In the last few chapters we have dealt extensively with achieving a balanced set of mass and energy flows; now we examine how a balance can be achieved in the reverse flow of waste products back to the environment. Because the waste flows are inexorably intertwined with the flow of mass and energy into the economy, establishing a balance for waste flows will have feedback effects on the input flows as well.

Two questions must be addressed: (1) What is the appropriate level of waste flow? (2) How should the responsibility for achieving this flow level be allocated among the various sources of the pollutant when reductions are needed?

In this chapter we shall lay the foundation for understanding the policy approach to controlling pollution. We define efficient and cost-effective levels of control for a variety of pollutant types, compare these control levels with those achieved by market forces, and demonstrate how these insights can be used to design desirable policy responses. This overview is then followed by a series of chapters that show how these principles have been applied to the design of pollution control policies in various countries around the world.

A Pollutant Taxonomy

The amount of waste products emitted determines the load upon the environment. The damage done by this load depends on the capacity of the environment to assimilate the waste products (see Figure 14.1). We will refer to this ability of the environment to absorb pollutants as its absorptive capacity. If the emissions load exceeds the absorptive capacity, then the pollutant accumulates in the environment.

FIGURE 14.1 The Relationship Between Emissions and Pollution Damage

 Pollutants for which the environment has little or no absorptive capacity are called stock pollutants. Stock pollutants accumulate over time as emissions enter the environment. Examples of stock pollutants include nonbiodegradable bottles tossed by the roadside; heavy metals, such as lead, that accumulate in the soils near the emission source; and persistent synthetic chemicals, such as dioxin and PCBs (polychlorinated biphenyls).

Pollutants for which the environment has some absorptive capacity are called fund pollutants. As long as the emission rate does not exceed the absorptive capacity of the environment, these pollutants do not accumulate. Examples of fund pollutants are easy to find. Many organic pollutants injected into an oxygen-rich stream will be transformed by the resident bacteria into less harmful inorganic matter. Carbon dioxide is absorbed by plant life and the oceans. The point is not that the mass is destroyed; the law of conservation of mass suggests this cannot be the case. Rather, when fund pollutants are injected into the air or water, they may be transformed into substances that are not considered harmful to people or to the ecological system, or they may be so diluted or dispersed that the resulting concentrations are not harmful.

Pollutants can also be classified by their zone of influence, defined both horizontally and vertically. The horizontal dimension deals with the domain over which damage from an emitted pollutant is experienced. The damage caused by local pollutants is experienced near the source of emission, while the damage from regional pollutants is experienced at greater distances from the source of emission. The limiting case is a global pollutant, where the damage affects the entire planet. The categories are not mutually exclusive; it is possible for a pollutant to be more than one. Sulfur oxides and nitrogen oxides, for example, are both local and regional pollutants.

The vertical zone of influence describes whether the damage is caused mainly by ground-level concentrations of an air pollutant or by concentrations in the upper atmosphere. For some pollutants such as lead or particulates, the damage caused by a pollutant is determined mainly by concentrations of the pollutant near the earth’s surface. For others, such as ozone-depleting substances or greenhouse gases the damage is related more to its concentration in the upper atmosphere. This taxonomy will prove useful in designing policy responses to these various types of pollution problems, since each type of pollutant requires a unique policy response. The failure to recognize these distinctions leads to counterproductive policy.

 Defining the Efficient Allocation of Pollution

Pollutants are the residuals of production and consumption. These residuals must eventually be returned to the environment in one form or another. Because their presence in the environment may depreciate the service flows received, an efficient allocation of resources must take this cost into account. What, precisely, constitutes the efficient allocation of pollution depends on the nature of the pollutant.

Fund Pollutants

To the extent that the emission of fund pollutants exceeds the assimilative capacity of the environment, such pollutants accumulate. When the emission rate is low enough, however, the discharges can be assimilated by the environment, with the result that the link between present emissions and future damage may be broken.

When this happens, current emissions cause current damage and future emissions cause future damage, but the level of future damage is independent of current emissions. This independence of allocations among time periods allows us to explore the efficient allocation of fund pollutants using the concept of static, rather than dynamic, efficiency. Because the static concept is simpler, this affords us the opportunity to incorporate more dimensions of the problem without unnecessarily complicating the analysis.

The normal starting point for the analysis would be to maximize the net benefit from the waste flows. However, pollution is more easily understood if we deal with an equivalent formulation involving the minimization of two rather different types of costs: (1) damage costs and (2) control or avoidance costs.

In order to examine the efficient allocation graphically, we need to know something about how control costs vary with the degree of control and how the damages vary with the amount of pollution emitted. Although our knowledge in these areas is far from complete, economists generally agree on the shapes of these relationships.

Usually, the marginal damage caused by a unit of pollution increases with the amount emitted. When small amounts of the pollutant are emitted, the incremental damage is quite small. However, when large amounts are emitted, the marginal unit can cause significantly more damage. It is not hard to understand why. small amounts of pollution are easily diluted in the environment, and the body can tolerate small quantities of substances. However, as the amount in the atmosphere increases, dilution is less effective and the body is less tolerant.

Marginal control costs commonly increase with the amount controlled. For example, suppose a source of pollution tries to cut down on its particulate emissions by purchasing an electrostatic precipitator that captures 80 percent of the particulates as they flow past in the stack. If the source wants further control, it can purchase another precipitator and place it in the stack above the first one. This second precipitator captures 80 percent of the remaining 20 percent, or 16 percent, of the uncontrolled emissions. Thus, the first precipitator would achieve an 80 percent reduction from uncontrolled emissions, whereas the second precipitator, which costs the same as the first, would achieve only a further 16 percent reduction. Obviously, each unit of emission reduction costs more for the second precipitator than for the first.

In Figure 14.2 we use these two pieces of information on the shapes of the relevant curves to derive the efficient allocation. A movement from right to left refers to greater control and less pollution emitted. The efficient allocation is represented by Q\*, the point at which the damage caused by the marginal unit of pollution is exactly equal to the marginal cost of avoiding it.1 (Tietenberg 301-304)

Tietenberg, Tom, Lynne Lewis. Environmental Economics & Policy, 6th Edition. Pearson Learning Solutions. VitalBook file.

Although they emit many of the same pollutants as stationary sources, mobile sources require a different policy approach. These differences arise from the mobility of the source, the number of vehicles involved, and the role of the automobile in the modern lifestyle.

Mobility has two major impacts on policy. On the one hand, pollution is partly caused by the temporary location of the source—a case of being in the wrong place at the wrong time. This occurs, for example, during rush hour in metropolitan areas. Because the cars have to be where the people are, relocating them—as might be done with electric power plants—is not a viable strategy. On the other hand, it is more difficult to tailor vehicle emission rates to local pollution patterns because any particular vehicle may end up in many different urban and rural areas during the course of its useful life.

Mobile sources are also more numerous than stationary sources. In the United States, for example, while there are only approximately 27,000 major stationary sources, well over 200 million vehicles travel on U.S. roadways. Enforcement is obviously more difficult the larger the number of sources being controlled. Additionally, in the United States alone, 20 percent of carbon emissions from anthropogenic sources come from the combustion of gasoline. As discussed in Chapter 15, creating incentives to reduce human-induced sources of carbon emissions is a large focus for environmental policymakers. When the sources are mobile, the problem of creating appropriate incentives is even more complex.

Whereas stationary sources generally are large and run by professional managers, automobiles are small and run by amateurs. Their small size makes it more difficult to control emissions without affecting performance, and amateur ownership makes it more likely that emission control will deteriorate over time because of a lack of dependable maintenance and care.

These complications might lead us to conclude that perhaps we should ignore mobile sources and concentrate our control efforts solely on stationary sources. Unfortunately, that is not possible. Although each individual vehicle represents a minuscule part of the problem, mobile sources collectively represent a significant proportion of three criteria pollutants—ozone, carbon monoxide, and nitrogen dioxide—as well as a significant source of greenhouse gases.

For two of these pollutants—ozone and nitrogen dioxide—the process of reaching attainment has been particularly slow. With the increased use of diesel engines, mobile sources are becoming responsible for a rising proportion of particulate emissions, and vehicles that burn leaded gasoline were (until legislation changed the situation) a major source of airborne lead.

Because it is necessaryto controlmobile sources, what policy options exist? What points of control are possible, and what are the advantages and disadvantages of each? In exercising control over these sources, the government must first specify the agent charged with the responsibility for the reduction. The obvious candidates are the manufacturer and the owner-driver. The balancing of this responsibility should depend on a comparative analysis of costs and benefits, with particular reference to such factors as (1) the number of agents to be regulated, (2) the rate of the sources’ emission deterioration over time, (3) the life expectancy of automobiles, and (4) the availability, effectiveness, and cost of programs to reduce emissions at the point of production and at the point of use.

Although automobiles are numerous and ubiquitous, they are manufactured by a small number of firms. It is easier and less expensive to administer a system that controls relatively few sources; therefore, regulation at the point of production has considerable appeal.

Some problems are associated with limiting controls solely to the point of production, however. If the factory-controlled emission rate deteriorates during normal vehicle usage, control at the point of production may buy only temporary emission reduction. Although the deterioration of emission control can be combatted with warranty and recall provisions, the costs of these supporting programs have to be balanced against the costs of local control.

Automobiles are durable, so new vehicles make up only a relatively small percentage of the total fleet of vehicles. Therefore, control at the point of production, which affects only new equipment, takes longer to produce a given reduction in aggregate emissions. Newer, controlled cars replace old vehicles very slowly. Thus, a program of control at the point of production would produce emission reductions more slowly than would a program securing emission reductions from used as well as new vehicles.

Some possible means of reducing mobile-source pollution cannot be accomplished by regulating emissions at the point of production because they involve choices made by the owner-driver. The point-of-production strategy is oriented toward reducing the amount of emissions per mile driven in a particular type of car, but only the owner can decide what kind of car to drive, as well as when and where to drive it.

These are not trivial concerns. Diesel and hybrid automobiles, buses, trucks, and motorcycles emit different amounts of pollutants than do standard gasoline-powered automobiles. By changing the mix of vehicles on the road, the amount and type of emissions can be affected, even if passenger miles are not changed.

Where and when the car (or other vehicle) is driven is also important. Clustered emissions cause higher concentration levels than do dispersed emissions; therefore driving in urban areas causes more environmental damage than driving in rural areas does. Local control strategies could internalize these location costs; a uniform national strategy focusing solely on the point of production could not.

Timing of emissions is particularly important because conventional commuting patterns lead to a clustering of emissions during the morning and evening rush hours. Indeed, plots of pollutant concentrations in urban areas during an average day typically produce a graph with two peaks, corresponding to the two rush hours.1 Because high concentrations are more dangerous than low ones, some spreading over the 24-hour period could also prove beneficial.

 The Economics of Mobile-Source Pollution

Vehicles emit an inefficiently high level of pollution because their owner-drivers do not bear the full cost of that pollution. This inefficiently low cost, in turn, has two sources: (1) implicit subsidies for road transport and (2) a failure to internalize external costs.

Implicit Subsidies

Several categories of the social costs associated with transporting goods and people over roads are related to mileage driven, but the private costs do not reflect that relationship. For example:

● Road construction and maintenance costs, which are largely determined by vehicle-miles, are mostly funded from tax dollars. The marginal private cost of an extra mile driven in terms of road construction and maintenance is zero, but the social cost is not.

● Despite the fact that building and maintaining parking space is expensive, parking is frequently supplied by employers at no marginal cost to the employee. The ability to park a car for free creates a bias toward private auto travel, because other modes receive no comparable subsidy.

Other transport subsidies create a bias toward gas-guzzling vehicles that produce inefficiently high levels of emissions. Until recently, in the United States, business owners who purchase large, gas-guzzling sport utility vehicles (SUVs) get a substantial tax break worth tens of thousands of dollars, while purchasers of small energy efficient cars get none (Ball and Lundegaard, 2002). (Only vehicles weighing over 6,000 pounds qualify.)

This tax break was established 20 years ago for “light trucks,” primarily to benefit small farmers who depended upon the trucks for chores around the farms. Today, most purchasers of SUVs, considered “light trucks” for tax purposes, have nothing to do with farming.

1The exception is ozone formed by a chemical reaction involving hydrocarbons and nitrogen oxides in the presence of sunlight. For the evening rush-hour emissions, too few hours of sunlight remain for the chemical reactions to be completed, so graphs of daily ozone concentrations frequently exhibit a single peak.

Externalities

Road users also fail to bear the full cost of their choices, because many of the costs associated with those choices are actually borne by others. For example:

● The social costs associated with accidents are a function of vehicle-miles. The number of accidents rises as the number of miles driven rises. Generally, the costs associated with these accidents are paid for by insurance, but the premiums for these insurance policies rarely reflect the mileage-accident relationship. As a result, the additional private cost of insurance for additional miles driven is typically zero, although the social cost is certainly not zero. (Tietenberg 366-369)

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Although various types of pollution have common attributes, important differences are apparent as well. These differences form the basis for the elements of policy unique to each pollutant. We have seen, for example, that although the types of pollutants emitted by mobile and stationary sources are often identical, the policy approaches differ considerably.

Water pollution control has its own unique characteristics as well. The following stand out as having particular relevance for policy:

1. Recreation benefits are much more important for water pollution control than for air pollution control.

2. Large economies of scale in treating sewage and other wastes create the possibility for large, centralized treatment plants as one control strategy, whereas for air pollution, on-site control is the standard approach.

3. Many causes of water pollution are difficult to trace to a particular source as in smokestacks or cars for air pollution. Examples of major nonpoint sources of water pollution include runoff from streets and agriculture as well as atmospheric deposition of pollutants. Control of these sources adds additional complexities for water pollution control.

These characteristics create a need for yet another policy approach. in this chapter we will explore the problems and prospects for controlling this unique and important form of pollution.

 The Nature of Water Pollution Problems

Types of Waste-Receiving Water

Two primary types of water are susceptible to contamination. The first, surface water, consists of the rivers, lakes, and oceans covering most of the earth’s surface. In the past, policymakers have focused almost exclusively on preventing and cleaning up lake and river water pollution. Only recently has ocean pollution received the attention it deserves.

Groundwater, once considered a pristine resource, has been shown to be subject to considerable contamination from toxic chemicals. Groundwater is subsurface water that occurs beneath a water table in soils or rocks, or in geological formations that are fully saturated.

Groundwater is a vast natural resource. It has been estimated that the volume of groundwater is approximately 50 times the annual flow of surface water. Though groundwater currently supplies only 25 percent of the fresh water used for all purposes in the United States, its use is increasing more rapidly than the use of surface water. Groundwater is used primarily for irrigation and as a source of drinking water.

Surface water also serves as a significant source of drinking water, but it has many other uses as well. Recreational benefits such as swimming, fishing, and boating are important determinants of surface water policy in areas where the water is not used for drinking.

Sources of Contamination

Although some contamination has been accidental—the product of unintended and unexpected waste migration to water supplies—a portion of contamination has been deliberate. Watercourses were simply a convenient place to dump municipal or private sewage and industrial wastes. Along the shoreline of many lakes or rivers, pipes dumping human or industrial wastes directly into the water were a common occurrence before laws limiting this activity were enacted and enforced.

Contamination of groundwater occurs when polluting substances leach into a water-saturated region. Many potential contaminants are removed by filtration and adsorption as the water moves slowly through the layers of rock and soil. Toxic organic chemicals are one major example of a type of pollutant that may not be filtered out during migration. Once these substances enter groundwater, very little, if any, further cleansing takes place. Moreover, because the rate of replenishment for many groundwater sources is small relative to the stock, very little mixing and dilution of the contaminants occurs.

For lake and river pollution policy purposes it is useful to distinguish between two sources of contamination—point and nonpoint sources—even though the distinction is not always crystal clear. Point sources of water pollution generally discharge into surface waters at a specific location through a pipe, an outfall, or a ditch, whereas nonpoint sources usually affect the water in a more indirect and diffuse way. Examples include agricultural and urban runoff. From the policy point of view, nonpoint sources of water pollution are more difficult to control because both the source and timing are hard to predict and as such, they have received little legislative attention until recently. As a result of the gains made in controlling point sources, however, nonpoint sources now compose over half of the waste load borne by the nation’s waters.

Rivers and Lakes.

The primary point sources are industries and municipalities. The most important nonpoint sources of pollution for rivers and lakes are agricultural activity, urban storm-water runoff, silviculture, and individual disposal systems. Contamination from agriculture has been attributed to eroded topsoil, pesticides, and fertilizer. Urban storm-water runoff contains a number of pollutants, including, typically, high quantities of lead. Forestry, if not carefully done, can contribute to soil erosion and, by removing shade cover, could have a large impact on the temperature of normally shaded streams. In the developing countries, more than 95 percent of urban sewage is discharged into surface waters without treatment.

The contamination of groundwater supplies usually results from the migration of harmful substances from sites where high concentrations of chemicals can be found. These include industrial waste storage sites, landfills, and farms.

Ocean Pollution.

The two primary sources of ocean pollution that we will discuss are oil spills and ocean dumping. Oil spills have become less frequent and have decreased in magnitude since 1970 (see Figure 18.1), but spills are still not uncommon, as shown in Table 18.1, which lists the largest ones. Various unwanted by-products of modern life have also been dumped in ocean waters based upon the mistaken belief that the vastness of the oceans allowed them to absorb large quantities of waste without suffering noticeable damage. Dumped materials have included sewage and sewage sludge, unwanted chemicals, trace metals, and even radioactive materials.

FIGURE 18.1 The Decreasing Frequency of Oil Spills

 (Tietenberg 393-396)

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As the level of waste rises and the amount of space available to store it safely without contaminating groundwater declines, what can be done? The traditional answer involves the three R’s: reduce, reuse, recycle.

How can economics help to assure that the three R’s play an appropriate role in managing waste? What measures can be taken to reduce the level of waste? What is an efficient amount of recycling? Will the market automatically generate this amount in the absence of government intervention? How does the efficient allocation over time differ between recyclable and nonrecyclable resources?

Our investigation begins by describing how an efficient market in recyclable, depletable resources would work. This benchmark is then used to examine recycling in some detail. We conclude by introducing the special complications that arise when the waste is hazardous or toxic and discuss the policy approaches that are targeted specifically at that category of waste.

 Efficient Recycling

Extraction and Disposal Costs

What determines the recycling rate? Historically, reliance has generally been on the natural inputs, because they have been cheaper. As the natural inputs have become scarce relative to the demand for them, industry has begun to search for other sources.

At the same time, the costs of disposing the products have risen as the world has experienced a large increase in the geographic concentration of people. The attraction of cities and the exodus from rural areas led an increasingly large number of people to live in urban or nearurban environments.

This concentration creates waste-disposal problems. When land was plentiful and the waste stream was less hazardous, waste could be buried in landfills. But as land has become scarce, burial has become increasingly expensive. In addition, concerns over environmental effects on water supplies and economic effects on the value of surrounding land have made buried waste less acceptable.

The rising costs of virgin materials and of waste disposal have increased the attractiveness of recycling. By recovering and reintroducing materials into the system, recycling provides an alternative to virgin ores and also reduces the waste-disposal load (see Example 19.1).

EXAMPLE 19.1 Population Density and Recycling: The Japanese Experience

Since Japan has a much greater population density than any of the other industrialized nations, it has been forced by necessity to come to terms with its solid waste problems somewhat earlier than countries with more land area available for disposal. Japan has accomplished this with a combination of technological solutions, reduction strategies, and recycling.

Currently, Japan recycles about 50 percent of its paper, 80 percent of its steel cans, and 75 percent of its glass bottles. For the sake of comparison, comparable numbers for the United States are 45 percent, 59 percent, and 21 percent.

Since the early 1970s Japanese citizens have been forced to separate combustible from noncombustible trash. Combustible waste, which is some 72 percent of the total, is burned in some 1,850 incinerators. (This compares to about 140 large incinerators in the United States.) About 80 percent of the volume of incinerated waste in Japan is used to generate power. What’s left, about 9 percent of the total waste generated, ends up in landfills. (In the United States about 56 percent of the generated waste ends up in landfills.)

Additionally, Japan has been a leader in mandating the return of appliances (washing machines, refrigerators, televisions, and air conditioners) for recycling. In April 2001 the Home Appliances Recycling Law was enacted. While it places most of the responsibility on manufacturers, it requires consumers to deliver the appliances to the appropriate collection sites and to provide the financing. When consumers trade in an old appliance for a new one or they deliver their used appliances to a collection site, they must pay a fee to cover the cost of recycling. Manufacturers are responsible for recycling the appliances. They are also responsible for ensuring that future products incorporate materials supplied by the recycling program and are easier to recycle.

Sources: Japanese Recycling Statistics, http://web-japan.org/stat/stats/19ENV51.html; U.S. Statistics http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm.

Consumers and manufacturers play a role on both the demand and supply side of the market. On the demand side, consumers would find that products depending exclusively on virgin raw materials are subject to higher prices than those relying on recycled materials. Consequently, consumers would have a tendency to switch to products made with the cheaper, recycled raw materials, as long as quality is not adversely affected. This powerful incentive is called the composition-of-demand effect.

As long as consumers bear the cost of disposal, they have the additional incentive to return their used recyclable products to collection centers. By doing so, they avoid disposal costs while reaping financial rewards for supplying a product someone wants.

For the cycle to be complete, the demand for the recycled products must be sufficiently high to justify making them available. New markets may ultimately emerge, but the transition has proved to be somewhat turbulent. Simply returning recycled products to the collection centers accomplishes little if they are simply dumped into a nearby landfill or if the supply is increased so much by mandatory recycling laws that prices for recycled materials fall through the floor. The purity of the recycled products also plays a key role in explaining the strength of demand for them. One of the reasons for the high rate of aluminum recycling and much lower rate of plastics recycling is the differential difficulty of producing a high-quality product from scrap. Whereas bundles of aluminum cans have a relatively uniform quality, waste plastics tend to be highly contaminated with nonplastic substances, and the plastics manufacturing process has little tolerance for impurities. Remaining contaminants in metals can frequently be eliminated by high-temperature combustion, but plastics are destroyed by high temperatures.

Recycling: A Closer Look

The model in the preceding section would lead us to expect that recycling would increase over time as virgin ore and disposal costs rose. This seems to be the case. Take copper, for example. In 1910 recycled copper accounted for about 18 percent of the total production of refined copper in the United States. By 2001 this figure had risen to 70 percent.

Recycling Faces Many Barriers.

The expectation that virgin prices are steadily increasing is not always valid (see Example 19.2). Coupled with artificially low disposal costs, these depressed prices contribute to depressed markets for recycled materials.

In most cases recycling is not cheap. Several types of costs are involved. Transport and processing costs are usually significant. The sources of scrap may be concentrated around cities where most of the products are used, while for historical reasons the processing facilities are near the sources of the virgin ore. The scrap must be transported to the processing facility and the processed scrap to the market.

Labor costs are also important. Collecting, sorting, and processing the scrap are typically very labor intensive. Higher labor costs can make the recycled scrap less competitive in the input market. Recognizing the importance of labor costs raises the possibility that recycling rates would be higher in areas where labor costs are lower and that does seem to be the case. Porter (1997), for example, shows how vibrant markets for scrap have emerged in Africa.

And, finally, since the processing of scrap of input into the production process can produce its own environmental consequences, complying with environmental regulations on processing facilities can add to the cost of recycled input. In the United States, for example, relatively low world copper prices, coupled with high environmental compliance costs created a cost squeeze that contributed to the closure of all U.S. secondary smelters and associated electrolytic refineries by 2001. (Tietenberg 424-427)

Tietenberg, Tom, Lynne Lewis. Environmental Economics & Policy, 6th Edition. Pearson Learning Solutions. VitalBook file.

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 1.Fullerton, D., & Stavins, R. (1998, Oct. 1). How economists see the environment. Nature, 395(6701), 433-434. Retrieved from Research Library. (Document ID: 35058211).