Chapter 9

Comparison of Risks Posed by Land-Based and Ocean Incineration

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Each of the several types of releases from land-based and ocean incineration has the potential to adversely affect exposed humans or organisms in marine and terrestrial environments. This chapter explores the key differences between land-based and ocean incineration technologies in terms of the relative risks they pose to human health and to the environment. The chapter also discusses the controversial topic of the surface microlayer's role and the potential for ocean incineration to adversely affect it.

An extensive literature describes the potential for the various aspects of incineration to adversely affect humans and the environment. A full analysis of this literature is well beyond the scope of this study. Moreover, such information rarely provides significant insight into the *comparative* aspects of risks posed by land-based and ocean incineration, partly because many risks cannot be quantified at all, and partly because the fundamentally different nature of the risks often precludes comparison. For example, no accepted methodology exists for comparing a risk to human health with a risk to the marine environment. Yet the comparative aspects of risk are the most relevant in the policy setting that surrounds the issue of ocean incineration.

Because of such limitations, the discussion is restricted primarily to two subjects: the primary types of risks posed by incineration technologies; and the differences between land-based and ocean incineration that bear on the risks each poses to human and environmental health. Where direct comparison of risks is possible, available data are discussed accordingly.

RISKS OF HUMAN EXPOSURE AND IMPACT

One of the major conclusions of EPA's incineration study was that ocean incineration would pose a substantially lower risk of human exposure and health effects than land-based incineration poses. This conclusion was reached by estimating direct exposures and the resulting incremental cancer risks associated with each of the several types of stack releases (POHCs, PICs, and metals).

The analysis, however, has several shortcomings:

- it only evaluated cancer risks, ignoring the potential for other health effects; in addition, the accuracy of the cancer risk estimates is questionable;
- it considered in detail only direct exposure to emissions via inhalation and did not sufficiently assess other routes of exposure (e. g., ingestion of seafood or terrestrial food crops contaminated through bioaccumulation of emission products);
- it analyzed risks for a hypothetical ''most exposed individual, and not for the population as a whole; although the level of risk would certainly be greater for the former, relative risks could differ if assessed for the population as a whole; and
- it considered only routine stack releases as sources of exposure and excluded spills, fugitive emissions, and releases due to incinerator upset.

Many exclusions were necessitated by the lack of data required to quantify the risks. For example, data on health effects other than cancer are generally lacking for many of the substances present in stack emissions. Similarly, estimation of risk to an entire population would require a quantification of exposure to various sectors of the population, which would be exceedingly difficult (and controversial) to perform.

Despite these shortcomings, however, the *general conclusion that ocean incineration poses substantially less risk to* **human health** *than does land-based incineration appears both logical and reason-*

able, if judged from within the limits of our current level of understanding. Several lines of reasoning support this conclusion.

The major releases from incineration are from the incineration process itself, and incineration at sea is much further removed from human populations than is land-based incineration.

The general population would be *exposed* to substantially fewer releases from ocean incineration than from land-based incineration. The two processes would release roughly comparable quantities of material, and several plausible or demonstrated routes could expose humans to waste products released even in the open ocean. Such factors as atmospheric and ocean dilution volumes, the relative human dietary intake of marine versus terrestrial food products, and distance, however, would lessen the exposure from ocean incineration.

EPA's estimates assign the major portion of incremental cancer risk to metal emissions, which are predicted to be higher for ocean incineration because scrubbers would not be required on incineration vessels. Nonetheless, the risks to human health from exposure to metals would probably not be greater for ocean incineration than for land-based incineration, for the following reasons:

- The 55 percent of land-based incinerators not equipped with scrubbers would release metals in the same uncontrolled fashion as ocean incinerators, but because land-based incineration occurs closer to humans, it would produce a higher exposure.
- Regulations governing land-based incineration do not specify limitations on metal content of wastes, as would the proposed regulation for ocean incineration.
- Although land-based incineration regulations control particulate (but not metals per se) and require scrubbers for wastes that would otherwise exceed the standard, the removal efficiency of scrubbers for metals is probably lower than assumed by EPA, particularly for the liquid wastes relevant to this discussion. Incineration of liquids generates only low levels of smaller than average particulate, and scrubbers operate less efficiently at low particulate density and on small particulate (l).
- Although toxic metals removed by scrubbers are deposited in scrubber effluents and sludges, EPA's study did not assess the considerable potential for human exposure to these wastes, for example, via groundwater for landfilled sludges, and drinking water for discharged effluent.

One recent study modeled the exposure of humans to emissions of PCBs, through both direct and indirect pathways, and concluded that exposure would be considerably lower from ocean incineration than from land-based incineration (9). For land-based incineration, the study evaluated human exposure to PCBs that could result from inhalation, drinking water, and diet (terrestrially grown food); for ocean incineration, it evaluated human exposure that could result from a seafood diet (fish and shellfish). In considering dietary exposures to PCBs, the study compared *average exposures* from land-based incineration with *worst-case* exposures from ocean incineration (i. e., individuals were assumed to receive all seafood from the ocean incineration site).

The study concluded that dietary exposures to PCBs would still be 20 times higher from land-based incineration. Predicted exposures from inhalation were two orders of magnitude higher for land-based incineration, and predicted exposures from drinking water were comparable to those expected from ingestion of seafood.

Because of a lack of information, the study did not model exposures that would result from the concentration of emissions in the ocean surface microlayer (see later section in this chapter). If the microlayer is an important contributor to the marine food chain, the relative magnitude of dietary exposures could be altered significantly.

One possible major exception to the generalization that ocean incineration would pose no greater risk to human health than land-based incineration poses is the unlikely event of a catastrophic spill, particularly one occurring close to shore. Estimating the extent of health risk from direct and indirect human exposure to spilled waste materials is fraught with difficulties. However, such risks would probably, under some circumstances, be much greater for ocean incineration than for land-based incineration, because the size of a spill could be expected to be much greater at sea than on land.

Despite many years of operating experience, the actual impact of land-based incineration has been very difficult to study and ascertain. In part, this is because of a general lack of understanding of two issues identified by EPA's Science Advisory Board (16)—the transport and fate of incineration products in terrestrial ecosystems and the use of monitoring strategies and technologies that are less than state-of-the-art. Environmental monitoring is complex on land, however, because similar emissions can arise from other land-based sources of pollution, greatly complicating attempts to assign exposure or impacts to land-based incinerators or even to study the transport and fate of incinerator emissions.

RISKS OF ENVIRONMENTAL EXPOSURE AND IMPACT

Comparing the environmental consequences of land-based and ocean incineration is much more difficult (if not impossible) than comparing their risks to human health, because marine and terrestrial environments and the potential impacts involved are so fundamentally different. Even when data allowing risks to be quantified are available, no accepted means exist for comparing the risks faced by different organisms or environments.

Because of these difficulties, the discussion in this section is limited to a description of the nature and expected extent of environmental risks posed by ocean incineration, and a sketch of aspects or resources unique to marine environments that might be affected by ocean incineration. Potential adverse effects of routine emissions and of accidental spills are discussed separately.

Impacts From Routine Emissions

The first area affected by incinerator emissions would be the ocean surface contacted by the incinerator plume. Particular attention has been focused on the so-called **surface microlayer,** represented by the *skin* or uppermost fraction of a millimeter of the ocean. This micro-environment has been shown to contain high concentrations of both living organisms and contaminants, relative to the water immediately below the surface. Information concerning the nature and ecological significance of the microlayer habitat is only beginning to emerge. With respect to ocean incineration's potential effect on it, EPA's Science Advisory Board (16) has identified the surface microlayer as a priority for further study and testing, partly because of its probable key role in the food chain of the ocean. The current state of knowledge regarding this habitat is discussed later in this chapter.

Various types of marine organisms have the potential to be affected by incinerator emissions. Plankton, which are microscopic organisms present in immense numbers in the water column, could suffer both short- and long-term damage from various components of incinerator emissions. During past U.S. burns, attempts were made to sample plankton and to look for short-term effects caused by changes in chlorine content, alkalinity, and the introduction of trace amounts of organochlorine compounds and metals. In addition, physiological indicators of plankton health (chlorophyll and adenosine triphosphate content) were also monitored. Although no effects were detected for any of these parameters, the number and size of samples analyzed may have been too small to detect changes. Moreover, an adequate method of measuring long-term effects has not been developed, so they cannot currently be assessed.

Fish and other swimming organisms near the settling plume might be affected briefly by the changes described above. These effects would be expected to be limited both temporally and spatially because of the mobility of affected organisms and the relatively rapid neutralization or dilution of the residual constituents to background levels.

Somewhat longer term effects can be studied by using certain physiological measures of stress caused by exposure to toxic pollutants. Laboratory and field experiments conducted during one of the past U.S. ocean burns, in fact, detected such a stress response (ref. 11; also see discussion of past U.S. burns inch. 11). Activation of an enzyme-detoxification system was detected in fish taken from the exposure zone, and similar results were obtained in parallel laboratory tests involving direct exposure of fish to raw (unburned) waste material. In the laboratory studies, enzyme levels decreased to normal levels when fish were returned to clean water, indicating that the response was a transient one.

These experiments provided the first direct evidence for an environmental effect attributable to ocean incineration. Because the response was transient and the duration and scale of the experiment were limited, the full significance of these results cannot yet be determined. EPA plans to study this phenomenon further as part of the Agency's Ocean Incineration Research Strategy (14).

Longer term or more subtle impacts (e. g., effects on reproduction or growth) are much more difficult to study, especially in the field, and have not been examined during past ocean burns. EPA's Research Strategy includes limited efforts to examine such effects.

Bottom-dwelling organisms could be affected by contaminants adsorbed to particles that eventually became incorporated into bottom sediments, Because water at existing or proposed incineration sites is deep, such effects would probably be minimal, exceedingly difficult to detect, and long term in nature.

Prior to settling or dispersion of the incinerator plume, there is potential for adverse impact on **migratory and open-ocean species of birds.** Both the Gulf incineration site and the proposed North Atlantic site lie in known migratory routes. The routes are extremely broad, and the incineration sites cover only a small fraction of their width. These facts, together with the intermittent nature of incineration activities and the typically high altitude of migratory paths, should limit the extent of this type of impact. However, migrating birds often seek out ships or other platforms for resting; indeed, some reports suggest that birds may be attracted to incineration vessels, particularly at night when the glow of the furnaces is visible for considerable distances. Whether birds would avoid the incinerator plume itself is not known (6,18).

The potential for adverse impact to marine mammals and turtles has also generated considerable debate. The proposed Ocean Incineration Regulation would require an endangered species assessment to be conducted and periodically updated, in compliance with the Endangered Species Act.

Several endangered or threatened species have been identified in the vicinity of existing or proposed burn sites. This issue has recently been raised in the context of EPA's designation process for the North Atlantic Incineration Site. An Environmental Impact Statement (EIS) on the site completed in 1981 concluded that the site lay in migratory routes for certain marine animals (13). New information from the National Marine Fisheries Service (NMFS), however, indicated that the site also lay within a *high-use* area for several marine mammals, including the endangered sperm whale (2).

Based on EPA's updated assessment of the site from the perspective of endangered species (17), NMFS granted conditional approval to using the site for a research burn (7). Final designation of the North Atlantic Incineration Site will require a more formal biological opinion fully addressing this controversial issue.

Impacts From Accidental Spills

The most severe environmental impacts associated with ocean incineration would be those resulting from an accidental spill of hazardous wastes. There is a general consensus that, under most circumstances, spilled material would be impractical or impossible to clean up, especially as distance from the loading dock increases. Although a spill is considered an unlikely event, the severity of its consequences and the difficulty of cleanup warrant a comprehensive evaluation of the risk involved.

Unfortunately, few data are available for assessing the magnitude of the damage that would result from a major spill of hazardous wastes in marine waters. Innumerable determinants of fate and effects must be understood in order to undertake such an analysis. These include the following:

- *the nature of the waste:* factors such as density and volubility would determine the waste's subsequent behavior (e. g., sinking, floating, or dissolution in the water column);

- *the composition of the waste:* the fate of mixtures of different wastes would be complex and hard to predict;
- *the properties of individual constituents:* factors like toxicity, persistence, and potential for bioaccumulation would dictate subsequent exposure and impact;
- *the location and characteristics of the spill site (harbor, coastline, open ocean):* water depth and bottom terrain; currents, tides and other determinants of dispersal rate; the presence and value of resources; nature and extent of biological activity; and ecological sensitivity would all influence the magnitude of impacts from the spill; and
- *the potential for cleanup or recovery:* the distance from shore and the expense and availability of appropriate technologies would affect response to a spill.

For most hazardous materials, a significant spill in almost any location would result in considerable immediate destruction of biomass and loss of most organisms in and around the spill. Acute effects could result from physical impacts (e. g., smothering of bottom-dwelling organisms, or coating of birds' wings) as well as from the immediate toxic effects of caustic or other highly reactive substances. Chronic effects would be more widespread and long-lasting, particularly for toxic and persistent chlorinated hydrocarbons, which are among the most likely candidates for ocean incineration.

The following discussion of the possible effects of spills focuses on two PCB wastes—one heavier than water (sinking) and one lighter than water (floating)-and on two possible spill locations—either an open-ocean setting, such as the burn site itself, or an enclosed harbor or bay, such as Mobile. Many of the effects described would be likely to occur only in a *worst-case* situation. [1] Effects from materials that differ from PCBs in toxicity or persistence would be more or less severe and long--lasting.

[1] Note that PCBs are only one of many wastes that could be incinerated at sea Although they are highly persistent in the environment, they arc not the most toxic of such wastes (see box B in ch. 3). Large quantities of chlorinated hydrocarbon *nonwaste* materials are routinely transported by sea (see ch. 8),

A spill of sinking material in the deep water of the incineration site would probably pose the least hazard, but would also be most difficult to clean up. Acute effects on plankton or other organisms would largely be limited to those caught in the waste mass itself as it descended toward the bottom, Currents and waste volubility, among other factors, could serve to further disperse waste as it passed through the water column, thereby increasing the area of immediate impact. The bottom-dwelling community would be immediately and most heavily affected in this scenario. In the worst case, a significant portion of the organisms in the affected zone could be eliminated, and long-term contamination of bottom sediments could severely limit recolonization. Chronic effects would be most likely for surviving bottom-dwelling organisms, although remobilization of contaminated sediments by bottom currents, bioturbation, or other means could increase the size of the affected area.

A floating waste spilled at the incineration site would probably spread over a broad area relatively rapidly. Damage would be greatest for the surface microlayer and for organisms living in or frequenting water near the surface. A significant portion of such organisms would experience acutely toxic or even lethal effects, whereas organisms with less exposure could be expected to show chronic effects from more gradual accumulation.

Compared to a spill in the open ocean, the consequences of a spill in a confined and shallow area, such as a harbor or bay, would probably be more severe. Planktonic effects from the high concentrations of PCBs could be expected. Because PCBs tend to adsorb strongly to organic matter, organisms like shrimp larvae, which feed on organic matter, could suffer serious acute and chronic effects. In the worst case, a sinking waste would kill most or all bottom-dwelling organisms. Greater opportunities for resuspension of contaminated sediments exist in shallow waters, so continued release of waste materials to the water column could be expected.

A floating waste spilled close to land would probably be the most likely to afford opportunities for partial cleanup. But it could also harm not only marine organisms, but humans and other shore life (e. g., birds, shellfish beds, and wetlands), as well. Volatilization of waste constituents from the surface slick could pose direct inhalation risks to nearby residents. Many or most marine commercial and recreational activities in the region would be affected immediately and possibly for the long term.

The potential effects of a PCB spill in the Delaware River and Estuary were recently assessed in relation to a proposed research burn in the North Atlantic Ocean (10). For a spill of about 800 metric tons[2] of waste containing 10 to 30 percent PCBs, three scenarios were modeled: 1) an upstream spill at or near the loading dock in Philadelphia, 2) a midstream spill near Wilmington, and 3) a spill at the midpoint of the Delaware Estuary. Conservative assumptions regarding the dispersion and fate of PCBs were used to generate a ' 'worst-case' prediction.

For the first two scenarios, the results indicated that during the first several hours at a given location, water quality criteria and aquatic toxicity levels would be exceeded and most fish would probably be killed. Predicted long-term concentrations in the river water or sediments would be much lower, probably below those that have been demonstrated to cause any ecological effects. For the third scenario—an estuarine spill-a kill also would occur during the first several hours, affecting fish, plankton, and invertebrates, and in the worst case involving the entire estuary. Long-term effects resulting from sediment contamination could include accumulation of measurable quantities of PCBs in shellfish such as oysters.

Most of the effects discussed above are difficult or impossible to quantify. Much of the criticism of ocean incineration identifies and focuses on the many sources of uncertainty inherent in determining actual risk. Indeed, uncertainty is a clear theme throughout this entire discussion of risks.

Both EPA and its Science Advisory Board recognize that much more information is needed to evaluate the full extent of risks posed by ocean incineration. Both have identified unresolved issues and areas that need further research. The SAB (16) noted the following topics as needing more attention:

- understanding the role of the microlayer in the marine food web and the nature of its apparent high biological activity and ability to trap contaminants;
- field-testing of the numerous models used by EPA in estimating impacts;
- better understanding the routes of exposure, food chains, and community structures in marine environments;
- determining toxicities and bioaccumulation potential of wastes and waste products in marine settings; and
- developing better means of assessing long-term and sublethal effects on marine organisms, communities, and ecosystems.

EPA has developed a research strategy for ocean incineration (14), which specifically addresses many of the remaining areas of uncertainty, and outlines additional research plans in both laboratory and field settings. Table 24 lists the major areas of concern identified in EPA's research strategy.

The SAB emphasized that uncertainty was by no means the exclusive domain of ocean incineration, and that many of the areas the Board identified also applied to land-based incineration and even to other common combustion processes. The discussions in previous chapters concerning risks associated with land-based hazardous waste disposal and with marine transportation of hazardous ma-

[2]Equivalent to one-fourth of the capacity of the *Vulcanus II*, corresponding to the loss of the entire contents of two of its eight cargo tanks.

Table 24.–Major Areas of Concern Identified by EPA in its Ocean incineration Research Strategy

1. Composition of emissions
- **A. Development of appropriate sampling and analysis methods**
- **B, Determination of the composition of emissions from an at-sea PCB research burn**

II. Exposure assessment
- **A. Incineration research site selection**
- **B. Environmental baseline sampling**
- **C. Environmental sampling during research burn**
- **D. Worst-case exposure scenarios**
- **E. Laboratory transport testing**
- **F. Transport model development, atmospheric and aquatic**
- **G. Transport model validation**

III. Biological effects assessment
- **A. Acute and chronic toxicity**
- **B. Bioconcentration**
- **C. Genotoxicity**
- **D. Effects on the surface microlayer**

IV. Comparative environmental risk/hazard assessment

SOURCE: U.S. Environmental Protection Agency, Office of Water, *Incineration-At-Sea Research Strategy* (Washington, DC: Feb. 19, 1965).

terials are indicative of uncertainties in these areas, as well. It is essential, therefore, to conduct a comparative assessment of risks and to view any single activity such as ocean incineration in as broad a context of related activities or risks as possible.

The Role of the Surface Microlayer[3]

The ocean's uppermost surface, or microlayer, is in many respects an environment unto itself, one that has properties distinct from the sea immediately below and the air immediately above. Yet the microlayer also appears to play a vital, but only poorly understood, role as an interface and medium of transfer between sea and air.

The dimensions and composition of the surface microlayer have not been thoroughly defined. Although it is most commonly visualized as a surface slick, which may be patchy, it is present even when it is not visible. Its thickness, which is mostly defined operationally through sampling procedures, ranges from less than one-tenth of a millimeter to several centimeters. Many studies have demonstrated that the microlayer can be enriched in a variety of materials, including organic matter, metals, toxic organic chemicals, and active populations of organisms (1 2). The organisms include a wide range of bacteria, minute animals or plants (the surface subset of plankton), and the eggs and larvae of many different fish and crustaceans. Certain species are entirely unique to the microlayer (8).

The enrichment of various materials in the microlayer can result in concentrations that are anywhere from 2 to 10,000 times higher than those found just a few centimeters below the surface (8). However, the level of enrichment varies with time of day, season, weather conditions, location, and the particular substance or organism being considered. This variability greatly complicates the study and definition of the microlayer.

[3]This discussion is based on information from papers presented at an EPA-sponsored workshop on the Sea-Surface Microlayer, held in Arlie, VA, on Dec. 18 and 19, 1985.

Various mechanisms for depositing and removing materials and organisms from the microlayer have been identified. These include wave and whitecap formation, surface interaction of gas bubbles, the natural buoyancy of eggs and larvae, the hydrophobic (water-repelling) nature of some organic materials, surface flows and currents, and wind action. The combined effect of these mechanisms is a steady turnover, in which loss and replenishment of essentially all components of the microlayer occurs continuously. For example, various organic compounds and metals can remain in the microlayer anywhere from a few seconds to many hours (3). Mixing by surface flows, wave action, or other means drives surface material downward to underlying waters, which is now recognized as an important transport mechanism for materials deposited on the ocean surface (19).

The ecological significance of the living portion of the microlayer is poorly understood. The enrichment of organic matter in the microlayer provides a food source for the minute plants and animals that reside there and accounts for their high densities in the microlayer. These surface organisms, in turn, may play an important role in the marine food web, because they provide a basic food source for the plankton that live in immediately underlying waters (8). These questions are currently under intense study, which should rapidly increase our understanding of the microlayer's role in marine communities.

The microlayer also appears to serve as an essential, if temporary, habitat for the embryonic life stages of many fish and crustaceans, including many commercially important species (e. g., shrimp in the Gulf of Mexico).

The surface microlayer's apparently vital roles and its ability to become enriched in toxic organic compounds and metals raise legitimate concerns over whether accidental spills and emissions from ocean incineration would cause significant environmental damage. Unfortunately, an evaluation of possible consequences must await further study, including the development of an adequate methodology to sample and monitor the surface microlayer.

ADDITIONAL FACTORS RELEVANT TO A COMPARISON OF LAND-BASED AND OCEAN INCINERATION

This section presents several additional points of comparison and contrast relevant to a consideration of hazardous waste incineration technologies. These issues have been raised repeatedly in the debate over ocean incineration and are particularly germane to determination of policy. The following discussion does not attempt to resolve these issues, but it presents common arguments that illustrate the range of existing opinion.

Onsite Versus Offsite Incineration

Ocean incineration is, by definition, an offsite activity, in which the manager of wastes is distinct from the generator of wastes. Virtually all current *commercial* land-based incineration also occurs offsite, whereas *private* incineration typically entails a generator processing wastes in a facility located at the site of generation.

Two concerns are raised about offsite incineration, and indeed, about all offsite hazardous waste management activity. The first is that offsite management generates additional risks (because of extra transportation and handling requirements) that could be avoided by management at the site of generation. The second concern stems from the fact that the party who actually disposes of or treats waste offsite is different from the party who generated it. Some observers believe that the generator's accountability for the generation and subsequent handling of waste is substantially weakened, which necessitates elaborate regulatory mechanisms for tracking wastes from ''cradle to grave. Furthermore, because the waste managers are paid for rendering their service, these observers fear that profit becomes a primary determinant of how carefully and safely wastes are handled. Addressing this concern requires a more elaborate set of regulations

Photo credit: SCA Chemical Services/Air Pollution Control Association

A commercial rotary kiln incineration facility,

to ensure proper waste management than would otherwise be needed.

Many other observers argue, however, that the development of large, offsite management capability is desirable because it centralizes hazardous waste management activities. According to this argument, centralization takes advantage of economies of scale and eases the tremendous regulatory burden of permitting, monitoring, and ensuring the regulatory compliance of many smaller facilities. Moreover, given the number of waste generators that cannot afford to manage their own wastes or use the best technological means available, commercial facilities in the business of managing wastes may be in a better position to do so safely and in compliance with regulatory requirements.

Both arguments have been legitimately raised in the debate over the relative merits of land-based and ocean incineration. Such a debate bears as well on the larger issue of the roles and responsibilities of the public and private sectors in solving complex societal problems such as hazardous waste management,

Cost to Generators

A related issue involves how much generators would have to pay for ocean incineration, relative to the price of commercial land-based incineration. Many critics of ocean incineration argue that it is an inexpensive option that would be used in place of more expensive but environmentally sounder practices. The major reason cited for the low cost of ocean incineration, relative to land-based incineration, is the absence of a requirement for costly air pollution control equipment.

Many widely varying estimates of the cost of ocean incineration have been offered (4,5, 15). The reliability of any of these estimates is questionable, however, because the many variables involved are difficult or impossible to determine in advance. Some of the variables include:

- size of the market for incineration of liquid wastes;
- type of wastes, including high-value markets (e.g., PCBs) and low-value markets (e.g., aqueous organic wastes);
- costs of other options for such wastes (competitive pricing);
- regulatory requirements, such as liability insurance levels and monitoring and analysis requirements;
- port and incineration site locations; and
- nature and cost of required port facility development.

In light of such hard-to-predict factors, estimated prices cover a broad range. For example, the following price ranges (expressed in 1983 dollars per metric ton), averaged for several waste types, have been estimated for land-based and ocean incineration and (for purposes of comparison) for landfilling (5):

Landfilling	$ 55 to $240
Land-based incineration . .	$360 to $500
Ocean incineration ., ...	$200 to $400

Other studies exhibit wide ranges and variations in price estimates, but virtually all support several generalizations:

- Incineration, whether on land or at sea, is consistently more expensive than traditional land disposal alternatives. Indeed, cost is cited as the primary reason for generators' minimal use of incineration to date.
- The gap between costs for disposal and incineration is expected to narrow as restrictions on land disposal are implemented and in response to generators' growing concerns about their long-term liability for wastes.
- On an average, ocean incineration is predicted to cost waste generators somewhat less than land-based incineration, although price ranges are likely to overlap substantially. Despite arguments that ocean incineration's lower costs would stem from the lack of a requirement for expensive air pollution control equipment, two operating factors are likely to be equally or more determinative:
  1. ocean incineration's annual throughput would be higher, enhancing income-generating potential; and
  2. ocean incineration would concentrate on a high-value waste market, predominantly on wastes with high chlorine and energy contents and on easy-to-burn liquid wastes,

rather than on a mixture liquids, solids, and sludges.

Whatever ocean incineration's eventual price, it probably will for the foreseeable future lie between the low costs of land disposal and the much higher costs of the new and emerging technologies discussed in chapter 4.

Ease of Monitoring and Surveillance

The fact that ocean incineration occurs far from shore has provoked two reasonable but opposing lines of argument by participants in the ocean incineration debate. Proponents point to the fact that the residual quantities of wastes or waste products released during incineration are far less likely to harm humans if the incineration occurs far from human populations. Opponents, however, consider ocean incineration an "out-of-site, out-of-mind' solution to the hazardous waste problem. Indeed, monitoring and enforcement probably would be more troublesome for an activity that occurs beyond the horizon. In the absence of compensatory measures, the government's (and perhaps equally important, the public's) ability to monitor the activity and to detect regulatory violations could be expected to decrease with distance from shore.

In response to such concerns, EPA has proposed several special regulatory provisions to be required only of ocean incineration. These include requirements for a full-time EPA shiprider on each voyage, use of tamper-proof or tamper-detectable recording devices for all automatic monitoring data, submission of all monitoring and waste analysis data to EPA after each voyage, and, on request, inspections of facilities and records. Not surprisingly, the adequacy of such measures is also the subject of considerable controversy.

Interestingly, a similar line of argument has been applied to private (onsite) incineration and other noncommercial hazardous waste management facilities. Concerns have been raised about the ease with which the government or the public could monitor such operations or could gain access to private information that was in the public interest. These concerns have arisen, for example, in debates over the siting of such facilities.

Degree and Nature of Public Participation

The high degree of public participation (and in general, opposition) in the debate over ocean incineration is somewhat surprising, in light of the commonly heard concern that the ocean has little political representation ("fish don't vote") and is ' 'in no one's backyard. This level of participation partly reflects the fact that designating specific ports and sites for ocean incineration does have clear local and regional consequences. The debate has broadened beyond these concerns, however, and has taken on national dimensions; indeed, a broad-based "ocean constituency' has developed. One result of this phenomenon is that the role of ocean incineration is increasingly being viewed in a broad context, as only one component in the debate over the shaping of a national hazardous waste management strategy.

In contrast, land-based incineration remains a chiefly local concern. Although public concern and opposition to the siting of land-based incinerators is often equally intense, broader issues are less likely to be raised in the process.

The government and the various interest groups working toward solutions to hazardous waste problems have an obligation to recognize and consider the interrelationships between these issues of local and national concern in order to raise the level and scope of the debate.

CHAPTER 9 REFERENCES

1. Arthur D. Little, Inc., *Overview of Ocean incineration,* prepared by J. R. Ehrenfeld, D. Shooter, F. Ianazzi, and A. Glazer, for the U.S. Congress, Office of Technology Assessment (Cambridge, MA: May 1986).
2. Bigford, T. E., letter dated Mar. 20, 1985, from Thomas E. Bigford, Chief of the Habitat Conservation Branch, National Marine Fisheries Service, to David P. Redford, Marine Permits and Monitoring Branch, U.S. Environmental Protection Agency.
3. Carlson, D.J., ''Organic Chemistry of the Sea Surface Microlayer, " paper presented at the Sea-Surface Microlayer Workshop, Arlie, VA, Dec. 18, 1985.
4. Chemical Week, "Waste Disposal by Burning At Sea, " *Chemical Week,* Apr. 11, 1979, p. 44.
5. Emison, J., "Review of Incineration At Sea, " EPA Memorandum, July 15, 1983.
6. GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Pollution), "Scientific Criteria for the Selection of Waste Disposal Sites At Sea, ' No. 16 in *Reports and Studies* of the Inter-Governmental Maritime Consultative Organization (London: 1982).
7. Gordon, W. G., letter dated Sept. 10, 1985, from William G. Gordon, Assistant Administrator for Fisheries, National Marine Fisheries Service, to Tudor Davies, Director of the Office of Marine and Estuarine Protection, U.S. Environmental Protection Agency.
8. Hardy, J. T., ''Phytoneuston: Plants of the Sea-Surface Microlayer, " paper presented at the Sea-Surface Microlayer Workshop, Arlie, VA, Dec. 18, 1985.
9. Holton, G. A., Travis, C, C., and Etnier, E. L., "A Comparison of Human Exposures to PCB Emissions From Oceanic and Terrestrial Incineration, *Hazardous Waste and Hazardous Materials* 2(4):453-471, *1985.*
10. ICF Technology, Inc., "Potential Effects to the Delaware River and Estuary Resulting From a Hypothetical PCB Spill From the Vulcanus II, " prepared for Chemical Waste Management, Inc. (Washington, DC: Dec. 13, 1985).
11. Kamlet, K. S., ''Ocean Disposal of Organochlorine Wastes by At-Sea Incineration, Ocean *Dumping of Industrial Wastes,* B.H. Ketchum, et al. (eds.) (New York: Plenum Publishing Corp., 1981), pp. 295-314.
12. Meyers, P. A., ''Processes Contributing to the Concentration of Polychlorinated Biphenyls at the Sea-Surface Microlayer, " paper presented at the Sea-Surface Microlayer Workshop, Arlie, VA, Dec. 18, 1985.
13. U.S. Environmental Protection Agency, Office of Water Regulations, Criteria and Standards Division, *Environmental Protection Agency Final Environmental Impact Statement (EIS) for North Atlantic Incineration Site Designation* (Washington, DC: Nov. 25, 1981).
14. U.S. Environmental Protection Agency, Office of Water, *Incineration-At-Sea Research Strategy* (Washington, DC: Feb. 19, 1985).
15. U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, "Summary and Conclusions, *Assessment of Incineration* as *a Treatment Method for Liquid Organic Hazardous Wastes* (Washington, DC: March 1985).
16. U.S. Environmental Protection Agency, Science Advisory Board, *Report on the Incineration of Liquid Hazardous Wastes by the Environmental Effects Transport and Fate Committee* (Washington, DC: April 1985).
17. U.S. Environmental Protection Agency, Marine Operations Division of the Office of Marine and Estuarine Protection, *Assessment of the Impact of Incineration of Chemical Wastes in the Proposed North Atlantic Incineration Site on Endangered and Threatened Species* (Washington, DC: July 9, 1985).
18. Wastler, T. A., Offutt, C. K., Fitzsimmons, C. K., et al., *Disposal of Organochlorine Wastes,* EPA-430/9-75-014, contract report prepared for the U.S. Environmental Protection Agency (Washington, DC: July 1975).
19. Weller, R. A., "Mixing Down From the Microlayer: The Role of Three-Dimensional Flows, " paper presented at the Sea-Surface Microlayer Workshop, Arlie, VA, Dec. 18, 1985.