Chapter 7

Comparison of Land-Based and Ocean Incineration Technologies

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Chapter 7

Comparison of Land-Based and Ocean Incineration Technologies

Although liquid organic wastes are currently managed in various ways, ocean incineration's primary competition and closest analog is land-based incineration. Therefore, it is important to compare and contrast their technical features, the nature and extent of their regulation, and their relative risks of environmental release and adverse impacts.

This chapter describes the nature of the combustion products arising from both land-based and ocean incineration and compares and contrasts their respective technical and regulatory requirements.

COMPOSITION OF INCINERATION PRODUCTS

The products resulting from incineration of hazardous waste, whether on land or at sea, can result from complete or partial thermal oxidation of waste components. The products can be grouped as follows: plume gases, residual parent compounds, products of incomplete combustion (PICs), metals and particulate, and solid residues. A brief description of each category is provided below.

Plume Gases

Total combustion of simple, nonhalogenated chemicals generates carbon dioxide and water as end products. If combustion is incomplete, carbon monoxide is also formed, and its level in emissions indicates the degree of incomplete combustion. Incineration of halogenated compounds generates acid gases (e. g., hydrogen chloride) and much smaller amounts of chlorine gas, in addition to carbon dioxide and water. The incineration of liquid wastes containing sulfur or nitrogen can produce a variety of sulfur oxides and nitrogen oxides.

Except for acid-forming emissions (dominated by hydrogen chloride), the Environmental Protection Agency (EPA) has not promulgated or proposed regulations limiting emissions of stack gases from hazardous waste incinerators. Relative to larger combustion sources like powerplants, the incinerators probably are a relatively minor source for most of these pollutants. For certain wastes or in certain geographic settings, however, hazardous waste incineration may contribute significantly to the risks posed by hazardous air pollutants.

Residual Parent Compounds and Products of Incomplete Combustion (PICs)

Parent compounds refer to those present in the original waste, a small fraction of which pass through the incinerator intact. PICs include both partially destroyed compounds and new chemical compounds not originally present in the wastes. PICs, which all types of combustion processes generate to some degree, include a wide range of compounds that are apparently synthesized during or immediately after combustion through chemical reactions or the recombining of molecular fragments.

PICs often bear little or no resemblance to the parent compounds from which they were derived; nor does the presence of a particular PIC necessarily correlate with the presence of a particular waste component. Very little is understood about how PICs are formed. They have been detected in the emissions from burning a wide range of materials, both hazardous and nonhazardous (e. g., municipal garbage, wood). The generation of PIGs might be correlated with the level of oxygen present during incineration and with the completeness of combustion.

Both dioxin and dibenzofuran compounds, known to be highly toxic to humans and in the environment, have been identified among PICs produced from incinerating various materials, including municipal garbage. Our understanding of the public health significance of these emissions, or even their major sources, is far from complete.

The quantities of both residual parent compounds and PICs present in incinerator emissions vary with operating conditions, such as residence time, turbulence, and temperature. An EPA study of land-based hazardous waste incinerators (13) found that the concentrations of PICs in the stack gases were typically as high as the concentrations of parent compounds, but that both were rarely above 0.01 percent of the concentration of the parent compounds in the original waste. EPA's Science Advisory Board's analysis of available studies characterizing emissions from land-based incinerators, however, led the Board to conclude that:

> It is apparent that even with the uncertainties related to sampling efficiencies and inadequate chemical analyses, as much as 1 percent of the mass of the waste feed could exit an incinerator as compounds other than carbon dioxide, carbon monoxide, water, and hydrochloric acid. (16)

Under such conditions, a *total* destruction efficiency (DE) of only 99 percent would be achieved, even though a much higher DE would probably be measured under EPA's current definition (see discussion of DE in ch. 2).

With respect to ocean incineration, EPA was unable to detect any dioxins or dibenzofurans in stack emissions from the *Vulcanus* ships burning poly-chlorinated biphenyls (PCBs) or the defoliant Agent Orange. Questions have arisen, however, about the adequacy of sampling and analytic methodology employed during those monitoring efforts (see refs. 3, 16; also see discussion of past U.S. burns in ch. 11).

EPA is currently devoting considerable effort to characterizing the PICs that result from hazardous waste incineration, and the Agency considers it a research priority. PICs are currently unregulated, although EPA proposed regulations under the Resource Conservation and Recovery Act (RCRA) in 1981 (46 FR 7684, Jan. 23, 1981). The proposed Ocean Incineration Regulation would not include any specific limits on the emissions of PICs, pending further study, but EPA is considering two approaches to their possible future regulation (see ch. 2, and proposed Ocean Incineration Regulation, 50 FR 8247, Feb. 28, 1985).

Metals and Particulate

These incineration products are the largely noncombustible, inorganic (mineral) remainder from the combustion of waste. In addition, substantial amounts of particulate matter are sometimes derived from the refractory firebrick lining of the combustion chamber, itself. How much of these products are generated depends on the type of waste incinerated; for example, the quantity of particulate from incineration of liquid wastes is generally significantly less than from incineration of solid wastes.

Because metals are not destroyed by incineration, those present in the waste feed are either deposited in ash residues or are emitted from the combustion chamber. Metals can be emitted in either a particulate (solid) or a volatilized (gaseous) state. Control strategies and environmental behavior vary considerably for these two forms and from metal to metal.

Incineration can alter the form and properties of metals in several important respects, which are discussed below.

Volatilization

The high temperatures typically employed in hazardous waste incinerators can volatilize heavy metals that are present in the waste; the degree of volatilization varies with the incinerator's operating conditions, and from metal to metal. Mercury, cadmium, and lead are generally considered most problematic because they are easily volatilized and are harmful if inhaled by humans. Although few data are available for hazardous waste incineration, one study examined the release of metals from incineration of sewage sludge at 1,6000 F in a facility possessing air pollution control equipment (6). At least 20 percent of the lead and cadmium, and essentially all of the mercury, were emitted because of the scrubber's low efficiency at removing volatilized metals.

Volubility

Incineration can also alter the chemical form and volubility of metals found in wastes, thereby altering the metals' potential availability and routes of exposure to organisms or humans. For example, incineration might change a water-insoluble form of cadmium in an organic wastestream to a more soluble form; when the resultant ash is disposed of in a landfill, the cadmium would be more likely to leach into nearby groundwater. Incineration increases the water volubility of cadmium and copper and decreases the water volubility of chromium, nickel, and lead (4).

Bioavailability [1]

Incineration can alter the bioavailability of certain metals. The ability of living organisms to absorb and detoxify a particular metal greatly depends on the metal's chemical form. Because metal chemistry can be greatly altered by high temperature, the potential for incineration to increase or decrease the bioavailability of a metal must be considered. Although this problem has been insufficiently studied, some data indicate that incineration increases the bioavailability of arsenic and chromium (4).

Although emissions standards for specific metals do not exist, for either land-based or ocean incineration, EPA has limited the total allowable quantity of particulate material from land-based incinerators, which should lower emissions of those metals bound to particulate matter. For ocean incineration, EPA has proposed limiting the individual concentrations of particular metals in waste *accepted* for incineration and, furthermore, the concentrations of metals in the final *blended* waste, as a means of reducing the quantity of emitted metals (see next section). Many observers, however, have called for further characterization and regulation of actual metal *emissions,* based on their potential contribution to the risk posed by hazardous air pollutants (see chs. 2 and 9).

[1]A *bioavailable* metal is one that can be taken up by a living organism and incorporated into its makeup or metabolic processes. Only certain metals, and only certain chemical forms of metals, are taken up, and the bioavailability of a particular metal also varies from one organism to another.

Solid Residues

These products include ash left behind in the combustion chamber and wastes generated when air pollution control equipment (e. g., scrubber sludges) is used.

Ash

The quantity and composition of ash resulting from incineration varies widely and primarily depends on the waste itself. For example, incineration generates substantially greater amounts of ash from solid wastes than from liquid wastes. Operating conditions can also influence the quantities of residuals. Ocean incineration typically produces very little or no ash, although periodic cleaning of the combustion chamber is necessary to remove slag.

Sludges and Dusts

Land-based incinerators that employ air pollution control equipment generate additional waste, including sludges and effluents (from the use of wet scrubbers) and dusts (from the use of dry scrubbers and other collection devices). The quantity of these additional wastes, which can be substantial (see ch. 8), depends on what waste is incinerated.

The existing regulations governing land-based incinerators (40 CFR 261 .3(c)2) and those proposed for ocean incineration (50 FR 8268, Section 234.56(j), Feb. 28, 1985) define ash and pollution control residues as hazardous wastes and specify that they be handled as such. Under RCRA, however, a variance can be granted if the residue is shown to be nonhazardous (Sections 264.351 and 261 .3(d)). Residues can also be delisted on a case-by-case basis by the EPA Administrator, under a provision of the 1984 RCRA Amendments.

The latter procedure may be used to delist residues from incineration of dioxin-contaminated materials generated by a mobile incinerator operating in Times Beach, Missouri (5). It may also be used to reclassify such residues as *hazardous,* rather than *acutely hazardous* (the designation given to all dioxin-contaminated materials). EPA sees such a step, which would significantly ease residue disposal requirements, as necessary to encourage incineration of dioxin wastes, but the reasoning is based on a controversial model of dioxin toxicity (7).

COMPARISON OF TECHNICAL AND REGULATORY REQUIREMENTS

This section summarizes and compares the various regulatory provisions that impose technical requirements on the use of land-based and ocean incineration. For land-based incineration, references are generally to EPA's Incinerator Standards for Owners and Operators of Hazardous Waste Management Facilities (46 FR 7666-7683, Jan. 23, 1981) and subsequent amendments (47 FR 27516-27535, June 24, 1982), developed under the statutory authority of RCRA. For ocean incineration, references are to the proposed Ocean Incineration Regulation (50 FR 8222-8288, Feb. 28, 1985), which was developed under the statutory authority of the Marine Protection, Research, and Sanctuaries Act (MPRSA).

Waste Analysis and Waste Limitations

An operating permit for either land-based or ocean incineration must specify what range of wastes an incineration facility has demonstrated its capability to satisfactorily treat. This range of wastes must be specifically tested in a trial burn. In specifying the wastes, the permit may limit waste composition, if necessary to meet performance or emissions standards. Some limitations are specific to a particular facility, whereas others apply to all incinerators.

Regulations for both land-based and ocean incineration require facility operators to perform periodic waste analyses in order to identify constituents to which performance standards apply (see below) and to ensure compliance with the terms of operating permits. The stringency of this requirement, however, differs considerably. For ocean incineration, a waste analysis would be required before each voyage; for land-based incineration, an analysis is required only when requested by EPA.

Wastes to be incinerated on land must be characterized with respect to the following:

- heat value,
- viscosity,
- physical form, and
- identification and approximate quantification of RCRA-hazardous organic constituents.

The waste description required for ocean incineration is somewhat more extensive than that for land-based incineration. In addition to those listed above, the following waste properties or components must be identified:

- moisture, solid, and ash content;
- specific gravity (density);
- presence of polychlorinated terphenyls;
- main inorganic constituents;
- halogens, sulfur, and nitrogen constituents; and
- other organic compounds not listed as hazardous under RCRA.

Limitations on chlorine content are commonly written into operating permits for land-based incinerators, in order to meet emissions standards or to stay within the operating limits of scrubbers. Solid or metal content may be similarly limited. If PCBs are to be incinerated, maximum concentrations of PCBs in the waste are specified for both land-based and ocean incineration.

Under the proposed Ocean Incineration Regulation, two additional kinds of waste limitations would be specified. First, EPA would specifically limit how much of each of the following 14 metals could be present in waste accepted *for incineration at sea:*

aluminum	iron	silver
arsenic	lead	thallium
cadmium	mercury	tin
chromium	nickel	zinc
copper	selenium	

Concentrations would be limited to a maximum of 500 parts per million (ppm) per metal. No limits on the aggregate quantity of metals in the waste or in the emissions would be specified.

Second, certain metals (and potentially other substances) would be limited by a proposed environmental performance standard (see next section). Under the standard, concentrations of particular waste constituents in the *final blended waste to be incinerated* would be limited to amounts that would prevent the resulting mixture of incinerator emissions and seawater from exceeding marine water quality criteria.[2] EPA has determined that limits for mercury, silver, and copper would have to be below 500 ppm to meet marine water quality criteria (50 FR 51362, Dec. 16, 1985).

Both technical and regulatory distinctions between land-based and ocean incineration account for the differences in waste limitations and requirements for waste analysis. Limitations on chlorine content are not considered necessary for ocean incineration, because of natural seawater's ability to neutralize hydrochloric acid gas. This phenomenon is also the reason EPA would not require incineration vessels to carry air pollution control equipment. Because the lack of scrubbers would allow the emission of essentially all metals present in the waste, however, the metal content of wastes incinerated at sea would be strictly controlled.

The waste analysis requirements are more stringent for ocean incineration than for land-based incineration, partly because the two activities are regulated under entirely different statutes. Ocean incineration falls under the definition of ocean dumping specified in MPRSA. In general, international and domestic regulation of ocean dumping has strictly controlled the types of waste that could be dumped and has, therefore, mandated extensive waste analysis as a condition for obtaining permits.

Performance Standards

EPA's approach to regulating land-based and ocean incineration has relied primarily on standards for incinerator performance rather than standards governing incinerator design. Thus, any facility that possessed a combination of design features capable of meeting minimum performance standards would be eligible for an operating permit. This capability has typically been demonstrated by trial burns carried out prior to the granting of operating permits. For ocean incineration, EPA has proposed a combination of incinerator performance and environmental performance standards. The latter are proposed as alternatives to the land-based incinerator performance standards governing hydrogen chloride and particulate emissions.

Table 12 summarizes incinerator *and* environmental performance standards applicable to land-based and ocean incineration facilities. Each of these standards is defined and discussed below.

Combustion Efficiency (CE)

This measure of incinerator performance indicates the overall efficiency of the combustion process and can be monitored on a continuous basis. CE is represented by the relationship between the concentrations of carbon dioxide (CO_2) and carbon monoxide (CO) in the incinerator exhaust:

$$CE = \frac{[CO_2] - [CO]}{[CO_2]} \times 100$$

The CE standard is more stringent for ocean than for land-based incineration in two respects: the standard applies to all wastes, not only PCBs; and it is numerically higher (see table 12). The higher value is required because regulations promulgated under MPRSA must equal or exceed international regulations developed under the London Dumping Convention, which specifies a minimum CE of 99.95 *0.05 percent for all wastes.

Destruction Efficiency (DE) or Destruction and Removal Efficiency (DRE)

These measures of incinerator performance indicate the extent to which particular compounds that were present in the waste feed are absent from emissions. DE and DRE must be calculated separately for each designated compound and, because the chemical analysis is complex and time-consuming, cannot be determined on a continuous basis. Consequently, the usefulness of DE and DRE in monitoring incinerator performance is limited.

DE and DRE are defined as follows:

$$DE \text{ or } DRE = \frac{[W_{in}] - [W_{out}]}{[W_{in}]} \times 100$$

Where [Win] is the concentration of a particular compound in the waste feed and $[W_{out}]$ is the concentration of the same compound in the emissions vented to the atmosphere.

[2] Where there are no critera, the mixture could not exceed a marine aquatic life no-effect level or a toxicity threshold defined as 1 percent of an ambient marine water concentration shown to be acutely toxic to appropriate sensitive marine organisms (in a bioassay carried out in accordance with EPA-approved procedures). Marine water quality criteria have been developed for each of the 14 metals specified by EPA.

Table 12.-Performance Standards Applicable to Land”Based and Ocean Incineration

Performance standard	Land-based incineration	Ocean incineration
Combustion efficiency (CE)	99.9% for PCBs (TSCA)[a] No CE specified for any other wastes (RCRA)	99.95 *0.05°/0 for all wastes
Destruction efficiency (DE) or destruction and removal efficiency (DRE)	99.99% DRE except: 99.9999% DRE for PCBs, dioxins, dibenzofurans	99.99% DE except: 99.9999% DE for PCBs, dioxins, dibenzofurans
Hydrogen chloride (HCl) emissions	If >1.8 kg/hr, control to larger of either: a) ≤1.8 kg/hr or b) 1% of total HCl	After initial mixing, change in seawater alkalinity in release zone must be ≤10%
Particulate or metals emissions	≤180 mg/dry standard cubic meter, when corrected to 50% excess air	Metal emissions less than amount exceeding marine water quality criteria after mixing

[a]Incineration of PCBs requires a separate approval from the Assistant Administrator of the Office of pesticides and Toxic Substances, in compliance with TSCA (40 CFR 761.70). EPA believes (and generally requires) that a CE >99.9°/. results in a DRE > 99.9999%. (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: 1985).)

SOURCES: Land-baaed incineration: Incinerator Standards for Owners and Operators of Hazardous Waste Management Facilities (46 FR 7666-7663, Jan. 23, 1981) and subsequent amendments (47 FR 27516-27535, June 24, 1982). Ocean incineration: The proposed Ocean Incineration Regulation (50 FR 8222-8288, Feb. 28, 1985). PCBs: TSCA PCB incineration regulations (40 CFR 761.70).

The only difference between DE and DRE is that any removal of compounds accomplished by air pollution control equipment is included in the calculation of DRE, because DRE is measured *after* the devices have acted on emissions. Because air pollution control equipment is generally poor at removing organic constituents (2, 13, 15), however, DE and DRE are often functionally equivalent.

The waste destruction standard would be identical for land-based and ocean incineration (see table 12). Thus, despite their lack of scrubbers, incinerator vessels would have to achieve an emission rate for organic materials no higher than that allowed for land-based facilities.

Hydrogen Chloride (HC1) Emissions

Incineration of chlorinated wastes generates highly corrosive HCl gas. On land, if the rate of HCl production exceeds 1.8 kg/hr (4 lbs/hr), scrubbers must be employed to limit emissions to less than that amount or to remove 99 percent of the total, whichever results in the larger emission. EPA regards 99 percent removal as achievable using current technology.

For a land-based incinerator operating at median capacity (1 ,250 lbs/hr), any waste whose chlorine content was greater than 0.3 percent could be expected to exceed the HCl emission limitation of 4 lbs/hr and, hence, would require a scrubber. Once equipped with a scrubber that achieves 99 percent HCl removal, the same facility could incinerate waste with a chlorine content of up to about 30 percent without emitting more than 4 lbs/hr of HCl.

Incineration of waste with a chlorine content greater than 30 percent would be legal as long as 99 percent of the HCl were removed, but other practical constraints (e. g., corrosion, scrubber capacity, formation of chlorine gas) limit chlorine content to a maximum of about 35 percent.

For ocean incineration, EPA has proposed an environmental performance standard that would limit emissions to an amount that would result in no more than a 10 percent change in alkalinity of seawater in the release zone, measured 4 hours after release. EPA has calculated that this standard would be met even for incineration of pure carbon tetrachloride, whose chlorine content is over 90 percent, at the very high feed rate of 25 metric tons per hour, Given the significantly lower chlorine content and feed rates that would realistically be employed, it is highly unlikely that this environmental performance standard would ever be exceeded.

Particulate Emissions

The existing particulate standard for land-based incinerators is 180 mg per dry standard cubic meter, measured after correction to 50 percent excess air. The correction is designed to prevent operators from achieving the standard by simply diluting the emissions with excess air rather than actually controlling particulate.

The rationale for controlling particulate is twofold: First, particulate matter itself can be hazardous, because it can include toxic metals, which are not destroyed during incineration; and second, other hazardous constituents, including unburned or partially burned organic compounds, can adsorb to particulate matter. Although the chemical analysis used to calculate DRE accounts for unburned parent compounds bound to particulate matter, the DRE standard does not in any way measure or limit *partial* combustion products (e. g., PICs) or metals.

The particulate standard applicable to land-based hazardous waste incinerators is identical to that required of municipal incinerators under the Clean Air Act's New Source Performance Standards (12).

For ocean incineration, EPA has proposed an environmental performance standard for metals instead of establishing a direct particulate emissions standard. The proposed environmental standard would limit incinerator emissions so that:

> . . . the effect of the emissions would not unreasonably degrade or endanger human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities or recreational or commercial shipping or boating or recreational use of beaches or shorelines (Section 234.48(b) of EPA's proposed Ocean Incineration Regulation, 50 FR 8266, Feb. 28, 1985).

EPA has interpreted this rather vague language to mean that concentrations of particular constituents in wastes to be incinerated would be limited to amounts that would prevent the resulting mixture of incinerator emissions and seawater from exceeding marine water quality criteria.[3]

This standard would theoretically apply to any substance present in incinerator emissions. In practice, however, criteria and toxicity thresholds have been developed for few chemicals, and this standard would primarily be used to limit metal concentrations allowed in wastes incinerated at sea. Because liquid wastes suitable for ocean incineration typically generate low levels of particulate, EPA considers the proposed limitations to be a justifiable alternative to requiring particulate control devices on incinerator vessels.

Although the environmental performance standard appears to address harmful metal emissions, whether it can adequately control emissions of PICs associated with particulate is controversial. EPA argues that at the high temperatures employed in ocean incineration, essentially all organic compounds would be in a volatilized state and not adsorbed to particulate matter. Thus, particulate removal equipment would not help to reduce PIC emissions (l). However, some observers argue that certain organic compounds, including PCBs, dioxins, and dibenzofurans, can to some extent associate with particulate matter even at high temperatures. In addition, these observers maintain, other mechanisms exist for including organic matter in the particulate fraction of incinerator emissions (9,10).

Further research will probably be essential for resolving this controversy. EPA's proposed research strategy for ocean incineration would include tests designed to address the issue (14).

Operating Conditions

Operating permits for both land-based and ocean incineration facilities specify sets of operating conditions that were demonstrated in trial burns to be capable of achieving the performance standards discussed above. A set of conditions is determined for each waste feed expected to be burned. Periodic waste analyses must be performed to demonstrate that wastes actually incinerated are within the range for which a permit is written.

Land-Based Incineration

For land-based incinerators, each set of operating conditions includes limits on at least the following parameters:

- the carbon monoxide level in the exhaust stack gas (indicates combustion efficiency, completeness, or upset);
- waste feed rate;
- combustion zone temperature, with location of sensor specified;
- appropriate indicator of combustion gas ve-

[3]See footnote 2.

locity (indicator of residence time in the combustion zone); and

. air pollution control device operating conditions.

In addition to these waste feed-specific conditions, several operating requirements are uniformly applied to all land-based incinerators:

- during startup and shutdown, hazardous wastes cannot be fed to incinerators unless they are operating under specified conditions;
- combustion zones must be completely sealed and maintained under negative pressure in order to control fugitive emissions; and
- automatic shutoff systems must be employed to halt waste feed when operating conditions deviate from specified limits.

Incineration of PCBs requires separate approval from the Assistant Administrator of the Office of Pesticides and Toxic Substances, in compliance with the Toxic Substances Control Act (TSCA). Additional operating conditions are specified:

- 1,200 + 1000 C, 2.0 second residence time, 3 percent excess oxygen; or
- 1 1,600 + 1000 C, 1.5 second residence time, 2 percent excess oxygen.

Photo credit: SCA Chemical ServicedAir Pollution Control Association

The computerized control room at a land-based incineration facility.

Other operating conditions are allowed if they can be demonstrated to achieve the required DRE.

Ocean Incineration

The proposed Ocean Incineration Regulation would also use a trial burn to determine appropriate sets of operating conditions and waste feeds. For certain wastes specified in London Dumping Convention (LDC) regulations, if a contracting party to the Convention "has doubts as to the thermal destructibility of the wastes, " then a separate test burn would have to be conducted to ensure that all standards could be met. Because of the anticipated difficulty in achieving their complete thermal destruction, the following wastes would receive special attention:

- polychlorinated biphenyls (PCBs);
- polychlorinated terphenyls (PCTs);
- tetrachlorodibenzo-p-dioxin (TCDD);
- benzene hexachloride (BHC); and
- dichlorodiphenyl trichloroethane (DDT).

EPA considers available data sufficient to document the ability of incinerators to destroy PCBs, BHC, and DDT to the level specified by the LDC (50 FR 8228, Feb. 28, 1985). Because a 99.9999 percent standard applies to PCBs and TCDD and data are lacking for PCTs, however, test burns would be mandated for these three substances.

Operating permits for incineration vessels would have to specify allowable limits for at least two operating conditions:

- carbon monoxide concentration in combustion gases, and
- waste feed rate t. th$_e$ incinerator.

The proposed regulation specifically sets limits on the following additional operating parameters:

- minimum flame temperature of 1,2500 C;
- minimum wall temperature of 1,1000 C;
- minimum 3 percent oxygen concentration in the combustion gases; and
- residence time in the combustion zone of at least 1.0 second.

For all of these except residence time, alternate values could be substituted in the operating permit, if other conditions were demonstrated in a trial burn to be capable of achieving the performance standards.

The proposed regulation also specifies a set of general operating requirements that would apply to all vessels at all times:

- no black smoke or flame may extend above the stack plane;
- between startup and shutdown, hazardous waste could not be fed to incinerators unless they were operating under specified conditions;
- automatic shutoff systems would have to be employed to halt waste feed when operating conditions deviated from specified limits; and
- all residues would have to be incinerated at sea or transported back to land for proper disposal.

This comparison of requirements for operating conditions shows that the proposed Ocean Incineration Regulation generally tends to specify values for more operating parameters and leaves less to the judgment of individual permit writers than do the regulations governing land-based facilities.

Air Pollution Control Technology

Effect of Scrubbers on Emissions From Hazardous Waste Incinerators

Currently available air pollution control equipment generally controls emissions of particulate and acidic gases very effectively but removes organic compounds (parent compounds and PICs), certain metals (e. g., mercury), and nitrogen oxides very poorly.

An EPA study of land-based incinerators found that, for various wastestreams, scrubbers had little or no detectable effect on the levels of unburned waste (parent compounds) present in emissions (13). Based on these and other data, air pollution control devices cannot be expected to remove residual parent compounds or PICs from incinerator exhausts or to provide an extra margin of safety in the event of operation upset (2, 15).

Although scrubbers effectively control emissions of particulate metal oxides and gaseous sulfur oxides, controlling volatilized metals and nitrogen oxides is exceedingly difficult, particularly for hazardous waste incinerators, This is because: 1) wet scrubbers are ineffective at removing them; and 2) other control measures often entail decreasing the operating temperature, which must be maintained to ensure complete combustion of hazardous wastes.

Land-Based Incineration

Scrubbers are required for land-based incinerators that burn wastes whose chlorine or particulate content would otherwise cause emissions standards to be exceeded. EPA estimates that about 45 percent of land-based incinerators currently operating, including the large commercial incinerators, carry some sort of air pollution control equipment (8). Scrubber technology, especially for removing particulates, is well-developed but expensive.

Land-based incinerators regulated under RCRA (or TSCA for PCBs) are also subject to controls on scrubber waste disposal. Scrubber operation generates very large amounts of scrubber water (see ch. 8), which is itself classified as a hazardous waste. Several methods, all subject to RCRA regulation, are used for treating this residual. The methods include impoundment, deepwell injection, treatment, and landfilling. Treatment generates two products: a sludge, which is generally disposed of in a hazardous waste landfill; and an effluent, which can be legally discharged to surface waters or into sewer systems if the effluent meets the requirements of the Clean Water Act,

Ocean Incineration

Proposed domestic regulations, as well as existing international regulations, do not require the use of any air pollution control equipment on incineration vessels. Separate rationales are offered for the two major categories of incinerator emissions: acid gases and particulate. EPA argues that acid gases emitted from the stack would be effectively neutralized on contact with seawater because of its natural buffering capacity. As an additional control, the proposed Ocean Incineration Regulation would impose an environmental performance standard for acid gas -emissions (see previous section).

EPA also considers that burning only liquid wastes at sea would generate very low levels of particulates and that controls over metal content in waste would further limit harmful metal emissions. Limitations on metal content of wastes burned at sea would be based on EPA's interpretation of the London Dumping Convention's guidelines with reference to water quality criteria.

Two companies, SeaBurn, Inc., and Environmental Oceanic Services, Inc., have proposed plans for incineration vessels that would be equipped with seawater scrubbers, but their purpose would only be to dilute the plume and direct it more quickly into the ocean. The scrubbers, therefore, would not generate any scrubber residuals (see ch. 6).

Sampling and Monitoring Requirements and Procedures

Three levels of monitoring are generally discussed with regard to incineration: monitoring of trial burns; routine monitoring of emissions and incinerator operating conditions; and ambient monitoring of surrounding air, water, and biota. Each of these is discussed below for land-based and ocean incineration.

Land-Based Incineration

Sampling and analysis procedures for incinerator emissions are specified in Federal regulations and EPA manuals. For the trial burn, actual locations for sampling and monitoring devices are indicated, and data collected are used to determine performance of the incinerator by providing for the following:

- quantitative analysis of waste feed, stack emissions, scrubber water, and ash and other residues;
- computation of DE or DRE;
- acid gas removal efficiency;
- quantification of particulate emissions;
- measurement of average, maximum, and minimum combustion temperature;
- continuous measurement of carbon monoxide concentration in the stack gases; and
- identification of the sources of fugitive emissions.[4]

Operating permits for routine incineration specify waste analysis and monitoring requirements. A waste analysis plan is required and must provide for periodic verification of the chemical and physical composition limits specified in the permit. RCRA requires that temperature, carbon monoxide, waste feed rate, and combustion gas velocity be continuously monitored during operational burning and that an automatic waste feed shutoff system be continuously operated, as well. Waste feed shutoff is triggered by deviation from permit limits in any of several operating parameters, as determined by the continuous monitoring devices. Sampling and analysis of waste feed or emissions must be conducted on request by the EPA Regional Administrator. All sampling and monitoring data must be recorded.

RCRA does not require ambient monitoring for land-based incinerators, although some individual States might have such requirements under the Clean Air Act. EPA offers three reasons for not mandating ambient monitoring: the Agency believes that if stack emissions are within regulatory limits, no adverse effects will occur; accurate and reliable ambient monitoring would not be feasible because concentrations are extremely low; and other industrial activities contribute similar or identical emissions, which would impede attempts to assign sources to emissions or their effects.

Ocean Incineration

For trial burns, proposed Federal regulations specify sampling and analysis procedures for parent compounds. Routine operations would require continuous monitoring, which would have to be recorded in sealed tamper-resistant devices, of the following parameters:

- incinerator wall and flame temperatures;
- oxygen, carbon dioxide, and carbon monoxide concentrations in the combustion gases;
- waste and auxiliary fuel feed rates to the incinerator;
- air flow to the combustion chamber;
- status of the flame (to monitor continuous combustion); and
- amount of waste incinerated.

An automatic waste feed shutoff system would have to be operated continuously and be triggered by deviations from specified limits for: minimum wall temperature and minimum oxygen and maximum carbon monoxide in combustion gases; flame-outs; or failure in continuous monitoring devices.

Tests of ballast waters, tank washings, pump-room bilge waters, and wash waters from decontamination operations would have to be performed

[4]Fugitive emissions are small, sporadic losses of waste from sources like leaking valves, vents, and seals.

and recorded to ensure compliance with permit requirements.

Vessel operators would be required to monitor ambient air, water, and biota, using approved methods under the direction of EPA. The monitoring would be conducted periodically or at the request of the permit program managers. Costs would be borne by individual vessel operators.

EPA would have authority to review and approve the qualifications of all personnel involved in collecting and analyzing samples for monitoring emissions and the ambient environment.

As was the case for operational requirements, proposed sampling and monitoring requirements are generally more detailed and stringent for ocean incineration than for land-based incineration.

Additional Provisions Not Required of Land-Based Incineration

The proposed Ocean Incineration Regulation contains several requirements that do not have counterparts in RCRA regulations governing land-based incineration. These requirements include the following:

- all data from waste analyses and monitoring would have to be submitted to EPA;
- operators would have to meet additional requirements regarding the collection and reporting of monitoring data. The requirements would specify, for example, the frequency of recording and the use of tamper-resistant devices;
- a full-time EPA shiprider would be required on each voyage, and the U.S. Coast Guard could require an additional shiprider;
- facilities and records would be inspected yearly by the U.S. Coast Guard and on request by EPA;
- permit applicants would have to assess the effects of their activities on endangered or threatened species, and EPA would have to conduct and periodically update its own endangered species assessment, under the authority of the Endangered Species Act;
- the activity would have to be consistent with the Coastal Zone Management Act; and
- operators must demonstrate the need for ocean incineration (see ch. 2).

Although many of these requirements address concerns arising from the fact that ocean incineration takes place far from land, together they reinforce the conclusion that the proposed Ocean Incineration Regulation would be considerably more explicit and stringent than the corresponding regulations for land-based incineration.

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