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Final Report

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The pollution prevention audit/assessment reported on herein was conducted by a team of EP3 and industry representatives. The primary purpose was to assist industry or facility management in creating a sustainable pollution prevention and waste minimization program. This report presents information from the first step in the process; a base line survey and a definition of actions which can be taken to prevent pollution, improve efficiency and pay back any required investments.

The overall EP3 program in the countries in which EP3 has activities includes a wide range of activities including audits/assessments, information dissemination, training and small scale demonstrations. These country programs are all designed to create the conditions in the country which will assure the continuation of urban and industrial pollution prevention and establish locally sustainable pollution prevention programs.

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1.1 Evaluation Criteria and Methodology

The main purpose of identifying priority industries is to increase the efficiency and effectiveness of EP3 country activities, especially in early implementation during the first two to three years. The use of ten priority industries in EP3 programs in many different countries promotes the maxium application of information and guidance developed by core EP3 activities. Most importantly, there has been considerable pollution prevention success in the ten priority industries, so there is an important global opportunity to transfer successful pollution prevention methods and technologies by focusing on these ten industries. EP3 spending to develop technical guidance can focus initially on the ten priority industries and maximize the return on investment. Also, because a number of EP3 projects in developing countries will be working in the same industries, there will be more effective transfer of information and technology of special significance for developing countries. As new information and experience accumulates, particularly from EP3 projects worldwide, the list of priority industries may change and expand.

Identifying ten priority industries for EP3 program implementation should not be viewed as having any significance with regard to the importance of industries in a particular country. They only represent priorities for EP3 implementation. Governments, for example, may view other industries in their country as being more important in the context of environmental regulation, economic development, or other donor programs.

EP3 country projects should first examine the ten priority industries to determine whether they are relevant for their country. Those industries that are relevant should be used in initial EP3 activities. Not all of these ten priority industries, however, may exist or be important in a country, and other industries may be very important from an environmental or economic perspective, or both, in a country. If other industries are believed to merit priority status, the EP3 country project should use the analytical framework presented below, and used originally to select the ten priority industries, for supporting any decision to use an alternative industry. In this analytical framework, the first of three evaluation criteria (pollution prevention opportunity) is independent of a country's circumstances, but the other two criteria (presence and importance) pertain to conditions in a country. This analytical framework can also be useful in explaining to people in government and industry why only certain industries have been targeted for initial pollution prevention activities in EP3 programs.

One source of alternative industries is a second group of five industries that have also been identified by EP3 and are presented below, after the ten priority industries are discussed. These five alternative industries also offer significant pollution prevention opportunities, but have received lower evaluations because of implementation issues, as discussed below. One or more of these five industries may be appropriate for project inclusion, because in some developing countries they offer important opportunities or have special significance. These

five industries also should be considered once a country project has exhausted the initial list of ten priority industries and is prepared to tackle more challenging industries after the first few years of operation.

Lastly, a number of other industries offering longer term opportunities for EP3 activities are presented and discussed. Longer term planning for EP3 country projects should consider the potential of working in these industries.

Three evaluation criteria of Opportunity, Presence, and Importance were used in selecting each of the ten industry categories as priority industries for EP3. These three criteria can also be used by EP3 country projects for evaluating other industries. Other evaluation criteria were also considered, but were found too difficult to use.

For example, environmental importance was seriously considered, but rejected for several reasons. The main problem is the difficulty of making conclusions about very different kinds of environmental problems (e.g., air pollution versus toxic waste), which are very difficult to compare against each other. Such comparisons are difficult because of very different health and environmental impacts, which may affect different groups of people or parts of the ecosystem. Also, the level of public and government attention to individual environmental problems varies enormously among countries and in any one country over time. Any one industry may have diverse environmental impacts at different stages of attention. Therefore, it was decided to place the focus on the level of pollution prevention solutions available to industrial sectors for addressing significant environmental problems, as well as water and energy use.

The three criteria and the way they are to be interpreted are:

1. Opportunity: There should be a significant number of commercially proven and documented pollution prevention opportunities that address significant environmental problems, as evidenced through government recognition, attention, and possibly regulation. Most of the pollution prevention actions should be low or medium cost options for new equipment or other plant changes. These pollution prevention actions should have proven technical feasibility and net economic benefits that are applicable for developing countries. Also, EP3 country projects should have the potential for serving as unique sources of pollution prevention solutions and assistance. Even though adoption of cleaner technologies may have originated in industrialized countries, the economic benefits (paybacks) should not be dependent on extensive, enforced environmental regulations, and capital costs should be low. Actions that have been used successfully in one or more developing countries have special importance.

2. Presence: The industry should exist in many developing countries having the potential of being involved in EP3, so that EP3 efforts in one country can build on previous

efforts. Also, there should be a significant number of facilities (companies) in any one country, thereby providing greater opportunity for technology demonstration and adoption for a given EP3 investment in a country. Medium and small size plants are especially important because they have fewer technical and financial resources to introduce and implement pollution prevention opportunities.

3. Importance: Industries should have special significance in the context of sustainable economic growth, rapid industrialization and urbanization, and privatization. There should also be some balance between large industrial facilities (companies) versus smaller enterprises; there should also be some diversity of business sectors, including manufacturing and service sectors, for example. In addition to economic importance, industries may also be important because they are identified with major national environmental problems, to such an extent that their role in the national economy may be threatened by potential government regulation and expensive pollution control actions. Industries that have received attention by NGOs, newspapers, and the general public are also important. In such cases, pollution prevention may be especially important in safeguarding the national economy. Government owned industries are likely to provide fewer opportunities than private companies, because of more focus on production quotas and fixed prices, and less attention to profitable operations and efficiency measures that result from cost-cutting pollution prevention actions.

Each proposed industry was evaluated, with a score from 1 to 3 given for each of the above factors, with 3 representing the highest rating. For the most part, all the proposed industries are likely to be found in any developing country, although the actual presence and importance will vary from one country to another. However, the evaluations made here are based on a broad view of developing countries.

Initially, a larger number of industries were considered, based on general information about developing countries and, particularly, an assessment of the pollution prevention literature (e.g., U.S. EPA publications, U.N. publications and database, books, and journals). These were then evaluated, using the above three factors. Generally, only those industries receiving a score of 5 or higher (out of a possible 9) have been recommended as priorities for EP3. Clearly, there is some subjectivity in this evaluation process. However, the goal is not quantitative precision, but rather to offer a standard, defensible methodology for including or excluding industries, which ensures that many complex factors are considered. Thus, there is no significance to total score differences between 5 and 9 in terms of making distinctions among the ten priority industries. Therefore, they are not numbered from one to ten, for example.

1.2 Proposed Industries

The numerical results are presented in the accompanying table, followed by a brief discussion of each of the proposed ten industries, including the identification of key subcategories when appropriate. The textile and leather tanning industries are listed first because they are the focus of Task 2 of this report.

Industry	Opportunity	Presence	Importance	Total
Textile	3	3	2	8
Leather Tanning	3	3	2	8
Metal Finishing	3	3	2	8
Printing	3	3	2	8
Paper/Paperboard	2	2	3	7
Auto Repair/Transport Maint.	2	3	2	7
Paint Manufact.	2	3	2	7
Printed Circuit Boards	3	1	3	7
Wet Battery Mfg.	2	2	2	6
Soaps & Detergents	2	2	1	5

Textile

A fairly large amount of pollution prevention success stories have been published for the textile industry. A number of subcategories are possible for this industry. However, only the fabric dyeing industry segment is selected as a priority industry for EP3. Other subcategories are either too small or specialized for developing countries, such as carpet manufacture. Other segments are likely to have far fewer environmental issues and pollution prevention opportunities, such as finished clothing manufacture. Of course, some textile companies are very integrated and diversified and they may include significant operations other than those associated with fabric dyeing.

The industry offers considerable pollution prevention opportunities because it is chemical, water, and energy intensive. Although there is a broad diversity of specific operations in textile plants worldwide, positive results have been reported for virtually all types of plants, including ones in developing countries.

The presence of the industry in developing countries is high, as evidenced, in part, by the major role developing countries have in the world export market for clothing. In nearly all countries where textile plants exist, there is a relatively large number of them, often a mix of both large and small facilities that are privately owned. Thus, there is a major opportunity for EP3 programs to offer services that can improve the economics of the industry.

Because of expanding domestic and foreign markets, the textile industry plays an important role in the economies of developing countries. The industry is important in terms of contributions to GDP, foreign exchange, and as a source of jobs. In many developing countries, the textile industry is one of the five largest manufacturing sectors. The linkage to cotton crops, sheep, and chemical plants producing synthetic fibers is also important. Atlhough many companies have been able to achieve success in international markets because of low labor costs, it is clear that as global competition intensifies it will be necessary for textile companies in developing countries to remain competitive through reductions in other components of manufacturing costs, especially chemical and energy costs. Moreover, textile plants have traditionally been seen as major sources of water pollution, especially from chemical dyes, and, therefore, have a high priority within government environmental programs.

Leather Tanning

Leather tanning has received considerable attention by pollution prevention programs. Companies that only finish leather and purchase tanned leather from other sources are not included in this priority industry category. However, such companies are more likely in industrialized countries than in developing ones. The chief reason for this is the historical visibility of tanning facilities as sources of water pollution, and as industrial facilities often deemed undesirable by local residents because of odors. The chief environmental issue has been the discharge of chromium in wastewater effluent, originally hexavalent chrome, which is rarely use today, but also of trivalent chrome that is still widely used. Various pollution prevention approaches have been successful in virtually eliminating the chrome problem; they are cost-effective alternatives to use of wastewater treatment plants.

In a large number of developing countries the leather tanning industry has a strong presence. There usually is a large number of plants, sometimes very small ones which pose significant opportunities for EP3 programs. The use of similar technologies and processes offers an opportunity to transfer proven pollution prevention methods efficiently.

The industry is important in economies of developing countries because it provides the demand for animal skins and an important source of income for the farm sector. Additionally, companies are likely to have export markets for finished leather and, often, for final leather products from larger, integrated companies. Because the industry is usually targeted by government for pollution control through wastewater treatment, EP3 programs that can offer the benefit of avoided end-of-pipe investments are especially attractive for maintaining the economic health of this sector.

Metal Finishing

There is a large literature on pollution prevention opportunities in various metal parts finishing operations in the U.S. There is a broad range of finishing technologies which fit

into the finishing category, including: electroplating, galvanizing, anodizing, and certain cleaning operations that are integral to the finishing of metal parts. Pollution prevention efforts have addressed diverse wastewater and hazardous waste problems. Older, and often smaller facilities in developing countries can use modern methods, materials and equipment that fit into the pollution prevention category. Virtually all companies in different industries producing metal parts have the potential to use many of these clean technologies.

In virtually every developing country there will be many small and some larger companies involved with the manufacture of metal parts, both ferrous and nonferrous. Although they may be classified as belonging to a certain industry, such as electrical equipment, transportation, aircraft, or consumer products, very large numbers of companies have metal finishing operations.

Also, often such companies are suppliers for other manufacturing firms, which makes them especially important for economic development. This multiplier effect means that firms in the metal finishing category have an importance beyond their direct sales and employment figures.

Printed Circuit Boards

This industry has received considerable attention for identifying pollution prevention opportunities, because of the extensive use of toxic materials, such as solvents and toxic metals, and the substantial potential for causing air, water, and waste problems.

At this time there is probably uneven presence of printed circuit board manufacturers in developing countries, but the potential for more presence is significant.

However, when this high-tech industry is present, it is important to growing economies that have made a commitment to the electronics industry. It is also important because it is a high growth, high tech industry with enormous potential for growth. Also, it is often an important export for developing countries.

Papermaking/Paperboard Manufacture

Although a large scale materials processing industry with limited low cost pollution prevention opportunities, the industry is usually a source of substantial environmental problems. For this reason there is a significant literature to document successful pollution prevention actions, including reduced water use, greater in-plant recycling, reduced energy use, and reduced chemical use.

Three subcategories are proposed: papermaking and paperboard manufacture; conversion of post-consumer paper discards into recycled pulp; and pulp manufacture (both wood and non-

wood). However, because of limited low cost actions in pulp manufacture, the first two categories should be considered the priority subcategories. Also, pulp is an export commodity that some papermaking companies in developing countries import.

Unlike many other large scale processing industries, papermaking companies in developing countries may be locally owned and, therefore, be more interested in EP3 assistance.

Many developing countries have papermaking companies, especially countries with timber resources, although paper also is a significant import worldwide. When papermaking companies are present in a developing country they usually are deemed important to the economy, because of their large scale of investment and employment, use of natural resources, and relationship to other domestic companies.

Printing

Commercial printing companies have implemented many pollution prevention options that have addressed solid and hazardous waste, air emissions, and sometimes wastewater. The chief environmental problem is the use and releases of solvents in their pure form for various cleaning operations and as bases of liquid inks. Secondarily the use of inks and pigments containing toxic metals is also a problem. Most problems have been very effectively addressed in the U.S. and other industrialized countries, generally without changing capital intensive equipment.

While often ignored, printing companies are likely to be found in every developing country. In addition to independent printing companies at the wholesale and retail levels, many other types of companies have printing operations, including, for example, newspaper publishing, packaging companies, and stationary firms.

Larger companies provide printing services for industrial, business, and government customers; they print on paper and plastic materials. Because many industries and business enterprises depend on local printers, this industry has an important, but not critical role in developing country economies.

Auto Repair/Transport Maintenance Facilities

In the U.S. significant attention has been given to auto repair shops, mainly because of solid and hazardous waste generation, and sometimes air emissions (e.g., solvents and CFCs). Reducing chemical solvent use, improving housekeeping and other maintenance activities, and possibly energy reduction are significant opportunities. The pollution prevention methods can also be applied to larger scale transportation equipment maintenance facilities, including: airports, railroad yards, and truck terminals.

In nearly all developing countries there is explosive growth of the use of automobiles, obviously in major urban areas. Although small auto repair shops in developing countries would be considered part of the informal business sector, the larger auto repair shops and maintenance facilities for fleets of cars of government agencies or large private companies, trucks, buses, railroad yards and airports would be considered a high priority for pollution prevention in developing countries. Their environmental significance is very important due to problems from oils, solvents and other chemicals, and they are often ignored because they are a service industry rather than manufacturing. In developing countries, there is great use of older automobiles and other motor vehicles, requiring considerably more repair and these repair shops are especially important in rapidly expanding urban areas. This is true not merely for automobiles, but also for buses and trucks which are essential for expanding local infrastructures and economies.

Wet Battery Manufacture

There is relatively little available pollution prevention information in the published literature on the manufacture of lead batteries, used principally for motor vehicles. However, significant information has been obtained from initial EP3 work, which is transferrable to other lead battery plants. The release of metallic lead into all environmental media is recognized as a major environmental problem and it can be effectively addressed by pollution prevention actions offering fast payback periods, and that also improve product quality.

This industry is likely to be present in most developing countries, because motor vehicle batteries are needed everywhere, and the manufacturing technology is relatively simple. Increasing industrialization and higher standards of living imply sharply rising demand for batteries.

The importance is that the product is needed for both personal and commercial use, the industry poses significant environmental problems, and the product does not lend itself to importing, because of heavy product weight.

Paint Manufacture

This industry has a number of proven pollution prevention approaches to use; these address air releases of VOCs, dangerous disposal of solid and hazardous waste, and high toxic loadings to municipal wastewater treatment plants. The use of chemical solvents and pigments containing toxic metals are problems addressed by clean technologies.

Virtually all developing countries are likely to have relatively small paint manufacturing companies and sometimes a few large ones, which purchase locally made and imported raw materials for processing into different types and grades of paints.

While paint manufacturers are not likely to account for large numbers of workers or revenues, they are needed for many local users. They also account for significant environmental problems that often receive little regulatory attention.

Soaps and detergents

Because of their bulk and weight, as well as relatively low costs, many consumer soaps and detergents are made locally rather than being imported. Raw materials vary considerably, from sophisticated chemicals to rather low cost agricultural materials. The two subcategories are: soaps and solid and liquid detergents, which differ considerably with regard to raw materials and manufacture, but are often made by the same company. The primary raw material for soaps is generally a local organic substance, such as palm oil, olive oil, and meat byproducts, for example, plus some caustic material. Raw materials for detergents include: various chemicals, such as emulsifiers and wetting agents, for example. Companies in this sector will also be major users of water.

Although the pollution prevention literature is quite limited, this is a significant and expanding industry in developing countries, especially for large urban areas where rising standards of living increase demand for more complex soaps and detergents designed for specific types of personal, household, and commercial cleaning tasks. Wastewater discharges containing chemicals and non-biodegradable substances pose particular problems. Many companies in this sector are also likely to make low cost plastic containers, such as bottles for detergents, by purchasing plastic resins and using relatively simple equipment for molding packaging containers. Such operations produce solid waste, such as imperfect containers, much of which can be recycled onsite.

1.3 Five Alternative Industries

As discussed previously, some of the ten priority industries may not be relevant in a particular country. For this reason, five industries (two manufacturing and three service) are also presented, because they do have significant pollution prevention opportunities. Also, they may be present in significant numbers and may have important roles in growing economies of developing countries.

Food Processing

A host of food processing industries are important in most developing countries. Subcategories include: diary, meat and rendering, seafood, coffee, sugar, fruits and vegetables, wines, and agriculturally based edible oil production. However, this category was not selected for the priority list, primarily because of limited no cost/low cost pollution prevention opportunities with substantial economic benefits. The economic implementation issue is whether there is significant reductions in operating costs to attract management attention.

Most opportunities relate to water conservation and recycling, whose economic benefits are very dependent on local water costs that usually are kept relatively low by government policy. Increasing the conversion efficiency from agricultural inputs to canned, bottled, or frozen food products is also an important approach. Solid waste management is unlikely to be regulated or costly in most developing countries, and thus avoidable waste disposal costs are not likely to be significant. Water pollution may be regulated, but wastewater treatment avoidable costs cannot be completely eliminated through pollution prevention actions. For example, BOD loading cannot be reduced enough to avoid all water treatment of effluents from food processing plants.

However, this is a very important and large industry in many developing countries and it should be considered a for replacing one of the ten priority industries not important in a specific country, and for longer term EP3 efforts.

Chemicals

The chemical industry has not been selected, primarily because the majority of chemical plants in developing countries are wholly or partly owned by multinational companies that already provide extensive technical support. In such cases, local managers are likely to have little need for in EP3 services.

Another complexity is that there is considerable diversity among chemical manufacturers, making it difficult to transfer many pollution prevention solutions among chemical plants. Major subcategories include: organic chemicals, inorganic chemicals, petrochemicals (associated with petroleum refineries), and plastics.

Therefore, it is recommended that EP3 country projects give serious consideration to the chemicals industry, either as a substitute for one of the ten priority industries that is not relevant or important, or as a priority for longer term activities. The focus, however, should be on small and medium size locally owned chemical companies.

Hotels and Tourism

Various service industries also offer longer term opportunities, often because of rising solid waste management problems and costs, and water use. A most important example is hotels and tourism attractions, which have solid waste and water pollution problems amenable to pollution prevention approaches. In many developing countries hotels and tourism is a rapidly expanding part of the economy. Whether they be in urban centers or rural and seaside locations in sensitive ecosystems, many pollution prevention actions can be worthwhile alternatives or supplements to conventional pollution control measures.

Dry Cleaners

Dry cleaners might be a significant opportunity in the retail sector of countries with an expanding middle class. Because of their extensive use of chemical solvents, this sector has been addressed successfully in the U.S. Equipment changes may be even more attractive in developing countries where chemical solvents are expensive.

Photo Processing

These facilities have received some significant pollution prevention attention because of the environmental problems and economic importance of silver.

This service industry is likely to undergo considerable growth in developing countries as incomes rise. In addition to large central facilities in urban centers, it is conceivable that smaller, convenience shops will become more important in developing countries, as they have in industrialized countries.

However, this industry received a relatively low score for both presence and importance, and it could be replaced by one of the industries discussed in the following section.

1.4 Other Industries for Longer Term Activities

While it is true that every conceivable industry can make use of some pollution prevention principles and technologies, some categories are best seen as longer term opportunities for EP3 projects. The following industries, including some not in the manufacturing or service sectors, may be very important in national economies and they may be major sources of environmental pollution. Yet because of limited low and medium cost pollution prevention actions, they are best seen as longer term opportunities for national pollution prevention programs that have proved themselves through extensive experience and success.

A number of large scale basic, materials conversion industries have not been selected, primarily because they offer few no cost/low cost pollution prevention opportunities. These industries include: cement; mining; phosphate fertilizer; foundries and steelmaking; nonferrous metals; glass making; petroleum refining; and energy, including electric, coal and nuclear power plants, for example. Clearly, these industries are crucial for economic development based on industrialization. Experience has revealed that such large companies can be difficult to interest in receiving pollution prevention assistance from external sources. There are also problems introducing pollution prevention into government-owned industries. Therefore, priority is given to small and medium size private sector companies.

Technically, the unit operations are very large and offer limited pollution prevention opportunities. But many materials handling, plant maintenance, and equipment cleaning

operations offer significant pollution prevention opportunities. In-plant recycling of materials is also often a cost-effective option. Also, substantial environmental problems, usually air and water pollution, can be effectively addressed by conventional pollution control approaches. These are also industries that are often government owned and operated.

Hospitals and other sources of medical waste could be longer term clients of pollution prevention services. Opportunities include solid and hazardous waste reduction, energy conservation, and replacement of wet chemical processing for developing x-ray and other images by new electronic methods.

There are several major industries also related to use of natural resources and the land, namely agriculture, forestry, and rubber, that would require very special expertise for applying pollution prevention principles in the field, especially a host of sustainable agriculture methods. In mills and plants in these industries, water and energy conservation and in-plant recycling offer the greatest pollution prevention opportunities. These should be seen as longer term opportunities for mature national pollution prevention programs.

Certain manufacturing industries also have not been selected for several reasons, including, most importantly, the fact that they are likely to be dependent on foreign technology and technical support, because of foreign ownership, technology licensing or controls by foreign customers. Important examples are: pharmaceutical manufacture, refineries, motor vehicle assembly, and electrical equipment.

The purpose of Task 2 is to illustrate how a system that establishes best industrial practice targets for pollution prevention actions can be used in EP3 facility-level activities by applying it to two priority industries. The critial ratio methodology and its application in EP3 programs is further discussed in Task 3 of this report. The general approach, used in Part 1 for the leather tanning industry and in Part 2 for the textile industry, is to present the following topics:

1. Industry Subcategories: define key industry subcategories or unit operations, following the order of material flows in a facility, and describe them in simple, clear language; the emphasis is on commonly found operations that are material, water, and energy intensive and that are the major sources of waste and pollution.

2. Priority Pollution Prevention Actions: present and describe pollution prevention priorities that are linked to specific subcategories given in first section; describe these in terms of the technical action and its economic benefits by reference to actual industrial applications given in the literature, if available; actions have been screened so that only actions that offer economic benefits for developing countries and do not result in environmental media shifting have been selected.

3. Best Industrial Practice Targets: present numerical BIPs for the same specific pollution prevention priorities in terms of critical ratios that are technically linked to the basic industrial activity and pollution prevention action; these ratios can be used to measure and track pollution prevention performance and progress at a facility. They are also used as "benchmarks" for quantifying best industrial practice with commercially available technology and equipment. It is very important to emphasize that a specific facility should be seen as an opportunity to apply ALL BIPs that are applicable to unit operations present in the facility. One important reason for this viewpoint is environmental, because when only some BIPs are used there is some potential for creating "loopholes" when waste is shifted from one medium receiving attention to another that is not receiving attention. The other reason is economic, because benefits will be maximized when all relevant BIPs are recognized as facility goals.

4. Implementation Methods and Issues: discuss implementation issues for the BIPs to elaborate on how the pollution prevention actions can be applied and what problems may have to be addressed, especially in developing countries.

5. Comments and Discussion: present other pollution prevention actions that can also be considered for implementation, depending on the exact configuration of a facility; these are second order priority pollution prevention actions, which for some facilities, however, may be important opportunities and which may over time become first order priorities.

6. References: identify the sources of technical information and data used.

Tables 1 and 2 present summaries of the critical ratios and BIPs for the leather tanning and textile dyeing industries, respectively.

Table 1: Summary
Leather Tanning Industry
Critical Ratios for Best Industrial Performance Measurement

Unit Operation	Critical Ratio	Benchmark BIP
Solvent degreasing of hides	Kilograms of solvent per kilogram of hides	0
Chrome fixing of hides	Parts per million of trivalent Chrome in wastewater effluent	2
Chrome fixing of hides	Kilograms of purchased Chrome sulfate per tonne of wet raw hides	40
Use of solvents in finishing operations	Kilograms of solvents per kilogram of finished leather	0
Total facility water use	Cubic meters of water per tonne of wet hides	40

Table 2: Summary
Textile Dyeing Industry
Critical Ratios for Best Industrial Performance Measurement

Unit Operation	Critical Ratio	Benchmark BIP
Wool scouring	Kilograms of Biological Oxygen Demand (BOD) per kilogram of wool	0.25
Recovery of PVA sizing material	Chemical Oxygen Demand (COD) after recovery to COD before recovery	0.8
Reuse of caustic stream in Mercerizing	Kilograms of caustic for makeup per tonne of yarn	100
Dyebath reconstitution	COD with reconstitution compared to COD before reconstitution	0.3
Low liquor dyeing	Liters of water per kilogram of fabric	6.0
Pad batch dyeing	COD of new process compared to COD of beck process	0.25
Vacuum extraction dyeing	COD of new process compared to COD of beck process	0.25
Water conservation	Liters of water used facility-wide per kilogram of fabric	200
Energy conservation	Amount of fuel after pollution prevention audit compared to original fuel consumption	0.75

2.1 Leather Tanning Industry

Industry Subcategories (three major unit operations (three major unit operations)

A. Pre-Tanning in Beamhouse

(A-1) Beaming: soaking of wet and especially dried hides in water, then in strong alkali solution to remove hair and residual flesh; mechanical trimming; possible lime splitting (produces solid waste from low quality split layer); de-liming with weak acid; bating (an enzymatic process) to control leather properties; and pickling of skins for reaching acidity to prevent chrome precipitation on skins in tanning and improve chrome penetration.

(A-2) Degreasing: use of solvent (e.g., perchloroethylene, monochlorobenzene, kerosene) on hides prior to tanning to remove grease (generally necessary for sheepskins, pigskins, and camel skins).

B. Tanning

Chrome tanning with chromic sulphate, producing acidic effluent with unused chrome salts. Alternatives to chrome are available (see discussion below).

C. Post-Tanning Finishing

Pressing to remove moisture (sammying); mechanical shaving and possibly mechanical splitting; possible secondary tanning; dyeing and possibly softening; drying and final trimming; surface coating(s); and buffing for finishing. There are companies that buy tanned hides and do finishing only.

Priority Pollution Prevention Actions

The focus for pollution prevention in leather tanneries should be chemical costs. These are typically the second highest fraction of tannery manufacturing costs, about 40%, compared to 50% for hides, without accounting for pollution control spending. Often chemicals are imported, making them especially important targets for reduction in developing countries.

Four high priority pollution prevention actions are presented (not in any priority order, but following the logic or process flow of the unit operations presented above); other possible actions are presented in the discussion section. These four priorities are designed to maximize the effectiveness of an initial tannery assessment or audit.

Priority One. In beaming (A-2) - solvent recovery or elimination for degreasing operation (not applicable if only cattle hides used):

A distillation unit in system takes effluent from degreasing of skins (e.g., sheep) and recovers reusable solvent; it also produces a concentrated solid organic phase for disposal (or for reuse because of value of grease). In one case the capital cost was $48,600 but the unit offered a net savings from reduced solvent purchases, even with increased energy use (no specific savings given).(2) In some plants the resulting mixture of solvent, grease and water is pumped to tanks where some separation occurs through decanting of grease and the solvent is reused; however, this leads to water effluent with significant solvent.(8)

An alternative to solvents is to use surfactants, preferably biodegradable ones making wastewater treatment easier. There is still a need to deal with grease and BOD in wastewater treatment, as compared to obtaining solid residual in solvent recovery equipment which must be disposed.(4)

Priority Two. In tanning (B) - chrome recovery and recycling:

This is a major pollution prevention action that has already been widely used. Three specific examples are given below. All of these specific examples are variations of the same basic scientific and well demonstrated approach, which is the ability to precipitate chrome hydroxide rather easily at a pH of 8.5 to 10.5, then dissolving the resulting solid phase and producing a liquid that can be used in the primary tanning operation in place of virgin material.(4)

Method 1 (U.S.) - 99% chrome recovery by: screening of tanning effluent; caustic soda reaction and precipitation of chrome hydroxide; pressing to concentrate; clarified water released; chrome hydroxide sludge redissolved in sulfuric acid; and liquid reused for tanning. Capital cost was $1.2 million for a production capacity of 3,000 hides per day, producing annual savings of $360,000 from reduced chrome purchases (payback for developing country about 40 months) and $150,000 from avoided offsite treatment charges for wastewater.(1)

Method 2 (Greece) - 95-98% recovered by screening, magnesium oxide used for precipitating chrome oxide at pH of at least 8; clarified water released; sludge dissolved with sulfuric acid at pH of 2.5 and liquid reused for tanning. Capital cost was $40,000 for plant handling 2,200 tons per year (about 300 cattle hides per day or about 10% of previous example), producing annual savings of $73,750 in chrome purchases (payback for developing country about 6 months) and $30,200 in operating costs (probably wastewater treatment).(5)

Method 3 - (France) sodium carbonate used for precipitation. Capital cost was $69,500 for plant handling 1,000 hides per day, producing annual savings of $147,400, presumably from chrome savings (payback for developing country about 6 months).(2)

The ability to reduce chrome in effluent by using chrome recovery and reuse has been demonstrated. A U.S. company reduced chrome from 10 ppm to less than 1 ppm, for savings of $40,000 to $50,000 annually in avoided wastewater treatment costs.(7) Minnesota's regulatory limit was 8 ppm total chrome content in wastewater and the facility reached average of 2 ppm after chrome recovery from wastewater.(1) The Greek tannery mentioned above could reach 2 ppm chrome content in wastewater.(5) The French case reduced chrome in wastewater from 7.5 to 3 ppm.(2) Regulatory limits for chrome (trivalent) in wastewater vary widely among countries, but rarely are below 2 ppm. Untreated effluent from chrome tanning facility can be as high as 100 ppm.(4)

Priority Three. In post-tanning, finishing (C) - solvent recovery or elimination:

Finishing operations generally use coatings, colorants and other surface modification products; all of these may contain solvents, such as aromatic and aliphatic hydrocarbons, esters, and alcohols.(6) Environmental and occupational impacts are substantial (e.g., from trichloroethylene, toluene, methylethylketone, xylene that produce air concentrations easily as high as 25 to 100 ppm in the workplace).(4) A U.S. leather finishing company produced over 118 tons of solvent waste yearly.(6) Solvents can either be recovered, reduced, or eliminated altogether. However, non-solvent based coatings are not available for all types of final coating steps that may be used to obtain certain leather products.

It is possible to use advanced mechanical techniques for contact application to increase transfer efficiency and minimize air releases, as well using high efficiency and automated spraying methods. Nevertheless, air losses may still be relatively high, possibly 30% or much more, especially in tanneries in developing countries. Use of modern solvent recovery equipment is not likely to be cost-effective either, especially in developing countries, and the use of materials with different solvents adds an additional complexity and burden. However, in a U.S. facility an investment of $300,000 for a solvent capture system was deemed feasible, producing annual savings of $200,000 by recovering about 90% of the solvents used.(6) As long as solvent based materials are used, some leaking and spills are also unavoidable, even with recovery.

Priority Four. In all operations (A, B, C) - water use reduction

Other than bad odors, which are very difficult to reduce, plant wastewater is usually the main focus of environmental attention to a tannery. Large volumes of water are used for three main purposes in all leather tanning companies: process waters (22%), rinse waters (55%), and general plant washdown (23%).(3) Various water conservation methods can be used to reduce water use. There is even some potential for reusing the effluent from wastewater treatment. Wastewater treatment may be required, even with recovery of chrome from the original plant effluent, because of BOD and TSS considerations, for example. The economics of water conservation are extremely dependent on the cost of water, which all too frequently

is a no cost raw material or a very low cost one that provides little incentive for water conservation. If onsite wastewater treatment is required, or if significant charges are levied for use of a central water treatment plant, then water conservation can cut costs.

Expert opinion is that a typical tannery consumes 50 cubic m/tonne of wet hide processed.(3) And the generally accepted range of water use is from less than 25 to greater than 80 cubic m/tonne of hide processed.(4) Another set of data for six plants showed a range of 20 to 63 cubic m/tonne of raw hides.(8) Tanneries in developing countries are likely to be at the high end of these ranges.

Best Industrial Practice Targets

Corresponding to the above four pollution prevention priorities, four specific BIP targets have been developed, as presented below. These do not address all of the many environmental issues for leather tanneries, but they do provide a relatively quick and easy method for people performing a facility assessment. It is a strategic framework for identifying and evaluating the major pollution prevention opportunities in a facility, especially important, immediate pollution prevention opportunities. In all cases, the objective is to numerically reduce the parameter. When the target is to achieve a zero level, reducing actual values of the ratio to approach zero is appropriate, which is why units are given.

BIP No. 1 - Solvent use in degreasing (not applicable if only cattle hides used):

On balance, considering both the equipment cost of solvent recovery and the need to maintain good operating practice, the preferred practice is to eliminate the use of solvents in favor of using biodegradable surfactants which have become increasingly available, and are not likely to increase costs significantly.

BIP = zero kg solvent/kg of hides processed

BIP No. 2 - (a) Concentration of chromic oxide in plant wastewater effluent after chrome recovery:

Although it is a back-end parameter, the widely used parameter of chrome concentration in wastewater effluent from the plant is used in conjunction with the second BIP.

BIP = 2 ppm chrome (trivalent) in wastewater effluent achieved by chrome precipitation and recovery

AND (b) level of purchased chrome:

The second BIP is defined in terms of the amount of purchased chrome sulphate necessary for chrome tanning. The lower this value the better. It is reduced by chrome recovery and possibly by other approaches, such as use of more expensive high fixation chrome tanning agents and recycling of chrome liquor (see discussions below). For conventional chrome tanning the critical ratio is:

BIP = 40 kg chrome sulphate/tonne of wet raw hides tanned

BIP No. 3 - Use of solvents in dyeing and finishing operations

The best approach for developing countries is maximum conversion to aqueous dyes and non-solvent finishing technologies to avoid the solvent problem altogether or to reduce solvent use to the maximum degree. If alternative raw materials are available, this approach imposes fewer challenges than purchasing and maintaining solvent recovery equipment, which can be especially difficult if there are complex mixtures of different solvents. The amount of solvent refers to components in finishing products and pure solvents that may be purchased for making additions to commercial products or for cleaning purposes.

BIP = zero kg solvents/kg of finished leather

BIP No. 4 - Total facility water use

The selected BIP is deemed appropriate for an ambitious pollution prevention goal in developing countries, considering the broad range of water use in leather tanneries and the experience that a 50% reduction in total water use at a tannery is often feasible and cost-effective.

BIP = 40 cubic m of water used at facility/tonne of wet hides (total facility water except water used for sanitary purposes)

Implementation Methods and Issues For BIPs

BIP No. 1 - Solvent use in degreasing

If a person conducting a site assessment determines that the company uses sheepskins, pigskins, or camel skins, then there is a need to also determine if solvent degreasing is used. If solvent degreasing is used in a tannery, then the need is to accurately identify the total cost of using such solvents. The next step is to identify commercial sources of alternative surfactants and their costs, but it may be difficult to get comparable data, because of uncertainty about the amount of surfactant needed for the job. If appropriate information is obtained on surfactants, then the next step is to consider how a simple lab test or plant demonstration can be conducted to show whether the surfactant has the potential to work as

effectively as the solvent(s) being used. Even in developing countries, leather tanneries are likely to have experience with such simple testing or demonstration, because it is used routinely to ensure processing and product quality acceptable to customers. Plant personnel should also be asked whether they know of a tannery that uses surfactant in place of solvents.

The following points can be used to persuade industry or government persons to conduct such a test or demonstration. Replacing solvent with surfactant will have no real impact on wastewater quality (assuming no solvent recovery), because both methods result in grease in the water effluent. However, there is an environmental advantage in replacing solvent in the wastewater with biodegradable surfactant. Indeed, combined with other actions, namely BIP No.2 and No. 3, replacing solvent with surfactant could help reduce the need for wastewater treatment by removing the most toxic substances from wastewater. A careful economic analysis will show whether use of a surfactant decreases total costs, including raw material purchases and water related costs.

BIP No. 2 - Chrome recovery

There are two main issues or incentives for developing interest in chrome recovery: there is a history of documented net savings by reducing purchases of chrome sulfate for tanning; and chrome is usually the substance of highest environmental concern driving government requirements for wastewater treatment and its significant costs for a company. The first BIP for chrome in effluent shows the environmental need for chrome recovery, with values of 100 ppm or more likely in untreated effluent from plants in developing countries.

Capital cost is likely to be a major company concern. The data from the three cases given above indicate that a rough guide for estimating capital cost is about $130 per hide processed daily as a measure of production capacity. The BIP for chrome sulphate usage can be used to judge the potential for cost savings. A tannery using few if any methods for reducing chrome purchases may lose 30% of purchased chrome into effluent; recovery should be able to save at least 95% of the wasted chrome. Payback is likely to be about six months, based on reduced chrome purchases alone. Avoidance or downsizing of wastewater treatment plant, or lower costs for using a municipal or industrial estate treatment plant, adds another economic benefit. If wastewater treatment is not currently required, the probability for future regulatory requirements during the next five years should be assessed.

The implementation challenge is to design and construct the necessary equipment (i.e., various tanks and piping) to carry out the precipitation and dissolution stages, and also to control chemical usage (alkali and sulphuric acid) and pH to achieve a well controlled and efficient process. One decision is what alkali to use for precipitation, with the two likely ones being sodium hydroxide or magnesium oxide.

Chrome recovery is likely to be embraced by plant managers, but it may be resisted by tannery owners because of capital cost, the need for trained staff, or the physical limitations of the plant. However, it should also be emphasized that the "fall-back" position in the case of determined opposition to chrome recovery is to consider the alternatives of:

-- emphasizing high chrome fixation methods (e.g., 90% versus 70%) by using special tanning compounds;

-- reducing purchased chrome (up to 20%) by recycling of used chrome liquors to tannage and to pickle, also referred to sometimes as reconstitution of the chrome bath when new chrome sulphate is added;

-- switching to alternative tanning agents (e.g., vegetable, titanium sulphate, or syntans).(4)

While these may seem simpler, they do not yield the same benefits as chrome recovery and reuse. See the discussion below also.

BIP No. 3 - Use of solvents in finishing operations

The chief challenge is determining how to maximize conversion to aqueous dyes and non-solvent finishing materials. Plant managers may have already received information on such substitutes from chemical suppliers. Any previous decision to address or ignore such substitutions should be identified. Also, the fixing of resins with formaldehyde can be changed to UV light fixing. Implementation of this BIP is an especially difficult task, because it is very much linked to product quality and customer satisfaction, especially for higher priced leather products. Alternative materials must be identified and then tested to determine cost and product acceptability. Conducting a facility pollution prevention assessment requires identifying all currently used finishing materials and determining the extent to which solvents and formaldehyde are used, and also determining the costs of them accurately in order to fairly judge the economic impacts of switching to different materials. Testing the use of specific substitutes will probably require significant attention and commitment by company owners and managers.

BIP No. 4 - Total facility water use

The first implementation need is to accurately determine the total water use at a facility, which may be difficult if the plant does not meter its water intake. Water use may vary widely as batch production changes as a function of seasonal hide supply variations or sales variations. Nevertheless, some representative average figures must be determined or estimated. Any figure above about 60 cubic m/tonne (l/kg) of hides processed definitely indicates a large potential for water conservation, perhaps as much as 50%. The current and

future costs of water and wastewater treatment must be assessed. It is probably useful to consider a number of implementation actions in an aggregate way so that total cost savings can be estimated relative to total implementation costs. Otherwise, only the simplest of water conservation measures may be used.

Waste reduction or water conservation methods include: reducing water used in beaming (un-hairing) by reducing duration of rinsing (e.g., from one 4-hour running water rinse to two batch stages of 20-25 minutes each); using pistol-grip self-closing nozzles on facility hoses used for equipment washdowns;(3) using batch rather than running water washes wherever possible; reusing some wastewaters in less critical processes (e.g., second lime wash to start a new lime liquor; used lime washes for soaking); recycling individual process liquors; and using low float methods and water flow meters for equipment are additional approaches.(4) Also, identifying and correcting leakages in equipment and piping should prove useful. For example, the costs of a leak of about 2 l/min from a hose will buy a new hose every month, even in a developing country with very low water costs (i.e., about $.25/cubic meter).

Comments and Discussion

Chromium Alternatives

There are alternative approaches to the chrome problem, if chrome tanning is used. High chrome fixation (absorption) is an alternative to chrome recovery. It requires use of self-basifying chrome compounds and dicarboxylic acid. While it may achieve 90% chrome fixation, higher cost chemicals are needed and more complex processing is required. However, it probably cannot achieve very low chrome effluent standards. Overall it is not especially attractive for developing countries.(4) New tanning agents may contain two-thirds less chromic oxide than traditional tanning agent.(7) Another alternative is recycling of used chrome liquors for tanning. New plant designs can recycle 80% chrome but they probably cannot achieve very low chrome effluent standards.(4) The conclusion, therefore, is that although these alternatives are less costly than chrome precipitation approach, chrome recovery and recycling through precipitation is generally cost-effective for developing countries because of savings in purchased chrome.

Also, there are three main alternatives to the use of chrome for tanning: use of vegetable tanning agents; use of syntans (e.g., sulphonated products of phenol, cresol and napthalene); and use of titanium sulphate. Many plants may be using one or more of these in addition to chrome tanning. These other approaches, however, pose issues related to product quality and customer acceptance as well as major process changes unlikely to be attractive to existing companies for their major products. They also have their own environmental impacts that may require pollution control actions.(4) The conclusion is that the main opportunity for assisting existing tanneries in developing countries is through using chrome precipitation and recovery as the BIP.

The more traditional end-of-pipe alternative to chrome recovery through precipitation is wastewater treatment that can meet effluent standards for chrome. Typically, 20-40% of chrome is discharged in wastewaters and untreated effluent can contain up to 100 ppm chrome. A very well designed and operated wastewater treatment plant can achieve less than 1 ppm of chrome in treated water effluent and less than 4 ppm of chrome in the treatment sludge.(4) Overall, considering the costs of constructing and operating wastewater treatment facilities without any offsetting payback through cost reduction, the BIP remains chrome recovery through precipitation. Moreover, many factors may contribute to less than optimal operation and maintenance of a wastewater treatment operation.

Solid waste

In finishing operations, mechanical buffing dust is classified in the U.S. as a hazardous waste.(6) But this is not likely to be the case in developing countries. A U.S. facility produced only 100 pounds yearly, and this could be sold for beneficial reuse by another company, saving only $325 annually.(6)

Other types of solid wastes are also produced and have some potential for reuse, but overall there is minimal economic incentives for reducing solid waste disposal through reuse. Therefore, no BIP has been presented. If solid waste disposal incurs significant costs, which is not the case in most developing countries, than a tannery may benefit from finding companies that can make use of certain solid wastes. Even without significant disposal costs it would be environmentally preferable for a tannery to facilitate free commercial access to its solid wastes. For example, fleshings can be used by local rendering companies for extraction of tallow and grease; untanned hide and skin trimmings can be used to make gelatine and glue; tanned shavings and trimmings can be used to make leatherboard; and some solid waste can also be used to recover protein for conversion into feed supplements for animals or fish.

BOD and TSS

No pollution prevention actions for addressing BOD and TSS in water effluent have been presented, because the very nature of tanning means that they cannot be substantially avoided. Conventional and relatively simple wastewater treatment can remove around 70% of BOD and up to 95% of suspended solids through physical-chemical treatment.(4) The use of screens in various effluent locations can also provide a low cost way of cutting BOD and TSS. Even in developing countries wastewater treatment is likely to add less than 2% to production costs, although significant capital construction costs can pose a serious barrier to implementation and times of poor market demand and low profits can undermine proper operation and maintenance.(4)

Leather Tanning Industry References

1. Institute for Local Self-Reliance, "Proven Profits From Pollution Prevention vol. II," Case Study 57, pp. 61-64, 1989. Presentation of a project for chromium recycling at a tannery in Minnesota.

2. Overcash, Michael R., "Techniques for Industrial Pollution Prevention," pp.182-185, Lewis Publishers, 1986. A translation of an earlier French document; a brief presentation of a new process to reduce chromium and one to recycle solvent from degreasing, probably developed in France.

3. United Nations Environment Programme, "Audit and Reduction Manual for Industrial Emissions and Wastes," Case Study 2: Leather Manufacture, pp. 56-77, 1991. A case study of a tannery in south-east Asia processing cattle hides into finished leather, mainly for shoes, that received a facility waste reduction assessment; however, chrome recovery was not chosen over wastewater treatment.

4. United Nations Environment Programme, "Tanneries and the Environment - A Technical Guide," 1991. A very comprehensive treatment of the subject, completely different than previous reference.

5. United Nations Environment Programme, "Cleaner Production Worldwide," pp. 6-7, 1993. Description of a successful project for recovering and recycling chromium at a Greek tannery.

6. U.S. EPA, "Environmental Research Brief - Waste Reduction Activities and Options for a Manufacturer of Finished Leather," 600/S-92/039, October 1992. Presentation of Pollution Prevention actions at a smaller U.S. company resulting from a facility assessment; the company no longer tans hides, but finishes tanned leather.

7. U.S. EPA, "Guides to Pollution Prevention - Municipal Pretreatment Programs," 625/R-93/006, October 1993. A very brief description of an effort at a U.S. firm to reduce chromium.

8. World Bank, "Environmental Guidelines," 1988. A description of various practices with no focus on pollution prevention.

2.2 Textile Dyeing Industry

Companies in the textile dyeing industry vary greatly, both in terms of raw materials and products, as well as unit operations and degree of integration. Moreover, textile plants can be

very complex in terms of material flows and handling, as well as the equipment used for various operations. Different production lines may carry out similar operations, especially dyeing, but in different types of equipment. The approach taken here is to focus on several main unit operations for which there are some clear pollution prevention priorities with economic incentives, and which are present to a considerable degree in textile dyeing plants worldwide which may produce cotton, wool, or synthetic goods, especially woven fabrics.

Industry Subcategories (major unit operations)

A. Wet raw material preparation (pre-fabric, pre-dyeing):

A-1 -- Wool is scoured or washed in water, and possibly organic solvents (e.g., carbon tetrachloride, kerosene) to free it from natural grease, soluble salts, and sand and dirt. A detergent or alkali solvent is used, and rinsing is the last step.

A-2 -- Yarn of cotton and many cotton/synthetic mixtures is sized with starch, polyvinyl alcohol (PVA), carboxymethyl cellulose, gelatin, glues, or gums to facilitate weaving. A lubricant may also be applied to facilitate fiber manufacture.

B. Fabric treatment or preparation (pre-dyeing):

B-1 -- Wool is carbonized with dilute acid (usually sulfuric) solution to remove impurities, dried and baked, and mechanically treated. Then it is rinsed and neutralized with sodium carbonate, and rinsed again. A fulling operation, either alkali (soap or detergent and sodium carbonate) or acid (usually sulfuric), conditions the material which is then heavily rinsed to remove all chemicals and foreign materials.

B-2 -- Cotton and cotton/synthetic blends are rinsed and de-sized with enzymes or acid, then scoured with hot alkaline detergents or soap solutions to remove wax and other non-cellulosic materials, and final rinsed to remove residual detergents or soaps. Bleaching whitens the material and is done with sodium hypochlorite or hydrogen peroxide; this may be done before or after de-sizing. Mercerizing may follow to increase dye affinity and strength, but is not likely with cotton-synthetic blends.

C. Dyeing, printing, and finishing:

C-1 -- Dyeing. There are many variations, including batch and continuous dyeing, using different types of equipment, but most situations in developing countries are batch processes,

because the production lots are relatively small and vary considerably from one to another. The use of atmospheric beck (tank) dyeing is very dominant. Printing of fabric is also in this category. Rinsing is likely to follow.

C-2 -- Chemical finishing. Many textile products require the application of various chemicals, including: resins, softeners, flame retardants, water repellents, and fluorocarbons.

Priority Pollution Prevention Actions

Actions which reduce the use of purchased chemicals represent the highest priority, followed by water and energy conservation, because textile plants are chemical, water, and energy intensive. Measures which are strictly energy conservation in nature, however, particularly improving boiler efficiency, are not included in this report.

Five high priority pollution prevention actions are presented (not in any priority order, but following the logic of the unit operations presented above); other possible actions are presented in the discussion section. These five priorities are designed to maximize the effectiveness of an initial assessment or audit performed at any textile facility in a developing country.

Priority One. In A-1, there are two versions of recovery of materials from wool scouring liquids. Each kilo of scoured and produced wool may produce 1 to 1.5 kilos of waste impurities, including oil and grease, various other animal organic substances, and dirt. Consequently, wool scouring produces a potentially large contribution to BOD from a textile plant. In fact, if a mill handles wool, a high BOD in final plant effluent indicates the need for this action, which is economically justified chiefly because of reduced or avoided wastewater treatment costs. Thus, without required wastewater treatment or sewer charges,

this option is not likely to be pursued. However, it is also possible to recover the scouring bath by separating and removing the grease by, for example, ultrafiltration, which may have some market value.

Priority Two(a). If a textile mill includes the sizing of fiber to facilitate weaving, then there is an opportunity for recovery of sizing of some sizing materials. In B-2, the recovery of PVA or other chemicals in the de-sizing and rinsing of cotton and synthetic blends, offers an important method for reducing chemical purchases and greatly reducing the pollution loading of the water effluent. This option, however, is not relevant if a mill purchases fabric from another company, which is often the case. In some of these situations, however, there may be some potential to recover sizing chemical for sale or credit to the fabric provider, sufficient to justify investment in implementing this option, perhaps as a joint venture with the fabric supplier.

A U.S. textile mill reported that it recovered 2.5 million pounds of PVA at a net savings of 88 cents per pound, and reduced the COD load by 23,000 pounds per day. Approximately 80% to 85% of the PVA is recovered from the system, including the efficiency of the ultrafiltration (over 95% recovery) and losses during sizing. For recovering 2.5 million

pounds of PVA annually, capital costs were $1.275 million, and the payback was 9 months, primarily due to the reduced purchase of PVA and not considering reduced wastewater treatment costs.(2) Thus, the economics are attractive for developing countries.

Priority Two(b). If a mercerizing process (B-2) is used, then there is major opportunity to cut chemical and water use. In a traditional process, a strong caustic soda and wetting agent solution is used for the mercerizing, and this is followed by two hot water rinses and then a cold water rinse (a total of 600 liters for processing 7.5 kg of yarn, or 80 l/kg). The three rinsewaters are then neutralized with hydrochloric acid prior to wastewater treatment. Forming and recycling a concentrated caustic stream provides a number of benefits.

In a French mercerizing process, water use was reduced from 80 cubic m/tonne (80 l/kg) of yarn to 12 cubic m/tonne (12 l/kg); caustic soda was reduced from 360 kg/tonne of yarn to 100 kg/tonne of yarn; COD was reduced from 22 to 10 kg/tonne. This approach added about $100,000 to the capital cost of the mercerizing line, but annual savings exceeded $200,000 from reduced chemical use, producing a payback of about six months, which should be applicable to developing countries.(6)

This type of caustic soda recovery was also done in a plant in India, where feedstock use was reduced by 35% and produced significant savings.(18)

Priority Three. In dyeing operations (C), the chief pollution prevention goal is to reduce chemical use, followed by reduced water and energy use, and wastewater treatment demand. A number of basic methods following two strategies can be used to implement this priority, as presented below. The two strategies are dye bath reconstitution and alternatives to beck dyeing.

A major pollution prevention opportunity is to reconstitute an exhausted dye batch bath by analyzing it for remaining chemical/dye quantities and using new dye to obtain a suitable bath for subsequent reuse and dyeing. This reduces purchased dye and cuts pollution loading of the effluent and wastewater treatment capacity needs. In one case, wastewater flow was reduced 34% and COD was reduced 33%.(4)

As to the economic costs and benefits, for a U.S. dyehouse with five 1,500 gallon becks the capital cost was reported to be $89,000 (for instrument, computer, labware, five 2,000 gal. holding tanks, pumps, controls, piping) with yearly operating costs of $10,000. The yearly savings were $105,000 ($75,000 from chemical savings, $22,500 from energy savings, and the remainder from reduced water and sewer costs), yielding a payback of about a year (16 months with chemical savings only).

In another U.S. plant a $15,000 investment for modification of a jet dyeing machine produced savings of $120 to $140 per cycle from reduced chemical, energy, and water costs (a 72%

reduction in water), yielding a payback of 2 months.(15) A U.S. nylon pantyhose company saved $.02 per pound of finished goods by obtaining a 19% reduction in dyebath usage, a 35% reduction in auxiliary chemicals, a 57% energy reduction, and a 43% water costs.(16)

Generally, the U.S. experience is that using this approach reduces auxiliary chemical costs by 60%, dye costs by 19%, and water/sewer costs by 43%.(4)

In a French application of this approach, water use was reduced from 50 cubic m/tonne (50 l/kg) of fabric to 35 cubic m/tonne (35 l/kg), a 30% reduction (consistent with above example). COD was sharply reduced and operating costs were reduced by about 90%, producing a payback of about six months.(6)

Thus, even in developing countries with no/low cost water, this approach is likely to be justified economically because of chemical savings. This strategy is widely applicable, and not only to repeat shade dyeing.

The second basic strategy is to use some alternative to conventional beck dyeing, including: low liquor ratio jet dyeing; batch pad dyeing; or vacuum extraction dyeing. All of these offer solid economic benefits while also reducing dye and water consumption. See implementation discussion below. However, because they represent significant capital investments and the need for new dye practices, they pose serious issues.

Priority Four. Total facility water conservation (A - C) is crucial, because virtually every significant textile processing step involves water and, hence, an opportunity for water conservation. Generally, water consumption is greatest for rinsing and washing operations, rather than direct processing water needs. Although each operation in a plant should be

examined and optimized, it is useful to assess total facility use; one reason is that this helps establish the total economic incentive for taking what can be a large number of small actions that individually may be perceived as insignificant.

The use of multiple rinsing to replace overflow and soak rinsing offers benefits. In one case for a mill in Chile, three small rinses could remove more dye than two large rinses, requiring only 60% of the time and 60% of the water.(1)

In a U.S. example, reusing 75,000 gallons per day of bleach wastewater for scouring had a capital cost of $23,000, with yearly operating costs of $1,300. With an annual saving of $95,000, the payback was three months, without considering avoided wastewater treatment costs, such as might be the case in a developing country.(5)

A French case described the use of vacuum draining of fabric after dyeing followed by rinsing. This reduced water use from over 400 cubic m/tonne (400 l/kg) of fabric to 150 cubic m/tonne (150 l/kg), and it also reduced COD and BOD by about 50%. Operating costs were reduced 22%.(6)

A U.S. review of water conservation in textile mills has stressed the important potential of cutting water use by 30% or more.(5) In developing countries, where water has been free or very low cost, it is probably more realistic to think of a 50% reduction being possible, because of lack of attention to water use. For example, a plant in India cut its fresh water consumption by 93% through a host of water conservation measures and cut production costs

significantly.(19) Thus, it should be practical to identify and act on a host of water conservation actions in developing countries.

Priority No. Five. Total facility energy conservation (A - C) is appropriate for a pollution prevention audit, because there is a strong link between many different types of pollution prevention actions and energy consumption. [Note that strictly energy conservation measures outside of primary processing areas, such as improving boiler efficiency, are not included.] The use of heat exchangers within the manufacturing area has been widely successful in textile mills, because large volumes of heated water batches are used.

A U.S. case study described the use of a heat exchanger system by a hosiery manufacturer. The system recovers heat from spent dye solutions and uses the heat to preheat subsequent dyebaths from 55 degrees F to about 105 degrees F; it saved about 52,000 gallons of fuel oil yearly and reduced air pollution from the plant heating plant. The $100,000 capital investment was paid back in two years.(3) A French case described the use of a heat exchanger that used the heat from dyebath water to heat water for rinsing. This reduced energy consumption by 15%.(6)

Best Industrial Practice Targets

Corresponding to the above pollution prevention priorities, specific BIP targets have been developed, as presented below. These do not address all of the many environmental issues for textile plants, but they do provide a relatively quick and easy method for people performing a facility assessment. Other actions are presented in the discussion section. The set of BIPs offers a strategic framework for identifying and evaluating the major pollution prevention opportunities in a facility, especially important, immediate pollution prevention opportunities. In all cases, the objective is to numerically reduce the BIP critical ratio.

BIP No.1 - Wool scouring

The reduction in BOD by recovery of oil and grease is the basis of the BIP:

BIP = .5 kg BOD/kg of wool processed

BIP No. 2(a) - Recovery of PVA sizing material

Measuring COD change in the de-sizing effluent is probably the easiest way to measure this action:

BIP = 0.8 COD after recovery/COD before recovery of sizing material

BIP No. 2(b) - Reuse of caustic stream for mercerizing

A major reduction in new caustic is the key to measuring success:

BIP = 100 kg makeup caustic/tonne of yarn

BIP No. 3(a) - Dyebath reconstitution

The problem in establishing a target that can be easily measured is that the amount and type of dyes used vary enormously as do dyebath practices. The simplest solution is probably to use COD reduction:

BIP = .3 COD with reconstitution /COD before, without reconstitution

BIP No. 3(b) - Alternatives to beck dyeing

Low liquor dyeing:

The liquor ratio is the critical ratio of the amount of water in liters to kilograms of fabric in the dye bath. In conventional dyeing the ratio can be in the range 10 to 20 l water/kg fabric or even more. The goal is to reduce this ratio as much as possible without reducing product quality.

BIP 3(b) = 6 l water in dyeing operation/kg fabric dyed

Pad Batch Dyeing:

The reduction in dye quantity is measured through COD reduction.

BIP = .25 COD new process/COD beck process

Vacuum Extraction Dyeing

Use of modern vacuum dyeing equipment offers considerable potential to reduce dyestuff and auxiliary chemicals. The reduction can be measured through COD reduction.

BIP = .25 COD new process/COD beck process

BIP No. 4 - Water conservation

Probably the most pragmatic approach is to consider the amount of water use facility-wide. Amounts of water used in each facility operation can be optimized, but it is useful to take a systems approach also, one that looks at the entire facility (excluding sanitary uses) and evaluates the total costs and benefits of many water conservation actions. Assuming that a facility is integrated and includes raw material preparation, fabric preparation, and dyeing/finishing the following BIP is applicable.
BIP = 200 l of water facility wide/kg of produced fabric (or 200 cubic m/tonne)

BIP No. 5 - Energy conservation

There are a multitude of potential energy conserving options in a typical textile mill, including: reducing use and waste of hot water, remedying steam trap losses, and correcting boiler inefficiencies. Use of a vacuum water removal system can reduce energy consumption for drying. Unless a plant has already received an energy audit and acted on recommendations, a pollution prevention assessment should be considered capable of identifying at least a 25% energy reduction, mainly because of the actions taken related to improvements in dyeing and various water conservation actions.

BIP = .75 amount of fuel after assessment/amount of initial fuel consumption (for same period of time and level of production)

Implementation Methods and Issues For BIPs

BIP No. 1 - Wool scouring

There are two main options for recovery of oil and grease from wool scouring effluent. First, some type of grease recovery is practical through centrifuging. The low density, concentrated stream on top contains about 60% of the grease for recovery (assuming some market demand). The medium density stream is recycled upstream for reuse in scouring, thus reducing water and chemical use. The heavy density bottom layer, with considerable dirt and grit, can be sent to the treatment plant or sewered.(10)

Using acid cracking, sulfuric acid breaks the grease water emulsion after initial separation; the liquor is neutralized with lime, and 90 to 95% of the grease is recovered.(10) Thus, this action can largely eliminate the BOD from wool scouring, which otherwise can be several

hundred mg/l. Technically, the above actions are comparable in complexity to existing textile mill operations.

Other than finding a market for the recovered grease, another possibility that has been described is to use an evaporator and drying oven to process the recovered material and then use the dry, oily distillate as a fuel in the plant's boiler. This eliminates the wastewater stream from wool scouring altogether, but produces some solid ash (about 100 kg/tonne) and is likely to be an expensive action.(6) This option only makes economic sense if a significant wastewater treatment facility cost can be eliminated, and where fuel costs are significant also.

BIP No. 2(a) - Recovery of PVA sizing material

Accurate base level data on sizing chemical use and costs must be obtained. Implementation of recovery options requires considerable technical and cost information for specific, commercially available ultrafiltration or reverse osmosis equipment. All the issues for advanced technology usage in developing countries exist, including: concerns about importing equipment; having effective technical and maintenance support; spare parts for equipment; training facility technical staff; and feeling confident about payback and maintaining production output and product quality.

In one case of PVA recovery, ultrafiltration was reported to cost 12 cents per pound of recovered PVA that costs $1 per pound to purchase as virgin material. Ultrafiltration produces two recyclable streams, and the cross-flow filters are self-cleaning. The concentrate stream contains the size material, oils, and waxes that can be reused for yarn sizing. The permeate stream consists of hot water and detergent which is returned to the washer. This reduces raw chemical, water, and energy costs.(6)

PVA and other sizing compounds, such as PEG, polyacrylates, and starch, can also be recovered, if not with ultrafiltration, then with reverse osmosis, which is more technically complex than ultrafiltration. An Italian company has reported success with reverse osmosis in plants producing acrylic, cotton and wool products, claiming to virtually eliminate highly polluted effluents, from dyeing, wool washing, and de-sizing, and creating reusable water for basic processing, because virtually all contaminants are removed and reused. Benefits cited include: 95% waste reduction, and 95% water reduction. Payback varied from 1 to 2 years, depending on costs of chemicals, energy, and water.(11)

BIP No. 2(b) - Reuse of caustic stream for mercerizing

Implementation requires accurate data on the current costs of mercerizing. The pollution prevention alternative of forming a concentrated reusable caustic stream for mercerizing is to use a series of three countercurrent rinses. Passing the first, concentrated, rinse water through

an evaporator produces a concentrated caustic stream for reuse in the mercerizing tank and a small amount of condensate for acid neutralization prior to wastewater treatment.(6)

BIP No. 3(a) Bath Reconstitution

As to implementation of dyebath reconstitution, there are four steps:

-- Bath retention. Saving the just exhausted dye bath by pumping to a holding tank, while the product is rinsed in the same machine in which it was dyed; the dye bath can be returned after the rinsed product is removed. Alternatively, the dyed product can be pulled and moved to another tank for rinsing, depending on what equipment or plant space is available.

-- Analysis. Typically, only about 10% of the dye may be carried off in the product, but certain operating conditions require an estimate of the quantity needed to replenish the bath to ensure consistent dyeing. Some instrument, such as a spectrophotometer, must be used together with a computer to calculate the required dyestuff additions. This should only take a few minutes per cycle.

-- Reconstitution. This means adding back the quantities of water, auxiliary chemicals, and dyestuffs needed for the next dyeing cycle. Even if there is some build-up of surfactants, this can be compensated for by slightly increasing the amount of dye added. Yet there is some finite number of maximum reuse cycles, which for many plants is in the order of 10 to 20 reuse cycles.

-- Reuse. The major difference in reusing a dyebath is that the starting temperature is generally higher than that of a fresh water bath. In general, however, the loss of heat during storage and the cooling effect of the make-up water are sufficient to decrease the dye bath temperature to a safe level. If the stored and make-up waters do not lower the temperature to a safe level, a heat exchanger may be cost-effective.

The key implementation need is to convince facility managers of the technical feasibility and economic benefits of this approach. Some instruments will be necessary to make appropriate measurements for achieving effective process control.

BIP No. 3(b) Alternatives to Beck Dyeing

There are significant obstacles to implementation. Using alternatives to traditional beck dyeing means investing in major new plant equipment. This means capital investment, training needs, and addressing concerns about production scheduling and product quality. A lot of detailed and accurate information must be assembled to raise the level of comfort about using different technology. Usually, senior plant managers and engineers are likely to have

had some exposure to these alternatives, through technical literature, attendance at industry exhibits, or visits to other facilities.

Low Liquor Ratio Jet Dyeing

The liquor ratio is critical. It is the ratio of the amount of water (in liters) to the amount of fabric (in kilograms) in the dye bath. For successful dyeing, modifications to the process are generally required. Jet dyeing is probably the key, important version of this method. It takes place in a closed system where nozzles emit a high pressure stream of dye that penetrates the fabric and moves the fabric along a tube. The fluid moves faster than the fabric to move the fabric through the tube without touching the walls of the tube. Another variation consists of air transport.(9)

Benefits include: shorter dyeing cycles, reduced dyestuffs and chemicals, less steam and water, less energy consumption, and less pollutant loading in wastewater and treatment.

Pad Batch Dyeing

This is a cold method of dyeing cellulosics. The fabric is saturated with the premixed dye liquor, then passed through rollers that squeeze out the excess and cause dye penetration.

This is followed by storage in containers (e.g., boxes, steamers) covered with plastic film for 2 to 12 hours. Then the fabric is washed.(9)

Benefits include: a simple, fast, and flexible process for woven and knitted fabrics; use of high reactivity dyes promotes rapid fixation and stability that provide shade reliability and repeatability; virtual elimination of a number of auxiliary chemicals (e.g., anti-migrants, fixatives, leveling agents); less water and energy consumption; and reduced pollutant loading and wastewater treatment (up to 80% less BOD and COD over atmospheric becks). Water use of 17 l/kg of fabric and energy use less than 4,400 BTUs per kilogram of fabric are possible, as compared to 170 l/kg and 20,000 BTUs for conventional use of an atmospheric beck.(9)

Vacuum Extraction Dyeing

Various pieces of commerciai equipment are available and used worldwide; they make use of vacuum extraction principles and a low add-on approach. A vacuum unit is used after wet dye is applied to the fabric; the vacuum can be precisely controlled so that the amount of dye is controlled plus or minus one percent. Benefits include improved dyeing as well as reduced dye, chemical and energy use for drying. Waste dye bath is reduced from 90 liters per change in a high quality dye padder to 12 liters on vacuum equipment that is especially efficient for short runs. Various chemical finishes can also be applied by low material add-on

vacuum equipment. Reductions of 30% - 50% in chemical consumption and associated raw material cost savings offer a payback of weeks or months, not years. Dyebath and chemical finishes can be recovered, filtered, and reused.(14)

BIP No. 4 - Water conservation

A key implementation issue is obtaining accurate data on water use for the total facility as well as individual operations and separate production lines. Even if metering is used, it is usually necessary to verify data by measuring actual flow rates, especially if there are multiple sources.

The economic incentive for conservation, of course, may be reduced in developing countries, because of low water cost and in many cases no requirement for wastewater treatment (or no sewer or municipal wastewater treatment costs). However, the cost of water conservation actions tends to be low and there are clear indications that costs will be rising in most developing countries, both for water inputs and wastewater treatment. In most cases it probably is wise to package all water conservation actions together so that the best investment cost-payback scenario is described and communicated to plant management. Otherwise, some actions which seem less profitable than others may not be implemented, even though the total collection of actions offers a very handsome payback.

Also, product quality concerns and physical plant limitations can sometimes block some water conservation actions. But the former should be evaluated through testing for negative impacts, rather than always assuming that any water conservation change is detrimental to product quality. Most industrial processes err on the side of over-using water, especially in countries where water has been essentially a no cost input. Pollution prevention experience is that considerable water conservation can take place without harming production rates or product quality.

The reconstitution of dyebaths, discussed above, is a fundamental method of water conservation. Reuse of dirty water for less critical processing is another fundamental method. For example, the colored wastewater from a soaping operation can be reused at a backgrey washer, which does not require very clean water. Or the wastewater can be used for cleaning floors and equipment in the dye or print shop. Similarly, rinsewater from scouring can be reused for de-sizing, or for washing floors and equipment. Mercerizing or bleaching rinsewater can be reused in scouring and de-sizing, if size recovery is not practiced, because the caustic or bleach stream will likely degrade sizing compounds. Jet weaving wastewater can be reused in the de-sizing or scouring process, if fabric impurities and oils are removed with in-line filters.(5)

Counter-current washing should always be considered. This means using the cleanest water for the cleanest fabric, with the most contaminated water contacting the fabric that first exits a process step for washing or rinsing. This method can be used for: de-size washing, scour washing, mercerizing washing, bleach washing, and dye rinsing.

Other fundamental actions that can cumulatively produce large reductions in water include: replacing overflow rinsing with more controlled actions; use of automatic shutoff valves, based on time, level or temperature; use of flow control valves, especially in cleaning areas; and general good housekeeping such as minimizing leaks and spills, proper maintenance of production equipment, and identification of unnecessary washing of equipment.(5)

Vacuum extraction washing is a modern approach, requiring little space and relatively low capital. A major commercial U.S. equipment maker offers a stage washer using vacuum technology and state-of-the-art computer process controls. It has counterflow and chemical addition capabilities; it reduces water consumption, energy consumption, washing time, and labor, and it adds considerable flexibility and effectiveness.(9)(14)

Another company makes a low wash process which offers benefits, especially for piece dyeing of cotton fabrics with reactive dyes. Compared to conventional drop/fill or overflow methods, this equipment reduces rinse water by about 30%, rinse cycle times by more than 50%, and overall cycle times for complete dye procedure by about 18%, while still achieving the equivalent level of rinsing effectiveness of conventional methods.(9)

BIP No. 5 - Energy conservation

There are a multitude of potential energy conserving options in a typical textile mill, including: use of heat exchangers, reducing use and waste of hot water, remedying steam trap losses, and correcting boiler inefficiencies. Use of a vacuum water removal system can reduce energy consumption for drying. A key implementation issue is obtaining accurate data on energy consumption and costs relative to the implementation costs of specific actions.

Comments and Discussion

The relatively large number of actions presented below is indicative of the diversity in textile dyeing plants. It is extremely important to have an accurate and complete characterization of a textile plant in terms of descriptive process diagrams of different production lines and operations in the facility.

Wool carbonizing

With use of sulfuric acid and hard water containing calcium ions, calcium sulphate may precipitate, requiring periodic dumping of the bath and a potential Ph spike in the effluent.

Using an in-tank filter for the bath can remove the calcium sulphate, eliminate contamination of the fabric, save water and wastewater treatment chemicals. A payback of 2 years has been reported.(1)

Recovery of fiber lubricant

A U.S. fiber manufacture had a problem with high BOD caused by a costly proprietary mineral oil lubricant compound carried away by a continuous rinse process. A reverse osmosis system concentrates the lubricant (to a 20% solution) and separates the water. A feedback control system uses an automatic sensor-controlled valve to compensate for feed concentration increases. The recovery of the lubricant reduced processing costs and gave a payback of six months.(12)

Zinc recovery in rayon yarn manufacture

In a U.S. plant making rayon yarn, zinc is used as a regeneration retardant in the acid spinning bath of the process to slow down the formation of the yarn. The zinc is not consumed, but enters the yarn wash water and equipment wash water. A two-stage precipitation process produces a zinc hydroxide sludge which is treated with sulfuric acid to produce zinc sulfate that is reused in the spinning bath. This is an improved precipitation system that saved $383,000 annually.(13)

Reconstituting bleach baths

Another pollution prevention opportunity is to reconstitute bleach baths, and use them for many cycles. The basic approach is to establish some procedures for determining how much fresh chemical must be added to a bath. The chief benefits are reduced chemical purchases and reduced water use.(4)

Dyeing material change

A French case described the use of a more dilute solution of "white spirit" (i.e., presumably kerosene solvent) in the preparation of paste for color printing (dyeing) of fabric. The amount of white spirit was reduced from 770 g/kg of paste to 200 g/kg, and a process controller was added to the paste preparation line. Discharge of the solvent in water was reduced by about 85%, in air it was reduced by 70%, and the amount of waste coloring paste was reduced by 50%. The small additional capital cost for the process controller was paid back in about six months.(6)

Dyeing auxiliary chemical substitution

A large textile company in India uses sulphur deep color dyes. The original process required the use of sodium sulphide, which causes a major toxic sulphide loading of effluent. The company discovered through a study that an alkaline solution of glucose could perform as well as the sulphide. It found a low cost source, which was a by-product of the maize starch industry, called hydrol, that had about 50% of reducing sugars. The sodium sulphide could be replaced by a combination of hydrol and caustic soda. The dyed product quality was improved. Sulphide concentration in effluent was reduced from 30 ppm to less than 2 ppm, with only a slight increase in BOD. No new equipment was necessary, and there was a significant avoided cost for more wastewater treatment capacity.(7)

De-oiling of fabric

Some textile plants use some type of simple fabric cleaning to remove oil. The traditional approach is to use a water-detergent washing solution that is then allowed to settle. The decanted water is discharged or sent to the wastewater treatment plant, and the sludge is disposed. Water use is about 45 cubic m/tonne of fabric. If wastewater treatment is required, then the alternative of using a chemical solvent approach might be economically attractive. However, the key need is to use an efficient solvent recovery unit. In a description of this approach, using solvent distillation equipment, water was eliminated altogether and annual costs were reduced by 50%.(6)

Chemical finishing

A variety of toxic chemicals may be used to achieve certain desired properties of fabric. The pollution prevention goal should be to find less toxic alternatives, preferably ones that are not significantly more expensive. However, because no major operation is likely to be done after finishing, there is little potential to avoid pollution control costs, although some water pollution is possible from equipment washing and washing after spills, for example.

Total Suspended Solids

If wastewater treatment is being required, then attention can be given to the use of filters and screens throughout the facility. This can trap lint and other sources of TSS and sharply reduce TSS in treated effluent. This type of action can also reduce water and chemical uses by removing the cause of various types of leaks in equipment.

Solid waste reuse

Many types of solid waste are created in a textile mill. Material combings, cuttings, and shavings, for example, can be used by other companies, including stuffing for toys, furniture, and padded shipping envelopes. This kind of recycling is preferable to landfilling and, at the very least, can reduce solid waste transportation costs for the textile plant. A plant in India, for example, dewatered solid residues were bagged and sold to board and cellulose powder manufacturers or packing uses.(21)

Equipment cleaning solvent reuse

Many textile plants use strong chemical solvents to clean equipment. In fact, although rarely focused on, this use of synthetic chemical solvents has been found to be very substantial in the U.S. and is likely to be important in foreign textile plants also. For example, an analysis of legally defined hazardous waste generation in South Carolina found that in 1988: the average plant producing yarn and fabric generated 4,415 pounds of solvents; the average finishing mill, engaged only in bleaching, dyeing or printing fabrics generated 20,307 pounds of solvent; the average plant producing fabrics of exotic materials or carpets generated 87,470 pounds of solvent; and the average plant producing finished apparel only generated 7,480 pounds of solvent waste.(23) Although solvent use has been decreasing rapidly in the U.S. because of regulatory and cost pressures, it is likely to be at high levels in textile plants in developing countries.

This use of solvents offers an opportunity to reuse solvent or substitute with a non-toxic, biodegradable water based solvent, because the intrinsic need for cleaning agents cannot be avoided. Both alternatives should be seriously considered for any textile mill, and there are significant opportunities to reduce plant costs through either buying less synthetic solvent because of recycling, or using water based solvents that reduce the need for wastewater treatment. In most developing countries it may be easier and more cost effective to use the onsite recycling approach, unless there are local, commercial sources of alternative water based cleaners.

A U.S. manufacturer of high twist filament yarn originally was using the solvent 1,1,1-trichloroethane to remove greases, oils, dyes and chemicals from yarn cleaning machinery parts. They installed a solvent recovery distillation unit, which recovered 90% of the solvent. The payback period was about a month. It was also reported that the company had intentions of finding an alternative, non-toxic solvent.(8)

A U.S. plant recovered 90% of isopropyl alcohol in a distillation unit purchased for $7,500 and the still bottoms were used by the company in another product line. The annual savings of $90,000 produced a payback of less than one month.(17) Another U.S. plant installed a

distillation unit to recover iso-propyl acetate and achieved a payback of 2 years.(20) A different U.S. plant segregated waste toluene used for cleaning printing press equipment, and then used the materials for thinning the same type and color of ink, and a carbon adsorption recovery system provides 90% recovery from the printing lines.(22)

Textile Industry References

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21. Case study abstract from UNEP ICPIC database titled "Recovery and Reuse of Solid Waste from a Synthetic Textile Industry," undated.

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3.1 Benefits of the Approach

Although there have been many hundreds of facility pollution prevention audits or assessments over the last decade, it is clear from examining published and unpublished documents that the process has not been optimized. One of the most frequent problems, other than a complete lack of data, is the presentation of data without other necessary information that would allow the calculation of an appropriate ratio. In the latter case, the usefulness of a published case example is made very difficult, because the information and experience remains purely site-specific. The lack of standard approaches to gathering information for assessing opportunities and performance has contributed to a generally low level of post-assessment implementation by facility engineers and managers.

The critical ratio pollution prevention priorities methodology developed by Hirschhorn & Associates establishes a framework for optimizing facility audits or assessments, and also making them more consistent. The approach of using ratios rather than data for a single parameter intrinsically provides a normalization of data that has important meaning when working among different industrial facilities. In this way, even when there are major differences in plant size, production outputs and material flows, specific figures for a unit operation in one facility can still have meaning for a different facility. Thus, it is important to use ratios that provide a context or basis for a quantity, such as amount of chemical not by itself, but in terms of amount of chemical used per metric tonne of either raw material processed or final product produced, whenever that is possible. Moreover, in addition to supplying flexibility of application, the process of identifying BIPs or benchmarks for significant unit operations or, in some case, total facility use, is an evolutionary process. As more site-specific audits are performed and data obtained, there will be more opportunities to define new BIPs in an industrial sector.

Another major limitation of previous work is that widely varying facility assessment approaches have also contributed to ineffective transfer of commercially proven and available clean technologies that could be widely adopted by companies in developing countries. Thus, the benchmarking aspect of the methodology used in this report should improve wide use of commercially available cleaner production technologies, equipment, and materials.

It is also reasonable to believe that the ad hoc approaches used in collecting and presenting data have not effectively supported the creation of in-country technical capabilities and sustainable pollution prevention programs. The concept of identifying benchmark data as representing best industrial practice has been shown to be extremely effective in promoting industrial improvements, often described as Total Quality Management methods. While there is always some legitimate need for experts, a standardized methodology and a set of benchmark data will promote effective facility assessments by technically educated professionals in developing countries who may, however, have had little field experience or formal pollution prevention training.

The general benefits of the BIP/critical ratio approach used in this report are summarized as follows:

-- a focus on a relatively small number of unit operations at a facility, increasing the likelihood that audit time and effort are not wasted on relatively insignificant aspects of a facility, or the audit being overly narrow in scope, either intentionally or unintentionally, and ignoring some important parts of a plant

-- a focus on priority pollution prevention methods, materials, or equipment that have already been used successfully, and avoiding spending a lot of time and effort on less important, feasible, and proven actions, or even on actions that are really end-of-pipe type steps

-- use of metrics or critical ratios that guide the collection and analysis of data, including the very important pre-audit activity by plant personnel, avoiding the frequent problem of pollution prevention audits or assessments producing marginally useful data or little quantitative information necessary for maximum implementation by plant personnel

-- having BIP or benchmark critical ratio data that allow evaluation of current plant operations and practices against a rational standard of performance, and minimizing inaccurate assessments of a facility's prior accomplishments or future opportunities to use the most effective clean technologies

-- using numerical values that establish clear technical objectives for developing and managing economically justified plant programs based on the use of specific kinds of clean technology

-- having the ability to consistently track facility performance over time, even if different people from the company or outside agencies obtain data, avoiding efforts that do not allow accurate assessments of changes and implementation of recommended actions over time

-- being able to make meaningful and accurate comparisons among companies in a particular industry sector, either in one country or several, providing improved technology transfer and policy assessments of country needs and progress

3.2 Specific Steps for Collecting Data

The exact data to be collected at a facility depends on the industry it is in. The Task 2 sections for leather tanning and textiles present what should be done for all 10 priority

industries discussed in Task 1. Assuming that such an analysis has been done and is made available, the basic steps in data collection for either a company employee or EP3 person, or preferably both, are:

Step 1 -- review the industry subcategories or generic unit operations to identify which ones are present at the facility and, therefore, which BIPs are relevant; simplified process flow diagrams are an important part of pre-audit activities; process and materials flow diagrams

can be used to show what a facility contains in terms of basic unit operations and equipment in different production lines, and they can be modified to show amounts of materials as they move through the facility operations

Step 2 -- analyze the definitions of priority pollution prevention actions in EP3 guidance material to assess whether any have already been used completely or partially, and whether facility personnel have any familiarity with any of them

Step 3 -- examine each relevant BIP to understand what data are required; pay special attention to the units of measurement, which may be different than ones currently used; also pay special attention to data regarding production output or raw material inputs and how they may vary over time

Step 4 -- identify what required data exist at the facility, and what data have to be obtained; pay special attention to obtaining accurate data to establish current facility operating conditions that serve as the "before" or baseline figures prior to implementing a pollution prevention action; also focus on accurate economic cost data, including direct and indirect costs to the maximum degree

Step 5 -- check the implementation discussions for each relevant BIP to identify potential obstacles and their solutions; this should be done very carefully with attention to technical, economic, and organizational issues; government policies and regulations that may pose impediments or disincentives for pollution prevention actions should also be identified; the focus should be on practical, real world conditions that could stand in the way of implementation

Step 6 -- develop a workplan to obtain the data required for BIPs and to verify their accuracy, paying special attention to changes in production at certain times of the day or year that may affect the data, the need to obtain data for different pieces of equipment, and to instruments or devices that may have to be purchased or calibrated in order to make necessary and accurate measurements; various sources of facility data should be considered, including: company purchase records, laboratory test data, records of equipment changes, sales data that may best describe plant production, and any data from government testing of facility effluents

Step 7 -- obtain the facility data for the relevant BIPs and compare them with the numerical values presented as the benchmark figures for the industry sector

Step 8 -- develop an explanation of differences between the plant critical ratio data and the BIP benchmark data established for the industry sector; separate into two categories: worse than and better than, but submit all data for EP3 database

Step 9 -- if facility performance is worse than (numerically greater than) a relevant BIP, then develop a pollution prevention implementation plan and make preliminary estimates of potential implementation costs (capital and O&M) and potential savings to calculate simple payback periods, perhaps by assuming best case and worst case scenarios for each action so that a range of payback periods is obtained; identify problems to address in terms of plant implementation, such as impact on production lines, as well as locating sources of materials or equipment, and the possible need for tests and demonstrations regarding impacts on production, product quality and pollution prevention effectiveness (reaching the BIP value); eventually, if there is implementation, new data for the critical ratios should be obtained and submitted to EP3

Step 10-- if facility performance is better than (numerically less than) relevant BIPs, provide data to EP3 for establishing a new benchmark figure for that particular unit operation; also identify any differences in applied methods, materials, or equipment that explain the improved level of pollution prevention performance over the previous BIP numerical value

Step 11-- evaluate the additional, second priority pollution prevention actions presented in the discussion section for the industry sector and if some appear applicable develop a pollution prevention implementation plan for them also; the establishment of new BIPs should also be considered for inclusion in the EP3 database and industry protocol, and if one seems appropriate a brief proposal should be prepared following the approach given for leather tanning and textile industries

3.3 Establishing an EP3 Database for Benchmark Critical Ratio Data

Each industry sector should contain clearly defined critical ratios and the current benchmark BIP target values. In addition, EP3 needs to establish a system for collecting and storing numerical values of critical ratios worse than BIP values, together with some explanation of why a particular facility had those values. Also, some plant data may offer values that establish new BIPs that are obtained from EP3 in-country activities, and possibly from other sources, including information from suppliers of materials or equipment.

In addition to numerical values, narrative discussions and descriptions of the specific methods, materials, or equipment used to reach the values, as well as implementation issues, should also be placed into the database. What has been presented above for leather tanning and textiles

serves as an example of the type of information that should be collected and made retrievable. Someone in the field, whether in-country personnel or "experts" from the U.S. should be able to retrieve industry-specific information for immediate use.

The database should also allow analysis and comparisons of different companies in one or more countries with regard to critical ratio data that have been flagged to be less than the current BIP value at the time the data were obtained, or data that have established new benchmark BIP values. Additionally, the database can store values of critical ratios obtained at different times for any one facility, providing a statistical tracking capability.

The database should also permit analysis that reveals whether some EP3 projects or personnel show some systematic tendency with regard to performance improvements in facilities and industry sectors, either worse or better than other offices or personnel.

There is also a potential for EP3 to serve as a worldwide source of benchmark performance data for many unit operations in a number of industries. Should a new method or technology become the basis for a higher level of performance, then the EP3 system could rapidly disseminate the new benchmark and the basis for it to the network of companies that have already participated in the build-up of the database. In this sense, the EP3 system has the potential to serve as an effective stimulus for transferring clean technologies worldwide.