Evaluation of Volatile Organic Emissions from Hazardous Waste Incinerators

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Conventional methods of risk assessment typically employed to evaluate the impact of hazardous waste incinerators on public health must rely on somewhat speculative emissions estimates or on complicated and expensive sampling and analytical methods. The limited amount of toxicological information concerning many of the compounds detected in stack emissions also complicates the evaluation of the public health impacts of these facilities. An alternative approach aimed at evaluating the public health impacts associated with volatile organic stack emissions presented is that relies on a screening criterion to evaluate total stack hydrocarbon emissions. If the concentration of hydrocarbons in ambient air is below the screening criterion, volatile emissions from the incinerator are judged not to pose a significant threat to public health. Both the screening criterion and a conventional method of risk assessment were employed to evaluate the emissions from 20 incinerators. Use of the screening criterion always yielded a substantially greater estimate of risk than that derived by the conventional method. Since the use of the screening criterion always yielded estimates of risk that were greater than that determined by conventional methods and measuring total hydrocarbon emissions is a relatively simple analytical procedure, the use of the screening criterion would appear to facilitate the evaluation of operating hazardous waste incinerators.

Introduction

Federal, State, and local statutes and regulations govern permitting hazardous waste incinerators in California (1–4). Federal requirements include a 99.99% destruction and removal efficiency (DRE) for compounds that are difficult to incinerate, limits on the emissions of particulates and HCI (1), and proposed controls on carbon monoxide, total hydrocarbon, and the emission of certain metals (5). California requirements that govern permitting incinerators necessitate the preparation of an environmental impact report that includes an assessment of the impact of the proposed facility on public health (4). Local air districts that have authority to regulate the operation of hazardous waste incinerators (3) in California have required that a risk assessment be performed before a permit to operate the facility is issued.

The requirement to undertake a risk assessment does not necessarily ensure that the facility will not pose a significant risk to public health. Risk assessment methodology, when applied to incineration technology, is extremely tenuous. Given the environment of the stack, emissions are difficult to sample and characterize. As indicated by the Science Advisory Panel, only a limited number of constituents emitted from the stack have been “qualitatively or quantitatively identified” (6). Even if a complete inventory of the stack emissions were ascertained, little is known concerning the toxicity associated with many of the constituents.

In addition to the problems associated with identifying and quantifying the risk associated with stack emissions, risk assessments of hazardous waste incinerators generally do not reflect the changing nature of wastes received at commercial facilities and may not address the actual operating conditions at a facility. Due to expense and to major technical difficulties, the routine monitoring of stack emissions for hazardous constituents is currently impractical.

Given the difficulties of evaluating the emissions of hazardous substances using conventional risk assessment methodology, several alternative approaches have been advanced as a method to screen out certain facilities that do not appear to pose a significant risk to public health (7–9). One approach employs a generic criterion to screen out facilities with relatively low levels of noncancerogenic stack emissions (7). If the emission of any noncancerogenic compound results in an ambient air concentration below the generic screening criterion, the compound is considered not to pose a significant risk to public health.

A second alternative approach uses the criteria for the most potent organic compounds identified in the stack emissions to evaluate the risk associated with stack emissions (8). Using an iterative procedure, the criterion for the most potent toxicant identified in the stack emission is first employed to evaluate the risk associated with the emissions of all hydrocarbons. If significant risk is demonstrated due to the assumption that all hydrocarbons are as potent as the most potent identified compound, the risk is quantified for this compound alone and all of the remaining compounds are evaluated using the criterion for the next most potent compound. The evaluation is continued until a determination of whether the stack emissions pose a significant risk to public health.

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Recently, the EPA proposed controls on carbon monoxide or total hydrocarbon (THC) stack emissions from hazardous waste incinerators to ensure that the emissions of the products of incomplete combustion (PICs) do not significantly impact public health (9). Concerned that even if an incinerator demonstrated a 99.99% DRE, high levels of PICs could be emitted from the stack, the EPA proposed to control the emissions of PICs by limiting CO or THC emissions. Studies by the EPA indicate that when CO emissions or THC emissions are low, PIC emissions do not pose an unacceptable risk to public health. Since the routine monitoring of PIC emissions is currently impractical, limitations on CO or THC were proposed to ensure that PIC emissions do not adversely impact public health.

Under the right circumstances, any of the aforementioned procedures could simplify the evaluation of the public health impacts associated with emissions of hazardous substances into ambient air. Any alternative approach should, at a minimum, provide estimates of risk that are as conservative as conventional methods of risk assessment and should simplify the evaluation of the health impacts of stack emissions from hazardous waste incinerators or facilitate the routine monitoring of stack emissions.

Screening Criteria for Volatile Compounds

Several different sampling methods currently need to be employed to detect metals, volatile compounds, and semivolatile compounds that compose most of the constituents emitted by an incinerator. Compounds captured by one sampling method generally will not be captured by the other methods. Previous work has demonstrated that semivolatile compounds emitted from the stacks of hazardous waste incinerators do not pose a significant risk to the public health (10). Therefore, the routine monitoring of semivolatile compounds at hazardous waste incinerators does not appear to be warranted. In the same study, the emission of cadmium and perhaps chromium appeared to pose a significant risk to public health at certain facilities. Therefore, monitoring of the emission of metals from hazardous waste incinerators should be targeted at these metals and evaluated using conventional methods of risk assessment.

Volatile compounds detected in the stack emissions of hazardous waste incinerators may include numerous substances that can pose a significant risk to public health. The development and use of a screening criterion that should facilitate the evaluation of volatile stack emissions from hazardous waste incinerators is the focus of the present study.

Methods

Three different approaches are described that yield separate candidate screening criteria for volatile compounds. All of the candidate screening criteria are based on existing ambient air or drinking water criteria (Table 1).

Screening Criteria Based on Ambient Air Criteria

Table 1. Criteria used to develop screening criteria.

| Criteria                          | Agency                        | Reference |
|----------------------------------|-------------------------------|-----------|
| Applied action levels            | CA Department of Health Services | (11)   |
| Proposed maximum combustant levels | CA Department of Health Services | (12)   |
| Air criteria                      | CA Department of Health Services | (13)   |
| Health advisories                | EPA Office of Drinking Water  | (14)   |
| Maximum containment level goals  | EPA Office of Drinking Water  | (15)   |
| Health effects assessment        | EPA Emergency and Remedial Response | (16)   |
| IRIS database                    | EPA Office Research and Development | (17)   |
| Ambient water quality criteria   | EPA Water Regulations and Standards | (18)   |
| Health assessment documents      | EPA Health Environmental Assessment | (19)   |

into the environment.

Having resulted from a number of different programs, the bases behind these criteria are quite variable. Even different programs within the same agency have employed different approaches to develop criteria. Irrespective of these differences, the criteria were developed for the same purpose, that is, to carry out the agency’s mandate of protecting public health.

Since these criteria were developed with a similar intended use, they can be of value by providing a basis for the development of a screening criterion. Existing ambient air criteria provide the basis of the first set of screening criteria. In order to be used properly, adjustments to some of the criteria are necessary.

Criteria from various agencies have been expressed using several formats. Some criteria are expressed as a concentration of a toxicant in the medium of exposure (e.g., micrograms per cubic meter of air) or as a daily intake of a toxicant from the medium of exposure (e.g., micrograms/day). Criteria that are expressed as daily intake were transformed into criteria expressed as a concentration in air by allocating the allowable daily intake to 20 m³ of air.

Criteria for carcinogenic compounds have been expressed using different formats. Some criteria are expressed as a potency factor (in units such as [milligrams/kilograms/day]⁻¹), other criteria are expressed as the concentration of the carcinogen in the medium of exposure associated with 10⁻⁶ risk. Criteria have been reported as a range of concentrations in a medium associated with various levels of risk. Other criteria are expressed as a unit risk factor, i.e., the risk associated with exposure to given level of the compound in the medium of exposure (e.g., 1 μg/m³). To obtain the necessary uniformity in the manner that the criteria are expressed, all criteria for carcinogenic substances were transformed so that they are expressed as the concentration of the compound in air associated with 10⁻⁶ risk.

In addition to health-based concerns, many other considerations have been employed in the development of a number of the criteria. These considerations include the technical feasibility of achieving a health-based objective, economic considerations, organoleptic considerations, and analytical detection capabilities. A number of criteria have been established at the level of an existing standard. Other criteria have been established at the level of a criterion of a similar compound. In this instance, equivalence in the toxicity and the potency of the two similar compounds is assumed.
All existing criteria, except those based on an extrapolation from a similar compound, were used to develop the first set of screening criteria. Even criteria based primarily on nonhealth considerations or whose basis could not be ascertained were used. A criterion that was established at the level of an existing standard or that duplicated the development of another criterion was included, as long as it appeared that the criterion was based on a new independent analysis. These criteria were included because it appeared that the new evaluation could have established any one of the criteria at a different level, but instead reconfirmed the basis of the earlier criterion. Criteria established at the level of a similar compound were excluded from the development of the candidate screening criteria. The bases of these criteria were judged not to be independent of the related compounds. Inclusion of these criteria would have disproportionally weighted those criteria from which such an extrapolation occurred.

Screening Criteria from Ambient Air Criteria

Ambient air criteria developed by various agencies were first segregated into the three classes of compounds associated with stack sampling: metals, volatile compounds, and semivolatile compounds. Criteria for volatile compounds were arranged from the most potent to the least potent criteria. The most potent, 95% most potent, and 90% most potent criteria were selected to compose the first set of candidate screening criteria.

Maximum Exposure Limits

The use of unmodified criteria would inevitably introduce many nonhealth-based considerations into the development of a screening criterion. Should a screening criterion based on unmodified criteria be employed to evaluate the impact of incinerators on the public health, the analysis would reflect these nonhealth-based considerations. Therefore, a second set of candidate screening criteria was developed from ambient air criteria that were modified to reflect only health-based considerations. A third set of candidate screening criteria was developed from both modified ambient air and drinking water criteria.

All modifications to the criteria were undertaken by using the documentation describing the bases of the criteria. All adjustments to the criteria were instituted to reflect the situation had only health-based considerations been employed in the development of the criteria. When insufficient or no information was available that documented the derivation of a criterion, that criterion was excluded. A criterion that was not based in part on health consideration was also excluded.

Using the basis documents, which described the development of the criteria, maximum exposure levels (MELs) were ascertained. The MEL for a carcinogenic substance is the lifetime daily exposure (micrograms/day) associated with a $10^{-6}$ risk. For all other compounds, the MEL is the maximum daily exposure (micrograms/day) anticipated not to produce an adverse effect. The MEL is the daily intake of the toxicant from the medium of exposure and not the absorbed or retained dose.

The fundamental tenet in generating a MEL from a criterion was to make as few modifications as possible from the approach employed to develop the criterion. The derivation of a MEL and a criterion were essentially identical for most of the compounds. A number of issues needed to be addressed to ensure that a uniform approach was employed in developing MELs from the large number of available criteria. They included:

a) Toxicokinetics: Toxicokinetic considerations are always addressed in the development of a criterion, even when no specific information concerning toxicokinetics is available. The same toxicokinetic considerations used to develop a criterion were employed in the derivation of the MEL.

b) Low-dose extrapolation: For carcinogenic substances, the approach used in the derivation of the criterion was employed to estimate the potency of the compound in the development of the MEL.

c) Uncertainty factors: A wide range of uncertainty factors have been employed in the development of criteria. The identical uncertainty factors that were used to develop the criterion were retained in the derivation of the MEL.

d) Route of exposure allotment: The derivation of a number of criteria include the assumption that only a portion of the total exposure is contributed by the medium of exposure. For example, only 20% of the total exposure may be allocated to drinking water when developing a criterion for that medium. The other 80% of the total exposure is assumed to occur from other media of exposure. The development of MELs from all criteria is based on 100% of the total exposure being derived from the medium of exposure.

e) Toxic end point: The toxicological end point that served as the basis in the derivation of the criterion was used to develop the MEL. If more than one end point was described, the most sensitive end point was selected. The most sensitive end point was usually related to chronic exposure.

f) Medium of exposure: A number of criteria have been developed assuming exposure from more than one medium of exposure. For example, Ambient Water Quality Criteria are based on exposure to the toxicant by the ingestion of drinking water and the consumption of fish that have been exposed to the toxicant in ambient water. Since uniformity in the exposure scenario underlying the various criteria is required for the development of screening criteria, the Ambient Water Quality Criteria were adjusted to reflect exposure due only to the ingestion of ambient water.

As described earlier, criteria have been expressed either as a concentration of the toxicant in the medium of exposure or as the daily intake from the medium of exposure. All MELs were expressed as the daily intake from the medium of exposure.

Candidate Screening Criteria from MELs Derived from Ambient Air Criteria

The MELs derived from ambient air criteria were segregated into the three classes of compounds associated with stack sampling: metals, volatile compounds; and semivolatile compounds. MELs derived from volatile compounds were arranged from the most potent to the least potent MEL. The most potent, the 95% most potent MEL, and the 90% most potent MEL were selected as the second set of candidate screening criteria.
Candidate Screening Criteria from MELs
Derived from Ambient Air or Drinking Water Criteria

The number of ambient air criteria for volatile compounds that are available to provide a basis for a screening criterion is very limited. Using MELs derived from both drinking water criteria or from ambient air criteria would markedly expand the number of available criteria. However, the use of drinking water criteria as a basis for establishing a screening criteria for exposure to toxicants in air introduces additional questions concerning the technical defensibility of the screening criterion.

MELs derived from both drinking water or ambient air criteria were segregated into the three classes of substances associated with stack sampling: metals, volatile compounds, and semi-volatile compounds. MELs derived for volatile compounds were ordered from the most potent to the least potent MEL. The most potent, 95% most potent, and 90% most potent MEL were selected as the third set of candidate screening criteria.

Facilities

Over the past decade, a variety of different incineration technologies have been evaluated primarily for their efficiency in destroying hazardous wastes. The determination of the destruction and removal efficiency for an incinerator involves quantifying both the amount of certain difficult to incinerate compounds that are in the waste processed during a trial burn and the level of these compounds emitted from the stack. When a variety of compounds are monitored during a trial burn, the results from these studies provide useful data for comparing an evaluation of the impact of a facility on public health based on using screening criteria with that based on conventional risk assessment methods.

Trial burns at 20 facilities were judged to be suitable for inclusion in this study. Most types of incineration technology are represented by these facilities (Table 2). The wastes processed during the tests and the air pollution control equipment at each facility were quite variable (Table 3).

| Facility name | Commercial off site | Type of waste feed | Air pollution control device |
|---------------|--------------------|--------------------|-----------------------------|
| American Cyanamid | No | Aniline and mono-nitrobenzene waste | None |
| Du Pont | No | Liquid organic and coke waste | Quench section followed by a cyclone and HCl scrubber system |
| Mitchell | Yes | Liquid organics and aqueous waste | None |
| Zapata | No | Varnish and lacquer | None |
| Site B | Yes | Alkyd resin wastewater | None |
| Site C | Yes | Primarily α-methyl styrene dimers and phenolic/benzene residues | None |
| Site D | Yes | Solvents consisting primarily of methanol, toluene and xylene | None |
| Site F | Yes | Purge thinner from the purging of paint spray guns | None |
| Site G | Yes | Highly halogenated organics | Dual scrubber columns |
| EPA research | No | PCB-laden oil; trade name Askarel | Venturi scrubber followed by packed scrubber, high-efficiency particulate filter, and carbon bed absorber |
| Dow | No | Three types of solids: substituted cellulose, polyethylene wax, and chlorinated pyridine tars | Quench section followed by a three-stage ionizing wet scrubber |
| Ogden (Alaska) | No | PCB-contaminated soil | Addition of limestone for the control of chloride acid gases, a flue-gas cooler, followed by a fabric filter |
| Ogden (California) | No | Acid refinery sludge/sand | Identical to Ogden, Alaska |
| Rollins | Yes | Liquid organic and solids containing organics | Quench section followed by a saturator, packed tower condensers, and a venturi scrubber |
| Florida Solite | Yes | Liquid organics including solvents, alcohols, ethers, still bottoms and chlorinated hydrocarbons | Cyclone section followed by wet scrubbers and a knockout chamber |
| Rockwell | Yes | Waste fuel consisting of solvents, lacquer thinners, alcohols, still bottoms, paint wastes, and chlorinated hydrocarbons | Radiator coolers followed by an eight-module baghouse |
| Chevron | No | Agricultural chemicals and fuel additives | Quench section followed by a venturi scrubber, knockout chamber, and mist eliminator |

Table 2. Hazardous waste incinerators.

| Facility | Type of Unit | Reference |
|----------|--------------|-----------|
| American Cyanamid | Liquid injection | (20) |
| Du Pont | Liquid injection/rotary kiln | (20) |
| Mitchell | Liquid injection | (20) |
| Zapata | Liquid injection | (20) |
| Trade Waste Incinerator | Liquid injection | (20) |
| Rollins | Liquid injection/rotary kiln | (21) |
| Florida Solite | Aggregate kiln | (22) |
| Rockwell | Lime kiln | (23) |
| Chevron | Liquid injection | (24) |
| Site B | Industrial boiler | (25) |
| Site C | Industrial boiler | (25) |
| Site D | Industrial boiler | (25) |
| Site F | Industrial boiler | (25) |
| Site G | Industrial boiler | (25) |
| EPA research | Liquid injection | (26) |
| Dow | Rotary kiln | (27) |
| Ogden (Alaska) | Fluidized bed | (28) |
| Ogden (California) | Fluidized bed | (29) |
| Cincinnati, Ohio | Liquid injection | (30) |
Stack Sampling and Analytical Procedures

The levels of volatile organic compounds in stack gases in these studies were determined using a volatile organic sampling train (VOST). Samples of stack gases were drawn through a series of tenax traps and tenax/charcoal traps for approximately 20 min. Typically, six pairs of traps were collected sequentially during a run. Field blanks were exposed to the same environment at the time traps were inserted and replaced in the VOST apparatus. All traps were then spiked with internal standards and analyzed by gas chromatography/mass spectrometry.

The level of each constituent was determined by subtracting the level of toxicants in the blank from the level detected in the samples. A second evaluation did not correct for the level of toxicants detected in the blank. The correction for blank values did not appreciably alter the estimate of the concentration of toxicants in stack emissions (data not shown).

Many toxicants were not detected in all runs of a trial burn. In runs where a toxicant was not detected, the toxicant was assumed to be present at the detection limit for that run if it had been detected in another run of the trial burn or not present if the detection limit was not reported. In the second evaluation, the concentration of a compound was assumed to be zero in runs where it was not detected. Both approaches yielded essentially the same estimates of the concentration of toxicants in stack emissions (data not shown).

Once the concentration of toxicants in the stack emissions were ascertained, the emission rates from the stack were derived using the reported stack exhaust gas flow rates. The emission rates of the volatile compounds in combination with air dispersion modeling was employed to estimate the potential impact of the emissions on air quality.

Air Dispersion Modeling

Gridded, fine-scale air dispersion modeling was performed using the UNAMAP 6 version of the Industrial Source Complex Short Term (ISCST) model. Each incinerator was centered in a 5-km square grid with receptors spaced 100 m apart. The stack emissions from each facility were modeled by assuming that the incinerator was located at two locations in California: a large urban area and a rural location. Meteorological data from Los Angeles International Airport and Edwards Air Force Base were employed to model the air emissions for the urban and rural areas, respectively. A rural diffusion setting was employed in the ISCST model for the rural location, and an urban diffusion setting was employed to model the urban location. The maximum annual average concentration, as determined by air dispersion modeling, was used to assess the risk associated with each incinerator.

Determination of Risk

The results of the air modeling were evaluated using both a conventional method of risk assessment and the candidate screening criteria. The evaluation using a conventional method of risk assessment focused on determining the risk associated with exposure to volatile carcinogenic compounds. Each carcinogenic compound was evaluated by employing the most conservative identified ambient air criteria (when available) or a MEL derived from a drinking water criterion. The individual risk associated with exposure to each carcinogenic compound was cumulated to determine the aggregate risk associated with stack emissions [Eq. (1)]. Brominated compounds were assumed to exhibit the same toxicity and be equivalent in potency to comparable chlorinated compounds.

\[
\text{Aggregate Risk} = \sum \frac{\text{[compound } n\text{]}}{\text{criterion for } \text{compound } n} \tag{1}
\]

where [compound n] = the maximum annual average concentration of compound n based on air dispersion modeling.

The screening criteria were developed to evaluate the risk associated with total volatile emissions. The criteria were employed to evaluate the risk associated with total stack hydrocarbon emissions [Eqs. (2) and (3)]. Total hydrocarbon emissions, as measured by employing a flame ionization detector by cumulating total (FID) and as approximated semi-volatile and volatile compounds, were both evaluated. Comparisons were made between estimates of risk based on both measures of total hydrocarbon emissions and estimates based on conventional methods of risk assessment.

\[
\text{Risk} = \frac{[\text{THC}]}{\text{Screening criteria for MELs from ambient air criteria}} \cdot \frac{20}{20} \tag{2}
\]

\[
\text{Risk} = \frac{[\text{THC}]}{\text{Screening criteria for MELs from ambient air and drinking water criteria}} \cdot \frac{20}{20} \tag{3}
\]

where [THC] = the maximum annual average concentration of total hydrocarbon based on air dispersion modeling.

Results

Seven hundred assorted health-based criteria were compiled for the purpose of evaluating stack emissions from incinerators using health-based screening criteria. Candidate screening criteria were derived from available ambient air criteria, from MELs derived from ambient air criteria, or from MELs derived from both ambient air or drinking water criteria. The most potent, 95 % most potent, and 90 % most potent criterion or MEL were selected to constitute the candidate screening criteria (Appendix, Tables A1 and A2).

The set of candidate screening criteria based on ambient air criteria were virtually identical to the set of candidate screening criteria based on MELs derived from ambient air criteria. Therefore, only two sets of screening criteria need to examined to determine if they can be employed to evaluate the public health impacts of hazardous waste incinerators. Although developed using somewhat different approaches, the screening criteria based on MELs or ambient air criteria are quite similar (Table 4). The comparable screening criterion in each group differed at most by 33%.

| Table 4. Candidate screening criteria for volatile compounds. |
|-------------------------------------------------------------|
| Screening criteria | 100% | 95% | 90% |
| MEL, μg/day<sup>a</sup> | 0.0004 | 0.02 | 0.12 |
| Criteria, ppm<sup>b</sup> | 0.00002 | 0.0008 | 0.004 |

<sup>a</sup> Concentration or daily intake associated with 10<sup>-4</sup> risk.
<sup>b</sup> Screening criteria based on maximum exposure levels (MELs) derived from ambient air or drinking water criteria.
<sup>c</sup> Screening criteria based on ambient air criteria.
All of the MELs or ambient air criteria selected as screening criteria are based on the carcinogenic activity of the compound. Therefore, the evaluation of risk to the public health associated with incinerator emissions using the screening criteria is expressed as a risk of developing cancer.

Screening Criteria Based on Maximum Exposure Levels Derived from Ambient Air or Drinking Water Criteria

The screening criteria based on MELs were employed to evaluate the results of the air dispersion modeling of emissions from various incinerators. A conventional method of risk assessment was employed to evaluate the risk associated with carcinogenic volatile hydrocarbon emissions. The evaluation was undertaken for both an urban coastal environmental setting (Table 5) and a rural inland environment (Table 6).

The estimates of risk derived by employing the screening criteria varied considerably. The estimates of risk ranged from $60,000 \times 10^{-4}$ for the site G incinerator, based on the most potent MEL and an urban location, to $0.004 \times 10^{-4}$ for the Ogden, California, facility, based on the 90% most potent MEL and the facility being located in a rural inland environment.

Using $10^{-6}$ risk of developing cancer as a benchmark, the risk associated with stack emissions as delineated by the various screening criteria were compared. Based on meteorological data for a rural setting, 18 of the 19 facilities evaluated exceeded the $10^{-4}$ level of risk when the screening criterion for the most potent MEL was employed. Nine facilities exceeded a level of $10^{-6}$ risk based on the screening criterion established at the 95% most potent MEL. Three facilities exceeded a $10^{-6}$ risk using the screening criterion established at the 90% most potent MEL.

The risks associated with the incinerators based on meteorological data from the urban setting were considerably higher than those determined using data from the rural environment. All of the facilities exceeded a level of $10^{-6}$ risk using the screening criterion established at the most potent MEL. Twelve facilities exceeded a level of risk of $10^{-6}$ when the screening criterion established at the 95% most potent MEL was employed. Eight facilities exceeded a level of risk of $10^{-6}$ using a screening criterion established at the 90% most potent MEL.

Using a conventional method to estimate risk, only the emissions from one facility and only when the incinerator was located in an urban setting did the risk exceed $10^{-6}$ of developing cancer. In all instances the level of risk derived by employing any of the screening criteria markedly exceeded the level of risk derived using a conventional risk assessment methodology. The level of risk estimated by employing the 90% most potent MEL always exceeded the level of risk determined by a conventional method of risk assessment.

All three screening criteria yielded estimates risk that were significantly elevated above that determined by the conventional approach (chi square goodness of fit, $p < 0.05$). Of the three screening criteria, the level of risk delineated by the 90% most potent MEL most closely predicted the level of risk estimated by a conventional method of risk assessment (chi square goodness of fit).

Screening Criteria Based on Ambient Air Criteria

Estimates of risk employing screening criteria based on Federal and California ambient air criteria closely resembled that determined by using screening criteria based on MELs (data not shown). This result was expected, since both sets of screening criteria are similar. Employing a level of $10^{-6}$ risk as a benchmark, estimates of risk at four facilities derived by employing a screening criteria based on ambient air criteria slightly exceeded $10^{-6}$ where comparable estimates based on MELs did not exceed $10^{-6}$ risk.

Comparative to the evaluation based on screening criterion

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Table 5. Risk associated with stack emissions from hazardous waste incinerators located in an urban environment.*

| Facility            | Screening criteriab | Conventional method |
|---------------------|---------------------|---------------------|
|                     | 100%  | 95%  | 90%  |               |
| American Cyanamid   | 50    | 1    | 0.2  | 0.002          |
| Du Pont             | 1,000 | 20   | 4    | 0.2            |
| Mitchell            | 20    | 0.4  | 0.06 | 0.0009         |
| Zapata              | 40    | 0.7  | 0.1  | 0.005          |
| Trade Waste Incinerator | 600  | 10   | 2    | 0.09           |
| Rollins             | 2,000 | 40   | 7    | 0.9            |
| Florida Solite      | 80    | 2    | 0.3  | 0.00001        |
| Rockwell            | 7     | 0.1  | 0.02 | 0.00005        |
| Chevron             | 60    | 1    | 0.2  | 0.02           |
| Site B              | 50    | 1    | 0.2  | —              |
| Site C              | 2,000 | 40   | 6    | 0.005          |
| Site D              | 400   | 8    | 1    | 0.07           |
| Site E              | 4,000 | 80   | 10   | 0.4            |
| Site F              | 2,000 | 40   | 6    | 0.3            |
| Site G              | 60,000| 1000 | 200  | 4              |
| EPA research        | 300   | 5    | 1    | 0.06           |
| Dow                 | 4,000 | 90   | 20   | 0.3            |
| Ogden (Alaska)      | 200   | 4    | 0.6  | 0.003          |
| Ogden (California)  | 3     | 0.06 | 0.01 | 0.0002         |

*Results based on air dispersion modeling using Los Angeles International Airport meteorological data.  
*bScreening criteria derived from maximum exposure levels from both ambient air and drinking water criteria.  
*cResults expressed as risk ($\times 10^{-6}$).

Table 6. Risk associated with stack emissions from hazardous waste incinerators located in an urban environment.*

| Facility            | Screening criteriab | Conventional method |
|---------------------|---------------------|---------------------|
|                     | 100%  | 95%  | 90%  |               |
| American Cyanamid   | 20    | 0.5  | 0.08 | 0.001          |
| Du Pont             | 200   | 4    | 0.7  | 0.04           |
| Mitchell            | 6     | 0.1  | 0.02 | 0.0003         |
| Zapata              | 10    | 0.2  | 0.04 | 0.002          |
| Trade Waste Incinerator | 100  | 3    | 0.5  | 0.02           |
| Rollins             | 500   | 9    | 2    | 0.2            |
| Florida Solite      | 20    | 0.3  | 0.05 | 0.000002       |
| Rockwell            | 2     | 0.04 | 0.01 | 0.00001        |
| Chevron             | 10    | 0.3  | 0.04 | 0.004          |
| Site B              | 20    | 0.4  | 0.06 | —              |
| Site C              | 100   | 2    | 0.4  | 0.003          |
| Site D              | 100   | 2    | 0.3  | 0.02           |
| Site E              | 1000  | 20   | 4    | 0.1            |
| Site F              | 400   | 8    | 1    | 0.07           |
| Site G              | 20000 | 300  | 50   | 1              |
| EPA research        | 70    | 1    | 0.3  | 0.02           |
| Dow                 | 900   | 20   | 3    | 0.06           |
| Ogden (Alaska)      | 40    | 0.8  | 0.1  | 0.0007         |
| Ogden (California)  | 1     | 0.03 | 0.004| 0.00006        |

*Results based on air dispersion modeling using Edwards Air Force Base meteorological data.  
bScreening criteria derived from maximum exposure levels from both ambient air and drinking water criteria.  
cResults expressed as risk ($\times 10^{-6}$).
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derived from MELs, estimates of risk based on screening criteria derived from ambient air criteria always exceeded estimates using a conventional method of risk assessment. The screening criterion based on the 90% most potent ambient air criteria also yielded the best estimate of risk when compared to that derived by a conventional method of risk assessment (chi square goodness of fit analysis).

Flame Ionization Detector

At a limited number of facilities, total hydrocarbons in stack emissions were monitored using a flame ionization detector (FID). Air dispersion modeling was used to estimate the maximum annual average concentration of THC adjacent to the incinerator associated with the stack emissions. The risk associated with THC as determined using an FID were compared with that approximated by cumulating volatile and semivolatile compounds emitted from the stack (Table 7). The risk based on total THC as measured using an FID exceeded the risk based on THC as approximated by cumulating volatile and semi-volatile emissions by an order of magnitude for all of the facilities.

The feasibility of achieving stack THC emissions associated with $10^{-4}$ risk was investigated. Only one of seven incinerators achieved THC emissions associated with a risk level of $10^{-4}$ based on the use of the screening criterion (Table 8). However, at four facilities, total hydrocarbons were not detected, and therefore could have achieved a level of emissions associated with $10^{-4}$ risk. Only at two facilities did the levels of THC emissions substantially exceed levels associated with $10^{-4}$ risk.

### Table 7. Risk associated with stack total hydrocarbon (THC) emissions.

| Facility          | Risk $(10^{-4})$ | Volatiles and semivolatiles | Ratio FID to volatile + semivolatile |
|-------------------|------------------|------------------------------|------------------------------------|
| Trade Waste FID   | 5                | 0.5                          | 10                                 |
| Incinerator       | 100              | 0.7                          | 10                                 |
| Mitchell          | < 2              | 0.02                         | 100                                |
| Du Pont           | < 4              | 0.08                         | 50                                 |
| American Cyanamid | < 4              | 0.04                         | 100                                |
| Zapata            | 7                | 0.01                         | 700                                |
| Cincinnati        | 1                | 0.1                          | 10                                 |
| Ogden (Alaska)    | 4000             | 3                            | 1000                               |

*Risk determined using screening criterion based on the 90% most potent MEL derived from both ambient air and drinking water criteria.

**THC as determined using a flame ionization detector (FID).

THC as approximated by cumulating volatile and semivolatile compounds.

Based on air dispersion modeling using Edwards Air Force Base meteorological data.

Based on modeling provided in the report.

### Discussion

Many difficulties are usually encountered in an evaluation of the public health impacts associated with emissions from hazardous waste incinerators using conventional methods of risk assessment. Conventional methods require the identification and quantification of chemical constituents in stack emissions, an extremely difficult and expensive undertaking. Even if analytical procedures properly characterized various constituents in stack emissions, the lack of health-based criteria for many of these compounds complicates any evaluation of the risk associated with a hazardous waste incinerator.

The use of a screening criterion to assess the risk to the public health could alleviate many of the problems encountered when employing conventional methods. Only total hydrocarbon emissions may need to be measured, instead of the technically difficult and costly procedure of measuring the individual volatile hydrocarbons in stack emissions. This reduced requirement could facilitate a more routine monitoring of stack emissions.

### Screening Criteria

Various health-based criteria developed as the result of a wide range of mandated California and Federal programs were assembled to provide the basis for the screening criterion. This universe of health-based criteria was assembled because it was judged to best represent the diverse spectrum of chemicals that could be encountered in waste streams generated by industrial processes. From the assembled criteria for volatile compounds, three sets of candidate screening criteria were developed.

The screening criteria were employed to evaluate total hydrocarbon emissions. THC emissions and not the emissions of volatile compounds were evaluated using the screening criteria, even though only the volatile constituents were of concern. Although the evaluation for most of the facilities could have been limited to just volatile compounds, the monitoring of individual volatile compounds in stack emissions is very difficult. Since it had previously been shown that semivolatile components of THC do not present a significant threat to public health (10), an evaluation based on THC and not total volatile compounds could only yield a more conservative estimate of the risk.

Three sets of screening criteria were developed as candidates for a screening criterion. One set of candidate screening criteria is based on essentially unmodified ambient air criteria. The principal advantage associate with this set of candidate screening criteria is that existing criteria themselves provide a basis for evaluating incinerators. The major disadvantage stems from the limited number of criteria available that serve as the basis for the screening criterion. This group of screening criteria, based on the limit number of available ambient air criteria, was judged to least represent the universe of chemicals found in hazardous wastes.

A second group of candidate screening criteria was generated from MELs derived from ambient air criteria. The major advantage associated with this set of candidate screening criteria is that the MELs are based solely on health considerations. The principal disadvantage associated with this set of criteria is that only a limited number of ambient air criteria are available to provide a basis for the screening criterion. Since this set of screening
criteria was virtually identical to that derived directly from the ambient air criteria, no evaluation of the stack emissions was undertaken.

A third set of candidate screening criteria was based on MELs derived from both ambient air and drinking water criteria. The advantage of this approach is that many more criteria are available to provide the basis for the development of screening criteria. This group of screening criteria was judged to best represent the universe of chemicals that can be encountered in hazardous wastes generated by various industries. The major drawback associated with this set of criteria is that the drinking water criteria, which are usually based on studies where the toxicant was administered by an oral route, are employed to provide the basis of a screening criterion for air toxicants. Using toxicity data developed from a different medium of exposure is not without precedent since many criteria are based on studies where exposure occurred by a route or in a vehicle different from the medium of exposure. Problems can arise when extrapolating toxicity information from one medium of exposure to another. Some toxic effects observed following exposure to a toxicant in one medium may not be observed following exposure to the same toxicant in a different medium.

With the understanding that toxicity can be influenced by the route of exposure, studies where exposure occurred by one route have been employed to develop criteria for a different medium. Differences in toxicokinetics should be addressed when employing studies where exposure occurred from a different medium. Usually, differences in absorption are the major concern, although differences in metabolism should be investigated.

In general, ambient air criteria based on studies where the toxicant was administered by the oral route would be expected to provide a conservative basis for criteria aimed at evaluating long-term exposure to toxicants in air. Most criteria are based on low-level, long-term exposures to toxicants. More complete absorption would be generally be anticipated to result from exposure from the oral route when compared to exposure by the inhalation route.

The more rapid absorption that would be expected following exposure to a toxicant in air would be a major concern for high levels of exposure. The more rapid absorption resulting from exposure to the toxicant in air could result in acute toxic effects. However, these levels of exposure are much greater than the levels associated with criteria based on chronic toxicity. At the lower levels of exposure associated with most of the criteria developed to evaluate chronic exposure to toxicants, the total amount of absorption and not the rate of absorption is the critical issue in evaluating the potential impact on public health.

### Evaluating the Candidate Screening Criteria

The two sets of candidate screening criteria were employed to evaluate THC stack emissions from the various hazardous waste incinerators. THC emissions were measured at only a limited number of facilities using an FID detector. Therefore, THC emissions were approximated by cumulating the emissions of all volatile and semivolatile compounds. Both of these measures of THC were evaluated using the screening criteria.

**THC As Approximated by Volatiles and Semivolatiles**

While each of the three sets of candidate criteria have advantages and disadvantages, all could be employed to assess the impact of hazardous waste incinerators on the public health. As indicated earlier, any screening criterion should be as conservative in estimating the public health impact of an incinerator as conventional approaches of risk assessment typically employed to evaluated these facilities. Use of the screening criteria should also provide some important advantages for evaluating an incinerator when compared to a conventional approach of risk assessment. In order to determine if any of these screening criteria fulfill these conditions, it was necessary to compare an evaluation of incinerators based on the screening criteria with a conventional approach to risk assessment.

Both sets of screening criteria always yielded estimates of risk to the public health that were more conservative than a conventional method of risk assessment. Two screening criteria, the 90% most potent MEL or the 90% most potent ambient air criteria, provided the best estimate of risk when compared to a conventional method of risk assessment. Since the screening criterion based on MELs captures a much greater range of the universe of chemicals emitted from a stack, this criterion is considered to be the best choice for use as a screening criterion.

Estimates of risk based on the screening criterion would always exceed that determined by conventional methods of risk assessment if any compounds emitted from the stack are no more potent than the screening criterion. Only if compounds more potent than the screening criterion compose a large fraction of the total stack emissions would the use of the screening criterion underestimate risk.

**THC As Measured by an FID**

Estimates of risk based on THC as measured by an FID were substantially greater than that based on detected volatile and volatile emissions. Use of the FID yielded estimates of risk an order of magnitude greater than that based on using volatiles and semivolatiles. Very little information is available describing the nature of the compounds detected by the FID from the stack of a hazardous waste incinerator. A trial burn at the Dow incinerator focused on identifying all of the organic constituents emitted from the stack. A large portion of the organic emissions measured by the FID could be accounted for by the semivolatile, methane, and in some of the runs, ethylene (27) components of stack emissions. Other volatile compounds accounted for less than 10% of the mass of emissions detected by the FID.

The evaluation based on THC as measured by the FID resulted in at least a 10-fold increase in the estimate of risk when compared to that based on THC as approximated by volatile and semivolatile emissions. Both methods yielded estimates of risk considerably more conservative than conventional methods of risk assessment. Since the screening criterion is aimed at evaluating the risk associated with carcinogenic volatile emissions, THC as measured by the FID may substantially overestimate risk, because volatile carcinogenic emissions are a small portion of the compounds detected by an FID.
Sources of Uncertainty

Estimates of risk based on either employing a screening criterion or a conventional method of risk assessment appear to be influenced by the same sources of uncertainty. The difficulty of sampling hazardous waste incinerator stack emissions contributes to the uncertainty associated with both estimates of risk. Many of the source tests were undertaken to demonstrate the destruction and removal efficiency of the incinerators. Therefore, the analytical procedures were not designed to comprehensively characterize stack emissions. The uncertainty associated with the analytical procedures influenced the nature of the compounds detected and their respective emission rates, and, as a consequence, influenced the estimates of risk associated with the various incinerators.

In addition to the uncertainty associated with identifying and quantifying the emissions rates of various compounds in stack emissions, there are also the usual sources of uncertainty associated with estimating the risk associated with human exposure to toxicants. The screening criteria employed in the current study are based on available health based criteria developed by DHS and EPA. The methods employed to develop these health-based criteria are uncertain. Sources of uncertainty include whether the animal studies were properly designed, if the animal studies were adequately conducted, and how one selects one study as the basis the criterion when several are available. Other sources of uncertainty include how to select an appropriate method of extrapolating results in animals studies to estimate the risk associated with human exposures and what is the appropriate mathematical model to extrapolate results at high doses to lower exposure levels.

Conclusion

In this study, which evaluated 20 separate incinerators, the use of a screening criteria provided a conservative estimate of the risk associated with hydrocarbon emissions when compared to a conventional method of risk assessment. Use of a screening criteria would appear to simplify the evaluation of many hazardous waste incinerators and may facilitate the routine monitoring of these facilities by using an FID to assure that public health is not at significant risk.

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Appendix

Table A1. Ambient air criteria used to develop screening criteria.

| Compound                        | Criteria, µg/m³ | Agency* |
|---------------------------------|-----------------|---------|
| N-Nitrosodimethylamine          | 0.00002         | EPA/IRIS, 100 % |
| Hydrazine                       | 0.0002          | EPA/IRIS |
| Acrylamide                      | 0.0008          | EPA/IRIS, 95 % |
| Ethylene oxide                  | 0.003           | HAD/EPA |
| 1,3-Butadiene                   | 0.004           | EPA/IRIS, 90 % |
| 1,2-Dibromoethane               | 0.005           | EPA/IRIS |
| Acrylonitrile                   | 0.01            | EPA/IRIS |
| Ethylene oxide                  | 0.01            | ARB    |

(Continued)

Table A2. Maximum exposure levels (MEL) used to develop screening criteria.

| Compound                                      | Media | MEL, µg/m³ | Agency* |
|-----------------------------------------------|-------|------------|---------|
| N-Nitrosodimethylamine                        | Air   | 0.0004     | EPA/IRIS, 100 % |
| N-Nitrosodiethanol                            | Water | 0.0004     | EPA/IRIS |
| 1,2-Dibromoethane                             | Water | 0.0008     | EPA/IRIS |
| Ethylene dibromide                            | Water | 0.001      | MCLg/EPA |
| Diethylchloroform                              | Water | 0.0006     | Ambient water/EPA |
| Hydrazine                                     | Air   | 0.0004     | EPA/IRIS |
| N-Nitroso-N-methylaminic acid                 | Water | 0.004      | EPA/IRIS |
| N-Nitroso-N-propylamine                       | Water | 0.01       | EPA/IRIS |
| Acrylamide                                    | Water | 0.016      | EPA/IRIS |
| Acrylamide                                    | Air   | 0.016      | EPA/IRIS |
| Acrylamide                                    | Water | 0.019      | HA/EPA |
| Acrylamide                                    | Water | 0.02       | MCLg/EPA, 95 % |
| Vinyl chloride                                | Water | 0.03       | HA/EPA |
| Vinyl chloride                                | Water | 0.03       | HEA/EPA |
| Vinyl chloride                                | Water | 0.03       | MCLg/EPA |

(Continued)
| Compound | Media | MEL, µg/m³ | Agency* | Compound | Media | MEL, µg/m³ | Agency* |
|----------|-------|------------|---------|----------|-------|------------|---------|
| DBCP     | Water | 0.05       | HA/EPA  | Trichloroethylene | Water | 5.6        | Ambient water/EPA |
| DBCP     | Water | 0.05       | MCLg/EPA | Trichloroethylene | Water | 5.6        | MCLg/EPA |
| Ethylene oxide | Air | 0.059     | HAD/EPA | Methylene chloride | Water | 5.7        | HAD/EPA |
| 1,1-Dichloroethylene | Water | 0.062 | Water | Methylene chloride | Water | 5.9 | ARB |
| 1,3-Butadiene | Air | 0.08      | EPA/IRIS | Trichloroethylene | Water | 6        | HAD/EPA |
| 1,2-Dibromoethane | Air | 0.1 | 1,4-Dioxane | Water | 6 | EPA/IRIS |
| Acrylonitrile | Water | 0.12 | EPA/IRIS | Epichlorhydrin | Water | 6 | EPA/IRIS |
| 1,1-Dichloroethylene | Water | 0.12 | EPA/IRIS, 90% | Trichloroethylene | Water | 6 | EPA/IRIS |
| Acrylonitrile | Water | 0.13 | Ambient water/EPA | Epichlorhydrin | Water | 7 | MCLg/EPA |
| Acrylonitrile | Water | 0.14 | HAD/EPA | Epichlorhydrin | Water | 7.1 | HA/EPA |
| Acrylonitrile | Air | 0.2 | EPA/IRIS | Epichlorhydrin | Water | 7.1 | HA/EPA |
| Ethylene oxide | Air | 0.23 | ARB | Methacrylonitrile | Water | 8 | EPA/IRIS |
| Tetrachloroethane | Water | 0.35 | HEA/EPA | Chloroform | Water | 8.8 | AAL/TOXICS |
| 1,1,2,2-Tetrachloroethane | Water | 0.35 | Ambient water/EPA | Chloroform | Air | 8.6 | AAL/TOXICS |
| Chloroform | Water | 0.38 | Ambient water/EPA | Acetaldehyde | Water | 9.1 | HAD/EPA |
| Benzene | Water | 0.39 | AAL/TOXICS | Methylene chloride | Water | 9.5 | HAD/EPA |
| 1,3-Dichloropropene | Water | 0.4 | EPA/IRIS | Dichloromethane | Water | 10 | EPA/IRIS |
| 1,1,2,2-Tetrachloroethane | Water | 0.4 | EPA/IRIS | Trichloroethylene | Air | 11.7 | HEA/EPA |
| 1,1,2,2-Tetrachloroethane | Air | 0.4 | EPA/IRIS | Trichloroethylene | Air | 12 | HAD/EPA |
| 1,1-Dichloroethylene | Air | 0.4 | EPA/IRIS | Chloroform | Water | 12 | EPA/IRIS |
| 1,1-Dichloroethylene | Air | 0.48 | Chloroform | Water | 13 | AAL/TOXICS |
| 1,1-Dichloroethylene | Water | 0.48 | Chloroform | Water | 13 | AAL/TOXICS |
| Carbon tetrachloride | Air | 0.48 | Chloroform | Water | 16 | EPA/IRIS |
| Carbon tetrachloride | Water | 0.54 | HA/EPA | Trichloroethylene | Air | 16 | EPA/IRIS |
| Carbon tetrachloride | Water | 0.54 | HEA/EPA | Epichlorhydrin | Air | 16.7 | HAD/EPA |
| Carbon tetrachloride | Water | 0.54 | HEA/EPA | Methylene chloride | Water | 20 | PMCL/DHS |
| Ethylene dichloride | Air | 0.58 | ARB | Ethylene dichloride | Air | 20 | EPA/IRIS |
| Carbon tetrachloride | Water | 0.6 | MCLg/EPA | 1,1-Dichloroethylene | Water | 20 | PMCL/DHS |
| Carbon tetrachloride | Water | 0.6 | MCLg/EPA | 1,1-Dichloroethylene | Water | 60 | AL/DHS |
| 1,2-Dichloroethane | Water | 0.77 | HAD/EPA | 1,2-Dichloroethane | Water | 63 | PMCL/DHS |
| 1,2-Dichloroethane | Water | 0.77 | HAD/EPA | Pyridine | Water | 70 | EPA/IRIS |
| 1,2-Dichloroethane | Water | 0.8 | EPA/IRIS | Bromomethane | Water | 98 | EPA/IRIS |
| Carbon tetrachloride | Water | 0.85 | Ambient water/EPA | Chloral | Water | 98 | EPA/IRIS |
| Chloroform | Air | 0.87 | HAD/EPA | N,N-Dimethylaniline | Water | 150 | EPA/IRIS |
| Chloroform | Water | 0.87 | HAD/EPA | cis- and trans-Dichloroethylene | Water | 160 | AL/DHS |
| Chloroform | Water | 1 | HAD/EPA | 1,1-Dichloroethylene | Water | 175 | Ambient water/EPA |
| Chloroform | Water | 1 | HAD/EPA | 1,1-Dichloroethylene | Water | 190 | AL/DHS |
| 1,2-Dichloropropene | Water | 1.1 | HA/EPA | Furfural | Water | 190 | EPA/IRIS |
| 1,1,2-Trichloroethane | Water | 1.2 | HEA/EPA | Methylene chloride | Water | 200 | PMCL/DHS |
| Benzene | Water | 1.4 | Ambient water/EPA | Decabromodiphenyl ether | Water | 200 | EPA/IRIS |
| Benzene | Water | 1.4 | HAD/EPA | 1,4-Dibromobenzene | Water | 300 | EPA/IRIS |
| Tetrahydroethylene | Water | 1.4 | MCLg/EPA | Tetrachloroethylene | Water | 350 | EPA/IRIS |
| Benzene | Water | 1.4 | MCLg/EPA | Tetrachloroethylene | Water | 350 | EPA/IRIS |
| Carbon tetrachloride | Water | 1.4 | MCLg/EPA | 1,1-Dichloroethylene | Water | 810 | HEA/EPA |
| Benzene | Water | 1.5 | HAD/EPA | 1,2, 1,4-Dichlorobenzene | Water | 940 | Ambient water/EPA |
| Tetrahydroethylene | Water | 1.5 | HAD/EPA | Tetrachloroethylene | Water | 980 | EPA/IRIS |
| 1,2-Dichloroethane | Water | 1.9 | Ambient water/EPA | Acetaldehyde | Water | 1000 | AL/DHS |
| 1,4-Dichlorobenzene | Water | 2 | AL/DHS | Chlorobenzene | Water | 1000 | HEA/EPA |
| Benzene | Water | 2 | EPA/IRIS | Ethylene glycol monobutyl ether | Water | 1000 | PMCL/DHS |
| Benzene | Water | 2 | EPA/IRIS | Ethylene glycol monobutyl ether | Water | 1120 | HEA/EPA |
| Vinyl chloride | Air | 2.6 | HEA/EPA | Methylene chloride | Water | 1200 | EPA/IRIS |
| Benzene | Air | 2.9 | HEA/EPA | 1,2-Dichloroethylene | Water | 1250 | EPA/IRIS |
| Trichloroethylene | Water | 3.7 | HEA/EPA | Bromoform | Water | 1250 | EPA/IRIS |
| Vinyl chloride | Water | 4 | Ambient water/EPA | Styrene | Water | 1400 | MCLg/EPA |
| Dichloromethane | Air | 4 | EPA/IRIS | Dibromochloromethane | Water | 1500 | EPA/IRIS |
| Methylene chloride | Air | 4.9 | HEA/EPA | Ethylbenzene | Water | 1600 | Ambient water/EPA |
| Methylene chloride | Air | 4.9 | HEA/EPA | Ethylbenzene | Water | 1620 | HA/EPA |
| Trichloroethylene | Water | 5.6 | HEA/EPA | Ethylbenzene | Water | 1680 | AAL/TOXICS |

(Continued)
| Compound                        | Media      | MEL, µg/m³ | Agency*  |
|--------------------------------|------------|------------|----------|
| Ethylene glycol monomethyl ether | Air        | 1700       | HEA/EPA  |
| Methyl ethyl ketone             | Water      | 1720       | HA/EPA   |
| Xylene                         | Water      | 2000       | AAL/TOXICS |
| Xylene                         | Air        | 2000       | AAL/TOXICS |
| 1,1,2-Trichloroethane           | Water      | 2100       | EPA/IRIS  |
| Ethylbenzene                   | Air        | 2800       | AAL/TOXICS |
| Bromomethane                   | Water      | 2800       | Amb/EA    |
| Methyl ethyl ketone             | Water      | 3200       | EPA/IRIS  |
| Methyl isobutyl ketone          | Water      | 3500       | EPA/IRIS  |
| Methyl ethyl ketone             | Water      | 3530       | AAL/TOXICS |
| Cumene                         | Water      | 3600       | EPA/IRIS  |
| Chlorobenzene                  | Air        | 3700       | HEA/EPA   |
| Toluene                        | Water      | 4000       | AAL/TOXICS |
| Toluene                        | Air        | 4000       | AAL/TOXICS |
| Methyl ethyl ketone             | Air        | 5000       | AAL/TOXICS |
| Dichlorodifluoromethane         | Water      | 5600       | Amb/EA    |
| Acrylic acid                   | Water      | 5800       | EPA/IRIS  |
| Chlorobenzene                  | Water      | 6300       | HA/EPA    |
| 1,1,1-Trichloroethane           | Water      | 6300       | EPA/IRIS  |
| Xylene                         | Water      | 6740       | HPA       |
| Xylene                         | Water      | 6740       | MCLg/EPA  |
| Ethylbenzene                   | Water      | 6800       | AL/DHS    |
| Ethylbenzene                   | Water      | 6800       | H/EA      |
| Ethylbenzene                   | Water      | 6800       | MCLg/EPA  |
| Ethylbenzene                   | Water      | 6800       | EPA/IRIS  |
| Acetone                        | Water      | 7000       | EPA/IRIS  |
| Maleic anhydride                | Water      | 7000       | EPA/IRIS  |
| Nitric oxide                   | Water      | 7000       | EPA/IRIS  |
| Chloromethane                  | Water      | 7500       | Amb/EA    |
| para-Dichlorobenzene            | Water      | 7500       | H/EA      |
| para-Dichlorobenzene            | Water      | 7500       | MCLg/EPA  |
| Carbon disulfide                | Water      | 7700       | EPA/IRIS  |
| 1,1,1-Trichloroethane           | Water      | 8190       | MCLg/EPA  |
| tri-N-butanol                   | Water      | 8750       | H/EA      |
| 1,1-Dichloroethane             | Air        | 9700       | H/EA/EPA  |
| Benzenaldehyde                 | Water      | 10000      | EPA/IRIS  |
| Dichlorodifluoromethane         | Water      | 10000      | EPA/IRIS  |
| Cyclohexyamine                 | Water      | 13000      | H/EA      |
| Styrene                        | Water      | 14000      | H/EA      |
| Styrene                        | Water      | 14000      | H/EA      |
| Methyl ethyl ketone             | Air        | 15000      | H/EA/EPA  |
| Toluene                        | Water      | 20000      | H/EA/EPA  |
| Toluene                        | Water      | 20000      | EPA/IRIS  |
| Isobutyl alcohol               | Water      | 22000      | EPA/IRIS  |
| Trichlorofluoromethane          | Water      | 24000      | EPA/IRIS  |
| Methylene chloride             | Water      | 24800      | Amb/EA    |
| Toluene                        | Water      | 29500      | Amb/EA    |
| Ethylene glycol monomethyl ether | Water    | 32600      | H/EA/EPA  |
| Diethylene glycol monomethyl ether | Water     | 34300      | H/EA/EPA  |
| Caprolactam                     | Water      | 35000      | EPA/IRIS  |
| Malic hydrizine                 | Water      | 35000      | EPA/IRIS  |
| Methanol                       | Water      | 35000      | EPA/IRIS  |
| 1,1,1-Trichloroethane           | Water      | 37500      | Amb/EA    |
| Toluene                        | Water      | 40000      | H/EA      |
| Toluene                        | Air        | 40000      | H/EA      |
| Propylene glycol monomethyl ether | Water    | 40000      | H/EA/EPA  |
| Toluene                        | Water      | 40000      | MCLg/EPA  |
| Ethyl acetate                  | Water      | 63000      | EPA/IRIS  |
| Trichlorofluoromethane          | Water      | 64600      | Amb/EA    |
| Xylene                         | Air        | 82000      | H/EA/EPA  |
| Xylenes                        | Water      | 125000     | EPA/IRIS  |
| Ethylene glycol                 | Water      | 140000     | EPA/IRIS  |
| Formic acid                    | Water      | 140000     | EPA/IRIS  |
| Freon 11                       | Water      | 180000     | AL/DHS    |
| Acetone                        | Air        | 209600     | H/EA/EPA  |
| Cyclohexanone                  | Water      | 320000     | EPA/IRIS  |
| 1,1,1-Trichloroethane           | Water      | 375000     | H/EA/EPA  |

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