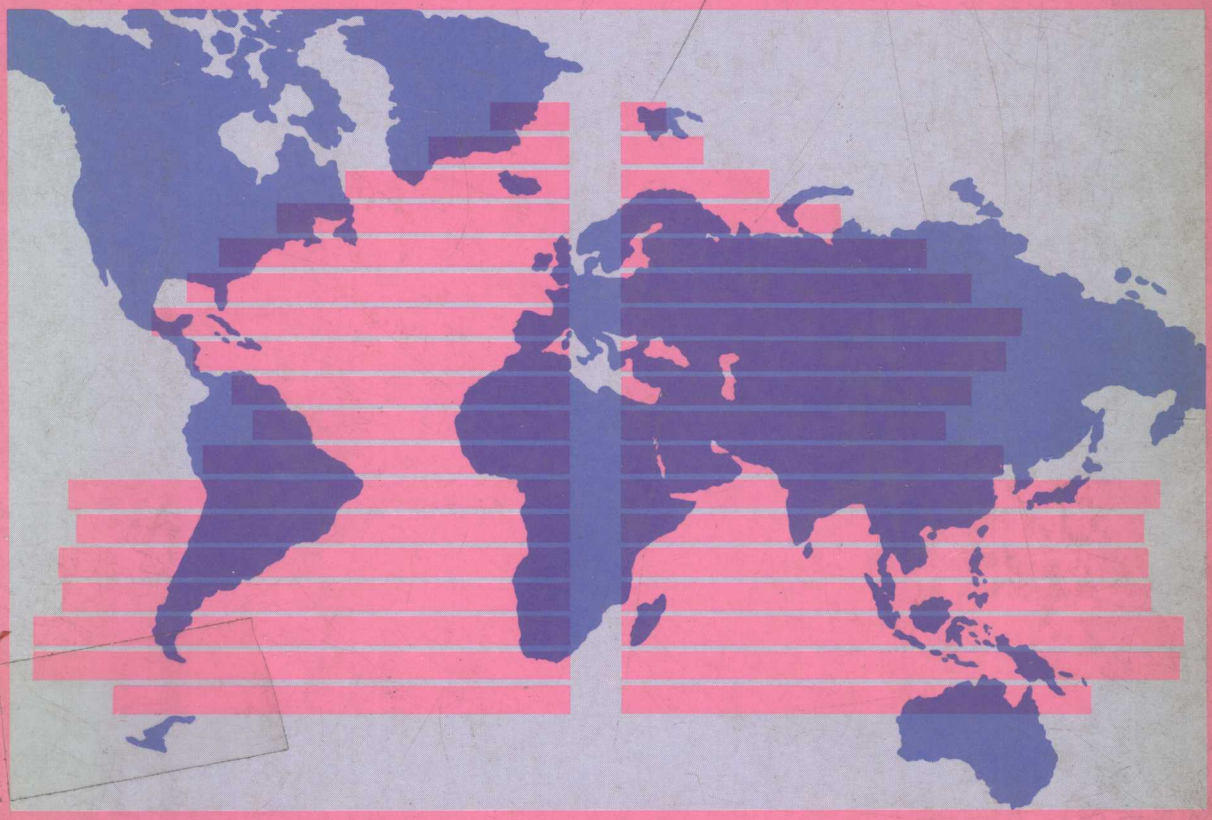
Jonathan Turk

Introduction to Environmental Studies

Second Edition



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Jonathan Turk, PhD

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Second Edition

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Preface

INTRODUCTION TO ENVIRONMENTAL SCIENCE was written in response to the need for a short text in the environmental sciences. This book is designed to complement the successful hardbound text, ENVIRONMENTAL SCIENCE by Turk and Turk (Saunders College Publishing, 1984). In comparing the two, ENVIRONMENTAL SCIENCE offers more complete coverage of the course material, whereas INTRODUCTION TO ENVIRONMENTAL SCIENCE presents a less rigorous treatment of the same subject. It can be used for a one-semester course, a course supplement, or a two-semester course used in conjunction with additional material.

Environmental science is inherently a complex subject. It consists of an integration of many varied disciplines, such as biology, the physical sciences, economics, and political science. Perhaps the one single generalization that can be made about this discipline is that there are no simple answers or quick solutions to the environmental problems that we face. For one, there are radical differences in people's perceptions of what actions should be taken in response to any given disturbance. In addition, vast differences in economic, political, or ethnic background necessarily affect people's patterns of thought.

The problem in writing any text in environmental science, but especially a short one, is to emphasize the true complexity of the subject without making the book itself complex or hard to read and understand. The overall pedagogic strategy is to use a principles-oriented approach. Important concepts are introduced, and the relationships among these concepts are discussed. Supporting data are given, but the student is not required to memorize large quantities of unrelated facts. When necessary, principles normally taught in more advanced courses are explained, but previous background in mathematics, physics, and chemistry is not a prerequisite for this book. I believe that a student can grasp the essence of a potentially difficult subject without being exposed to the rigors that a specialist in the field must face.

The publication of the second edition of INTRODUCTION TO ENVIRONMENTAL SCIENCE represents a major reorganization of the text. In recent years, many environmental issues, once of interest mainly to scientists, have increasingly become serious issues of public awareness and policy. Therefore, the integration

of scientific and social issues has grown ever more tightly woven, and the current revision emphasizes the interactions among many seemingly separate fields of study. The stage for this emphasis is set in the very first unit, in which both legal and technical limitations on environmental improvement are introduced.

When the topic of environmental science first reached the broad spectrum of public awareness over a decade ago, the primary focus of concern was directed towards problems generated in and by industrial societies. Although these same problems are still with us, and still warrant continued scrutiny, it has become obvious that serious environmental disturbances are generated in and by less industrial societies as well. If any particular topic is examined, the difficulties surrounding growth, consumption, and pollution in the developing countries are vastly different from those in the more developed ones. Yet underlying all is the human search for a better life. Another major goal of this revision is to emphasize the differences and similarities in environmental problems viewed on a global scale.

It has been my aim to offer logical, orderly sequences of presentation and to avoid awkward breaks in the continuity. At the same time, I recognize that the instructor requires flexibility and may choose to emphasize certain topics more than others. Therefore, the material has been arranged so that the presentation can be individualized to suit the particular course objectives. It is for this reason that the text is organized into units that are individually self-contained and need not be presented in the sequence in which they appear in the text. The units are as follows:

Unit 1. Environmental Science: An Overview

This unit introduces environmental science and its relation to the human condition, discusses the classification of environmental problems, shows how environmental improvement is tied to economic and legal concerns, and discusses how the laws of nature limit our response to environmental challenges.

Unit 2. The Ecological Background

This unit provides a comprehensive look at the biology of natural ecosystems, populations, speciation, extinction and genetic resources.

Unit 3. Human Impact on the Earth

This unit discusses the growth of human populations and the effects of chemical and hazardous wastes on human health.

Unit 4. Energy

This unit, extensively revised and expanded in this edition, discusses sources of energy; nuclear energy and its environmental effect; the search for and use of energy and its environmental, economic, and political consequences; and the need for both short-term and long-term planning.

Unit 5. Soil, Land, and Minerals

This unit deals with food production, the Green Revolution, and the consequences of world hunger; the control of pests and weeds and the debate over insecticides; land use and encroaching urbanization; and nonrenewable mineral resources.

Unit 6 Air, Water, and Wastes

This unit discusses water resources; water and air pollution and their environmental effects; the social, legal, and economic aspects of water and air pollution; and the disposal of solid wastes.

Epilogue Planning for a Sustainable Society

This coda discusses some of the realistic options we do have and stresses the need for planning.

Various case histories and special topics (which appear in boxes) are interspersed throughout the text. They are presented, for the most part, because they are interesting. Many offer a human outlook that is not necessarily conveyed in a purely didactic approach. However, they are not required for a reading or understanding of the chapter, nor are questions at the end of the chapter based on them.

Several pedagogic elements are incorporated into the text. These include: chapter summaries, end-of-chapter questions, suggested readings, an appendix and an extensive glossary.

Three supplementary items are available to adopters of INTRODUCTION TO ENVIRONMENTAL STUDIES. An Instructor's Manual provides teaching suggestions, and other useful information. A set of 100 Overhead Transparencies containing about 100 illustrations from the text is also available. An environmental simulation entitled "WORLD: The Fate of Civilization"

is available on disk for microcomputers and is accompanied by a manual explaining the use of the software.

Throughout this book I have always attempted to be realistic in discussing the true complexity of the world in which we live; yet I have, at the same time, strived to convey a picture of humans in their environment that is understandable and relevant to scientists and nonscientists alike.

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JONATHAN TURK

Table of Contents

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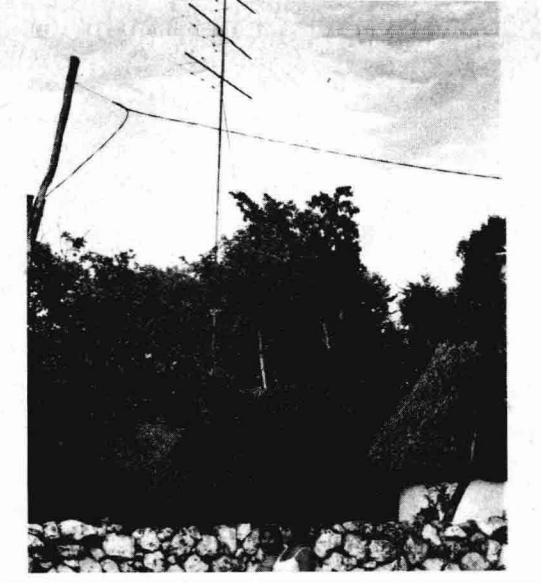

Studying the Environment

During the 1960s and 1970s people began to listen seriously to predictions that human existence would be threatened unless humans adjusted their relationship with their environment. Scientists said that the Earth was becoming polluted and that the soil, mineral, and fuel resources were being used faster than they were being replaced. Many planners said that the world's human population was growing faster than its food supply. Economists pointed out that the gap between the rich and the poor was growing wider. These concerns were the incentive for the development of the discipline of environmental science—the study of the relationship between human beings and their environment.

The human environment is the Earth we live on. It includes all the physical parts of the Earth, such as air, soil, minerals, rocks, and water, and all its living organisms, such as animals and plants. Environmental science provides an approach toward understanding the environment of our planet and the impact of human life upon that environment. It is also a search for solutions to the environmental problems that confront us.

1.1 The Human Condition

Consider the state of humankind on Earth, the planet we call home. In the past, life was hard and short for most people. Then, at the beginning of the twentieth century, rapid progress in medicine, agriculture, and industrial techniques seemed to promise that everyone might soon be able to enjoy long life, decent food, satisfying employment, and adequate housing. This promise has not been realized. In 1983 there were nearly five billion people on Earth. One quarter of them had a greater life expectancy and lived in greater luxury than anyone a hundred years ago would have believed possible. But at the same time, an uncounted number had inadequate or unsatisfactory water and shelter, and more than one third suffered from malnutrition and hunger (Figs. 1–1 and 1–2).

Most of the people who starve to death live in poverty-stricken developing nations. But now, at the end of the twentieth century, the wealthy nations are in trouble too. According to most estimates, the average standard of living in

Figure 1–1 A woman holds her starving child in the Sahel region of North Africa. Today, many people starve to death every year and many more are permanently crippled by malnourishment. (Photo courtesy of Agency for International Development.)

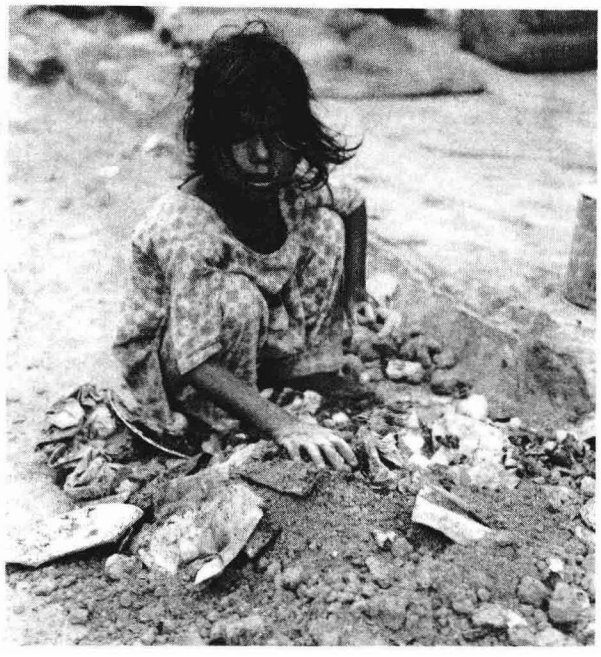

Figure 1–2 A hungry girl searches through a pile of garbage for something to eat in a slum in New Delhi.

North America and Western Europe reached a high in about 1967 and has been declining since then. Even the wealthiest nations are running out of fuel, hardwoods, and some minerals. As a result, necessities such as housing, food, and fuel are demanding more and more of the family budget, leaving less available for luxuries. Pollution contaminates cities, towns, and even rural environments. Sewage or poisonous pesticides in waterways, smog-laden air, and garbage in streets or parks lower the standard of living for everyone, no matter how wealthy.

Our vast and swiftly growing population consumes the Earth's resources of farmland, minerals, water, and fuel faster than natural processes can replace them. This is a serious problem in itself. But global conditions are further endangered because these resources are not distributed evenly. One quarter of the population, those that live in the developed nations, use nearly 80 percent of the resources consumed by humankind in any one year. The other three quarters of the population consume only about 20 percent of the resources used in a year. People in the United States alone, although they make up only 5 percent of the Earth's population, use about 35 percent of all raw materials. The gap between the "haves" and the "have-nots" is growing ever wider. Today, when transistor radios can be found in the most remote villages, the world's poor know how underprivileged they are (Fig. 1–3). This knowledge produces political instability. Years ago, political tension in one nation meant little to the rest of the world. But times have changed; modern technology ensures that nearly all nations possess weapons that can cause terrible destruction far beyond their own borders. As a result, no nation can afford to ignore the problems of another.

There is considerable disagreement about how serious our environmental problems really are. Some pessimists believe that the very survival of the human race is in question. Others

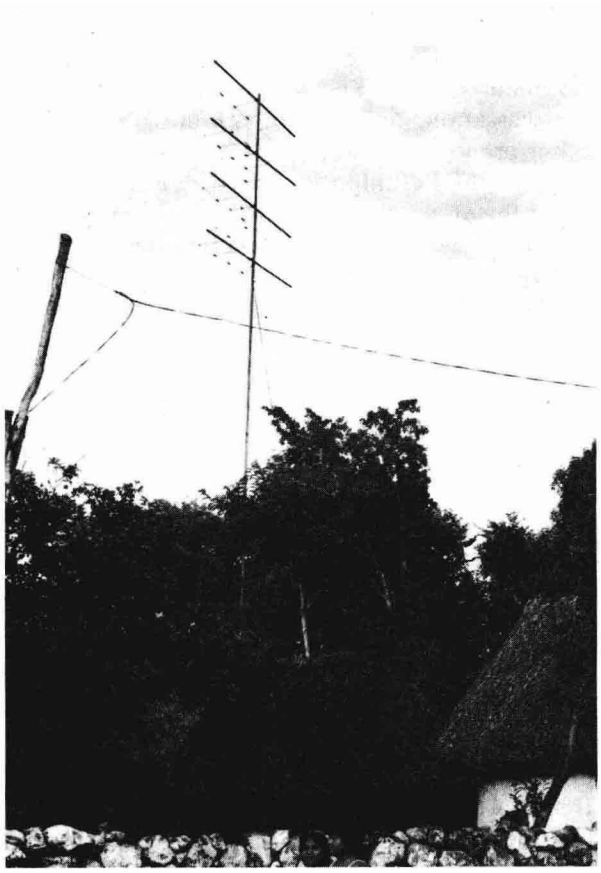

Figure 1–3 This house, found in a small village on the Yucatan Peninsula of Mexico, is built out of local materials such as stone, sticks, and grass thatch. Yet the television antenna rising out of the roof provides a positive link with the rest of the world.

think the human plight is serious but not desperate. They believe that technology can be used to solve environmental problems as it has solved so many others and that the developed nations will see the wisdom of spending more of their wealth on improving the human condition. No one knows the answer, but surely everyone must agree that a better understanding of the relationship between humankind and the environment is one positive step forward. To this end, the rest of this book is a beginning.

1.2 Classifying Environmental Problems

The study of our planet and the human impact on the planet is complex. In order to make the task a bit more manageable, we have classified environmental disruptions into five main types.

(1) Overpopulation Overpopulation may be defined as the presence in a given area of more people than can be supported adequately by the resources available in that area. Many people argue that the population explosion that has taken place in the twentieth century is now the most important problem we face (Fig. 1–4). It is important, first, because overpopulation is a major cause of all other environmental problems: Fewer people would use less oil, chop down fewer trees, and pour less sewage into rivers.

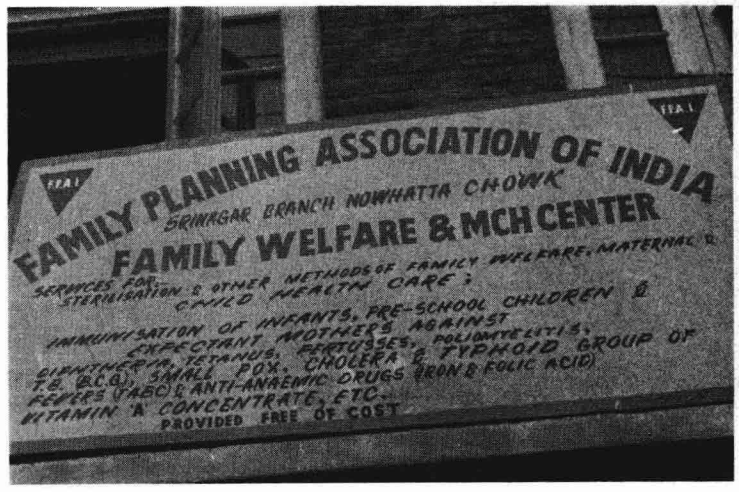

Figure 1–4 Some densely populated nations view overpopulation as one of their most devastating problems and encourage small families. This sign appears above a family planning clinic in northern India.

Second, overpopulation and the starvation that accompanies it are generally higher on our list of priorities than other environmental concerns. It is hard to argue that an area should be set aside as parkland to preserve a vanishing forest or prairie when that land might be used to raise crops that would prevent fellow human beings from starving to death.

(2) Depletion of Resources A **resource** is any source of raw materials. Fuels, minerals, water, soil, and timber are all resources. A material is depleted, or used up, as it becomes less available for its intended function. Material resources can become depleted in three different ways.

First, a substance can be *destroyed*, that is, converted into something else. Fuels are destroyed when they are used. For example, coal is converted to ashes and gas, and uranium is converted to radioactive waste products. The ashes and waste products are no longer fuels.

Second, a substance can be lost by being *diluted* or by being *displaced* to some location from which it cannot easily be recovered. If you open a helium-filled balloon, the gas escapes to the atmosphere. Not one atom of helium is destroyed, but the gas is lost because it would be prohibitively costly to recover it. The same concept of loss by dilution applies to minerals. Minerals are found in the Earth's crust mixed with rock and other materials that have no commercial value. An **ore** is considered to be a rock mixture that contains enough valuable minerals to be mined profitably with currently available technology. Today, iron becomes profitable to mine when the ore contains about 40 percent iron. However, iron is also widely dispersed in the soil, in many rocks, and even in the ocean, where its concentration is about one millionth of 1 percent. It would take far more energy and equipment to recover the iron from such dilute sources than the iron is worth. When products containing iron, such as automobiles or paper clips, are thrown away, the metal rusts. The rust is iron oxide, which could be reprocessed to produce iron again. However, much of the iron used in today's society is scattered so widely over the countryside that it is uneconomical to find and collect it. It is in this way that our reserves of iron are being depleted.

Third, a substance can be rendered unfit for use by being *polluted*. In this way pollution and depletion are related to each other. If chemical wastes are dumped into a stream, the water is not removed, but it becomes less fit for drinking, for recreation, and for the support of fish and other organisms.

(3) Pollution Pollution is a reduction in the quality of the environment by the introduction of impurities. Smoke pollutes the air; sewage pollutes the waters; junk cars pollute the land. We know for a fact that such contamination exists; it can be seen, smelled, or even tasted. The effects of pollution on human welfare and on the economy, however, are matters of considerable disagreement.

(4) Changes in the Global Condition Scientists have begun only recently to wonder whether human activities might affect the global environment. Aerosol sprays, aircraft exhaust, and other forms of air pollution may alter the atmosphere and change planetary weather patterns. Pollution of the oceans threatens plant and animal life and thus endangers a major source of food for humans. Throughout much of the world, forests, jungles, shrublands, and other natural systems are being converted to farmland. In many areas, this process is depleting the fertility of the soil, altering the climate, and causing the extinction of literally thousands of species of plants and animals. Some people fear that all these changes could possibly alter the global climate and even affect the natural systems so severely that our society could be endangered.

(5) War In many ways, war is a combination of all environmental problems rather than a separate category. Throughout history, overpopulation and want have led human groups into wars over food, land, or some other valuable resource. In modern times, war and the preparation for war have led to pollution and depletion of resources far more extreme than any single peacetime activity. Finally, a nuclear war would place the global systems of the Earth, human civilization, and even the human species itself at risk (Fig. 1–5).

1.3 The Tragedy of the Commons

Some people were aware of environmental problems a long time ago. In 1789 Thomas Robert Malthus, an English clergyman and econo-

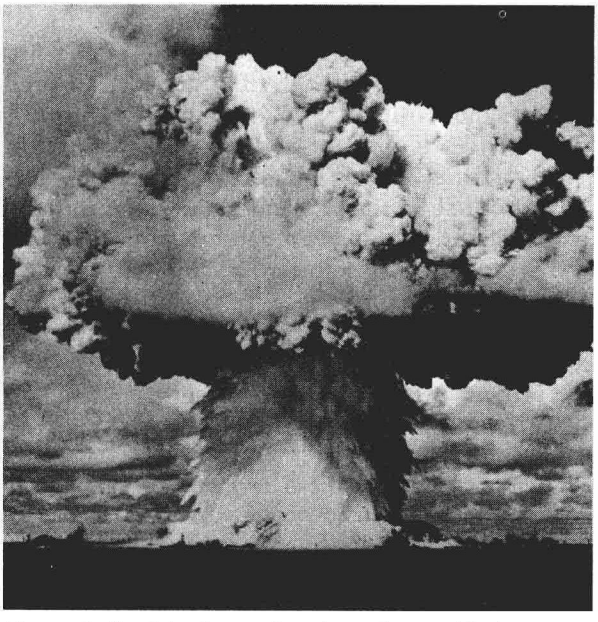

Figure 1–5 A hydrogen bomb explosion. Nuclear war has the potential to be the ultimate ecological disaster. (Photograph by H. Armstrong Roberts.)

mist, published his *Essay on the Principle of Population.* In this essay he argued that human populations must invariably outgrow their food supplies and then be reduced by starvation, disease, and war. The English poet William Wordsworth was well aware of air pollution. In his poem "On Westminster Bridge" he celebrated one of the rare nineteenth-century days when the air was clear and the London skyline was visible. If people have known about environmental disruptions for centuries, then why has so little been done?

One basic problem arises because there is a conflict between the short-term welfare of individuals and the long-term welfare of society. Garrett Hardin has called this phenomenon "the tragedy of the commons." He illustrates it with the case of commons in medieval Europe. A common was grazing land that belonged to a whole village. Any member of the village could graze cows and sheep there. It was in the interest of each individual to put as many animals on the common as possible to take advantage of the free animal feed. However, if too many animals grazed the common, they eventually destroyed the grass. Then everyone suffered because no one could raise any cattle on it at all. For this reason, common land was eventually replaced by individually owned, enclosed fields. If the field were your own, you would be careful not to put too many cows on your private patch of grass, because overgrazing one year means that fewer cows can be raised the following year.

In the same way, our air, water, and land are commons. Today, individuals or corporations are "overgrazing"—or, more precisely, depleting—many natural resources because it is profitable to do so. But what is profitable in the short term may be disastrous in the long run. Similarly, pollution is profitable if anyone can dump wastes into the air and water and thereby save the cost of disposing of the pollutants in other ways. Then every smoky factory can avoid the cost of air pollution controls and every household can discharge its wastes directly into the local stream. The difficulty is that polluting, like overgrazing, often benefits individuals or corporations in the short run. It is cheaper for a firm to operate its factory without pollution controls than with them, even though pollution is expensive to society in the long run. If the "tragedy of the commons" is to be avoided, this situation must be reversed by increasing short-term incentives for protecting the environment (Fig. 1–6).

Figure 1–6 It takes time and effort to bring cans to a recycling center, so most people don't do it. Paying consumers even a small amount to bring cans in enormously increases the number of cans that are recycled.

1.4 The Human Condition—Looking into the Future

Simple observation tells us much about the condition of the environment today. Although the long-term effects of some of our problems are not always understood clearly, it is relatively easy to measure both the quantities of pollutants in our air and water and the availability of resources. But what about the future? What will our world be like 10, 25, 50, or 100 years from now? This is a much more difficult question to answer.

During the latter part of his term in office, President Carter directed a group of scientists to write a report predicting what general living conditions for the human race would prevail by the year 2000. This paper, entitled the *Global 2000 Report*, gives cause for alarm. The following excerpts are from the introduction:

> If present trends continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now. Serious stresses involving population, resources, and environment are clearly visible ahead. Despite greater material output, the world's people will be poorer in many ways than they are today.
>
> Serious deterioration of agricultural soils will occur worldwide, due to erosion, loss of organic matter, desertification, salinization, alkalinization, and waterlogging. Already, an area of cropland and grassland approximately the size of Maine is becoming barren wasteland each year, and the spread of desert-like conditions is likely to accelerate.
>
> Atmospheric concentrations of carbon dioxide and ozone-depleting chemicals are expected to increase at rates that could alter the world's climate and upper atmosphere significantly by 2050. Acid rain from increased combustion of fossil fuels (especially coal) threatens damage to lakes, soils, and crops. Radioactive and other hazardous materials present health and safety problems in increasing numbers of countries.
>
> Extinctions of plant and animal species will increase dramatically. Hundreds of thousands of species—perhaps as many as 20 percent of all species on earth—will be irretrievably lost as their habitats vanish, especially in tropical forests.

These statements sound grim. Yet not all hope is lost. Reread the first phrase of the first sentence of the report carefully. It says, "If present trends continue. . . ." Optimists claim that present trends are not at all likely to continue. They say that human ingenuity and resourcefulness will rise to the challenge and build a future environment that is even better than the one we have today. This solution is sometimes called the **technological fix,** because it claims that technology will solve our problems. The *Global 2000 Report* recognizes the power of technology and sees many promising developments. But at the same time it issues a warning:

> Encouraging as these developments are, they are far from adequate to meet the global challenges projected in this Study. Vigorous, determined new initiatives are needed if worsening poverty and human suffering, environmental degradation, and international tension and conflicts are to be prevented. There are no quick fixes.

Some people claim that there always have been and always will be solutions to the problems we face. They point to historical successes. For example, in the 1950s people feared that as the richest iron mines were being rapidly depleted, iron shortages would develop, thereby threatening our entire civilization. In fact, there has been no shortage of iron. Technological improvements in mining and metallurgy have made it possible to extract metals from ores that were uneconomical to mine 35 years ago. As a result, the real price of iron in the United States has actually decreased in recent years (Fig. 1–7).

If this type of reasoning seems encouraging, remember two important points. First, the world is different today than at any other time in its history. It is much more densely populated. Technology, and especially weaponry, is much more sophisticated. As a result, human activities pose a greater threat to the environment than they ever have before.

Second, although there are many cases where technology has helped people avoid environmental disasters, there are other examples where no easy fixes have been found. In several ancient civilizations people have depleted their resources so severely that the environment did not recover. In some situations, environmental disruptions eventually contributed to the decline