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Building a Healthy Economy:

Chemicals Risk Management as a Driver of Development

Rachel Massey
Global Development and Environment Institute
Tufts University

A study performed for the Swedish Chemicals Inspectorate

THE SWEDISH CHEMICALS INSPECTORATE

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PREFACE

The Strategic Approach to International Chemicals Management to be adopted at the International Conference on Chemicals Management in Dubai in February 2006 aims at creating a better future for us all through improved management of chemicals at all levels, local national, regional and international. Its implementation will require the combined efforts of all stakeholders and all sectors of society. One aspect of implementation where views usually diverge is that of the costs and benefits of improved chemicals management, including risk reduction. Anecdotal evidence of the negative cost side abound, while the positive side of better materials efficiency, improved market access and health and environmental gains is often neglected. The science in the field needs to be improved to provide decision makers with an adequate basis for taking action.

This report was commissioned by the Swedish Chemicals Inspectorate (KemI) in order to promote thinking and research on the links between improved chemicals management and economic benefits to the individual, to industry and to the society at large. It was funded by the Swedish international development agency (Sida) through an agreement with KemI as part of the increased cooperation between KemI and Sida on development cooperation in the chemicals area. Within KemI Dr. Bo Wahlström, Senior International Advisor, and Mr. Torbjörn Lindh, Senior Advisor, Supervision of Chemicals Control, have been responsible for developing the terms of reference of the study and supervising its completion.

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Rachel Massey
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Global Development and Environment Institute
Tufts University, 44 Teele Avenue, Medford, Massachusetts 02155
http://ase.tufts.edu/gdae

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EXECUTIVE SUMMARY

Industrial development drives economic growth. But chemical pollution caused by industry runs directly counter to the goals of economic development, creating human illnesses as well as animal and plant diseases, and preventing people from developing to their full potential. In this report, we look at the ways in which developing countries can achieve economic growth without pursuing the polluting path that industrialized countries have followed. We focus in particular on the ways in which pollution prevention can support economic success among small and medium-sized enterprises.

This report consists of six parts. Part 1 explores the importance of a healthy environment for economic development, with a particular focus on toxic chemicals. Part 2 presents the logic of pollution prevention as a strategy to reduce or eliminate toxic exposures. Part 3 looks in detail at pollution prevention initiatives in four industry sectors. This discussion draws primarily on case studies that have been developed from work at the individual facility level. Part 4 goes beyond the facility-specific discussions by exploring the experience of selected programs that have worked to build pollution prevention capacity at the national level. Part 5 synthesizes lessons from both the case studies and the program descriptions as they apply to pollution prevention efforts in the developing world. Finally, Part 6 offers suggestions about directions for future research.

1. Healthy Environment, Healthy Economy

A healthy environment is crucial to achieving sustainable economic development.

- *Human capital:* Building human capital is a crucial component of economic development. Good health is a necessary foundation for all efforts to develop human capital. Any factor that prevents people from learning new skills and working effectively undercuts the effort to build human capital.

- *Costs of illness:* When people become sick due to toxic exposures, the resulting costs cascade through an economy. Economic studies in Europe and the US show that avoidable illnesses caused by toxic exposures place a large economic burden on families, communities, government and industry.

2. The Logic of Pollution Prevention and Cleaner Production

Preventing pollution at the source, rather than cleaning it up at the end of the production process, is a particularly good way to avoid toxic chemical problems. Pollution prevention frequently saves economic as well as human and natural resources, and thus can offer significant financial, human health and ecosystem benefits.

3. Industry portraits

We look at facility-specific case studies drawn from four industry sectors: tanneries, textile production, metal finishing and artisanal gold mining. We look at the major pollution problems, principal opportunities for pollution prevention, and broader economic implications of pollution prevention for individual facilities within each sector.

4. Pollution Prevention Programs

In this section, we look at several examples of efforts to promote pollution prevention at the national or international level. We begin with a discussion of the National Cleaner Production Centres, a UN-sponsored network of national-level institutions that provide information and pilot programs to support pollution prevention. We then look at lessons from one bilateral aid program for pollution prevention, the US-sponsored Environmental Pollution Prevention Program (EP3). At the national level, we examine the experience of India's DESIRE Project, a program that worked for pollution prevention among small-scale industries in three sectors. Finally, we examine the case of Cleaner Production in China, a successful program that has worked with both large and small industries in a range of industrial sectors.

5. Promoting Pollution Prevention: Opportunities and Challenges

In this section, we synthesize information from both facility-specific and program-level experiences, drawing out some general observations on opportunities and challenges for promotion of pollution prevention in developing countries. Among other themes, we discuss the following:

- *Financial benefits:* Pollution prevention can be a way to help improve the viability of small businesses, and a way to help small businesses survive difficult economic conditions. Where the conditions are right, cleaner production investments can be self-financing: many facilities can often afford to make the change themselves, without financial help from an outside organization. Aggregate statistics show that the success stories of financial benefits from pollution prevention are not mere exceptions, but rather are the rule in many industry sectors.

- *Scaling up and sharing knowledge:* To ensure effective transfer of pollution prevention information and capacity through an economy, it is important to include pollution prevention in mainstream capacity building services to industry. There are also promising areas for collaboration among facilities in creative arrangements such as formation of industrial parks.

- *Transferability:* Successes at one firm or in one region are not necessarily transferable to another. Factors that help determine transferability include the size of the facility, the level of investment required to make a change, and the local cost of raw material inputs.

- *Financing:* Although pollution prevention options often pay for themselves within as little as six months, there is a major need for creative financing mechanisms to jump-start the process, especially among small and medium-sized enterprises that lack reliable access to credit. Partnering with existing micro-credit operations may be a promising way to help the smallest facilities in developing countries to adopt pollution prevention techniques.

6. Directions for Future Research

Based on our review of the literature on pollution prevention in an economic development context, we offer suggestions about possible directions for future research projects. Among other themes, we recommend exploring the options for partnering with micro-credit agencies to finance cleaner production among very small facilities, and addressing the particular challenges of disseminating pollution prevention information to regional clusters of very small facilities.

SAMMANFATTNING (SUMMARY IN SWEDISH)

Industriell utveckling för den ekonomiska tillväxten framåt. Men de föroreningar som industrin orsakar går helt på tvärs mot målen för den ekonomiska utvecklingen, orsakar sjukdomar och hindrar människor att utveckla sin fulla potential. I denna rapport granskar vi hur utvecklingsländerna kan åstadkomma ekonomisk tillväxt utan att gå den föroreningsväg, som industriländerna tagit. Vi koncentrerar oss särskilt på hur metoder som förebygger uppkomst av föroreningar kan främja ekonomisk framgång för små och medelstora företag.

Rapporten har sex delar. Del 1 undersöker hur viktigt det är med en god miljö för en sund ekonomisk utveckling, inte minst med tanke på användningen av giftiga kemikalier. Del 2 pekar på det rationella med åtgärder som förebygger att miljöföroreningar uppkommer som strategi för att minska eller stoppa exponering för gifter. Del 3 detaljgranskar initiativ till förebyggande åtgärder inom fyra industrisektorer. Granskningen tar främst upp fallstudier som utförts på enskild fabriksnivå. Del 4 går längre än till fabriksspecifika resonemang, och beskriver erfarenheterna från några program som använts till att bygga upp kapacitet för förebyggande miljöåtgärder på nationell nivå. Del 5 förenar kunskaperna från fallstudierna och programbeskrivningarna såsom de kan tillämpas på förebyggande miljöåtgärder i utvecklingsländer. Del 6, slutligen, föreslår vägar för fortsatt forskning.

1. God miljö, sund ekonomi

En god miljö, fri från giftiga kemikalier är nyckeln till att nå en ekonomiskt hållbar utveckling.

- *Mänskliga resurser:* Att bygga upp ett humankapital är en grundläggande del i den ekonomiska utvecklingen. God hälsa är en nödvändig stomme till varje bemödande att utveckla humankapitalet. Varje omständighet som hindrar människor att lära sig nya färdigheter och arbeta effektivt undergräver försöken att bygga upp humankapitalet.

- *Sjukdomskostnader:* När människor blir sjuka på grund av exponering för gifter flödar de uppkomna kostnaderna över på ekonomin/får detta följder för ekonomin. Ekonomiska studier i USA och Europa visar att sjukdomar orsakade av exponering för gifter som hade kunnat undvikas, lägger en stor ekonomisk börda på familjer, samhällen, regeringar, och industrin.

2. Det rationella med förebyggande miljöåtgärder och renare produktion

Att starta med förebyggande miljöåtgärder, snarare än att vidta städningsinsatser i slutet av en produktionsprocess, är ett särskilt bra sätt att undvika problem med giftiga kemikalier. Förebyggande miljöåtgärder sparar ofta resurser och kan därför ge betydande ekonomiska fördelar.

3. Industriexempel

Industrispecifika fall från fyra industrisektorer beskrivs: garveri, textilproduktion, metallförädling samt småskalig guldgrävning. De största föroreningsproblemen tas upp, huvudsakliga tillfällen till förebyggande åtgärder samt de vidare ekonomiska följderna av förebyggande miljöåtgärder för enskilda fabriker inom varje sektor.

4. Program för förebyggande miljöåtgärder

Denna del beskriver flera exempel på satsningar som gäller stöd till förebyggande miljöåtgärder på nationell och internationell nivå. Ett FN-stött nätverk, National Cleaner Production Centres, lyfts fram. I nätverket ingår institutioner på nationell nivå som tillhandahåller information och pilotprogram som stöd till förebyggande miljöåtgärder. Erfarenheter från ett bilateralt hjälpprogram för förebyggande miljöåtgärder, det USA-stödda Environmental Pollution Prevention Program (EP3), tas upp. På den nationella nivån undersöks erfarenheterna från Indiens DESIRE Project, ett program som främjade förebyggande miljöåtgärder inom småskalig industri i tre sektorer. Slutligen presenteras fallet med Cleaner Production i Kina, ett framgångsrikt program som fungerat med både stora och små industrier inom en rad industrisektorer.

5. Stöd till förebyggande miljöåtgärder: möjligheter och utmaningar

I denna del sammanför vi kunskap om erfarenheter på såväl fabriksnivå som programnivå och pekar på några allmänna iakttagelser om möjligheter och utmaningar för att stödja förebyggande miljöåtgärder i utvecklingsländer. Bl.a. tar vi upp följande ämnen:

- *Ekonomiska fördelar:* Förebyggande miljöåtgärder kan vara en väg till att förbättra små företags livskraft och hjälpa dem att överleva svåra ekonomiska förhållanden. Om förhållandena är de rätta kan investeringar i miljöanpassad teknik vara självfinansierande. Många anläggningar kan ofta ha råd att genomföra förändringarna själva, utan ekonomisk hjälp från en utomstående organisation. Den sammantagna statistiken visar att framgångsexemplen på ekonomiska fördelar med förebyggande miljöåtgärder inte utgör några undantag utan snarare bildar regel i många industrisektorer.

- *Öka och överföra kunskap:* För att säkerställa att informations- och kapacitetsöverföringen är effektiv inom det ekonomiska systemet är det viktigt att ta med förebyggande miljöåtgärder i den traditionella kapacitetsuppbyggnaden av industrin, Det finns också lovande samarbetsområden bland företag, t.ex. nyskapande arrangemang som att bilda industriparker.

- *Överförbarhet:* Framgångar hos ett företag eller inom en region är inte nödvändigtvis överförbara på andra. Faktorer som hjälper till att bestämma överförbarheten är företagets storlek, den investeringsstorlek som krävs för att genomföra en förändring och de lokala kostnaderna för det råmaterial som behövs.

- *Finansiering:* Trots att förebyggande miljöåtgärder ofta betalar sig inom en så kort tidsrymd som sex månader, finns det ett enormt behov av konstruktiva finansieringsmekanismer för att snabbt få igång processen, särskilt hos små och medelstora företag som inte har säkra krediter. Partnerskap med befintlig, småskalig utlåningsverksamhet (mikrokrediter) kan vara ett lovande sätt att hjälpa de minsta företagen i utvecklingsländer att börja med förebyggande miljöteknikåtgärder.

6. Riktlinjer för framtida forskning

På basis av litteraturgenomgången av förebyggande miljöåtgärder inom ramen för ekonomisk utveckling ger vi förslag på möjliga inriktningar på framtida forskningsprojekt. Bland flera möjligheter, rekommenderar vi att undersöka möjligheterna till partnerskap med företag som ger mikrokrediter för att finansiera renare tillverkning hos mycket små företag samt att ta sig an den särskilda utmaning som ligger i att sprida information om förebyggande miljöåtgärder till regionala sammanslutningar av mycket små företag.

INTRODUCTION

Toxic chemicals are a serious threat not only to people's health, but also to national economies. Chemical exposures can cause severe damage to human health, ranging from cancers and endocrine disorders to birth defects and learning disabilities. In addition to the human suffering they cause, these exposures have economic effects. From an economic standpoint, the costs of treating environmentally induced illnesses deplete the resources of individual families and can strain the capacity of government agencies that provide health and social services. Furthermore, when fetal, infant, or childhood exposure to toxic chemicals impairs the ability of children to learn and develop normally, the long-term costs to an economy can be enormous. For all these reasons, finding ways to reduce or eliminate chemical pollution is a crucial element of the broader effort to achieve sustainable livelihoods.

In this report, we look at the ways in which developing countries can achieve economic growth without pursuing the polluting path that industrialized countries have followed. We focus in particular on the ways in which pollution prevention can support economic success among small and medium-sized enterprises.

The points we develop here are intended to be useful for industry planners, NGOs, and government. Our discussion can, in particular, serve as background for the development of environmental legislation in countries that are currently developing new environmental legislation. In light of the economic development advantages of pollution prevention, policy-makers would do well to build specific incentives for pollution prevention into their environmental legislation.

We begin our discussion, in Part 1, by exploring the importance of a healthy environment for economic development, with a particular focus on toxic chemicals. In Part 2, we present the logic of pollution prevention as a strategy to reduce or eliminate toxic exposures. Part 3 looks in detail at four industry sectors in which substantial work has been done to develop pollution prevention techniques; this discussion draws primarily on case studies that have been conducted at the individual facility level. Part 4 goes beyond facility-specific discussions, exploring the experience of selected programs that have worked to build pollution prevention capacity at the national level. Part 5 synthesizes lessons from both the case studies and the program descriptions as they apply to pollution prevention efforts in the developing world. Finally, Part 6 offers suggestions about directions for future research and action.

1. HEALTHY ENVIRONMENT, HEALTHY ECONOMY: TOXICS AND DEVELOPMENT

Many of the industrial activities that power economic development have serious environmental and health consequences. Pollution from both small and large industrial facilities has major implications for public health, as well as for the ability of developing economies to achieve their full potential.

1.1 Scope of the problem

Toxic chemicals are a worldwide problem, but their presence in developing countries presents unique challenges. The effects of toxic exposures can compound the human health consequences of inadequate nutrition. In situations where occupational health and safety standards are lax or poorly enforced, use of toxic chemicals in the work place can have particularly severe consequences for worker health, leading to a cascade of problems for families and communities. In communities with low literacy rates, tragic exposures can occur due to a lack of clear information about chemical hazards.

Compounding problems of poorly designed manufacturing facilities and inadequate legislation on chemicals and environmental protection more generally, many countries have no infrastructure for chemicals treatment, incineration, neutralization, or stabilization. This means that chemical waste is either treated and disposed of on-site, or commingled with other trash in open, unlined dumps.[1]

Developing countries have often served as the dumping grounds for substances that have been recognized as hazardous and banned for use in the developed world. Pesticides that were banned decades ago in the north continue to be sold in the south. The processing of waste electrical and electronic equipment is another case in which toxic substances flow from developed to the developing countries, with devastating consequences for public health. In China, India, and Pakistan, electronics "recycling" is associated with hazardous activities including open burning of plastics and exposure to toxic solders. Many of the workers who are exposed to these hazardous byproducts are children.[2]

The health and environmental “side effects” of polluting industrial activities can cripple communities. Economic development planning must take human health and the environment into consideration, and must ensure that poor communities are able to retain their most valuable resources: physical health, mental capacity, and biological resources. Countries that are currently engaged in the process of industrial development have the opportunity to avoid the problematic development path of the past, and to build pollution prevention into their development agenda from the outset.

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[1] Commingling of industrial chemicals with other trash is dangerous not only because it can contaminate water resources, but also because of the hazards posed to people who routinely sort through garbage for recoverable items. Kevin McDonald, Minnesota Office of Environmental Assistance, National Pollution Prevention Roundtable, and former coordinator, international Pollution Prevention Roundtables, personal communication.

[2] See Puckett, Jim et al. Exporting Harm: The High-Tech Trashing of Asia (Seattle, WA: Asia Pacific Environmental Exchange, February 2002). Available at http://www.svtc.org/cleancc/pubs/technotrash.pdf.

1.2 The human capital perspective

Human capital is generally understood to include education broadly, and technical knowledge and abilities specifically. No matter how rich its resources or how great the opportunities in the wider world, no country will progress economically beyond a certain point unless its citizens have access to education and can apply their creativity to solving new problems. Yet human health is the foundation on which human capital is built. Sick workers can increase their productivity only up to a certain point. Opening schools will raise children's level of education only if those children are able to learn. Children who are malnourished cannot learn effectively; neither can children whose brains have been affected by exposure to toxic chemicals, either in utero or during the first years of life.

Widespread notions of economic development hold that developing countries must accept a certain level of pollution in order to boost GDP. In theory, once a country has achieved a certain level of economic development, the focus can shift to improving production processes and reducing pollution. The concept of the "environmental Kuznets curve" suggests that pollution levels first rise and then fall as an economy grows. From this perspective, developing countries should worry about economic growth first, and environmental quality will follow. This hypothesis has been challenged on a number of dimensions, and is dismissed by some researchers as a statistical artifact.

Even if the statistics point to a real phenomenon – e.g. declining levels of air pollution beyond a certain point in economic development – this is a highly problematic approach to development planning. Once created, pollution is not easily removed. Many pollutants are persistent and bioaccumulative; many leave a legacy of disease or defect in the human body. Pollution that impairs children's mental and physical development runs directly counter to the goals of economic growth as well as being directly contrary to the goals of an equitable, ethical and sustainable society.

1.3 The natural capital perspective

Similarly, natural capital is affected by chemical pollution. To name one example, fish are a valuable source of protein and other nutrients for many communities. Persistent, bioaccumulative chemicals have contaminated aquatic resources in much of the world, making fish unsafe to eat in many places. In relatively wealthy countries, people can usually choose to avoid fish; in the US, for example, pregnant women are counseled to avoid a number of specific fish species. Even in a wealthy community, this is an enormous problem, both because information is not widely available on hazards of eating fish, and because people are deprived of this otherwise very healthy food source. In a poor community, however, a pregnant woman cannot necessarily choose to forgo fish without losing a vital source of protein for the developing fetus.

1.4 Costs of human illnesses

A substantial literature exists on the economic costs of avoidable toxic exposures. Here, we briefly present the work of economists and physicians who have estimated the economic costs of illnesses that are associated with avoidable chemical exposures. These costs include direct treatment costs as well as the costs of children's school days missed, parents' work days missed, and future income foregone due to impaired brain development. Costs of occupational exposures that make people sick include costs of treating, compensating, and retraining workers, as well as of work days missed.

In the US, a recent study looked at the costs of children's illnesses associated with environmental exposures. A team of researchers estimated costs for four categories of childhood illness that have been linked to environmental factors: cancer, asthma, neurobehavioral disorders, and lead poisoning.[3] The researchers looked at the costs of treating and managing the disorders, including physician visits, hospitalizations, medications, special equipment to transport disabled children, and income foregone by parents who must stay at home to care for their disabled children. They also estimated foregone future earnings of children whose ability to learn was impaired by illness. They then calculated what they called an "environmentally attributable fraction" (EAF) for each category. The EAF represents the estimated percentage of cases that are caused by environmental factors.[4] For example, the EAF for asthma among children in the United States was estimated in the range from 10% to 35%. Using these figures, they calculated the total cost of avoidable, environmentally induced children's illnesses in the US. Total costs were estimated at around US $55 billion per year (between 2 and 3 percent of total US health care costs).

Important work has also been done on defining the costs to employers of occupational illnesses. For example, one recent study looked at the costs of certain occupational illnesses in Germany, working from data provided by the industrial employers' liability insurance associations.[5] The costs faced by these associations provide a window into the magnitude of costs associated with avoidable occupational hazards in a developed country. One of the cases examined is that of cement dermatitis, a disease caused by exposure to hexavalent chromium compounds (chromates) in cement.[6] Over all, the study estimates compensation costs for skin diseases and asthma caused by occupational chemical exposures at €275 million in Germany. Interestingly, the cost of work days missed is estimated at about the same magnitude, likely doubling the total cost to employers.[7]

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[3] Philip J. Landrigan et al., "Environmental Pollutants and Disease in American Children: Estimates of Morbidity, Mortality, and Costs for Lead Poisoning, Asthma, Cancer, and Developmental Disabilities." Environmental Health Perspectives 110: 7 (July 2002), 721-728. Available at http://ehpnet1.niehs.nih.gov/members/2002/110p721-728landrigan/EHP110p721PDF.PDFs

[4] In this study, the researchers applied a restricted definition of the word "environmental," using it to mean *only* "chemical pollutants in the ambient environment." Thus, their EAFs do not include factors that are under individual control, such as diet, exercise habits, or use of tobacco, alcohol, or drugs. (Landrigan et al. 2002: 721-2)

[5] Reinhold Rühl, Niddatal and Henning Wriedt, "An Assessment of the Benefit of REACH," 2004.

[6] Rühl et al. 2004, p. 9.

[7] Rühl et al. 2004, p. 10.

These studies, among others, make it clear that the failure to prevent toxic exposures has enormous economic effects in terms of direct and indirect costs of illness. These costs are borne by families, communities, government agencies, and industry, and in the aggregate they constitute a major drain on social resources.

2. THE LOGIC OF POLLUTION PREVENTION AND CLEANER PRODUCTION

Pollution control, including end-of-pipe measures, is a crucial component of ensuring a healthy environment. However, pollution prevention offers opportunities to achieve even better environmental results in some instances, and to gain economic advantages at the same time. Ideally, environmental regulations, government assistance programs, and industry training resources should be designed to facilitate adoption of pollution prevention approaches.

The formal development of the pollution prevention concept began in the United States, and much of the early writing on the topic was done in the US context. This includes both statements of the theory of pollution prevention, and development of "success story" case studies at the individual facility level.

Definitions: Pollution Prevention and Cleaner Production

The terms Pollution Prevention and Cleaner Production are often used interchangeably, and we do so in this report. However, there are subtle differences between the terms when they are defined formally. The following information on definitions is drawn from an overview by the United Nations Environment Programme.

Pollution Prevention
The US Environment Protection Agency (EPA) defines Pollution Prevention as preventing or reducing waste at the source, "including practices that conserve natural resources by reducing or eliminating pollutants through increased efficiency in the use of raw materials, energy, water and land."[8]

Cleaner Production
The United Nations Environment Programme has adopted the following definition of Cleaner Production.[9] "Cleaner Production is the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency, and reduce risks to humans and the environment. Cleaner Production can be applied to the processes used in any industry, to products themselves and to various services provided in society."

"For production processes, Cleaner Production results from one or a combination of conserving raw materials, water and energy; eliminating toxic and dangerous raw materials; and reducing the quantity and toxicity of all emissions and wastes at source during the production process. For products, Cleaner Production aims to reduce the environmental, health and safety impacts of products over their entire life cycles, from raw materials extraction, through manufacturing and use, to the 'ultimate' disposal of the product. For services, Cleaner Production implies incorporating environmental concerns into designing and delivering services."

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[8] UNEP Cleaner Production Website:
http://www.uneptie.org/pc/cp/understanding_cp/related_concepts.htm#3, viewed August 2005.
[9] UNEP Cleaner Production Website:
http://www.uneptie.org/pc/cp/understanding_cp/home.htm#definition, viewed August 2005.

2.1 Pollution Prevention: how it works

Traditional pollution control may include such activities as installing scrubbers on smokestacks, operating a water purification system to clean dirty effluent as it leaves a facility, or disposing of hazardous wastes in a specially designated landfill or other waste storage or treatment facility. Pollution prevention, in contrast, examines the causes of pollution and explores options to change production processes and inputs to eliminate or reduce that pollution.

In addition to its benefits for environmental quality and human health, pollution prevention can be an excellent way to cut costs, because it often increases efficiency and reduces the total volume of inputs required.[10] Pollution prevention audits often allow facilities to identify areas of inefficiency in their production processes, such as loss of raw materials through leaks and fugitive emissions, or disposal of materials that could be used productively. In addition, the pollution prevention audit process sometimes has broader benefits for the facility in terms of improved communication among workers and management, increased knowledge of shop floor conditions by managers, and better worker health.

Substitution of safer chemicals or processes in place of highly toxic ones can be a key component of pollution prevention measures. Substitution does not necessarily refer to dramatic new inventions; rather, substitution can be a common-sense process of using one well understood ingredient or process in place of another.

For example, eliminating use of toxic solvents for cleaning metal parts can be as simple as making sure that metal products are kept clean throughout the production process. The Association of Swedish Engineering Industries carried out a campaign in the 1990s to introduce a management concept of “keeping goods clean from the start.” In this approach, manufacturing activities involving metal parts or products are designed to keep the metal parts clean throughout the process, avoiding the need for degreasing agents. In the industries targeted by this project, use of degreasing agents has largely become obsolete.[11]

Pollution prevention and pollution control are tools that can be implemented side by side. Both have a role to play; they are not necessarily in competition with one another, especially in situations where a facility already exists and is working to decrease its environmental impact. However, in designing industrial development and investing in future facilities, it makes sense to prioritize pollution prevention explicitly, encouraging its adoption wherever possible.

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[10] In some instances, the goals of energy conservation and toxics use reduction may be at odds with one another; for example, increased mechanization may increase energy use while allowing decreased use of toxic chemicals.

[11] Torbjörn Lindh, Swedish Chemicals Inspectorate, personal communication.

Methods for Pollution Prevention

A few of the simple strategies in the pollution prevention toolbox include:

Good housekeeping: Pollution prevention can be as simple as closing leaks, identifying and eliminating fugitive emissions, and cleaning up spills.

Equipment modification: Low-tech changes in equipment can eliminate hazards from accidental mixing of incompatible chemicals (chemicals that may react with one another in dangerous ways) or allow more efficient use of inputs.

Recovery and reuse of raw materials: Pollution prevention often enhances production efficiency. There are many options for reducing pollution simply by reusing chemicals, rather than discharging them in wastewater. Care must be taken to avoid dangerous occupational exposures in the course of raw materials recovery and re-use; closed loop systems are preferable.

Substitution: Often, an alternative input can be used in place of a toxic chemical. In other instances, changing production processes can eliminate the need for a toxic chemical.

2.2 Making fresh choices: beyond path dependency

Many of society's important economic and technological choices are path dependent. A technology that gains a slight lead early in its history may solidify that lead by gaining market share and lowering prices, "locking out" other technologies that might be equally or more efficient if adopted on a large scale.[12] By this principle, many industries use unnecessarily dangerous materials or technologies simply because this is the way the industries first developed. The fact that a certain material or technology is used widely does not necessarily indicate that it is ideally suited for the uses in question. It may simply mean that this material or technology enjoyed an initial advantage that "locked it in" as the material or technology of choice in the future.

Strategic interventions can be particularly important in overcoming the artificial advantage gained by certain materials and technologies through path-dependent development. The goal of pollution prevention is to break the hold of path dependency and to make good choices about how to design industrial development. Thus, it is particularly important to consider pollution prevention options in the course of designing a strategy for new industrial development.

[12] Brian W. Arthur, *Increasing Returns and Path Dependence in the Economy* (Ann Arbor: University of Michigan Press, 1994).

2.3 Pollution prevention for SMEs

Small and medium-sized enterprises (SMEs) play a particularly important role in industrial development. SMEs can be established without very large initial capital investments, and can respond flexibly to changing demands of the marketplace.

SMEs can also create significant pollution. Solving production problems at SMEs poses special practical problems, including difficulties of disseminating information to large numbers of small facilities, and poor access to credit. SMEs generally operate on tighter profit margins and with less access to reserve capital than larger enterprises. For this reason, the financial benefits of pollution prevention efforts can be particularly significant for SMEs. Thus, part of the logic of introducing pollution prevention in a development context is that crucial health benefits can be achieved through measures that also improve the viability of small businesses.

2.4 What we know now: elements of a concrete agenda

Some chemical threats to human health and the environment are well understood. We have ample epidemiological and toxicological information showing the hazards of certain chemicals, and we know that practical alternatives to these chemicals exist. Current knowledge about these chemicals can serve as a point of departure for programs to reduce chemical risks, whether at an individual company or at a national level. There may also be scope for focused research initiatives on the options for eliminating certain categories of toxics.

Toxic metals are one clear priority area for intervention. Lead and mercury have long been recognized as potent neurotoxicants; in recent decades, scientists have documented adverse effects at increasingly low levels. Chromium compounds, used in industries such as leather tanning, metal plating, and paint manufacture, are major water pollutants; hexavalent chromium is a potent carcinogen.

Exposure to organic solvents, such as toluene, trichloroethylene, and xylene, during critical stages of fetal, infant, and child development can cause a range of problems ranging from birth defects to learning disabilities. Organic solvents are used to clean metal products, and in dyeing and finishing of textiles, among other areas. In many cases, alternatives are readily available. Halogenated organic compounds are another growing area of concern in industrialized countries.

Other important pollution problems can include discharge of effluent containing large amounts of organic material, killing aquatic organisms and making water unfit for human consumption. Tanneries and textile facilities, for example, often discharge large amounts of organic material into waterways; while this is not a chemical problem per se, it is a serious environmental and human health problem that can be addressed as part of a program focused primarily on chemical hazards. Contaminated water may also be used for irrigation and aquaculture and as drinking water for domestic animals, producing additional problems.

Advantages of Pollution Prevention

The following list shows some of the advantages that the pollution prevention can offer as an alternative to traditional pollution control options. Of course, pollution prevention and pollution control are complementary approaches. It is often necessary to employ elements of both methodologies.

Pollution Prevention	Pollution Control
Reduced raw material purchases in some cases	No change in raw material purchases
Reduce or eliminate hazardous waste	Remove, store, or treat hazardous waste
Upgrade or add equipment to increase efficiency	Add new equipment to capture pollutants
Boost efficiency in some cases	No change in process efficiency
May eliminate need for protective equipment	Protective equipment for workers may be needed
May reduce monitoring needs	Monitor discharges, air quality, etc.
Can reduce operating costs	Often increases operating costs

3. INDUSTRY PORTRAITS

As government agencies, businesses, universities, and nongovernmental organizations have worked to advance the cause of pollution prevention, they have generated case studies of their efforts. Taken as a group, these case studies offer a rich picture of pollution prevention efforts in a range of contexts and industries. In the following sections, we provide a portrait of selected industries that have been the target of multiple cleaner production efforts. As policy-makers and others work to design optimal environmental legislation, it can be useful to bear in mind the examples we see here, and to design legislation that will facilitate adoption of pollution prevention measures in these and other industries.

3.1 Introduction to the case studies

Case studies are available from sources including the United Nations, governmental and nongovernmental agencies, and academic analyses. Both the United Nations Industrial Development Organization (UNIDO) and the United Nations Environment Programme (UNEP) have developed databases of cleaner production case studies; most of the examples we discuss below are drawn from these databases. In addition, bilateral aid programs and individual country, state, and regional programs have compiled their own collections of case studies. (For more detail on the information in the UN databases in particular, see the Appendices.)

Among the important industries discussed in pollution prevention case studies are auto repair shops, tanneries, textile facilities, printing, metalworking, and metal finishing. Each of these industries could be the subject of a report in its own right. Rather than attempt an equal discussion of each industry, we look at a few selected areas: metal finishing and plating, tanneries, textile facilities, and artisanal gold mining. In the first three of these areas, cleaner production investments at the facility level have frequently proven to pay for themselves quickly. In the fourth area, artisanal gold mining, available documentation is different, focusing more on community-wide economic conditions and environmental impacts.

It is important to note that small-scale industrial pollution prevention case studies are just one window on the pollution problem in developing countries. For example, the health, environmental, and economic development issues associated with use of agricultural chemicals are not discussed in these case studies. Pesticide exposure is responsible for widespread harm to human health. Leaded gasoline, of course, has been another major threat to children's development in many parts of the world.

Finally, while this report focuses primarily on small and medium sized enterprises, this focus should not obscure the fact that enormous damage results from the activities of large domestic and multinational corporations. For example, nothing in this report addresses the environmental and health problems that result from oil exploration and extraction in developing countries. It is important not to lose sight of the role played by large polluters, even when developing policy aimed at helping small producers to reduce their contribution to pollution.

3.2 Metal finishing and plating

Metal finishing and plating can pollute water sources with chromate and hexavalent chromium -- both carcinogens -- as well as with other toxic metals including lead, cadmium, nickel, zinc, silver, and copper. Lead is a potent neurotoxicant, and fetal, infant, or childhood exposure damages the developing brain; cadmium is toxic to the kidneys and lungs. Plating baths often contain cyanide, a potent poison. In addition to the hazards associated with the actual plating process, hazardous chemicals are often used to prepare metal for plating. Toxic solvents may be used to clean the metal before plating, and dust from mechanical cleaning operations can pose respiratory health hazards.

A range of options exists to reduce pollution in metal finishing operations. For example, using water more efficiently can significantly reduce water use volume. Some companies have adopted counter flow and cascade rinsing systems; both of these are simple process modifications that minimize water use.[13] Others reduce water use by re-using solutions. Conserving water, however, does not necessarily translate into decreased use of toxic chemicals. Reducing total use of toxic chemicals can be achieved either by making existing processes more efficient, or through substitution. For example, one large metal plating company in the US installed automated metering equipment that allowed it to reduce the total amount of chemicals used to neutralize acid wastes.

A large number of case studies have been written on cleaner production interventions at metal finishing and plating facilities. Among several databases, there are more than 100 detailed case studies of cleaner production efforts at metal finishing and plating facilities. These case studies document at length the fact that the financial benefits can be achieved through cleaner production interventions in metal finishing operations. Here, we look at two sample case studies, one from a medium-sized company with around 200 employees and the other from a very small company.

A 1993 case study looks at the experience of PT Dharma Polimetal, an electroplating company in Indonesia with 199 employees. Hazardous waste produced by the facility included nickel sulfate, nickel chloride, chromic acid, and sulfuric acid. The facility undertook a number of cleaner production measures. One important measure was to reduce “drag out volume” – that is, taking care not to “drag” excessive amounts of solution from one chemical bath to another, as a piece of metal is moved from one solution to the next. This is accomplished simply by moving items more slowly from one bath to the next, so that the solution can drip off before the item is moved. This approach reduces cross-contamination among baths, so that each bath can be used for a longer period of time. Other changes included reducing the velocity of rinse water to reduce total water consumption; setting up a countercurrent rinsing system, again to conserve water; and heating the chrome bath overnight to extend the life of the solution.

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[13] Descriptions are available in a facility-specific case study available at http://es.epa.gov/techinfo/facts/eastside.html.

The case study includes detailed information on the costs and financial benefits of the cleaner production interventions that were undertaken. As shown in **Table 3.1**, total expenditures were around US $1,300, while total savings were more than US $15,000.[14] A couple of points are worth noting in looking at these figures. First, nearly half the savings were achieved with no expenditure at all: reducing drag-out volume and certain reductions in rinse water use were achievable in this instance without any new equipment. Second, even the largest line item (reducing chlorine drag-in to the chrome bath) cost less than US $1,000.

Table 3.1: Cleaner Production Costs and Savings: PT. Dharma Polimetal, Indonesia

Cleaner Production Measure	Cost (US $)		First year financial benefit (US $)	
Reducing drag-out volume	$	-	$	5,565
Reducing rinse water use	$	-	$	1,685
Improvement of cascade rinse system	$	90	$	73
Reducing chlorine drag-in to chrome bath	$	806	$	8,312
Addition of anodes to improve product quality	$	318		*
Energy conservation	$	126		**
Totals	**$**	**1,340**	**$**	**15,635**

Source: BAPEDAL, *Cleaner Production in Indonesia, reproduced at* http://www.emcentre.com/unepweb/tec_case/

* benefits included in other line items
** expected benefits from increased production capacity, not quantified

Another case study, completed in 2002, looks at the experience of Msasa Plating, an electroplating facility in Zimbabwe with just eleven permanent employees.[15] The facility electroplates a variety of items with zinc. Problems at the facility included high water use and discharges of highly polluted waste water, including cyanide and heavy metals, into the municipal sewer.

An initial assessment in 2000 identified a set of no-cost and low-cost cleaner production options for the facility, most of which the company was able to implement. In a second phase, higher cost options were identified. The entire electroplating process was carried out manually, making it difficult for workers to allow sufficient dripping time after

[14] Figures converted from Indonesian rupiahs to US dollars at 2005 rates without inflation adjustment.
[15] H. Anyway Munjoma, "Msasa Plating Ltd: Report of the Cleaner Production Demonstration Project: Installation of a Semi Automatic Electroplating Rack System." (January 2002). Cleaner Production Project Report produced through a joint project between Zimbabwe and DANIDA. Available through UNIDO at https://www.unido.org/NCPC/ReportTexts/NCPC00001017.pdf.

plating. This led to rapid contamination of the post-plating baths, and consequent waste of raw materials. The cleaner production assessment determined that this problem could be solved through installation of a semi-automatic electroplating rack system, combined with a counter-current rinsing system.

Msasa Plating partnered with the Danish international aid organization, DANIDA, to solve this problem. DANIDA and Masasa Plating each invested about US $22,000, for a total of US $44,000. For this cost, the company was able to move its operations to a new, more spacious location, and install sixteen new tanks allowing the use of two cranes to move items from one bath to another, avoiding spills and allowing appropriate dipping and dripping times.

The case study provides a materials balance analysis showing materials use and waste before and after the installation of the semi-automatic system. The new system allowed the facility to reduce its waste water by a third, cyanide waste by 25%, chromium (III) waste by nearly a fifth, chromium (VI) waste by a third, and zinc waste by half. Complete elimination of these toxic metals would be even better, of course, but these changes represent a significant reduction in total water pollution produced by the facility.

Financial benefits to the company included a significant reduction in manual labor requirements; [16] increased efficiency of production; improvement in the quality of final products; and a greater than 40% reduction in chemical costs due to decreased drag-out of chemicals from one bath to another. Total annual savings are calculated at US $12,000, implying a payback period of about three and a half years.[17]

The Msasa Plating case differs from the Dharma Polimetal case in that it involved a substantial investment, and it took several years to produce financial benefits equal to the initial investment. In this instance, funding was provided by an aid agency (DANIDA) but a domestic actor could just as well have provided it. When political conditions make it possible, one useful approach can be for a government agency to levy a fee on use of certain toxic substances. This fee can then be used to finance assistance programs to help companies purchase new equipment that allows them to reduce their use of toxic chemicals, and to develop demonstration projects at individual facilities. (We discuss this option further below, when we present the case of the Toxics Use Reduction Act in Massachusetts, in section 5.)

[16] Any intervention involving automation can potentially lead to job loss, complicating the picture. According to this case study, the employees whose labor was no longer required in the electroplating process "are now involved in other activities at the company." The case study also states that "the production capacity of the plant has increased and more jobs are going to be created in the near future." It cannot be determined from reading this case study whether this prediction was accurate, or merely optimistic.

[17] The case study states that the payback period is "less than 32 months"; however, with savings of $12,000 per year, it would take about 3.7 years to recover these funds.

Exact Springs: A Case Study in Creative Solutions

Adapted from a report by Jan Govella, environmental consultant, translated by the Swedish National Chemicals Inspectorate, October 1999.

The Exact Springs company in Sweden manufactures metal springs for use in door locks, staplers, and electric switches. The company has 40 employees, and its annual turnover is about €3 million per year. For many years, the company used a large number of chemicals, including greasing oils, solvents, and others. In 1996, the management decided to reduce the company's environmental impact. The company hired an environmental consultant, who developed more than sixty proposals for production changes. As a result of pursuing just a few of these proposals, the company dramatically reduced its environmental impact, and achieved major financial savings at the same time.

Eliminating Trichloroethylene
One major goal was to find a way to clean the metal springs without using trichloroethylene, a toxic chlorinated solvent used to clean metal parts in many industries. Sweden has adopted a ban on trichloroethylene, effective for professional users as of 1996.

After exploring a variety of alternative chemicals, the company asked a broader question: Why do the springs need to be washed at all?

It turned out that most washing was unnecessary. Sometimes the springs were not really dirty; in other cases, the springs had become dirty or greasy unnecessarily, and could be kept clean through simple changes earlier in the production process.

After coming to this realization, within a year the company was able to achieve a 90% reduction in its use of trichloroethylene. After this change, only 2% of the springs ever had to be washed; this was done in a supersonic machine, which did not require use of hazardous chemicals. Today, the company does not wash any of its products, as all are kept clean throughout the production process.

Eliminating Anti-Corrosive Agents
Traditionally, the company had sprayed anti-corrosive agents into the boxes where the completed springs were stored. This posed occupational hazards, causing eye and skin irritation as well as respiratory problems among the workers.
The solution was as simple as it was ingenious. By chance, the environmental consultant found a roll of anti-corrosive paper. Putting this paper at the top and bottom of each box prevented corrosion without any toxic exposures. Goods can safely be stored for years when protected in this way.

Financial Benefits
Through these two creative solutions, Exact Springs significantly reduced its environmental impact and improved working conditions for all its employees. In addition, the company achieved financial benefits, saving more than US $13,000.[18]

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[18] SEK 100,000 converted at 2005 rates, without inflation adjustment.

3.3 Tanneries

Leather tanning can pose severe environmental and human health problems. The discharge of large amounts of organic material in the form of hair and even flesh stripped from animal hides can severely pollute waterways. In addition, wastewater from tanneries often contains large amounts of sulphides and toxic metals such as chromium. In some countries, groups of tanneries create enormous amounts of water pollution, threatening the health of tens of thousands of people who use that water. In Pakistan, for example, a study estimated that 50,000 to 60,000 people were at risk of harm from contaminated water from one group of tanneries, in the town of Kasur.[19]

Most of the tannery case studies discuss "first order" interventions -- production changes that mitigate particularly large and clearly avoidable sources of pollution. For example, options include system changes that reduce total organic material discharged into waste water. Some tanneries remove the hair from hides by dissolving it chemically. This process produces particularly high water pollution with organic material. Through substitution, tanneries can adopt a process in which a chemical is used simply to remove the hair from the hide without dissolving it; the hair can then be easily filtered out of the wastewater. Other common options include segregation of waste streams to prevent mixing of incompatible chemicals, and adjustments to allow more efficient use of chromium and other chemical inputs.

Tanneries may be relatively small facilities, with fewer than fifty employees, or may have several hundred employees. As shown in **Table 3.2**, case studies of cleaner production efforts at tanneries in developing countries document a range of expenditures, some very small and others more substantial. Here we look at four sample case studies: two small facilities in Latin America, one that carried out cleaner production options successfully, and another that chose not to do so; and two facilities in Africa, one medium-sized and the other small.

[19] United Nations Development Programme (UNDP) project description: Kasur Tannery Pollution Control (KTPC). Available at http://www.soc.titech.ac.jp/~sakano/atiq/kasur/ktwma.html, viewed May 2005.

Table 3.2: Cleaner Production at Tanneries: Sample Investments and Savings

Facility	Cleaner Production Interventions	Investment	Savings
San Miguel Tannery, Guatemala	Reduction of sodium sulphide use by changing process formulation; reusing liquor; improved chromium fixing; reduction of drying time.	$659	$10,294
Societe Moderne des Cuirs et Peaux, Tunisia	Reduction of chromium use; recycling of black dye solution; raising temperature and controlling pH of tanning baths; segregating waste waters to eliminate sulphide generation.	$25,000	$98,000
Tannery in Tunisia (name not given)	Recycling used chromium effluent; recycling black dye solution; segregating liming and washing waters to eliminate sulphide generation; raising temperature to increase chromium fixation.	$20,000	$50,000

Sources: United Nations Environment Programme;
United Nations Industrial Development Organization.

Some case studies document large financial benefits resulting from small investments. Options of this kind have the potential to improve the financial viability of small businesses. For example, San Miguel tannery in Guatemala, a small facility with about forty employees, processes cow, sheep, and alligator skins.[20] The facility tans these hides either with vegetable tanning agents, or with chromium. A cleaner production assessment at this facility identified problems including unnecessarily high chemical use to remove the hair from the hides, and discharge of waste water containing chromium (III). A series of cleaner production options were implemented for a total investment of only US $659, leading to annual savings of $10,294. Thus, savings achieved were more than fifteen times as great as the initial investment; furthermore, the initial investment was small by any measure.

In contrast, a case study of another tannery in Guatemala, Tenería Guatemala, describes a cleaner production audit whose recommendations were *not* carried out. In this case, the investments recommended would not have produced significant immediate savings; it would have taken eight years for the total package of CP recommendations to pay for itself. However, even within this audit a couple of possible interventions were identified for which savings would have exceeded costs.[21]

[20] https://www.unido.org/NCPC/ReportTexts/NCPC00008045.pdf
[21] It is possible that this company had fewer prospects for easy pollution prevention than others because it starts the tanning process from "wet blue" hides, and thus has a lower environmental impact than other

Imponente Tanning, in Zimbabwe, employs 200 people and has an annual turnover of US $10 to $15 million, with profits of $1 to $2 million. In this instance, government regulation played a role. The facility was in violation of municipal regulations due to the high chemical oxygen demand (COD) levels in its wastewater. The solution was to adopt a new chemical recipe for the unhairing process, and to use a compacting filter for hair recovery. The case study states that the company achieved significant savings through adoption of this new system.

A case study from Tunisia[22] looks at the case of a tannery, Société Moderne des Cuirs et Peaux (SMCP), that employs 45 permanent and 30 seasonal workers. Pollution problems at the facility included chromium pollution, sulphide pollution, and "inefficient use of dye chemicals." A cleaner production assessment identified four options for achieving both environmental and economic benefits: recycling chromium effluent to reduce chromium discharge into waste water; recycling used black dye solution; raising the temperature and controlling the pH of the tanning baths to increase efficiency of chromium use; and segregating the liming and washing waste waters, to eliminate generation of sulphides. All of these interventions required some investment in new equipment or systems, although in some cases the initial investment required was small compared with the savings that would be achieved in the first year. The entire undertaking was estimated to cost US $25,000, and was expected to yield annual savings of $98,000, or nearly quadruple the amount invested. Interestingly, reducing chromium pollution was expected to be particularly cost effective, requiring a total investment of $5,000 and yielding an expected savings of $42,000. It is worth bearing in mind that even where a full cleaner-production overhaul looks too expensive to undertake, there may be interventions that can significantly reduce pollution and yield considerable savings.

Tannery Clusters

Looking at the isolated examples of pollution prevention of individual facilities is not necessarily sufficient to understand the complex interactions among pollution prevention, public health, and economic development. For a deeper understanding of the interplay among these factors, here we look in more depth at the situation of small tanneries in Pakistan, where large clusters of very small tanning facilities are a major pollution source.

The leather industry in Pakistan is a major exporter of manufactured goods.[23] Some 600 individual tanning facilities are grouped in four principal clusters in the municipal areas of Kasur, Sialkot, Korangi/Karachi and Lahore. The facilities in Korangi/Karachi are medium sized; in the other areas, most are small, family-operated businesses.[24]

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tanneries. Therefore, there may have been less "low hanging fruit" (easily identified and implemented changes) to be addressed at this facility.

[22] Case study available at http://www.emcentre.com/unepweb/tec_case/, viewed June 2005.

[23] "Sustainable Development in the Coastal City of Karachi: The Links between Conservation and Industry in Pakistan" December 2004. Available at http://casestudies.lead.org/index.php?csid=11&PHPSESSID=b0f2dfa900bd96987cfd117152f55ab0, viewed June 2005.

[24] Ferenc Schmel, Senior Industrial Development Officer at UNIDO, personal communication, June 2005.

The tanneries discharge organic waste including hair and decaying carcasses, as well as toxic chemicals, into local water sources. Chromium pollution is a particular concern. A 2002 article noted that in Kasur, chromium pollution levels in water were several times as great as the World Health Organization standard for allowable levels of chromium in water.[25] In another town, researchers collected water samples from people's homes near the tanneries and determined that the water was not safe for human consumption; these residents had no choice, however, about whether to continue using the water.

A number of projects have worked to address these problems. In Kasur, home to a cluster of 240 small tanneries, the government of Pakistan collaborated with UNDP and UNIDO on a joint initiative, the Kasur Tanneries Pollution Control Project (KTPCP). Completed in 2001, the project aimed to "contain and reduce environmental deterioration caused by tannery waste," "improve the tanners' existing inadequate technical and managerial skills in tanning operations," and "promote environmental awareness" among tanners.[26]

The project has worked to solve the pollution problem in Kasur through a combination of pollution control and pollution prevention approaches. Perhaps most important has been the construction of a common effluent treatment plant (CETP) and a solid waste disposal site. As of 2005, the town now has a chrome recovery unit that can be used by all facilities; in addition, water meters have been installed in all the tanneries, allowing tracking of their water consumption. An effluent collection channel moves effluent from all tanneries to the common effluent treatment plant. An effluent testing laboratory tracks levels of pollution in wastewater.

Most of the project objectives have been achieved; as of 2005, "no tannery effluent is penetrating into the soil," and "solid waste is collected and properly disposed."[27] A project leader at UNIDO observed that while pollution prevention is important, it is not sufficient to solve the problems that were faced in Kasur:

> Introduction of cleaner production techniques is essential, but alone cannot result in meeting discharge standards.[28]

The project leader observed, further, that wherever small and medium sized tanneries are grouped in a cluster within a limited geographic area, creation of a common effluent treatment plant is likely to be a good solution. End-of-pipe solutions of this kind are necessary because "not all pollution can be eliminated in the leather processing itself." It is also worth noting that pollution prevention does not always have to happen at the individual facility level: chrome recovery from collective effluent can also help to reduce total chrome pollution.

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[25] Equator Initiative overview, November 2002, available at www.tve.org/ho/doc.cfm?aid=899&lang=English, viewed June 2005.
[26] UNIDO, *Kasur Tannery Pollution Control Project*, description available at http://www.unido.org/Data/Project/Project.cfm?c=6236, viewed June 2005.
[27] Schmel, personal communication, June 2005.
[28] Schmel, personal communication, June 2005.

In summary, pollution prevention is an important element of solving problems at tanneries, but especially where large numbers of small facilities are concerned, it is also important to consider end-of-pipe solutions.

3.4 Textiles

Textile production is one of the world's largest industries in terms of output and employment. Facilities range in size from large mechanized factories to small household operations. Textile facilities can release effluents that are hot, alkaline, and contain toxic dye metals; they may also contain large amounts of organic material, such as fibers and grease, or toxic metals such as zinc, copper chromium, lead and nickel. Organic compounds commonly found in textile facilities include toluene, ethylbenzene, chlorobenzene, naphthalene, phenol and others.[29]

For all of these reasons, textile facilities can wreak havoc on water resources, killing aquatic life and making the water unsafe for human use. Other problems at textile facilities can include air pollution, especially with volatile organic compounds (VOCs). Occupational hazards at textile facilities include exposure to fumes from dyeing and finishing agents, exposure to oil mists created by machines within a facility, and hazards from direct handling of toxic chemicals during production. Air pollution in and around textile facilities include oil and acid mists; solvent vapors (including a range of toxic chemicals used in dyeing and finishing, such as chlorobenzene, hexane, and styrene); odors; and dust and lint.[30]

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[29] UNEP, *The Textile Industry and the Environment* (UNEP technical report, 1993), p. 39, citing Environment Canada, *Environmental Assessment of the Canadian Textile Industry* (1989).
[30] UNEP, *The Textile Industry and the Environment* (1993), pp. 17, 42.

Small-Scale Textile Production in India:
Uncontrolled Water Pollution

Adapted from Anil Agarwal, "Dilemma in the developing world: small-scale industries drive India's economy, but pollute heavily," Centre for Science and the Environment.[31]

Small-scale industry in general is a major driver of the Indian economy, accounting for some 40% of total industrial production. Small-scale industries are also responsible for large amounts of pollution; they are responsible for an estimated 40% of total industrial wastewater in the country.

Textile dyeing facilities are one major source of water pollution. Clusters of dyeing facilities, along with the facilities that produce dyes or their components, have caused widespread contamination of groundwater and surface water. In one village, flooding during the monsoon season turned all the wells black with dyes.

To a large extent, these industries avoid regulatory oversight. No license is required to operate a small facility in cities where the population is under one million. Larger cities have some regulatory controls, but they are difficult to enforce.

The pollution not only contaminates drinking water, but also threatens agricultural production. In one region, farmers have filed suit against dyeing and bleaching units that have virtually destroyed their source of irrigation water.

Cleaner production interventions help companies to cut costs by conserving expensive chemicals, among other opportunities. These interventions can include upgrading of existing technology, adoption of new technologies, and adoption of safer substitutes to hazardous chemicals. An overview of the textiles industry by the UN Environment Programme notes that replacing existing equipment with new equipment can often be cost effective, with a short payback period.[32]

Some textile facilities have achieved substantial savings through cleaner production interventions that required a relatively small investment. Some case studies also describe problems that have arisen in the course of cleaner production interventions.

For example, the Phuoc Long Textile Company in Vietnam is a large textile mill with more than 1200 employees plus almost an equal number of contract workers. The company produces a range of synthetic and natural fabrics and includes facilities for

[31] Anil Agarwal, "Dilemma in the developing world: small-scale industries drive India's economy, but pollute heavily. What can be done?" (Centre for Science and the Environment). Essay available at http://www.siwi.org/downloads/WF%20Articles/WF%20Small%20Scale%20Industry.pdf, viewed June 2005.

[32] UNEP, *The Textile Industry and the Environment* (1993).

weaving, knitting, and wet processing of fabrics. Effluent from the facility contains high levels of dyes and other chemicals. A cleaner production audit at this facility identified 33 feasible cleaner production measures, of which 19 had been implemented at the time the case study was written. The total investment was US $4,400 while direct cost savings amounted to $40,000.

This case study appears to be a success story. Costs are just a few thousand US dollars for a plant with more than a thousand employees, and savings are ten times as large. However, the case study also describes production, management, and personnel problems that arose during the assessment and intervention. The case study notes that the project encountered some barriers in both the assessment and the implementation phases of the project. For example, baseline data were not collected appropriately to allow tracking of financial and environmental progress. In addition, loss of personnel part way through the process made it difficult to track progress. Interestingly, company management preferred adopting new technologies rather than improving existing equipment; this may have led to some inefficient choices.

The authors of the case study note that the effort to adopt cleaner production processes at Phuoc Long ran into difficulties in part due to a recession in the textile industry. However, the authors suggest that cleaner production interventions can actually be a strategy for surviving difficult economic conditions, because they can produce significant savings, often without a large up-front investment.

Another interesting case study is that of a cleaner production project for a group of textile companies in Brazil.[33] This case study looks at the experience of relatively large textile manufacturers.

The National Industrial Learning Center/Center for Technology for the Chemical and Textile Industry (SENAI/CETIQT)[34] in Brazil is a school and technology centre for the textile industry. It has carried out a number of pollution prevention projects. UN-supported programs have allowed the centre to establish a colorimetry laboratory and to provide technical assistance to a number of textile dyeing and printing companies, helping them to adopt new technologies.

The case study notes that dyeing and printing fabrics (including preparing the fabrics before dyeing, and finishing them afterwards) are the processes associated with the most pollution:

> Dyes, polymers, sizes, surfactants and other chemical products are discharged which are difficult or even impossible to biodegrade. The basic approach of the technical assistance projects has therefore been to introduce advanced techniques and technologies to reduce

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[33] "Optimizing Textile Dyeing and Printing Operations in Brazil" (no date given). Technical case study included in UNIDO, *Cleaner Industrial Production* and edited for UNEP's ICPIC diskette in 1998. Available from the Environmental Management Centre at http://www.emcentre.com/unepweb/tec_case/.

[34] Serviço Nacional de Aprendizagem Industrial/Centro de Tecnologia da Industria Química e textil.

the amount of polluting material at the source rather than to suggest end-of-pipe treatment.[35]

Cleaner production options at these facilities included optimizing existing processes (e.g. making sure machinery was operating efficiently and settings were correct); and automation of various processes. Useful innovations have included introducing electronic and computerized control of activities such as weighing and dispensing of dyes and matching of colors on the dyed fabric. According to the case study, changes including automation of the dye house, lead to significant reductions in dye use, due to the decreased need for corrections. Getting dye levels and other factors "right the first time" leads to significant water and energy savings as well as decreased consumption of chemicals and dyes.[36] Use of a computerized color matching system also makes it easier to adopt safer substitutes to particularly toxic dyes and pigments, according to the study.

The case study cites significant savings achieved through a reduction of water, energy, chemical, and dye consumption. The study cites savings of 5 to 10% in water and energy consumption and 10 to 20% in consumption of dyes and chemicals, leading to "equivalent cost-savings" on average for a number of companies. Some aspects of computerized color matching can "generate another 20-30 percent cost savings." For one medium to large dyeing and printing facility, a combination of these changes has allowed the facility to save $480,000 annually, with an initial investment of $150,000.

Thus, this case provides an illustration of a successful collaboration between UN agencies and a domestic technical assistance program serving relatively large companies that have a capacity to upgrade to electronic, automated, and computerized systems. One theme that emerges from this case study is that established technical services are a good route for disseminating cleaner production techniques.

It can also be instructive to look at some examples from industrialized countries. **Table 3.3** shows a sampling of cases drawn from textile facilities in the US. Pollution prevention techniques at these facilities included reducing use of toxics by re-using solutions or by adopting safer substitutes. For example, one company began using peroxide instead of chlorine in its bleaching process; another substituted an ozone depleting solvent with a water-based detergent; and yet another adopted safer substitutes to a range of toxic solvents.

A couple of differences between the industrialized and developing country contexts emerge. One interesting pattern to note is that while all the US cases shown here achieved financial benefits, these benefits did not necessarily result from toxics use reduction specifically. Rather, in some cases the main financial benefits resulted from adoption of a recycling program as part of a larger pollution prevention program. The financial benefits

[35] "Optimizing Textile Dyeing and Printing Operations in Brazil," Technical Case Study available through the Environmental Management Centre at http://www.emcentre.com/unepweb/tec_case/, viewed June 2005.

[36] "Optimizing Textile Dyeing and Printing Operations in Brazil," Technical Case Study available through the Environmental Management Centre at http://www.emcentre.com/unepweb/tec_case/), viewed June 2005.

these companies achieved through materials recycling depended on the existence of an active market for a range of recycled products. Another interesting pattern is that for many of the US case studies, regulatory pressure is cited as a motivation for undertaking pollution prevention measures. In general, regulatory pressure can help to motivate financially beneficial production changes that might otherwise have been overlooked.

Table 3.3: Selected Cleaner Production Projects at US Textile Facilities

Facility	Cleaner Production Interventions (Selected)	Annual Savings
Renfro (sock manufacturer)	Substitution of chlorine with peroxide	$ 55,280
Springs Industries (sheets, bedding)	Replacement of metal drums with safer containers; substituting a hazardous solvent with a safer cleaner; re-use of sizing mixture.	$ 200,000
Guilford Mills (knit and woven fabrics)	Substitution of solvents with water-based system (acrylic latex emulsion) in some processes.	Investment of "a few thousand dollars" led to "at least 6,000 per year in the form of avoided permitting fees"
Bloomsburg Mills (dyeing and finishing)	Substitution of tetrachloroethylene, biphenyl, trichlorobenzene, and trichloroethane with safer alternatives; use of a computerized dyeing system.	Savings over $38,000 annually through introduction of a materials recycling program. Costs and savings are not listed for chemical substitution.
Hoechst Celanese (polyester fibers)	Substitution of trichloroethylene with a water-based detergent soap degreaser; leak detection and repair to prevent fugitive emissions of ethylene glycol and biphenyls.	Savings of almost $240,000 annually from materials recycling. No net savings from addressing chemical problems.

Source: Pollution Prevention Resource Exchange (www.p2rx.org)

3.5 Artisanal gold mining

There are an estimated 15 million artisanal gold miners in the world; collectively, they produce about a third of all the gold that goes to market. The health and environmental effects of this industry are multiplied far beyond the number of people working in it directly. UNIDO estimates that some 80 to 100 million people are touched in some way by the health and environmental side-effects of artisanal gold mining.[37]

The case of artisanal gold mining offers a particularly stark perspective on the relationship between poverty and chemical pollution. This is not an industry for which facility-level case studies have been generated, and it is not included in the pollution prevention case study databases on which we have drawn for much of the prior discussion. Rather, this is an industry that is carried out almost entirely at the family level, and in which interventions involve education of individual families or projects at a community or regional level.

Artisanal gold miners extract ore from small mines, then process it to extract gold. They mix the ore with metallic mercury in water, often stirring the mixture with their bare hands. The mercury forms an amalgam with the gold. Workers then heat the amalgam so that the mercury evaporates. They are exposed to large amounts of toxic mercury vapor in the process. Entire families, including children, work in this industry and suffer the resulting exposures.[38] In many regions, men collect the ore while women and children do the processing[39]; this means that the most vulnerable members of the population suffer the highest mercury exposures.

Mercury vapor that escapes into the air settles on the ground or in water, where it can react to form methylmercury, a toxic and bioaccumulative compound. People can be exposed to high levels of methylmercury when they eat contaminated fish, among other sources.

One study found that artisanal gold miners had mercury levels thirty times higher than people not involved in gold mining, and that soil and sediment in the vicinity of gold amalgamation locations had twenty to sixty times the background level of mercury. Another study estimates that about "two grams of mercury are released into the environment for each gram of gold recovered"[40] – a truly enormous cost in terms of damage to human health and the environment.

Economic conditions. The economic and social profile of artisanal gold miners varies among countries and among regions, but in general, they are severely marginalized. In some regions, the families that participate in the gold industry have been displaced from their homes due to economic or political pressures. These families have often been forced to abandon family farms that once provided their livelihood and source of nutrition. Artisanal gold miners may sometimes exist in an adversarial relationship with large-scale

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[37] Pablo Huidobro, UNIDO, personal communication, June 2005, citing statistics drawn in part from the International Labor Organization. Additional information on environmental management associated with small-scale mining of gold and other resources can be found in a special issue of the *Journal of Cleaner Production* Vol. 11 (2003).
[38] "Feature: Artisanal Gold Mining without Mercury Pollution" (Vienna, Austria, February 14, 2001), available at http://www.unido.org/en/doc/4571, viewed April 2005.
[39] Pablo Huidobro, UNIDO, personal communication, June 2005.
[40] "Feature: Artisanal Gold Mining without Mercury Pollution" (Vienna, Austria, February 14, 2001), available at http://www.unido.org/en/doc/4571, viewed April 2005.

gold mining operations, or official government-sanctioned operations; this can also lead to isolation and block access to resources. Perhaps most importantly, many small-scale gold miners ply their trade because they have no alternative source of income. Thus, any effort to address the health and environmental effects of their work must in some way address the broader question of these families' economic situation and their lack of access to economic alternatives.

Lessons from UNIDO programs. Since 2001, UNIDO has been operating a six-country program to address pollution of international waters with mercury from artisanal mining. This program operates in Brazil, Laos, Indonesia, Sudan, Tanzania, and Zimbabwe.[41] UNIDO works to approach the problem from a perspective of job creation, poverty alleviation, and economic development.

UNIDO's immediate approach is to teach artisanal gold miners how to make and use retorts to condense the vapor and recapture the mercury. Retorts are simple devices that significantly reduce the miner's direct exposure to mercury. The introduction of these devices is, however, only a stop-gap measure; retorts do not solve the broader problem of the widespread use of this highly toxic metal.

A sustainable solution is to help artisanal gold miners to find alternative sources of income. In one region of Brazil, men excavate areas of sandy river bank to extract gold ore, which they send to a separate location where it is processed by women and children. The mining creates wide pits, one or two meters in depth and fifteen or more meters wide. Communities in this region have begun experimenting with the idea of filling the pits with water and using them for small-scale aquaculture. The initiative has been so successful that some communities have given up gold mining and switched entirely to aquaculture, a far healthier and more sustainable industry.[42]

Earlier UNIDO programs included a program in the Philippines to assess the health of the more than 100,000 people who are connected in some way to artisanal gold mining, and to educate workers about cleaner production options. This program included an analysis of mercury pollution levels in water, fish, and other food; an analysis of blood, urine, and hair samples of miners to assess exposure levels; and training of 100 trainers in cleaner production methods. The project also involved equipping a laboratory to conduct on-going monitoring of mercury pollution in surface waters. A UNIDO program in Venezuela introduced a system called the Unit of Gold Extraction and Controlled Amalgamation (UNECA). In this system, artisanal miners bring ore to a UNECA centre, where amalgamation is carried out for them using safer technologies than those available to the individual miners themselves. These centres can also provide training and health education.[43]

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[41] "Feature: Artisanal Gold Mining without Mercury Pollution" (Vienna, Austria, February 14, 2001), available at http://www.unido.org/en/doc/4571, viewed April 2005.
[42] Pablo Huidobro, UNIDO, personal communication, June 2005.
[43] "Feature: Artisanal Gold Mining without Mercury Pollution" (Vienna, Austria, February 14, 2001), available at http://www.unido.org/en/doc/4571, viewed April 2005. The source does not specify the technologies used at the UNECA centres, stating simply that they significantly reduce use of mercury.

Infrastructure for cleaner production: Shamva Mining Centre. One case study of a project in Zimbabwe looks at an attempt to address mercury exposure and pollution among gold miners holistically while also opening new economic avenues. The Shamva Mining Centre was established as a "multi-functional service provider" serving miners from about 40 different mining sites. The project was developed as a collaboration between the National Miners' Association of Zimbabwe and an international NGO, the Intermediate Technology Development Group (ITDG).[44]

The Shamva Mining Centre allows miners to process their ore at a centralized location, completely bypassing the small-scale amalgamation process that is responsible for so much mercury exposure. Miners transport their ore to the Centre, and process it themselves using the equipment provided there. They pay for the processing services by the hour.

The case study describes various problems that have arisen with this project, despite its apparent promise. The equipment provided at the Centre allows miners to increase their gold production by speeding up the processing; thus, it potentially increases total mining activity and thus increases environmental damage associated with excavation. According to the case study, the process used at the Centre involves cyanide, another highly toxic substance; this is now considered an obsolete technology. The case study notes in passing that conflicts between the two sponsoring agencies led to the eventual breakdown both of the relationship and of the plant itself.

Given these problems, the Shamva Mining Centre may not exemplify an ideal pollution prevention intervention. However, it does present an interesting possible model for interventions: creating infrastructure that helps reduce pollution while providing a self-sustaining economic service and, possibly, offering associated services such as health care. Collective infrastructure of this kind may be a particularly promising way to facilitate adoption of pollution prevention approaches.

3.6 Summary

The industries we have discussed above pose a range of pollution problems. Metal finishing and plating poses problems including water pollution with chromium compounds and other toxic metals, as well as cyanide and toxic solvents used to clean metal items. Problems at tanneries also include discharge of toxic chromium compounds, as well as sulphides and large amounts of organic material. Textile production involves pollution with toxic dye chemicals, heavy metals, a range of toxic organic compounds, and solvents, as well as organic material such as fibers and grease. Artisanal gold mining poses severe hazards from mercury exposure.

[44] John Simpson, "The Shamva Mining Centre," ITDG Case Study available at http://livelihoodtechnology.org/home.asp?id=csShamva1, viewed June 2005.

Solutions to some of these problems include making existing processes more efficient, as well as outright substitution. In some instances, mechanization can help to solve some pollution problems. In the cases we have seen above, solutions in metal plating and finishing have included reducing dragout volume, setting up countercurrent rinsing systems, or heating chrome baths to extend the lifetime of the solution; in addition, in some cases, mechanization facilitates pollution prevention. In tanneries, options include segregation of waste streams, chemical substitutions, and recycling of chromium effluent, among other options.

In addition, for clusters of small facilities, important options include creating infrastructure for collective waste treatment. This can include both end-of-pipe treatment and measures to recycle chemical raw materials, in particular chromium recapture. In textile facilities, solutions can include replacing equipment, mechanizing, and even computerizing some processes to reduce the volume of chemicals consumed per unit of output. Although our focus has been on pollution prevention options, we have also seen that end-of-pipe solutions can play a critical role. The construction of a common effluent treatment facility for tannery clusters in Pakistan is one illustration of this point.

Many of the examples we have reviewed have discussed the financial benefits of pollution prevention. Some point the way toward pollution prevention initiatives that can actually be self financing. For example, we have seen a case of a metal plating and finishing facility where a very modest initial investment (just over $1300) produced financial benefits many times greater (with a first year payback of more than $15,600). Similarly, among tanneries and textile facilities, we have seen cases in which the payback is several times greater than the initial investment.

We have also seen cases in which the adoption of a cleaner production option required a substantial initial investment, and the payback took several years. In cases like this, the participation of an actor external to the facility (whether a government agency, an aid agency, or another entity) can be crucial to getting the project off the ground.

Most of the facility-level case studies do not include significant discussion of the regulatory environment. Despite this, the key role played by the regulatory environment does become evident in some instances – for example, in the case of a tannery where change was motivated by the fact that the facility was in violation of municipal water standards, and in the changes that were undertaken at US textile facilities in the face of regulatory pressure.

In some instances, the lack of regulatory traction is a component of the broader problem; for example, Indian government authorities have limited ability to control the activities of clusters of small-scale textile facilities.

Significant results can be achieved through projects that create common infrastructure and resources to build capacity for an entire community. It may be particularly promising to create resources that provide a range of services -- for example, a combination of health, economic, and pollution preventions services for artisanal gold miners, or combined infrastructure for chromium recapture or other effluent treatment for tanneries. In general, the idea of reducing risk from toxic chemicals by creating a common site with safe production facilities appears particularly promising.

Such sites could offer options for safer handling of effluents, sharing of knowledge, and research and development to reduce waste and identify safer substitutes. They could also undertake common measures to protect workers' health. We revisit some of these ideas in more detail in the following section.

4. A BIRD'S EYE VIEW: POLLUTION PREVENTION PROGRAMS

The case studies on which we have relied to develop the industry portraits, presented above, look primarily at the experience of individual facilities. While they provide rich detail on the technical and financial challenges at the facility level, these case studies offer little wisdom on some of the questions that are most pressing for those interested in industrial policy more broadly, such as how best to disseminate pollution prevention capacity among large numbers of facilities. In this section, we present overview insights that are available from the literature on pollution prevention efforts at a national or regional level, and from interviews with pollution prevention professionals. Our review of these programs is not intended to be exhaustive, but rather aims to highlight and draw lessons from a few important and interesting programs.

We begin with a discussion of the international network of UN-sponsored National Cleaner Production Centres. We then look at the experience of the Environmental Pollution Prevention Project, a five-year pollution prevention effort carried out in nine countries with sponsorship from the US Agency for International Development. Next we look at a program that worked to introduce pollution prevention measures among small-scale facilities in three industrial sectors in India. Finally, we look at the Cleaner Production in China program, which has achieved important results in a number of industry sectors.

4.1 Cleaner Production Centres

A network of National Cleaner Production Centres (NCPCs) have helped to promote cleaner production world-wide. The first eight NCPCs established were in China, India, Mexico, Tanzania, Zimbabwe, Brazil, the Czech Republic, and Slovakia; there are now more than thirty such Centres. These centres offer in-plant demonstrations, training, and other services. The NCPCs were initially funded through a collaboration of the United Nations Industrial Development Organization (UNIDO) and the United Nations Environment Programme (UNEP), beginning in 1994.

The National Cleaner Production Centres: An Overview

Adapted from United Nations Environment Programme, "The National Cleaner Production Centres: Building and Supporting Local Capacity."[45]

The UNIDO/UNEP National Cleaner Production Centre (NCPC) program is based on the premise that Cleaner Production will only be truly integrated into a country's industries and policies if local capacity is in place to sustain it. The purpose of an NCPC is to promote and implement the Cleaner Production strategy in enterprises and government policies, and to develop local capacity to create and meet Cleaner Production demand throughout the country.

The Centres do not deliver ready-made solutions. Rather, they train and advise their clients on how to find the best solutions for their specific problems. Services provided by the Centres include awareness raising; providing training and technical information; conducting in-plant cleaner production assessments; facilitating cleaner production investments; and providing policy advice to national and local governments. The Centres also work to disseminate case studies of Cleaner Production techniques that emerge as a result of local demonstration projects. The Centres are hosted by national institutions, including industry associations, academic institutions, and research institutions.

UN-sponsored NCPC's generally receive funding for an initial period of 3 to 5 years. During this period, the Centres are able to draw on the expertise of specialist institutions known as Reference Centres, or from other mature Centres to build their own capacity. Subsequently, the NCPCs run on a self-financing basis by charging for their services.

A recent article[46] reviews accomplishments, strengths, and weaknesses of the Centres, notes challenges they have faced, and makes suggestions about the way forward. The author notes that most of the NCPCs lack standardized systems for tracking environmental or economic data associated with their efforts; as we will see, this is a limitation that is cited in reviews of other programs as well.[47]

One of the review's most important findings is that demand for the services of NCPCs, especially from small and medium sized enterprises (SMEs), has been low.[48] Several reasons are suggested for this pattern. First, environmental objectives are often not integrated into the company's over-all business plan, especially if there is no expectation of serious regulatory oversight. Second, even when savings can be achieved through cleaner production interventions, company managers may be concerned about the staff time and organizational effort required to achieve these savings, and there may be concern about adopting new, unfamiliar procedures.

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[45] UNEP cleaner production website: http://www.uneptie.org/pc/cp/ncpc/NCPCs%20Note.doc, viewed August 2005

[46] Ralph A. Luken and Jaroslav Navratil, "A programmatic review of UNIDO/UNEP national cleaner production centres," *Journal of Cleaner Production* 12:3 (2004). 195-205.

[47] An exception, according to this article, is Mexico, which has relatively good record keeping.

[48] Luken and Navratil 2004, p. 200.

Furthermore, if an initial investment is required to implement a cleaner production option, SMEs may lack access to funds to implement it. The authors note that SMEs may have trouble obtaining loans for cleaner production interventions for various reasons, including the fact that the sums of money involved may be too small to be of interest for a commercial bank. Furthermore, internal company accounting systems sometimes omit the cost categories in which savings are likely to be achieved. Thus, it may be difficult for a company to perceive and account for the savings that will be generated by a given intervention.

Finally, when environmental regulations are introduced that require a rapid improvement in company environmental standards, end-of-pipe solutions often are (or appear to be) the fastest way to bring a company into compliance; thus, cleaner production options may be overlooked in the rush to improve standards for a regulatory deadline.

For these reasons and others, the article finds that the creation of NCPCs has not generated a lively market in cleaner production advisory services:

> a spontaneous, commercially driven unfolding of the CP advisory services beyond the NCPCs' control has been rather limited or at least there is little evidence of it.[49]

One suggestion the authors offer is that NCPCs should work to integrate the information they have to offer into other, existing advisory services to industry.

It is worth noting that while the goals and agenda of the NCPCs are ambitious, funding has been quite limited; one of the challenges they have faced is the difficulty of identifying funding sources to continue their work beyond the three to five years of support provided through the UN.

4.2 The Environmental Pollution Prevention Program (EP3)

The Environmental Pollution Prevention Program, which existed from 1993 to 1998, worked in three broad areas: technical assistance to industry, training and outreach, and policy development. EP3 developed multi-year programs in Bolivia, Chile, Ecuador, Egypt, Indonesia, Jamaica, Mexico, Paraguay, and Tunisia, in addition to providing technical consultation in many more countries. The program was funded by the US Agency for International Development (USAID). A recent overview of the EP3 experience describes a series of lessons learned in this experience.[50]

In several countries, EP3 worked out of the office of an existing domestic organization; for example, the program partnered with national industry associations in Bolivia, Paraguay, and Jamaica. In Mexico, EP3 worked in partnership with the UNIDO-sponsored Mexican Cleaner Production Center. In Tunisia, Egypt, and Indonesia, EP3 did

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[49] Luken and Navratil 2004, p. 201.

[50] James Gallup and Betsy Marcotte, "Technology Transfer and the Environmental Pollution Prevention Project (EP3)," *Journal of Cleaner Production* 12:3 (April 2004).

not form a partnership with any existing organization. In retrospect, the success of EP3 programs appears to have been closely associated with having strong domestic ties and an office based in an existing local organization.

EP3 achieved particular successes in the areas of battery manufacture, electroplating, leather tanning, printing, and textiles. The program also encountered difficulties. A quarter to a half of recommended cleaner production options were implemented; this resulted in a significant amount of pollution prevention, but higher implementation rates would have been better.

Furthermore, none of the countries targeted by the program developed a "sustainable program or market for pollution prevention services as a result of EP3's efforts." Although program designers had assumed that firms would adopt cleaner production techniques once they were made aware of their financial benefits, this did not turn out to be the case. Cleaner production techniques proposed or modeled for individual facilities did not necessarily take hold at the broader economy level.[51]

Value of sector-wide programs. The EP3 evaluation finds that sector-wide programs are more effective than programs planned at the facility level. The authors note that "working at one plant at a time did not result in broad adoption of pollution prevention practices across the sector." Better results were achieved through an "industry circle" approach in which the expertise of local experts was used in combination with that of short-term consultants from the US.

One reason why facility specific interventions tended not to take hold more broadly was that companies were reluctant to share information with competitors.

> [E]ach firm closely guards its production techniques, not wanting to help its competitors. Agreements were made to protect this proprietary information. As a result there was limited dissemination to other firms in the same industry. The exceptions took place when the audit was done at a firm where the owner was an influential leader in the industry trade association. Replication will not take place if it is a trade secret.[52]

Preference for comprehensive solutions. EP3 was designed to focus primarily on no- and low-cost interventions with "immediate, substantial, and visible benefits." But it turned out that many companies wanted more than this:

> [I]ndustrial plants often wanted comprehensive solutions that could address all their environment-related needs, including investments in new, cleaner production technologies and integration of pollution prevention and control.[53]

Targeting companies of diverse sizes. EP3 was designed to work primarily with small and medium-sized enterprises, but found that "large firms were actually more likely to follow up on EP3-conducted assessments and training." The authors suggest that despite the

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[51] Gallup and Marcotte 2004, p. 23-24.
[52] Gallup and Marcotte 2004.
[53] Gallup and Marcotte 2004.

importance of small and medium-sized industries in developing countries, successful interventions at large companies offer the advantage of greater visibility for the pollution prevention agenda.

This lesson from the EP3 program may simply indicate difficulties faced by EP3 representatives in engaging effectively with SMEs. For example, the program's greater success with large firms may show that the program was not adequately equipped to solve the financing problems that SMEs face. However, as the review suggests, it may be valuable to engage both the large and small companies in a given area, and to use the example of large companies to motivate specific technical changes among smaller operations.

Lower than expected implementation rates. EP3 prioritized spreading the word broadly about pollution prevention, rather than insuring that individual projects were implemented. But the report notes that "although the levels of implementation were still significant … many industries lost momentum after the assessment." This finding indicates that it is not sufficient to demonstrate that a cleaner production option will be cost-effective; factors other than cost effectiveness can play a role in determining whether an option is implemented. For example, the need to invest money at the start of the project can be a barrier for some facilities even when the expected payback period is very short.

Financing problems. The EP3 program found that financing cleaner production was a major problem: "Often the money was offered at interest rates too high for most plants to afford. Also, the programs were sometimes only available to a very small number of plants, usually very large facilities." The report also notes that "even where investment funding is available, it is almost never targeted toward small and medium size facilities;" thus, there is a particular need for interventions in this area.

Institutionalization. One of the problems encountered by the EP3 program was that it did not form strong ties to institutions that would be able to move projects forward after the direct aid ended:

> EP3 was successful in creating a cadre of pollution engineers and working with the private sector. But it did not extend its message throughout the industrial sector and failed to develop close ties with the government or NGOs. There was no institutional arrangement to carry on the effort after USAID assistance ended.[54]

4.3 DESIRE: Pollution Prevention among Small Scale Producers in India

DESIRE is a creative acronym for a UNIDO-sponsored program that was carried out in India in the mid-1990s: Project Demonstrations In Small Industries for Reducing

[54] Gallup and Marcotte 2004, p. 23-24.

Waste.[55] The DESIRE project worked with small-scale industries in three sectors: pulp and paper based on agricultural residue; textile dyeing and printing; and pesticides formulation. A review and evaluation of this project was published in 2002; here, we look at some of its findings.

Net savings were achieved by participating facilities in all three sectors. Of the three sectors, pollution prevention was found to be most financially feasible in the area of textile dyeing and printing, and least good in pesticides formulation. Total initial expenditures, as well as total savings, were greatest in the pulp and paper industry.

The project made use of several techniques to promote change. One approach was to develop demonstration projects, working with a single facility to show the practicality and value of a pollution prevention option. Another was to sponsor the formation of "waste minimization circles." In a waste minimization circle, representatives from multiple facilities within an industrial sector meet regularly with the explicit purpose of exchanging information on pollution prevention options.

The program evaluation assessed the sustainability of pollution prevention among demonstration facilities after the project ended, the level of pollution prevention adoption among non-demonstration facilities, and effects of the project on the broader policy environment. Once again, lack of data was an issue: these assessment categories were not defined at the start of the project, so that data were sparse for some of these questions. One lesson from this project's experience is that clear data categories should be established at the outset so that evaluations can be carried out successfully over the course of the project. Despite the data limitations, some interesting results emerged.

Demonstration facilities: Of a total of twelve demonstration facilities, five were included in the evaluation. All of these facilities sustained the pollution prevention practices they had adopted during the project. In addition, other options that had been identified but not implemented during the project period were put into practice in subsequent years. While the data are limited, the assessment suggests that the interventions at the demonstration companies did make a lasting difference.

Non-demonstration facilities: The DESIRE project was intended to produce a multiplier effect, in which other companies would adopt the measures carried at demonstration companies. The assessment found that the capacity built during the project continued to be used after the project was over. However, there were some problems. In particular, in the textiles sector, the principal staff person resigned, and it took time for new sector-specific expertise to be developed.

Individual companies played an important role in continuing to disseminate information after the project ended. For example, two or three of the demonstration companies in the pulp and paper and textile areas took responsibility for continuing to provide workshops

[55] Rene Van Berkel, "Assessment of the Impact of the DESIRE Project on the Uptake of Waste Minimization in Small Scale Industries in India (1993-1997)," *Journal of Cleaner Production* 12 (2004), 269-281.

and other educational activities. However, there appear to be limited data on how many companies actually acted on the information they received at these workshops, and what benefits they achieved. A small survey of companies that participated in some of these post-project dissemination activities found that at least a few of them successfully implemented waste minimization activities, but did not indicate how widespread this success was.

Interestingly, the DESIRE project helped to influence credit markets, by demonstrating the value of pollution prevention investments. The evaluation notes that the World Bank's industrial development program in India decided to finance the creation of several new waste minimization circles after seeing the successes of the DESIRE project, and that the World Bank at least considered requiring a pollution prevention audit or plan as a condition for receiving new loans.

4.4 Cleaner Production in China

The Cleaner Production in China program involves a partnership between the Chinese government and the Canadian International Development Agency (CIDA).[56] In the course of this project, the Chinese government identified priority areas for intervention, and CIDA assisted by providing sector-specific technical experts to help with demonstration projects. Additional assistance was provided by Norway. The Cleaner Production in China program is currently in its tenth and final year.

The Canadian-assisted portion of China's cleaner production program worked in six industry areas: pulp and paper, fertilizer, beer, chlor-alkali, oil extraction, and aluminum and copper smelting. Most of the facilities addressed in the program were large compared with the facilities we have looked at in African and Latin American examples; however, compared with their counterparts in industrialized countries, they are relatively small.

The program focused on interventions that would produce the "the biggest bang for the buck": the best results for the lowest costs. Audits were performed to identify a range of cleaner production options; these were then prioritized to identify those with the smallest initial investment and the largest impact for a given expenditure.

The program began with pilot projects, in which a selected group of demonstration facilities adopted low-cost pollution prevention options. These demonstration projects showed that significant financial returns could be achieved within less than a year. Engineers from these successful companies then visited other companies to explain what they had done.

According to the Canadian program manager, the biggest barrier to progress in the program was facility managers' belief that they could not achieve significant pollution

[56] The information we present here is based on the program's website, as well as personal communication from Kenneth Parent, program manager in Canada (June 2005). Because our contact is in Canada, the aspects of the program that involved Canadian participation are emphasized in our discussion.

prevention unless they received large grants for capital investment. This conviction turned out to be unfounded: in each of the six industry areas, the project demonstrated that significant environmental improvements could be achieved through relatively small investments. These investments generally paid for themselves within six to eight months, thanks to reduced requirements for raw material inputs. In summary, the project proved that pollution prevention could be self-financing in the six industry sectors. Rather than requiring major new capital investments, most measures were a matter of "tweaking" existing production systems.

Again, it is important to note that the facilities in the China program are much larger than those addressed in the Africa, Latin American, and South Asian examples we have looked at. Thus, a "tweak" in production could cost on the order of US $0.5 to $1 million[57] -- a very different level of expenditure from those we have seen in other discussions.

Another reason why the Chinese case is very different from others we have examined is that in China, facilities are centrally planned and industrial development is centrally managed. Facilities in a given industry sector tend to be planned according to a single design; thus, innovations at one plant are easily transferred to another. Political authorities play an active role in determining the direction taken by industry. This means that in China, government officials can require individual facility managers to undertake cleaner production efforts.[58]

57 Kenneth Parent, personal communication, June 2005.
58 Kenneth Parent, personal communication, June 2005.

5. MAKING POLLUTION PREVENTION HAPPEN: OPPORTUNITIES AND CHALLENGES

In this section, we offer a thematic review of cleaner production opportunities and challenges. Areas of particular interest include the challenge of disseminating knowledge and infrastructural capacity across multiple facilities, and the opportunities for creative financing of cleaner production investments. In this discussion, we draw on insights derived from the case studies and program evaluations above; we also draw on information and observations that are available elsewhere in the literature on pollution prevention, and on information gathered in interviews with pollution prevention experts.

5.1 Financial Advantages: Facility Level and Beyond

As we have now seen in some detail, pollution prevention can offer significant financial advantages. Examples of this phenomenon are available in most of the facility case studies discussed above. Cleaner production projects often pay for themselves within a short period of time. Thus, pollution prevention can be a way to help improve the viability of small businesses, a way to help small businesses survive difficult economic conditions, or even a means to fund expansion of facility activities regardless of broader macroeconomic conditions.

Where the conditions are right, cleaner production investments can be self-financing: many facilities can often afford to make changes on their own, without financial help from an outside organization. For a facility that has identified a list of possible interventions and prioritized them according to cost, savings from one pollution prevention option can sometimes help to finance investments in the next. Thus, for example, a facility could begin with a no-cost measure that reduces the need to purchase toxic chemicals, and then could use the funds saved on that process for an investment in capital equipment to pursue some more ambitious cleaner production measure. At the same time, however, it is important to be realistic about how much this self-financing process can accomplish. Even when payback periods are short, small facilities may lack access to the capital they need to make their first pollution prevention investment.

Beyond facility-specific data. It is clear that there are many opportunities for financial benefits through pollution prevention at the facility level. But how useful are these individual, facility-level success stories? Have they been selected from a broader pool in which there were many failures as well as successes? Are savings through pollution prevention efforts the rule, or merely the exception?

One way to answer this question is to look at aggregate figures developed for multiple facilities participating in pollution prevention activities. These statistics show that the cost savings cited in individual facility case studies actually do indicate a broader pattern. Taken as a group, the companies participating in pollution prevention programs attain considerable returns on their investments.

This pattern has been documented at the national level in the US. According to an overview report by the National Pollution Prevention Roundtable (NPPR), pollution prevention efforts in the US have consistently proved to be financially beneficial. An NPPR survey found that in a single year, 1998, pollution prevention efforts in the US saved some $256 million in the aggregate. Over a period of just two years, from 1998 to 2000, 13 programs surveyed reported "total cost savings equal to $404 million." The authors note that these findings did not necessarily match the assumptions of participating companies at the outset:

> One of the most common barriers to the implementation of pollution prevention cited by respondents was the perceived high cost. Despite this, in every case documented in the report all costs were recuperated within several years ... and in some cases companies began seeing added profits as soon as a few months after the adoption of pollution prevention measures.[59]

Another interesting case in the US is that of the Massachusetts Toxics Use Reduction Act (TURA), passed in 1989. Under TURA, companies with more than ten employees that exceed a specified threshold in toxic chemical use are required to prepare a Toxics Use Reduction Plan, examining how toxic chemicals are used in their facility and what alternatives are available.[60] Since passage of the law, more than 1,000 Massachusetts companies have participated in the program. Many of them have subsequently left the program because they have reduced their use of the listed toxic chemicals to a point below the regulatory threshold.[61] Between 1990 and 2002, production-adjusted use of toxic chemicals by regulated companies decreased by 42%.[62]

Case studies of Massachusetts companies regulated under TURA show substantial savings achieved in the course of reducing use of toxics. As of 1995, the most recent year in which costs and savings were evaluated, these reductions were associated with substantial monetary savings. The total costs to businesses of implementing the TURA program, including training programs, data collection, and capital investments, amounted to $76.6 million. Savings in operating costs resulting from these activities added up to $88.2 million, producing a net savings of $11.6 million.[63]

Other aggregate data are available from surveys of waste minimization clubs, in which a group of companies work together to exchange information and ideas on pollution

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[59] National Pollution Prevention Roundtable (NPPR), *An Ounce of Pollution Prevention is Worth Over 167 Billion Pounds of Cure: A Decade of Pollution Prevention Results, 1990-2000* (NPPR, January 2003), p. 15.

[60] "What is TURA?: An Overview of TURA," available at http://www.turadata.turi.org/WhatIsTURA/OverviewOfTURA.html, viewed June 2005.

[61] "Success Stories: Results to Date," available at http://www.turadata.turi.org/Success/ResultsToDate.html, viewed June 2005.

[62] "Success Stories: Results to Date," available at http://www.turadata.turi.org/Success/ResultsToDate.html, viewed June 2005.Using the same adjustment, companies regulated under TURA are calculated to be generating 67% less byproduct or waste per unit of product, and have reduced their releases of priority toxic chemicals to the environment by 92%. Again adjusted for the production increase, the total volume of chemicals "shipped in product" have decreased by 58% over all.

[63] Massachusetts Toxics Use Reduction Program, 1997.

prevention.[64] In South Africa, for example, a survey found that among fifteen members of a Metal Finishing Club, aggregate savings were equal to nearly US $300,000 annually.[65] Most of these benefits were derived through no- or low-cost options. Companies that achieved the greatest financial benefits attributed them in part to changes in their over-all approach, including "an increased awareness of the process requirements … and a greater management presence on the shop-floor." As we saw in the three industry sectors that participated in the DESIRE project in India, and six sectors addressed in the Cleaner Production in China project, aggregate financial benefits were achieved in each sector.

5.2 Internal Barriers to Change

Some cleaner production projects have been designed on the assumption that if a cleaner production option is shown to be cost effective, it will be adopted. It turns out this assumption is not necessarily valid, in part because of how decisions are made within facilities.

A report by the National Pollution Prevention Roundtable in the US looks at the dynamics behind the decision whether or not to adopt a cleaner production option. It would be natural to assume that if an intervention costs, for example, $1,000 and will yield benefits of $15,000 within a year, it should be sufficient to point out this fact to a facility manager. However, there are several reasons why this will not necessarily be the case. These can include internal company dynamics that resist change; failure to properly account for costs and benefits within the facility; hidden costs associated with changing processes; and accounting approaches that can lead companies to discard one cost effective measure in favor of another, more profitable measure.

Resistance to change: Company managers may be reluctant to adopt new production techniques, simply because they are different from the tried-and-true techniques. The evaluation of the EP3 program suggests that "good factory managers" with a good understanding of costs and other factors were better at adopting pollution prevention measures; in contrast, sometimes the companies most in need of intervention also had managers who had difficulty understanding the case for pollution prevention.

> Which types of firms to focus on? Good factory managers are those who understand costs, product development and marketing. They also did well with pollution prevention. Industrial firms with severe pollution problems often had financial problems due to weak management. They were producing the wrong product mix with inefficient machinery. They were the "losers." In contrast, good managers saw pollution prevention as an integral part of efficient production. They adopted pollution reduction and waste minimization as a way to save money and improve product quality.[66]

Hidden costs: Research on energy efficiency innovations has found that companies often fail to adopt energy efficiency measures even when they are clearly cost-effective. One

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[64] Report on the First Africa Roundtable on Cleaner Production and Sustainable Consumption, p. 52-53.
[65] 1.9 million Rand/year, converted at 2005 rates; not inflation adjusted.
[66] Gallup and Marcotte 2004, p.24-25.

explanation that has been offered for this pattern is that there are "hidden costs" to adopting apparently no- or low-cost measures. The need for employee training, or other changes in company structure, may act as genuine deterring "costs," even if they do not show up on the books.

Accounting: A study of US companies found additional complicating factors in the company decision process. Even if an investment in cleaner production will pay a large return, if the firm has other investment options that will produce even larger returns, by economic logic it should choose to pursue those other options first. Thus, a clearly reasonable cleaner production option may be set aside because the initial investment required for that option is allocated instead to a more profitable project. The study also found that in some cases, large companies may overlook options for pollution prevention precisely because they are not expensive: the small cost of some options can mean, ironically, that they fail to come to the attention of company management.[67]

Another possible accounting-related problem is that companies may not perceive the savings associated with a cleaner production measure. For example, company accounts may not clearly reflect costs associated with work days missed due to occupational illness, or inefficiencies in production due to health problems among workers. In addition, of course, the regulatory environment affects some costs. For example, if permitting requirements or fines on toxic emissions are not enforced, they do not create an effective financial incentive for change.

5.3 Scaling Up and Disseminating Knowledge

The advantages of pollution prevention for individual facilities are well documented. The real challenge is figuring out how to scale up – how to ensure that multiple facilities adopt a given practice. What are the best ways to move from individual success stories to broad adoption of pollution prevention techniques?

One important insight on this topic is that cleaner production efforts should be packaged with other services to industry; they should be a “mainstream” service to industry, not a specialized add-on. The failure to “mainstream” pollution prevention as part of an industrial capacity building agenda may explain its failure to take hold more broadly in some settings.

The example of textile facilities in Brazil illustrates this point. In this case, cleaner production methods were introduced to the companies as part of a package of services to industry that also included a range of options for technical upgrades and boosting profits through other means.

Solving chemical problems often goes hand in hand with addressing other inefficiencies, such as excessive use of energy and water. As several of the case studies highlighted in this report illustrate, reducing use of energy and water can produce significant savings.

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[67] U.S. General Accounting Office (GAO), *Environmental Protection: EPA Should Strengthen its Efforts to Measure and Encourage Pollution Prevention* (Washington, DC: GAO, February 2001), p. 39.

In some instances, companies achieved significant reductions in chemical use, but achieved real financial savings through a separate route, such as cutting water use or starting a recycling program. This can affect transferability of experience: if energy conservation was the main source of savings in a given facility that adopted cleaner production techniques, the lessons of that experience may not be transferable to a country or region where energy costs are much lower.

Materials Exchange and Eco-Industrial Parks. Another promising area for interchange among facilities is materials exchange. In some cases, this means that one facility's waste can be another facility's productive input. In addition there are instances in which waste from two facilities can be combined to reduce the total environmental impact. For example, if one facility produces acid wastes and another facility produces alkaline wastes, these wastes can be combined to neutralize one another. This approach can help to avoid dumping of caustic wastes into waterways.[68]

The creation of industrial parks, or eco-industrial parks, can facilitate efficient materials exchange. In an industrial park, a group of industrial facilities are located together, preferably in an area that is remote from large population centres. This proximity can allow facilities to share infrastructure for chemical treatment and other needs; it can also, at least in principle, allow companies to combine their wastes when that is appropriate, or to use one another's wastes as industrial inputs. Industrial parks have been introduced in a number of developing countries, especially in Southeast Asia.

5.4 Transferability

The large volume of case studies on pollution prevention attests to the widespread hope that lessons from one facility will be transferable to others. Many case studies are available from industrialized countries; there is a question as the extent to which these are transferable to developing countries. Even among developing countries, approaches that work in one context will not necessarily work in another. In assessing transferability of experience, issues to consider include the size of the facility, the size of the investment required to make a change, the presence or absence of regulatory pressure, and the availability of loans.

The cost of inputs, including chemicals as well as water and energy resources, can also play a role. The relative financial benefits from reducing chemical use versus reducing demand for utilities vary among countries and even regions. Within the US, a review by

[68] A number of materials exchange programs exist in the United States; some focus on exchange of reusable materials of many kinds, while others focus primarily on chemicals. In at least one instance, an effort is under way to introduce a materials exchange program in a developing country with assistance from a US program. The Minnesota Materials Exchange program is working to help set up a materials exchange program in Sri Lanka. The program is in its earliest phase; partners in Sri Lanka are still being identified. A professional at the Minnesota Materials Exchange program notes that one obstacle to successful operation of chemical exchanges in the US is the fact that companies are liable for the uses of their chemicals even after they have exchanged them. Due to liability concerns, facilities may prefer to have their wastes picked up by a hazardous waste hauler rather than engaging in a materials exchange program. Barbara Nesheim, Materials Exchange, Minnesota, personal communication, May 2005.

the National Pollution Prevention Roundtable documented substantial financial benefits achieved through pollution prevention efforts over the period 1990 to 2000. These benefits were derived from a combination of toxics use reduction and water and energy conservation, with water and energy conservation accounting for a substantial portion of the total savings. This finding supports the logic of combining toxics use reduction efforts with energy and water conservation measures to maximize the financial impact. In some cases, the greatest benefits for workers' health may be achieved through toxics use reduction, for example, while rapid payback of investments may come primarily from energy conservation.

However, transferability of these findings is not assured. For example, the cost of water is highly variable across countries and even among regions within a single country. In one case in Tanzania, for example, a low-cost intervention was used to save a very large amount of water; however, because water costs were extremely low, the intervention did not produce large savings.[69]

5.5 The Role of Regulation

It is particularly important for rapidly industrializing countries to put strong regulations into place as early as possible, so that they can encourage industry to adopt pollution prevention methods from the outset, rather than retrofitting or changing production processes later. Regulation is an area in which developing countries have a particularly good opportunity to "leapfrog", bypassing the path-dependent errors and omissions of regulations as they developed in the now industrialized countries.

Regulations can motivate companies to reduce pollution. As we saw in the discussion of textile production in the United States, regulation played a major role in motivating adoption of cleaner production measures. We also saw that in the case of the Imponente facility in Zimbabwe, the initial impetus to investigate cleaner production options came from the fact that the facility was in violation of municipal water quality standards. Had there been no such standards, this facility might not have been motivated to undertake cleaner production, even if it potentially offered a way to cut costs. Fees on waste disposal, or fines for hazardous waste emissions, can also help reinforce the inherent financial incentives for pollution prevention.

In contrast, in the cases of tannery-related pollution in Pakistan, and textile pollution in India, some efforts to regulate have created an impasse; and facilities are too small and numerous to be policed easily. In cases like this, regulatory requirements may be useful as one ingredient to propel adoption of pollution prevention, but regulations alone may not inspire facilities to change their production systems.

Regulations must be designed appropriately. If a regulation creates a short timeline in which there is pressure to show immediate results, it can inadvertently create a bias toward end-of-pipe remediation measures, rather than more holistic cleaner production approaches. Of course, short timelines can be very important in achieving cleanup goals;

[69] Report on the First Africa Roundtable on Cleaner Production and Sustainable Consumption, p. 65.

however, it is good to build in some guidance to steer companies toward cleaner production whenever possible.

Some successful programs in the US have combined regulation of toxic chemicals with financing mechanisms to support cleaner production. For example, the Massachusetts Toxics Use Reduction Act creates an incentive not to pollute through imposition of a fee on targeted toxic chemicals. The money collected through this fee is largely channeled back to corporations in the form of technical assistance programs to help them reduce total use of toxics. Another interesting model for combining regulatory control with financing is the Southern California program to reduce toxics use in dry cleaning, as we discuss in the section below.

When a country is working to write or revise its environmental legislation, it is important to identify and take advantage of opportunities to promote and facilitate pollution prevention. Legislation can and should be designed specifically to encourage and promote adoption of pollution prevention measures.

The fact that pollution prevention often saves money should be borne in mind in the process of developing legislation. The private sector may argue that strong regulations will impose unmanageable new costs on industry. Legislation that explicitly promotes pollution prevention can avoid this criticism, since pollution prevention so often results in financial benefits for firms. As in the Massachusetts case noted above, environmental legislation can be used to create technical assistance programs that help industry to boost productivity and profits while simultaneously reducing or eliminating use of toxic chemicals.

Certain principles should be kept in mind in designing environmental legislation. Legislation must define clear obligations for firms, including both domestic producers and importers. Firms should be required to share information on the chemicals they produce and/or use, and should be required to carry out precautionary assessments of the properties and effects of these chemicals. Detailed secondary law can be designed to carry out these general principles.

Other useful guidelines for environmental legislation include creating clear divisions of responsibility among ministries. It is important to mainstream pollution prevention at the governmental level; in particular, pollution prevention should be built into mainstream industrialization efforts. There should also be an institutional superstructure that gives sufficient authority to inspectors working in the field and on the shop floor.

5.6 Financing Pollution Prevention

As we have seen from the discussion above, pollution prevention options often pay for themselves within a short period of time. Thus, pollution prevention efforts in some cases can be self financing: an individual facility can make the investment itself, because the payback period will be so short.

In the China-Canada collaboration, for example, facility managers initially argued that they could not undertake the recommended cleaner production options unless they received substantial financial assistance for capital investments. As it turned out, they were wrong: in all six of the industry areas dealt with in the China Canada program, it was demonstrated that the changes could be financed within the facility. As the program manager put it, "they didn't need our money."

However, it would be unrealistic to ignore financing problems on the assumption that self financing will work in all cases. As we saw in the discussion of Msasa Plating, for example, the pollution prevention measure paid for itself eventually, but the payback period was several years; thus, there was a need for outside assistance. No matter how cost-effective pollution prevention may be, creative financing schemes for cleaner development should be a priority in program development.

Financing challenges for SMEs. SMEs often lack access to the funds necessary to move beyond no-and low-cost options and invest in new cleaner production technologies. Credit markets in many of the countries of interest are underdeveloped; and SMEs operating at the margin of financial viability may be considered poor credit risks. In some instances, loans are available in theory, but actually obtaining a loan is too time consuming and complicated to be worth while. As noted in the discussion of National Cleaner Production Centres, SMEs may also be blocked from receiving loans because the size of the loans they need for cleaner production investments are too small to be of interest to lending agencies.

In this regard, it may be worth investigating options to partner with micro-credit agencies to help finance cleaner production investments. In Bangladesh and other countries, the micro credit model has been highly successful in helping poor families to improve their economic situation, and indeed in improving the economic condition of whole communities. The logic of micro credit is that small infusions of money can allow individuals or families to develop a business, purchase equipment, or take other actions that will allow them to begin generating income. Micro credit agencies provide sums of money that would be too small to be of interest to regular banks. They use payback systems that are designed appropriately for the community in question; for example, sometimes a group of loan recipients bear collective responsibility for ensuring that each loan is repaid, so that there is an incentive for people to collaborate, hold one another responsible, and ensure one another's success.

Supply chain. USAID is currently experimenting with a "Supply Chain Environmental Management" strategy to promote cleaner production among SMEs in developing countries. In this approach, multinational companies make cleaner production a requirement for their suppliers. The logic is that these multinational purchasers have the option to specify the characteristics required in any products they buy; just as they can specify quality, size, and color of a product they order, they can specify use of cleaner production options.[70] The supply chain approach may help to harness market forces in

[70] Gilbert Jackson, USAID, personal communication (May 2005), and PA Consulting Group, "Supply Chain Environmental Management" (March 2002).

creating incentives for cleaner production. However, it is not clear how this approach compares in effectiveness with interventions that finance cleaner production directly.

Grant-making for pollution prevention. In the effort to identify creative ways to finance cleaner production, and to make cleaner production interventions a sustainable process over time, it is important not to overlook the instances in which a simple grant can make the difference. As in the case of Msasa Plating, a grant or loan from a government agency (or an aid agency) can enable a small or medium-sized facility to purchase new equipment that allows cleaner production. Purchasing this new equipment essentially locks in the cleaner production measure.

In some instances, a well-designed fee on use of toxic chemicals can help to generate the funds for direct grants to industry. An interesting example is the experience of the Southern California program to reduce use of perchloroethylene in small-scale dry cleaning operations. Although dry cleaning is not an industry of particular interest in a development context, the approach used in California is worth examining as a model for other endeavors. This program provides block grants to SMEs, allowing them to purchase safer production equipment. The first phase of the project was based on grants only. In the second phase, there is an added element of a fee, which simultaneously creates a disincentive to use perchloroethylene and helps to support further grant making. In this instance, simply giving dry cleaners the money to buy equipment in the first phase was the fastest, most direct, and most efficient way to decrease perchloroethylene use.

Dry Cleaners in California:
A Model for Financing Cleaner Production at SMEs

California has created a program to help dry cleaners reduce or eliminate use of perchloroethylene by purchasing safer equipment. Under a 2003 law, a fee of $3 per gallon is levied on perchloroethylene sold in California, starting in January 2004. The fee is set to increase by $1 per gallon each year through 2013, to a maximum of $12 per gallon.

Funds collected through this fee will be used to establish a trust fund to help cleaners make the transition to safer cleaning technologies. Most funds will go to provide grants of $10,000 each to cleaners switching to wet cleaning and carbon dioxide cleaning systems; the remainder are designated for use in a demonstration program.[71] Thus, the fee will simultaneously create a disincentive for perchloroethylene use and make it easier for businesses to switch to safer alternatives.

Before this fee structure was established, other programs were set up to help cleaners make the transition to safer technologies. The California South Coast Air Quality Management District (AQMD) allocated $2 million for grants to cleaners starting in January 2003.[72]

In addition, a program based at a college supports creation of demonstration sites for wet cleaning. Cleaners that volunteer to create a demonstration site receive $12,500 to purchase a wet cleaning system. Demonstration sites offer certain special services, such as classes.[73]

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[71] Assembly Bill 998, available at http://departments.oxy.edu/uepi/copy%20of%20pperc/AB998.htm, viewed June 2005.
[72] Jackson Yoong, California South Coast Air Quality Management District, personal communication.
[73] Peter Sinsheimer, Director, Pollution Prevention Education & Research Center, Urban and Environmental Policy Institute, Occidental College, personal communication.

6. DIRECTIONS FOR FUTURE RESEARCH

The model of the facility-specific case study, or "success story," has been widely replicated. There is a substantial and impressive body of these facility-specific studies. It makes sense to continue generating case studies of this kind as new kinds of interventions are undertaken; the case studies tend to include relatively detailed technical information, and thus can be used in training programs and peer-to-peer information exchange programs. However, there are many important questions that facility-specific case studies either cannot or do not address. Some of these questions are addressed in program evaluations, which offer a bird's eye view of interventions at multiple facilities. Others have not yet been answered, or have only been touched upon briefly, in existing program evaluations.

The following are some potentially promising areas for future research. Ideally, these research projects should not be undertaken in isolation, but rather should be carried out as part of the design and implementation of on-going projects.

Tracking Factors that Facilitate or Impede Progress: Factors both internal and external to a facility can help to determine the success of a cleaner production intervention. Factors facilitating change include company management that is committed to cleaner production and understands its financial implications; access to credit when needed; and a regulatory environment that supports investigation and adoption of cleaner production measures. It could be worth while to develop an overview study that focuses specifically on defining progress factors such as these. It would also be helpful to develop a checklist of factors facilitating success in adoption of cleaner production measures.

Broadening the scope of facility-specific case studies: There are several ways in which facility-specific studies could be broadened in scope. Specifically, it would be very interesting to collect quantitative data on ambient environmental conditions before and after a given intervention. It would also be helpful to develop facility-specific case studies that include a discussion of the economic circumstances of the community in which the facility is located. Most case studies do not indicate whether the facility in question is one of several in an area, or whether it exists in relative isolation; they also do not indicate, in general, whether the facility was intended specifically to serve as a demonstration site for other facilities. It could be valuable to develop facility-specific case studies that also include a discussion of surrounding facilities. For example, one could envision a description of cleaner production measures adopted at one printing shop, paired with a discussion of other printing shops in the same geographic area. Does the facility that undertakes cleaner production capture market share away from those that have not attempted cleaner production? In general, it will be useful to "look outside the facility gates" in future research -- not just to look at what happened inside the facility, but to look at the broader economic community of which it was a part. It could also be very useful and interesting to examine whether facilities manage to expand, adopt new technologies, hire additional workers, or increase pay scales as a result of the benefits achieved through cleaner production.

Relationships between small facilities and government authorities: It would also be worth looking at the dynamics of how small industries interact with government authorities. We have seen, for example, that small-scale gold miners are often seen as illegitimate and in an adversarial relationship with official government sanctioned operations. The isolation that results from this situation is likely to severely inhibit information exchange between authorities and the small-scale operators. In the discussion of small-scale tanneries and textile producers, we have seen that regulatory authorities often find they have little or no ability to regulate these large numbers of small facilities. Again, the lack of easy communication between government authorities and informal small industry may be an important barrier to progress. Defining industry-government interaction as an area to monitor and track from the start of a project could yield useful information to guide policy planning.

Consolidating knowledge on "low-hanging fruit": The question of what constitutes "low hanging fruit" for a given industry is relatively well understood by professionals working in the field, but is still incompletely documented. From a first look at the large volume of existing case studies, as well as technical articles on individual cleaner production options, one might conclude that this question has been answered repeatedly in the existing literature. But when we inquired with experts about how to identify "low hanging fruit" for a given industry, they responded that it would take substantial time and work to obtain realistic answers about what is genuinely feasible. Some interventions are commonly identified as "low hanging fruit" but are not necessarily easy to adopt in practice. Some cleaner production options that clearly save money, and have been adopted many times, may still be difficult for a small company to undertake. Many individual facility specific audits provide a list of options, in a hierarchy from easiest to hardest or cheapest and most expensive; it might be useful to group this information at a higher level.

Clusters of small facilities: There is ample room for more data collection, research, and writing on past and present experiences with large clusters of very small facilities. As we saw in our discussion of small tanneries and textile facilities, clusters of small facilities present a unique set of challenges and opportunities. The interventions that have been undertaken to date have been only partially documented; thus, this appears to be a rich area for further study. In particular, it would be useful to research the prospects for taking advantage of existing, "natural" clusters of facilities to create competency clusters, similar to industrial parks albeit on a small scale. For example, as in the experience of tanneries in Pakistan or the Shamva mining centre in Zimbabwe, it would be useful to identify opportunities to create clusters of small facilities that share infrastructure for safer production.

Financing: More research is needed on the options for effective financing of cleaner production efforts. A particularly interesting area for investigation is the possible role of micro credit in facilitating adoption of pollution prevention among the smallest facilities.

Collecting good baseline data for sound analysis over time: There is a need for data collection at every stage of cleaner production programs, so that outcomes can be measured accurately. Ideally, baseline data should be collected on both economic and environmental factors at the outset of a project, in order to make it possible to gauge accurately the effects of an intervention. For projects that aim to disseminate cleaner production practices via pilot or demonstration projects, baseline data should be collected not only on the facilities that will be direct beneficiaries of the pilot project, but also on the surrounding facilities to which project managers hope the cleaner production information will spread over time. For projects that attempt to transform small-scale production practices throughout a community, it would be useful to collect baseline data not only on levels of pollution but also on community-wide indicators of well-being, including health and economic status. In the case of small-scale gold mining, for example, it would be useful to collect information on the number of families that adopt cleaner production methods over time, and on levels of mercury in the blood and hair of children and women of childbearing age.

A couple of additional cautions are in order. Although there is ample scope for additional research on the nexus between pollution prevention and economic development, much is already known. Research is important, but not more important than continued action. As we have seen in the literature on pollution prevention in the United States, lack of funding and government support have meant that obvious pollution prevention opportunities have been missed. Pollution prevention professionals find easy opportunities for pollution prevention on almost every site visit; the limiting factor in many instances is simply that there is no pollution prevention professional to make those site visits. No amount of research can compensate for a lack of dedicated professional time on the ground.

In a similar vein, many of the international cleaner production programs described in the literature were designed to last two, three, or five years. As a result, program managers have had to end projects or shift their attention to fundraising just when their work is beginning to show results. It would be far preferable to create programs that are designed from the outset to last longer.

Appendix A: The World of Pollution Prevention Case Studies

In this Appendix, we outline the major sources of case studies on pollution prevention and cleaner production efforts world-wide.

UN Sources. The United Nations Industrial Development Organization (UNIDO) provides a database of cleaner production case studies on its website. All of the case studies provided by UNIDO are drawn from developing countries; most of them describe efforts linked to the National Cleaner Production Centres (NCPCs) that UNIDO has helped to establish. Most of the case studies indicate the magnitude of investment required for the project, as well as expected or actual savings.[74]

The United Nations Environment Programme (UNEP) Cleaner Production program has compiled a wealth of information on cleaner production, including a number of regional overview reports. UNEP also has a large database of cleaner production case studies drawn from both developed and developing countries.[75]

The United Nations Development Programme (UNDP) has also initiated projects to address pollution from small-scale industries, and has produced reports on these experiences.

National Cleaner Production Centres. UNIDO has sponsored the establishment of National Cleaner Production Centres (NCPCs) in some thirty countries world wide. Each of these centres serves as an information hub and a source of pollution prevention expertise. Case studies generated by the NCPCs are available through the UNIDO database, described above; however, individual NCPCs are also a source of more detailed, country-specific information on pollution prevention experiences.

Environmental Management Centre. The Environmental Management Centre (EMC), based in India, provides a compilation of case studies on the internet; these overlap with the case studies provided by UNEP.

Bilateral aid programs. Some programs sponsored by international aid agencies have produced detailed case studies of their projects. For example, a number of very detailed case studies are available through a cooperative project between Canada and China; there are also case studies from collaboration between Norway and China. Case studies

[74] The case studies provided by UNIDO are quite detailed, although there are some ambiguities in the discussion of costs. In some instances, it is unclear whether the costs and benefits listed are simply estimates developed in the course of an audit, or whether the figures represent the actual outcome of the intervention. It is also unclear in some instances whether funds were provided by the company, or by a supporting agency such as a National Cleaner Production Centre (NCPC).

[75] The UNEP compilation of case studies is available on a new CD-ROM, the "Cleaner Production Companion." It is also available through an internet resource provided by the Environmental Management Centre (http://www.emcentre.com/unepweb/tec_case/).

developed by the US AID Environmental Pollution Prevention Project (EP3) appear in the UNEP case studies database.[76]

Pollution Prevention Roundtables. In the US, the National Pollution Prevention Roundtable (NPPR)[77] is an important source of pollution prevention information. NPPR has also worked to create resources for use internationally, and has spawned other regional pollution prevention roundtables. NPPR's mission is to provide a national forum for promoting source reduction of pollution (as opposed to end-of-pipe mitigation approaches). NPPR provides a number of overview documents and maintains a "P2 Pays Library," a searchable database; it also works in tandem with the Pollution Prevention Resource Exchange Regional Centers to provide access to case study material. Pollution prevention roundtables for other regions have also developed case study resources; for example, a report by the Africa Pollution Prevention Roundtable includes an overview of pollution prevention programs in many countries, combined with individual facility case studies for each of the countries considered.

Pollution Prevention Resource Exchange. Within the US, nine Pollution Prevention Resource Exchange (P2RX) Regional Centers have been established to provide expert information on specific areas of industry.[78] For example, one regional center specializes in pollution prevention in the areas of auto body repair, metal finishing and coating, and mercury, among others. Other regional centers offer different areas of expertise, helping to avoid overlap of efforts. "Topic hubs" provided on the P2RX website include case studies on a range of industries.

US Government Sources. The US Environmental Protection Agency (EPA) maintains a web resource called "Envirosense,"[79] which contains case studies, guidance documents, and fact sheets on cleaner production and pollution prevention. Much of this information is relevant primarily for large companies in the US. As of April 2005, the website includes web pages on metal finishing, petroleum refining, printing, and electronics and computer manufacturing.

Scholarly Journals. The *Journal of Cleaner Production* is a particularly valuable source for country- and industry-specific case studies, as well as for broader methodological discussions. Recent special issues of this journal have been devoted to topics including options for financing cleaner production, cleaner production as an engine of sustainable development, and the experiences of SMEs in adopting environmental management systems.

Other sources. Other interesting case studies are available from a variety of organizations and agencies. Individual country programs have developed their own sets of case studies; for example, the Bolivian Center for Promotion of Sustainable Technologies (CPTS) has

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[76] Many USAID case studies are anonymous, omitting the name of the company involved and the country in which the project was located (specifying only that it was a developing country).
[77] National Pollution Prevention Roundtable website: http://www.p2.org/
[78] Pollution Prevention Resource Exchange website: http://www.p2rx.org/
[79] See the "international" section of the Envirosense website at http://es.epa.gov/cooperative/international/.

developed more than a dozen detailed case studies. The Swedish Association of Environmental Managers provides some cases on its website,[80] and the Swedish Chemicals Inspectorate has compiled some useful case studies as well.

In the US, individual state governments have developed compilations of case studies, some of which are very detailed. The state of Massachusetts has a particularly well developed set of "success stories" documenting the experience of companies that have undertaken projects to reduce their use of toxic chemicals.[81] Although these case studies come from a developed country context, many of the companies are small firms of a size that could also be found in developing countries; furthermore, the expenditures in many cases are small enough to be practical in almost any setting. Industries examined in these case studies include metal finishing, metal working, paper coating, printing, and textiles.

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[80] Swedish Association of Environmental Managers website: www.bestpractice.nu.
[81] See http://www.mass.gov/ota/ and click on "Case Studies."

Appendix B: UNIDO and UNEP Database Resources

Case studies available from UNIDO:

UNIDO Case Studies

Industry	Number of case studies
Textiles - manufacturing and finishing	7
Cordage, rope, twine	1
Fur	1
Leather	5
Wood	1
Pulp, paper	9
Printing	1
Basic chemicals	3
Fertilizers	2
Plastics	1
Paints	1
Pharmaceuticals	1
Soap, cleaning materials, perfume	2
Other chemical	5
Other rubber	1
Plastic products	5
Glass	1
Iron & steel manufacture and casting	7
Structural metal products manufacture	2
Treatment and coating of metals	5
Metal manufacturing	2
Food	2
Insulated wire and cable	1
Accumulators, batteries	1
Construction	1
Auto repair	1
Architecture/engineering	1

Manufacturing case studies available from UNEP:

UNEP Case Studies in Manufacturing

	Economy		
	Developed	Developing	Transitional
Chemicals and chemical products	34	8	16
Electrical machinery and apparatus	2	2	2
Furniture	11	0	1
Machinery and equipment	11	0	3
Transport equipment	4	2	2
Radio, Television, etc.	16	3	0
Textiles	18	19	1
Publishing & Printing of Recorded Media	13	1	0
Basic Metals	19	2	2
Coke and Refined Petroleum Products	1	2	4
Fabricated Metal Products	48	7	4
Motor Vehicles, Trailers and Semi-trailers	6	4	1
Non-Metallic Mineral Products	4	4	2
Paper and Paper Products	47	22	1
Rubber and Plastic Products	2	0	4
Wood & Cork Products	2	0	0
Tanning and Dressing of Leather	9	7	2

Appendix C: Additional Case Study Material: Textiles

As noted in Appendix A, above, a substantial number of facility-specific case studies can be found in two databases, maintained by UNEP and UNIDO respectively. As a sample of the information that is available, we provide an overview of case studies on textile facilities available from the UNEP and UNIDO databases. This exists in addition to information found in country-specific databases; for example, dozens more case studies of this kind are available from the Pollution Prevention Resource Exchange in the US.

From this overview, we can see that facilities featured in the case studies range in size from fewer than 100 workers to several thousand. Investments in pollution prevention can range from a few thousand US dollars to hundreds of thousands of dollars. Financial benefits from these investments can be several times as great as the initial investment, or can be less than or equal to the initial investment.[82] We have noted in italics a few cases in which the facility-specific case study explicitly discusses the role of legislation as an impetus for pollution prevention.

Sample Case Studies: Textile Facilities
Source: UNIDO and UNEP Databases

Country, company name, & facility type	Date	Size, # of workers	Problems and solutions	Money invested	Money saved
Brazil: Serviço Nacional de Aprendizagem Industrial/Centro de Tecnologia da Industria Química e Têxtil (textiles - general)	1992-1995	"large"	Pollution in dyeing and printing; discharge of dyes, polymers, sizes, surfactants and other chemicals. Solutions: A range of interventions to reduce pollution at the source.	US $150,000	US $480,000
Chile: Quimica y Textiles Proquindus SACI (dye house) (audit only)	1992	90	High use of water, energy, dyes, and bleaches; wastewater containing high concentrations of suspended solids. Solutions: Housekeeping, process modification.	US $1,850	US $105,700

[82] Cost figures have been converted to US dollars without adjustment for inflation.

Chile: Hilados y Tejidos Garib S.A. (dyed yarn and fabric)	1993	270	High use of water, dyes, bleaches and other chemicals. Solutions: recovery, reuse, and recycling; process modification.	US $10,950	US $7,000
China: Beijing No.2 Worsted Mill (textiles - general)	1995	5,000	Dyeing wastewater and high concentration wool washing water. Solutions: Process modification; housekeeping.		
El Salvador: Charles Products (garment industry, assembling clothing)	2000	1,240	Excessive water use in washing and rinsing stages. Solutions: process modification; recovery, reuse, and recycling; material substitution.	n/a	n/a
El Salvador: Vinyl Cloth Manufacturing Co. (vinyl fabric production) (audit only)	2001	130	Raw material consumption, energy use, emissions. Solutions: housekeeping; process modification; recovery, reuse, and recycling.	US $411,052	US $194,805
India: Oriental Dyeing & Finishing (cotton hosiery bleaching and dyeing)	2002	60	Excessive use of energy and raw materials. Solutions: recovery, reuse, and recycling.	US $4,500	US $25,800
India: textile mill	Pre-1985	n/a	Caustic soda in wastewater. Solutions: Process modification; housekeeping.		US $15,700 (annual)
India: Century Textiles and Industries Limited (cotton manufacturing)	1990	7,000	Sulphur dyes producing caustic soda and sodium sulphide. Solutions: material substitution. *Role of legislation: Project inspired by the need to comply with sulphide standards for effluent.*	US $4,800 (annual)	US $32,000 (annual)
India: Research by Bombay Textile Research Association	1995	n/a	Interested in kerosene recovery.	US $40,000	6 year payback period

Latvia: Joint Stock Company Lauma (cotton and polyester fabric manufacture)	NA	>2,000	Oil contamination in water, pollutants, excessive energy use. Solutions: housekeeping.	US $45,000	US $81,600 (annual)
Netherlands: KTV company (textile finishing)	ca. 1975	"large"	Excess pollution in weaving process. Solutions: material substitution.	n/a	n/a
Spain: Nylstar textile plant (textile manufacture)	1994	633	Raw material consumption. Solutions: process modification.	US $68,000	US $57,398 (annual; 13 month payback period)
Vietnam: Trung Thu Textile Company (yarn manufacture and textile processing)	1998	130	Not specified. Solutions: material change; process control; recycle, reuse; housekeeping; equipment modification.	$12,608 US	$1,699
Vietnam: Phuoc Long Textile Company (manufacture and dyeing of fabrics)	1999	1,283	Excessive chemical pollution. Solutions: housekeeping; process modification; recovery, reuse, and recycling.	US $4,400	US $40,000 US (less than 2 month payback period)
Vietnam: Nam Dinh Textile Silk Company (cotton, silk, polyester fibre processing)	1998	1,750	Problems not specified. Solutions: material substitution; process modification; housekeeping; recovery, reuse, and recycling.	US $22,860	US $9,928
Vietnam: Thanh Cong Textile Company (manufacture of processed fibers) (audit only)	1999	4,475	No pollution control for effluent; inefficient use of raw materials. Solutions: housekeeping; process modification.	n/a	n/a
Country unlisted: EP3 Programme (acrylic yarn and fabric dyeing)	1990	"small"	Excessive use of energy and water, inefficient use of raw materials. Solutions: recovery, reuse, and recycling; process modification.	US $13,000	$36,000 US

Country unlisted: EP3 Programme (cotton and wool dyeing) (audit only)	1992	70 shift workers; 20 technical & admin.	Excessive water use (twice the amount for another facility of the same size), inefficient use of raw materials, discharge of chemicals. Solutions: process modification; housekeeping.	$4,500 US (estimated)	US $105,700 (estimated)
Country unlisted: EP3 Programme (cotton and synthetic blend dyeing) (audit only)	1992	n/a	Excessive water use in the rinsing, dyeing, and bleaching processes, excessively hot effluent, unnecessary energy use due to ineffective heat recovery, excessive biological oxygen demand (BOD) of effluent, overuse of dyes and other chemicals. Solutions: process modification; housekeeping.	US $4,200 - $6,700 (estimated)	US $51,000-65,000 (estimated)

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KEMI

The Swedish Chemicals Inspectorate • P.O. Box 2 • S-172 13 Sundbyberg
Phone +46 8 519 41 100 • Fax +46 8 735 76 98 • www.kemi.se • e-mail kemi@kemi.se