanks. This also streamlines the plating process and reduces drips on the floor.
- **Reduce chemicals needed in painting operations**.
  - Increase transfer efficiency of spray-painting by switching to a high-volume low-pressure (HVLP) system. This can increase transfer efficiency by 30 to 60 percent and thereby reduce supply costs for paint. Siphon-fed HVLP systems produce a fully atomized spray pattern with even surface coverage. Kits for converting conventional siphon sprayers to HVLP sprayers are inexpensive and practical to set up in small operations. All HVLP systems should be used in an enclosed space for maximum efficiency. **Workers should always wear respirators when using spray guns to keep them from inhaling overspray and hazardous vapors.**
  - Schedule paint jobs to start with light colors and end with dark ones so as to minimize cleaning between colors. Also, paint all products of the same color at the same time.
  - Scrape out paint cups and tanks before rinsing with solvent; this will make the solvent go further/last longer.

❑ *Hazardous and Non-Hazardous Waste Generation*

Metal finishing operations have many sources of non-hazardous and hazardous waste, including depleted or contaminated process baths, spent etchants and cleaners, waste from strip and pickle baths, exhaust scrubber solutions, degreasing solvents, and miscellaneous solid wastes (absorbants, filters, empty containers, etc.). Spills and accidental bath discharges, in particular, are an easily correctible source of hazardous waste.

Surface preparation for metal coating generally involves removing soils and imperfections such as oxidation, rust, corrosion, heat scale, tarnish, smut and old paint. The process of removing these flaws generates waste oils and/or greases, as well as waste solvents and cleaners. Clean-up of spray guns, hoses and other paint equipment generates paint sludge and waste solvent. Also, expired chemicals and paints are waste materials that require special disposal considerations.

Cleaner production can help reduce the amount of hazardous and non-hazardous wastes generated by (1) preventing spills and leaks, (2) retraining employees, and (3) maximizing the efficiency of operations to use fewer inputs. These methods are discussed in detail below.

Key Questions to Consider:

- What types of wastes does the facility generate?
- Do these wastes contain hazardous chemicals and/or toxic metal concentrations?
- How are you disposing of these wastes? How much does it cost to dispose of these wastes?

Selected Mitigation Strategies:

- **Use inventory controls.**
  - Ensure materials are labeled with expiration dates; use a first-in, first-out policy to minimize the amount of expired materials.
  - Secure storage areas, and grant access to only a few designated employees.
  - Require a one-for-one exchange policy, where workers must return an empty container in order to receive a new container. This will control the number of open containers, reducing the risk of spills, contamination and wasted materials.
- **Prevent spills**.
  - To prevent losses due to spills, purchase chemicals in the smallest possible quantities. When economic needs require purchasing chemicals in bulk, use spigots or pumps to transfer materials from large storage containers to smaller “working” containers to minimize drips and spills.
  - Keep containers tightly sealed at all times to prevent spills and evaporation of volatile chemicals.
  - Material storage areas should have a spill containment system such as a concrete pad with earthen berms enclosing the area.

- Install drainboards between tanks. (A drainboard is a board that is placed over the lips of two adjacent tanks to catch drag-out.) Ensure that the drainboard is tilted to allow drag-out to flow back into the earlier tank in the process.
- Prevent and contain spills and leaks with drip trays and splash guards around processing equipment.

- **Prevent leaks**. Create regular inspection and maintenance schedules for process equipment and filters. Prevent leaks by frequently inspecting piping systems, racks, storage tanks, tank liners, air sparging systems, and automated flow controls.
- **Make sure process controls are accurate**. Setting up schedules for calibrating all temperature controls , speed controls, and pH meters is a no-cost, preventative measure to ensure that operating conditions meet production requirements, reducing the number of substandard parts as well as energy, water, and raw materials usage.
- **Hold training sessions** to instruct employees on the proper handling of chemicals in order to reduce spillage and to minimize leaks and evaporative losses, which reduces supply and clean-up costs. Training can include low-cost, effective techniques such as:
    - proper use of spouts, funnels, and drip pans during material transfer.
    - use of drainboards to reduce drag-out.
    - maintaining liquids in tanks at the correct levels to reduce spilling from overflows.
    - use of containment berms to contain spills.
- **Prevent substandard parts.**
    - Sort for substandard parts and set them aside before electroplating or painting to prevent unnecessary operations.
    - Preparing surfaces well is key to preventing parts from failing to meet coating requirements; 80 percent of coating adhesion failures can be attributed to improper surface preparation.[8]
- **Reduce contamination of baths.**
    - Reduce contamination of bathwater, and thereby reduce the costs of replacing it with new bathwater, by ensuring that any dropped parts and tools are immediately retrieved. Locate rakes near baths to help pull dropped items out of the bathwater.
    - Clean racks between baths to minimize contamination.
    - Install a rain cover for outdoor tanks so that rain will not dilute chemicals.

[8] See Northeast Waste Management Officials Association, 1998

- In areas with “hard water” (water with high concentrations of calcium, magnesium, chloride, or other soluble minerals), use softened, distilled, or deionized water for rinsing in order to reduce contaminant build-up in baths. This will result in less drag-out and generate less sludge.
- Use electrowinning to remove unwanted metal contaminants from plating solutions, such as copper contaminating zinc-and nickel-plating baths. Electrowinning involves placing a sheet of metal in a bath and running a low current through it. This allows the copper, for example, to attach to the metal plate, leaving the rest of the solution intact. Although small amounts of the plating metals will be removed along with the copper, generally the cost of replacing them is offset by savings from extending the overall life of the bath.

- **Reduce waste in painting operations.**
  - Use various sizes of paint-mixing and sprayer cups to make it easier to prepare only the amount of paint needed.
  - Use old paint as a base coat or primer.
  - Prevent nozzle tips for spray containers from clogging by inverting the can and spraying the nozzle to clear any residual paint. Repair clogged aerosols by cleaning or replacing the nozzle tip.

- Ensure that a spray gun’s air supply is free of water, oil and dirt. Prevent spray gun leaks by submerging only the fluid control portion in cleaning solvents.

❑ *Air Pollution*

Vapor degreasing operations and hot plating baths generate used solvents that emit volatile organic compounds (VOCs). VOCs can cause serious health problems for workers, and they also contribute to air pollution in the lower and upper reaches of the atmosphere. Poor handling practices can result in the loss of as much as 30 percent of solvents and degreasing agents. This can be a significant cost, as these chemicals would otherwise be re-used. VOCs are also emitted during paint application, curing and drying.

In general, some sort of pollution control investment will be necessary to fully control air emissions from metal finishing facilities. Cleaner production can help to reduce air pollution by preventing solvents from escaping into the air (i.e., volatilizing) and improving the efficiency of pollution control systems. These methods are described in detail below.

Key Questions to Consider:

- What types of air emissions are generated at the facility?
- What methods are being used to control these emissions?

Selected Mitigation Strategies:

- Cover the degreasing unit during idle or down times to prevent solvent from volatilizing.
- Use a speed of 10 feet per minute or less to remove parts from solvent in order to minimize disturbance of the "vapor line"—the volume of air above the surface of the solvent that is saturated with solvent vapor. Rapid movement of the parts or basket disrupts the vapor zone, which allows new air to mix in with the vapor and then to escape the degreaser or bath, taking some of the vapor with it. Increasing the freeboard height above the vapor level to 50–100 percent of tank width will also help keep air from mixing with the vapor and reduce loss of solvent.
- Exhausts should be treated to reduce VOCs and heavy metals before venting to the atmosphere. Carbon filters can both reduce VOC levels and allow employees to recover solvent using steam stripping and distillation.
- Use mist collection and scrubbing systems to control vapors and mists from process baths.
- Use noncaustic paint removers such as alkaline or non-phenolic strippers to reduce phenol emissions.
- Use waterborne, powder, UV-curable, or high-solids paints instead of solvent-borne options. If solvent-based coatings must be used, consider alternative application technologies such as roller/curtain coating; tumbling, barreling, and centrifuging; or HVLP sprays.

❑ *Wastewater Problems*

Metal finishing, especially electroplating, generates large quantities of wastewater, primarily from rinsing between process steps. Because of the hazards to the community associated with the chemicals involved in metal finishing operations, wastewater should always be treated before disposal into ground or surface waters. Improperly treated wastewater can contaminate drinking water and irrigation supplies, with long-term consequences for the health of the local population, including employees.

Cleaner production can best help reduce impacts of wastewater by reducing the toxicity of the wastewater at the source. Once options for reducing source pollution are used, however, it will still be necessary to build or share use of a wastewater treatment plant. In order to be effective, wastewater treatment plants need to be properly designed for the types of wastes to be treated and the volumes of wastes generated. Operating such plants can be costly, although in areas where water is scarce or expensive, treating wastewater may help pay for itself by permitting re-use of water in facility operations.

Key Questions to Consider:

- What are the sources of wastewater at the facility?
- What types of contaminants are in the wastewater?
- How is the wastewater being treated before disposal?
- What options exist for reducing the volume or toxicity of wastewater generated?

Selected Mitigation Strategies:

- A waste treatment plant should treat wastewater to destroy cyanide, equalize flows, neutralize pH, and remove toxic metals.
- Separate waste streams. If cyanide and acidic wastewaters mix, it can generate lethal hydrogen cyanide gas. Also, nickel solutions must be separated from cyanide and ammonium solutions in order to allow nickel to precipitate out of solution.
- Treat degreasing baths separately, since the oils and grease in the wastewater will interfere with any metal precipitation processes.
- Use a reducing agent such as a sulfide to reduce wastewater containing hexavalent chromium, which is water-soluble, to trivalent chromium, which is insoluble. Add lime to the wastewater to precipitate out the chromium, and dispose of the solids in a sanitary landfill.
- Use sodium sulfides and iron sulfates to remove metal from rinsewater instead of tartarates, phosphates, EDTA and/or ammonia.
- Sludge from water treatment operations must be treated before disposal in order to control metals. Use electrolytic methods to recover metals from the sludge when metal concentrations are high. Sludges should be thickened, dewatered, and stabilized with lime before disposal in a controlled landfill. Oxidize chromium acid wastes with sodium bisulfite and sulfuric acid. Use magnesium oxide instead of caustic soda to adjust pH.

❑ *Water Use*

Metal finishing requires water in almost every stage of the process. Many metal finishing businesses have yet to seize major opportunities to reduce their water use. Often, limited water resources in an area must satisfy the needs for public drinking water, sanitation, irrigation, river transport and industrial needs. Inefficient use of these resources for metal finishing can leave insufficient or highly polluted waters in lakes, rivers and wetlands, degrading their ability to perform crucial economic and ecological functions. Water efficiency also has numerous financial advantages for an MSE, most notably the decrease in the water bill and in wastewater treatment costs. There are various cost-effective ways for metal finishing enterprises to reduce their water use that could provide substantial savings.

Key Questions to Consider:

- What type of rinsing technique is currently being employed?
- Is fresh water used in every new bath? Could some water be reused?
- Is there a system in place that measures the number of liters or gallons of freshwater used at various stages of the metal finishing process?

Selected Mitigation Strategies:

- **Ensure the proper design of rinse tanks** in order to improve rinsing efficiency, reduce water use, and reduce drag-out. Tanks should be the smallest size necessary for all parts/products that will be used in them, in order to reduce water usage. Using a static rinse tank before a running rinse tank will reduce drag-out in the running rinse tank, using less water for the same degree of cleanliness.

  Carefully placing water inlets and outlets on opposite ends of the tank will maximize water mixing in the tank, improving the effectiveness of the rinse. Inlet flow baffles, diffusers, distributors or spray heads can also help control the injection of freshwater into the rinsing tank and aid in mixing the water. Also, adding air blowers, mechanical mixing, or pumping/filtration systems can improve mixing by agitating tank water. Mechanical agitation is preferable to air agitation, however, since air blowers can introduce contaminants like oil into the bath.

- **Consider alternatives to tank rinsing.** Tank rinsing may not be the most water-efficient solution for rinsing certain types of parts. Consider spray rinsing instead of immersion for flat-surfaced parts. Ultrasonic rinsing works well for cleaning parts with small crevices or irregular shapes.

- **Employ a flow control technique.** Three effective flow control techniques are flow restrictors, flow cut-off valves, and conductivity meters and controllers. Flow restrictors ensure that excessive water is not fed to the process line. Flow cut-off valves are simple mechanisms that shut off water flow to rinse tanks when the process lines are not in use. Conductivity meters and control valves reduce rinse water flow and retain a set standard of water purity in the tank (electrical conductivity increases as the concentration of contaminant ions increases).

- **Measure usage at individual production points.** Install an inexpensive flow meter or accumulator on the main water feed line (leading to the process line) or on individual rinse tanks. Flow meters indirectly conserve water by allowing careful monitoring of usage and can identify optimum water usage (or excessive waste), leaks, and system failures.

- **Implement an alternative rinsing configuration.**

  Counter-current rinsing: This involves having rinse water circulated through a series of rinse tanks. Fresh water (preferably deionized) is fed into the rinse tank farthest from the process tank and overflows to the rinse tank closest to the process tank. The work piece is dipped in the cleanest water last. Counter-current rinsing uses significantly less water than a single flowing rinse. **Two counter-current rinse tanks can reduce water use by 90 to 97 percent.**

Reactive rinses and reuse: This system diverts the overflow from an acid rinse to an alkaline rinse tank. The reuse of acid rinse baths for alkaline cleaner rinses makes the alkaline cleaner rinse more effective, typically reducing water consumption by 50 percent.

Spray rinsing: Spray rinsing reduces the water needed for final rinsing by spraying drag-out back into its process tank or into a concentrated holding tank. Spray rinsing works best for flat sheets, or in conjunction with immersion rinsing for irregular objects.

- **Change the mechanics of the rinsing process.** Rinsing is more effective when the parts are dipped into the rinsing tank multiple times than when parts are dipped once and agitated while submerged. **Dipping parts twice in rinse baths is 16 times more effective at reducing drag-out than dipping once.**[9]
- **Re-use treated wastewater for minor rinsing steps,** such as after alkaline cleaners and acid pickling steps. Note: Caution should be exercised in re-using wastewater that has been conventionally treated (via hydroxide precipitation) as it can introduce high amounts of dissolved solids into the plating line.

[9] Source: *CP Manual for the Metal Finishing Industry*, 1998.

References and Other Resources

References consulted in preparing this fact sheet:

- *CP Manual for the Metal Finishing Industry* (1998). Developed by the UN Environment Programme Working Group for Cleaner Production and the Cooperative Research Centre for Waste Minimisation and Pollution Control Ltd on behalf of the Queensland Department of Environment and the Brisbane City Council. http://geosp.uq.edu.au/emc/cp/res/Metal%20Finish/Metal%20Finish_manual.htm

  Completed in April 1998, this manual provides information about CP opportunities within the metal finishing industry, to point the way towards greater profitability and improved environmental performance. It focuses on those aspects which are most achievable in the short and medium term, and which require limited effort or expense.

- The International Cleaner Production Information Clearinghouse (ICPIC) at http://www.uneptie.org/PC/cp/library/icpic.htm.

  The ICPIC was developed by the UN Environment Programme's Division of Technology, Industry, and Economics (DTIE) for the effective promotion of CP worldwide. The ICPIC contains a compilation of CP case studies, CP contacts, profiles of CP-related national policies and CP publications. Case studies used in preparing this fact sheet include:

  - *EP3: Pollution Prevention Assessment for a Metal Finishing Facility* http://www.p2pays.org/ref/10/09356.htm

  - *Toxic Waste Reduction in Chrome Plating* http://www.p2pays.org/ref/10/09381.htm

  - *Cleaner Production for Reducing Water Consumption at a Metal Plating Industry* http://www.p2pays.org/ref/10/09110.htm

  - *Eco-efficiency at a Metal Finishing Factory in the Czech Republic* http://www.p2pays.org/ref/10/09160.htm

- *Management Options for Old Paint and Paint-Related Materials* (1995). Minnesota Technical Assistance Program (MnTAP) Fact Sheet. http://www.p2pays.org/ref/01/00609.pdf

  This fact sheet provides information on how to effectively reduce and manage wastes from painting operations. These include (1) *ignitable wastes*, such as solvents and other cleaners; paints and paint thinners; and adhesives and glues, and (2) *toxic wastes* with heavy metals.

- National Metal Finishing Resource Center. http://www.nmfrc.org/

  The National Metal Finishing Resource Center (NMFRC) is an Internet-based organization established in 1995 under a program jointly funded by the U.S. Commerce Department's National Institute of Standards and Technology (NIST) and the U.S. Environmental Protection Agency (USEPA). Their site is a comprehensive collection of environmental and technical resources for pollution prevention in metal finishing, including a searchable technical database containing over 5,000 articles, papers and reports; specifications (with index) used in metal finishing; shop, supplier and people directories containing over 6,000 entries; and online calculators designed for finishing needs.

Their "Ask the Expert Question-and-Answer Archives" on wastewater treatment were used in creating this fact sheet. http://www.nmfrc.org/wwarchive/aug02b.cfm

- North Carolina Department of Environment and Natural Resources, Division of Pollution Prevention and Environmental Assistance. http://www.p2pays.org/

  This Web site offers an extensive collection of resources on CP and pollution prevention for a variety of industry sectors. The page on waste reduction in electroplating (http://wrrc.p2pays.org/industry/electroplating.htm) houses an excellent online collection of technical resources for the metal plating industry. Several "Fact Sheets" linked to this Web site that were used in preparing this CP fact sheet include:

  - *Water Efficiency, Industry-Specific Processes: Metal Finishing*. http://www.p2pays.org/ref/04/03097.pdf
  - *Water Conservation for Electroplaters: Counter-Current Rinsing* http://www.p2pays.org/ref/01/00051.htm
  - *Pollution Prevention Tips: Drag-out Management for Electroplaters* http://www.p2pays.org/ref/01/00222.pdf
  - Ben Graves. *Never Dump Cleaner*. http://www.p2pays.org/ref/02/01366.htm
  - Virginia Waste Minimization Program (1995). *Fact Sheet: Waste Reduction for Metal Finishers*, 1 (4). http://www.p2pays.org/ref/11/10308.htm

- Northeast Waste Management Officials' Association (1998). *Pollution Prevention in Metal Painting and Coating Operations: A Manual for Pollution Prevention Technical Assistance Providers*. http://www.p2pays.org/ref/01/00777/toc.htm

  The Northeast Waste Management Officials' Association (NEWMOA) designed this manual to provide environmental assistance staffers with a basic reference on metal finishing—a single publication to jump-start their research on pollution prevention for companies with which they are working. The manual is explicitly designed to be useful both to assistance professionals with experience working with metal platers and to those who have never encountered metal finishing before. The USEPA Pollution Prevention Division funded this manual as a model of a comprehensive packet of information on a single industry.

- Pallen, Dean (1997). *Environmental Sourcebook for Micro-Finance Institutions*. Asia Branch, Canadian International Development Agency. http://www.microfinancegateway.org/files/1914_Pallen_Dean.pdf

This sourcebook describes the environmental impacts of a variety of important MSE sectors. It is designed to help micro-finance institutions improve the environmental performance of their lending activities, and offers guidance for improving MSEs' economic performance as well.

- Pennsylvania Department of Environmental Protection (1997). *Pollution Prevention Opportunities for Painting and Coatings Operations.* http://www.p2pays.org/ref/01/00151.pdf

  This fact sheet describes alternatives for reducing releases of volatile organic compound (VOCs) from solvents, as well as good operating practices for painting operations.

- U.S. Environmental Protection Agency (1994). *Guide to Cleaner Technologies: Alternative Metal Finishes*. EP/625/R-94/007. http://www.p2pays.org/ref/02/01052.pdf

  This guide presents information on process alternatives that can reduce or eliminate generation of some wastes and emissions from metal finishing operations. It is particularly applicable to firms that apply cadmium and chromium finishes, as well as to finishers that use cyanide-based baths or copper/formaldehyde solutions.

Additional Useful Web sites

- Business Assistance. *Metal Finishing Industry Resources* http://pprc.org/hubs/toc.cfm?hub=24&subsec=7&nav=7

  This site catalogs a variety of metal finishing resource sites. It maintains links to several metal finishing trade associations as well as a database of current research projects. A joint project of the Business Assistance Programs in Alaska, Idaho, Oregon and Washington, the site is funded by a grant from USEPA.

- Cleanerproduction.com offers two catalogs of sites relevant to the metal finishing industry:

  http://www.cleanerproduction.com/Directory/sectors/subsectors/metalplating.html and http://www.cleanerproduction.com/Directory/sectors/subsectors/metalproducts.html.

  The site is run by Hamner and Associates LLC, based in Seattle, Washington, USA, and Manila, Philippines.

- http://www.svti.sk/CleanVOC.htm is an annotated guide to resources available on the Internet for metal finishers.

Chapter 4.5
Small-Scale Mining: Cleaner Production Fact Sheet and Resource Guide

Purpose

This fact sheet offers basic information on the important adverse environmental impacts of small-scale mining, as well as associated health and safety impacts. It also discusses opportunities for mitigating those impacts, with an emphasis upon "cleaner production" strategies that may also provide financial benefits to micro- and small enterprises (MSEs). In addition, each fact sheet offers a substantial, annotated list of resources for organizations seeking more information.[10]

This fact sheet has been prepared for (1) **business development services (BDS) providers**, which offer services such as management training or marketing support to MSEs, and (2) **intermediate credit institutions (ICIs) and direct lenders** that provide financial credit to MSEs. It is intended to be used in concert with other sections in Part III of the *Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Development Activities,* which is USAID Africa Bureau's principal source of sector-specific environmental guidance.

Why Focus on Cleaner Production for Mitigation?

Cleaner production is a preventive business strategy designed to conserve resources, mitigate risks to humans and the environment, and promote greater overall efficiency through improved production techniques and technologies. Cleaner production methods may include:

- substituting different materials
- modifying processes
- upgrading equipment
- redesigning products

[10] At the time of writing, USAID cleaner production fact sheets are available for the following subsectors that are likely to have substantial adverse impacts on the environment and/or workers' health: brick and tile production; leather processing; small-scale mining; food processing; metal finishing; wood processing and furniture making, and wet textile operations.

In addition to environmental, health and safety benefits, many cleaner production techniques provide opportunities to substantially reduce operating costs and improve product quality. MSEs can profit from CP through more efficient use of inputs and machinery, higher quality goods that can command higher prices, and reduced waste disposal costs. Improved safety measures can also help MSEs avoid costly accidents and worker absences.

Experience has demonstrated that, with assistance, MSEs can frequently identify cleaner production opportunities that produce a positive financial return, sometimes with little or no investment. Many enterprises that change to CP methods may realize substantial financial and environmental benefits, indicating that CP should be the first option considered in addressing MSEs' environmental problems.

Yet, although this approach can offer tremendous advantages, readers should also recognize that cleaner production options showing clear financial benefit will only be available to varying degrees among different enterprises and often may not completely mitigate environmental problems. In some cases, even when pursuing CP techniques, some businesses may need to use solutions that offer no measurable financial return—if such solutions are required by USAID's Regulation 216 or local regulations or desired for other reasons, such as community goodwill.

Small-scale mining activities can generate many kinds of environmental damage. It is important to ensure that they use resources more efficiently and that they prevent serious health problems from occurring.

Adverse Environmental Impacts and Mitigation Opportunities

Several key environmental issues associated with small-scale mining are listed in the box at right and discussed below. For each environmental impact, the fact sheet provides a list of questions to assist in the assessment of individual MSEs. These questions are followed by a number of mitigation strategies that can be considered, with an emphasis on cleaner production strategies where possible. The strategies presented typically represent a range of available options, from profitable activities that require no investment to other activities that may increase MSE costs.

Important Environmental Issues Addressed by This Fact Sheet

- Open pit mining
- Mercury use
- Inefficient extraction
- Dust
- Noise
- Underground hazards
- Long-term hazards

❑ *Open pit mining*

Open pit mining activities can alter the landscape in ways that are potentially dangerous and costly. Excessive land clearing or steeply sloped pits can lead to landslides that destroy working sites, harm workers, or block waterways. Costly work stoppages, loss of future mining sites, or damage to water bodies may result.

Key questions to consider:

- Is the structure of the pit stable?
- How much loose rock or soil is above the work site?
- Does each rainfall move significant amounts of soil?

Selected mitigation strategies:

- Before mining starts, assess the site and see how close it is to sensitive resources (e.g., unique ecological, cultural, historical or archeological sites or areas of scenic value). Assess the full range of alternatives for avoiding or minimizing impacts on these resources, including selecting an alternative site or taking no action at all.
- Once a mining site has been selected, assess the full extent of the resource. Devise a engineering plan for reclaiming and restoring the mined area at the same time the resource is being extracted. If owners or managers do not know the extent of the resource, many mines remain open longer than is useful and restoration is delayed indefinitely. If possible, engage a geotechnical engineer and landscape architect to help develop the mine extraction and reclamation plan.
- If land is being cleared, try to leave enough trees and vegetation to prevent soil erosion. Use cleared brush or other materials to create erosion barriers.

- Ensure that the road leading to the mine is well-designed, with low slope and good drainage to keep water off the road. (See the chapter on rural roads in the *Guidelines*.) Avoid creating roads that pass close to sensitive resources (e.g., forests or wetlands).

- While mining, where feasible, avoid creating pits that will accumulate water, presenting health and safety hazards (e.g., dangers from drowning and creation of breeding grounds for mosquitoes).

- Plant vegetation on the site before leaving the area. Bare soil causes landslides, which can occur both before and after mining activities are completed. Landslides may destroy working sites and make future mining more difficult. Landslides may also kill workers, innocent community members, and animals, and they can seriously damage the local ecology.

- Angle the mine's pit faces to prevent unexpected collapse. This preserves the investment in excavation, guaranteeing a longer life to the working site and less danger for those working inside. It may be necessary to disturb additional land in order to make the angle less steep, but take care to disturb as little land as possible.

- Retain topsoil for later use in reclaiming the site. Segregate other subsurface materials which might have potential value in construction or road works. Store these materials away from water bodies to reduce the potential for cumulative siltation, interference with water flows, and subsequent damage to ecosystems, as well as to the people who depend on these for their livelihood.

❑ *Mercury*

Using mercury to extract gold or silver from ore can severely affect worker and community health. Mercury entering the human body may cause kidney problems, headaches, tremors, comas and other serious health problems. It is especially hazardous to children. Mercury exposure can occur directly, through physical contact, or indirectly, through contaminated water or fish. Mercury poisoning will result in the loss of skilled labor and long-term damage to communities. Reducing mercury use may also lower production costs, although in many countries the cost of mercury is low.

Key questions to consider:

- Do managers or workers experience tingling or tremors in fingers or toes?

- Does the business use mercury to process ore near a water source or in your home?

- Where does the business dispose of water with mercury in it?

- Does the business use extra mercury to speed up the extraction process?

Selected mitigation strategies:

- Recognize mercury poisoning. In the short term, high levels of mercury exposure result in tingling and tremors in fingers or toes. Be aware of the signs and reduce contact before long-term damage occurs.

- Dispose of mercury-contaminated water far away from water sources, fish-bearing waterways, and human settlements. Make sure rain cannot wash away mercury or mercury-contaminated materials.

- Avoid inhaling mercury vapor. Try to recycle mercury, and avoid emissions by using an open oven to capture and condense mercury vapor for reuse. This method can save money on the purchase of mercury. In addition, heat amalgam in a well-ventilated room or outside, to allow any mercury vapor to disperse.

- Reduce mercury use through more efficient production. For example, miners frequently overuse mercury during amalgamation. Miners should use only the correct amount of mercury, since additional mercury does not speed or improve the amalgamation process—it only increases costs and risks. Miners should avoid grinding and amalgamating at the same time. Separating these processes helps ensure that mercury is not overused.

❑ *Inefficient extraction*

Mining wastes often pose serious threats to human health and wildlife, and have persistent and hazardous impacts to groundwater, surface waters, and soils. Small-scale mining often uses inefficient extraction methods that result in substantial loss of the product. Finding and removing ore from pits with inadequate or poorly operated machinery reduces yields. Crude processing technologies can lead to lost earnings and more waste.

Key questions to consider:

- How often does the business conduct maintenance or repairs on machinery?

- How much waste is produced for a given amount of product? Could this waste be reduced?

- Have workers been trained in operating machinery efficiently and safely?

Selected mitigation strategies:

- Maintain machinery. To maximize efficiency, make sure machinery is working properly and train workers in operating and maintaining it. Ensure that operators are keeping maintenance logs.

- If little or no machinery is used, consider low-cost technologies that may increase yields. Improving separation methods, such as by using sluices or gravity centrifuge machines, increases productivity and reduces waste.

- Evaluate mining techniques to see if product is being lost in the extraction process. Check rock waste or the extraction area to see if mineral is being wasted or if potentially valuable mineral veins are being destroyed. Train workers in proper techniques for identifying and removing ore.

❑ *Dust*

Dust generated by rock, metal and coal mining can be harmful. Using wind to separate metal from ore, or using machinery that generates rock dust, can lead to silicosis. Silicosis is a disease caused by inhaling silicates in the dust of crushed rocks; it can severely decrease workers' lung capacity and productivity, and it sometimes results in their deaths.

Key questions to consider:

- How much dust is produced in a typical working day?

- What protective materials are available?

- Is ore being ground or crushed by hand?

Selected mitigation strategies:

- Small-scale mines can produce a substantial amount of dust; maintain tree or vegetation cover to capture dust and prevent dust clouds from traveling long distances.

- Ventilate underground mines so dust can escape and ease working conditions.

- If possible, wet materials so less dust is produced. Use water when running a pneumatic drill. Dampen ore before crushing in a mortar and pestle. However, use water conservatively to avoid wasting this resource, and prevent water used in these activities from contaminating other water sources.

- Avoid crushing or grinding ore in the home. The transport of raw ore to the home can be inefficient. In addition, this practice produces a great deal of dust since it is often done by hand, and most homes are not properly ventilated. This makes workers and their families, especially small children, particularly vulnerable to silicosis.

- Provide all workers with face masks and instruct them to wash their hands after working so they will not ingest dust with their food.

❑ *Noise*

Mining activities can involve equipment that can be very noisy or cause strong vibrations. This can affect workers' hearing and health, as well as the community around the working site. This may work against the enterprise's ability to expand production in the future.

Key questions to consider:

- Are some machines louder than others?

- Is machinery left running when not in use?

Selected mitigation strategies:

- Provide earplugs for workers.

- Repair and maintain machinery so that excessive grinding or squeaking is minimized. Frequent repair and maintenance will typically also make the machinery operate more efficiently, reducing fuel costs.

- Provide protective insulation or cushioning to those working with vibrating machinery.

- Use machinery efficiently. Do not run machinery longer than necessary. This saves energy and reduces environmental damage.

- Try to use noisy machinery only at times when the surrounding community is least likely to be disturbed. For example, it may be better to operate such machinery during the daylight hours.

❑ *Underground hazards*

Underground mines are often hazardous to work in and are extremely susceptible to major accidents. Poorly constructed mining spaces can lead to injuries that reduce productivity, as well as large-scale accidents that destroy working sites.

Key questions to consider:

- How old is the mine?
- What kind of supports are in the walls and ceilings? Are these supports in good condition?
- How are explosives used to clear new spaces?
- Is the site for the mining operation geologically stable?
- Is the site subject to periodic flooding?

Selected mitigation strategies:

- Eliminate minor safety hazards. For example, construct underground space so that falls are minimized. Make passageways wide and tall enough to accommodate workers comfortably. Workers who cannot walk or stand normally are apt to suffer from debilitating chronic musculoskeletal injuries that reduce their productivity.
- Use explosives wisely. Explosions can weaken underground structures and cause cave-ins. Any worker using explosives should have training in their proper and safe use. Take care to evacuate the mine before detonating any explosives, even when trained personnel are using them.
- Ventilate coal mines well to reduce excessive heat and dust and minimize chances of spontaneous fires. Sink new shafts or widen existing mine openings to increase airflow. Doing so can improve worker health and productivity and decrease the risk of destroying the mine through an accidental explosion.
- Reinforce walls and ceilings to avoid an unexpected collapse of the mine. When working in older and abandoned mines, be aware that removing pillars or wall supports to extract ore can quickly lead the mine to collapse.

❑ *Long-term hazards*

The environmental impacts of even a short-term mining operation often last many years, even centuries, beyond the working life of the mine. Unless they are mitigated, contaminated waste, hazardous mine structures and disturbed land can pose problems long after mining operations close. Adequate waste disposal and careful mine closure represent additional cost to the mining operation, but may reduce community and government opposition to future mining activities.

Key questions to consider:

- How will time affect waste disposal sites or mine structures?
- Has the landscape significantly changed as a result of mining activities?
- How will the community use the mine area in the future?

Selected mitigation strategies:

- Seal underground mines. Cover entrances to underground mines so they do not present safety hazards.
- Construct waste disposal sites that will last. Make sure tailing ponds or chemical waste dumps are secure and can withstand severe weather.
- Plant trees. This prevents landslides and keeps remaining topsoil on the land.

Mining is dangerous for both workers and local communities. Be sure that small mining operations are aware of safety measures and protect workers and community health.

❑ *Mining camps and mine workers*

Mining activities are sometimes undertaken by transient groups of laborers who come in from outside and can indirectly lead to social and sanitation problems. Unsanitary living conditions in mining camps can spread contagious diseases like dysentery and typhoid. Epidemic disease disrupts work and can destabilize communities. Unsafe sex practices can promote the spread of AIDS. Social problems may occur, including gambling, alcohol abuse, theft, violent behavior and prostitution.

Key questions to consider:

- Where is human and food waste disposed of?
- How often do people get sick? Are there any nearby medical facilities?
- What water sources are available?
- What kinds of social problems exist at other small-scale mining sites in the region?

Selected mitigation strategies:

- Improve sanitary measures. Construct enough toilet facilities and make sure they cannot contaminate water sources. Ensure that there are enough water sources for workers to wash themselves, and promote clean food preparation.
- Educate workers about HIV/AIDS and other sexually transmitted diseases (STDs). Encourage the use of safe sex practices.
- Establish miners' committees for health, safety and welfare. Create mechanisms for democratic self-policing.

References and Resources

- *Developments in Small-Scale Mining* (1996). Committee on Natural Resources, Report of the Secretary-General, United Nations.

- Jennings, Norman S. ed. *Small-Scale Gold Mining: Examples from Bolivia, Philippines and Zimbabwe*. Industrial Activities Branch Working Paper, International Labour Organization (ILO). <date available?>

  http://www.ilo.org/public/english/dialogue/sector/papers/goldmine/index.htm. This document is a case study of three pilot projects in small-scale mining. A practical example of problems and solutions in mining activities; it includes a section on lessons learned as well as examples and diagrams of alternative amalgamation machinery.

- "Mercury." *The Pollution Prevention Abatement Handbook* (1998).World Bank.

  http://www.ifc.org/ifcext/enviro.nsf/Content/PPAH. A good explanation of the hazardous characteristics of mercury and the different health impacts of mercury exposure.

- *Social and Labour Issues in Small-Scale Mines*. Report for discussion at the Tripartite Meeting on Social and Labour Issues in Small-Scale Mines, in Geneva, 17–21 May 1999. International Labour Organization (ILO).

  http://www.ilo.org/public/english/dialogue/sector/techmeet/tmssm99/tmssmr.htm. An excellent discussion of health issues associated with small-scale mining. Attention is paid to solutions to occupational health and safety issues, including reducing mercury use and decreasing the incidence of silicosis.

- "Surface Mining." In *Environmental Handbook: Documentation on Monitoring and Evaluating Environmental Impacts*, Vol. 2.German Federal Ministry for Economic Cooperation and Development (GTZ).

  http://ces.iisc.ernet.in/energy/HC270799/HDL/ENV/enven/vol212.htm. A short discussion of two different methods of surface mining—wet and dry extraction—and the environmental impacts associated with them. Contains information more relevant to medium than small mining operations.

Other Resources

- Acquah, Peter Claver. *Natural Resources Management and Sustainable Development: The Case of the Gold Sector in Ghana* (1996). Ghana: Environmental Protection Council. United Nations Conference on Trade Development.

  http://www.mineralresourcesforum.org/docs/pdfs/G9552829.PDF. A case study of natural resource management and sustainable development in the gold mining sector of Ghana. This document sets out the main environmental and socioeconomic impacts of gold mining, including water pollution, land degradation and effects on coastal and marine resources.

- *Chemicals Management: DAC Guidelines on Aid and Environment* (1993). The Organisation for Economic Co-operation and Development (OECD).

http://www.oecd.org/dataoecd/37/5/1887724.pdf. This document targets aid agencies and the need for chemical management programs. It briefly discusses the dangers of certain chemicals, including mercury, and the capacities required for adequate chemicals management.

- Maponga, Oliver and Anderson Mutemererwa (1995). *Management of Natural Resources and the Environment in Zimbabwe: The Case of Gold.* University of Zimbabwe, The Institute of Mining Research. United Nations Conference on Trade and Development.

  http://www.mineralresourcesforum.org/docs/pdfs/g9550334.pdf. A case study of natural resources management and sustainable development in the gold sector of Zimbabwe. A description of the main environmental impacts from gold mining is followed by a discussion of economic development and legislation.

- McDivitt, James F. (1990). *Small-Scale Mining: A Guide to Appropriate Equipment*. Intermediate Technology Publishing.

  http://styluspub.com/Books/BookDetail.aspx?productID=20833. A guide to available equipment on all aspects of small-scale mining, from prospecting and surveying through haulage, handling and transport. It includes a discussion of safety equipment. The book features world-wide coverage, with particular relevance to the developing world, and costs around US $28.

- McMahon, Gary, Jose Luis Evia, Alberto Pasco-Font and Jose Miguel Sanchez (1999). *An Environmental Study of Artisanal, Small, and Medium Mining in Bolivia, Chile, and Peru*. World Bank Technical Paper.

  http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/1999/10/13/000094946_99092905340059/Rendered/PDF/multi_page.pdf. This paper synthesizes a study examining the environmental performance of artisanal, small, and medium mining in Bolivia, Chile and Peru. Includes summaries of the three country studies. Significant emphasis is placed on the viability of artisanal, small, and medium mines if environmental costs are taken into account, as well as policy actions to improve the environmental performance of viable mines.

- Priester, M., T. Hentschel and B. Benthin (1993). *Tools for Mining*. GTZ: Information and Advisory Service on Appropriate Technology, 537 p.

  http://sleekfreak.ath.cx:81/3wdev/CD3WD/APPRTECH/G10TOE/INDEX.HTM. This handbook serves as an information source for technicians, engineers and advisors associated with small-scale mining in developing countries. In the part of the handbook devoted to techniques, special attention is paid to (1) ensuring local production in developing countries, (2) offering environmentally friendly technologies and (3) taking into account the social and cultural conditions of the miners when selecting the techniques.

- *Regularizing Informal Mining: A Summary of the Proceedings of the International Roundtable on Artisanal Mining* (1996). Roundtable organized by the World Bank, Washington, D.C. May 17–19, 1995. World Bank Industry and Energy Department Occasional Paper No. 6.

  http://www.natural-resources.org/minerals/cd/ssm.htm#Workshops. A general discussion of the challenges associated with small-scale mining activities that often occur outside the reach of environmental or financial regulation.

- Zamora, Armando (2000). "Small Scale Mining: A Social and Environmental Problem Turned into an Opportunity for Economic Development." *Internet Journal of the Centre for Energy, Petroleum and Mineral Law and Policy*, Vol. 6–6.

  http://www.dundee.ac.uk/cepmlp/journal/html/vol6/article6-6.html. This article discusses the economic development implications of small-scale mining in developing countries and possible sustainable and legal solutions to the industry's social and environmental problems.

Chapter 4.6 Wet Textile Operations: Cleaner Production Fact Sheet and Resource Guide

Purpose

This fact sheet offers basic information on the important adverse environmental impacts of wet textile operations, as well as associated health and safety impacts. It also discusses opportunities for mitigating those impacts, with an emphasis upon "cleaner production" strategies that may also provide financial benefits to micro- and small enterprises (MSEs). In addition, each fact sheet offers a substantial, annotated list of resources for organizations seeking more information.[11]

This fact sheet has been prepared for (1) **business development services (BDS) providers**, which offer services such as management training or marketing support to MSEs, and (2) **intermediate credit institutions (ICIs) and direct lenders** that provide financial credit to MSEs. It is intended to be used in concert with other sections in Part III of the *Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Development Activities,* which is USAID Africa Bureau's principal source of sector-specific environmental guidance.

Why Focus on Cleaner Production for Mitigation?

Cleaner production is a preventive business strategy designed to conserve resources, mitigate risks to humans and the environment, and promote greater overall efficiency through improved production techniques and technologies. Cleaner production methods may include:

- substituting different materials
- modifying processes
- upgrading equipment
- redesigning products

In addition to environmental, health and safety benefits, many cleaner production techniques provide opportunities to substantially reduce operating costs and improve product quality. MSEs can profit from CP through more efficient use of inputs and machinery, higher quality goods

[11] At the time of writing, USAID cleaner production fact sheets are available for the following subsectors that are likely to have substantial adverse impacts on the environment and/or workers' health: brick and tile production; leather processing; small-scale mining; food processing; metal finishing; wood processing and furniture production, and wet textile operations.

that command higher prices, and reduced waste disposal costs. Improved safety measures can also help MSEs avoid costly accidents and worker absences.

Experience has demonstrated that, with assistance, MSEs can often identify cleaner production opportunities that produce a positive financial return, sometimes with little or no investment. Many enterprises that change to CP methods may reap substantial financial and environmental benefits, indicating that CP should be the first option considered in addressing MSEs' environmental problems.

Dyes and other chemicals from textile processing can be recycled and reused, saving resources and costs for micro- and small enterprises.

Yet, although this approach can offer tremendous advantages, readers should also recognize that cleaner production options showing clear financial benefit will only be available to varying degrees among different enterprises and often may not completely mitigate environmental problems. In some cases, even when pursuing CP techniques, some businesses may need to use solutions that offer no measurable financial return—if such solutions are required by USAID's Regulation 216 or local regulations or desired for other reasons, such as community goodwill.

Important Environmental Issues Addressed by This Fact Sheet

- Water use
- Chemicals
- Improper use and poor maintenance of machinery and equipment
- Poor production practices
- Inefficient energy use
- Wastewater

Adverse Environmental Impacts and Mitigation Opportunities

Several key environmental impacts associated with wet textile operations are listed in the box at left and discussed below. For each impact, the fact sheet provides a list of questions to aid in the assessment of individual MSEs. These questions are followed by a number of mitigation strategies that can be considered, with an emphasis on cleaner production strategies where possible. The strategies presented typically represent a range of available options, from profitable activities that require no investment to other activities that may increase MSEs costs.

❑ *Water use*

Wet textile production requires water at almost every stage of the production process. If well or pump water is used, excessive water use can deplete water sources for future production or community use. Energy costs for pumping, as well as environmental impacts from energy consumption, will be higher than necessary. Excessive water use can lower the water table and require frequent redrilling of wells.

If the enterprise pays by volume for the water it uses, reducing water usage can be expected to provide substantial savings. Using water more efficiently guarantees less costly production and reduces the risks of water shortages that could interrupt production.

Key questions to consider:

- Is water left running when it is not in use?
- Is fresh water used in every stage of production? Could some water be reused?
- How much money does the business pay for water, and how much could it reduce that cost through more efficient use?

Selected mitigation strategies:

- Reuse water from “cleaner” stages of production in “dirtier” stages of the next production cycle. For example, use rinse water from the final stage of one production cycle in the first-stage rinsing of the next batch.
- Decrease water usage through “dry cleanup.” Dry cleanup involves initial cleaning without water (by sweeping or wiping down) before washing. This method reduces the amount of water required to dislodge solid or semi-solid wastes from floors or machinery.
- Regulate water flow. Using high-pressure water hoses can ease cleaning and cut water use; often this can be accomplished simply by adding a new nozzle to the end of a hose.
- Limit water loss between production stages. Turn off water when transferring materials from one bath to another, since leaving the water running causes substantial water loss. Prevent baths from overflowing by monitoring water levels closely or installing an automatic shut-off mechanism.

❑ *Chemicals*

Chemical dyes and solvents may represent a significant part of production costs; costs rise if chemicals are overused due to inefficient production methods. Excessive chemical use also increases risks of contamination and may affect the health of workers. Efficient chemical use lowers production costs and lessens environmental impacts.

Key questions to consider:

- Where are chemicals stored? In what quantities?
- Are workers trained in correct measurement and application techniques?
- Are different kinds of chemicals available for the same application? Are any more efficient, safer, or less harmful to workers' health or the environment?

Selected mitigation strategies:

- Improve chemical application techniques. Spot-apply solvents instead of pouring; this helps avoid spills and stops excessive chemical use. Use correct measurements to reduce waste or spoilage.
- Consider using less dangerous or damaging chemicals. Replace potentially carcinogenic (cancer-causing) chemical inks with vegetable-based inks. To reduce pollution, use lower-foaming detergents or solvents with less isopropyl alcohol.
- Reuse certain chemicals. Investigate which chemicals can be reused or recycled. Caustic soda, for example, can be recaptured from the mercerizing process (an intermediate step in textile refinishing) through evaporation.
- Improve chemical storage. Monitor storage area for signs of chemical leakage. Make sure containers are well built and have no cracks.

❑ *Improper use and poor maintenance of machinery and equipment*

Improper use of machinery or equipment can increase waste, raising costs for inputs and, often, for waste disposal. Chemical or fuel leaks from machinery waste energy, can contaminate water supplies, and may threaten workers' health. Better management of machines and equipment lowers costs and reduces losses.

Key questions to consider:

- How well are workers trained in machine operation and maintenance?
- Are machines used to their full capacity?
- Is equipment well maintained? Is there a regular maintenance schedule and checklist?

Selected mitigation strategies:

- Train workers in proper maintenance and operation of machines. Use machines at full capacity. This increases output and saves fuel.

- Use appropriately sized equipment. Equipment that is too large wastes water; equipment that is too small may lead to waste and spills.

- Minimize leakage and blockage in equipment. Monitor machinery to prevent fuel or water leakage; clean debris from sumps and screens to improve efficiency.

❑ *Intermittent Production*

Intermittent textile producers—job shops that produce textiles on a contractual basis—face production inefficiency and pollution problems similar to those of permanent producers, but these are made worse by the temporary nature of production. Advance planning can lessen waste that occurs in between production stages and reduce some of the inefficiencies.

Key questions to consider:

- How unpredictable are production requests? Do they follow a pattern?

- How are inputs or machinery stored in between production cycles?

Selected mitigation strategies:

- Increase production efficiency through improved record-keeping. Documenting production requests helps producers determine if there are any general production trends over time—for example, during certain seasons—and makes it easier for producers to anticipate demand. Maintaining a logbook of inputs also allows producers to check stocks and replace inputs if they are no longer effective.

- Maintain equipment even if it is not in use. Check equipment for leaks and repair immediately so that production will not be delayed when it restarts. Ensure that chemicals and dyes are stored in tightly sealed containers that do not leak.

- Plan input purchases to minimize leftovers (of chemicals, materials, etc.) once production has ended. Use minimum amounts of chemical or fuel inputs to increase efficiency and reduce losses in between production stages.

❑ *Working conditions*

Textile production may result in hazardous working conditions—excessive heat caused by operating machinery, lack of ventilation, skin-irritating chemicals—that can damage workers' health. Unhealthy workers may be less productive, miss work too often and make costly mistakes.

Working conditions that guard workers' health and safety can help to increase productivity, lower costs, and make a small enterprise a better neighbor to the community.

Key questions to consider:

- What kinds of fumes are produced in the different stages of production?
- Are there any by-products from production that cause skin, eye or breathing irritation, even occasionally?
- Are any of the chemicals used known to be potentially cancer-causing?
- Are gloves, boots, face masks or other protective clothing available for workers?

Selected mitigation strategies:

- Develop and implement a health and safety plan. Sometimes small changes such as buying face masks or rubber gloves can dramatically reduce potential harm to workers. Find ways of preventing accidents.
- Train workers in accident prevention. Designate one person as the safety trainer and have that person train others. Check existing safety equipment regularly; replace elements like filters frequently.
- Provide tight-fitting covers for chemical baths, to reduce sickening fumes and minimize evaporation of costly chemicals.
- Increase ventilation inside buildings and around chemical baths. Fumes from chemicals, even if the chemicals are outside, can sicken workers. Inside, increase ventilation by improving the building's layout. Outside, orient chemical baths downwind from workers and from other production areas. The use of fans, covers and/or chimneys can help minimize fume inhalation outdoors or indoors.
- Consider reorganizing production, such as by rotating shifts, so that individual workers do not spend too much time at once exposed to fumes.

❑ *Poor production practices*

Some common production practices use resources inefficiently and cause more pollution. For example, two common mistakes can cause unnecessary waste of inputs and extra water pollution: using too much salt in color fixing, and not properly matching colors among different batches. Salt is particularly damaging to water sources used for drinking water and agriculture, and can be difficult and/or expensive to remove from wastewater. Changing textile production in simple ways can reduce environmental harm, lower costs, and raise output.

Key questions to consider:

- How well are workers trained in production methods?
- Can two stages of production be combined into one?

- Where can improvements be made in the production process?

Selected mitigation strategies:

- Improve machines' efficiency. Controlling drafts and improving firing techniques in boilers saves fuel and speeds production.

- Train workers in proper use of salts and dyes. Require all workers to measure salts, and provide simple measuring equipment, e.g., measuring cups. To prevent wasting material from a bad dye mix, make a small test batch to determine whether a dye will yield the desired colors.

- Investigate alternative production strategies. Using hot water instead of cold to process fabric can save a scouring stage; note, however, that this may result in higher fuel costs. Improving the scouring process can reduce alkali consumption.

- Institute housekeeping measures to speed production, such as putting screens on drains, preventing boil-overs, and improving the vessels in which dyeing takes place to avoid leaks.

❑ *Inefficient energy use*

Most energy used in textile production occurs in heating dye baths and in rinsing and drying fabrics. Inefficient use or overuse of fuel during these production stages contributes to pollution and higher operating costs. Reducing use can save costly or scarce resources.

Key questions to consider:

- What type of fuel is used in production? In what quantities?

- What various fuel sources are available in your area? At what cost?

- Which production stages use the most fuel?

Selected mitigation strategies:

- Use alternative fuel types. Organic wastes, such as rice husks and bagasse, can supplement scarce fuel sources such as wood. Renewable energy sources, such as solar hot water heating or photovoltaic (solar) cells, may be a cost-effective option in some cases, but cost, availability and applicability of the technology should be carefully assessed.

- Improve heat transfer and insulation. Insulate pipes and bath containers to reduce energy loss and decrease fuel needs.

- Regulate fuel use to meet needs. Use only enough fuel to meet production requirements.

- Implement energy conservation methods. Use a thermometer to maintain the most efficient bath temperature. Make more efficient use of production time, and prevent excessive use of fuel (due to overheating or reheating baths). Consider planning the facility's production cycles to reuse bathwater that is still hot from a previous use.

❑ *Wastewater*

Wastewater from textile production is often contaminated with chemical dyes, solvents or salts. Contaminated water endangers the health of workers and the surrounding community. Wastewater can also gather in stagnant pools and create breeding grounds for insects, particularly mosquitoes. In the long run, contaminated wastewater can make the local water supply undrinkable and ruin local farmers' crops. These problems may force textile operations to pay for procuring clean water from other locations or to clean the water on-site before using it.

Key questions to consider:

- Where is wastewater discharged?
- What treatment methods are currently used in production?
- What kinds of chemicals are used and what dangers do they pose?

Selected mitigation strategies:

- Separate chemically contaminated water from organic wastewater. Water with undyed fibers or dirt in it does not present a health hazard and can even be used as fertilizer. However, water that is contaminated by chemicals or other substances will need some type of treatment to make it safe for release into the environment. Consult with an expert to determine what treatment methods are appropriate for the individual facility's wastewater.
- Minimize contaminated water. Ensure that dyes or chemical-coated materials are cleaned away from water sources and with as little water as possible.
- Avoid spills that can contaminate water supplies.

Resources and References:

- *Cleaner Production in Cloth Printing and Dyeing Operations*

  http://www.p2pays.org/ref/10/09351.htm. Useful description of general cost-effective pollution prevention tips (ranging from limiting chemical use to saving water or fuel costs).

- *Cleaner Technology Transfer to the Polish Textile Industry: Idea Catalogue and Selected Options* (1999). Danish Cooperation for Environment in Eastern Europe (DANCEE).

  http://www.mst.dk/udgiv/publications/1999/87-7909-255-1/html/helepubl_eng.htm. This study was commissioned by the Danish environmental protection agency for improvements in the Polish textile industry. Although the report refers to medium-scale producers, it provides an excellent example of diagnosis and options for cleaner production. The report discusses different methods of improving resource efficiency, chemical substitution, and optimization.

- *Energy Conservation in the Textile Industry* (1992). United Nations Industrial Development Organization (UNIDO) and Ministry of International Trade and Industry (MITI), Japan.

  http://www.unido.org/userfiles/PembletP/sectorstextile.pdf. This manual presents a lengthy discussion of textile production in a variety of subsectors—yarn and fiber production, knitting, weaving, clothing, dyeing and finishing—and provides guidance on energy-saving technologies for each one.

- *Pollution Prevention Tips for Wet-Processing Textile Mills*. Georgia Pollution Prevention Assistance Division. Georgia Department of Natural Resources.

  http://www.p2pays.org/ref/09/08015.htm. This report gives specific cleaner production guidelines for improving textile processing. Concentrates mostly on water conservation methods and improving chemical use.

- *Sectoral Profile of the Textile Industry* (1998). United Nations Industrial Development Organization (UNIDO) Sustainable Development Program. January.

  http://www.p2pays.org/ref/11/10489/sectors701.html. An extensive overview of textile production, including subsectors. Also includes a very detailed technical description of cleaner production techniques such as chemical substitution, water conservation and waste minimization.

- Smith, Brent and Vikki Bristow. *Indoor Air Quality And Textiles: An Emerging Issue.* Raleigh, North Carolina: School of Textiles, North Carolina State University.

  http://www.p2pays.org/ref/03/02906.pdf. Fairly technical discussion of possible air pollutants present inside textile processing buildings.

- "Textiles" (1998). *Pollution Prevention and Abatement Handbook.* World Bank Group.

  http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187511&siteName=WDS&entityID=000094946_99040905052283. This chapter is part of a larger pollution prevention handbook

published by the World Bank. The document discusses major sources of pollution and lists technical requirements for limiting chemical pollutants.

- *The Textile Industry and the Environment* (1993). United Nations Environmental Program (UNEP) Technical Report No.16.

  http://www.uneptie.org/pc/cp/library/catalogue/related.htm. This booklet gives an overview of environmental impacts associated with textile production and strategies for cleaner production. For sale at earthprint.com for US $35.

- *The Textiles Industry: Improvement of Resource Efficiency and Environmental Performance* (2000). CleanerProduction.com, Hamner and Associates LLC.

  http://www.cleanerproduction.com/Directory/sectors/subsectors/textiles.html. A short discussion of cleaner production issues and a checklist of possible areas of attack. This Web site also includes links to a number of other textile sites.

- Wanucha, David J. *Land Application of Textile Biosolids: North Carolina's Experience.* North Carolina Division of Pollution Prevention and Environmental Assistance.

  http://www.p2pays.org/ref/02/01124.pdf. A low-tech discussion of the beneficial reuse of textile wastewater treatment sludge in agriculture.

- *Water Conservation for Textile Mills: A Waste Reduction Fact Sheet*. North Carolina Division of Pollution Prevention and Environmental Assistance.

  http://www.p2pays.org/ref/01/00026.htm. Methods of conserving water at various points in the production process. Although primarily aimed at large-scale producers, it contains a useful discussion on reuse and water conservation relevant to the small-scale producer.

4.7 Wood Processing and Furniture Making: Cleaner Production Fact Sheet and Resource Guide

Purpose

This fact sheet offers basic information on important adverse environmental impacts of wood processing and furniture making, as well as associated health and safety impacts. It also discusses opportunities for mitigating those impacts, with an emphasis upon "cleaner production" strategies that may also provide financial benefits to micro- and small enterprises (MSEs). In addition, each fact sheet offers a substantial, annotated list of resources for those organizations seeking more information.[12]

This fact sheet has been prepared for (1) **business development services (BDS) providers,** which offer services such as management training or marketing support to MSEs, and (2) **intermediate credit institutions (ICIs) and direct lenders** that provide financial credit to MSEs. It is intended to be used in concert with other sections in Part III of the *Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Development Activities,* which is USAID Africa Bureau's principal source of sector-specific environmental guidance.

Why Focus on Cleaner Production for Mitigation?

Cleaner production (CP) is a preventive business strategy designed to conserve resources, mitigate risks to humans and the environment, and promote greater overall efficiency through improved production techniques and technologies. Cleaner production methods may include:

- substituting different materials
- modifying processes
- upgrading equipment
- redesigning products

[12] USAID cleaner production fact sheets are available for the following subsectors that are likely to have substantial adverse impacts on the environment and/or workers' health: brick and tile production; leather processing; small-scale mining; food processing; wet textile operations; wood processing and furniture making; and metal finishing.

In addition to environmental, health and safety benefits, many CP techniques provide opportunities to substantially reduce operating costs and improve product quality. MSEs can profit from cleaner production through more efficient use of inputs and machinery, higher-quality goods that command higher prices, and reduced waste disposal costs. Improved safety measures can also help MSEs avoid costly accidents and worker absences.

Experience has demonstrated that, with assistance, MSEs can frequently identify cleaner production opportunities that produce a positive financial return, sometimes with little or no investment. Many enterprises that change to CP methods may realize substantial financial and environmental benefits, indicating that CP should be the first option considered in addressing MSEs' environmental problems.

Yet, although this approach can offer tremendous advantages, readers should also recognize that cleaner production options showing clear financial benefit will only be available to varying degrees among different enterprises and often may not completely mitigate environmental problems. In some cases, even when pursuing CP approaches, some businesses may need to use solutions that offer no measurable financial return—if such solutions are required by USAID's Regulation 216 or local regulations or desired for other reasons, such as community goodwill.

Adverse Environmental Impacts and Mitigation Opportunities

Important Environmental Issues Addressed by This Fact Sheet

- Air pollution from adhesives
- Air pollution from coating material
- Wastewater
- Hazardous waste
- Wood waste

Several key environmental impacts associated with wood processing and furniture making are listed in the box at left and discussed below. For each environmental impact, the fact sheet provides a list of questions to aid in the assessment of individual MSEs. These questions are followed by a number of mitigation strategies that can be considered, with an emphasis on cleaner production strategies where possible. The strategies presented typically represent a range of available options, from profitable activities that require no investment to other activities that may increase MSE costs.

❑ *Air Pollution from Adhesives*

Adhesives, either synthetic or natural, are used in assembling wooden furniture parts. Adhesive formulations used in this industry contain toxic solvents (for upholstered wood furniture) and hot melts (for non-upholstered wood furniture). Adhesives are also used to apply veneer (a thin piece of wood of uniform thickness) to the piece of furniture. For both assembly and veneer, the use of adhesives releases solvents into the air and damages the environment and health of workers. Alternative approaches to adhesives could reduce both production costs and environmental harm. [13]

---

[13] This fact sheet specifically discusses air pollution from adhesives and coating materials. Readers should also recognize that similar air pollution can be caused by poor handling and inefficiency related to wood preservatives and industrial solvents. Many of the mitigation strategies presented for adhesives and for coating materials are also relevant to wood preservatives and industrial solvents.

Key questions to consider:

- What types of adhesives are used in production? What less toxic alternatives are available?
- How are adhesives usually applied?
- Is waste of adhesives a common occurrence?

Selected mitigation strategies:

- Employ the variable application rate strategy (VARS). The VARS adjusts the glue-spread rate for each individual plywood panel according to its moisture content. The primary benefit of VARS is lower adhesive consumption, which reduces both input costs and emissions.
- Minimize overspray of adhesive. Of the four conventional ways that glue is applied to wood, the most efficient is foam extrusion—a technique in which foamed adhesive is forced under pressure to the extrusion head. The result is less wasted adhesive.
- Replace existing adhesives with less toxic substitutes: e.g., switch to naturally derived adhesives to replace the petroleum-derived chemicals currently used in the manufacture of wood adhesives. Two non-petroleum options that are currently in the experimental phase are furfuryl alcohol resin and lignin adhesives, both of which reduce harmful pollution. The naturally derived adhesives may also be more cost-effective than their petroleum-based counterparts.
- Equip workers with masks or respirators. Masks and respirators may be available to keep workers from inhaling toxic emissions from adhesives and coating material (covered in next section), and can also protect against the inhalation of small airborne particles, such as wood dust, that damage the lungs.

❑ *Air Pollution from Coating Material*

Applying coating material (i.e., stains, paints and finishes) in furniture making generates air emissions that can cause potentially serious health problems. The source of these air emissions is the solvents in the coating material, which in turn emit volatile organic chemicals (VOCs). The VOCs escape into the air when the coating is applied or when containers of liquids containing VOCs are left open. There are various options that could reduce VOC emissions and thereby reduce harm to workers' health.

Key questions to consider:

- What technique is being used to apply coating? Is there a more efficient option?
- Are workers adequately trained in the application of coating material?
- Are containers of coating material covered when not in use?

Selected mitigation strategies:

- Use reformulated coating materials that contain fewer VOCs to finish wood furniture. Alternatives include waterborne, ultraviolet-curable, polyurethane, and polyester coatings.[14]
- One method used for spray coating involves a high-volume low-pressure (HVLP) spray system. This uses a high volume of air delivered at low pressure to turn the coating material into a very fine spray. The use of low pressure results in less overspray, and therefore uses less coating material used and emits fewer VOCs.
- Consider investing in a spray booth equipped to recirculate air, to decrease the volume of exhaust emitted to the atmosphere. This process has lower operating costs than other VOC control systems.
- Ensure that containers of coating material are tightly sealed when not in use.

❑ *Wastewater Problems*

Furniture making requires the use of wood preservatives and coating materials, all of which contain solvents. Both preservatives and coating material can contaminate wastewater if they drip from the wood surface, leak from the drums where they are stored, or are discarded after use. In the long run, contaminated wastewater can raise the concentration of toxins in the local water supply to levels that harm people's health and the firm's productivity. This may require wood processing operations to pay for the clean water they need or to clean and recycle their used water on-site.

Key questions to consider:

- What kinds of chemicals are used?
- Which of these chemicals are the most harmful? Are less toxic alternatives available?
- Where are chemicals stored?
- Are methods in place to control spills and leaks?
- How is wastewater discharged? Is it separated into hazardous and non-hazardous wastewater?

Selected mitigation strategies:

- Increase efforts to dry the wood before finishing. This will lessen the need for surface treatment, because high water content leads to sap stain. In drying wood, try to choose the most energy-efficient option.

---

[14] These options are described in EPA (1995a), page 58.

- Spray preservatives or coating materials on the wood using a high-velocity spray system. This system results in fewer process residuals and less drippage.
- Install a drainage collection device on rooftops to divert rainwater away from process wastes.
- Store additives, solvents, wood treatment chemicals and fungicides in drums with a spill collection system to reduce the risk of leakage. An effective way to collect spills is to build a berm (e.g., a mound of earth) around the floor of the storage area that could potentially contain more than the stored volume of liquids. If the spill collection system is non-porous (e.g., with a plastic lining on the berm), recaptured spills can most likely be reused.
- Minimize drippage from sprayed-on preservatives or coating materials in two wayas: (1) by mechanically shaking the furniture piece to remove extra preservatives/coating from the wood surface, and/or (2) by allowing enough time for dripping in a catchment area after the preservatives/coating is applied. The drippage should be recaptured so that it does not eventually enter the drainage system. Treated wood should be sent to storage once dripping has stopped.
- Use concrete pads for the wood treatment area and intermediate storage areas to ensure that all drippage is collected.
- Do not store materials in sites that are prone to flooding or that are next to water intake points or groundwater resources.
- Switch to water-based preservatives, which are less toxic and damaging than typical solvent-based preservatives.

❑ *Hazardous Waste*

The waste from wood processing and furniture making is often thrown away like trash—but should not be, because of its hazardous nature. Hazardous waste cannot be safely disposed of without carefully following procedures for protecting the environment. Unfortunately, proper hazardous waste disposal facilities are typically unavailable in African countries. Therefore, preventing or recycling such waste is most desirable. Two prominent sources of this waste are **paints** and **industrial solvents**.

The spray-painting of furniture objects has a transfer efficiency of approximately 40 to 65 percent (depending on the spraying technique, the shape of the object and whether it is sprayed manually or automatically). The remaining paint—"overspray"—is considered hazardous waste.

In wood-coating and painting operations, industrial solvents (e.g., lacquer thinnier, xylene, or isopropyl acetate) are used to clean application equipment, such as spray guns, spray nozzles, etc. Such equipment must be cleaned often, including each time there is a color change. Contaminated solvents are a by-product of cleanup operations and are considered hazardous. Processing contaminated solvents using recovery units can allow the solvent to be reused, which lowers supply costs and lessens the volume of hazardous waste that must be dealt with.

Key questions to consider:

- How well are workers trained in machine cleaning and maintenance?
- What is the storage procedure for solvents?
- Are solvent containers covered as often as possible?
- How are solvents currently disposed of? Is solvent recycling a viable option?

Selected mitigation strategies:

- Strategies for reducing paint waste:
    - Place a recovery screen behind the object when spray painting. The overspray can be captured onto the screen, scraped off with a special knife and deposited into a container. This recovered paint can be reused without further processing.
    - Save unused or lower-grade paint to be used as undercoat in future jobs.
    - Train spray gun operators in proper spray techniques to minimize waste generation.
- *Strategies for solvents:*
    - Keep solvent containers and equipment containing solvents covered as often as possible to reduce loss of solvent through evaporation. For example, if equipment is soaked in a solvent bath, place an airtight cover over the bath to minimize evaporation. This makes solvent last longer and reduces environmental and health damage from airborne VOCs.
    - Plan the painting process to minimize color changes, if possible, by (1) doing all work related to one color at once, and (2) finishing a color before the shop closes for the day, if possible. The latter suggestion allows the end-of-day cleaning to also serve as a color-change cleaning. Such strategies will decrease waste, increase productivity by decreasing the time spent cleaning, and decrease the amount of money spent on both paint and solvents.

Use distillation equipment to treat contaminated solvents. Distillation involves heating the contaminated solvent until it boils and then evaporates. The evaporated solvent is cooled and recovered as clean product. The residue should be removed and handled as hazardous waste. (See the chapter on solid waste in the *Guidelines*.) Regular distillation is capable of treating solvents with a boiling point of 40°–200° C. Vacuum distillation can treat those with a boiling point of 140°–250° C. For flammable solvents, the equipment should be explosion-safe. Recycling solvent in this way may be more cost-effective than purchasing new solvent all the time.

- ### ***Wood waste***

Wood waste in wood processing and furniture making contributes to the problem of unsustainable timber use. This wood waste includes sawdust and end pieces of various materials, including wood, particleboard, and various types of fiberboard. Wood waste is largely created by inefficient sawing and cutting of wood, as well as improper storage practices. Another cause of wasted wood is inadequate drying of the wood, which causes the boards to split, reducing their usefulness. Improvements in all of these areas can enhance the cost-effectiveness of these operations while reducing environmental problems.

Key questions to consider:

- How does wood become ruined/unusable?
- What contributes most to wood waste?
- How can production processes be changed to reduce waste?

Selected mitigation strategies:

- Train workers in efficient wood-cutting techniques.
- Consider redesigning the product so that wasteful cuts may become unnecessary.
- Order into inventory only wood products that are commonly used or needed for a specific job. Avoid over-ordering. Return unused, damaged or obsolete materials to the supplier for a refund, if possible.
- Store wood so that it is protected from the elements, to avoid spoilage.
- Designate a central cutting area at the work site so reusable wood pieces can easily be collected and stored for future use.
- Find new, productive uses for wood scrap. For instance, dry wood residues can be bonded together with a synthetic resin to form particleboard.
- As a last option, identify and segregate scrap wood available for fuel use by the business or others, if more productive uses cannot be found. However, avoid using laminated materials, as the glue may form toxic emissions when burned. Use sawdust and log ends as fuel for boilers that fire up the drying kiln or oven used to dry raw lumber.

References and Other Resources

References Used in Preparing This Fact Sheet:

- "Distillation of Spent/Contaminated Solvents" and "Recovery of Paint Overspray Using a Recovery Screen." Green Profit (a not-for-profit initiative of BECO Environmental Management, cleaner production consultants based in the Netherlands and Belgium).

  http://www.greenprofit.net/cases.html The two case studies used from the wood and furniture sector provide concise information on the environmental effects and mitigation measures of specific aspects of the industry. Each case study briefly summarizes one company's experience using a particular mitigation technique.

- *EPA Office of Compliance Sector Notebook Project: Profile of the Lumber and Wood Products Industry* (1995a). U.S. Environmental Protection Agency (EPA). September.

  http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/lumber.html This sector notebook provides a comprehensive assessment of the lumber and wood products industry. The publication is one of a series of sector publications published by the EPA and posted on the EPA Web site.

- *EPA Office of Compliance Sector Notebook Project: Profile of the Wood Furniture and Fixtures Industry* (1995b). U.S. Environmental Protection Agency (EPA).

  http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/wood.html This is another of the EPA's series of sector publications.

- "Improved Wood Processing Saves Money and Forest Resources." Winrock International

  http://v1.winrock.org/reed/ftf/mercury.htm This success story was culled from the Winrock Volunteer News and Information section of the Web site. The feature articles provide useful information about Winrock's volunteer projects.

- "Integrated Life Cycle of Wood: Tree Quality, Processing and Recycling." U.S. Department of Agriculture, Forest Service.

  http://www.srs.fs.usda.gov/research/rwud/rwud/rwud_4702.pdf This project description is structured as a government report. The scope of the project is national, but the themes addressed could be relevant to other countries that have a substantial wood processing industry.

- *Pollution Prevention and Abatement Handbook: Wood Preserving* (1998). World Bank Group. July. This handbook was prepared to update and replace the 1988 World Bank *Environmental Guidelines.*

  http://www.ifc.org/ifcext/enviro.nsf/Content/PPAH This handbook can be downloaded, section by section, from the above Web site. The Industry Sector Guidelines cover 40 industries, including wood preserving.

Other Resources:

- *Best Practices in Wood Waste Recycling* (1997). Clean Washington Center.

http://www.cwc.org/wood_bp.htm This note offers detailed and technical information on wood waste recycling as it relates to sourcing, processing and product manufacturing.

- *Integrated Pollution Prevention and Control, BAT Guidance Note: Wood and Furniture* (1999). Prepared by IPPC project, Estonia.

  http://www.envir.ee/ippc/docs/wood_and_furniture_bat.pdf This note provides an overview of the best available techniques regarding the wood and furniture industry in Estonia.

- *Investment Projects in Wood Works and Furniture in Tanzania.* United Nations Industrial Development Organization (UNIDO).

  http://www.envir.ee/ippc/docs/wood_and_furniture_bat.pdf A database of specific projects related to wood processing and furniture manufacturing in Tanzania. Includes links to information on individual companies and proposed projects.

- Susilo, Kasru and Achmad Djani. *Cleaner Production Assessment at an Indonesian Plywood Facility: A Case Study* (1997). Forum KMB Indonesia (Indonesian Pollution Prevention Roundtable).

  http://www.encapafrica.org/documents/Cleaner_Production_Plywood_fac.pdf This paper discusses how cleaner production diagnosis and assessment was conducted for one of six plywood facilities, located in East Kalimantan, Indonesia.