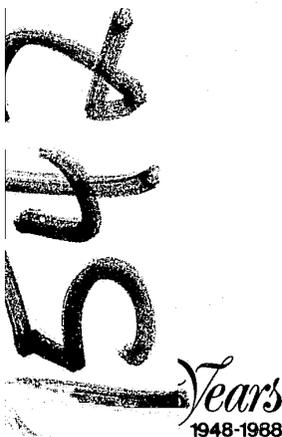




# Measuring and Deterring Illegal Disposal of Hazardous Waste

## A Preliminary Assessment

James K. Hammitt, Peter Reuter



The research described in this report was sponsored by the U.S. Environmental Protection Agency under Cooperative Agreement No. CR-814029-01-0. Publication of the report was funded by a grant from the John M. Olin Foundation.

ISBN: 0-8330-0933-8

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1700 Main Street, P.O. Box 2138, Santa Monica, CA 90406-2138

147542

R-3657-EPA/JMO

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James K. Hammitt, Peter Reuter

October 1988

Prepared for the  
U.S. Environmental Protection Agency

*40 Years*  
1948-1988

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## PREFACE

This report was prepared under a cooperative agreement with the Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency. It is the product of an exploratory project to help evaluate what is known about the extent of illegal hazardous-waste disposal, the types of firms and wastes involved, and effective enforcement strategies. The project draws on existing literature and interviews with approximately 40 enforcement personnel and industry representatives in three jurisdictions: Los Angeles County, Massachusetts, and Pennsylvania.

Publication of this report was funded by a grant from the John M. Olin Foundation.

## SUMMARY

Regulations that affect hazardous-waste treatment, storage, and disposal have become increasingly stringent in recent years, leading to dramatic increases in the financial cost of legal waste disposal. Waste generators and haulers can potentially respond to the changed conditions in several ways: by paying the increased costs of legal on- or off-site disposal, reducing the amount of waste generated, recycling, or disposing illegally to air, water, or soil. A danger of policies that increase the costs of legal disposal methods is that firms may respond by diverting larger quantities of waste to illegal disposal routes. This study is a preliminary attempt to describe what is known about the extent and nature of illegal disposal, the types of firms that are involved, and the most promising enforcement strategies.

To this end, we reviewed the available literature and interviewed approximately 40 enforcement personnel and industry representatives in three disparate jurisdictions: Los Angeles County, Massachusetts, and Pennsylvania. These jurisdictions were selected in part because each has an established hazardous-waste-enforcement program, so government and industry officials can be expected to have greater experience with, and understanding of, the issues involved in deterring illegal disposal.

Incentives to dispose of wastes illegally are likely to vary markedly among firms, and so the frequency of illegal disposal should also vary. Among the factors that may be related to frequency of illegal disposal are the type and quantity of waste generated, industry, location, technical sophistication, size, cost of waste disposal relative to profits, and the extent to which the firm's assets are at risk or are salvageable if it is caught disposing of wastes illegally. In principle, it should be possible to target enforcement efforts by taking account of such factors. Unfortunately, systematic data on compliance frequency needed to design such targeted strategies are not currently available. In Sec. V we offer some suggestions on the type of information that could help guide such strategies in the future.

Current enforcement regimes vary significantly among the three jurisdictions we studied. In Los Angeles County, most enforcement and inspection activities are undertaken by about ten city and county agencies, whose efforts are coordinated through a county strike force. A state agency is responsible for a limited subset of enforcement activities. In contrast, enforcement in Pennsylvania is almost entirely the

responsibility of a single state agency, which does everything from inspection to prosecution. The Massachusetts system is more like the centralized Pennsylvania model, although other agencies are involved to a limited extent.

Another important difference between enforcement regimes is the universe of firms they attempt to regulate. Los Angeles County and Massachusetts attempt to inspect essentially all hazardous-waste generators, whereas Pennsylvania inspects only large-quantity generators (producing at least 1,000 kg/mo), leaving small-quantity generators to the federal Environmental Protection Agency (EPA). Perhaps because of this difference, Pennsylvania officials seem to believe illegal disposal is much less of a problem in their jurisdiction than do officials in the other jurisdictions.

All three jurisdictions prosecute serious hazardous-waste violators as criminals and impose administrative fines on lesser violators. In general, enforcement agencies depend on unsolicited tips for leads to serious enforcement cases; inspections tend to uncover numerous, smaller violations.

Data needed to estimate the quantity or describe the nature of illegally disposed of hazardous wastes are not available. Even the quantities of hazardous wastes that are generated or disposed of legally are not accurately known. In part, data limitations reflect inconsistencies in the definition of hazardous waste across jurisdictions and over time. Estimates of hazardous-waste generation within a state vary by an order of magnitude or more, and jurisdictions that attempt to inspect small-quantity generators do not know how many such generators exist.

To maximize social welfare, enforcement programs should balance the marginal costs of maintaining detection and prosecution systems against the marginal environmental and human-health costs caused by the illegal disposal of hazardous wastes. Because reliable data on the quantity, types, disposition, and consequences of illegal waste disposal, and on the types of firms most likely to be involved, are unavailable, it is not possible to make these evaluations at present. We suggest that EPA seriously consider ways to collect new data to learn more about the nature of illegal disposal and how serious a problem it is. Appropriate data might be obtained by instituting a periodic compliance monitoring system relying on intensive inspection of randomly selected firms, and by encouraging better monitoring of possible illegal disposal sites, such as sanitary landfills, sewers, and storm drains.

## ACKNOWLEDGMENTS

Much of the information in this report was provided by officials representing hazardous-waste-enforcement agencies; waste-hauling, treatment, and disposal firms; hazardous-waste generators, and academics. Because some of these people wish to remain anonymous, we do not identify any of them. We gratefully acknowledge their willingness to share their knowledge and suspicions about illegal disposal.

Our EPA project officer, Michael Northridge, was extremely helpful. He identified and provided copies of a large number of relevant EPA and other documents, carefully read and commented on several drafts of the report, and coordinated comments on the drafts from others at EPA.

At RAND, Jan Acton helped define the project. Frank Camm and Joseph Bolten thoughtfully reviewed an earlier draft and offered several useful suggestions. Patricia Bedrosian edited it quickly and skillfully. Without implicating them for any errors or misinterpretations, we thank these people for their contributions.

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## I. INTRODUCTION

Hazardous waste is perceived by the American public as the most important environmental issue today (Roper poll data reported in EPA, February 1987). Names like Love Canal and Times Beach have become familiar codewords for the dangers of mismanaging hazardous wastes, although it is significant that considerable doubt remains as to just how much damage actually occurred at these sites. This concern has led to the promulgation of numerous federal and state statutes and regulations to control the handling of hazardous wastes from generation to disposal.

The objective of this study is to examine one component of the effort to reduce the damages arising from hazardous waste—government enforcement (both civil and criminal) of the Resource Conservation and Recovery Act (RCRA). RCRA enforcement is only one of several interacting mechanisms for controlling damages from hazardous wastes; others include Superfund (covering closed waste sites), insurance contracts, and private civil liability. Government enforcement may or may not turn out to have an important role; this depends in part on the effectiveness of the other instruments. It may have a residual function, to be used where other formal and informal controls fail.

This study is an exploratory effort to assess the importance of illegal disposal and to describe how some agencies are going about the enforcement task. It describes what is known about the extent of illegal disposal and the types of firms most likely to be involved; characterizes examples of the current enforcement regime; and suggests ways to improve decisionmaking with respect to enforcement. The study relies on review of other reports and on interviews with approximately 40 enforcement personnel and industry representatives in three jurisdictions: Los Angeles County, Massachusetts, and Pennsylvania.

## HISTORICAL BACKGROUND

The primary statute—RCRA—was adopted in 1976 with relatively little fanfare. It established a framework for regulating hazardous waste from generation to disposal. The statute defines the characteristics that make a waste hazardous (toxicity, reactivity, corrosivity, and flammability) and grants EPA broad authority to regulate waste labeling, containment, transportation, and record-keeping, and to establish

a system for permitting treatment, storage, and disposal facilities (TSDFs).

Subsequent discovery of the number of contaminated disposal sites led, in 1980, to the passage of Superfund (The Comprehensive Environmental Response, Compensation, and Liability Act or CERCLA), requiring all firms that contributed hazardous waste to a closed site to undertake cleanup of that site if leakage threatens human health or the environment. By 1984, the perception that EPA had done little to prevent future problems led to passage of the Hazardous and Solid Waste Amendments (HSWA). These amendments to RCRA required that EPA promulgate many significant new regulations and include "hammer provisions" that become effective if EPA fails to act before stringent deadlines. The HSWA provisions include bans on land disposal of a broad range of chemical wastes, more stringent technical and financial requirements for TSDFs, and extension of regulations to small-quantity generators (SQGs)—facilities that generate less than 1,000 kg of hazardous wastes a month. Very-small-quantity generators (VSQGs), generating less than 100 kg/month, remain exempt from federal regulations, although they are covered by some state laws.

Largely as a result of the new statutes, the costs of hazardous-waste disposal have increased manyfold since the 1970s and are likely to continue to increase. The causes include not only the increasingly stringent regulations themselves but also the difficulty of expanding treatment and disposal capacity by siting new TSDFs (partly because of local opposition, wherever the proposed site), and industry and insurer fear of potential Superfund or other civil liability for cleanup or damages. There appears to have been a substantial change in the manner in which hazardous wastes are handled and disposed of.

A particular concern arising from the increasing costs of proper hazardous-waste disposal is that firms will resort to improper and illegal disposal methods. Waste generators face an array of options for responding to disposal-price increases, including paying the higher rates, reducing waste generation through process or product changes, recycling or selling wastes to other firms that can use them, and dumping wastes illegally. A firm's response may include more than one of these options. As costs of legal disposal rise, the financial incentive for illegal disposal also increases, leading to more disposal in sewers or storm drains, evaporation, burial, or abandonment on land.

Haulers and TSDFs also have heightened incentives to dispose of wastes improperly. As described in Sec. II, however, there is reason to believe that the incentives are greater for generators.

## HOW SERIOUS IS THE PROBLEM OF IMPROPER DISPOSAL?

The previous paragraphs describe incentives. As discussed in Sec. II, there are many factors other than cost that affect compliance with disposal regulations and these have changed in complex ways as the incentives for improper disposal have risen. We cannot infer that the rising costs have led to a large increase in illegal disposal. In fact, it turns out that very little is known about the extent or nature of improper hazardous-waste disposal; we simply do not know whether a significant quantity of hazardous waste is being disposed of in ways that produce significant health risks or environmental damage.

There are two methods by which one might estimate the extent of illegal disposal. (1) *Residual Method*. Estimate the total quantities of waste generated and legally disposed of. The difference between them is the quantity illegally disposed of. (2) *Audit Method*. Direct observation (audit) of a sample of firms to determine their level of compliance. If the sample has been appropriately selected, the results can be extrapolated to the universe of firms.

In this subsection we consider the first of these methods, for it provides considerable insight into the difficulties of data collection generally. We discuss the audit method in the final section, since a good deal of the material presented in Sec. III is necessary background to understanding the possibilities of audit techniques.

The residual method requires very accurate estimates of generation and legal disposals. Since the quantity illegally disposed of is presumably very much smaller than the quantity generated, any uncertainty about generation will result in proportionately much greater uncertainty about illegal disposals. If illegal disposal accounts for only 1 percent of total generation, a 1 percent error in the generation estimate will produce a 100 percent error in estimated illegal disposal. It seems unlikely that estimates of total generation and legal disposals will ever approach the accuracy needed for this type of estimate.

There are at least four basic problems in estimating total quantities of hazardous waste generated. (1) Hazardous waste is an extremely heterogeneous set of materials; it includes liquids and solids of enormously varying chemical composition. Changes in dilution practices can dramatically affect the total. (2) The definitions of waste and of what part is hazardous vary across levels of government and over time. A waste stream that would be legally hazardous if produced by a large-quantity generator (LQG) might not be hazardous if generated by a household or VSQG in states where these are not regulated. (3) It is difficult to create an accurate list of generators; the set of firms

involved is very large and heterogeneous and many cannot be readily identified as hazardous-waste generators. (4) The various data systems that are available for measuring the total quantity generated use varying conceptual definitions. Some trap quantities that move through legal recording systems and thus inevitably miss quantities improperly disposed of, whereas others do not take account of on-site disposal, which may be legal or illegal.

In light of this, it is not surprising that there is substantial variation in estimates of the total quantities of hazardous waste generated, both at the national and state levels. Appendix A analyzes the basis for the available estimates.

To our knowledge, no significant effort has been made to estimate the national quantity of hazardous waste disposed of illegally, by this method or any other. Laws have been enacted and are enforced, mostly by state and local agencies. But enforcement is not complete; no one expects it to be and society cannot afford to make it so. Improper disposal is frequently invisible, at least for some time after it has occurred (perhaps many years). Measuring the extent of crime is always difficult, expensive, and intrusive. It is particularly so for these less visible offenses, and agencies have not been motivated to undertake (and not seriously charged with) responsibility for measuring the problem.

It is difficult then to determine how well agencies are doing in their basic task of enforcing the laws. We shall describe how a few agencies are undertaking this responsibility. We shall make some judgments about how well they are doing it. But those judgments are tentative, for we are unable to say anything definite about the social costs arising from any failure on the agencies' part. We suspect that the law is under-enforced; that society would be better off if more resources were devoted to enforcement. However, we do not claim to be able to persuade a skeptic of that view, for we cannot say how much is being improperly disposed of, what costs that imposes on society, or how much the costs might be reduced by more intensive (and presumably more expensive) enforcement.

As a final preliminary, it is important to note that we make no independent judgment about the appropriateness of the standards embodied in RCRA, HSWA, or the regulations promulgated under them. If these standards are not set appropriately, significant under- or overcompliance with them may improve social welfare.

## OVERVIEW OF THE REPORT

Hazardous-waste generators and haulers constitute a diverse population, varying in size, industry, location, and other attributes. Their choice among legal and illegal disposal methods is affected by these and other factors; that is the subject of Sec. II. Both as a matter of observation and of argument, SQGs are thought to be more likely than LQGs to dispose of some or all of their wastes illegally; they are also more difficult to monitor because of their sheer number and lack of prominence. SQGs are the focus of much of the analysis of Sec. II.

Section III summarizes our field work concerning current enforcement efforts in three jurisdictions. Detailed descriptions of enforcement in these jurisdictions are provided in Appendix B. The three show considerable variation in many dimensions: structure, methods of monitoring, targeting, and sanctioning. In all three jurisdictions, enforcement of hazardous-waste-disposal regulations is a relatively new area and most agencies are still developing procedures and strategies. Statistics on numbers and types of cases brought reflect this fact: More cases are brought each year and the distribution among civil and criminal prosecutions, administrative orders, and other categories changes. In none of the jurisdictions, however, do inspection or other monitoring activities predominate as the source of new cases; unsolicited tips appear to be the single most important source. Nor do any of the jurisdictions have estimates of the extent or composition of non-compliance.

Section IV presents a simple conceptual model for determining the appropriate level of enforcement resources to commit and comments on the likely efficacy of alternative enforcement methods. It also describes some results from the economics literature that provide new insights into these questions.

In conclusion, Sec. V summarizes what is known about the scale and significance of illegal hazardous-waste disposal. Current understanding of these matters does not allow us to determine how important a problem illegal disposal is; in this section, we suggest possible methods for developing the necessary data.

## II. FACTORS AFFECTING COMPLIANCE WITH HAZARDOUS-WASTE-DISPOSAL REGULATIONS

Hazardous-waste generators vary widely in their compliance with, and knowledge of, hazardous-waste regulations. Some firms are extremely cautious of potential risks. According to industry personnel we interviewed, one major oil refinery employs a certified laboratory to conduct waste profiles on each of 40 to 50 waste bins disposed of weekly, at a cost of perhaps \$1,000/bin. In recent years, this firm has reduced its off-site waste shipments by an estimated 90 percent. Similarly, a major aerospace firm formerly shipped thousands of gallons per month off site; it now treats most hazardous wastes on site and ships only 70 drums every three months for destructive incineration.

At the other extreme, industry and enforcement officials described a major national department store that was recently caught dumping acids down a storm drain, and a cardboard-container manufacturer that was, until recently, oblivious to potential fines and liabilities for its disposal of waste ink. The container firm assumed its waste hauler would take care of any problems and became aware of its own potential liability only when informed by the hauler after a sanitary landfill refused to continue accepting the firm's wastes. As a result, the hauler reports this firm will see its disposal costs increase from about \$600 per truckload to perhaps \$10,000; it currently ships four to five truckloads per month.

As these examples illustrate, hazardous-waste generators may choose from a large array of possible responses to the increased costs of legal waste disposal, including (1) paying the higher costs of legal treatment and disposal; (2) reducing the quantities of wastes generated; (3) recycling wastes or selling them to other firms; (4) treating or disposing of wastes in legal on-site facilities; and (5) disposing of wastes illegally, by depositing them in sewers or storm drains, on land (on or off site), or allowing them to evaporate. A firm may divide its response among more than one of these options. Its choice is likely to be affected by the cost and technical feasibility of each alternative, knowledge and understanding of the regulations, technical expertise in waste management, difficulty in siting and permitting treatment facilities, and the perceived threat of legal liability for cleanup or damages. Similarly, waste haulers can choose among various alternatives—legal or illegal—for disposal of wastes they accept from generators.

The relative costs of alternative disposal methods, and particularly the costs of legal as opposed to illegal methods, vary systematically and significantly among firms. Relative costs may be affected by the firm's location; technical sophistication; size; industry; cost of waste disposal relative to profits, revenues, or other economic measures; the extent to which the firm's assets are at risk or are salvageable if it is caught disposing of wastes illegally; the specific wastes produced; and other factors. In this section, we analyze some of the factors that are likely to influence a firm's compliance and describe the available empirical evidence.

We restrict our analysis to hazardous-waste generators and haulers, since these appear more likely than TSDFs to dispose of wastes outside of hazardous-waste facilities. Moreover, ensuring TSDF compliance is probably much easier than ensuring generator and hauler compliance, and it requires different strategies. This follows because there are comparatively few TSDFs and they operate under stringent permits.<sup>1</sup>

## **INCENTIVES AND DETERRENTS TO ILLEGAL DISPOSAL**

Hazardous-waste generators can choose from among several legal and illegal methods for disposing of their wastes. The factors affecting this choice can be characterized as incentives or deterrents to illegal disposal and can vary significantly among firms.

### **Incentives to Illegal Disposal**

The primary factors encouraging illegal disposal appear to be economic and informational. That is, firms may dispose of wastes illegally to save disposal costs, because they are not aware of the regulations and their responsibility to comply, or because they do not know how to comply with the regulations. The relative importance of these factors is not established and is likely to vary systematically among firms, by industry and region, for example.

**Knowledge of Regulations and Technical Expertise.** Hazardous-waste management is usually a small part of a firm's

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<sup>1</sup>There are approximately 3,000 active TSDFs nationwide subject to permitting (EPA, December 1986), of which 508 are commercial facilities that accept wastes from other firms (EPA, August 1987). Pennsylvania (1986) reports the existence of approximately 125 TSDFs in the state, of which seven are commercial, although EPA (August 1987) lists 28 commercial facilities there. Massachusetts Department of Environmental Management (1987) reports that 18 of 83 TSDFs are commercial facilities; EPA (August 1987) lists 13 commercial facilities in the state. California has approximately 1,200 TSDFs subject to permitting (interview with California Department of Health Services personnel), of which 49 are commercial facilities (EPA, August 1987).

operations. Consequently, it may not attract the attention of senior management; indeed, it may receive little attention from anyone. Some observers think that much illegal disposal is almost inadvertent, through lack of attention to waste disposal (Schwartz et al., 1987). Firms may delay disposing of wastes because of the high costs of legal handling, thereby accumulating an illegal quantity or storing it beyond the allowed period. Firm personnel often do not view the familiar chemicals with which they work as hazardous, in part because adverse health effects may be infrequent or latent (Rebovich, 1986).<sup>2</sup> Some observers suggest that illegal disposal may be more frequent in firms with poorly educated workers, or with immigrant or illegal-alien workers who are unfamiliar with English and may be either more easily directed to actions that violate regulations or less knowledgeable about those regulations.

Hazardous-waste-disposal regulations are a fairly recent development, especially for SQGs in many states. Such regulations must overcome inherent resistance to changing standard operating procedures, and small firms in particular are less likely to have staff who keep informed of current regulations and approved disposal methods. EPA has established programs to improve SQG awareness of RCRA requirements. It works with trade associations to publicize the regulations, publishes documents that assist SQGs in determining what requirements they face, and staffs telephone hotlines for small-business inquiries. The EPA Office of the Small Business Ombudsman responded to approximately 12,000 telephone and mail inquiries in 1986, and 5,400 in the first half of 1987 (EPA, October 1987).

In 1985 and 1986 EPA conducted a major campaign to inform SQGs of the new RCRA requirements. In addition to placing general articles in the trade press, the agency developed and distributed through trade associations general brochures and industry-specific inserts for 18 industries, including motor-vehicle maintenance, printing, and dry cleaning, that were identified by an EPA survey (Ruder et al., 1985) as likely to include a large number of SQGs. The inserts identified the likely types of hazardous waste these industries would generate and listed the corresponding EPA hazardous-waste identification numbers needed for waste manifests.

Waste haulers offering standard route-service collection can also be an important factor in overcoming generator ignorance and resistance. Such firms typically handle manifesting and other paperwork for generators, recycle the wastes, or find a disposal facility that will accept

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<sup>2</sup>Akerlof and Dickens (1982) and Viscusi and O'Connor (1984) analyze whether and why workers persist in discounting job-related risks.

them. These firms have been very successful in identifying and recruiting generators to their service. As described in Appendix A, one such firm had 30 percent more California dry-cleaning firms as customers than the state knew existed. Another firm currently serves over 16,900 dry cleaners in the United States and Canada (Safety-Kleen Corporation, 1987). (For comparison, the 1982 Census Bureau figures report 32,400 dry-cleaning establishments in the United States; Wolf and Myers, 1987).

A survey of SQGs in New Jersey found that compliance was more often related to a firm's legal and environmental expertise than to the perceived incremental costs of legal disposal (Bozeman et al., 1986). The direction of causality is not clear, however: Firms that dispose of wastes legally may, as a result, have become more interested and expert in legal and environmental matters. But many of the generators and haulers we interviewed believe that it requires a conscious effort for a hazardous-waste generator to remain ignorant of disposal requirements.

**Disposal-Cost Savings.** The cost savings a generator or hauler can achieve by illegal disposal depend on the type and quantity of wastes and the accessibility and cost of legal disposal methods. These can vary substantially among firms, by industry and location.

As regulations on waste haulers and disposal facilities have tightened, prices for commercial waste treatment and disposal have increased markedly. Prices for legal disposal of most hazardous wastes are currently much higher than prices for traditional disposal (although the full social costs, including the expected costs of health and environmental damage and future cleanup, are presumably lower for legal than for traditional methods). Table 1 illustrates the substantial price increases for most waste types and treatments over the past decade; this information was provided by firms in Massachusetts. (The apparent decrease in the halogenated-waste and incineration columns is not explained.) Similarly, prices at the Kettleman Hills, California, facility have increased from about \$10 to \$30/ton in 1979 to about \$75 to \$450/ton in 1986, depending on waste type and treatment. Disposal costs for a typical dry-cleaning facility have increased from near zero to estimated current costs of \$5,000/year for landfilling or \$8,000 to \$13,000/year for incineration (Wolf and Myers, 1987). Table 2 provides estimates of recent prices for a range of waste types and treatments, based on EPA's annual survey of waste-management firms (EPA, March 31, 1988).

Further adding to disposal costs, legally disposed of wastes are frequently taxed. In California, for example, these taxes vary by waste type and total between about \$2/ton and \$150/ton. They are collected on the manifested waste quantities either directly from generators or

Table 1

ILLUSTRATIVE WASTE-DISPOSAL PRICES IN MASSACHUSETTS  
(Dollars per ton)

Year	Corrosives	Nonhalogenated	Halogenated	PCBs	Inorganic Sludges	Waste Oil	Incineration
1976	na	na	na	na	na	na	108
1978	131	118-197	240	350	240	52	186
1980	131	131-371	393	480	262	131	269
1982/3	201	131-459	415	874-1748	327	131-459	389
1984	240	135-459	459	874-1748	393	135-459	433
1986	350	262-961	961	1311-2403	590	262-961	280
1987	371	284-1005	284-1005	1311-2403	371-1005	262-961	na

SOURCE: Monsanto (incineration) and Clean Harbors, Inc. (all others), as reported in Massachusetts Department of Environmental Management (1987).

NOTE: na—not available.

by TSDFs when the manifests do not show a state tax account number.

Waste-hauling costs vary with waste type, quantity, whether it is stored in drums or can be pumped into tanks, distance shipped, and other factors. Hazardous waste must often be shipped hundreds of miles, because of the limited number of TSDFs. For example, there are currently no operating hazardous-waste land-disposal sites in Southern California, except Casmalia in the far northern part of the region, 100 miles or more from the principal generation sites. An estimated 75 percent of Massachusetts waste is shipped out of state (half of it to New York). Average shipping costs there are estimated at \$13/barrel in state and \$27.50/barrel out of state (Massachusetts Department of Environmental Management, 1987). In California, typical prices for a full truckload are about \$10/barrel for shipments within state and \$25/barrel out of state. (These estimates are consistent with the \$0.20/ton-mile reported in Table 2 if in-state trips average about 250 miles and out-of-state trips average about 500 miles, assuming an average of five barrels/ton.)

Shipping rates for partial loads can be much higher (Schwartz et al., 1987). SQGs may benefit from regional collection facilities that would allow aggregation of shipments into larger loads. Also, the longer storage period they are allowed (under federal law, 270 days compared with 90 days that LQGs are allowed) should allow SQGs to consolidate their shipments into larger loads.

Table 2

RECENT PRICES FOR HAZARDOUS-WASTE MANAGEMENT NATIONWIDE  
(Dollars per ton)

Technology	Type of Waste	1985	1986	1987
Landfill	55-gallon drum	241-659	212-601	308-895
	Bulk (per ton)	69-140	86-154	97-166
Incineration	Clean liquids, high BTU	26-503	370-503	370-794
	Liquids, low BTU	344-1110	423-688	344-899
	Sludges and solids	741-1270	1030-1850	1430-2280
	Highly toxic liquids	556-2200	582-873	635-1320
	PCB liquids	661-926	873-952	635-1140
	PCB solids	1190-3310	1060-2090	1010-2170
Chemical/ biological	Aqueous inorganic liquids	na	79-317	79-317
	Inorganic sludges, solids	na	106-926	106-926
Resource recovery	Aqueous organics	na	106-265	106-265
	Nonaqueous organics	na	79-291	106-635
	Oils	0-106	53-265	53-291
Deep well injection	Aqueous organics	na	26-132	26-132
	Oil wastewaters	26-132	26-132	26-132
	Other toxic liquids	132-317	53-159	53-159
Transportation (per ton-mile)		0.20	0.22	0.23

SOURCE: EPA (March 31, 1988).

NOTES: Prices converted from dollars/gallon using a factor of 3.78 kg/gallon.  
na—not available.

In addition to hauling fees, generators face other costs that can bear disproportionately on SQGs. TSDFs may require laboratory testing to characterize a waste before accepting it. Such tests may cost about \$250 for each waste, independent of the quantity disposed of. Some incinerators only accept tankloads of waste, since they are not equipped to handle drums. TSDFs may also require haulers to schedule deliveries many weeks ahead. Interacting with the limits on storage times, this requirement can increase the difficulty of complying, especially for SQGs.

**Competitive Significance of Disposal Costs.** Firms that dispose of their wastes illegally, and thereby avoid the high costs of legal disposal, can gain a competitive advantage. In industries where legal disposal costs are large relative to profits, this advantage may be so significant that legal disposers cannot compete. For example, according to a waste hauler we interviewed, legal disposal may cost a small dry cleaner \$200/month, a substantial share of its typical \$2,000/month net

revenues. A small metal cleaner with similar profits might face \$2,000/month disposal costs. In cases like these, nearly all competing firms must comply with disposal restrictions, or none can comply and survive. In many other industries, legal disposal costs are small relative to net earnings and firms have more discretion.

**Cost and Feasibility of Alternative Technologies.** The costs of alternative waste-management techniques, such as on-site recycling and source reduction, can vary among each other and from those of legal off-site disposal. Differences in both fixed and variable costs may be important. Often these alternative waste-management approaches will pose increased fixed costs that capital-constrained firms may be unable to bear. Difficulties in siting and permitting new treatment units can add substantially to the costs of adopting alternative waste-management practices.

### **Deterrents to Illegal Disposal**

Deterrents to illegal disposal can be characterized as legal or business penalties, depending on who imposes them. Legal penalties are generally imposed by government agencies and include fines, imprisonment, loss of a permit necessary to conduct business, or payment for site cleanup. They may also include payment of civil judgments for personal injury or private-property damage, but such suits are apparently rare. Legal penalties and government enforcement are described in Sec. III.

**Private-Sector Oversight.** Business penalties are potentially more important to haulers and commercial TSDFs than to generators. They involve the loss of business that may result if generators are not confident that wastes will be handled properly, since under both RCRA and Superfund, generators remain liable for cleanup of sites in which their wastes were deposited. Generators have been determined to be jointly and severally liable for site cleanup; any one firm can be liable for the entire cost. This provision is of particular concern to large firms that believe they are prominent targets for cleanup suits because of their "deep pockets." According to our interviews, this has motivated some large firms to bring their waste-management activities in house, reducing their reliance on other firms. Similarly, some generators are joining together to investigate and evaluate haulers and TSDFs, to reduce the chance of contracting with an unreliable firm. Increased in-house waste management may increase social costs if large generators have a comparative disadvantage in properly treating and disposing of hazardous wastes relative to specialized waste-management firms. However, this reduction, if it occurs, may be more than offset

by the improvement in social welfare resulting from curtailing improper waste disposal.

To further reduce their risks, some generators treat many of their nonhazardous wastes as hazardous, erring on the side of overcompliance to reduce the risk of inadvertent noncompliance. According to our interviews, some firms do not bother to test each waste stream but send all potentially eligible wastes to TSDFs, thereby increasing demand for these facilities and disposal prices, and increasing incentives for others to engage in illegal disposal.

Just as generators may attempt to force haulers and TSDFs to comply with hazardous-waste regulations, liability insurers may oversee generators (in addition to haulers and TSDFs). The possibility of varying insurance rates in proportion to a generator's chance of violating the standards appears to be limited, however, because of extreme uncertainty about expected insurance losses. This uncertainty arises from the potentially long delay between the generators' actions and the ultimate discovery of damage, suit, and judgment; uncertainty about future legal standards that may apply (partly as a result of the rapidity with which the current rules have developed); and the difficulty in estimating one firm's share when it may be one of many firms liable for cleaning up a site. Under claims-made policies, where the insurer will pay only for damages that are discovered during the policy term, the insurer has less incentive to oversee the generator's current actions, since most claims the insurer will face may derive from activities that preceded the policy term, and claims that result from current activities may fall to a later insurance carrier.

An additional factor weakening insurers' ability to influence generator behavior is that insurers fear they may be unable to enforce contract provisions voiding coverage if the firm fails to comply with special requirements set by the insurer, since the insurer can be liable for compensation under the Superfund direct-action provision. The direct-action provision may have limited applicability, because insurance can be voided if the insured violates laws or government regulations, however (Cheek, 1982; Kunzman, 1985; Kehne, 1986). But the possibility that in the future courts will interpret contracts to impose liability retroactively cannot be discounted. In addition, it is not clear whether insurers have or will obtain the technical sophistication to evaluate hazardous-waste-management practices. Eads and Reuter (1983) report that insurers have failed to develop such expertise with respect to products liability; they provide little or no monitoring of manufacturer design processes.

**Private Monitoring of Waste Haulers.** Potential business penalties and corresponding private-sector oversight may be most relevant to possible illegal disposal by haulers. Generators have the incentive

(because of their own potential liability) and the ability to monitor hauler behavior.

The form of the contract between generator and hauler can strongly influence the hauler's incentive to deliver the wastes to a suitable TSDF or dispose of them elsewhere. If the generator pays the hauler for transport and disposal, the hauler can potentially retain the entire disposal fee by dumping the wastes illegally. A Santa Clara County firm that collected wastes from automobile-repair shops did just this, dumping the wastes into sewers (Schwartz et al., 1987). Similarly, enforcement officials report that some Los Angeles firms that are permitted to dump sewage they collect (from cesspools and outhouses) into public sewers have disposed of hazardous wastes with the sewage.

If the generator pays the TSDF directly and pays the hauler for transport alone, the hauler's profit from illegal dumping is much smaller. As a variant of this approach, the hauler may have a credit account with the TSDF and charge the generator for disposal after it is billed by the facility. In this case, the generator can demand proof that the waste was delivered, in the form of the TSDF bill. This arrangement is vulnerable to collusion between the TSDF and hauler, but the TSDF is likely to have much more at stake than the hauler.

Both types of contracts are common. Their prevalence depends in part on generator size. Larger generators are more likely to have an account with a TSDF and pay the facility directly, whereas smaller generators may pay the hauler for disposal and rely on it to identify a suitable TSDF. Generators that contract with a route-service firm may have little control, and perhaps little interest, in where their wastes go.

The waste manifests required under RCRA can be a valuable tool for generator control of haulers. TSDFs are required to return a copy of the manifest to the generator when the waste is received. Generators are required to check these and to report to the state if they do not receive a copy of the manifest from the TSDF. Even if the state fails to identify cases in which the waste did not reach the TSDF, the generator can.

These monitoring and compliance methods are not perfect, of course. A hauler could forge the TSDF's signature on the manifest or the TSDF bill it shows the generator. There are reports of fraudulent manifesting in Massachusetts, involving haulers' names and EPA identification numbers being used on manifests in regions or states where the haulers do not operate (Massachusetts, 1985). However, these methods make for easier detection. Moreover, it would be difficult for a hauler to fraudulently send the TSDF's copy of the manifest to the state, since TSDFs typically send a large number of manifests together and a lone manifest would appear suspicious.

## OTHER DETERMINANTS OF BEHAVIOR

The previous section discussed incentives and opportunities for illegal disposal. But a firm's behavior is not simply a function of incentives and opportunities. There is a good deal of evidence that firms, like other complex organizations, behave in ways that reflect internal values and organizational structure. Two apparently similarly situated firms may thus respond in very different ways to the same set of incentives and opportunities. One may aggressively seek to minimize its costs by noncompliance, even while incurring some risk of adverse publicity and fines; another may be extremely risk averse with respect to noncompliance and even overcomply with new regulations, for example by treating as hazardous some wastes that are not legally so.

Corporations vary in their behavior, just as individuals do. But corporations cannot be treated in the same way as individuals. A different set of characteristics must be observed to predict firm behavior. Further complicating matters, individuals within firms have their own interests and one of the goals of management, never fully achieved, is harmonizing the interests of employees and those of the corporation. To some extent that is done through selection of employees; a firm will attract to itself a particular kind of employee and will not attract others. The firm will make an attempt to shape a new employee's values (with respect to the firm), particularly if he is young, to reflect the values embodied in what is often called the firm's "corporate culture." A firm's corporate culture affects the set of issues it chooses to address and the manner by which it does so. Consequently, it can significantly affect compliance behavior (Boyer et al., 1987).

Individual and corporate behavior, and variation among corporations, can be illustrated by considering the significance of adverse publicity as a method for controlling corporate behavior. One distinguished criminologist argued that "there is very little evidence to suggest that the stigma of criminality means anything very substantial in the life of a corporation. John Doe has friends and neighbors; a corporation has none" (Packer, 1967). More recently, Fisse and Braithwaite (1983) in their study of the impact of publicity on major corporations find significant differences among firms in their responses to publicity about regulatory violations. Some made major changes in personnel or structure, others did little. All did something, which is itself a remarkable finding, given the depressing literature on individual rehabilitation. Moreover, the authors suggest that it was not the financial cost of the violation and accompanying publicity but precisely the "loss of corporate and individual prestige, decline in morale, distraction from getting on with the job, and humiliation in the witness

The EPA SQG survey (Ruder et al., 1985) reports a similar distinction. It found that VSQGs are proportionally more often in service-oriented, and less often in manufacturing, industries than other SQGs. If compliance is related to size (and not just to the threshold between LQG and SQG) then together these hypotheses suggest that it may be useful to distinguish between service-oriented or commercial VSQGs that are unlikely to comply, and manufacturing or industrial SQGs that are more likely to comply. (Federal law does not require VSQGs to comply with most RCRA requirements, although many states impose these requirements on them.)

Several of our sources indicated that SQGs can quickly learn to defeat the regulations. One trick is to legally dispose of only part of the firm's wastes, to obtain the required documents to show in case of inspection. The remaining wastes are dumped illegally (Massachusetts, 1985). Several sources report that when waste haulers serving SQGs increase their fees or change from a flat rate for collecting all of a generator's wastes to a per-unit charge, the quantities hauled drop dramatically, suggesting diversion to illegal alternatives. Other explanations (such as process changes) are possible, of course, but were not considered likely in these instances. In one case, when a firm that collected wastes from automobile-repair shops raised its price from a flat \$55/month to \$88/month plus \$2/gallon it lost 40 to 50 of its 500 customers (Schwartz et al., 1987). A hauler that served dry cleaners found a similar response. One of his customers whose solvent recycling equipment routinely produced 42 spent filter cartridges per month surrendered only 21 per month thereafter; others were sometimes seen in his dumpster.

## ESTIMATES OF COMPLIANCE

Estimates of the share of firms that dispose of their hazardous wastes illegally, and of the quantities illegally disposed of, are few and of limited reliability. However, they support the claim that SQGs are more likely than LQGs to fail to comply with disposal regulations.

A survey in North Hollywood, California, estimated that 5 to 28 percent of SQG wastes are improperly disposed of there, most going to sewers, sanitary (nonhazardous-waste) landfills, buried on site, or evaporated (SCS Engineers, 1985). A New Jersey survey estimated that about 30 to 50 percent of SQGs do not use required manifests (Bozeman et al., 1986). A survey of San Francisco Bay area SQGs found that 57 percent dispose of at least some of their waste illegally. Half of the firms surveyed claimed not to be familiar with the rules. When

asked the maximum amount they would be willing to pay for proper disposal, half the firms said they would not pay anything and 85 percent stated an amount less than \$50 per month, suggesting they do not have much demand for legal disposal services (Russell and Meiorin, 1985). In 42 Florida counties that have surveyed their SQGs, only about half the waste is estimated to be disposed of properly (Schwartz et al., 1987). In addition, the District Attorney of Santa Clara County, California, estimates that one-half the automobile-repair shops there dump their wastes down sewers or storm drains, as did a hauler that collected their wastes (Schwartz et al., 1987).

A telephone survey in Massachusetts found that only 25 of the 36 SQGs surveyed had EPA identification numbers required for manifesting wastes, compared with 21 out of 22 LQGs. The surveyed LQGs claimed to comply with disposal regulations largely as a matter of good citizenship and public image. They reportedly did not think the threat of enforcement was great and believed any penalties assessed would be modest and negotiable between the firm and government agencies. In contrast, although the SQGs also mentioned good citizenship as a factor, they indicated that the fear of enforcement was a much more important reason for compliance. Although the probability of being detected may be low, the surveyed SQGs apparently fear the possibility of ruinous fines or imprisonment (Massachusetts, 1985). Unfortunately, no information is provided on the way the sampled firms were chosen or which individuals within the firms were interviewed. These findings are suggestive, but they are also consistent with a view that the larger generators are simply more skilled in public relations.

The only published study of LQG compliance (Savant Associates, 1983) is now somewhat dated. It found that, even in a period of less stringent enforcement, there was generally a high level of compliance. For example, one-fifth of the generators surveyed in the study reported overcomplying by treating as hazardous some wastes that were not regarded as such by EPA. Savant Associates used two independent methods designed to obtain more truthful answers to potentially embarrassing questions when estimating the fraction of surveyed firms that had disposed of waste illegally. One method was to ask respondents whether they knew of other firms that had disposed of wastes illegally. The second method, known as the "random response technique," asks respondents to answer either a question about whether they dispose of waste illegally or an innocuous question, depending on the outcome of a random device (such as a coin toss) that is concealed from the interviewer. Estimates produced by the two methods were in reasonable agreement: About 10 to 15 percent of firms had "disposed of some of their wastes illegally in the previous two years."

## DIFFERENTIAL INCENTIVES TO FIRMS

Theoretical considerations suggest that incentives and deterrents to illegal disposal differ systematically by observable characteristics of firms. These differential incentives should lead to varying rates of compliance among firms, and may be useful in targeting enforcement actions.

One potentially important characteristic is the ratio of legal disposal costs to profits. As described above, in industries where the costs of legal disposal are large relative to profits, it may not be possible for firms to bear these costs and remain in business unless almost all firms comply. In such markets, there are strong incentives to dispose of waste illegally.

A related point is the ratio of fixed to variable legal disposal costs. Where the variable costs are small, the incentives for noncompliance are also small. Thus, a hauler that contracts for both transport and disposal at an unaffiliated TSDF has a greater incentive to dump than one who contracts only for transport.

The extent to which a firm's value can be salvaged if it is forced to shut down as a result of legal or business penalties may also be important. If a large part of the firm's value is in assets with ready resale markets, such as a hauler's trucks, the owner may lose relatively little if he is caught disposing of waste illegally. In contrast, TSDF owners may lose a large share of their assets if forced to shut down, since the physical facility may not be readily transferable to other operators without significant delay.

Firm size can affect the magnitude of business penalties resulting from disclosure that a firm violated a disposal standard. The effect of a single disclosure on other firms' estimates of the reliability of a hauler, for example, may not be properly adjusted for the hauler's size. That is, if the probability of violating a standard and being caught is proportional to the amount of waste the firm hauls, firms that haul large amounts are more likely to be caught than other firms. If generators do not properly account for this effect, their estimates of the comparative reliability of haulers may be biased against the larger-volume firms.<sup>3</sup> This suggests that the threat of business penalties will be more important for large-volume firms than for small.

Similarly, the amount of waste a firm generates or handles can affect its opportunities for illegal disposal. It is surely easier to illicitly dispose of a small amount than a large amount, although the larger generator may face different opportunities and may be able to illegally

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<sup>3</sup>Kahneman et al. (1982) report that individuals often fail to give adequate weight to prior probabilities.

dump a proportionately small, but absolutely large, quantity of hazardous waste.

## CONCLUSIONS

Given the scanty evidence available concerning the extent of illegal disposal by different classes of firms, we are forced largely to rely on *a priori* theorizing, stressing the costs, knowledge, and incentives of each class of firm. Combining this with the available empirical evidence suggests that SQGs are very likely to dispose of a larger share of their hazardous wastes illicitly than are LQGs or TSDFs. Similarly, it would appear that haulers are more likely than TSDFs to dispose of others' wastes illegally. To assess the social cost of illegal disposal by each class of firm requires additional information on the quantities and types of wastes involved and their ultimate disposition.

### **III. CURRENT MONITORING AND ENFORCEMENT PRACTICES**

Monitoring and enforcement of hazardous-waste-disposal laws and regulations are carried out in quite different ways in different jurisdictions. There is also considerable variation in enforcement agencies' perceptions of the extent and character of illegal activities they seek to control. Although EPA and other federal agencies help to shape enforcement strategies, the actual monitoring, investigation, and prosecution of violators are largely performed by state and local agencies. The following characterizations of enforcement activities are based on interviews with officials of the state and local agencies that have major roles in hazardous-waste enforcement in the three jurisdictions we studied (Los Angeles County, Massachusetts, and Pennsylvania) and on review of state and other documents.

This section provides some general observations about enforcement practices. More detailed descriptions specific to each jurisdiction are provided in Appendix B.

#### **INSPECTION AND ENFORCEMENT RESOURCES**

In a priority-setting exercise, EPA rated hazardous-waste enforcement as the third most important of 31 enforcement areas (EPA, May 1984). Similarly, state and local environmental and law-enforcement agencies nominally give high priority to enforcement against illegal disposal of hazardous wastes. Attention and resources assigned to this area have increased significantly in recent years. Yet in the three jurisdictions we studied, resources devoted to inspection and enforcement seem modest in comparison with the likely extent of illegal disposal. In part, this reflects the fact that the responsibility is a new one and the programs are just developing. There is a great deal of uncertainty about how best to proceed. Standard monitoring, surveillance, and inspection procedures have not been well developed and experienced personnel are few in number. Similarly, there is much uncertainty about the scale of illegal disposal, as demonstrated in Sec. II. The universe of generators, especially SQGs, has not been identified, hindering the development of generator inspection or monitoring programs.

Compared with the number of hazardous-waste generators and the plausible extent of illegal disposal, the number of enforcement cases investigated and prosecuted at the federal level is modest. The EPA National Enforcement Investigations Center (NEIC) received 240 allegations that were categorized as having good potential for criminal prosecution during FY82 through FY84, most of them in FY83 and FY84. Of these it could investigate only 70 because of limited resources. Information on the outcome of these cases is not reported (GAO, February 1985).

In FY83 and the first half of FY84, EPA referred only 14 illegal disposal cases to the Department of Justice (DOJ) for criminal prosecution (GAO, February 1985). (DOJ has jurisdiction over cases that require appearance in court.) EPA referred 20 criminal and 66 civil cases in FY86. The 66 civil cases represent a significant increase over the 19 civil cases referred in FY85, but most of the FY86 increase is apparently due to prosecution of TSDFs under the loss of interim status (LOIS) provisions, rather than to prosecution of generators and haulers for disposal of wastes outside of TSDFs (EPA, April 1987). In addition to these cases involving litigation, EPA enforcement officials issued a total of 235 administrative complaints, consent agreements, and final orders in FY86 (EPA, April 1987).

A large share of enforcement activity occurs at the state or local level. EPA has delegated primary enforcement responsibility for the basic RCRA program to most states, but only one state is authorized to administer the HSWA program that includes the federal SQG regulations. Many states, including California and Massachusetts, regulate SQGs under state law, however.

It is difficult to judge the appropriate level of enforcement resources, but the resources devoted to enforcement and monitoring activities in the jurisdictions we studied appear modest, in comparison with the plausible extent of illegal hazardous-waste disposal, and in comparison with resources devoted to other environmental and safety issues. For example, in Los Angeles County, home to eight million persons and about 200,000 businesses, there are only about 25 agents specifically concerned with investigating and prosecuting cases of illegal disposal. In addition, there are about 100 positions authorized for inspectors, who inspect firms for compliance with state and federal hazardous-materials regulations, but not all of these positions are filled. In comparison, until the California Occupational Safety and Health Administration transferred its responsibilities for inspecting firms to federal OSHA in mid 1987, there were approximately 170 California OSHA inspectors in Southern California. The state Industrial Relations Department has about 25 pressure-vessel inspectors in Southern

California, and nine elevator inspectors in the L.A. County region, excluding the City of Los Angeles.

Interviews with representatives of these agencies suggest that the 170 state OSHA inspectors and 25 pressure-vessel inspectors are too few to routinely inspect the facilities under their purview and to respond to the number of complaints received, although the nine elevator inspectors are nearly able to inspect the 16,000 elevators in their region annually, as required. However, there is an important difference in setting between OSHA and pressure-vessel inspectors, and hazardous-waste inspectors. In the former case, the workers and firms face strong incentives to avoid worker injury and equipment failure, since they bear many of the costs directly. Workers are likely to inform the regulatory agencies of dangerous conditions, and firms are likely to maintain pressure vessels and other equipment, at least to the extent necessary to avoid catastrophic failure. In contrast, firms and workers risk little from illegal hazardous-waste disposal, except the possibility of sanction by enforcement agencies.

Published analyses of RCRA enforcement at the state level have found small numbers of prosecutions. These studies are somewhat dated, however, and may not accurately represent current enforcement efforts, which are changing rapidly. A study of enforcement in four mid-Atlantic and northeastern states (Maine, Maryland, New Jersey, and Pennsylvania) found that only 71 criminal cases had been filed between 1977 and 1984 (Rebovich, 1986). The majority of these were filed in one state, New Jersey. From December 1980 to December 1983, before its strike force was established, Los Angeles County prosecuted 24 cases; the states of Illinois and New Jersey each had a total of only six prosecutions during this period (GAO, February 1985).

State enforcement efforts may virtually ignore whole classes of businesses. For example, Pennsylvania does not routinely inspect SQGs, claiming this to be EPA's responsibility, since Pennsylvania has not been authorized to administer the HSWA program. Similarly, although Massachusetts regulated SQGs under state law before HSWA, a 1985 legislative report found that inspections were heavily concentrated on the 115 largest LQGs. Generator inspections are apparently allocated more uniformly now (Massachusetts, 1987), but the authors report that 75 percent of inspection resources were devoted to the 115 largest LQGs, each of which was inspected four times annually; another 12 percent went to inspect smaller LQGs an average of only once every 15 years, and no resources were allocated to inspect SQGs (the remaining 13 percent of inspection resources went to smaller TSDFs; Massachusetts, 1985). Savant Associates (1983) report that

approximately three-fifths of the LQGs they surveyed had been inspected by state agents, and about one-fifth by federal agents.

## DEPENDENCE ON TIPS

In light of the limited inspection resources and uncertainty about the number and location of generators, it is not surprising that our interviews and other sources suggest that about half or more of the criminal cases originate through tips rather than regulatory inspections. Of the 36 cases analyzed by GAO (February 1985), 34 came from tips. The other two were developed incidentally by investigators assigned to other cases. Rebovich (1986) reports a smaller fraction, but still a majority: Of the 87 percent of all cases he examined where the source could be determined, 53 percent originated from tips by unrelated citizens or current or former employees of the offending firm. Twenty-three percent came from state regulatory inspections, 18 percent from local enforcement and regulatory agencies, and 6 percent were discovered as a result of industrial accident, such as an explosion or injury to a worker.

Tips are typically unsolicited and come from a variety of sources: disgruntled current or former employees, business competitors, and unrelated citizens who observe suspicious activity or abandoned drums (GAO, February 1985; Rebovich, 1986). Regular informants do not appear to be particularly valuable, although a few agents claim to use such informants. Some prosecutors develop strings of cases by using information obtained from one violator to apprehend the next (Rebovich, 1986).

Frequent inspections may increase the number of useful tips received, at least from employees, by increasing employee awareness of government concern and potentially providing employees with improved access to regulators. However, there appears to be no systematic evidence on this point.

The preponderance of tip-generated cases may reflect the higher quality of evidence often available in these situations. Some prosecutors claim that it is difficult to prove knowledge or intent without tips. Although it is not formally necessary, even for a criminal case, successful prosecution often requires a witness who can testify to details of the violation.

The majority of tips received are of low quality, however. Many agencies are overwhelmed with citizen complaints or reports to toll-free telephone tip systems. Most of these tips are believed to concern unimportant violations, and they provide too little information to identify any that may be important cases.

Other cases derive from regulatory inspections, surveillance, and emergency-response operations. Trash collectors on occasion find hazardous waste mingled with other solid waste; workers have been injured when these wastes spill, ignite, or explode during compaction (EPA, October 1986a). (Note that these injuries may have been caused by wastes legally disposed of by households or VSQGs.) The elaborate manifest system has not proven useful for developing cases, in part because most states have apparently not yet developed adequate data-processing systems. Where the system is operating smoothly it can be useful for confirmation and development of cases, but rarely for initiation. Moreover, some prosecutors are concerned about the evidentiary value of the system, fearing defense lawyers could easily show it to be error-prone.

Our interviews and review of other literature point to no discernible pattern in the types of firms that are most likely to violate rules. Violators include generators and haulers of all sizes, representing a broad range of industries. The lack of an apparent pattern may reflect the relatively limited numbers of cases brought, sample-selection effects that result from largely tip-driven prosecution, and the paucity of systematic analyses of cases.

Rebovich (1986) reports that almost two-thirds of the firms prosecuted in his four-state sample had no more than 50 employees. He suggests that larger firms' illegal activities are under-represented among prosecutions because they are more likely to occur on site where they are more difficult to detect. Larger firms may also shelter their officers from prosecution more effectively than smaller firms. Alternatively, large firms may not be under-represented among prosecutions. According to the Small Business Administration about 95 percent of U.S. firms have no more than 50 employees, but we do not know the corresponding figure for firms that generate hazardous waste.

## **DIVERSITY OF AGENCIES INVOLVED**

Enforcement can be diffuse, involving many kinds of agencies such as local police and fire departments, state environmental agencies, and county and state health agencies. State and local prosecutors may also play a role. There is, even in the three states we studied, a striking diversity of arrangements: Massachusetts and Pennsylvania have highly centralized systems, whereas California enforcement is dominated by local agencies. The variety of agencies that can be involved, even if only peripherally, may increase effectiveness by expanding the domain of sources from which enforcers can obtain information, but it can also create difficulties in coordination.

Business establishments are typically inspected by several agencies, including fire departments, the Occupational Safety and Health Administration or similar state agencies, and air and water quality control boards in California. Although none of these agencies are specifically charged with enforcing hazardous-waste regulations, they may notice apparent violations and refer these to the appropriate enforcement agencies. Moreover, many firms are not sensitive to differences in authority between government agencies, so inspection by any such agency can have a generalized effect to improve compliance with all health and environmental regulations. However, communication among agencies with different missions and orientations is probably not as effective as many businesses believe it to be.

Enforcement should be facilitated somewhat by the implementation in 1988 of the community right-to-know provisions, Title III of the Superfund Amendments and Reauthorization Act (SARA). Under these provisions, firms will be required to list any hazardous chemicals used in their processes or stored at their sites. California has adopted even more stringent reporting requirements. Such requirements are an additional tool for the RCRA monitoring agencies, though clearly raising their own enforcement problems.

Transportation of hazardous wastes across jurisdictional boundaries can further fragment enforcement, because of the need to coordinate efforts between jurisdictions. Interstate shipment of wastes is quite common: The majority of hazardous wastes generated in Massachusetts and Pennsylvania is disposed of in other states because of a lack of disposal facilities in the originating states. Transportation may cross international boundaries as well: Some California wastes are disposed of in Mexico, and enforcement agents we interviewed suggested that Mexican wastes may be disposed of in California. State records reportedly show 360 legal waste shipments to Mexico in the first half of 1986, but some observers believe illegal shipments to Mexico, Latin America, and even the South Pacific are significant (Porterfield, 1987). Illegal disposal by European firms has been reported in West Africa (Brooke, 1988).

## **CONFLICT BETWEEN ENFORCEMENT AND REGULATORY CULTURES**

Cultural differences between enforcement and regulatory agencies weaken the criminal-enforcement effort—regulators are typically more interested in obtaining compliance than penalties, and are not trained in evidence chain of custody and other prosecution procedures.

Enforcement agencies complain that regulators do not investigate or refer cases quickly enough, so the trails grow cold. More generally, regulators focus forward on compliance, whereas enforcers focus backward on crimes. Regulators are also likely to have on-going relationships with firms and to be more sensitive to business pressures for seeking noncriminal enforcement.

On their side, criminal enforcement agencies sometimes resist involvement in the investigation of environmental crimes. They may perceive the offense as technical and ambiguous, simply the latest hoop constructed by politicians. Environmental crimes often lack the clear "bad guys" associated with other areas of criminal investigation. Frequently, investigators drawn from police and other conventional enforcement agencies are not well trained in chemistry and other technical fields that are important in understanding and prosecuting this kind of offense. Similarly, prosecutors, judges, and juries may not appreciate the possible severity of hazardous-waste crimes and may be reluctant to prosecute or convict for seemingly technical violations, particularly where local regulatory standards (such as sewer permits) may be more lenient than federal standards (OTA, March 1986).

## AMBIGUITIES IN LEGAL INTERPRETATION

Some enforcement problems arise from ambiguity about the status of particular wastes under different laws. California law may consider infectious wastes discharged to waterways hazardous, but the same waste may be allowed by a federal permit under the Clean Water Act. Similarly, firms in California are required to report oil spills in accordance with guidelines to be published by the state, but those guidelines have apparently not yet been issued.

RCRA regulations are highly complex and impose numerous specific requirements. Even determining whether a particular waste is legally hazardous may require expensive laboratory analysis. This complexity frustrates industrial managers trying to decipher their responsibilities as well as law-enforcement officers trying to determine whether a violation has occurred. Industry attorneys complain of uncertainty about EPA policy resulting from the apparently large number of EPA guidance documents that exist, but that are difficult for outsiders to acquire or even to identify.

Ambiguities can also affect government activities: Under California's Proposition 65 (the Safe Drinking Water and Toxic Enforcement Act of 1986), certain government employees are required to notify the public within 72 hours of learning of an illegal release of hazardous waste. There is an exemption for undefined "law-enforcement" activities, including ongoing investigations, but because

violations are punishable as felonies, enforcement personnel are concerned about how this statute may be applied.

Confusion about legal obligations is likely to diminish with time, as firms and government agencies gain experience with the rules and any conflicts between them are resolved. Continued major revision of the laws will sustain confusion about proper behavior, however. At present, these uncertainties appear to have a significant effect on many firms' activities.

## STAFF TURNOVER

Part of the difficulty with hazardous-waste enforcement is that the programs are new and developing. Standard procedures have not been well developed, and experienced personnel are few. Aggravating this situation, there is substantial turnover in personnel. Inspectors and investigators are often hired away by industry after they are trained by government. Thus we found agencies in both California and Massachusetts that were unable to keep all their available slots filled with appropriately trained personnel.

In the last two years the Los Angeles County Health Department lost 24 inspectors to industry, from an authorized staff of 44. Formal training requires four months (one month of classroom instruction plus three months in the field with another inspector), but veterans believe that it really takes one and a half years to become proficient. Typically in their first professional job, many inspectors have master's degrees or are working toward them. It is scarcely surprising that these jobs become a revolving door as many inspectors move to industry and environmental-consulting firms after training. To mitigate this loss, the L.A. department has recently reclassified inspectors in order to pay them more competitive salaries.

The revolving-door nature of inspector positions can cause serious problems in the operation of programs. Rebovich (1986) reports that many inspectors believe that opportunities for advancement in government are limited, in contrast with opportunities in industry, and are receptive to industry offers.

Finally, hazardous-waste-enforcement personnel, like other hazardous-waste workers, require special equipment and training. One California official estimated the cost of outfitting each worker with protective suits and other equipment at about \$5,000, and reported that 40 hours of special training are required each year.

## **PENALTIES**

Agencies often have severe penalties available; RCRA allows for fines of up to \$25,000/day per violation. Some state laws are even more severe, with the prospect of felony charges where the violation is deliberate and significant. In California, a defendant can be convicted of a felony based on a "should have known" or negligence standard. Ambiguities of the law can make it difficult to enforce these penalties, however, and enforcement personnel may be unwilling to seek such severe sanctions in cases that are not perceived to be egregious. But the value of a felony prosecution for attracting the attention of the corporate community, and presumably improving compliance, is widely acknowledged.

There is a perceived need for, and movement toward, use of administrative penalties. These are more severe than the Notices of Violation (NOV) typically issued by administrative agencies but less demanding in time and evidence than criminal actions. They can be particularly important given that criminal conviction may be difficult to obtain with all the ambiguities in the law. Such administrative penalties have recently been authorized in Massachusetts, where they can be assessed by inspectors.

## **CONCLUSIONS**

The monitoring and enforcement of compliance with hazardous waste laws and regulations is a new enough responsibility that it should come as no surprise that there is considerable variation in the response of state and local governments. And, given the weakness of measures of the extent of the problem and the absence of any measures of the effectiveness of different approaches, it is also not surprising that the current system in some states looks unfocused or arbitrary.

That identifies a problem. How should the experiences of the different jurisdictions be used to learn about what is an appropriate level and mix of resources and instruments? We turn to that issue in the last two sections of this report.

## IV. OPTIMAL ENFORCEMENT

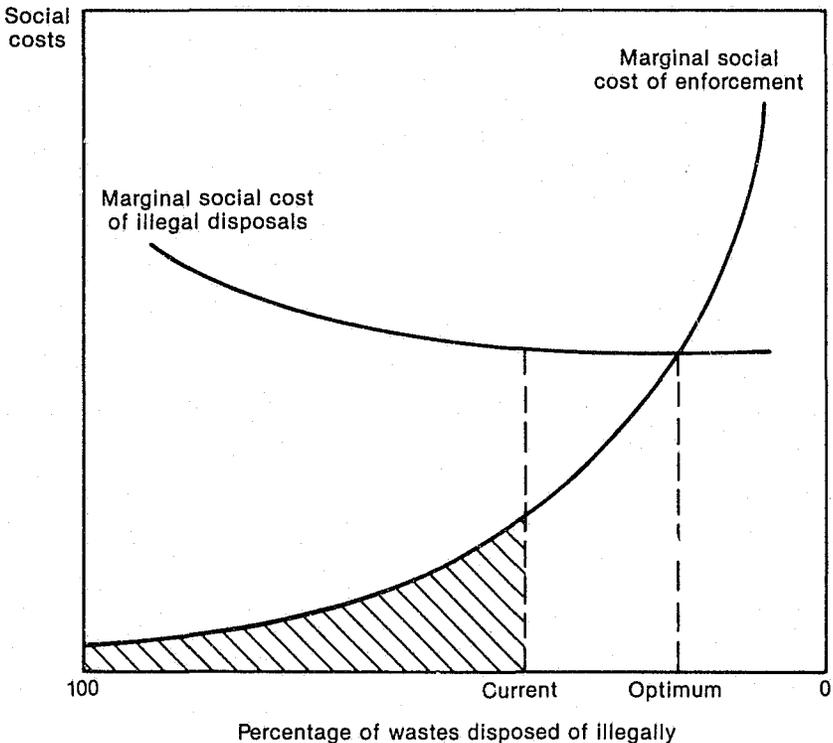
Efficient enforcement programs must consider both the appropriate level of resources to commit to enforcement and their allocation among enforcement methods. In this section, we describe a simple economic framework for estimating the appropriate level of enforcement resources, although the information needed to implement it is not presently available. In addition, we consider several insights from the economics literature that merit attention: the possibility that more than one level of illegal disposal may be consistent with a specific enforcement effort; how uncertainty about interpretation of the disposal regulations may lead firms to overcomply, increasing the social costs of waste management; and why limiting inspection or monitoring to a publicly identified subset of potential violators may improve compliance.

### APPROPRIATE LEVELS OF ENFORCEMENT RESOURCES

To maximize economic welfare, the level of resources committed to enforcing hazardous-waste regulations should reflect information on the marginal efficacy of enforcement resources as well as on the extent and environmental costs of illegal disposal. Although available information is not adequate to quantify the relationship, we can provide a simple conceptual model for the analysis. As illustrated in the figure on the following page, an optimal enforcement budget would equate the marginal costs of additional enforcement, measured in terms of the cost of decreasing the quantity of waste disposed of illegally, with the marginal social cost of illegal disposal (assuming well-behaved cost and benefit functions). Because these costs may be incurred at different times—enforcement costs are incurred immediately whereas the costs of damages may not be incurred until much later—the curves represent some form of appropriate present values.

Enforcement strategy should allocate resources to the most efficient enforcement methods. Conceptually, all potential violations could be ranked in terms of the ratio of marginal social damage to marginal social cost of averting the violation. Enforcement efforts should be targeted to potential violations for which this ratio is highest, and the level of resources set so that all potential violations for which the social cost exceeds the cost of averting it can be addressed.

Knowledge of the set of potential violators, the social costs of violations, and the marginal costs of deterring them is inadequate to rank potential violations in this way. As a result, enforcement agencies cannot accurately target their efforts on the highest-social-cost violators. The marginal social cost of detected violations will vary widely, but the average will be relatively constant for levels of illegal disposal between negligible and current levels, as illustrated in the figure. If it were possible to accurately target enforcement resources on the most significant



Optimal enforcement resources equalize the marginal social cost of enforcement and the marginal social cost of illegal disposals. The current level of illegal disposal appears to exceed the optimal level, although it is not possible to estimate either the current or optimal level with available data.

violators, the marginal social cost of damage would decline sharply with increasing compliance, since the most damaging illegal disposal methods and waste types could be controlled first.

At high compliance levels the marginal cost of further enforcement is likely to rise sharply, since the remaining types of illegal disposal will be the types that are most difficult to deter. At some level, the marginal cost of enforcement is almost sure to exceed the damage from illegal disposal, implying that allocating enough resources to enforcement to achieve nearly 100 percent compliance would be too much. In the figure, the marginal cost of enforcement is drawn as asymptotic to the perfect compliance level; elimination of illegal disposal is not achievable in this situation.

From currently available information, we can only begin to estimate the values of the parameters illustrated in the figure. The fraction of SQG wastes that is illegally disposed of has been estimated to be substantial, perhaps as much as 50 percent (Sec. II). The share of LQG wastes illegally disposed of is unknown but is believed to be significantly smaller. Since most hazardous wastes are generated by LQGs, the fraction that is disposed of illegally is most sensitive to LQG compliance and cannot be reasonably estimated.

The marginal social cost of illegal disposal depends on the extent to which the wastes will damage human health or the environment; this in turn depends on the specific chemicals involved and the methods and location of disposal. These costs are probably impossible to estimate reliably; however, by adopting RCRA and subsequent amendments, Congress has apparently concluded that the social costs of disposal in accordance with the RCRA requirements are less than the social costs of other disposal methods. If this assessment is correct, we can infer that the social costs of illegal disposal exceed the difference between the costs of legal and illegal disposal. The cost of legal disposal is currently on the order of \$100 to \$1,000/ton (Tables 1 and 2); the cost of illegal disposal is presumably much smaller.

This estimate represents only an average across various types of wastes and disposal routes, however. The social cost of disposing of highly toxic wastes in ways that are likely to damage health or sensitive environments could be many times larger, whereas the social costs of other illegal disposal could be much smaller. Wastes that are more expensive to dispose of legally may be more frequently disposed of illegally, although illegal disposal opportunities can also vary. Moreover, the current costs of legal disposal may overestimate the true resource costs. This could occur if current disposal prices exceed their long-run values because, for example, TSDF operators overestimate the long-run difficulty of siting additional disposal capacity, or insurers overestimate future liabilities and thus charge excessive premiums.

The marginal efficacy of enforcement resources cannot be estimated from currently available data. It is possible to estimate the enforcement budget, corresponding to the shaded area in the figure. Such an estimate should account for all of the important enforcement agencies, but should not include amounts included in the agency budgets that do not contribute to enforcement. However, without an estimate of the marginal efficacy of enforcement resources, it is not possible to determine whether the amount spent on enforcement is too large or too small.

### POTENTIAL MULTIPLE COMPLIANCE EQUILIBRIA

The marginal cost of enforcement depends on surveillance technologies, monitoring strategies, and other factors. It may also depend on historical factors. That is, a given level of enforcement resources might produce one of several levels of illegal disposal, depending on how that level was reached. Equivalently, the curve representing the marginal cost of additional enforcement in the figure may shift as a result of change in the compliance level. As illustrated by an overlapping-generation model developed by Lui (1986), multiple stable equilibria can exist in contexts where the probability of detecting and prosecuting a given violator depends on the number of other firms that violate.

Current enforcement cases are generated in large part from tips. Consider the probability that potential tipsters who know that a specific firm is disposing of its wastes illegally will report this fact to enforcement officials. If this probability is higher when illegal disposal is rare than when it is widespread, then the cost of detecting and prosecuting violations by that firm is higher when many firms are violators.

Under these conditions, the same level of enforcement effort may be consistent with either a high or low level of compliance. When compliance is high, the probability that enforcement officials will be informed of a violator's activities is also high, so a firm that violates the rules is likely to be detected and prosecuted and will choose to comply. Thus, a high level of compliance can be maintained. Alternatively, if compliance is low, the probability that a particular violator will be reported to officials is also low. Consequently, the chance of being detected and prosecuted is low, more firms will dispose of waste illegally, and only a low level of compliance can be maintained.

For multiple stable equilibria to exist, the cost of detecting and successfully prosecuting a representative violator must be higher when

overall compliance is low. Whether this condition is characteristic of illegal disposal activities is not known, although there are reasons to think it is plausible. As noted, much enforcement activity depends on tips. If illegal disposal is widespread, potential informants may not feel that a specific firm's violations are significant enough to warrant reporting. Moreover, investigation and prosecution may be more expensive if they require cooperation of other firms or individuals that are also engaged in hazardous-waste disposal. If these firms are also disposing of waste illegally they may be less willing to cooperate with enforcement officials, fearing either that the authorities will discover their own violations or that the prosecuted firm will inform authorities of their activities, for clemency or revenge.

The possibility that multiple equilibria may exist is reinforced by competition among firms in industries where legal disposal costs, and cost savings by disposing illegally, represent a large share of profits. As discussed in Sec. II, it may not be possible for a firm to dispose of its wastes legally and survive in a market where legal disposal costs are high relative to profits and its competitors are not burdened with these costs. In such a case, nearly all firms must comply or few will be able to.

If multiple equilibrium compliance levels are possible, the current equilibrium is likely to be a low-compliance one. The current hazardous-waste-disposal rules have only recently come into effect, especially for SQGs in many states. These new rules require a substantial change in traditional practices in an area that is generally peripheral to the firm's principal activities. They must overcome generator resistance to changing practices and shift perceptions of some in industry that familiar substances are not really dangerous. When the regulations were adopted, continuation of conventional waste-disposal practices became a low-compliance outcome; as suggested above, this outcome may be a stable equilibrium.

If the current situation is a low-compliance equilibrium, it may be possible to shift to a high-compliance equilibrium by a temporary increase in enforcement activities. Lui (1986) shows that if sufficient enforcement pressure can be applied to shift overall compliance to a higher level, behavior may converge to the high-compliance equilibrium and remain there even if enforcement resources are subsequently reduced. Similarly, transient high-visibility enforcement activities, including prosecution of major firms and imprisonment of their officials, may increase the perceived enforcement threat enough to shift industry to a higher-compliance equilibrium. The question of how long increased enforcement efforts must persist to shift industry practices has not been addressed.

## POTENTIAL OVERCOMPLIANCE

Industry uncertainty about regulatory requirements that produces the possibility of being penalized or held liable for cleanup or other costs, even if the firm believes it complies with all current regulations, can create an incentive for overcompliance (Craswell and Calfee, 1986). If disposal regulations are set optimally, overcompliance imposes resource costs on the economy as some firms devote too many resources to compliance.

Overcompliance can occur if a firm that it is in compliance with all regulations may nevertheless be penalized, and the firm can reduce the chance of incurring penalties by overcompliance. Firms that believe they are in compliance may be penalized through firm or government error in interpreting the law or future retroactive changes in legal standards. This overcompliance may appear in the form of firms managing more of their wastes on site, even if they do not have a comparative advantage over more specialized waste-management firms. Alternatively, firms may send nonhazardous wastes to hazardous-waste TSDFs, possibly increasing pressure on limited treatment and disposal resources, the price of legal disposal, and the incentive for other firms to dispose of waste illegally.

Industry representatives we interviewed in California report that some firms send significant quantities of nonhazardous wastes to TSDFs. Savant Associates (1983) found that 18 percent of a sample of LQGs treat some of their nonhazardous wastes as hazardous, with a higher proportion among firms that generated larger quantities. As described in Sec. II, larger firms may believe they have more to lose if detected disposing of waste illegally, so may be more cautious and more likely to overcomply than smaller firms.

We cannot determine how important this overcompliance may be. Measures that would reduce overcompliance are likely to have offsetting costs. The best regulatory policy will optimally balance these costs. For example, the costs of overcompliance by some firms can be reduced by decreasing enforcement efforts, though at the cost of increasing undercompliance by others. A preferable approach might be to improve industry understanding of the current regulations and to reduce uncertainty about future, retroactive standards to the extent possible. But effective communication of standards is difficult and expensive, and it may not be wise to limit society's options for responding to future discoveries of harm by prospectively curtailing the use of retroactive liability.

Concern about possible overcompliance is predicated on the assumption that current waste-disposal regulations optimally balance the costs

of environmental degradation against those of more environmentally protective waste-disposal measures. If current regulations are not sufficiently stringent, overcompliance may be preferred from a social perspective.

## PROVIDING AN ADEQUATE DETERRENT

Economic analyses of environmental-regulatory enforcement (Russell, 1987) and of criminal behavior more generally (Becker, 1968) suggest that a firm will violate if and only if the expected benefits (disposal cost savings) exceed the expected penalty (legal sanction weighted by the probability of apprehension). A standard result of this literature is that a very low probability of detection and prosecution combined with a very large fine will produce a sufficiently large expected penalty to deter violators at minimum enforcement cost (Polinsky and Shavell, 1979).

In the real world, the size of the penalty levied on convicted violators is limited by other considerations, including bankruptcy and equitable judgments of proportionality to the harm produced by the violation. In addition, individuals often act as risk-seekers in situations involving a small probability of a large loss (Kahneman and Tversky, 1979; Kunreuther, 1976). Consequently, available enforcement resources may not be adequate to ensure that the perceived expected penalty for violation exceeds the perceived benefit to the violator. In this case, Russell (1987) shows that higher overall compliance can be achieved by explicitly restricting enforcement to a subset of potential violators, so as to sufficiently raise the probability that a violation by one of these firms will be detected to deter the violation. This policy requires that the target firms believe they face a higher-than-average probability of prosecution, since it is the expected sanction that deters prospective violators. Thus, it may be necessary to publicize the strategy, although it could also be desirable to mislead nontargeted firms into believing their probability of detection is higher than it really is.

This "triage" strategy is analogous to the RCRA policy of exempting SQGs, and later only VSQGs, from most of the hazardous-waste regulations. If restricting primary attention to a subset of potential violators is appropriate, this subset should be identified by consideration of the costs of violation and detection. The RCRA strategy of directing resources to the largest-quantity generators assumes that quantity of hazardous waste generated is the most appropriate classification. Although quantity is clearly an important consideration, it may help to consider other factors as well for targeting enforcement efforts. Other

factors could include waste type, proximity to population centers or sensitive environments, cost and availability of legal waste-management alternatives, and others.

Russell (1987) also suggests a method for effectively increasing the size of the penalty for conviction. If the set of firms that are targeted for above-average inspections is determined, at least in part, by past convictions, then the penalty for conviction includes the cost of submitting to additional future inspections and reduced future ability to avoid compliance.

## CONCLUSIONS

Economic analysis of enforcement focuses attention on characteristics of the waste-disposal situation that have not been well described, but that are important for developing enforcement strategy. These include the average levels, and the distribution across potential violators, of the social costs of violations; the average and distribution of the social costs of deterring violations; and the distribution of compliance levels across firms. The analysis also highlights issues that have not been considered in this area, such as the possibility that current behavior may be trapped at a low-compliance equilibrium.

## V. CONCLUSIONS AND RECOMMENDATIONS

Appropriate enforcement of hazardous-waste-disposal regulations requires an understanding of the scale and distribution of illegal disposal, to determine the level of resources that should be committed to enforcement and to efficiently target those resources. As described in Sec. II, however, little is known about how much illegal disposal occurs, its composition in terms of types of wastes and disposal routes, or the characteristics of firms most likely to be involved. In this section, we assess what is known about the magnitude and nature of illegal disposal and suggest methods for collecting and using improved data.

### SCALING THE PROBLEM

Measurement of social phenomena is often difficult; measurement of illegal behavior is particularly so. Unlike many nonenvironmental crimes, however, where reasonable data on the frequency of occurrence are available through victimization surveys and systematic collection of crimes reported to policy agencies, the quantity of hazardous waste that is disposed of illegally is not known within one or perhaps two orders of magnitude. There is no basis for measurement of year-to-year fluctuations; the direction of change in successive years is largely a matter of speculation. Even the quantities of hazardous waste generated or disposed of legally are uncertain: State-level estimates vary by an order of magnitude or more (Appendix A).

We have uncovered no estimate of the share of LQG wastes disposed of illegally, although Savant Associates (1983) estimate that about 10-15 percent of LQGs disposed of some of their wastes illegally during a two-year period in which enforcement was considerably weaker than it is today. It appears that SQGs are likely to dispose of a larger proportion of their wastes illegally than LQGs. Some surveys have suggested that a substantial share of SQG waste, perhaps as much as half, is disposed of illegally (Sec. II). The number of SQGs and the quantity of waste they generate are highly uncertain, but since SQG waste probably constitutes only a small share of the total hazardous waste generated, the SQG contribution to total illegal disposal may be comparatively small.

In addition to measuring the quantity of wastes disposed of illegally, it is important to characterize the types of wastes and disposal routes. The potential harm to human health and the environment caused by

illegal disposal can vary widely, as a function of waste type, chemical properties, and environmental fate. Highly toxic wastes released to streams or permeable soil above aquifers that feed into drinking-water supplies can be much more harmful than less toxic wastes dumped into storm drains that rapidly empty into the ocean and are quickly diluted.

Although we have no estimate of the extent of illegal disposal, there are reasons to believe it is significant. Compliance with hazardous-waste-disposal regulations is expensive for many firms. The regulations are relatively recent, technically complex, and require substantial departures from past practices in an area—waste management—that is peripheral to most firms' activities. Firms that generate hazardous wastes, and thus must learn about the requirements, number at least in the hundreds of thousands nationwide. A large number of firms might be expected to fail to comply.

Furthermore, the evidence we have accumulated suggests that enforcement programs present only a modest threat to some classes of violators. Many generators, especially SQGs, apparently face a very slight risk of being detected if they choose to dispose of their wastes improperly. From a purely profit-maximizing view, they have little incentive to incur the costs of proper disposal. Nonetheless, we cannot infer that illegal disposal is massive. The expected cost of noncompliance is only one of the factors that enters into firms' compliance decisions. On the whole, citizens, even corporate citizens, prefer to comply rather than violate, if only because it is consistent with their self-image.

On the other hand, some firms apparently remain unaware of the requirements, or see them as arbitrary and unreasonable. Noncompliance may seem to them a technical violation, comparable to driving over the speed limit, rather than a crime. For some, compliance will be very difficult, particularly if legal disposal costs are a large share of profits and competing firms do not comply. Some firms, perhaps falling in quite specific categories, may massively violate the requirements of RCRA and its state counterparts.

It is possible that current levels of illegal disposal are significant, but available indicators are not adequate to identify an important problem, if one exists. Some indicators of illegal disposal, like the number of barrels abandoned in nonremote areas, are readily apparent, but other manifestations may not be detected for many years. For example, wastes leaching through uninspected soil may not be detected until they contaminate water sources; wastes in abandoned wells or mineshafts may remain contained until flushed out by unusually heavy rains. Wastes disposed of through other routes, such as sanitary landfills, sewers, and storm drains, may or may not be detected, depending on the extent to which these facilities are monitored.

But even if it is agreed that there may be significant levels of illegal disposal of hazardous waste, it is not certain that more resources need to be devoted to enforcement. Enforcement of hazardous-waste laws competes for resources directly with enforcement of laws against a variety of white-collar or corporate crimes (such as fraud, price-fixing, and workplace-safety violations) and indirectly with other law-enforcement and government activities. Already, enforcement officials in some jurisdictions argue that the resources committed to hazardous-waste enforcement are large relative to those committed to other areas. To justify further increases in resources for hazardous-waste enforcement, there must be some showing that the deterrent effect of increased enforcement is sufficient, and the resulting gains in social welfare are large enough, to make reallocation worthwhile. We have no basis for evaluating the deterrent effect of hazardous-waste enforcement.

Nor is there a literature on other kinds of corporate crime that we might use as a basis for assessing deterrence here. Measurement of the frequency of particular classes of corporate crimes reflects only what is found through enforcement. There is no equivalent to the household victimization surveys that have been so important in the measurement of violent crime and thefts against individuals or households; even the equivalent of "reports to the police" is much weaker for corporate crimes.

We start then with little understanding of the scale of importance of illegal hazardous-waste disposal and with little knowledge of how well the available instruments of control might work. Ignorance is of course no reason for inaction. But it suggests that better data to characterize the problem and the effects of enforcement must be developed. The next pages provide some preliminary suggestions about how to proceed along this path.

## **COLLECTING DATA ON ILLEGAL DISPOSAL**

Data on illegal disposal are inherently difficult to collect. Data from prosecuted cases, such as those analyzed by GAO (February 1985) and Rebovich (1986), may not accurately represent the universe of hazardous-waste crime as they are filtered through the screen of past and current detection and prosecution procedures. An aggressive enforcement system might generate numerous violations initially but then lead either to increased compliance or to forms of noncompliance that are more difficult to detect. Lax enforcement would generate little evidence of violation, precisely because it looks for little.

Similarly, generator surveys may not produce reliable estimates of illegal disposal. The universe of generators is not identified; even their

number is subject to substantial uncertainty. A census of generators would be extremely difficult and would not be cost-effective. If reliable extrapolations are to be drawn from a sample, it must be carefully selected to reflect the substantial heterogeneity among generators in their incentives to engage in illegal disposal, the types of wastes generated, and the sensitivity of the environments to which illegal disposal occurs. Surveyed firms may not respond accurately, fearing increased regulation. Those that do will be self-selected and may be unrepresentative of nonrespondents. Some firms may not even know how much waste they produce, and waste quantities may vary over time or between regions, in magnitude, and in the concentration of toxic compounds. Although some of these difficulties can be mitigated by sophisticated survey techniques, for example by querying firms about the frequency with which other firms they know of violate waste-disposal regulations or by using random-response techniques (Savant Associates, 1983), reliable results are likely to remain elusive. Because of these difficulties, Massachusetts reportedly elected not to survey generators, fearing to legitimize an estimate that would be of dubious validity.

One possible approach for estimating the scale and nature of the illegal disposal problem is to carry out intensive inspections of a large random sample of generators. There is a model for this approach in the Internal Revenue Service's Taxpayer Compliance Measurement Program (TCMP; Long, 1980). Approximately every third year, the IRS selects a stratified random sample of income-tax returns for intensive auditing. The results of the TCMP audits are used by IRS to develop its audit strategy; those kinds of returns that TCMP finds to have a high noncompliance rate are assigned high probabilities of being selected for audit in following years. TCMP also provides the basis for IRS estimates of the level of noncompliance generally.

We suggest that EPA explore the possibility of creating a similar system for periodically measuring noncompliance across classes of generators. Sampled establishments would be subject to a much more intensive inspection than is currently undertaken. The purpose would be less to establish a legal basis for prosecution, or even civil sanction, than to learn about the level and nature of violations of particular kinds of establishments.

To develop such a system efficiently, it is important to have an initial basis for stratifying the universe of businesses. We believe that there is enough knowledge in the community of enforcement officials, broadly defined, that it should be possible to develop an initial, crude taxonomy in terms of firms' propensity to illegally dispose of hazardous wastes. The taxonomy might be based on the size of the business, the

technology it uses, its location, and its corporate structure. A sample can then be drawn from Census lists, in which each business is given an initial sampling weight based on the taxonomy.

The major product of the system would be, in effect, a reweighting system—a classification of establishments in terms of the potential damage caused by hazardous wastes they dispose of illegally. The new weights would be used to guide monitoring and enforcement agencies in their allocation of resources among targets.

In considering the feasibility of this system, it is important to know whether intense inspection, of the kind that would be carried out for the sample, is likely to detect illegal disposal. The offenses are not continuous (the establishment may cumulate waste in proper containers and dump them intermittently), but intensive record checks should have a reasonable prospect of establishing at least a *prima facie* case and the basis for a targeted investigation.

Such a program could be complemented by encouraging local agencies to improve monitoring of the types of facilities to which wastes are illegally disposed of. Although routine monitoring of potential land sites is impracticable, continuous monitoring of sewers, storm-drain channels, and sanitary landfills appears to be feasible and valuable (Appendix B). Such monitoring would provide a better understanding of the quantities and types of wastes disposed of to these facilities; this could assist in developing appropriate enforcement strategies.

Because of the uncertainties about how effective an intense audit strategy would be, it may be appropriate to test pilot programs incorporating alternative design features in a limited number of jurisdictions. In designing such programs, however, the possibility that violators will shift their activities from the pilot jurisdiction to another jurisdiction must be recognized.

## POTENTIALLY EFFECTIVE MONITORING AND ENFORCEMENT STRATEGIES

With a better understanding of the extent and character of illegal hazardous-waste disposal, and of the relative likelihood that specific kinds of firms will violate the regulations, enforcement agencies could develop improved monitoring and enforcement strategies. In principle, an optimal allocation of enforcement resources to methods can be designed using estimates of the marginal efficacy of each enforcement tool and taking account of complementarities and other interactions, such as the possibility that frequent inspections may stimulate employees to become informants. Such estimates cannot be calculated, but we can speculate about the relative effectiveness of enforcement measures.

The appropriate allocation of enforcement resources is likely to vary among jurisdictions, in recognition of differences in number, size, and industry of hazardous-waste generators, soil and groundwater conditions, population distribution, and other factors.

Because potential violators are so numerous and diverse, tips may continue to be an important source of information. Policies to stimulate informed tips, such as rewarding informants with a share of fines collected, might be valuable. But enforcement agents we interviewed already receive many more reports of possible illegal disposal than they can investigate, and most of these are perceived to concern unimportant violations or provide too little information to be of value.

Inspection or surveillance programs targeted on the most likely and dangerous violators could probably improve on a system that relies on tips as the primary source of leads. But targeting requires information on differences in compliance rates among firms. Such differences may be related to factors such as the ratio of legal disposal costs to profits, the ratio of variable to fixed disposal costs, the share of a firm's value that can be salvaged if it is detected, or others suggested in Sec. II. Without compliance data such as might be obtained from the program of periodic intensive inspections suggested above, targeting may not be feasible.

Routine inspections of all firms, as the jurisdictions we studied apparently intend to conduct, may not be as cost-effective as random, intensified inspections of fewer firms. Meaningful inspection requires experienced inspectors who understand some of the details of industrial processes and significant analysis to correlate legal disposals with raw-material inputs or process outputs. Except as they can detect gross inadequacies in physical equipment or operating procedures, routine inspections may not be adequate to prevent episodic illegal disposal; a more continuous monitoring system may be necessary. Inspecting each generator once, largely for educational purposes, may be appropriate, but once hazardous-waste programs become better established, compliance may be improved by random, unannounced, and more thorough inspection of fewer firms, accompanied by vigorous prosecution of violations detected. (Abandoning a policy of inspecting all TSDFs and generators would probably require amendment of RCRA and analogous state laws.)

Manifests can probably be used more effectively than they are at present. Once computerized manifest systems are in place, routine tracking of waste quantities shipped by a firm over time and comparison of wastes to industry norms should be relatively inexpensive. Similar programs could be used to analyze the data submitted by TSDFs in their periodic operating reports.

Similarly, continuous monitoring of sewers and storm-drain channels could provide evidence of the amount of hazardous wastes

disposed of there. We do not envision monitoring all access points to these systems, but continuous monitoring of main lines appears to be technically feasible and may not be overly expensive if automated systems for chemical analysis are available. Although these monitoring systems would not identify the responsible firms, they would suggest the types of wastes, approximate location, and timing of intermittent disposals. Monitoring disposals at sanitary landfills can also provide data on the magnitude of illegal disposals and lead to identification and prosecution of violators (Appendix B).

Air surveillance currently appears to be helpful, according to our interviews and Rebovich (1986). However, if such programs spread, violators are likely to adapt by conducting their activities at night or indoors.

In addition to detection strategies, policymakers should consider the appropriate penalty schedules. These should recognize not only the potential environmental harm resulting from each crime, but also the varying probabilities of detecting each crime. More severe penalties should be imposed for crimes that are less likely to be detected to avoid giving potential violators the incentive to engage in these practices, as recognized in EPA guidance documents (EPA, 1986). Some jurisdictions have felt a need for easily administered enforcement penalties, to avoid using the resource-intensive judicial process for many cases; however, substantial criminal penalties and criminal or civil fines commensurate with the damage done by significant violators may be important in large cases.

As with any kind of enforcement activity, there is a significant tradeoff between the probability of detection and the severity of sanction once a violator is detected (Becker, 1968). A given level of deterrence may be achieved by increasing either the level of penalties or the probability of detection. Since enforcement is expensive and penalties are cheap, it is attractive to push for harsh penalties and reduced enforcement expenditures. Indeed, particularly with civil fines assessed against corporate violators, penalties can provide significant revenue to the prosecuting jurisdiction, and do not require expenditure on incarceration facilities and operations.

However, the allowable penalties are limited by other factors. Equity considerations (such as the widely held view that similarly severe offenses should have similar penalties) imply that environmental penalties will have to be calibrated against other offenses. The harsher the penalty the more expensive agencies will find it to administer, since detected violators will contest the matter more vigorously and courts will provide more protections. As discussed in Sec. IV, limitations on available penalties combined with limitations on enforcement resources

may require explicitly concentrating enforcement on a subset of potential violators to achieve any deterrence.

## CONCLUSIONS

Efficient enforcement strategies for RCRA and similar state laws cannot be developed without better information on the magnitude and character of illegal disposal. Such information might be developed through a program of intensive inspection of a stratified random sample of generators and waste haulers, perhaps accompanied by improved monitoring of sewers, storm drains, sanitary landfills, and other frequent destinations of illegally disposed of wastes.

Enforcement of hazardous-waste-disposal regulations must be recognized as a dynamic enterprise. The primary legislation is relatively recent, the regulations are continually changing, legal disposal alternatives and their prices are changing, and regulatory and enforcement agencies are still developing appropriate procedures and strategies. Industry is adapting to changes in waste-management opportunities, enforcement strategies, and other features of its environment. Illegal disposal is widely perceived as having become more sophisticated in recent years, because of increasing enforcement pressure. In part, it is apparently shifting on site, behind industry walls (Rebovich, 1986). Such adaptation by violators will continue and will require continuing monitoring and innovation by enforcement agencies.

## Appendix A

### ESTIMATES OF HAZARDOUS-WASTE GENERATION

One method of estimating the quantity of waste illegally disposed of is to calculate the difference between waste generated and waste legally disposed of. In Sec. I, we labeled this the "residual method." Unfortunately, it requires very accurate estimates of generation and legal disposals. Since the quantity illegally disposed of is presumably orders of magnitude smaller than the quantity generated, any uncertainty about generation will result in proportionally much greater uncertainty about illegal disposals. If illegal disposals total only 1 percent of generation, a 1 percent error in estimated total waste generation will produce a 100 percent error in estimated illegal disposal.<sup>1</sup>

It appears unlikely that estimates of total generation and legal disposals will ever approach the accuracy needed to reliably estimate illegal disposal. As described in this appendix, measuring the quantity of hazardous waste generated is inherently difficult. Examination and comparison of the published estimates and other information suggest that wide confidence intervals should be associated with current estimates of waste generation and of the number and types of generators.

Total generation of hazardous waste is conceptually and practically difficult to measure. First, hazardous waste is heterogeneous, including both liquids and solids, and a large, diverse set of chemicals. Because nonhazardous waste that is mixed with hazardous waste becomes legally hazardous itself, total hazardous waste is sensitive to changes in industrial practices and processes that affect dilution, even if they do not affect the mass of hazardous components generated. For example, water used to flush out a container of hazardous waste may become legally hazardous; if firms use less water to clean these containers, the quantity of hazardous waste will be smaller.

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<sup>1</sup>If the estimated quantities of waste generated and disposed of legally are independent random variables, the variance of their difference (estimated illegal disposals) is equal to the sum of their variances. Thus, the variance of estimated illegal disposals exceeds the variance of each of the other terms. The coefficient of variation depends on the fraction of wastes that are disposed of illegally. If the fraction is about 10 percent, the coefficient of variation of illegal disposals is at least an order of magnitude larger than that of waste generation or treatment; if the fraction is about 1 percent, the coefficient of variation is two orders of magnitude larger.

Second, the definition of hazardous waste differs between EPA and some states, and both federal and state definitions change over time as wastes are listed or de-listed. The distinction between legally hazardous and nonhazardous waste can be subtle. Whether a waste stream is legally hazardous can depend on how much other waste the generator produces, and thus on whether it exceeds the VSQG limit. As another example, some treated wastewaters discharged to surface waters under a Clean Water Act National Pollutant Discharge Elimination System (NPDES) permit are defined as hazardous by RCRA, but others are not. Wastewater that would be hazardous if treated in ponds is exempted from RCRA coverage if it is treated exclusively in tanks (Dietz et al., 1984). This distinction is vital to interpreting generation estimates, since the total of self-reported estimated quantities of wastewater discharged under NPDES permits by TSDFs (322 million metric tons or Mt) exceeds the quantity of RCRA hazardous waste managed by these facilities (247 Mt; EPA, December 1986). Any change in this definition, or misunderstanding on the part of surveyed firms, could have substantial effects on estimated waste generation.

Third, the universe of hazardous-waste generators is diverse and difficult to identify. Lists of firms that initially notified EPA that they were hazardous-waste generators include many that are not RCRA-regulated generators. A sample drawn from this list revealed that only 38 percent of the firms that had notified EPA actually generated sufficient quantities of wastes to be subject to RCRA regulations (Savant Associates, 1983). The majority had notified either mistakenly or protectively, to avoid sanction for failure to notify if they were in fact required to do so.

SQGs are particularly hard to identify. As discussed below, special efforts to identify SQGs in limited regions find many more than extrapolation from nationwide estimates would suggest. However, estimates of total waste quantities are much more sensitive to the set of LQGs identified. Because the quantity of waste generated varies widely across firms, survey strategies that do not concentrate on LQGs may produce estimates subject to large sampling error.

Fourth, conceptual distinctions are not always kept clear when estimating wastes. Often, quantities shipped off site (that are subject to manifest requirements) or quantities managed by registered TSDFs are reported as estimates of generation. Obviously, such estimates do not include wastes that are disposed of illegally. Manifested waste quantities also do not include wastes disposed of on site, but may double-count wastes shipped from generator to treatment facility and then to disposal facility. Because the quantities and characteristics of the waste are changed by treatment, it is not possible to accurately

adjust for this multiple counting without analysis of the specific treatments used.

Possible double-manifesting of wastes is unlikely to offset the failure to include wastes disposed of on site, however. Estimates of the proportion of wastes disposed of on site are inconsistent, but the fraction is probably large. EPA (June 1987) estimates that, nationwide, 96 percent of waste treatment and disposal occurs on site. In the states we studied, published estimates of the proportion disposed of on site are substantially lower: Pennsylvania, about 85 percent (Pennsylvania, 1986); Southern California, about half (Louis Berger and Associates, 1985); California, 38 percent (California, 1986); and Massachusetts, 10 percent (Massachusetts Department of Environmental Management, 1987).

In the remainder of this appendix, we compare the major estimates of hazardous-waste generation nationwide and in the three states whose enforcement regimes we studied.

## **ESTIMATES OF NATIONAL HAZARDOUS-WASTE GENERATION**

Several agencies have published estimates of total hazardous waste generated nationwide. Almost all hazardous waste is believed to be generated by LQGs. In this section we review estimates of total hazardous waste generated and independent estimates of wastes generated by SQGs.

### **Total Hazardous Waste**

Table 3 summarizes the primary estimates of national hazardous-waste generation. All but the 1985 EPA estimates are reported by GAO (February 1987). The point estimates appear to reflect a consensus of about 250 to 275 Mt/yr. However, each estimate has weaknesses and the apparent agreement may reflect coincidence more than accuracy, since many of the cited values estimate different quantities. For example, the Chemical Manufacturers Association (CMA) value is based on a survey of CMA members and is intended to estimate only the hazardous wastes generated by the chemical industry; it does not represent an estimate of total national hazardous-waste generation. The difference between estimates of chemical-industry and total national wastes is large: CBO (1985) estimates the chemical-industry share of total hazardous-waste generation as 48 percent, Dietz et al. (1984) estimate it as 68 percent. Thus, the CMA estimate for

Table 3

ESTIMATES OF NATIONAL HAZARDOUS-WASTE  
GENERATION AND TREATMENT  
(Mt/yr)

Year	Source	Point Estimate	Range
1981	EPA <sup>a</sup>	264	135-402
1981	OTA <sup>b</sup>		255-275
1983	CBO <sup>c</sup>	266	223-308
1984	CMA <sup>d</sup>	247 <sup>e</sup>	
1985	EPA <sup>f</sup>	247 <sup>g</sup>	
1985	EPA <sup>h</sup>	275	

<sup>a</sup>Dietz et al. (1984).

<sup>b</sup>OTA (1983).

<sup>c</sup>CBO (1985).

<sup>d</sup>CMA (1986).

<sup>e</sup>Chemical industry only.

<sup>f</sup>EPA (December 1986).

<sup>g</sup>Waste managed by regulated facilities.

<sup>h</sup>EPA (June 1987).

chemical-industry hazardous wastes is perhaps 50 to 100 percent larger than the quantity attributed to that industry by the other studies.

The 1981 EPA estimate (Dietz et al., 1984) is based on mail surveys of hazardous-waste generators and TSDFs. It estimates all RCRA-defined hazardous wastes generated in that year. It excludes SQG waste, which was not subject to RCRA at the time. It makes no attempt to include illegally disposed of wastes. The reported range, 135 to 402 Mt, is intended to represent a 95 percent confidence interval to account for sampling variability. It does not account for uncertainty resulting from nonsampling variance, such as generators misunderstanding which wastes are regulated and which are not and thereby misreporting, or uncertainty about the total number of firms the sample is supposed to represent. The assumptions underlying the calculated confidence interval appear inadequate, since the quantities generated by each facility are apparently so highly skewed that their mean is not approximately normally distributed.

The wide sampling-variance-based confidence interval reflects the highly skewed distribution of wastes generated. Two samples were surveyed, selected randomly from EPA lists of generators and TSDFs. Within each sample, firms had equal probabilities of being surveyed; firms that generated larger quantities did not have higher probabilities

of being selected. (This strategy was chosen because relative quantity data were not available and because the survey was also directed to measuring other characteristics of firms for which the sampling plan was better suited.) Because of the highly skewed distribution of waste generation, the method for estimating total waste was changed after preliminary survey results were announced. The initial estimate of about 150 Mt was based on the sample of waste generators alone, but the sample variance was extremely large: The calculated 95 percent confidence interval ranged from about 30 to 270 Mt. Moreover, the estimated waste managed by TSDFs substantially exceeded the estimated 150 Mt generated (Dietz et al., 1984).

Because of these difficulties, a methodology incorporating results of the TSDF survey was used to generate the final estimate. The majority of TSDFs are associated with waste generators and are more likely to be associated with large than small generators. As a result, more large generators are surveyed through the TSDF than the generator survey. Unfortunately, many of the TSDFs were not asked how much waste was generated on site; for these facilities, the quantity was inferred by subtracting reported waste accepted from off site from total waste managed. The final reported point estimate and confidence interval are based on combining this estimate with the estimate from the generator survey.

Even this improved estimate has difficulties. As noted by the authors, the 164 Mt generated by surveyed firms and TSDFs (using the difference between waste managed and accepted from off site as the estimate of generation for most of the surveyed TSDFs) exceeds the lower end of the reported confidence interval (135 Mt). This outcome strongly suggests that alternative statistical methods that do not assume a normal distribution of quantities should be employed. A more accurate confidence interval might be obtained using other distributional assumptions, a logarithmic or other transformation of waste generation (Duan, 1983), or data-reuse techniques such as the bootstrap (Efron, 1982; Efron and Gong, 1983).

Congressional Budget Office (1985) uses a radically different approach to estimate a different quantity. CBO developed a simulation model of hazardous-waste generation as a function of industrial output (using employment as a proxy) and type of industry. The model is calibrated to plant-level data from Dietz et al. (1984), state agencies, and the Dun and Bradstreet Company. Thus, it is closely tied to the 1981 EPA estimate and should not be considered an independent validation. Moreover, the CBO model attempts to estimate a broader set of wastes than those regulated under RCRA in 1983, including waste oils, industrial scrubber sludges, air pollution control dusts, and certain liquid waste streams (CBO, 1985).

The Office of Technology Assessment estimate is based on a survey of state estimates. Only 40 states responded, and these produced estimates using diverse methods including state inventories, manifest data, and EPA notifications. Many of the states apparently used their own definitions of hazardous waste. At the time, only nine states regulated wastes using the federal definition (GAO, February 1987).

The first 1985 EPA estimate (EPA, December 1986) is based on a census of the treatment, storage, disposal, and recycling (TSDR) facilities that identified themselves to EPA as active in 1985. As such, it should provide reliable information on the quantities of hazardous waste managed by such facilities, although there may be some inaccuracies involving the distinction between RCRA and non-RCRA regulated wastes. Such inaccuracies could be important, since these facilities also report managing 322 Mt of RCRA-exempt wastewater regulated under the Clean Water Act. But any error resulting from misclassifying wastes should be smaller than in a comparable survey of generators, since TSDR facilities may be expected to be better able to make this distinction. Of the reported 247 Mt of hazardous waste managed, 243 Mt are defined as hazardous under RCRA and an additional 4 Mt are hazardous under state, but not federal, law. This estimate does not include illegally disposed of wastes or others that do not reach a TSDR facility, and it may double-count some wastes that are treated at one facility and disposed of at another. But it should provide a good estimate of legally disposed of wastes.

EPA apparently revised the December 1986 estimate to obtain its current estimate of 275 Mt managed by RCRA-regulated TSDFs (EPA, June 1987).

Estimates of the number of generators also vary. As noted above, the number of facilities that notified EPA that they may be generators is apparently much larger than the number of actual generators. Dietz et al. (1984) estimated that 14,100 facilities—approximately one-quarter of the 55,000 notifiers—generated more than 1,000 kg/mo of RCRA-defined hazardous waste in 1981, thereby qualifying as LQGs. Subsequent EPA estimates place the number of LQGs at 40,000 to 60,000 (EPA, June 1987), although EPA staff report that this estimate, based on state reports, has been revised to 20,000 to 40,000, since some states apparently included SQGs in their reports.

Dietz et al. (1984) estimated the number of active TSDFs in 1981 as about 4,800, compared with approximately 8,000 that had filed Part A permit applications with EPA. The more recent 1986 screening survey (EPA, December 1986) reports that only 2,959 treatment, storage, disposal, and recycling facilities managed hazardous waste in 1985.

## Hazardous Waste Generated by SQGs

Most estimates of the number of SQGs and the waste they generate rely on the Ruder et al. (1985) national survey conducted for EPA. Results are presented in Table 4. As shown, estimated SQG wastes (0.9 Mt) amount to less than one-half percent of estimated LQG wastes (about 265 Mt).

The Ruder et al. (1985) estimates are based on a survey of firms in selected industries and extrapolation to other industries. Using information from industry experts, literature review, and professional judgment, a set of industries (denoted by Standard Industrial Classification or SIC codes) was identified as likely to contain significant numbers of SQGs. These industries were divided into three groups. A sample of the first group was surveyed to determine the types and quantities of hazardous waste generated. Estimates for the second group are based on extrapolation from industries in the first group that are believed to generate similar waste streams, and from secondary sources. For the third group, estimates are based on crude extrapolations from the other groups. This third group, for which estimates are least reliable, accounts for about 100,000 of the estimated 630,000 SQGs. Estimates of the number of firms in each industry are based on Census Bureau *County Business Patterns* and the sample was drawn from the Duns Market Identifiers file (Ruder et al., 1985).

Ruder et al. estimate that approximately 62 percent of wastes generated by SQGs in the surveyed group consist of lead-acid batteries, and that about 90 percent of these are recycled. Subsequently, EPA excluded lead-acid batteries from RCRA regulation except when stored by the recycler. This action reduced the estimated number of SQGs by 190,000, to a total 440,000. The corresponding estimates of SQGs

Table 4

### ESTIMATED HAZARDOUS WASTE GENERATED NATIONWIDE, BY GENERATOR

	Number of Generators	kt/yr <sup>a</sup>	Average kg/mo
SQGs <sup>b</sup>	175,000	760	362
VSQGs	455,000	180	33
Total	630,000	940	124

SOURCE: Ruder et al. (1985).

<sup>a</sup>Thousand metric tons per year.

<sup>b</sup>SQGs generating at least 100 kg/mo.

generating more than 100 kg/mo and VSQGs are 90,000 and 350,000. EPA has apparently revised this estimate of 90,000 SQGs subject to RCRA regulation to 100,000 (EPA, June 1987).

The Ruder et al. (1985) estimates represent a reasonable attempt to estimate the waste generated by SQGs but may substantially underestimate this total. Accuracy depends on the preliminary screening of industries, judgment of how similar waste streams are across industries, and extrapolation to nonsurveyed industries. The great diversity and number of firms generating hazardous wastes makes accurate estimation difficult. As described below, efforts to identify SQGs in limited areas have found many more than suggested by the Ruder et al. estimates.

### ESTIMATES OF HAZARDOUS-WASTE GENERATION IN SELECTED STATES

Inconsistent as the national estimates are, state-level estimates show even greater variance. As shown by Table 5, even though the OTA (1983) and CBO (1985) estimates of national generation virtually coincide (255 to 275 Mt/yr and 265 Mt/yr, respectively), their estimates for Pennsylvania diverge widely: 3.6 and 18.3 Mt/yr, respectively. The state estimates 4.9 Mt/yr, excluding about 12 Mt/yr of wastewater that is presumably not subject to RCRA regulation (Pennsylvania, 1986). The CBO (1985) estimate includes a broader category of wastes than defined by RCRA. If CBO's estimate includes this wastewater, but OTA's estimate does not, the estimates may be more consistent than they first appear; however, this cannot be determined.

Massachusetts' hazardous waste is variously estimated between 111 and 4,563 thousand metric tons (kt) annually, as shown in Table 6.

Table 5

#### ESTIMATES OF PENNSYLVANIA HAZARDOUS- WASTE GENERATION (Mt/yr)

Year	Source	Estimate
1981	OTA (1983) <sup>a</sup>	3.6
1983	CBO (1985)	18.3
1985	Pennsylvania (1986)	5.1

<sup>a</sup>Reported in GAO (February 1987).

Table 6

ESTIMATES OF MASSACHUSETTS HAZARDOUS-WASTE  
GENERATION AND TRANSPORTATION  
(kt/yr)

Year	Source	Estimate
Hazardous Waste Generated		
1979	New England Regional Commission <sup>a</sup>	170-230
1980-83	Arthur D. Little <sup>b</sup>	159
1980-83	Gould <sup>b</sup>	1,851
1980-83	New England Congressional Institute <sup>b</sup>	111
1981	OTA (1983) <sup>b</sup>	172
1983	CBO (1985)	4,536
1986	State Environmental Impact Report <sup>c</sup>	270
None	EPA <sup>a</sup>	850-1,020
Hazardous Waste Transported		
1980	GCA, Inc. <sup>a</sup>	120
1980	Booz, Allen, and Hamilton <sup>a</sup>	260
1982	State Environmental Impact Report <sup>a</sup>	250-390
1983	State Environmental Impact Report <sup>a</sup>	190-240

<sup>a</sup>Massachusetts (1985).

<sup>b</sup>Reported in GAO (February 1987).

<sup>c</sup>Massachusetts Department of Environmental Management (1987).

Estimates made by the state include quantities generated by SQGs that produce over 20 kg/mo, as these are regulated by the state. Again, the OTA (1983) and CBO (1985) estimates diverge widely and nearly span the range of reported estimates.

As noted in Table 6, several of the earlier estimates are of waste shipments. States often rely on waste manifests to estimate total generation. As described above, manifest data may lead to double-counting if wastes are shipped to one facility for treatment and later to another facility for disposal. In addition, they do not account for waste stored or disposed of on site, legally or illegally. Massachusetts officials estimate that only 10 percent of hazardous wastes generated in state are disposed of on site. If so, manifest data may provide a reasonable approximation to wastes legally disposed of there (Massachusetts Department of Environmental Management, 1987).

Of the 2,300 LQGs registered in Massachusetts, only 115 are considered "major generators" by the state because they generate more than 5,000 gallons of hazardous waste per month (about 20,000 kg/mo).

The largest 100 of these produce about 170 kt/yr, about two-thirds of the total (270 kt) estimated by the state. SQGs are estimated to generate about 15 to 25 percent of the waste, about 40 to 70 kt/yr, with a figure of 20 percent or 53 kt reported by the Massachusetts Department of Environmental Management (1987). The number of SQGs is variously estimated as 3,000 to 6,000; 10,000; 15,000 (derived from the Ruder et al. estimates of the proportion of firms in each SIC that are SQGs); or 86 percent of all generators (14,000, calculated assuming 2,300 LQGs) (Massachusetts Department of Environmental Management, 1987; Massachusetts, 1985; 1987).

Estimates for California are similarly varied. Table 7 reports a range of estimates of 1 to 44 Mt/yr. Unlike the case for the other states, however, the CBO (1985) and OTA (1983) estimates for California are reasonably consistent.

The Governor's Task Force estimate is clearly too low. It apparently reports only manifested wastes and only the part of these included in the "history" file. California excludes manifests containing apparent errors or omissions from this file, placing them in a "suspense" file. Since the suspense file may include one-third or more of manifested wastes, relying on the history file alone clearly produces a substantial underestimate of manifested wastes and, since not all wastes are manifested, an even greater underestimate of waste generated.

Table 7

ESTIMATES OF CALIFORNIA HAZARDOUS-WASTE  
GENERATION  
(kt/yr)

Year	Source	Estimate
1980-83	Gould <sup>a</sup>	4,502
1981	OTA (1983) <sup>a</sup>	15,000
1983	CBO (1985)	17,284
1983	Air Resources Board, Department of Health Services <sup>b</sup>	8,900-44,000
1985	Governor's Task Force <sup>c</sup>	2,000
None	Other <sup>a</sup>	1,179

<sup>a</sup>Reported in GAO (February 1987).

<sup>b</sup>Reported in Lennard and Belsher (1987).

<sup>c</sup>California (1986).

The range of estimates for Los Angeles County and the seven other counties<sup>2</sup> constituting Southern California is similarly broad. Manifest data for 1983 show 1,176 kt/yr originating in L.A. County—2,009 kt/yr in all Southern California (total history and suspense files; the history file alone reports 683 kt/yr for L.A. County, 1,072 kt/yr for the region). An estimated additional 1,900 kt/yr is disposed of on site, for a total of about 4 Mt/yr generated in Southern California (Louis Berger and Associates, 1985). If the CBO (1985) and OTA (1983) estimates for California are accurate, this total may be too small by a factor of two, since Southern California is believed to account for about half the waste generated in the state.

Using the Ruder et al. (1985) estimates of SQGs in each SIC, Southern California has 16,000 to 26,000 SQGs, but the corresponding proportion of wastes is not reported (Louis Berger and Associates, 1985). A 1982 survey of the North Hollywood area (part of L.A. County) reported 7 million gallons (about 25 kt) of waste generated annually, of which 98 percent is wastewater generated by LQGs. Whether this wastewater is subject to RCRA regulation is not clear. Of the remaining 120,000 gallons, about half is generated by SQGs (SCS Engineers, 1985).

Anecdotal evidence suggests that the estimates of generators and wastes, especially for SQGs, may be grossly in error. One waste hauler we interviewed reported serving approximately 3,800 dry-cleaning establishments in California, even though the official state lists showed only 2,885 such facilities (these figures exclude the roughly 15,000 retail facilities that send clothing off site for cleaning). Similarly, although the state list of automobile-body-repair shops reported only 11 facilities in a two-zip-code area, he identified over 50 along the major business streets there.

Because SQGs are apparently so difficult to identify through business-license and other standard lists, some government agencies have performed door-to-door or drive-by inspections of neighborhoods. In Florida, each county is attempting to survey its SQGs. In the 42 of 67 counties that have completed surveys, 25,000 SQGs generating 270 kt/yr were identified (Schwartz et al., 1987), nearly 30 percent of the 940 kt/yr Ruder et al. (1985) estimate are generated by SQGs nationwide. Note that the average waste generated by these facilities—900 kg/mo—is 2.5 times larger than the average 362 kg/mo for the SQGs producing over 100 kg/mo in the Ruder et al. (1985) survey. This average seems implausibly high, since none of the facilities in the sample

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<sup>2</sup>Imperial, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, and Ventura.

may produce more than 1,000 kg/mo, and Ruder et al. (1985) and other sources suggest that the distribution of wastes generated by facilities is highly skewed toward smaller generators, even among SQGs.

Household hazardous wastes are exempt from RCRA regulation and are not included in the estimates cited. However, they can also contribute to environmental degradation and a few attempts to estimate their magnitude have been made. Massachusetts Department of Environmental Management (1987) estimates that households produce 3 to 10 gallons/yr on average, or 30 to 90 kt/yr statewide (11 to 33 percent of the state-estimated 270 kt/yr commercially generated). Russell and Meiorin (1985) estimate only 1.8 to 3.5 gallons/yr (7 to 13 kg/yr) per household, for a sample of San Francisco Bay area households. Approximately three-quarters of these wastes are oil, paint, thinner, cleaner, antifreeze, and radiator fluids. University of Arizona et al. (1987) sampled garbage put out for pickup by households in Marin County, California, and New Orleans. They found an average 55 to 60 gallons/week of hazardous waste per household, about 3 kg/yr. The largest categories were household maintenance, automotive maintenance, and batteries and electrical products.

## Appendix B

### CURRENT MONITORING AND ENFORCEMENT PRACTICES IN LOS ANGELES COUNTY, MASSACHUSETTS, AND PENNSYLVANIA

This appendix describes the structure and conduct of monitoring and enforcement activities in the three jurisdictions we studied. The information is based on interviews with approximately 40 enforcement and regulatory officials and industry representatives in these jurisdictions as well as literature review. Summary observations are presented in Sec. III.

#### MONITORING AND ENFORCEMENT IN LOS ANGELES COUNTY

The state Department of Health Services (DHS) is the lead agency for RCRA implementation in California. Although California is no longer authorized by EPA to administer RCRA, in practice state and local agencies continue to administer the program, albeit with increased EPA supervision. DHS's role varies from county to county. In 18 of the 58 counties in California, DHS has delegated much of its authority to the county health agency through a memorandum of understanding (MOU). All of the southern counties, including Los Angeles, have such MOUs with the state. In the remaining counties, DHS administers monitoring and enforcement programs through its four regional offices.

Counties that operate hazardous-waste regulatory programs obtain revenues to support their programs from generator-registration fees (varying with the number of employees from about \$100/yr to \$400/yr in L.A. County) and criminal penalties (half of which are retained by the prosecuting county).

California hazardous-waste law is in many respects more stringent than federal law. Under RCRA, a waste is hazardous if it is specifically "listed" by EPA or if it possesses one of four characteristics: ignitability, corrosivity, reactivity, or toxicity as measured by the extraction procedure (EP) test. The California EP criterion is more stringent, since it requires testing for 23 contaminants in addition to

the 14 specified under RCRA. California also uses an additional toxicity criterion involving lethality to test fish under specified conditions and defines materials in mislabeled or damaged containers as wastes (McKenna, Conner and Cuneo, 1987).

### **Scale and Structure of Enforcement**

In Los Angeles County, the county health department is responsible for inspecting generators but DHS retains responsibility for TSDFs. Many agencies are involved in enforcement activities; these are coordinated through the Los Angeles County Hazardous Waste Strike Force, headed by the District Attorney's office. The strike force succeeded the original L.A. city strike force when City Attorney Ira Reiner became District Attorney. The major agencies represented (and numbers of personnel contributed in mid 1987) include: the District Attorney's office (six attorneys, nine investigators), the county health department (approximately 45 inspectors but only two specifically involved in developing cases), the Los Angeles Police Department (five), the California Highway Patrol (two), the Los Angeles County Sheriff (five, but only 30 percent of their time goes to hazardous waste), and the Los Angeles City Sanitation Department (approximately 40 inspectors). In total there are about 100 inspectors and investigators; 25 can be described as purely enforcement personnel. DHS is also represented on the strike force. It has 40 full- or part-time inspectors in the southern section of the state, which includes L.A. County, and 10 criminal investigators statewide.

Other agencies provide information and resources. For example, the city and county fire departments and the regional air and water quality control boards inspect firms and may refer specific violations to the strike force. The strike force cooperates with EPA, the Federal Bureau of Investigation, the local U.S. Attorney, and the Attorney General on occasional cases, but there seems to be some competition among these agencies for prosecutable cases and some have organized independent environmental crime units.

The diversity of agencies involved in enforcement can make coordination of efforts difficult. For example, strike-force personnel think the regional air and water quality control boards may have significant amounts of useful data that are not made available to them. Even practical details are complicated: Some argue that a central evidence facility and standard collection methods are required, since some of the agencies use different sample containers and sealing tapes and it is awkward to testify to the chain of custody when waste samples may be sent to several laboratories run by differing agencies.

## Measures of Activity

The number of cases resulting from strike-force activities is growing, from about five in FY84 to about 50 in FY87. Between its establishment, at the beginning of 1985, and March 1988, the strike force has obtained criminal convictions of over 100 defendants. Of the first 54 cases closed, the mean fine was about \$58,000, for a total of approximately \$3.1 million in penalties. Five cases resulted in fines of \$250,000 or more; half were less than \$15,000. At present, an estimated 90 investigations are under way, with about 50 cases in court.

Similarly, L.A. Police Department activity has been growing, as shown in Table 8. The annual rate of investigations has perhaps tripled since 1985 and arrests average about 10 per year. In addition, the L.A.P.D. participates in approximately 150 emergency-response incidents per year.

One indicator of the scope of illegal disposal is the number of abandonments of hazardous waste, typically in barrels left on vacant lots or by the roadside. Jurisdiction over these abandonments is fragmented: The city Sanitation Bureau is responsible for abandonments on public property, the county health department for those on private property, and the fire departments for those posing imminent hazards. As shown in Table 9, the number handled by the Sanitation Bureau increased during spring 1986 from a rate of two to four incidents/quarter to a rate of about 11 to 14 per quarter and 16 to 18 in the last two quarters of 1987. These abandonments cost about \$100,000 per year to clean up, and the bureau believes that the problem is still getting worse.

The county health department maintains a detailed log of the many complaints received: about 3,000 in the first half of 1987. Of these, few are prosecutable or at least prosecuted. In the first half of 1987,

Table 8

### LOS ANGELES POLICE DEPARTMENT ACTIVITY

Activity	1987		
	1985	1986	(through July)
Arrests	0	10	6
Investigations	25	52	44
Emergency response	50	151	76

SOURCE: Los Angeles Police Department.

Table 9

HAZARDOUS WASTE ABANDONED ON PUBLIC  
PROPERTY IN LOS ANGELES

Year	Quarter	Abandonments	Cleanup Cost (dollars)
1985	1	2	7,000
	2	2	12,700
	3	2	9,000
	4	3	2,600
1986	1	4	3,100
	2	12	36,400
	3	11	15,200
	4	11	27,200
1987	1	14	24,100
	2	13	20,200
	3	16	33,000
	4	18	39,900

SOURCE: Los Angeles City Bureau of Sanitation.

the log indicated about 200 reported illegal disposals/month off site, and an additional 50/month on site.

### Monitoring

Responsibility is clearly divided among the monitoring agencies. DHS inspects TSDFs, including permitted generators; the L.A. County health department is responsible for all other generators, including SQGs.

DHS has 40 full- or part-time inspectors in the southern section of the state. DHS currently estimates that the southern section contains about 450 TSDFs out of 1,200 statewide. Although about 13,000 Southern California firms filed Part A permits, many apparently notified incorrectly or have since reduced quantities to get under the SQG limit. In addition, liberalization of the storage rule may have allowed some firms to drop their TSDF status: Whereas the 90 days required before treatment or disposal must occur was formerly tolled from the first drop of eligible waste, it is now tolled only when 100 kg have been accumulated.

DHS believes that its priority, as determined by EPA, is to inspect the universe of TSDFs. At about 10 TSDFs per inspector-year in the southern section, such a goal appears manageable. However, DHS claims that the emphasis on inspecting all generators and TSDFs statewide requires that the inspections be rather cursory and inadequate to permit building cases. Generator inspections in many counties are apparently viewed as more educational than enforcement-oriented, but 95 percent of first inspections yield violations. In counties with established programs, between 1 and 5 percent of these are for illegal disposal (Schwartz et al., 1987).

The county health department believes that there are about 30,000 to 50,000 hazardous-waste generators in L.A. County. It hopes to inspect each of these annually, but has so far identified only about 15,000 eligible firms. For comparison, the Census Bureau reports about 200,000 business establishments countywide (U.S. Department of Commerce, 1986). As noted in Appendix A, the standard lists used to identify generators are apparently incomplete and prone to error. The county health department hopes to expand its list through a new state program that requires firms to notify the local fire department of hazardous substances on the premises, by door-to-door surveys, and through the community right-to-know provisions of SARA.

County officials acknowledge that they cannot inspect even the number of generators they have currently identified because of a shortage of staff and competing responsibilities, notably emergency response. Indeed, the county health department is seriously understaffed. Though authorized for 44 inspectors with an additional 18 slots next year, currently only 12 positions are filled. Part of the problem is that industry hires inspectors away after training; the agency has lost 24 over the last two years. Delays in government hiring have also contributed to the problem.

In addition to inspections, the department emphasizes emergency response, providing 24 hour coverage seven days a week. There is a permanent nine-man team, supplemented by inspectors on a rotating basis. As a result, the staff works substantial overtime each week. In addition, the staff is responsible for receiving notifications of chemical releases that may affect groundwater required under Proposition 65.

Inspectors typically find many small violations, such as missing manifests and unlabeled containers. Approximately 75 to 90 percent of inspections result in the issuance of Notices of Violation (NOVs). Inspectors have an incentive to write up some violations to demonstrate to their superiors that they are thorough; they also can be personally liable for failure to detect if a later incident results in personal injury or property damage.

Some other counties are reportedly better organized. For example, Ventura County has computerized permit and inspection data, in contrast to the manual system used in Los Angeles. However, Ventura County is very much smaller than Los Angeles and includes only an estimated 1,200 generators.

The Bureau of Sanitation (part of the City Department of Public Works) inspections appear quite rigorous. Inspection is as frequent as monthly for some types of firms, but the bureau inspects only 7,700 of the approximately 75,000 firms with sewer permits. Inspections are targeted on firms that may discharge substances that will damage sewage treatment facilities or prevent the facilities from achieving discharge standards. Exempt establishments include restaurants with fewer than 130 seats or discharging less than 200 gallons of untreated wastewater each day and many smaller firms. Small firms with dangerous outputs, such as metal-plating firms, are not exempt. The bureau has about 40 inspectors, so each is responsible for approximately 200 firms. Firms must monitor their own outputs with pH meters and inspection traps. When investigating a potential violator, such as one whose equipment, seen at inspection, appears inadequate to treat the expected waste quantities, the bureau places ISCO samplers in the sewer line to monitor the firm's output. These devices collect samples of sewage in the line at predetermined times over a 24 hour period. The samplers are later removed and the samples taken to a laboratory for analysis.

In contrast to the relatively tight inspection of discharges into the sewage system, storm drains are given little attention; they are sampled only monthly, so that intermittent discharges are undetected unless noted by citizens. Enforcement officials believe that more dumping to these drains occurs during rainy periods when waste is flushed out quickly. With thousands of entry points to the system, effective surveillance may be impossible, but the strike force is seeking methods to apprehend at least a few violators and to deter others.

The California Highway Patrol routinely inspects hazardous-waste haulers' trucks and terminals. In addition, it enjoys several advantages over other enforcement agencies, including authority to stop vehicles without probable cause and to require sealed containers to be opened without a search warrant.

There are additional inspections by regional air and water quality control boards; these seem to yield few if any violations reported to the strike force.

## Other Surveillance Techniques

The strike force is attempting to lessen its reliance on tips by developing pro-active strategies. The estimated share of cases originating from unsolicited tips has fallen over time and is currently about a third.

The variety of agencies involved in enforcement and monitoring in Los Angeles leads to a considerable variety of methods for detecting violators. The Sheriff's Department, when the unit is not involved in an active case, uses helicopter surveillance. The unit reports that it is relatively easy to detect violations from the air—either loaded trucks on desert dirt roads or discolored ground within industrial facilities, although few prosecutions have been initiated from such observations.

Under a strike-force initiative, each of the seven L.A. County sanitary landfills now has full-time spotters who identify haulers dumping suspicious materials (such as containers, since liquids are not accepted). When apparent violations are observed, the California Highway Patrol is called in to question the driver. In addition, a few randomly selected truck loads are systematically inspected. This program seems to lead to a significant number of NOV's and occasional felony cases. Once a violator has been identified, the sanitation district may send it a letter directing the violator to reclaim the waste. Approximately 45 such letters were sent in 1986, and over 100 in the first half of 1987. Since the full-time spotter program began in summer 1987, four felony and two misdemeanor cases have been filed and about 20 others are under investigation.

The strike force has also experimented with "sting" operations to generate evidence against waste haulers suspected of routine illegal disposal. Haulers have been solicited to remove wastes and videotaped in action. To date, these operations have only led to convictions of rather small operators.

## Prosecution

The District Attorney relies exclusively on criminal prosecutions, primarily felonies. In the early years of the strike force, prosecutions were directed at large firms to maximize publicity and potential deterrent effect. Some misdemeanors are delegated to the L.A. City Attorney, who lacks jurisdiction for felony prosecutions. A significant share of the 50 cases currently in litigation comes from the Sanitation Bureau, which generates approximately seven felony and five misdemeanor cases per year.

Civil cases are not used because, with the notoriously clogged civil dockets of the Los Angeles court system the procedures simply take too long, particularly since the defendant has extensive opportunities to seek delay. The fact that criminal fines are so large also lessens prosecutors' interest in seeking civil penalties.

There are other sources of sanction for violators. The Bureau of Public Works can hold show-cause hearings within a few weeks of detecting a violation; such hearings are held an average of once per month. The outcome of such a hearing can be that the firm is put on a compliance plan or that its sewer connection is severed. The firm is also required to pay the city's investigation costs, which can range from \$5,000 for small cases to \$30,000 or more for larger ones. Over half of these hearings come from the Sanitation Bureau's monitoring and inspection program.

County health department officials feel that they currently lack appropriate administrative sanctions for violations uncovered through inspections. These are typically not of a magnitude to attract the District Attorney's attention, so health officials are trying to interest city attorneys in prosecuting them as misdemeanors. But the fines mandated under the Health and Safety Code are too high (\$2,500/day) for the agency to collect without time-consuming court proceedings. However, under recent legislation the state DHS has received authority to impose administrative penalties up to \$10,000/day for disposing of wastes at illegal locations, falsifying documents, or other violations (McKenna, Conner and Cuneo, 1987).

## Conclusions

Monitoring and enforcement activities in L.A. County are performed by a wide range of state and local agencies, from the county health department to the state highway patrol. Such a diverse effort creates difficulties in coordination but also produces a variety of potentially complementary strategies. The principal inspection agency—the county health department—is understaffed if it is to inspect the tens of thousands of generators thought to exist and to respond to the thousands of complaints received annually, but the Sanitation Bureau's program of inspecting a limited number of firms that discharge into city sewers appears quite rigorous and effective in limiting inspected firms' potential for routine illegal disposal through that avenue.

It appears that many classes of violators face a small risk of prosecution, however. In every agency, staff believe that a large number of undetected illegal disposals occur, although prosecutable offenses are not easy to uncover because of the large number and

diversity of potential violators and the ease with which they can dispose of wastes on plant facilities, in sewers or storm drains, frequently under cover of night.

## **MONITORING AND ENFORCEMENT IN MASSACHUSETTS**

Compared with California, monitoring and enforcement in Massachusetts are much more centralized. The Division of Hazardous Waste, part of the state Department of Environmental Quality Engineering (DEQE), has primary responsibility; it is assisted by a few Environmental Police officers, formally part of the Department of Fish and Wildlife but located in the Attorney General's office, and to a limited extent by the Boston and other local police agencies.

Massachusetts apparently differs from many other jurisdictions in that a relatively large share of hazardous wastes, an estimated 25 to 35 percent, are generated by SQGs. However, 35 percent of SQGs are characterized as industrial (Massachusetts, 1985), compared with only 11 percent nationwide (Ruder et al., 1985). As noted in Sec. II, industrial SQGs may be more likely than other SQGs to comply with disposal regulations.

In Massachusetts, all SQGs except those generating less than 20 kg/month are subject to the hazardous-waste manifest and disposal regulations. Thus, Massachusetts regulates a larger share of generators than required under federal law, although it does exclude some VSQGs. Estimates of the number of SQGs in the state range as high as 15,000; the number identified has increased rapidly from about 1,900 in July 1984 (Massachusetts, 1985) to 3,500 in January 1985 (Massachusetts Department of Environmental Management, 1987) to perhaps 8,300 in September 1987 (interviews with DEQE staff). In comparison, there are about 2,300 identified LQGs (Massachusetts Department of Environmental Management, 1987). The DEQE regional offices have used a number of approaches to identify nonnotifying generators including surveys based on industries or localities (industrial parks, for example). In response to a DEQE request, 311 of the 351 communities in the state designated a local hazardous-waste coordinator (usually a government employee with related tasks). Some of these officials were apparently quite active and successful in identifying nonnotifiers (Massachusetts, 1985).

DEQE has approximately 30 inspectors and investigators—seven in the Boston headquarters and the remainder in the four regional offices. Department policy is determined by the state headquarters, but the

regions are fairly autonomous and have substantial flexibility in implementing policy (Massachusetts, 1985). There are currently three Environmental Police officers assigned to the environmental crimes unit in the Attorney General's office. The unit is authorized for six, but loss of personnel to industry and delays in government hiring have limited the number.

### **Generator Inspections**

Generator inspections are conducted by approximately 23 inspectors located in four regional offices. Inspectors are allocated much more uniformly across regions than are generators; in particular, the Northeast region includes an estimated 60 percent of LQGs and 55 percent of all generators, but only 30 percent of inspectors (Massachusetts, 1987).

This nonproportional allocation of inspectors across regions leads to widely varying inspection frequencies. In the Northeast region, only about 3 percent of identified generators were inspected during the first half of FY86, corresponding to an annual inspection rate of about 6 percent. In the other three regions, about 40 to 50 percent of identified generators are inspected annually. Overall, about 45 percent of inspections lead to one or more citations (Massachusetts, 1987). There is some evidence that the rate of violation is higher among nonmajor LQGs (those generating less than 5,000 gallons/month) than among major LQGs: During the first three quarters of FY84, NOV's were issued to 19 percent of nonmajor generators inspected, compared with 11 percent of major generators (Massachusetts, 1985).

### **Enforcement Cases**

The numbers of cases referred to the Attorney General for prosecution and administrative orders assessed are shown in Table 10. Despite their relatively small number, civil prosecutions are viewed as important, particularly in cases involving multimedia pollution or many parties. Most civil and criminal cases are filed against unlicensed firms and originate from tips. Few arise as a result of inspections or manifest tracking (Massachusetts, 1987).

DEQE received authority to issue Penalty Assessment Notices (PANs)—a type of administrative order by which the department can impose fines of up to \$25,000/day—in autumn 1986. These notices are perceived to be very useful and have apparently substituted in large measure for criminal and civil prosecutions, leading to the decline in those categories in FY87 (Table 10). The advantage of using PANs is

Table 10

## MASSACHUSETTS ENFORCEMENT ACTIONS

Type of Action	FY85	FY86	FY87
Notice of Violation/ Notice of Noncompliance <sup>a</sup>	809	596	478
Administrative Orders	68	78	99
Penalty Assessment Notices <sup>b</sup>			38
Attorney General Civil Referrals <sup>c</sup>	7	18	1
Attorney General Criminal Referrals <sup>c</sup>	15	28	7
EPA Referrals	6	0	0

SOURCE: Massachusetts Department of Environmental Quality Engineering.

<sup>a</sup>Name changed from NOV to NON.

<sup>b</sup>Included in Administrative Orders.

<sup>c</sup>Attorney General may drop or prosecute referrals; five criminal convictions since 1984 or 1985; some cases remain open.

that they can be issued quickly; the department can issue a letter assessing the penalty within a few days of detecting the infraction, typically through an inspection. The firm can either pay the penalty or request a hearing before a DEQE hearing officer. Before the hearing, a settlement conference is held. If no settlement is reached, the firm can judicially appeal the hearing officer's decision to the Civil Branch of the Attorney General's office.

### Hazardous-Waste Manifests

Massachusetts officials report that the state has no approved commercial hazardous-waste landfills and limited treatment capacity; the only commercial treatment facilities in the state are for solvent recovery. (EPA, August 1987, lists 13 commercial TSDFs, some of which apparently offer additional services.) An estimated 83 percent of hazardous wastes is shipped off site; about 75 percent of this amount is shipped out of state, half to New York (Massachusetts Department of Environmental Management, 1987). If these figures are correct, most hazardous waste should be tracked through the manifest system.

The number of manifests submitted to the state has increased dramatically since the system was initiated in 1982, as reported in Table 11. The fraction of incomplete manifests was estimated at 9 percent in 1984, a marked reduction from 25 to 50 percent during 1982 (Massachusetts, 1985).

Table 11

MASSACHUSETTS HAZARDOUS-WASTE MANIFESTS  
(In thousands)

Fiscal Year	Quarter	Average Manifests Received per Month
1982	4	2.8
1983	1	3.7
1983	2	3.6
1983	3	4.4
1983	4	4.3
1984	1,2	5.0
1984	3	4.6
1984	4	5.4
1986	1,2	9.2-10.0 <sup>a</sup>
1987	Not specified	> 32 <sup>b</sup>

SOURCE: Massachusetts (1985) except as noted.

<sup>a</sup>Annual rate of 110,000-120,000 (Massachusetts, 1987).

<sup>b</sup>More than 7,400 per week (Massachusetts Department of Environmental Management, 1987).

The manifests have not proven effective in generating enforcement cases, at least in part because of difficulties in entering them into the computer system rapidly. It is thought to be necessary to identify inconsistent manifests within 10 or 12 days to investigate and develop a case if warranted, but identification of such inconsistencies has, in the past, taken approximately 12 weeks (Massachusetts, 1985). Systems for comparing wastes shipped by a firm over time and for comparing quantities to industry norms have not yet been developed (Massachusetts, 1987). About four or five manifests per week are referred to the DEQE enforcement unit, but apparently only three potential compliance cases have been identified in the history of the system, and only one of these appears to be a significant case (Massachusetts, 1987). Of the manifests referred for investigation, about 40 percent involve incorrect generator identification numbers, 25 percent incorrect or missing waste quantities, 25 percent incorrect or missing waste codes, and 10 percent other inaccuracies (Massachusetts, 1987).

## Conclusions

Massachusetts appears to have moderately well-developed inspection and manifest systems. In three of the regions, including almost half the identified generators, generators are inspected at a rate of about once every other year; inspections are much less frequent in the fourth region, containing slightly over half the generators. Manifests appear to be completed reasonably well and the data are entered on a computer that allows for identification of inconsistencies, although the system is believed to be too slow for effective investigation of apparent inconsistencies and systems for analyzing waste shipments over time have not been used. The manifest system is potentially a more valuable enforcement tool here than in other states, because most hazardous wastes are believed to be disposed of off site, partly because of limited in-state treatment and disposal capacity and partly because of the relatively large fraction of wastes that is apparently generated by SQGs. However, the large share of wastes shipped out of state requires effective coordination of the manifest system with those in destination states such as New York.

Despite the relatively strong inspection and manifest systems, few enforcement cases are developed from these sources. As in California, important enforcement cases depend largely on informants.

## MONITORING AND ENFORCEMENT IN PENNSYLVANIA

Pennsylvania's hazardous-waste enforcement system is also highly centralized, with relatively little county or municipal inspection and enforcement (ELI, October 30, 1987). Local agencies regulate and monitor sewer discharges, but monitoring of independent storm-water collection systems is not thought to be effective and is not undertaken. At the state level the Department of Environmental Resources (DER) is responsible for inspection and enforcement. Civil cases are handled by DER attorneys; criminal investigation and prosecution are handled by the Toxic Waste Investigation and Prosecution Section (TWIP) of the Attorney General's office, in coordination with DER. There is some coordination with federal and state transportation departments and state police have conducted road-stop safety inspections of hazardous-waste haulers.

DER has approximately 65 inspectors located in six regional offices. Generator inspections are focused on the 2,200 LQGs in the state, with a policy of inspecting each at least every three years. SQGs are occasionally inspected, usually when the facility is on the state list because it notified EPA that it was a LQG, or when the regional office

has reason for concern about the facility. State officials note that Pennsylvania is not authorized to enforce the HSWA program under RCRA and they consider SQGs to be primarily EPA's responsibility. Moreover, they argue that monitoring SQGs is less important than monitoring LQGs, citing the 1 percent share of hazardous wastes that SQGs are estimated to produce. This estimate is based on the national data discussed in Appendix A; independent estimates for Pennsylvania are not available.

In FY87, 1,564 facilities were inspected for RCRA compliance, requiring approximately 30 man-years of effort (the 65 inspectors also do non-RCRA associated inspections). Generator inspections are estimated to require about six hours to prepare, conduct, and report, exclusive of travel time. Approximately 550 NOV's were issued, as well as 175 escalated civil actions including penalty-assessment and consent orders. Fines associated with these escalated actions totaled \$400,000—an average of about \$2,300 per action.

The state reports no commercial hazardous-waste-disposal facilities, although about 120 on-site TSDF's exist. There were 16 commercial TSDF's in 1982. By July 1985 only seven were still operating and only one of them offered disposal services; by July 1987 none offered disposal services and about six were still offering a variety of treatment services (Pennsylvania, 1986; EPA, August 1987, lists 28 commercial TSDF's in Pennsylvania). Hazardous-waste exports from the state increased from about 153 kt in 1982 to 243 kt in 1984, although imports from other states continued at about 285 kt. Three destination states—Ohio, New Jersey, and New York—account for about 85 percent of the exports (Pennsylvania, 1986). Since Pennsylvania has had a ban on land disposal of liquid wastes for some time, the November 1986 HSWA ban on land disposal of chlorinated solvents caused little change in the flow of wastes.

Landfills, including those that accept only municipal wastes, are also inspected by DER. Because landfill operators must obtain a permit amendment from DER before accepting any wastes not currently permitted and have limited opportunity to effectively challenge DER rulings, they are apparently careful to avoid violating permit conditions (ELI, October 30, 1987).

DER staff believe that illegal disposal is a modest problem in Pennsylvania. As evidence, they point to high compliance with the manifest system and the absence of other indications of extensive violations. Only about 5 percent of manifest filings are in error, the errors are almost always minor, and they are often corrected voluntarily before DER has notified any of the parties. The most serious violations by transporters reportedly involve accepting incomplete

manifests (for example, manifests without waste quantities, EPA identification numbers, or generator signatures). Occasionally, transporters operating without a proper license are discovered.

The state has 240 licensed transporters, most with at least 10 employees, according to a DER official. The agency has uncovered no illegal disposal of hazardous waste by licensed transporters. Inspections carried out at generator or treatment facilities and transporter terminals have uncovered only minor violations.

### **Criminal Prosecution**

The criminal investigation and prosecution process is centralized in the Attorney General's office. TWIP has two DER attorneys and one, the chief, assigned from the Attorney General's office; they work together with approximately seven special agents and five environmental specialists. TWIP makes little use of other criminal-investigation agencies in the state. DER inspectors who find evidence of criminal violations are supposed to immediately inform TWIP and let it perform the investigation (except when emergency response is necessary), although not all do.

As in the other jurisdictions we studied, the bulk of the criminal cases here originate with informants. For example, a neighbor of a treatment facility noted that a nearby stream rose each night. He reported this to DER, which discovered that the operator disposed of liquid waste by simply opening the spigot at the end of the day. The manifest system provided confirmation, which the TWIP attorneys see as the usual role for the system. Officials note that part of the reason tips are important is that successful criminal prosecution often requires a witness willing to testify at trial.

As shown in Table 12, the unit has developed about 35 criminal cases each year, although nearly twice that many were opened in FY87. About 10 to 15 defendants are convicted each year, divided about evenly between individuals and companies. Corporate defendants are varied and include several large firms. Sentences are typically one to two years, although in one case the defendant was sentenced to 6 to 12 years.

One recent case involving a printing company is of interest because of the remedy the prosecutors accepted. The printing firm had offered to provide education programs to other firms operating in its area. The prosecutors were enthusiastic about this, believing that many smaller firms are ignorant of available technological solutions to their waste-disposal problem. One official suggested, for example, that distillation units are available for solvents that would permit generators to

Table 12

## HAZARDOUS-WASTE PROSECUTIONS IN PENNSYLVANIA

Type of Action	FY83	FY84	FY85	FY86	FY87
Cases opened	38	26	37	34	63
Individuals convicted	4	7	0	7	9
Individuals sentenced to jail	1	2	0	4	0 <sup>a</sup>
Companies convicted	5	8	5	10	5
Total fines (\$1,000)	226	142	42	530	133 <sup>a</sup>

SOURCE: Pennsylvania Toxic Waste Investigation and Prosecution Section.

NOTE: Convictions are listed in the year obtained, not the year the case opened. Jail sentences and fines are listed in the year of conviction, although they may not have been determined until the following year.

<sup>a</sup>Sanctions have not yet been determined for all FY87 cases.

handle their own recycling. Since these units cost only \$15,000 to \$20,000 he feels that many generators might find this an attractive alternative to off-site recycling or disposal. In other cases, defendants have been required to install pollution-control equipment or reclaim polluted land.

TWIP has used "sting" operations with apparent success. Officials were unwilling to describe these operations in detail, but they have apparently involved establishing false companies to solicit wastes.

Until recently TWIP had few dealings with federal agencies, either regulatory or investigative. However, in recent months it has turned over to EPA a number of cases which it felt did not merit criminal prosecution. This seems to be an episodic arrangement.

### Conclusions

Unlike the situation in L.A. County and Massachusetts, the Pennsylvania agency apparently believes that it is dealing with a relatively high-compliance population and that it has in place a set of monitoring and investigative programs that are adequate to the problem. The attorneys in charge of the criminal-prosecution program are not beset with a flow of cases that tax their resources; the overflow now being referred to EPA includes only the smaller cases, which they feel are inappropriate for criminal prosecution.

Does the agency have a reasonable basis for its confidence? On the one hand it appears that they have some monitoring systems,

particularly the manifest system, that are stringent and generate little evidence of significant noncompliance. On the other hand the lack of systematic monitoring of SQGs points to a potentially important weakness. Particularly if SQGs account for more than the 1 percent of total hazardous waste that DER assumes, noncompliance by SQGs may contribute a significant quantity of illegally disposed of hazardous waste.

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