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59p.

United Nations Industrial Development Organization

Training Course
Ecologically Sustainable Industrial Development

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Learning Unit 4

Cleaner Production

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Contents

Additional Course Materials

Reading: *Cleaner Production Worldwide*, a UNEP booklet

Video: *Pollution Prevention: Swedish Experiences*, a film by TEM, an environmental research organization at the University of Lund

Introduction

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In Learning Unit 4 we describe what Cleaner Production means, explain its role in achieving ESID and discuss how it can be achieved. Cleaner Production is important to industrial development because it offers the potential to reduce pollutants and to increase industrial productivity.

Objectives

The specific learning objectives of this unit are as follows:

- To understand the concept of Cleaner Production as essential for achieving ESID.
- To review the many activities that can achieve Cleaner Production.
- To learn what many enterprises already have achieved by implementing Cleaner Production.
- To be aware of the barriers to introducing Cleaner Production to industry.

Key Learning Points

1 Industry first tried to deal with pollution by using the natural environment to dilute the impact of pollutants. Subsequently, it became clear that some action had to be taken to minimize the impact of pollutants on the environment. This led to the use of pollution control (end-of-pipe) technology. These methods are expensive and, often, they are not fully effective.

2 Cleaner Production avoids industrial pollution by reducing waste generation at every stage of the production process in

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order to minimize or eliminate waste before any potential pollutants are created.

3 The terms pollution prevention, source reduction and waste minimization are often used to mean the same thing as Cleaner Production.

4 Cleaner Production can be achieved in a number of ways, such as good housekeeping and operating procedures, materials substitution, technology changes, on-site recycling and product redesign or any combination of these actions.

5 Cleaner Production is more cost-effective than pollution control. By minimizing or preventing waste generation, the costs of waste treatment and disposal are reduced. Furthermore, the systematic avoidance of waste and pollutants reduces process losses and increases process efficiency and product quality.

6 The environmental advantage of Cleaner Production is that it solves the waste problem at its source. Conventional end-of-pipe treatment often only moves the pollutants from one environmental medium to another, e.g. the scrubbing of air emissions generates liquid waste streams.

7 Cleaner Production is often not accepted because of human factors rather than technical problems. The traditional end-of-pipe approach is well known and accepted by industry and engineers. Existing government policies and regulations often favor end-of-pipe solutions, which are administratively easier to impose. There is a lack of com- munication between those in charge of production processes and those who manage the wastes that are generated. There is often a lack of easily accessible information. Managers and workers who know that the factory is inefficient and wasteful are not rewarded for suggesting improvements.

8 Although Cleaner Production techniques are preferable, some end-of-pipe treatment still may be necessary when it is impossible, at least for now, to eliminate completely the production of wastes.

9 Because Cleaner Production attacks the problem at several organizational levels at once, the introduction of an industry/plant-level Cleaner Production programme requires the

commitment of top management and a systematic approach to waste reduction in all aspects of the production process.

10 Future industrial development based on Cleaner Production would bring industrial activity closer to meeting the ESID criteria because it would both reduce pollutant discharges and increase the efficiency of raw material and energy utilization.

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Suggested Study Procedure

1 Look through the test at the beginning of the *Review*. Think about the questions raised and what you need to learn from this Learning Unit.

2 Work through the *Study Materials*, including the *Reading Excerpts*, the brochure and the video.

3 Prepare answers to the questions posed for the *Case Studies*. If possible, work with a small group to discuss the questions raised. Compare your answers with those suggested.

4 Complete the exercises in the *Review*.

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Study Materials

The following sections are designed to help you become familiar with Cleaner Production, to explain how Cleaner Production fits in with other approaches dealing with pollution, to outline the advantages of Cleaner Production, to acquaint you with many of the principal methods for achieving Cleaner Production and to discuss the barriers to implementing Cleaner Production in developing countries.

Background

The approach to pollution control has evolved through three stages over the last 50 years:

- Dilution
- Treatment
- Avoidance/Cleaner Production.

Many countries are still at the dilution and/or treatment stage.

The dilution approach involves the discharge of pollutants directly into the environment. It relies on the assimilative capacity of the water, air and soil to dilute or neutralize the impacts. This approach can work if the amount of waste is small compared to the volume of the receiving environment.

The treatment stage, traditionally called end-of-pipe treatment, has been used at the end of the production process to collect pollutants and then to separate or neutralize them in various ways, usually in specially built treatment installations. Treatment often merely separates the pollutants from the waste stream, but they still have to be disposed of somewhere.

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Dilution and treatment, and even recycling, are not long-run solutions. Natural systems have a limited assimilative capacity to dilute wastes (see Learning Unit 2). In areas where there is a heavy concentration of industry, this capacity is easily exceeded. Wastes can impair human health, reduce the productivity of fisheries and agriculture and damage man-made materials. The level of treatment is often limited because only so much of production costs can be allocated for pollution control, which is a non-productive investment. Recycling often suffers from poor or unpredictable markets for its products. Both treatment and recycling generate further residues themselves, some of which may be worse than the original waste product.

The costs of the end-of-pipe treatment approach are creating a barrier to further industrial development. The United States spent US$ 100 billion and the countries of the European Community spent more than US$ 30 billion on pollution control in 1992. There is little direct financial return to the industries that incur this expenditure.

The composition of the pollution is becoming more complex. Thousands of new chemicals are introduced into the market each year to add to those already there. Some of them find their way into emissions and wastes. Also, the potential toxicity of these chemicals means that safety regulations are required to protect workers and users. The costs of complying with these regulations must be borne by chemicals producers and users.

Strengthened environmental regulations are putting pressure on industry to increase its environmental performance. It is often difficult, however, to modify existing plants at a reasonable cost.

Cleaner Production, the preventive way, is a better approach to avoiding and minimizing environmental problems. Avoiding pollution by preventive methods often solves the problem rather than treating the symptoms. As a consequence of Cleaner Production, there are often cost savings and better quality products.

Next Steps

1 Read "The road to ecologically sustainable industrial development", included in the *Reading Excerpts* at the end of this Learning Unit.

2 Test your comprehension of the material by answering the questions below. Compare your answers with those suggested.

Questions

1 What are the three stages in the evolution of pollution control approaches?

2 Give two examples of how dilution still is used.

3 What are two weaknesses of end-of-pipe treatment?

4 Explain how a Cleaner Production approach was used to reduce dioxin discharges from pulp and paper mills.

Answers

1. Dilution, treatment and Cleaner Production.

2. Letting untreated effluent flow into a river and installing higher smoke stacks.

3. It does not reduce waste production hence it does not increase production efficiency. It is often more expensive than Cleaner Production. Often, it only transfers the pollution from one medium to another, e.g. from the air to the soil.

4. Sufficient reduction of dioxin discharge from pulp and paper mills by treatment of waste water is not possible. Thus, the industry had to change its bleaching process and significantly reduce chlorine use.

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Cleaner Production

Cleaner Production is defined by UNEP as the continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to humans and the environment.

- For production processes. Cleaner Production includes conserving raw materials and energy, eliminating toxic processing materials and reducing the quantity and toxicity of all emissions and wastes before they leave a production process.

- For products, the approach focuses on the reduction of environmental impacts along the entire life cycle of a product, from raw material extraction to the ultimate disposal of the product, by appropriate product design.

Cleaner Production is good for the environment because it reduces pollution from industry. There are also some direct benefits to the companies that follow this approach, such as:

- Cost-saving through reduced wastage of raw materials and energy.

- Improved operating efficiency of the plant.

- Better product quality and consistency because the plant operation is more predictable.

- Recovery of some wasted materials.

Cleaner Production requires:

- Applying know-how.

- Improving technology.

- Changing attitudes.

The Cleaner Production approach to industrial environmental management requires a hierarchical approach to pollutant management practices. The order of preference in decision-making on design and operation is as follows:

- Prevention of generation of wastes.
- Recycling.
- Treatment.
- Safe disposal.

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Only when prevention techniques have been fully adopted should recycling options be used. Only when wastes are recycled as far as possible should treatment of the residues be considered. To use off-site recycling or end-of-pipe technologies before prevention has been maximized is not Cleaner Production.

Cleaner Production does not always require new technologies and equipment. Some examples of practical Cleaner Production techniques include:

Good housekeeping and operating procedures:

- Tighten valves and check pipes to reduce leaks. Turn off water when not needed.
- Minimize dragout when objects are removed from processing baths.
- Optimize operating parameters of the plant.
- Reduce storage and transfer losses by revising procedures.
- Improve materials handling to reduce the incidence of spillage.

Material substitution:

- Replace solvents with water.
- Replace acid pickling of steel with peroxide treatment.
- Replace chlorine bleaching with oxygen bleaching.

Technology changes:

- Batch instead of continuous processing.

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- Mechanical instead of solvent cleaning.
- Powder painting instead of wet painting.
- Automatic instead of manual chemical feed.
- Dry heating instead of heat treatment baths for metal finishing.

On-site recycling:

- Internal recycling of rinse waters.
- More efficient washing or cleaning using counter-current principles.
- Steam condensate recovery and recyling.

Product redesign:

- Remove toxic substances from product components.
- Concentrate product to reduce packaging.
- Increase durability and improve repairability.
- Use materials that can be recycled.

In the PRISMA project, the Government of the Netherlands selected 10 of the most efficient companies in the electroplating, food and drugs, transportation, metalworking and chemicals industries. An initial assessment of Cleaner Production possibilities yielded 164 options, distributed as follows: improved housekeeping (28%), material substitution (22%), technology changes (39%), on-site recycling (10%) and product redesign (1%).

Because it often leads to cost savings and improved operating efficiencies, Cleaner Production enables business and other organizations to pursue their economic goals while improving the environment at the same time.

The implementation of Cleaner Production involves changes in human thinking and attitudes about production and the environment.

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Next Steps

1 Read "Deciding on pollution prevention" from the *Facility Pollution Prevention Guide*, included in the *Reading Excerpts* at the end of this Learning Unit.

2 Test your comprehension of the information by answering the questions below. Compare your answers with those suggested.

Questions

1 What is Cleaner Production?

2 What is the difference between Cleaner Production and traditional environmental protection approaches?

3 What are some of the environmental benefits of Cleaner Production?

4 What are some of the benefits to companies of Cleaner Production?

5 What are the three source reduction measures involving process changes mentioned in the *Facility Pollution Prevention Guide*?

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6 Why is off-site recycling not considered a Cleaner Production process?

Answers

1. *Cleaner Production is the continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to humans and the environment.*
2. *Cleaner Production looks for pollution prevention opportunities, such as product and process changes and on-site recycling and recovery, before turning to pollution abatement measures.*
3. *It eliminates toxic processing material, conserves energy and raw material and reduces the discharge of pollutants into the environment.*
4. *Company benefits include increased efficiency and financial returns.*
5. *Improved operating practices, technology changes, input material changes.*
6. *Off-site recycling requires transportation and there is often residual waste from the recycling process.*

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Cleaner Production Pays

Cleaner Production is cost-effective. It can increase process efficiency and improve product quality.

The payback period is the amount of time it takes the savings to pay back the amount invested in Cleaner Production. Some savings, e.g. housekeeping and changed procedures, can be made immediately; some require study and investment. Even when investment costs are high, the payback period can be short.

End-of-pipe treatment is an add-on cost and does not give a payback.

Many Cleaner Production techniques yield substantial savings in production costs. (See the *Reading Excerpts* and the video.)

Savings can come from reduced raw material and labor costs, lower energy consumption, less expensive maintenance, reduced waste management costs, improved worker safety and lower product liability.

In the PRISMA project, the 42 Cleaner Production options for small and medium companies were determined: 20 of them (49%) produced cost-savings, 19 (45%) were cost-neutral and 3 (7%) increased production costs. The cost-saving options had an average payback period of less than one year.

Thus, even though Cleaner Production does not always lead to cost-savings, it is the most cost-effective way to reduce pollution.

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Next Steps

1 Read the brochure *Cleaner Production Worldwide*, included in the training kit, and "The effects of cleaner production on unit costs," included in the *Reading Excerpts* that accompany this Learning Unit.

2 Test your comprehension of the information by answering the questions below. Compare your answers with those suggested.

Questions

1 Explain how Cleaner Production leads to savings.

2 Does Cleaner Production always have a payback?

3 How did Cleaner Production save money for the photographic firm PCA International?

Answers

1 Savings in raw materials and energy; decreased waste management costs, improved product quality, enhanced productivity, decreased down time, decreased long-term liability for the clean-up of wastes.

2 No, but in most cases it does, and it is always the most cost-effective way to reduce pollution.

3 Replacing the organic solvents by water-based solvents led to a 100 per cent reduction of waste, with a payback period of less than one year.

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Next Steps

1 Look over the questions below so that you have some idea of what you will want to learn from the video.

2 Watch the video *Pollution Prevention: Swedish Experiences.*

3 Test your comprehension of the information by answering the questions below. Compare your answers with those suggested.

Questions

1 What motivated the company Landskrona Emballage to try water-based inks?

2 How does the use of water-based printing inks improve the working environment?

3 What importance did the manager of Landskrona Emballage attach to his employees' involvement in developing the cleaner printing technology?

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4 **How can the traditional alkaline degreasing processes be replaced?**

Answers

1. They were forced by the authorities to reduce their solvent emissions.

2. The printer is no longer forced to work in close proximity to ethanol-based inks. He can wash out with water instead of volatile organic solvents.

3. It would not have been possible without their full support and enthusiasm.

4. An alternative is biological alkaline decreasing process, using naturally occurring bacteria which degrade the oil pollution.

Introduce Cleaner Production to Industry

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Industry can make Cleaner Production happen through a commitment to action within the company. Many corporations in industrialized countries have already introduced Cleaner Production without waiting for government action.

Because Cleaner Production often involves a change in attitudes, people need incentives to work towards an integrated, systematic approach to environmental protection.

Without a clear, written commitment from top management to Cleaner Production, other personnel will not contribute effectively.

Without the involvement of all workers at all organizational levels in a plant, good results will be hard to get. Motivation, incentives and a workplace culture where suggestions from the shop-floor are acted on are needed to achieve such universal involvement.

The internal training of workers, supervisors and managers is necessary to identify opportunities for Cleaner Production and to implement it.

Ten steps for introducing a Cleaner Production program in an enterprise are as follows:

- Develop and implement a comprehensive corporate environment policy that focuses on prevention.
- Set corporate goals for the Cleaner Production programme, with specific percentages and timetables.
- Allocate responsibility, time and financial support for the entire Cleaner Production programme.
- Involve employees at all levels.
- Develop waste reduction audit procedures within the company and use them on a regular basis to identify, evaluate and eliminate waste at each stage in the production process. This gives the information on which in-plant Cleaner Production options can be based.

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- Obtain and use the best possible technical and other information, from both inside and outside the company. Waste reduction criteria can cover technical environmental factors, regulatory compliance, public acceptance and economic viability. Research the industry specific Cleaner Production publications, newsletters and databases of UNIDO and IE/PAC.

- Monitor and evaluate progress of the company's Cleaner Production programme.

- Regularly inform all employees on the Cleaner Production progress made by the company in the last month, six months, year and five years.

- Encourage and reward successful individual and group efforts to implement Cleaner Production.

- Remember that success in Cleaner Production is a journey not a destination. Update the waste minimization goals and timetables on a regular basis.

Identifying Cleaner Production Opportunities in a Factory

In an existing plant, there is a need to study where the pollution comes from in order to take the most cost-effective remedial action.

One way of doing this is a waste audit, which systematically looks at all processes and operations. The idea behind the audit is that any raw material that does not end up in the product must go out as waste. The audit procedure systematically identifies these losses, many of which may be hidden from view.

UNIDO and UNEP have produced a technical guide to waste reduction audits. You will learn about waste reduction audits in Learning Unit 5.

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Barriers to Introducing Cleaner Production

The introduction of Cleaner Production is sometimes hampered by:

- Resistance to new ideas and approaches in which staff have no formal training. Demonstration projects are essential to show that Cleaner Production can work in "our country" or in "my company".

- Lack of financial resources, awareness and training, expertise and know-how, information and access to existing knowledge.

- Uncertainty about the right information, technology or regulations.

- Government policies/regulations that focus on single-medium pollutant reductions that discourage innovative solutions to pollution reduction and that offer tax incentives for investment in end-of-pipe technologies.

- Lack of familiarity with Cleaner Production practices and techniques on the part of engineers and consultants. Often they do not pay enough attention to improvements in housekeeping, small modifications of existing equipment and other less technical matters that can be very cost-effective.

- Fear of being put at competitive disadvantage as a result of perceived high costs.

Next Steps

1 Test your comprehension of the information by answering the questions below. Compare your answers with those suggested.

Questions

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1 **List some of the main barriers to the introduction of Cleaner Production.**

2 **How can a firm induce all workers to become involved in Cleaner Production?**

3 **Are engineers and consultants always familiar with Cleaner Production practices and techniques?**

4 **What should motivate consulting firms to advise clients on Cleaner Production rather than end-of-pipe treatment?**

Answers

1. Lack of know-how.
Resistance to the new approach by the staff.
Financial difficulties.
Uncertainty about the right way to apply Cleaner Production.
Difficulty in getting governmental support.

2. For good results, it is necessary to get the participation of all workers in a plant by motivation, incentives and a workplace culture where shop-floor suggestions are acted on.

3. No, often they do not pay enough attention to improvements in housekeeping or to small and less technical modifications of the production process.

4. What is good for the client is ultimately the best also for the consulting firm.

Additional Suggested Reading

This concludes the study section of Learning Unit 4. For additional information on Cleaner Production, you may refer to the following sources.

Berglund, R.L., and C.T. Lawson, "Preventing pollution in the CPI", *Chemical Engineering*, September 1991.

Crittenden, B.D., and S.T. Kolaczkowski, *Waste Minimisation Guide* (Institution of Chemical Engineers, 1992).

de Hoo, S., and others, "The PRISMA Project as a model for use in other countries: background, methodology, results and some follow-up projects", paper presented at the UNEP Ministerial Meeting and Second Senior Level Cleaner Production Seminar, 27-29 October, 1992, Paris.

Huisingh, D., and L.W. Baas, "Cleaner Production: the most effective approach to achieving improved water quality", *European Water Pollution Control*, vol. 1, No. 1, (1991).

Johansson, A., *Clean Technology* (Boca Raton, Florida, Lewis Publishers, 1992).

Case Studies

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Next Steps

1 Study these cases, all of which are adapted from the brochure *Clean Technology*, published by the Department of the Environment (United Kingdom). Then answer the questions that follow, if possible working in a small group.

2 Compare your answers with those suggested.

Case Study 1: Reduction of Chromium Pollution and Waste in Leather Tanning

The conversion of hides to leather has been carried out from the earliest times and still follows the same basic procedure. Many agents (vegetable, organic and metallic) can be used in the tanning stage, each conferring different characteristics to the leather.

The use of trivalent chromium as a tanning agent is comparatively recent, only becoming established on a large commercial scale by about 1910. Now it is the most widely used process. Chromium imparts desirable qualities of wear, softness, feel and texture to the leather. The level of chromium normally used for high quality leather is 4-5 per cent by weight. To achieve this, even by the most efficient processing, some 30 per cent of the chrome offered to the hide is left in the tanning liquor and wasted.

The British Leather Company, which processes about 6,000 hides a week employs a cleaner technology that entails two stages. The first stage uses a liquor based on titanium, aluminium and

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magnesium, with no chromium. This is the TAL process of ICI. In the second stage, a chromium tan is used with 9 per cent chromium instead of the normal 17 per cent. This results in a leather with a chromium content of about 3 per cent but with characteristics comparable to traditional leather. Residual chrome in the spent liquor is reduced because less chrome is used initially and the percentage uptake is greater. The overall effect is to reduce the chromium content of the spent liquor from 1,200 to 350 ppm and the level in the final effluent to 10 ppm.

Advances in leather technology combined with extensive tanning trials have made this process commercially viable. Considerable research was carried out to identify the optimum tanning properties of the various combinations of metals used in the first stage of the process.

The solution adopted has two advantages:

- The chromium level in the discharge is substantially reduced, removing a potential constraint on production.
- The technology requires no additional capital equipment and can be used in an existing plant.

There are also modest savings in tanning reagent costs. The main incentive to move to cleaner technology is the anticipation of higher future standards. The company can expect to save at least US$ 300,000 that would be required for an abatement plant to achieve the same chromium reduction as that obtained by cleaner technology.

Questions

1 **Which of the various techniques for Cleaner Production (good housekeeping/operating procedures, material substitution, technology changes, on-site recycling and product redesign) is illustrated in Case Study 1?**

2 **Why do you think the plant considered implementing a Cleaner Production approach?**

3 **Why do you think the tannery did not want to install pollution control equipment?**

4 **What do you think might be some barriers in transferring this Cleaner Production approach to other places?**

Answers

1. Basically a material substitution.

2. Increasingly stringent discharge standards for chromium and significant reductions in the cost of waste treatment.

3. Pollution control equipment would not recover chromium and it would entail a large capital investment, with no financial return.

4. Attitudes, lack of knowledge and lack of discharge standards.

Case Study 2: Cement Kiln Pollution and Waste Reduction by Improved Process Control

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The manufacture of cement in its present form was patented in 1824. Known as Portland cement, it requires the burning of fuel together with limestone and clay, yielding a clinker which is then ground with gypsum to give cement. Burning is carried out in a rotating, inclined kiln. The process is complex, in terms of the reaction chemistry, the thermal conditions in the kiln and the dynamics of the process. The temperature largely determines the quality of the product cement. However, both the NO_x and SO_x levels increase with higher temperatures.

The process must, therefore, be operated within a certain band of temperature, with the optimum at the lower end. If the process is operated too far below this optimum, an unusable product is generated. If the temperature is too high, energy is wasted, cement quality reduced and air pollution increased. There are many possible disturbances to the process, for example, changes in the calorific value of the coal and the composition of the feed, which make it difficult to operate manually.

The LINKman expert system, developed by Image Automation, continuously monitors all the appropriate process variables such as the flue gas temperature, oxygen, NO_x level and the power used to turn the kiln. It then makes adjustments to the coal, air and feed rates on the basis of a model of the plant's behaviour derived from operational experience. The system can also make smaller adjustments more frequently. This allows the plant to be run much closer to its optimum conditions than is possible under manual control. One significant novel feature of the instrumentation is the measurement of the NO_x level in the flue gas, which gives valuable information on the temperature in the firing zone and can be used to help minimize NO_x air pollution.

The system has been made possible by improvements in the science of expert system control and in measurement technology, which have led to a reliable and sensitive NO_x analyser.

The system was installed on two of its kilns by Blue Circle Industries in the United Kingdom. It generated cost savings of US$ 1,860,000 in 1987. The payback period for the capital investment of US$ 406,000 was three months.

The advantages are as follows:

- Coal wastage avoided.
- Better quality product.
- Less energy for clinker grinding.
- Kiln lining has longer life.
- NO_x and SO_x emissions are reduced from 500 ppm to 200 ppm.

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Questions

1 Which of the various Cleaner Production techniques is illustrated in Case Study 2?

2 Was the introduction of Cleaner Production cost-effective?

3 Why might workers in this plant have resisted the introduction of this Cleaner Production action?

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4 Do you think cement plants need end-of-pipe pollution control technologies?

Answers

1. Improved operating procedures.

2. Reduced fuel use and improved product quality. Three months payback.

3. They may fear that giving away their unique professional knowledge to a computer expert system may cause them to become redundant.

4. Yes. They need filters on their smokestacks to recover particulate matter.

Case Study 3: Upgrading of Tin Concentrate

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Tin has been mined from the earliest times. There has been a steady improvement in the percentage of tin in the concentrate that is sent to the smelters. The tin content of the concentrate has a strong bearing on its value. Other materials such as copper, tungsten and zinc are also recovered from the ore.

The traditional process involves a number of steps culminating in flotation. The slurry containing the tin ore flows cross-current to the rising bubbles, which float as a foam carrying the tin-rich particles. The separation and upgrading of the ore have now been improved by introducing column flotation. The rising bubbles and falling ore flow counter-current, giving the effect of multiple stages of normal flotation. A water wash gives improved separation at the top of the column.

Carnon Consolidated, in the United Kingdom, reported that based on annually upgrading concentrate with a tin content of 800 tonnes, the capital investment of US$ 32,000 had a payback period of only 18 days, because the price for the tin concentrate increased by US$ 640,000.

The advantages can be summarized as follows:

- Higher market value for the concentrate.
- Less waste from smelting.
- Less energy used for smelting.
- Low capital investment.

Questions

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1 **Which Cleaner Production measure was applied in this situation?**

2 **What is the main reason this Cleaner Production programme was successful?**

3 **What do you think was the company's main motive for this change—increased profits or environmental protection?**

Answers

1. Technology change

2. It resulted in a very short payback period

3. Increased profits. The example shows that environmental protection through Cleaner Production is fully compatible with normal business objectives.

Case Study 4: Trivalent Chromium Plating

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High quality chromium plating, used for decorative finishes and to impart resistance to wear and corrosion, has traditionally required a high concentration of toxic hexavalent chromium ions, which give a highly toxic effluent. One company in the United Kingdom, W. Canning Materials, has introduced an electrolyte with a much lower concentration of the less toxic trivalent chromium ion. Two technical problems had to be overcome:

- The tendency of the trivalent chromium to oxidize to hexavalent at the anode. This was overcome by using a membrane that had originally been developed for the mercury-free electrolysis of brine.

- The low rate of deposition at the cathode due to the kinetics of the reaction. This was overcome by in-house development of organic additives that modify the reaction and give a performance superior to the traditional process.

For a new plant, economic benefits arise from the use of smaller baths to achieve the same production rate and from reduced expenditure on effluent clean-up. Where there is a premium on quality or where hexavalent chromium is not permitted, savings are even greater. The new technology leads to five advantages:

- A safer working environment.

- Reduced discharges of toxic hexavalent chromium, typically from 80 ppm to less than 3 ppm of less-toxic trivalent chromium.

- Quality is improved because the plating is more uniform. This also saves chromium and allows more articles to be plated in the same bath.

- Only half as much electricity is required to deposit the same quantity of chromium.

- Reduced effluent treatment costs.

Questions

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1 **Which Cleaner Production technique is illustrated in Case Study 4?**

2 **Could this plant solve all its water pollution control problems with Cleaner Production?**

3 **Why do you think management might have resisted the introduction of an alternative electrolyte?**

4 **Why was the change cost-effective?**

Answers

1. Basically a material substitution.

2. No. It still needed traditional end-of-pipe waste-water treatment, but the plant was much smaller.

3. Concerns about the effects on product quality.

4. It reduced the operating cost of both the plating and the effluent treatment plant.

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Review

Test

The following test will help you review the material presented in Learning Unit 4.

1 The first step in improving Cleaner Production in industry is a change in

a. Technology
b. Customer preference systems
c. Attitudes
d. Legislation on recycling

2 The approaches to industrial environmental management have evolved through which three stages?

a. Abatement to prevention to dilution
b. Prevention to dilution to abatement
c. Dilution to prevention to abatement
d. Dilution to abatement to prevention

3 The most cost-effective management choice for combating industrial pollution is pollution

a. Prevention
b. Dilution
c. Abatement
d. Control

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4 Cleaner Production eliminates waste

a. During production
b. At every stage of the life cycle of a product
c. By disposing of wastes safely in approved facilities
d. By recycling processing residues

5 Cleaner Production does not include

a. Better housekeeping
b. Ecologically benign products
c. Recycling of wastes by outside contractors
d. Low- and non-waste technology

6 From the practical business point of view, pollution prevention

a. Often pays
b. Does not pay
c. Has a long payback period
d. Is not possible

7 Cleaner Production is all of the following except

a. Preventive or proactive
b. Idea-oriented
c. Reactive
d. Front-ended

8 Cleaner Production provides a competitive advantage in all of the following situations except

a. Environmental regulations becoming more severe
b. Company adopting quality management standards
c. Customers beginning to care
d. Government increasing energy and water subsidies

9 The implementation of Cleaner Production actions does not necessarily need

a. Training
b. Cooperation between government and industry
c. A change in management attitudes
d. Advanced technology

10 "Cleaner Production is just not realistic in developing countries where per capita GNP is below $1000." This statement is

a. False
b. Correct
c. True
d. Helpful

11 The 10 steps for introducing Cleaner Production in an enterprise include all of the following except

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a. Implementing an environmental policy
b. Conducting an environmental compliance audit
c. Setting goals and timetables
d. Allocating responsibility, time and financial support

12 The 10 steps for introducing Cleaner Production in an enterprise include all of the following except

a. Involvement of senior employees
b. Seeking government subsidies
c. Monitoring and evaluation
d. Disseminating information to employees

13 In a Cleaner Production project, funding will usually be

a. Donated by the workforce
b. Provided by eventual cost savings
c. Available from UNIDO
d. Needed before any plans can be implemented

14 All of the following are barriers to Cleaner Production except

a. Lack of financial resources, awareness, training, expertise and access to know-how
b. Uncertainty about the right information, technology and regulations
c. Attitudes of employees who feel threatened by change
d. Demonstration projects

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15 Cleaner Production is

a. Vital for business survival
b. Moral
c. A good management choice and sometimes profitable
d. A social rather than a business priority

Answers

1-5 c d a b c

6-10 a c d d a

11-15 b b b d c

Some Ideas to Think About

The following are some questions that arise in connection with Cleaner Production. Take some time to think about them. If possible, work in a small group.

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1 How will industry in a country with a per capita GNP of less than US$ 500 react to Cleaner Production concepts? Why? What can UNIDO, UNEP or UNDP do about it?

2 How is the concept of ESID interpreted in your country?

3 How will the manager of a nationalized company react to Cleaner Production? Why?

4 How will the manager of a multinational company react to Cleaner Production? How could this be helpful to you?

5 Why should industry in developing countries be interested in Cleaner Production?

6 Select an industry or company with which you are familiar. Describe briefly its environmental situation. Identify some obstacles that you think will prevent or delay Cleaner Production approaches. Think about what you, as a UNIDO representative, can do to help implement Cleaner Production in this situation.

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Reading Excerpts

The Road to Ecologically Sustainable Industrial Development

Excerpted, with permission, from UNIDO, *Proceedings of the Conference on Ecologically Sustainable Industrial Development*. Copenhagen, Denmark, 14-18 October 1991 (PL/112). Working paper No. I, chaps. V and VI.

Chapter V. The Road to Ecologically Sustainable Industrial Development

The Opportunity

Predicting the future is difficult, but a plausible scenario for achieving ESID is clear. A recent report from the World Resources Institute stated as follows: "human impact on the natural environment depends fundamentally on an interaction among population, economic growth and technology. A simple identity encapsulates the relationship:

$$Pollution = \frac{Pollution}{GDP} x \frac{GDP}{Population} x\ Population$$

Here, pollution, understood as environmental degradation, emerges as the product of population, income levels (the GDP per capita term) and the pollution intensity of production (the pollution GDP term)".

Clearly, the one variable that can be most easily affected in the short run in this relationship is pollution intensity. Over the next 20 years (the time frame for this analysis), world population is predicted to increase from 5.3 billion to 7.2 billion. Similarly, per capita GDP is predicted to increase from $2,900 to $4,100 and per capita MVA from $900 to $1,400. The only choice for avoiding environmental disruption is to reduce pollution intensity by, in the short term, cleaner production and, in the long term, closing the materials and product cycles and shifting to renewable energy resources.

The interaction of the three variables is much more complex than indicated by the simple identity above. For example, as per capita GDP increases, the resources needed for reducing pollution intensity increase and the growth of population declines. Similarly, as per capita income increases, the public demand for reducing pollution intensity increases.

Cleaner Production

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The concept of Cleaner Production is evolving from earlier concepts of clean technology and low and non-waste technology. The old concept of clean technology was seen in 1975 by the Commission of the European Communities as having three distinct but complementary purposes:

- less pollution discharged into the natural environment (water, air and soil);
- less waste (low waste and non-waste technology); and
- less demand on natural resources (water, energy and raw materials).

Although there is no agreed definition for Cleaner Production, just as there is no agreed definition for sustainable development, there is some consensus emerging as evidenced at the United Nations Environment Programme (UNEP) Seminar on the Promotion of Cleaner Production. The advisory group for the seminar suggested that Cleaner Production should be defined as "...a more global approach to environmental protection which would address all phases of the production process or product life cycles, with the objective of prevention and minimization of short- and long-term risks to humans and the environment. Such an approach includes 'cradle-to-grave' minimization of wastes and emissions to air, water and soil, as well as minimization of energy consumption and the use of raw materials".

The term Cleaner Production is technically and operationally very difficult to define, particularly in relation to the "cleanliness" of products. For the purposes of this paper. Cleaner Production is best thought of as two things at once: a new environmental quality goal for industry and, at the same time, a new approach for achieving that goal.

The new environmental quality goal would require industry to move beyond the current norm, which generally calls for meeting ambient standards which normally just consider the effects of one pollutant in the environment immediately surrounding the source. As stated earlier, ambient standards are not able to protect the environment from cumulative loadings of pollutants into it. The emerging environmental norm, total loading standards, initially calls for reducing wasteful loading into the environment. Industry would meet these total loading standards by increasing the efficiency of energy use, reducing dependence on non-renewable resources, reducing dissipative uses of toxic materials etc. In the long run (50-100 years), total loading standards would aim for closing the materials and product cycles and shifting to renewable energy resources. Closing the materials cycle would require industrial processes to move, as technically and economically feasible, to zero waste discharge, particularly of fossil-fuel-related pollutants and toxic chemicals. Closing the product cycle would require industry to manage products over their entire life cycle, from material extraction, manufacturing and use through disposal. Elements of such a policy are already in place, e.g. in the automobile industries of several countries.

The new approach for achieving this goal would turn the traditional approach to environmental management upside down. The current approach looks first for ways to reduce pollutants after industrial processes have already generated them. It requires the application of end-of-pipe technologies, such as waste-water treatment plants, filters on smoke stacks and the incineration or neutralization of wastes and, finally, the burial of the residue. The current hierarchy for pollutant reduction is as follows:

- Final disposal
- Treatment
- Treatment with energy and materials recovery
- Reuse and recycling
- Reduction
- Prevention.

The new approach that is emerging for environmental management reverses the priorities for management of pollutants at the firm or establishment level. The new hierarchy looks first for pollution prevention opportunities, such as product and process changes and on site recycling and recovery, before turning to pollution abatement measures. It is as follows:

- Prevention
- Reduction
- Reuse and recycling
- Treatment with energy and materials recovery
- Treatment
- Final disposal.

This new approach to environmental management is emerging for several reasons. First, industry, particularly progressive companies, is realizing that the new priorities are a less expensive and thus more profitable approach to environmental management. Secondly, it is aware that sooner or later it will be forced by Governments and public pressure to reduce pollutant loadings to the environment. Both industry and

Government know that the treatment and burial approach will not meet total loading standards and sometimes not even ambient standards.

One example of the inability to meet ambient standards is the reduction of dioxin discharge from pulp and paper mills. The treatment of waste water will not reduce dioxin discharge sufficiently to meet ambient standards, so industry is changing its bleaching process and significantly reducing the amount of chlorine use.

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The availability of Cleaner Production options, which includes both source reduction and pollution control equipment, depends on whether ambient or total loading standards are being pursued. Cleaner Production options are generally available for meeting ambient standards, as is attested to by the success of some industrialized and developing countries.

Although Cleaner Production options are generally available, they may not yet be applicable to all production processes. For example, some developing countries use agricultural residues (straw and bagasse) in the pulping process. Since these raw materials have different properties from wood pulp, e.g. a higher silica content, not all Cleaner Production options developed for reducing the conventional water pollutants associated with wood pulping are applicable to the pulping of agricultural residue.

The availability of Cleaner Production options for meeting total loading standards, which call for significant reduction in pollutants beyond that needed to meet ambient standards, can be questioned, but there is some evidence that significant reductions are possible. A number of approaches have proven themselves useful—and, in many cases, profitable—in practical applications in the industrialized countries. This is particularly true for technologies that optimize the use of energy. Indeed, many of these technologies are not only available today but, if implemented, could realize net savings of both energy and money and simultaneously decrease the burden on the environment.

The existing inefficiencies give an indication of potential energy savings. A comparison of energy consumption per unit of output in developing countries and industrialized countries shows that energy consumption, in tonnes of oil equivalent, per million dollars of real GDP is 440 in the former as opposed to 290 in the latter, i.e. over 50 per cent more per unit of output (table 1). Another comparison is industrial energy consumption per million dollars of real industrial value added. On average, developing countries use twice as much energy as developed countries to produce the same output. These inefficiencies may be attributed to factors such as the improper management of the industrial production process, lack of sophisticated technologies, and wrong pricing.

There are several options for achieving total loading standards for energy-related pollutants. These options include the following:

Table 1. Final Energy Consumption and Economic Activity in OECD Countries and Developing Countries, 1985

Item a/	**OECD**	**Developing countries**	**Ratio of OECD to Developing Countries**
Per capita final energy consumption, toe	3.102	0.323	9.6
Per capita industrial energy consumption, toe	1.096	0.159	6.89
Real GDP per capita, 1980 dollars	10 815.0	773	14.75
Real MVA per capita, 1980 dollars	2 769.0	289	9.58
Final energy consumption per million dollars of real GDP, toe	286.8	440.16	0.65
Industrial energy consumption per million dollars of real industrial value added, toe	276	550	0.50

a/ Tonnes of oil equivalent = toe.

Source: UNIDO, *Industry and Development: Global Report 1991/92*, forthcoming.

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- Devices to control the speed of rotating process equipment such as fans, pumps and agitators;
- The enhancement of heat recovery from gases and liquids and the recycling of this heat;
- Computer-aided systems to control the temperature, flow and speed of energy etc.;
- Cogeneration to produce both heat and power.

Several options are also available for achieving total loading standards for toxic chemical pollutants. These options include the following:

- The replacement of chemical processes by mechanical processes;
- The replacement of single-pass rinse processes by counter-current processes;
- The replacement of single-pass processes by closed-loop processes;
- The replacement of organic-solvent-based inks, paints and coatings by water-based ones;
- The replacement of mercury, cadmium and lead by other less toxic substances for pigments, catalysts, batteries etc.;

- The replacement of halogenated compounds by non-halogenated compounds;
- The installation of physical separation technologies such as ion exchange, ultrafiltration and reverse osmosis to allow the recycling of useful components;
- The installation of more accurate sensors, microprocessors and other types of monitoring equipment.

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Many dissipative uses of toxic metals could essentially be banned by a stroke of the pen. In the case of tetraethyllead, some cost was involved: the same octane number can be achieved only at higher cost, either by the addition of alcohols or by more intensive refining and the use of greater amounts of aromatics, such as benzene, xylene and toluene. It is difficult to generalize about the cost of eliminating other dissipative uses. Many have been replaced by better substitutes (largely the case with organometallic pesticides, for instance). A few may be very difficult to eliminate, in which case the emphasis should probably be on recovery and recycling.

The full attainment of sustainable practices remains an open-ended task. The main difficulty is clearly in the area of recycling and remanufacturing. The closing of the materials cycle and the product cycle is essential for long-run sustainability. Additional research into the potential for remanufacturing is needed because it remains an opportunity for both developed and developing countries that has yet to be exploited and that has significant implications for ESID. Remanufacturing may be defined as "the disassembly, inspection, refurbishing, reassembly and final testing of worn durable products, a process that renders them usable and less costly to both producers and consumers". It requires smaller capital investments and fewer labour skills than the manufacture of original equipment. In remanufacturing, the cost of energy is only 20-25 per cent that of the energy cost in original manufacture; the cost of materials is cut even more, to 15-20 per cent. In addition, recycling and remanufacturing activities will need supporting industries, such as those that manufacture measuring and automatic control devices, and they will in many cases offer new employment opportunities because they are labour-intensive.

The above is only part of the story, and in the long run probably the less important part. The adoption of Cleaner Production at the establishment level is clearly necessary, but it is not sufficient. It is increasingly clear that the world economic system must be re-oriented. There is a need to reduce dependence on fossil fuels, especially coal; the need to close the material and product cycles has already been mentioned. Structural changes like these will occur only if and when appropriate economic and regulatory incentives are created. Such incentives may include resource or emissions taxes, tradeable permits, subsidies and even outright bans on certain materials.

Chapter VI. The Effects of Cleaner Production on Unit Costs

Although neither UNIDO nor any other institution has assessed in detail the economic aspects of achieving ESID through Cleaner Production, fragmentary data suggest that such production would also be more efficient. Clearly, additional research is needed in this area.

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The evidence that Cleaner Production measures can reduce rather than increase unit production costs and hence improve productivity is still fragmentary. To date, such measures account for only a relatively small fraction of total environmental investments in both industrialized and developing countries. Nevertheless, numerous case-studies suggest that Cleaner Production systems can lower production costs and reduce emissions and are available for many sectors. An enterprise adopting

Table 2. Examples of Waste Reduction and Payback Periods of Clean Technologies in the United States

Industry	Method	Reduction of waste	Payback period
Pharmaceutic production	Water-based solvent replaced organic solvent	100%	< 1 year
Equipment manufacture	Ultrafiltration	100% of solvent	2 years
Farm equipment manufacture	Proprietary process	80% of sludge	2.5 years
Automotive manufacture	Pneumatic cleaning process replaced caustic process	100% of sludge	2 years
Micro-electronics	Vibratory cleaning replaced caustic process	100% of sludge	3 years
Organic chemicals production	Absorption, scrap condenser, conservation vent, floating roof	95% of cumene	1 month
Photographic film processing	Electrolytic recovery ion exchange	85% of developer; 95% of fixer; silver and solvent	< 1 year

Source: Huisingh, D. "Cleaner technologies through process modifications, materials substitutions and ecologically based ethical values", *Industry and Environment*, vol. 12, No. 1 (1989).

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Cleaner Production processes may realize one or more of the following benefits while reducing industrial pollution:

- Savings in raw materials and energy;
- Decreased waste management costs;
- Improved product quality;
- Enhanced productivity;
- Decreased down-time;
- Reduced worker health risks and environmental hazards;
- Decreased long-term liability for the clean-up of waste materials that might otherwise have been buried;
- Improved public image for the company.

A survey in the United States of more than 500 companies that adopted Cleaner Production processes found that each company reduced industrial wastes by between 85 and 100 per cent; even more importantly, the investment payback periods were short. only one month to three years. These benefits accrued to old industries as well as to high technology industries. The technological changes included the incorporation of advance technologies, such as ion exchange and ultrafiltration; process modifications involving the replacement of an old substance by a new, less-polluting material; and the adoption of processes that were less chemical-intensive and more mechanical-intensive. The most dramatic case was that of the photographic firm PCA International Inc.. which is included in table 2. The initial cost of 2,120,000 for the process modification was paid back in a few months by annual savings in the cost of developing solutions (2,360.000), fixer solution (225,000), bleach solution (2,780,000) and silver recovery (21,410,000), a total annual saving of 22.575,000.

Case-studies in Europe are reporting similar findings. The Landskrona in Sweden and the PRISMA projects in the Netherlands confirm results achieved in the United States.

Although Cleaner Production systems are penetrating industry in developing countries, the number of applications is probably not as great as in industrialized countries, and the documentation is minimal. There are some data, however in the International Cleaner Production Information Clearinghouse of UNEP, including reports on several textile mills in India. Where such data are reported, the payback is in the range of one month to a few years. Another example is a meat factory in Poland, which reports a payback period of five months for reduced water consumption and of one year for heat recovery.

There is, moreover, little reason to believe that meeting the requirements of ESID will require extraordinary resources, even in the case of the pollution control approach, which in the long run is likely to be more costly than the prevention of pollution through better management and technology. A recent OECD study of pollution control expenditures for eight countries with relatively complete data showed that expenditures varied between 0.8 and 1.7 per cent of gross national product (GNP). On average, countries with the most stringent environmental programmes spend about 1.5 per cent of their GNP to reduce pollutants from all sectors. On the basis of data from the United States and Germany, the manufacturing sector appears to account for about 25 per cent of the total expenditure, or about 0.4 per cent of GNP. The new approach to pollutant releases, which starts with source reduction (process and product changes) rather than pollution abatement and which emphasizes ambient rather than uniform discharge standards, would result in the manufacturing sector in developing countries spending reasonable sums on pollutant reduction to achieve compliance with ambient and total loading standards.

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Facility Pollution Prevention Guide

Excerpted, with permission, from the
Office of Solid Waste
U. S. Environmental Protection Agency
Washington, D.C. 20460

Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Chapter 1

Deciding on Pollution Prevention

Pollution prevention is the use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source. It includes practices that reduce the use of hazardous and nonhazardous materials, energy, water, or other resources as well as those that protect natural resources through conservation or more efficient use.

A pollution prevention program addresses all types of waste.

A pollution prevention program is an ongoing, comprehensive examination of the operations at a facility with the goal of minimizing all types of waste products. An effective pollution prevention program will:

- reduce risk of criminal and civil liability
- reduce operating costs
- improve employee morale and participation
- enhance company's image in the community
- protect public health and the environment.

This Guide is intended to assist you in developing a pollution prevention program for your business. It will help you decide which aspects of your operation you should assess and how detailed this assessment should be.

This chapter provides background information on pollution prevention. Specifically, it:

- Summarizes the benefits you can obtain from a company-wide pollution prevention program that integrates raw materials, supplies, chemicals, energy, and water use.

- Describes the US EPA's Environmental Management Hierarchy.
- Explains what pollution prevention is and what it is not.
- Provides an overview of federal and state legislation on pollution control.

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Those companies struggling to maintain compliance today may not be around by the end of the '90s. Those toeing the compliance line will survive. But those viewing the environment as a strategic issue will be leaders.

— Richard W. MacLean, chief of environmental programs at Arizona Public Service Co., as quoted in *Environmental Business Journal*, December, 1991.

Benefits of a Pollution Prevention Program

In the case of pollution prevention, national environmental goals coincide with industry's economic interests. Businesses have strong incentives to reduce the toxicity and sheer volume of the waste they generate. A company with an effective, ongoing pollution prevention plan may well be the lowest-cost producer and have a significant competitive edge. The cost per unit produced will decrease as pollution prevention measures lower liability risk and operating costs. The company's public image will also be enhanced.

Reduced Risk of Liability

You will decrease your risk of both civil and criminal liability by reducing the volume and the potential toxicity of the vapor, liquid, and solid discharges you generate. You should look at all types of waste, not just those that are currently defined as hazardous. Since toxicity definitions and regulations change, reducing the volume of wastes in all categories is a sound long-term management policy.

Environmental regulations at the federal and state levels require that facilities document the pollution prevention and recycling measures they employ for wastes defined as hazardous. Companies that produce

Above all, companies want to pin down risk... Because the costs can be so enormous, risk must now be taken into account across a wide range of business decisions.

— Bill Schwalm, senior manager for environmental programs and manufacturing at Polaroid, in an interview with Environmental Business Journal, December, 1991 excessive waste risk heavy fines, and their managers may be subject to fines and imprisonment if potential pollutants are mismanaged.

Civil liability is increased by generating hazardous waste and other potential pollutants. Waste handling affects public health and property values in the communities surrounding production and disposal sites. Even materials not currently covered by hazardous waste regulations may present a risk of civil litigation in the future.

Look beyond the wastes currently defined as hazardous.

Workers' compensation costs and risks are directly related to the volume of hazardous materials produced. Again, it is unwise to confine your attention to those materials specifically defined as hazardous. LU4

Reduced Operating Costs

A comprehensive pollution prevention program can reduce current and future operating costs.

An effective pollution prevention program can yield cost savings that will more than offset program development and implementation costs. Cost reductions may be immediate savings that appear directly on the balance sheet or anticipated savings based on avoiding potential future costs. Cost savings are particularly noticeable when the costs resulting from the treatment, storage, or disposal of wastes are allocated to the production unit, product, or service that produces the waste. Refer to chapter 6 for more information on allocating costs.

Materials costs can be reduced by adopting production and packaging procedures that consume fewer resources, thereby creating less waste. As wastes are reduced, the percentage of raw materials converted to finished products increases, with a proportional decrease in materials costs.

Waste management and disposal costs are an obvious and readily measured potential savings to be realized from pollution prevention. Federal and state regulations mandate special in-plant handling procedures and specific treatment and disposal methods for toxic wastes. The costs of complying with these requirements and reporting on waste disposition are direct costs to businesses. There are also indirect costs, such as higher taxes for such public services as land fill management. The current trend is for these costs to continue to increase at the same or higher rates. Some of these cost savings are summarized in box 1.

Optimizing processes and energy use reduces waste and controls production costs.

Production costs can be reduced through a pollution prevention assessment. When a multi-disciplinary group examines production processes from a fresh perspective, opportunities for increasing efficiency are likely to surface that might not otherwise have been noticed. Production scheduling, material handling, inventory control, and equipment maintenance are all areas that can be optimized to reduce the production of waste of all types and also control the costs of production.

Energy costs will decrease as pollution prevention measures are implemented in various production lines. In addition, energy used to

Box 1. Waste management costs will decrease as pollution prevention measures are implemented:

- Reduced manpower and equipment requirements for on-site pollution control and treatment
- Less waste storage space, freeing more space for production
- Less pretreatment and packaging prior to disposal
- Smaller quantities treated, with possible shift from treatment, storage, and disposal (TSD) facility to non-TSD status
- Less need to transport for disposal
- Lower waste production taxes
- Reduced paperwork and record-keeping requirements, e.g., less Toxic Release Inventory (TRI) reporting when TRI-listed chemicals are eliminated or reduced.

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operate the overall facility can be reduced by doing a thorough assessment of how various operations interact.

Facility cleanup costs may result from a need to comply with future regulations or to prepare a production facility or off-site waste storage or disposal site for sale. These future costs can be minimized by acting now to reduce the amount of wastes of all types that you generate.

Improved Company Image

Corporate image is enhanced by a demonstrated commitment to pollution prevention

As the quality of the environment becomes an issue of greater importance to society, your company's policy and practices for controlling waste increasingly influence the attitudes of your employees and of the community at large.

Employees are likely to feel more positive toward their company when they believe that management is committed to providing a safe work environment and is acting as a responsible member of the community. By participating in pollution prevention activities, employees can interact positively with each other and with management. Helping to implement and maintain a pollution prevention program should increase their sense of identity with company goals. This positive atmosphere helps to retain a competitive workforce and to attract high-quality new employees.

Community attitudes will be more positive toward companies that operate and publicize a thorough pollution prevention program. Most communities actively resist the siting of new waste disposal facilities in

> *We regard the environment as a long-term strategic set of issues. To have a strong, viable company, the environment has to be taken into account...by planning for [consumer demand for more environmental quality] we will be more competitive in the marketplace.*
>
> — Bill Riley, director of Environment-Marketing at Clorox, as quoted in *Environmental Business Journal*, December, 1991.

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their areas. In addition, they are becoming more conscious of the monetary costs of treatment and disposal. Creating environmentally compatible products and avoiding excessive consumption and discharge of material and energy resources, rather than concentrating solely on treatment and disposal, will greatly enhance your company's image within your community and with potential customers.

Public Health and Environmental Benefits

Reducing production wastes provides upstream benefits because it reduces ecological damage due to raw material extraction and refining operations. Subsequent benefits are the reduced risk of emissions during the production process and during recycling, treatment, and disposal operations.

The Environmental Management Hierarchy

Source reduction and reuse prevent pollution

The Pollution Prevention Act of 1990 reinforces the US EPA's Environmental Management Options Hierarchy, which is illustrated in figure 1. The highest priorities are assigned to preventing pollution through source reduction and reuse, or closed-loop recycling.

Preventing or recycling at the source eliminates the need for off-site recycling or treatment and disposal. Elimination of pollutants at or near the source is typically less expensive than collecting, treating, and disposing of wastes. It also presents much less risk to your workers, the community, and the environment.

What is Pollution Prevention?

Change products and production processes to reduce pollution at the source

Pollution prevention is the maximum feasible reduction of all wastes generated at production sites. It involves the judicious use of resources through source reduction, energy efficiency, reuse of input materials during production, and reduced water consumption. There are two general methods of source reduction that can be used in a pollution prevention program: product changes and process changes. They reduce the volume and toxicity of production wastes and of end-products during their life-cycle and at disposal. Figure 2 provides some examples.

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Redesign products to minimize their environmental impact.

Product changes in the composition or use of the intermediate or end products are performed by the manufacturer with the purpose of reducing waste from manufacture, use, or ultimate disposal of the products. Chapter 7 in this *Guide* provides information on designing products and packaging that have minimal environmental impact.

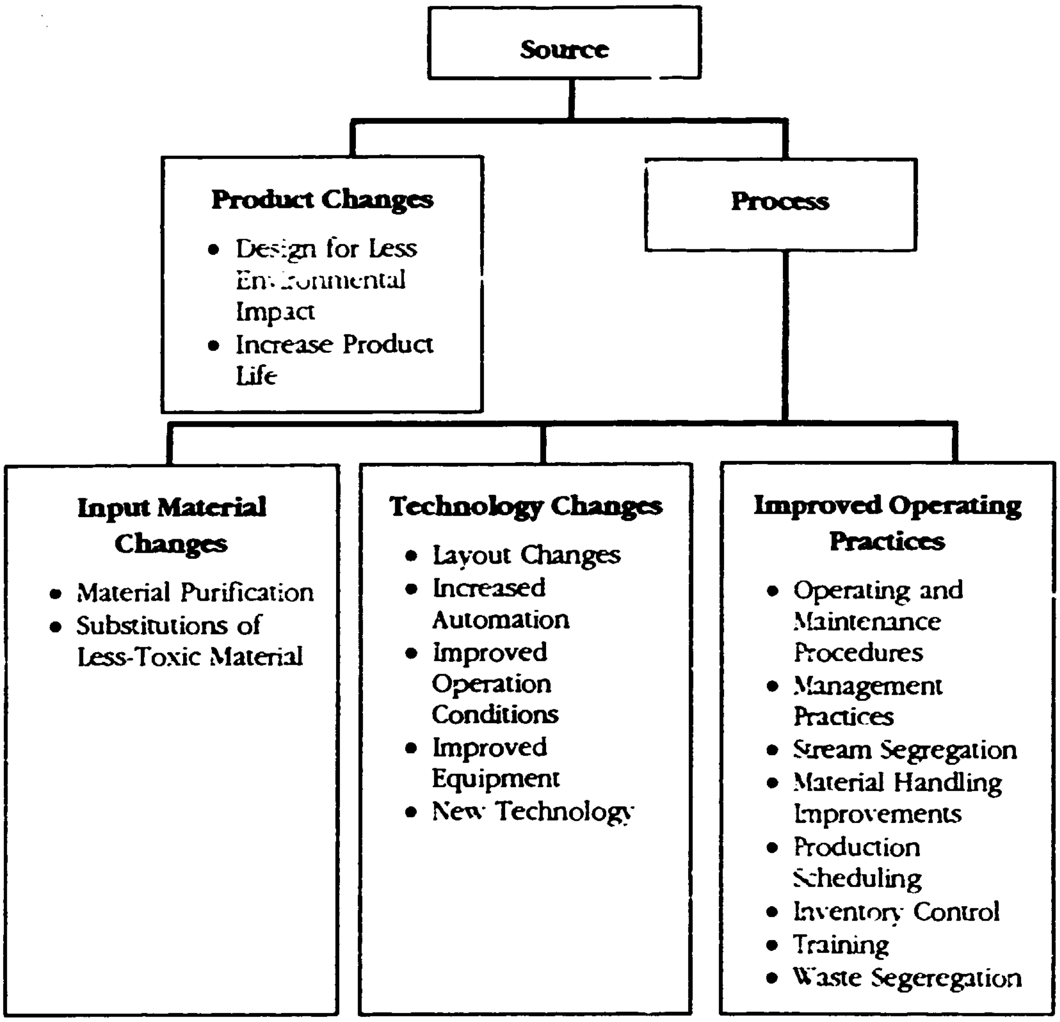
Process changes may be implemented more quickly than product changes.

Process changes are concerned with how the product is made. They include input material changes, technology changes, and improved operating practices. All such changes reduce worker exposure to pollutants during the manufacturing process. Typically, improved operating practices can be implemented more quickly and at less expense than input material and technology changes. Box 2 provides examples of process changes.

Figure 1: Environmental Management Options Hierarchy

Method	Example Activities	Example Applications
Source Reduction (Highest Priority)	• Environmentally Friendly Design of New Products • Product Changes • Source Elimination	• Modify Product to Avoid Solvent Use • Modify Product to Extend Coating Life
Recycling	• Reuse • Reclamation	• Solvent Recycling • Metal Recovery from a Spent Plating Bath • Volatile Organic
Treatment	• Stabilization • Neutralization • Precipitation • Evaporation • Incineration	• Thermal Destruction of Organic Solvent • Precipitation of Heavy Metal from a Spent Plating Bath
Disposal	• Disposal at a Permitted Facility	• Land Disposal

Figure 2: Source Reduction Methods



What Is Not Pollution Prevention?

Waste treatment is not pollution prevention.

There are a number of pollution control measures that are applied only after wastes are generated. They are, therefore, not correctly categorized as pollution prevention. Box 3 provides some examples of procedures that are waste handling, not pollution prevention, measures.

Off-site recycling carries some risk

Off-site recycling is vastly preferable to other forms of waste handling because it helps to preserve raw materials and reduces the amount of material that will require disposal. However, compared with closed-loop recycling (or reuse), performed at the production site, there is likely to be more residual waste that will require disposal. Further, waste transportation and the recycling process itself carry the risks of worker exposure and of release into the environment.

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Box 2. The following process changes are pollution prevention measures because they reduce the amount of waste created during production:

Examples of input material changes:
- Stop using heavy metal pigment.
- Use a less hazardous or toxic solvent for cleaning or as coating.
- Purchase raw materials that are free of trace quantities of hazardous or toxic impurities.

Examples of technology changes:
- Redesign equipment and piping to reduce the volume of material contained.
- Cutting losses during batch or color changes or when equipment is drained for maintenance or cleaning.
- Change to mechanical stripping/cleaning devices to avoid solvent use.
- Change to a powder-coating system.
- Install a hard-piped vapor recovery system to capture and return vaporous emissions.
- Use more efficient motors.
- Install speed control on pump motors to reduce energy consumption.

Examples of improved operating practices:
- Train operators.
- Cover solvent tanks when not in use.
- Segregate waste streams to avoid cross-contaminating hazardous and nonhazardous materials.
- Improve control of operating conditions (e.g., flow rate, temperature, pressure, residence time, stoichiometry).
- Improve maintenance scheduling, record keeping, or procedures to increase efficiency.
- Optimize purchasing and inventory maintenance methods for input materials.
- Purchasing in quantity can reduce costs and packaging material if care is taken to ensure that materials do not exceed their shelf life. Re-evaluate shelf life characteristics to avoid unnecessary disposal of stable items.
- Stop leaks, drips, and spills.
- Turn off electrical equipment such as lights and copiers when not in use.
- Place equipment so as to minimize spills and losses during transport of

Transferring hazardous wastes to another environmental medium is not pollution prevention. Many waste management practices to date have simply collected pollutants and moved them from one environmental medium to another. For example, solvents can be removed from waste water by means of an activated carbon absorber. However, regenerating the carbon requires the use of another solvent or heating, which transfer the waste to the atmosphere. In some cases, transfer is a valid treatment option. However, too often the purpose has been to shift a pollutant to a

Box 3. The following are not pollution prevention measures because they are taken after the waste is created:

- **Off-site recycling:**

  Off-site recycling (e.g., solvent recovery at a central distillation facility) is an excellent waste management option. However, it does create pollution during transport and during the recycling procedure.

- **Waste treatment:**

  Waste treatment involves changing the form or composition of a waste stream through controlled reactions to reduce or eliminate the amount of pollutant. Examples include detoxification, incineration, decomposition, stabilization, and solidification or encapsulation.

- **Concentrating hazardous or toxic constituents to reduce volume:**

  Volume reduction operations, such as dewatering, are useful treatment approaches, but they do not prevent the creation of pollutants. For example, pressure filtration and drying of a heavy metal waste sludge prior to disposal decreases the sludge water content and waste volume, but it does not decrease the number of heavy metal molecules in the sludge.

- **Diluting constituents to reduce hazard or toxicity:**

  Dilution is applied to a waste stream after generation and does not reduce the absolute amount of hazardous constituents entering the environment.

- **Transferring hazardous or toxic constituents from one environmental medium to another:**

  Many waste management, treatment, and control practices used to date have simply collected pollutants and moved them from one environmental medium (air, water, or land) to another. An example is scrubbing to remove sulfur compounds from combustion process off-gas.

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less-tightly regulated medium. In either case, media transfers are not pollution prevention.

Transfer to another environmental medium should be avoided in most cases

Waste treatment prior to disposal reduces the toxicity and/or disposal-site space requirements but does not eliminate all pollutant materials. This includes such processes as volume reduction, dilution, detoxification, incineration, decomposition, stabilization, and isolation measures such as encapsulation or embedding.