OAR Box 1787

Prepped by Ollie Stewart

Document Number:

5) II-A-5

Docket Number:

A-90-37

Contract No. 68-02-3889
Work Assignment No. 59

A-90-37
II-A-5

RECEIVED
JAN 25 1995
EPA AIR DOCKET

SUGGESTED APPROACHES FOR DETERMINING BEST AVAILABLE CONTROL TECHNOLOGY (BACT) AND LOWEST ACHIEVABLE EMISSION RATES (LAER)

(DRAFT)

January, 1986

Prepared for:

Mr. Gary McCutchen
New Source Review Section
Control Programs Development Division
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Prepared by:

Radian Corporation
P.O. Box 13000
Research Triangle Park, NC 27709

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

Draft 1
1/22/6

1.0 Introduction

This manual is intended for use by individuals involved in New Source Review (NSR) and Prevention of Significant Deterioration (PSD) permitting. A rudimentary knowledge of the permitting process for new sources of air emissions is required. Specifically, individuals should have a basic understanding of two things: the process by which New Source Performance Standards (NSPS) are developed and the requirements of Best Available Control Technology (BACT).

The manual is divided into two sections. The first section analyzes the BACT portions of all PSD permits issued in the U.S. between 1981 and 1984. The ultimate goal of this analysis is to determine whether requiring PSD applicants to consider applicable control alternatives would result in more stringent BACT emission rates.

The second section discusses the PSD permitting process and highlights those portions of PSD applications that are most relevant to BACT decision-making. A subsection examines how toxic air pollutants (TAPs) might be best folded into the BACT process. Included are an examination of TAP control technologies and suggestions for ways to evaluate TAP health risks. Four Appendices are also included. Appendix A describes references that may assist those responsible for preparing and evaluating PSD permit applications. Appendix B lists 402 chemicals recently listed by EPA as acutely toxic and Appendix C contains information on known and suspected human carcinogens. Appendix D lists source categories by SIC code and the toxic air pollutants typically associated with those sources.

2.0 VALUE OF REQUIRING BACT ALTERNATIVES

This first section analyzes PSD permits to determine whether the stringency of BACT decisions is related in any way to the number of BACT options considered either by the applicant or the review agency. Evidence from PSD permits issued from 1981 through 1984 suggests that more stringent emission controls may result when two or more control alternatives are considered for particulate matter (PM), oxides of nitrogen (NO_x), or sulfur dioxide (SO_2). However, similiar conclusions cannot be made for carbon monoxide (CO) because alternatives were considered in only a few of the BACT analyses for CO emissions in permits issued between 1981 and 1984 (Hayes, 1985). Similarly, it is difficult to assess degrees of stringency for many VOC control options because their control efficiencies are difficult to quantify.

In the following comparison, all BACT analyses in the PSD permits were divided into one of three categories based on the number of BACT options considered:

- zero alternatives,
- one alternative, and
- two or more alternatives.

Control stringency was analyzed by comparing permits with one BACT alternative to permits containing two or more alternatives. The zero alternative permits were omitted from the analysis for reasons discussed below.

2.1 PSD PERMITS WITH NO BACT ALTERNATIVES

There are a number of reasons why no BACT alternatives are considered in many PSD applications. Some PSD permits simply d~~ue~~o not completely fulfill all BACT analysis requirements. This is apparent when no control alternatives are considered and the proposed BACT control is generally not the "best" control.

For certain pollutants, emission controls options are very limited. For these pollutants or processes, only one feasible control option may exist. For example, there are few control alternatives (other than incineration) for CO emissions.

Certain PM, SO_2, and NO_x emission controls have become unofficially accepted as being the "best". For instance, for PM, a fabric filter or high efficiency electrostatic precipitator has become a standard "best" PM control device for stack (not fugitive) emissions. Whenever the "best" control device is preselected by the applicant, and no significant environmental, energy, or economic impacts exist, the applicant generally does not analyze alternatives.

As one would expect, BACT stringency often exceeds the NSPS level when the "best" control is selected. As shown in Table 2-1, for PM and SO_2, a relatively high percentage of the "zero" alternative PSD permits show BACT to be more stringent than the relevant NSPS level.

2.2 PSD PERMITS WITH ONE CONTROL ALTERNATIVE

Compared to those PSD permits that consider no BACT alternatives, permits that consider one alternative tend to be less stringent. In fact, it appears that the BACT analyses wherein only one alternative is presented results in the least stringent controls. Table 2-1 compares, for PM, SO_2, and NO_x, the stringency of BACT relative to NSPS to the number of BACT control options considered. For all three pollutants, the percentage of "zero" alternative permits with a BACT rate more stringent than the applicable NSPS is greater than when only one alternative was considered. Although this result appears to be counterintuitive, there is a logical explanation.

A common instance of "one alternative" BACT analyses appears to be when the BACT control level has been pre-determined by the applicant. In these cases, the chosen BACT control is usually less stringent than the "best" technology and may or may not be equal to the NSPS level. In such circumstances, the applicant may include one alternative in an effort to justify the preselected BACT option. Since preselected BACT levels are generally less restrictive than

Draft 1
1/22/6

TABLE 2-1. BACT DECISIONS INVOLVING THE NSPS FOR PM, SO_2, AND NO_x
(From 397 PSD Permits Issued from 1981 - 1984)

		Number of Control Alternatives		
Pollutant	Status	Zero	One	More than 1
PM	BACT Rate = NSPS	64	14	29
	BACT Rate more stringent than NSPS	44	4	16
	Percent more stringent	41	22	36
NO_x	BACT Rate = NSPS	109	85	53
	BACT Rate more stringent than NSPS	14	4	27
	Percent more stringent	11	4	34
SO_2	BACT Rate = NSPS	101	22	29
	BACT Rate more stringent than NSPS	164	5	10
	Percent more stringent	62	19	26

Source: Hayes, 1985; pp. 82-84

those attainable with the "best" technology, the one alternative option is likely to be less restrictive than the "no alternative" control option.

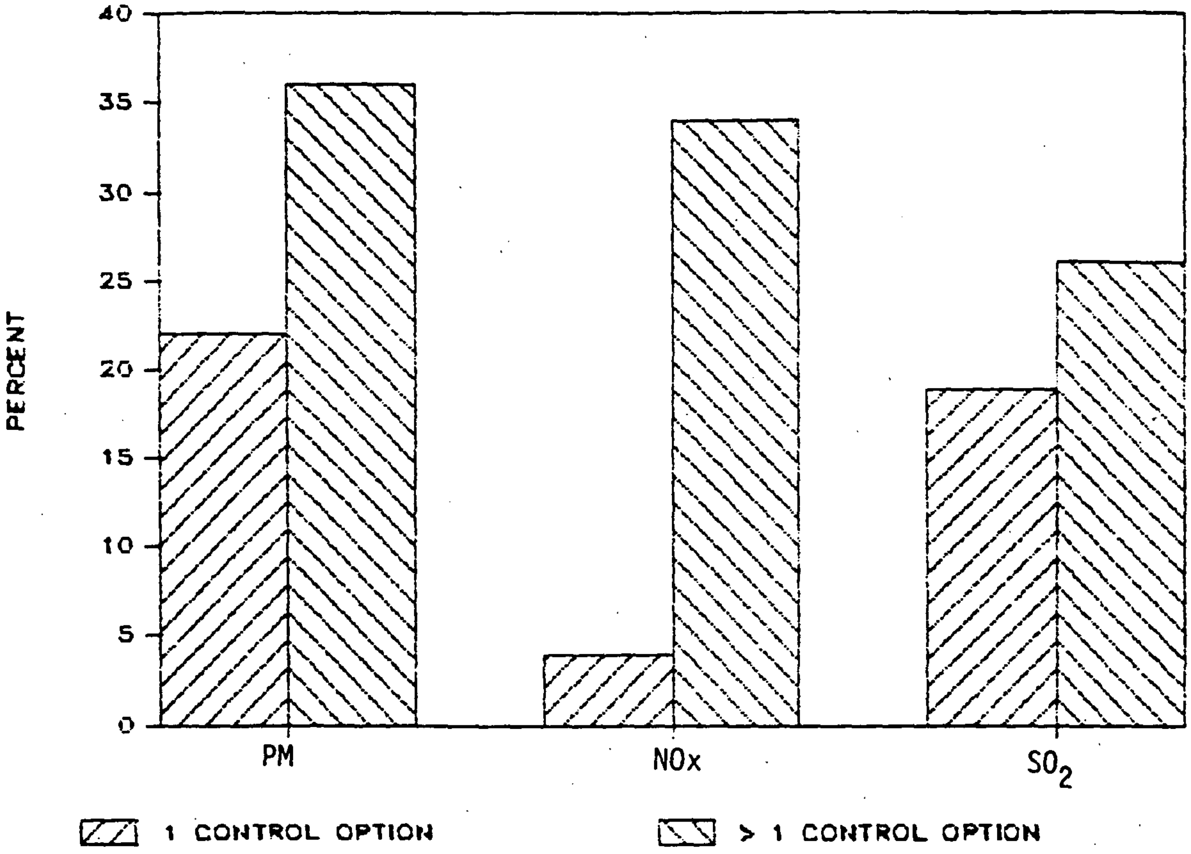
2.3 PSD PERMITS WITH TWO OR MORE CONTROL ALTERNATIVES

Since many "zero alternative" permits already have the "best" controls, comparing zero alternative permits to those with one or more alternatives is clearly incorrect and will likely produce misleading results. Instead, "one alternative" permits are used as the baseline case for comparison to the two or more alternatives case. As compared to permits with one BACT alternative, permits that include more than one alternative are more likely to have considered more alternatives as potential BACT control options.

Figure 2-1 shows those BACT decisions where the permitted control technology is more stringent than the applicable NSPS comparing those cases wherein one and more than one control options were considered. The percent of PM, SO_2, and NO_x BACT decisions more restrictive than the NSPS for the one control alternative is compared to the two or more alternative case. For each pollutant, the percent of BACT decisions more stringent than the NSPS is higher when two or more alternatives are considered than when only one alternative is considered.

These results suggest that those responsible for PSD permitting should require analysis of all potentially applicable control options, especially when considering BACT for PM, SO_2, or NO_x emissions. This would result in more meaningful data and more options upon which to make sound BACT decisions.

FIGURE 2.1. BACT DECISIONS MORE STRINGENT THAN NSPS



Source: Hayes, 1985; pp. 82-84

Draft 1
1/22/6

3.0 APPROACHES TO BACT/LAER ANALYSIS

The prevention of significant deterioration (PSD) regulations are designed to maintain air quality in areas already having clean air. An area is attainment for a particular pollutant if the concentration of the pollutant in the area is below the level designated by the National Ambient Air Quality Standards (NAAQS).

PSD regulations apply to all areas designated either "attainment" or unclassified for any criteria pollutant. For example, suppose a hypothetical county was attainment for SO_2 but nonattainment for PM. A new industrial source wishing to locate in this county whose only emissions were PM would not be subject to PSD regulations, although the source would have to comply with nonattainment portions of the state implementation plan (SIP) including lowest achievable emission rates (LAER) and emission offsets. However, if this source also emitted SO_2 in significant amounts, then that source would be required to also obtain a PSD permit for SO_2 prior to commencing construction.

Every potential source subject to PSD regulations must perform the following three analyses for each pollutant emitted in significant quantities:

- a BACT analysis,
- an air quality impacts analysis, and
- an additional impacts analysis.

Each of these is discussed in detail in the PSD Workshop Manual (EPA, 1980). Specific portions of the BACT and the additional impacts analysis not covered in the PSD Workshop Manual are discussed below as well as some suggestions for other approaches to these analyses.

Two similar yet slightly different approaches are available for determining BACT and LAER: the "bottom-up" and the "top-down" approach. The differences in these two approaches are discussed below and an example is provided to illustrate the differences.

3.1 BACT BOTTOM-UP APPROACH

The bottom up approach for determining the BACT (and LAER) is discussed in detail in the PSD Workshop Manual issued in October 1980 by EPA's Office of Air, Noise, and Radiation and the Office of Air Quality Planning and Standards (EPA, 1980). The steps in the bottom up approach are discussed briefly below, followed by an example.

The first step in the bottom up approach is to determine the pollutants and the emission units subject to BACT (and LAER). Such units can include either process or fugitive emissions but not secondary emissions. Secondary emissions are those that result indirectly from construction at a major source but are not under direct control of the source.

In the next step, a base case is chosen that reflects the control option that would have been either required or chosen in the absence of BACT (or LAER) decisionmaking. Alternative control strategies more stringent than the base case are then chosen that have been demonstrated to operate efficiently on identical or similiar processes. Control alternatives can be identified in sources such as the BACT/LAER Clearinghouse, the California Air Resources Board Automated Air Database or the Radian/EPA New Source Review Database. The chosen alternatives should afford greater levels of control than the base case. Each control option should be evaluated for its (1) economic (2) energy and (3) environmental impacts. The control strategy with the lowest level of overall impacts for the cost is generally considered to be BACT.

In the following example, the proposed project consists of installation and operation of a new 260 million Btu/hr coal-fired boiler at an industrial site in eastern North Carolina. Coal will be transported to the site by rail and stored in a 1.5 acre coal storage pile.

The first step in the PSD permitting process is to determine which pollutants emitted by the source must be analyzed for BACT. Table 3-2 gives the criteria pollutant emission increases for the new boiler. The net increase in emissions exceeds the PSD de minimus emission rate for SO_2, NO_x, and PM.

TABLE 3-2. CRITERIA POLLUTANT EMISSIONS FROM A 260 MILLION BTU PER HOUR COAL-FIRED BOILER

Criteria Pollutant	Net Increase (tons/year)	PSD Significant Emission Rate (tons/year)
SO_2	730.4	40
NO_x	520.6	40
PM	320.1	25
CO	92.6	100
VOC	6.5	40
Pb	0.5	0.6

The following section analyzes only the BACT for PM emitted from the boiler. A complete PSD application would include a BACT analysis for SO_2, NO_x, and PM emitted from the boiler and for PM for each point in the coal and ash handling process from which PM emissions are released.

Table 3-3 lists the most common alternative controls for PM emissions from the boiler. An alternative control strategy, to be considered as BACT, cannot produce emissions in excess of any applicable NSPS or the allowable emission levels of an applicable SIP. The new source performance standards limit PM emissions to 0.10 lb per million Btu heat input (40 CFR 60.42) from fossil-fuel-fired steam generators of more than 250 million Btu per hour. As shown in Table 3-3, only the multiclone cannot meet the NSPS level of 0.10 lb per million Btu. Thus, each control alternative except the multiclone is included in the analysis of BACT.

The next step is to determine which control technologies or strategies best control PM emissions from boilers. The scrubber is choosen as the baseline control technology because it offers the lowest control level while still being no less restrictive than the applicable NSPS. Each control is then evaluated for its economic, energy and environmental impacts.

Table 3-4 shows the estimated economic impacts of the control alternatives and Table 3-5 shows the controlled total PM emissions and incremental emissions in tons per year. Based on the numbers developed in these tables, cost-effectiveness values in dollars per ton can be calculated. Table 3-6 shows both cost-effectiveness and incremental cost-effectiveness values. The low-efficiency ESP has the lowest total and incremental cost-effectiveness values.

The next step involves estimating the energy impacts of each PM control alternative. Energy consumption is shown in Table 3-7. Only direct energy consumption is considered. Energy consumption used for industrial processes, such as the associated energy costs for manufacturing process materials, is not considered. Energy consumption is also considered when calculating the operating costs in the economic impacts analysis. The low- efficiency ESP unit is shown

TABLE 3-3. PM CONTROL EMISSION RATES

PM Control Strategies	Emission Rate (#/MM Btu Heat Input)	Percent Reduction
Multicyclone	0.15	85
Scrubber	0.10	90
Low-Efficiency ESP	0.08	95
High-Efficiency ESP	0.03	99
Fabric Filter	0.03	99

TABLE 3-4. ECONOMIC IMPACTS FOR PM CONTROL ON A 260 MM BTU/HR COAL-FIRED BOILER

Alternative	Annualized Costs ($1,000/yr) Total	 Incremental*
Scrubber	554.3	-
Low-efficiency ESP	525.6	-28.7
High-efficiency ESP	797.0	242.7
Fabric Filter	813.0	258.3

*As compared to baseline costs of scrubber

TABLE 3-5. PM EMISSION IMPACTS FOR PM CONTROLS ON A 260 MM BTU/HR COAL-FIRED BOILER

PM Control	Controlled PM Emissions (Tons/year) Emission Reduction	Incremental Reduction*
Scrubber	3200.0	-
Low-efficiency ESP	3377.8	177.8
High-efficiency ESP	3520.0	320.0
Fabric Filter	3520.0	320.0

*As compared to baseline emission reduction of scrubber.

TABLE 3-6. COST-EFFECTIVENESS OF PM CONTROLS ON A 260 MM BTU COAL-FIRED BOILER

Control Alternative	Total Annual Costs	PM Emissions Reduction	Cost Effect. ($/ton)	Incremental Cost Effect. ($/ton)
Scrubber	554,000	3200.0	173.2	-
Low-efficiency ESP	525,600	3377.8	155.6	(-161.1)
High-efficiency ESP	797,000	3520.0	226.4	758.6
Fabric Filter	813,000	3520.0	231.0	808.6

*Incremental cost-effectiveness calculated by dividing difference in annual costs by difference in emissions reduction.

Draft 1
1/22/6

TABLE 3-7. DIRECT TOTAL ENERGY CONSUMPTION FOR PM CONTROLS ON A 260 MM BTU/HR COAL-FIRED BOILER

Control Alternatives	Energy Consumption (MM Btu/yr)	Incremental* Energy Consumption (MM Btu/yr)
Scrubber	2,450	-
Low-efficiency ESP	596	-1,854
High-efficiency ESP	2,200	- 250
Fabric Filter	2,300	- 150

*As compared to scrubber energy consumption to have the lowest energy impacts. Both the high-efficiency ESP and the fabric filter consume less energy than the scrubber but more energy than the low-effiency ESP.

The environmental impacts of each alternative must also be considered. The applicant must assess the relative ambient air impacts of PM emissions by estimating stack parameters for each alternative in order to create input for a dispersion model. The modeling results show that, under the worst-case meterological conditions, the ambient impacts of PM from the scrubber is significantly different from the remaining three alternatives. In addition, the scrubber creates wastewater disposal problems while the other three alternatives create fly ash disposal problems. The level of these environmental impacts can be seem in Table 3-8.

To determine BACT, the economic, energy, and environmental impacts are evaluated against each other. Table 3-9 contains the impacts for each assessment category. As shown in Table 3-9, the low efficiency ESP unit is clearly favorable to the scrubber in terms of economic, environmental, and energy impacts. The low efficiency ESP also is favored over the high-efficiency ESP and the fabric filter due to its lower economic and energy impacts. The low-efficiency ESP has a higher predicted maximum ground level concentration but the difference is insignificant. Based on these results, the low-efficiency ESP is chosen as BACT for PM emissions from the coal fired boiler.

3.2 BACT TOP-DOWN APPROACH

The top-down approach to determine BACT (and LAER) works as follows. The first step is to determine, for the emission source in question, the most stringent BACT for a similiar or identical source type. The most stringent BACT/LAER level is best determined from information sources such as the BACT/LAER Clearinghouse, the California Resources Board Automated Air Database or the Radian/EPA New Source Review Database. If it can be proven that the chosen BACT is not applicable or is technically or economically infeasible for the source in question, the next most stringent BACT is choosen. The process continues until the BACT/LAER level can not be eliminated.

TABLE 8. ENVIRONMENTAL IMPACTS OF PM CONTROL ALTERNATIVES ON A 260 MM BTU COAL-FIRED BOILER

Control Alternatives	Maximum GLC* Impacts (ug/m^3)	Other Impacts
Scrubber	6.9	Wastewater discharge
Low-efficiency ESP	2.1	3377.8 tons/yr ash disposal
High-efficiency ESP	1.5	3520.0 tons/yr ash dispsoal
Fabric Filter	1.7	3520.0 tons/yr ash disposal

*Ground level concentration

TABLE 3-9. COMPARISON OF PM CONTROL STRATEGIES

			Economic		Environmental			Energy Impacts	
Emission Rate (lbs/m^2)	Control Alternative	% Red	$/ton Incremental	$/ton total	Max GLC Impacts	Impact Area (km)	Other Impacts	Btu/yr Increment	Btu/yr Total
0.10	Scrubber	90	---	173.2	6.9	12	Wastewater Disposal	3200	---
0.08	Low Efficiency ESP	95	(-161.1)	155.6	2.1	8	3377.8 tpy fly ash disposal	596	-2,604
0.03	Bagfilter	99	758.6	226.4	1.5	6	3520.0 tpy fly ash disposal	2200	-1,000
0.03	High Efficiency ESP	99	808.6	231.0	1.7	6	3520.0 tpy fly ash disposal	2300	-900
0.15	Multiclone	85	-- not evaluated --		-- not evaluated--			--not evaluated	

The following analysis uses the top-down approach to find the BACT for PM emitted by the same 260 MM Btu per hour coal-fired boiler proposed for eastern North Carolina. Close examination of the BACT/LAER Clearinghouse shows that the most restrictive BACT emission limit for a boiler of this size uses a fabric filter and dry scrubber in sequence to obtain 0.02 lbs PM per million Btu heat input.

Upon further analysis, the emission level of 0.02 lbs PM per MMBtu heat input is found to be for a one thousand m^2 Btu per hour electric utility coal-fired boiler located in south central Colorado. The control level is extremely stringent due to the proposed location of the boiler within 50 kilometers of two Class I areas.

The situation for the proposed North Carolina boiler differs from that of the Colorado boiler in the following ways. The new North Carolina boiler will be located in an area over 200 kilometers from the nearest Class I area compared to the Colorado boiler located within 50 kilometers of two Class I areas. In addition, the mountain terrain of Colorado dictates a different modeling approach than that used for the flat coastal plains of eastern North Carolina. The differing circumstances between the North Carolina versus Colorado boilers with regard to their source types (industrial and utility boilers), Class I area proximity and air quality modeling are each alone serious enough to eliminate further consideration of the most restrictive PM BACT as applicable to the North Carolina boiler.

In addition, the proposed boiler is but one fourth the size of the boiler with the most restrictive PM BACT. Since many control technologies have economies of scale, the most cost-effective controls for one size of boiler may not be the most cost effective for a boiler of a significantly different size. Although control costs and cost-effectiveness do not enter into top-down decision-making as often as in the bottom-up approach, in certain instances control costs may become the determining factor.

When plant or process size is the only major difference between the most restrictive BACT and the proposed BACT, a detailed cost-analysis may be necessary. If the most stringent BACT is for a process significantly larger than the proposed project, it is important that the costs of the most restrictive BACT be analyzed to determine whether any economies of scale inherent in the larger project disappear for the smaller proposed project.

The most restrictive BACT might be disregarded for any of the reasons just discussed. When all of the reasons are combined, it is clear that the most restrictive BACT level should be disregarded in favor of the next most stringent BACT level.

The next most restrictive BACT PM control for coal-fired boilers shows an emission limit of 0.0350 lbs PM per MM Btu using a high-efficiency ESP. This emission level (of 0.035 lbs per MM Btu heat input) is found to be for a utility boiler operating at 500 MM Btu heat input per hour burning a coal with extremely low resistivity. The high efficiency of this BACT option is due in large part to the low resistivity of the coal. The proposed new boiler for North Carolina plans to burn a coal with a much higher resistivity. Because the coal is highly resistive, the use of a high-efficiency ESP cannot meet the control level of 0.035 lbs PM per MM Btu heat input. One solution to this approach is to mix low and high resistivity coal to obtain a combination such that an ESP can be effectively used. Upon further study, it was found that low resistivity coal was unavailable at a competitive price. Due to these technical and economic constraints, this control option is dropped from further consideration and the next most restrictive option is examined.

The next most restrictive control option for coal-fired boilers was found to equal 0.05 lbs per MMBtu using a fabric filter. The fabric filter is installed on a boiler of 320 MM Btu per hour in an area with terrain similiar to that of the proposed boiler. The 0.05 lbs per MMBtu BACT boiler also burns a coal quite similiar to that proposed for the new boiler. No serious technical, environmental, or economic objections could be found to eliminate this BACT control level. Thus, a fabric filter capable of achieving 0.05 lbs per MM Btu heat input is choosen as BACT for the proposed 260 MM Btu per hour coal fired boiler.

It seems apparent that the bottom-up versus top-down approaches may not result in the same emission control level. The bottom-up approach could result in less restrictive BACT levels vis-a-vis the top-down approach, primarily because the bottom-up approach starts with the least restrictive allowable control while the top-down starts with the most restrictive control level. However, if all feasible control alternatives were required to be analyzed with the bottom-up approach, this bias may be eliminated.

3.3 TOXIC AIR POLLUTANTS (TAPs)

Toxic air emissions are an area of increasing concern to individuals involved in air permitting. As the air toxics problem grows in importance, permit engineers must deal with new emissions of toxic air pollutants within the framework of PSD regulations. The following section discusses when to consider TAPs, lists control device features to consider when dealing with TAPs, and suggests methods for evaluating the risk of human exposure to TAPs.

3.3.1 When To Consider TAPs

The first air toxics question regulators face when dealing with PSD permits is: When should TAPs be considered in the PSD decisionmaking process? Any emission level of a TAP, especially if the TAP is carcinogenic, warrants the attention of the permit authorities. Even if the TAP is not carcinogenic, the non-cancer health risk imposed on the population may require evaluation.

Pollutants defined as toxic can generally be classified as either PM or VOCs. At a minimum, TAPs should be regulated under PSD programs as species of the criteria pollutants whenever the criteria pollutants are subject to review. The environmental impacts of toxic species are important, especially when such impacts differ from those of the criteria pollutant. Some toxic compounds can pose significant health risks even when emitted in small amounts. The BACT decision process provides the opportunity to minimize risks to human health by controlling TAP emissions.

The key to taking advantage of this opportunity is understanding the physical and chemical properties of toxic species and how they affect the degree of control afforded by conventional emission control systems. Large gains in toxic pollutant control can be achieved simply by selecting the control strategy that optimizes control of the toxic species and which does not sigificantly impact either the overall efficiency or cost of PM or VOC control.

Although actual test data are limited, optimizing toxic emissions control starts with understanding the process by which the toxic compounds are generated and the environment in which they are available to be reduced. Next, a general understanding is needed of how traditional control devices will behave on individual compounds. Much of this understanding is derived on theoretical bases and is now becoming better understood with actual test data and parametric studies. In many cases, control alternatives achieve the same degree of PM or VOC control for about the same cost. However, if one option is more effective in controlling toxic specie(s), then that fact should be considered in the final analysis.

3.3.2 Techniques For Identifying Substances As TAPs

One of the first objectives in optimizing toxic emissions control is to understand what substances are classified as toxic and which industrial processes produce these substances. The tables in Appendices B, C, and D can help meet these objectives.

Appendix B lists 402 chemicals recently designated as acutely toxic by EPA. The EPA list contains both carcinogenic and non-carcinogenic substances. Appendix C contains three separate tables listing known human carcinogens (Table C-1), probable human carcinogens (Table C-2), and potential human carcinogens (Table C-3). The three appendix C tables also describe the most common processes from which each chemical is produced and the unit risk factor for each substance (if one exists). Unit risk factors are discussed in detail in Section 3.3.5. Appendix D lists source categories by SIC code and the toxic air pollutants associated with each source category. Appendix D is helpful when one is attempting to identify potential pollutants from a particular industrial process. A fourth source useful for determining whether a substance should be classified as a TAP is the threshold limit value tables published by the American Conference of Governmental and Industrial Hygienists (ACGIH, 1984).

The substances listed by ACGIH are those commonly found in the workroom environment and include both carcinogenic and non-carcinogenic substances. Based on the tables found in Appendices B, C and D, and the substances listed by ACGIH, permit officials can determine whether a potential new source will likely emit substances that can be classified as TAPs.

3.3.3 Toxic PM Control

The removal efficiency of the toxic components of particulate matter relative to the overall removal by PM control devices depends on a number of physical and chemical factors:

- the boiling point of the toxic substance,
- the toxic particle size distribution in the emission stream,
- the toxic particle density, and
- the resistivity of the TAP.

Each of these factors and how they govern actual control efficiency is discussed below and summarized in Table 3-10.

Figure 3-2 illustrates average collection efficiencies for various particulate removal equipment. Fabric filters have the highest removal efficiencies for particles of less than 1 micron in size. Since a large variety of toxic PM is emitted at smaller particle sizes, fabric filters are able to achieve high levels of TAP emission reduction.

The size distribution of TAPs emitted by coal and oil fired boilers has been widely studied by a number of investigators. One widely held theory designed to explain trace element behavior in coal combustion systems is the volatilization/condensation mechanism (VCM). The VCM theory states that volatile species are vaporized and later condense or absorb onto existing particles according to the available surface area or condense homogeneously forming fine particles (Baig, 1981; p.3-13).

The VCM theory describes why trace elements found in coal combustion are enriched on small particles. For vaporized toxics, the concentration on ash particles increases as ash particle size decreases. Smaller particles have a higher surface area relative to

TABLE 3-10. KEY EMISSION STREAM AND TAP CONSIDERATIONS FOR SELECTING CONTROL DEVICES FOR PARTICULATE MATTER FROM POINT SOURCES

Control Device	Achievable Efficiency Range	Particle Size Limits	Temperature	Corrosiveness/ Resistively	Monitoring Content	Pressure Drop	Additional Considerations
Venturi Scrubber	Up to 99+%	Operates best with >0.5u diameter.	No general limits.	Special construction required for corrosive emission streams.	Insensitive to changes in moisture content of emissions stream.	$\geq$ 40" H_2O. Pressure drop must be increased for smaller particle particle size capture.	Can simultaneously collect particles and gaseous matter.
ESP	Up to 99+%	Least efficient w/particles $\geq$.2u - $\leq$.5u in diameter.	Up to 1000°F	Corrosion resistant materials may be required. May require conditioning agents for highly resistive particles cannot be used to control organic matter due to fire hazard.	Sensitive to moisture changes. Can be designed to control streams with high moisture content (i.e., 34% vol).	$\cong$ 0.5" H_2O.	Wet ESPs can collect gasesours pollutants.
Fabric Filter	Up to 99%	Least efficient w/particles $\geq$.1M - $\leq$.3u in diameter. Mechanical collectors required upstream if sig. amounts of large particles (>20u) present.	Depends on fabric type but cannot exceed 550°F w/o precooler.	Special fiber types necessary to resist corrosion.	Extremely sensitive to changes in moisture changes. Poor efficiency with streams of high moisture content.	2-6" H_2O.	Control efficiency generally independent of inlet loading.

Source: Purcell, 1985; pp. 3-37 - 3-39

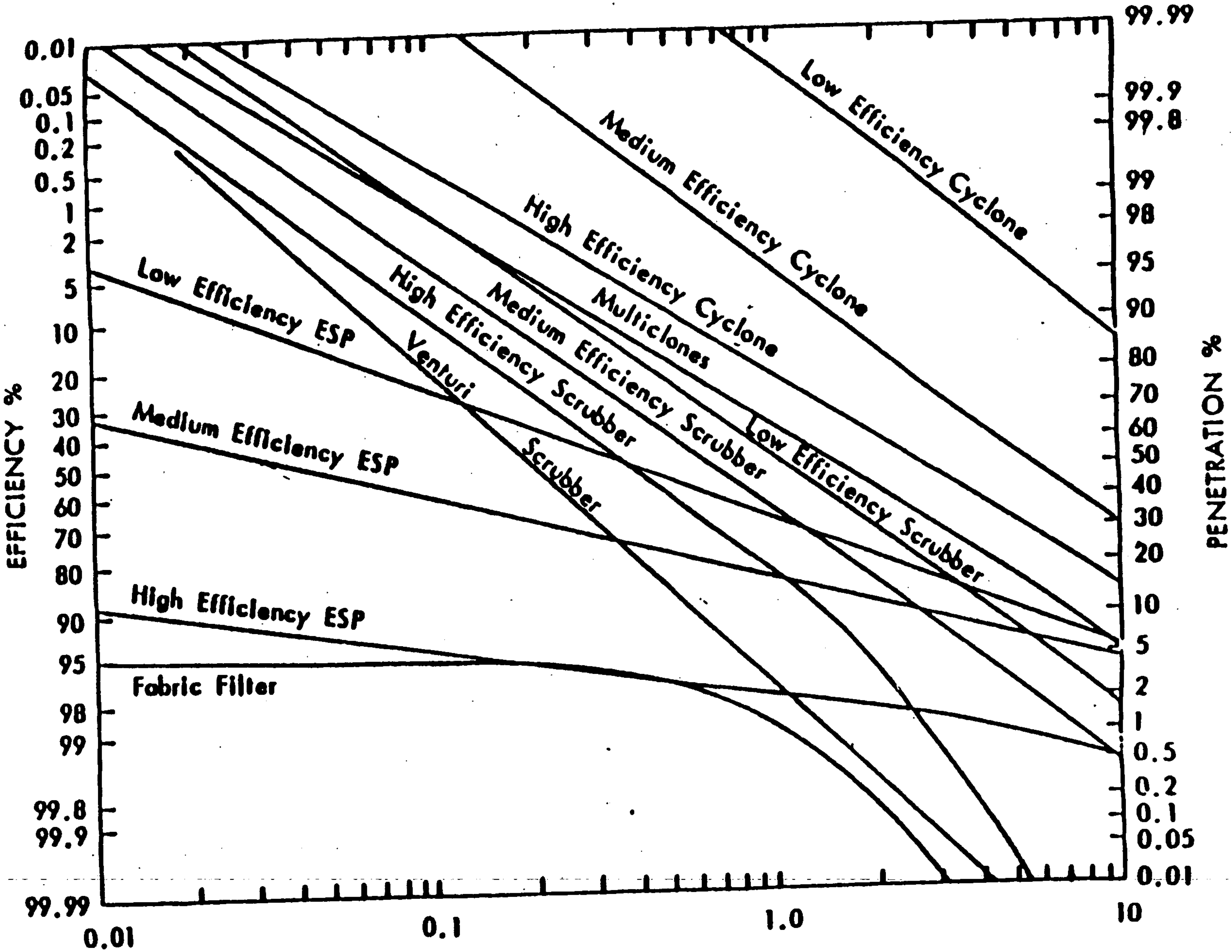


FIGURE 3-2 COMPARISON OF CONTROL DEVICE FRACTIONAL EFFICIENCIES[a]

[a] Baig, 1981;p.5-5.

their mass than the larger particles and thus have more available area on which trace elements can condense (Baig, 1981; pp. 3-13-3-14, 5-10).

The VCM theory also explains the distribution of elements between the fly and bottom ash. Elements that volatilize and recondense are depleted in the bottom ash and concentrated in the fly ash because the fly ash has more relative surface area than the bottom ash and because the bottom ash does not come in contact with the volatilized elements long enough and at sufficiently low temperatures for the elements to condense. Elements that do not volatilize are distributed evenly between the fly and bottom ash. Elements that only partially volatilize are intermediate between the first two classes. And lastly, elements that volatilize but do not recondense are not captured by PM control devices since they remain gaseous (Baig, 1981; pp. 3-13-3-14).

Another important consideration, especially for ESP units, is the resistivity of the toxic PM species. Although ESP units are less sensitive to particle size than venturi scrubbers or fabric filters, ESPs are more sensitive to both aerosol density and the electrical resistivity of the particulate. The electrical resistivity of particles affects the attraction between the particles and the collecting plate (Purcell, 1985; p. 3-40). The higher the resistivity, the lower the overall collection efficiency. Therefore, the higher the resistivity of particles containing one or more TAPs, the lower the removal efficiency of those TAPs by ESP units.

A technique has been developed to predict the electrical resistivity of coal fly ash from an ultimate coal analysis and and analysis of the chemical composition of the coal ash (Bickelhaupt, 1979). As yet, no method has been developed to predict the electrical resistivity of the individual species of which coal is composed.

SO_2 and NO_x controls, although not traditionally associated with PM reduction, are capable of removing certain toxics from the emission stream. The most significant reduction of toxic elements by SO_2 devices are for the semi-volatile elements. The cooling of gas in the FGD scrubber condenses the gases, resulting in control of the volatile elements. Toxic elements contained on particulates are also removed by SO_2 scrubbers. However, the primary method of removal for the less volatile elements appears to be removal of the particles on which the trace elements are deposited (Baig, 1981; pp.5-33-5-42).

NO_x controls do not result in the direct removal of toxic elements but, by changing combustion conditions, may have an impact on toxic emissions. For example, NO_x combustion modifications, such as flue gas recirculation, reduced air preheat, load reduction, or water injection, may lower flame temperatures, resulting in less volatilization (Baig, 1981; pp. 5-34-5-35). A lower rate of TAP volatilization implies that a higher percent of toxics will remain as particulate matter to be captured by PM control devices. Thus, in cases such as this, NO_x controls of this type are synergistic with PM control insofar as maximizing control of toxic pollutants.

NO_x controls are only successful at removing those TAP trace elements present in the fuel. In contrast, a class of TAPs known as products of incomplete combustion (PIC) form from combustion reactions. Benzo(a)pyrene (B(a)P) is the most common PIC. Although the formation and behavior of PIC are a function of many parameters, factors that reduce combustion efficiency tend to increase PIC formation.

Therefore, NO_x controls such as water injection, that reduce combustion efficiency, will result in less TAP volatilization and higher TAP control, perhaps at the expense of greater PIC formation. Permit engineers should be aware of this specific tradeoff and of other potential synergistic and antagonistic effects that the various control devices and techniques can have on TAP control.

3.3.4 Toxic VOC Control

Numerous advantages and disadvantages are associated with the removal of toxic pollutants by VOC control devices. For most devices, removal efficiencies generally depend on the physical and chemical characteristics of the compounds to be controlled. The following discussion identifies common VOC control strategies and the characteristics to be kept in mind when examining their capability for TAP removal.

VOC control technology can be grouped into two general categories. The first group includes devices that reduce the VOC into constituent elements through combustion: thermal and catalytic incineration, flares, boilers and process heaters. The second group includes devices that remove and/or recover the VOC from the emission stream: carbon adsorbers, absorbers, and condensers. The discussion of these devices is taken primarily from Purcell, 1985; pp. 3-8-3-14.

The following section also includes Tables 3-11 and 3-12. Table 3-11 summarizes the key emission and TAP stream characteristics for each VOC control device and Table 3-12 lists additional considerations to be kept in mind regarding these devices.

3.3.4.1 Thermal Incineration. For thermal destruction, residence time, mixing, and flame temperature determine the degree to which VOCs and individual species are destroyed. Wide fluctuations in flow rate are not favorable to incineration because reduced residence time and poor mixing lead to decreases in the completeness of combustion.

There are a couple of ranking schemes currently in use by which VOC destruction estimates are made. The most common amongst these is the heat of combustion method, the manner by which EPA has established incinerability criteria. This method implies that the abililty to completely destroy a VOC is directly proportional to its heat of combustion.

3.3.4.2 Catalytic Incineration. Catalytic incinerators are similiar to thermal incinerators in design and operation except the former employ a catalyst to enhance the reaction rate. The catalyst allows incineration to proceed at a lower temperature than thermal incineration, resulting in reduced energy costs.

Catalytic incineration is much more sensitive to pollutant characteristics and process conditions than is thermal incineration, largely due to the presence of the catalyst. The VOC emission stream must be free from compounds that could erode, mask, or poison the catalyst.

TABLE 3-11. KEY EMISSION STREAM CHARACTERISTICS AND TAP CHARACTERISTICS FOR SELECTING CONTROL TECHNIQUES FOR ORGANIC VAPORS FROM POINT SOURCES

	Emission Stream Characteristics					TAP Characteristics[a]			
Control Device	TAP/Organics Content[b] (ppmv)	Heat Content (Btu/scf)	Moisture Content (%)	Flow Rate (scfm)	Temperature (°F)	Molecular Weight (lb/lb-mole)	Solubility	Vapor Pressure (mm Hg)	Adsorptive Properties
Thermal Incinerator	>20; (<25% of LEL[c])			<100,000[d]					
Catalytic Incinerator	50 - 10,000; (<25% of LEL[c])			<100,000					
Flare		>300[e]		<2,000,000[f]					
Boiler/Process Heater[g]		>150[h]		Steady					
Carbon Adsorber	1,000 - 10,000 (<25% of LEL[c])		50%[i]	300-100,000	100-200	45-130			Must be able to adsorb on and from available adsorbents.
Absorber	250 - 10,000			1,000-100,000			Must be readily soluble in water or other solvents		
Condenser	>5,000			<2,000				>10 (at room temperature)	

---

[a] Refers to the characteristics of the individual TAP if a single TAP is present and to that of the TAP mixture if a mixture of TAP's is present.
[b] Determined from TAP/Hydrocarbon content.
[c] For emission streams that are mixtures of air and VOC; in some cases, the LEL can be increased to 40 to 50% with proper monitoring and control

[d] For packaged units; multiple-package or custom-made units can handle larger flows.
[e] Based on EPA's guidelines for 98 percent destruction efficiency.
[f] Units: lb/hr.
[g] Applicable if such a unit is already available on site.
[h] Total heat content.
[i] Relative humidity.

\- - - - - - - - - -

Source: Purcell, 1985, p. 3-3

TABLE 3-12. OTHER CONSIDERATIONS IN CONTROL DEVICE SELECTION FOR TAP ORGANIC VAPORS FROM POINT SOURCES

Control Device	Recycle/Recovery Possibility	Safety Considerations	Sensitivity to Environmental Considerations	Ancillary Equipment Requirements	Susceptibility to Contaminants	Changes in Process Conditions
Thermal Incinerator	Heat recovery	Due to explosion hazards, VOC concentrations of emission streams containing air should be kept below 25% of the LEL.[a]	Halogens and/or sulfur in emission stream may cause emission of HCl and/or SO_2 in flue gases.	Scrubbing of flue gases may be needed if halogens/sulfur are present in the emission stream.	Corrosion can be a problem with some contaminants (e.g., sulfur).	Little or none
Catalytic Incinerator	Heat recovery	Due to explosion hazards, VOC concentrations of emission streams containing air should be kept below 25% of the LEL.[a]	Spent catalyst must be regenerated or disposed of.	Scrubbing of flue gases may be needed if halogens are present in the emission stream.	Catalyst is susceptible to erosion, poisoning, and masking of active sites from liquid/solid particles and catalyst poisons.	Extremely sensitive to changes in process conditions; increase in heat content may cause catalyst to overheat and subsequently lose its activity.
Flare	None	Flame flashbacks may occur at low emission stream flow rates. The flare system should not present a radiation hazard to surrounding personnel and facilities.	Steam usage can aggravate the flare noise problem by producing high-frequency jet noise. Smoke may be produced. Halogens and/or sulfur in emission stream may cause HCl and/or SO_2 emissions.	A knock-out drum may be needed to remove water droplets that can extinguish the flame flame or organic droplets that can result in burning particles. When the flared gas flow rate is too low, a water seal, stack seal, or purge gas may be required to prevent flame flashbacks. Steam generator is required if the flare is steam-assisted.	Water and/or hydrocarbon droplets in the off-gases may create problems in the flame zone.	Capable of handling fluctuations in VOC and inerts content and flow rate of the emission stream.

TABLE 3-12. OTHER CONSIDERATIONS IN CONTROL DEVICE SELECTION FOR TAP ORGANIC VAPORS FROM POINT SOURCES
(Continued)

Control Device	Recycle/Recovery Possibility	Safety Considerations	Sensitivity to Environmental Considerations	Ancillary Equipment Requirements	Susceptibility to Contaminants	Changes in Process Conditions
Boiler/Process Heater	Heat recovery	Variations in emission stream flow rate and VOC content may lead to explosive mixtures in the boiler or process heater.	Halogens and/or sulfur in emission stream may cause emission of HCl and/or SO_2 in flue gases.	Scrubbing of flue gases may be needed if halogens/sulfur are present in the emission stream.	Corrosion can be a problem if sulfur or halogenated compounds are present in the emission stream.	Extremely sensitive to changes in process conditions; increase in emission stream flow rate or decrease in emission stream heat content can affect the performance of boilers or process heaters.
Carbon Adsorber	VOC recovery	Due to explosion hazards, VOC concentrations of emission streams containing air should be kept below 25% of the LEL.[a] When high VOC concentrations are involved, bed temperatures may rise due to heat of combustion. Bed fires may occur when emission stream contains oxygen and easily oxidizable compounds (e.g., ketones, aldehydes, organic acids) and when heat generated due to adsorption/oxidation of the VOC is not dissipated.	Recovery of VOC miscible with water by decantation, distillation, or extraction creates waste water problems. Spent carbon must be either regenerated disposed of.	Coolers and heaters may be required if the temperature and humidity levels of the emission stream are high. Filters may be needed if particulates are present in the emission stream. Mist eliminators may be needed if liquid particles are present in the emission stream. Decantation, distillation, or extraction may be necessary to separate water soluble organics from condensed steam (when steam is used as the regenerant).	Pretreatment of the emission stream may be necessary if it contains liquid or solid particles, high-boiling organics, polymerizable substances, and has a high moisture content.	Wide variations in emission stream flow rate, VOC content, temperature, and moisture content will affect the performance of the adsorber system.

(Continued)

TABLE 3-12. OTHER CONSIDERATIONS IN CONTROL DEVICE SELECTION FOR TAP ORGANIC VAPORS FROM POINT SOURCES (Concluded)

Control Device	Recycle/Recovery Possibility	Safety Considerations	Sensitivity to Environmental Considerations	Ancillary Equipment Requirements	Susceptibility to Contaminants	Changes in Process Conditions
Absorber (Scrubber)	VOC recovery		Effluent from the absorber system creates waste water problems (especially in once-through systems).	Stripping of the absorber effluent containing VOC may be necessary depending on the control requirements and whether the solvent is recycled to the column. (Note: Stripping is not expected to be used in HAP control applications.)	Little or none.	Changes in flow rate, VOC content, and temperature of the emission stream will affect the performance of the absorber system.
Condenser	VOC Recovery		The condensed VOC will have to be disposed of. If it is valuable, it can be recycled to the process (provided its purity level meets the process requirements) or it can be sold in market. (Note: if contact condensers are used, the spent coolant will create waste water problems. Therefore, they are not recommended for HAP control applications/without proper treatment/disposal.	Depending on the temperatures required for condensation, a refrigeration unit may be required.	If there is water vapor in the emission stream, ice might form on the condenser tubes, reducing the rate of heat transfer; in such cases, water must be removed upstream of the condenser using a dehumidifier.	Changes in VOC content, emission stream flow rate, and temperature of the coolant will affect the performance of the system.

---

[a] If on-line monitoring is provided, concentrations up to 4 to 50 percent of the LEL may be permitted.

Source: Purcell, 1985, pp. 3-5 - 3-7

Up to a certain point, a high VOC content in the emission stream is associated with a high VOC destruction efficiency. However, an increase in the heat content of the emission stream may cause the catalyst to overheat and subsequently lost its activity.

As with thermal incineration, the ability of catalytic incineration to destroy a VOC is proportional to the VOC's heat of combustion. Since catalytic incineration operates at a lower temperature than thermal incineration, the destruction efficiency of a VOC with a high heat of combustion may be lower with catalytic incineration compared to thermal incineration.

3.3.4.3 Flares. Flares can be used to control almost any emission stream. Flares are often used when the heating value of the emission stream cannot be recovered because of uncertain or intermittant flow. A 98-percent destruction efficiency can be achieved by steam-assisted flares when the emission stream heat content exceeds 300 Btu/scf (see Table 3-11).

3.3.4.4 Boilers And Process Heaters

Boilers and process heaters can be used to control toxic VOC emissions. Because boilers and process heaters are such a prevalent technology, enormous potential exists for their use as VOC combustion devices.

Precautions must be taken when boilers are used as VOC control devices. The minimum heat content of the VOC emission stream must be 150 Btu/scf; (Table 3-11) otherwise an auxilliary fuel must be added to raise the heat content to this level. Low furnance temperatures can cause incomplete combustion and reduce heat output. Boilers are extremely sensitive to changes in process conditions. An increase in the emission stream flow rate or a decrease in the emission stream heat content can affect boiler performance.

Boilers and process heaters can provide destruction efficiencies exceeding 98 percent with nearly complete recovery of the emission stream heat content. However, the presence of corrosive compounds may affect performance and reliability.

3.3.4.5 Adsorbers. Adsorber systems can use a variety of absorbents such as carbon, silica gel, and activated alumina. The degree of adsorption depends on the characteristics of the absorbent and the waste stream.

Adsorber systems can handle wide fluctuations in the emission stream flow rate, VOC content, temperature and moisture content. TAPs must be able to adsorb onto and from the adsorbent. Removal efficiency typically increases with VOC molecular weight but decreases with VOC volatility. In fact, for carbon adsorption, VOCs with boiling points less than 400 degrees F and molecular weights greater than 130 are so strongly adsorbed that they are difficult to remove from the carbon. Conversely, volatile materials with a molecular weight less than 45 do not readily adsorb onto carbon. Adsorbers operate at an optimum temperature between 100 and 200 degrees F.

High VOC concentrations may cause a rise in bed temperatures due to heat of combustion. In fact, bed fires may occur when the emission stream contains oxygen and easily oxidizable compounds and when heat generated due to adsorption/oxidation of the VOC is not dissipated.

Waste disposal may also become a problem with carbon adsorption. Recovery of VOC miscible with water by decantation, distillation, or extractions may create wastewater problems. Additionally, the spent adsorbent must be either regenerated or disposed of.

3.3.4.6 Absorption. Absorption is another method commonly used to remove organic vapors. The VOC should be readily soluble in the solvent and the solvent should be easily regenerated or disposed of. Generally, changes in the flow rate, VOC content, and temperature of the emission stream all affect absorber system performance. In addition, the effluent from the absorber system can create wastewater problems, especially in once-through systems.

3.3.4.7 Condensers. Lastly, condensers can be used to remove VOCs from waste gases. VOC removal with condensers is a function of the TAP vapor pressure-temperature relationship, the TAP concentration and the type of coolant used. Generally, the vapor pressure should be greater than 10 mm Hg at room temperature. Condensers are also

Acutely Toxic Chemicals
Alphabetic List of Common Names and CAS Numbers[a]

Common Name	CAS Numbe
Acetone cyanohydrin	00075-86-
* Acetone thiosemicarbazide	01752-30-5
Acrolein	00107-02-8
Acrylyl chloride	00814-68-
Aldicarb	00116-06-
Aldrin	00309-00-2
Allyl alcohol	00107-18-
Allylamine	00107-11-
Aluminum phosphide	20859-73-8
* Aminopterin	00054-62-6
* Amiton	00078-53-
* Amiton oxalate	03734-97-2
Ammonium chloroplatinate	16919-58-7
* Amphetamine	00300-62-
* Aniline, 2,4,6-trimethyl-	00088-05-
Antimony pentafluoride	07783-70-2
* Antimycin A	01397-94-
Antu	00086-88-
* Arsenic pentoxide	01303-28-2
Arsenous oxide	01327-53-3
Arsenous trichloride	07784-34-
Arsine	07784-42-1
* Azinphos-ethyl	02642-71-9
Azinphos-methyl	00086-50-
* Bacitracin	01405-87-
Benzal chloride	00098-87-3
Benzenamine, 3-(trifluoromethyl)-	00098-16-
Benzene, 1-(chloromethyl)-4-nitro-	00100-14-
* Benzenearsonic acid	00098-05-5
Benzenesulfonyl chloride	00098-09-9
Benzotrichloride	00098-07-
Benzyl chloride	00100-44-7
Benzyl cyanide	00140-29-4
* Bicyclo[2.2.1]heptane-2-carbonitrile, 5-chloro...	15271-41-
* Bis(chloromethyl) ketone	00534-07-
* Bitoscanate	04044-65-9
Boron trichloride	10294-34-
Boron trifluoride	07637-07-
Boron trifluoride compound with methyl ether (1:1)	00353-42-4
Bromadiolone	28772-56-7
Butadiene	00106-99-
Butyl isovalerate	00109-19-5
Butyl vinyl ether	00111-34-2
C.I. basic green 1	00633-03-
Cadmium oxide	01306-19-
Cadmium stearate	02223-93-0
Calcium arsenate	07778-44-
Camphechlor	08001-35-
* Cantharidin	00056-25-7
* Carbachol chloride	00051-83-2

---

[a] Chemical Emergency Preparedness Program Interim Guidance, U.S. Environmental Protection Agency, November, 1985.

Acutely Toxic Chemicals
Alphabetic List of Common Names and CAS Numbers

Common Name	CAS Number
* Carbamic acid, methyl-, O-[[(2,4-dimethyl...	26419-73-8
Carbofuran	01563-66-2
Carbophenothion	00786-19-6
Carvone	02244-16-8
* Chlordane	00057-74-9
Chlorfenvinfos	00470-90-6
Chlorine	07782-50-5
* Chlormephos	24934-91-6
Chlormequat chloride	00999-81-5
Chloroacetaldehyde	00107-20-0
Chloroacetic acid	00079-11-8
Chloroethanol	00107-07-3
* Chloroethyl chloroformate	00627-11-2
Chloromethyl ether	00542-88-1
* Chloromethyl methyl ether	00107-30-2
Chlorophacinone	03691-35-8
* Chloroxuron	01982-47-4
* Chlorthiophos	21923-23-9
Chromic chloride	10025-73-7
Cobalt	07440-48-4
Cobalt carbonyl	10210-68-1
* Cobalt, [[2,2'-[1,2-ethanediylbis(nitrilomethy...	62207-76-5
* Colchicine	00064-86-8
Coumafuryl	00117-52-2
Coumaphos	00056-72-4
* Coumatetralyl	05836-29-3
Cresylic acid	00095-48-7
* Crimidine	00535-89-7
Crotonaldehyde	00123-73-9
Crotonaldehyde	04170-30-3
Cyanogen bromide	00506-68-3
Cyanogen iodide	00506-78-5
* Cyanophos	02636-26-2
Cyanuric fluoride	00675-14-9
Cycloheximide	00066-81-9
Cyclopentane	00287-92-3
Decaborane(14)	17702-41-9
Demeton	08065-48-3
* Demeton-S-methyl	00919-86-8
* Dialifos	10311-84-9
Diborane	19287-45-7
Dibutyl phthalate	00084-74-2
Dichlorobenzalkonium chloride	08023-53-8
Dichloroethyl ether	00111-44-4
Dichloromethylphenylsilane	00149-74-6
Dichlorvos	00062-73-7
Dicrotophos	00141-66-2
Diepoxybutane	01464-53-5
Diethyl chlorophosphate	00814-49-3
Diethyl-p-phenylenediamine	00093-05-0

Acutely Toxic Chemicals
Alphabetic List of Common Names and CAS Numbers

	Common Name	CAS Number
*	Diethylcarbamazine citrate	01642-54-[illegible]
*	Digitoxin	00071-63-6
	Diglycidyl ether	02238-07-5
*	Digoxin	20830-75-5
*	Dimefox	00115-26-4
	Dimethoate	00060-51-5
	Dimethyl phosphorochloridothioate	02524-03-0
	Dimethyl phthalate	00131-11-3
	Dimethyl sulfate	00077-78-1
	Dimethyl sulfide	00075-18-3
	Dimethyl-p-phenylenediamine	00099-98-9
	Dimethyldichlorosilane	00075-78-5
	Dimethylhydrazine	00057-14-7
*	Dimetilan	00644-64-4
	Dinitrocresol	00534-52-1
	Dinoseb	00088-85-7
*	Dinoterb	01420-07-1
	Dioctyl phthalate	00117-84-0
	Dioxathion	00078-34-2
	Dioxolane	00646-06-0
	Diphacinone	00082-66-6
	Diphosphoramide, octamethyl-	00152-16-9
	Disulfoton	00298-04-4
	Dithiazanine iodide	00514-73-8
*	Dithiobiuret	00541-53-7
	EPN	02104-64-5
*	Emetine, dihydrochloride	00316-42-7
	Endosulfan	00115-29-7
*	Endothion	02778-04-3
	Endrin	00072-20-8
*	Ergocalciferol	00050-14-6
*	Ergotamine tartrate	00379-79-3
*	Ethanesulfonyl chloride, 2-chloro-	01622-32-8
*	Ethanol, 1,2-dichloro-, acetate	10140-87-1
	Ethion	00563-12-2
	Ethoprophos	13194-48-4
*	Ethyl thiocyanate	00542-90-5
*	Ethylbis(2-chloroethyl)amine	00538-07-8
*	Ethylene fluorohydrin	00371-62-0
	Ethylenediamine	00107-15-3
	Ethyleneimine	00151-56-4
*	Ethylmercuric phosphate	02235-25-8
	Fenamiphos	22224-92-6
	Fenitrothion	00122-14-5
	Fensulfothion	00115-90-2
*	Fluenetil	04301-50-2
	Fluorine	07782-41-4
	Fluoroacetamide	00640-19-7
*	Fluoroacetic acid	00144-49-0
	Fluoroacetyl chloride	00359-06-8

Acutely Toxic Chemicals
Alphabetic List of Common Names and CAS Numbers

Common Name	CAS Number
* Fluorouracil	00051-21-8
Fonofos	00944-22-9
Formaldehyde cyanohydrin	00107-16-4
* Formetanate	23422-53-9
* Formothion	02540-82-1
* Formparanate	17702-57-7
* Fosthietan	21548-32-3
* Fuberidazole	03878-19-1
Furan	00110-00-9
Gallium trichloride	13450-90-3
Hexachlorocyclopentadiene	00077-47-4
* Hexachloronaphthalene	01335-87-1
Hexamethylenediamine, N,N'-dibutyl-	04835-11-4
Hydrazine	00302-01-2
Hydrocyanic acid	00074-90-8
Hydrogen fluoride	07664-39-3
Hydrogen selenide	07783-07-5
* Indomethacin	00053-86-1
Iridium tetrachloride	10025-97-5
Iron, pentacarbonyl-	13463-40-6
* Isobenzan	00297-78-9
Isobutyronitrile	00078-82-0
Isocyanic acid, 3,4-dichlorophenyl ester	00102-36-3
* Isodrin	00465-73-6
* Isofluorphate	00055-91-4
Isophorone diisocyanate	04098-71-9
Isopropyl chloroformate	00108-23-6
* Isopropyl formate	00625-55-8
* Isopropylmethylpyrazolyl dimethylcarbamate	00119-38-0
Lactonitrile	00078-97-7
* Leptophos	21609-90-5
* Lewisite	00541-25-3
* Lindane	00058-89-9
Lithium hydride	07580-67-8
Malononitrile	00109-77-3
Manganese, tricarbonyl methylcyclopentadienyl	12108-13-3
* Mechlorethamine	00051-75-2
* Mephosfolan	00950-10-7
Mercuric acetate	01600-27-7
Mercuric chloride	07487-94-7
Mercuric oxide	21908-53-2
Mesitylene	00108-67-8
* Methacrolein diacetate	10476-95-6
* Methacrylic anhydride	00760-93-0
Methacrylonitrile	00126-98-7
Methacryloyl chloride	00920-46-7
Methacryloyloxyethyl isocyanate	30674-80-7
Methamidophos	10265-92-6
* Methanesulfonyl fluoride	00558-25-8
* Methidathion	00950-37-8

Acutely Toxic Chemicals
Alphabetic List of Common Names and CAS Numbers

Common Name	CAS Number
Methiocarb	02032-65-7
Methomyl	16752-77-5
* Methoxyethylmercuric acetate	00151-38-2
Methyl 2-chloroacrylate	00080-63-7
Methyl chloroformate	00079-22-1
Methyl disulfide	00624-92-0
Methyl isocyanate	00624-83-9
* Methyl isothiocyanate	00556-61-6
Methyl mercaptan	00074-93-1
* Methyl phenkapton	03735-23-7
Methyl phosphonic dichloride	00676-97-1
* Methyl thiocyanate	00556-64-9
Methyl vinyl ketone	00078-94-4
Methylhydrazine	00060-34-4
* Methylmercuric dicyanamide	00502-39-6
Methyltrichlorosilane	00075-79-6
* Metolcarb	01129-41-5
* Mevinphos	07786-34-7
* Mexacarbate	00315-18-4
* Mitomycin C	00050-07-7
Monocrotophos	06923-22-4
* Muscimol	02763-96-4
* Mustard gas	00505-60-2
Nickel	07440-02-2
Nickel carbonyl	13463-39-3
Nicotine	00054-11-5
* Nicotine sulfate	00065-30-5
Nitric acid	07697-37-2
Nitric oxide	10102-43-9
* Nitrocyclohexane	01122-60-7
Nitrogen dioxide	10102-44-0
Nitrosodimethylamine	00062-75-9
* Norbormide	00991-42-4
* Organorhodium complex	PMN-82-147
* Orotic acid	00065-86-1
Osmium tetroxide	20816-12-0
* Ouabain	00630-60-4
Oxamyl	23135-22-0
Oxetane, 3,3-bis(chloromethyl)	00078-71-7
* Oxydisulfoton	02497-07-6
Ozone	10028-15-6
Paraquat	01910-42-5
* Paraquat methosulfate	02074-50-2
Parathion	00056-38-
Parathion-methyl	00298-00-
Paris green	12002-03-8
* Pentaborane	19624-22-7
Pentachloroethane	00076-01-
Pentachlorophenol	00087-86-5
* Pentadecylamine	02570-26-5

Acutely Toxic Chemicals
Alphabetic List of Common Names and CAS Numbers

Common Name	CAS Number
Peracetic acid	00079-21-0
Perchloromethylmercaptan	00594-42-3
* Phenarsazine oxide	00058-36-6
Phenol	00108-95-2
* Phenol, 2,2'-thiobis(4-chloro-6-methyl-	04418-66-0
Phenol, 2,2'-thiobis[4,6-dichloro-	00097-18-7
* Phenol, 3-(1-methylethyl)-, methylcarbamate	00064-00-6
* Phenyl dichloroarsine	00696-28-6
Phenylhydrazine hydrochloride	00059-88-1
Phenylmercury acetate	00062-38-4
Phenylsilatrane	02097-19-0
* Phenylthiourea	00103-85-5
Phorate	00298-02-2
* Phosacetim	04104-14-7
* Phosfolan	00947-02-4
Phosmet	00732-11-6
Phosphamidon	13171-21-6
Phosphine	07803-51-2
* Phosphonothioic acid, methyl-, O-(4-nitrophenyl...	02665-30-7
* Phosphonothioic acid, methyl-, O-ethyl O-[4-...	02703-13-1
* Phosphonothioic acid, methyl-, S-[2-[bis...	50782-69-9
* Phosphoric acid, dimethyl 4-(methylthio)phenyl...	03254-63-5
Phosphorous trichloride	07719-12-2
Phosphorus	07723-14-0
Phosphorus oxychloride	10025-87-3
Phosphorus pentachloride	10026-13-8
Phosphorus pentoxide	01314-56-3
* Phylloquinone	00084-80-0
* Physostigmine	00057-47-6
* Physostigmine, salicylate (1:1)	00057-64-7
* Picrotoxin	00124-87-8
Piperidine	00110-89-4
* Piprotal	05281-13-0
* Pirimifos-ethyl	23505-41-1
Platinous chloride	10025-65-7
Platinum tetrachloride	13454-96-1
* Potassium arsenite	10124-50-2
Potassium cyanide	00151-50-8
Potassium silver cyanide	00506-61-6
* Promecarb	02631-37-0
Propargyl bromide	00106-96-7
Propiolactone, .beta.-	00057-57-8
Propionitrile	00107-12-0
* Propionitrile, 3-chloro-	00542-76-7
Propyl chloroformate	00109-61-5
Propylene glycol, allyl ether	01331-17-5
Propyleneimine	00075-55-8
* Prothoate	02275-18-5
Pseudocumene	00095-63-6
Pyrene	00129-00-0

Acutely Toxic Chemicals
Alphabetic List of Common Names and CAS Numbers

Common Name	CAS Number
Pyridine, 2-methyl-5-vinyl-	00140-76-1
Pyridine, 4-amino-	00504-24-5
* Pyridine, 4-nitro-, 1-oxide	01124-33-0
* Pyriminil	53558-25-1
Rhodium trichloride	10049-07-7
* Salcomine	14167-18-1
* Sarin	00107-44-8
* Selenium oxychloride	07791-23-3
Selenous acid	07783-00-8
Semicarbazide hydrochloride	00563-41-7
Silane, (4-aminobutyl)diethoxymethyl-	03037-72-7
* Sodium anthraquinone-1-sulfonate	00128-56-3
Sodium arsenate	07631-89-2
Sodium arsenite	07784-46-5
Sodium azide (Na(N3))	26628-22-8
Sodium cacodylate	00124-65-2
Sodium cyanide (Na(CN))	00143-33-9
Sodium fluoroacetate	00062-74-8
Sodium pentachlorophenate	00131-52-2
* Sodium selenate	13410-01-0
Sodium selenite	10102-18-8
* Sodium tellurite	10102-20-2
Strychnine	00057-24-9
Strychnine, sulfate	00060-41-3
Sulfotep	03689-24-5
* Sulfoxide, 3-chloropropyl octyl	03569-57-1
Sulfur tetrafluoride	07783-60-0
Sulfur trioxide	07446-11-9
Sulfuric acid	07664-93-9
* TEPP	00107-49-3
* Tabun	00077-81-6
Tellurium	13494-80-9
Tellurium hexafluoride	07783-80-4
Terbufos	13071-79-9
Tetraethyllead	00078-00-2
* Tetraethyltin	00597-64-8
Tetranitromethane	00509-14-8
Thallic oxide	01314-32-5
* Thallous carbonate	06533-73-9
Thallous chloride	07791-12-0
* Thallous malonate	02757-18-8
* Thallous sulfate	07446-18-6
* Thallous sulfate	10031-59-1
* Thiocarbazide	02231-57-4
Thiocyanic acid, (2-benzothiazolylthio)methyl...	21564-17-0
* Thiofanox	39196-18-4
* Thiometon	00640-15-3
* Thionazin	00297-97-2
Thiophenol	00108-98-5
Thiosemicarbazide	00079-19-6

Acutely Toxic Chemicals
Alphabetic List of Common Names and CAS Numbers

	Common Name	CAS Number
*	Thiourea, (2-chlorophenyl)-	05344-82-1
*	Thiourea, (2-methylphenyl)-	00614-78-8
	Titanium tetrachloride	07550-45-0
	Toluene 2,4-diisocyanate	00584-84-9
	Toluene 2,6-diisocyanate	00091-08-7
*	Triamiphos	01031-47-6
*	Triazofos	24017-47-8
	Trichloro(chloromethyl)silane	01558-25-4
	Trichloro(dichlorophenyl)silane	27137-85-5
	Trichloroacetyl chloride	00076-02-8
	Trichloroethylsilane	00115-21-9
*	Trichloronate	00327-98-0
	Trichlorophenylsilane	00098-13-5
	Trichlorphon	00052-68-6
	Triethoxysilane	00998-30-1
	Trimethylchlorosilane	00075-77-4
*	Trimethylolpropane phosphite	00824-11-3
	Trimethyltin chloride	01066-45-1
	Triphenyltin chloride	00639-58-7
*	Tris(2-chloroethyl)amine	00555-77-1
	Valinomycin	02001-95-8
	Vanadium pentoxide	01314-62-1
	Vinylnorbornene	03048-64-4
	Warfarin	00081-81-2
	Warfarin sodium	00129-06-6
	Xylylene dichloride	28347-13-9
	Zinc phosphide	01314-84-7
*	Zinc, dichloro[4,4-dimethyl-5-[[[(methylamino)...	58270-08-9
	trans-1,4-Dichlorobutene	00110-57-6

Draft 1
1/23/6

APPENDIX A

SOURCES USEFUL FOR PSD PERMITTING

REFERENCES

American Conference of Governmental Industrial Hygenists, TLVs, Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH, 1984

Baig, S, et. al., Conventional Combustion Environmental Assessment Final Report, for Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina, July, 1981.

Bickelhaupt, Roy E. A Technique for Predicting Fly Ash Resistivity, Southern Research Institute for EPA Industrial Environmental Research Laboratory and Office of Research and Development, EPA-600/7-79-204, August 1979.

Christiano, John and Mark Scruggs, Permit Application Guidance for New Air Pollution Sources - Natural Resources Programs, National Park Service, Natural Resources Report Series No. 85-2., National Park Service, Air Quality Division, Permit Review and Technical Support Branch, Denver, Colorado, August, 1985.

Hayes, L.C. et. al., Analysis of New Source Review (NSR) Permitting Experience - Final Report, prepared for U.S. EPA Office of Air and Radiation, U.S. EPA Office of Planning and Program Evaluation and U.S. Office of Air Quality Planning and Standards, September 1985.

Purcell, Robert Y. and Gunseli Sagun Shareef, Evaluation of Control Technologies for Hazardous Air Pollutants (Draft), for Office of Research and Development, U.S. EPA, October 1, 1985.

Radian Corporation and JSCF,Inc, Final Work Products Supporting the Development of Toxic Air Pollutant Regulation for the State of Maryland, for EPA Region III, July, 1985a.

Radian Corporation, North Carolina Air Toxics Survey Identification of Pollutants of Concern and Potential Emissions Sources, Final Report, for Air Quality Section, N.C. Division of Environmental Management and U.S. EPA Region IV, April 5, 1985b.

Smith, S.A. Air Toxics Information Clearinghouse: Second Interim Report of Selected Information on State and Local Agency Air Toxics Activities. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, March, 1985.

U.S. EPA Office of Air, Noise and Radiation and Office of Air Quality Planning and Standards, Prevention of Significant Deterioration Workshop Manual, October 1980.

This appendix lists sources that may be valuable to those involved in PSD permitting. A brief description is included after each source listing.

Hayes, L.C. et. al., Analysis of New Source Review (NSR) Permitting Experience - Final Report, prepared for U.S. EPA Office of Air and Radiation, U.S. EPA Office of Planning and Program Evaluation and U.S. Office of Air Quality Planning and Standards, September 1985.

- This report summarizes data collected on New Source Review permits issued from 1980 through 1984. The data was compared to New Source Review data collected from 1979 through 1981.

U.S. EPA Office of Air, Noise and Radiation and Office of Air Quality Planning and Standards, Prevention of Significant Deterioration Workshop Manual, October 1980.

- This manual is to designed to aid in understanding of the PSD program gain. The manual describes the requirements of the federal regulations but does not describe the requirements designed into each state's implementation plan (SIP).

BACT/LAER Clearinghouse - a Compilation of Control Technology Determinations

- Lists BACT and LAER determinations submitted to the Clearinghouse by state and locat air pollution control agencies. The most recent version (May 1984) contains 900 BACT and LAER determinations covering over 100 source categories and 2400 processes issued between 1980 and 1984.

Radian New Source Review Database

- Database that contains relevant permit information including BACT decisions, permit data, air quality analysis, and processing times.

California Air Resources Board Automated Air Database

- Lists BACT determinations submitted to the California Air Pollution Control Office. For each source, the following is listed: District, Permit #, Issue Date, Project, Pollutant, Source Code, Equipment Type, Control Technology, Remarks, Design Capacity, Emission Limit, Other Limits, Efficiency Limit, Controlled Emission Rate, Operating Hours, and Permitted Operating Level.

U.S. EPA, Compilation of Air Pollution Emission Factors (AP-42), Office of Air and Waste Management, Office of Air Quality Planning and Standards, Various Editions and Dates.

- Contains equations that can be used to estimate emissions from a variety of processes and source types. The equations are based on analyses of actual source emissions, mass balance estimates, and engineering judgement.

Vendor Information - numerous sources

NSPS/NESHAPS BIDs

- Presents, for each regulated industry, the principal processes and pollutants, emission estimates, potential emission controls, costs of control and the economic and environmental impacts of control.

Neveril, R.B. Capital and Operating Costs of Selected Air Pollution Control Systems (GARD Manual), GARD, Inc., Niles, Illinois, for U.S. EPA Office of Air and Waste Management and Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December, 1978.

- Document was designed to assist in estimating the cost of air pollution control systems.

Uhl, Vincent W. A Standard Procedure for Cost Analysis of Pollution Control Operations: Volumes I and II, Office of Research & Development, U.S. Environmental Protection Agency, EPA-600/8-79-018a, June, 1979.

- Presents a standard procedure for estimating engineering costs of pollution abatement operations and processes.

U.S. EPA, Health Impacts, Emissions & Emission Factors for Noncriteria Pollutants Subject to DeMinimus Guidelines and Emitted from Stationary Conventional Combustion Processes, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, EPA-450/2-80-074, June, 1980.

- Emission factors are developed for the trace elements emitted by stationary conventional combustion processes subject to de minimis guidelines (mercury, beryllium, fluorides, and sulfuric acid mist). A lack of information prevents development of emission factors for asbestos and vinyl chloride.

Baig, S, et. al., Conventional Combustion Environmental Assessment Final Report, for Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina, July, 1981.

- Evaluates stationary conventional combustion process emission stream characteristics that influence or affect the amount of noncriteria pollutant releases to the atmosphere. Also examines controllability of non-criteria pollutants from stationary conventional combustion sources.

Purcell, Robert Y. and Gunseli Sagun Shareef, Evaluation of Control Technologies for Hazardous Air Pollutants (Draft), for Office of Research and Development, U.S. EPA, October 1, 1985.

- This manual is designed to assist EPA regional, state and local air pollution control agency technical personnel to select, evaluate, and cost air pollution control techniques for reducing or eliminating the emission of potentially hazardous air pollutants from industrial and commercial sources. The information provided in the manual will be useful for reviewing permit applications or for informing interested parties of the type, basic design, and cost of available hazardous air pollutant control systems.

Christiano, John and Mark Scruggs, Permit Application Guidance for New Air Pollution Sources - Natural Resources Programs, National Park Service, Natural Resources Report Series No. 85-2., National Park Service, Air Quality Division, Permit Review and Technical Support Branch, Denver, Colorado, August, 1985.

- " This document provides guidance to persons intending to submit a PSD permit application for a major source that has the potential to impact a Class I area managed by the National Park Service or the U.S. Fish and Wildlife Service."

American Conference of Governmental Industrial Hygenists, TLVs, Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH (Updated Annually)

- Defines TLV and presents TLV values for numerous substances.

U.S. EPA, Industrial Guide for Air Pollution Control, Technology Transfer, EPA-625/6-78-004, June, 1978.

- Presents guideline for plant compliance with air pollution control regulations. Intended for industrial plant personnel responsible for a corporate program of environmental control.

APPENDIX B

402 ACUTELY TOXIC CHEMICALS LISTED BY EPA's CHEMICAL EMERGENCY PREPAREDNESS PROGRAM

sensitive to changes in VOC content, emission stream flow rate, and the temperature of the coolant. In addition, the condensed VOC must be either recycled or disposed of. Usually, condensed toxic pollutants will create a special handling problem no matter which disposal method is choosen.

3.3.5 Toxic Inorganic Vapor Control

In addition to toxic PM and VOC species, inorganic vapors are an additional source of TAPs. Inorganic TAP vapors typcially include gases such as ammonia, hydrogen sulfide, carbonyl sulfide, carbon disulfide, metals with hydride and carbonyl complexes, cholorides, oxychlorides, and cyanides.

Control options applicable to inorganic vapor emissions from point sources are primarily limited to absorption (scrubbing) and adsorption. Although combustion can be used for certain inorganic TAPs (e.g., hydrogen sulfide, carbonyl sulfide, nickel carbonyl), typical combustion techniques such as incineration are generally not used.

The applicability of absorption and adsorption as control methods depends on individual emission stream characteristics. Removal efficiencies are determined by the physical and chemical properties of the TAP under consideration.

Table 3-13 shows currently accepted control methods for various inorganic vapors. For absorption, typical removal efficiencies associated with various solvents are shown. Similiarly, for adsorption, removal efficiencies associated with various adsorbents are shown.

3.3.6 Methods For Estimating TAP Risk

Understanding techniques to control TAPs represents only part of the TAP problem. Methods to assess the risk of exposure to toxic substances must also be devised.

Two techniques that have been developed to measure the risk of human exposure to toxic substances include threshold limit values (TLVs) and unit risk factors (URFs). URF's have been developed by

TABLE 3-13. CURRENT CONTROL METHODS FOR VARIOUS INORGANIC VAPORS[a]

	ABSORPTION		ADSORPTION	
Inorganic Vapor	Reported Removal Efficiency (%)	Solvent	Reported Removal Efficiency (%)	Adsorbent
Mercury (Hg)	95	Brine/hypochlorite solution	90	Sulfur-impregnat activated carbon
Hydrogen chloride (HCl)	95	Water		
Hydrogen sulfide (H_2S)	98	Sodium carbonate/ Water	100	Ammonia-impregnate activated carbor
Calcium fluoride (CaF_2)	95	Water		
Silicon tetrafluoride (SiF_4)	95	Water		
Hydrogen fluoride (HF)	85-95	Water	99	Calcined alumin
Hydrogen bromide (HBr)	99.95	Water		
Titanium tetrachloride ($TiCl_4$)	99	Water		
Chlorine (Cl_2)	90	Alkali solution		
Hydrogen cyanide (HCN)				Ammonia-impregnate activated carbon

[a] Source: Purcell, 1985, p. 3-17

the Environmental Protection Agency; TLVs by the American Conference of Governmental and Industrial Hygienists (ACGIH). The URF measures the increased cancer risk of a person exposed to one microgram per cubic meter of a carcinogenic TAP over a period of 70 years. The TLV represents the upper bound of airborne concentration of a substance to which it is believed workers may repeatedly be exposed without adverse effects (Radian, 1985; pp. 7-8: ACGIH, 1984).

The primary difference between the URF and the TLV is that the TLV represents a threshold dosage below which no risk exists. In contrast, the URF says that some degree of risk exists no matter how minor the exposure. URFs have only been developed for human carcinogens whereas TLVs have been developed for a variety of carcinogenic and non-carcinogenic substances commonly found in the workplace that may adversely affect human health.

TLVs are based on the best available information from industrial experience, from experimental human and animal studies and, when possible, from a combination of these. The basis for TLVs differs from substance to substance. For example, some TLVs are based on protection against impairment of health, while others are based on reasonable freedom from irritation. The amount and nature of the information available for establishing a TLV varies from substance to substance. The American Conference of Governmental and Industrial Hygienists (ACGIH) urges users of TLVs to review the supporting documentation to understand the extent of the data available for a given substance. ACGIH publishes this documentation in Documentation of the Threshold Limit Values. TLVs are reviewed regularly by ACGIH and revised as new data show revisions are warranted (Radian, 1985a).

The ACGIH uses the term "time weighted average TLV" (TWA- TLV) for an 8-hour day, 40-hour week exposure period. STEL refers to the "short term exposure limit" or the maximum concentration safe for periods up to 15 minutes. A STEL is specified by ACGIH for some substances with recognized acute effects to supplement the TWA limit, because the TWAs are based primarily on toxic effects from longer exposures. The TLV-C (ceiling) represents the concentration that should not be exceeded even instantaneously (Radian, 1985a).

A number of options exist to assess the risk of exposure to TAPs. TAPs control could be used as the deciding factor to determine BACT when an analysis of two or more BACT alternatives shows no clear favorite. If one of the control alternatives is more efficient at capturing TAPs, then that alternative could be classified as BACT. This option is relatively simple to use because it does not require the use of TLVs or URFs.

Another option to assess TAP risk involves choosing a control level that minimizes exposure to pollutant(s) with the highest URF's. For example, assume a particular process produces PM emissions containing chromate and nickel sulfide, two known human carcinogens. Also assume that two control options are available, neither of which is clearly favored in terms of cost and overall PM control. Since chromium has a higher URF and therefore is more potent, the control option that controls chromium to the highest level might be chosen as BACT for PM. One drawback to this approach is that the combined risk of all TAPs for a chosen BACT option may actually outweigh the next best alternative.

The above approache could be used to deal with carcinogenic TAPs but they are inadequate for dealing with non-carcinogenic substances. An approach to deal with both carcinogenic and non- carcinogenic substances would be to follow the example taken by certain states in regulating TAPs. States with existing TAP regulations generally prohibit a source to emit TAPs in an amount whose maximum predicted concentration exceeds a predetermined fraction of the TLV.

States that use TLVs to develop acceptable ambient concentrations typically apply a factor to the TLV-TWA. The factor may account for time and safety considerations.

When ACGIH develops TLVs for occupational exposure, it assumes that workers will not be exposed to the substance when they are not working. During these periods of no exposure, the worker's body will repair most of the damage incurred during periods of exposure. In contrast, when developing acceptable ambient concentration levels, continuous exposure to residents of neighboring areas must be considered. In these areas, periods for recuperation and repair will not exist, Therefore, a safety factor is necessary to reduce the TLV to account for such continous exposures (Radian, 1985a).

Safety factors are also used to account for exposure of sensitive subpopulations, such as young childern or the elderly, who may be more susceptible to adverse effects at lower concentrations than healthy workers assumed in the development of TLVs. Safety factors may be used to reflect the fact that ambient air may contain mixtures of pollutants that may have synergistic or additive effects, or when there is the potential existence of background concentrations of the substance. In addition, safety factors reflect the principle that workers are exposed as a condition of employment while exposure of the general population is involuntary (Radian, 1985a).

There is no consensus on what factors should be used to reduce TLVs. Table 3-14 shows the fractions applied to TLV's and the averaging periods used by state agencies and air quality regions. Some states such as Alabama and Arkansas apply the same fraction to all toxic substances. Other states use different TLV fractions, depending on pollutant toxicity. For example, New York uses 1/300 of the TLV for substances of high or moderate toxicity and 1/50 of the TLV for substances of lower toxicity (Smith, 1985; pp.28-29).

The primary justification for using different TLV fractions is that some substances cause acute, reversible effects while other substances cause chronic, irreversible effects. Local conditions such as the existence of toxic substances in the ambient air and the potential for population exposure should also be considered if this approach is used.

The last and most expensive option for dealing with the risk of exposure to TAPs involves a full-scale exposure analysis using models designed specifically for this purpose. This option should be reserved for extreme situations since the cost and time requirements can be high to collect data and run these models.

The health risks posed by pollution of the ambient air by TAP continues to grow in importance. The suggested techniques described

TABLE 3-14. SAFETY FACTORS USED TO DERIVE ACCEPTABLE AMBIENT CONCENTRATIONS FROM OCCUPATIONAL LIMITS

State or Locality	Safety Factor Applied to Occupational Limit	Averaging Time
Alabama	2.5% (1/40)	1 hour
Arkansas	1% (1/100)	24 hour
Conecticut[1]	0.5% (1/200), 1% (1/100), or 2% (1/50), depending on pollutant group	8 hour
Georgia[1]	0.33% (1/300) if known human carcinogen, 1% (1/100) if not known human carcinogen	24 hour
Illinois	0.33% (1/300) for non carcinogens	24 hour
Indiana[1]	1% (1/100)	24 hour
Michigan	1% (1/100) for selected pollutants	8 hour
Minnesota	1% (1/100)	8 hour
Mississippi	3.3% (1/30), usually	NA[2]
Montana	2.4% (1/42)	1 year[3]
Nevada	10% (1/10)	8 hour
New Hampshire[1]	1% (1/100)	NA[2]
New York	0.33% (1/300), 2% (1/50) depending on toxicity category	1 year[4]
Rhode Island[1]	1% (1/100)	24 hour
South Carolina	0.24% (1/420)	NA[2]
Texas	1% (1/100), 0.1% (1/1000)	30 minute 1 year

TABLE 3-14. SAFETY FACTORS USED TO DERIVE ACCEPTABLE AMBIENT CONCENTRATIONS FROM OCCUPATIONAL LIMITS (Continued)

State or Locality	Safety Factor Applied to Occupational Limit	Averaging Time
Vermont	0.24% (1/420)	24 hour or 1 year depending on pollutant
Virginia	1% (1/100) for carcinogens 1.7% (1/60) for non-carcinogens	24 hour 24 hour
Wisconsin[1]	2.4% (1/42)	NA[2]
Wyoming[3]	2.4% (1/42), 2% (1/50), 0.33% (1/300)	1 year, 24 hour, 1 hour
SCAQMD, California	100% for slected pollutants	8 hour
Philadelphia, Pennsylvania	0.24% (1/420) or 2.4% (1/42)	1 year

---

[1] Tentative: program in preparation.

[2] Not available at the time of this writing.

[3] As reported in Radian Corporation, "Survey of State and Local Agency Programs for Control of Toxic Air Pollutants," Draft Report, Prepared for U.S. EPA, Office of Air Quality Planning and Standards, State and Territorial Air Pollution Program Administrators, and Association of Local Air Pollution Control Officials, June 8, 1983.

[4] New York has the flexibility to use shorter averaging times than those specified when the pollutant of concern has short term acute effects. (Reference New York State Department of Environmental Conservation, 1985-86 Edition Air Guide-1, Division of Air Resources, Albany, NY. Page 20).

Source: Smith, 1985; p. 28-29

here highlight possible methods for evaluating the health risks imposed by TAPs.

3.4 ADDITIONAL PSD CONSIDERATIONS

Toxic air pollutants are an area that will gain the increasing attention of PSD permit officials during the next few years. However, there are additional, often overlooked, portions of PSD permits that should be scrutinized.

3.4.1 BACT Control Options

One of the first BACT related items to examine in PSD permits are each pollutant's proposed control options. Each BACT option should be include an examination of: emission control costs, emission estimates and control efficiency, energy and environmental impacts, permit timing and limits, modeling, and additional impacts analysis. Each of these factors is discussed below along with a section that explains how to review multi-phase project BACT determinations. However, evidence should be provided to verify that the PSD applicant has examined all technically feasible control options that control emissions of the PSD pollutant greater than the base case. This is especially true when emission units are modified and only the applicant can acurately assess the costs and benefits of control options that may be applicable to the specific case.

3.4.2 BACT Costs

Each PSD permit application will contain BACT control costs that require close scrutiny. In many PSD permits, BACT control costs are not disaggregated enough to allow examination of the costing process. Disaggregation enables the reviewer to determine the time frame and site specificity of the costs and to check for double-counting. A common pitfall in BACT costing involves using different cost periods or different inflation/deflation rates. Cost estimates should be discounted or inflated to the same base year and all costs should be specific to the site, state or region in question.

3.4.3 BACT Emission Estimates

Emission estimates should also be scrtinized. All potential emissions need to be included: process, area, and fugitive emissions and both criteria and non-criteria pollutants subject to de minimis guidelines. The reviewer must ensure that calculations are reasonable and correct for uncontrolled and controlled emissions and emission reductions. Figure 3-3 and Tables 3-15, 3-16, 3-17, and 3-18 show typical control efficiencies for various emission control devices and procedures. While these tables cannot be taken as absolute numbers, they do provide general guidance as to what can be expected.

Permit officials should be aware of proposals that attempt to justify unusually high or low control efficiency. At either extreme of efficiency, and for all points in between, the proposed BACT must be justified by analyzing its economic, energy, and environmental impacts. Low efficiency controls are most likely for fugitive and area emission sources. PSD permits that attempt to justify extremely high control levels should also be examined closely, especially in borderline cases where a slightly lower control efficiency might change the results of the modeling and BACT analyses.

3.4.4 BACT Energy And Environmental Impacts

The energy and environmental impacts associated with each control alternative are often ignored or given only cursory treatment. Both energy and environmental impacts for every control technology must be addressed, even if the estimates are only qualitative. For processes that produce toxic air pollutants, the health impacts of those pollutants should be addressed. Even controls such as fabric filters or high efficiency ESPs, which are generally regarded as the "best" controls (for PM), must be examined for possible detrimental economic, energy, or environmental impacts.

3.4.5 Modeling Considerations

The PSD permit reviewer must ensure that modeling of short and long-term maximum pollutant concentrations has been performed correctly. Oftentimes, review agencies use an emission limit to determine 3-hour and 24-hour ambient air impacts but do not specify the averaging time for the emissions limit. For example, it would be incorrect to model peak 3-hour or 24-hour concentrations of a pollutant using the 30 day average emission rate for that pollutant.

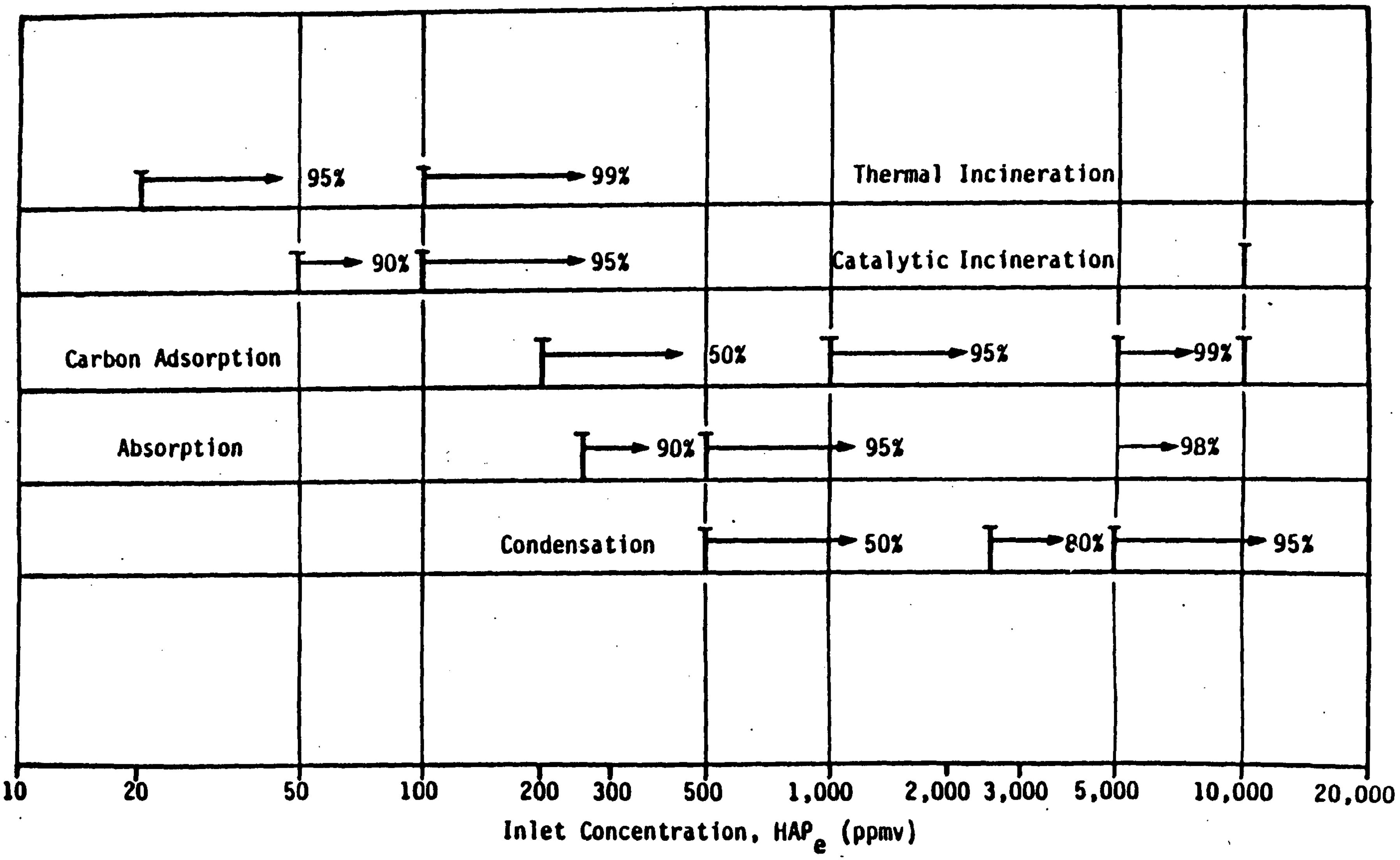


FIGURE 3-3. PERCENT REDUCTION RANGES FOR ADD-ON VOC CONTROL DEVICES[a]

[a]Source: Purcell, 1985, 1985; p. 3-4

TABLE 3-15. SUMMARY OF CONTROL EFFECTIVENESS FOR CONTROLLING ORGANIC AREA FUGITIVE EMISSION SOURCES

Emission Source	Control Technique/Equipment Modification	Control Effectiveness[a] (percent)
Pumps	Monthly leak detection and repair	61
	Sealless pumps	100
	Dual mechanical seals	100
	Closed vent system[b]	100
Valves		
- gas	Monthly leak detection and repair	73
	Diaphragm valves	100
- light liquid	Monthly leak detection and repair	46
	Diaphragm valves	100
Pressure relief valves	Rupture disk	100
	Closed vent system[b]	100
Open-ended lines	Caps, plugs, blinds	100
Compressors	Mechnical seals with vented degassing reservoirs	100
	Closed vent system[b]	100
Sampling connections	Closed purge sampling	100

[a] Source: Purcell, 1985; p. 3-24

[b] Closed vent systems are used to collect and transfer the fugitive emissions to add-on control devices such as flares, incinerators, or vapor recovery systems.

TABLE 3-16. CONTROL TECHNOLOGY APPLICATIONS FOR OPEN STORAGE PILES[a]

Emission Points	Control Procedure	Efficiency
Loading onto piles	Enclosure	70-99%
	Chemical wetting agents or foam	80-90%
	Adjustable chutes	75%
Movement of pile	Enclosure	95-99%
	Chemical wetting agents	90%
	Watering	50%
	Traveling booms to distribute material	No estimate
Wind erosion	Enclosure	95-99%
	Wind screens	very low
	Chemical wetting agents or foam	90%
	Screening of material prior to storage, with fines sent directly to processing or to a storage silo	No estimate
Loadout	Water spraying	50%
	Gravity feed onto conveyor	80%
	Stacker/reclaimer	25-50%

[a] Source: Purcell, 1985; p. 3-56.

TABLE 3-17. CONTROL TECHNOLOGY APPLICATIONS FOR PLANT ROADS[a]

Emission Points	Control Procedure	Efficiency
Paved streets	Street cleaning	No estimate
	Housecleaning programs to reduce deposition of material on streets	
	Vacuum street sweeping (daily)	25%
	Speed reduction	Variable
Unpaved roads	Paving	85%
	Chemical stabilization	50%
	Watering	50%
	Speed reduction	Variable
	Oiling and double chip surface	85%
Road shoulders	Stabilization	80%

[a] Source: Purcell, 1985; p. 3-54.

TABLE 3-18. CONTROL TECHNOLOGY APPLICATIONS FOR WASTE DISPOSAL SITES[a]

Emission Points	Control Procedure	Efficiency
Handling	Keep material wet	100%
	Covered or enclosed hauling	No estimate
	Minimize free fall of the material	No estimate
Dumping	Spray bar at dump area	50%
	Minimal free fall of material	No estimate
	Semi-enclosed bin	No estimate
Wind Erosion	Covering with dirt or stable material	100%
	Chemical stabilization	80%
	Revegetation	25-100%
	Rapid reclamation of newly filled areas	No estimate
Grading	Watering	50%

[a] Source: Purcell, 1985; p. 3-58.

By using average 30-day emission rates to calculate maximum 3-hour concentrations, the maximum 3-hour emission peaks are smoothed over, resulting in calculated 3-hour maximum concentrations that are lower than if the short-term peak emission values are used. The same logic argues against the use of any average emission rate to estimate the maximum concentration for a shorter time period.

A divergence exists between the NSPS emissions rate averaging time for fossil fuel fired utilitysteam generating units and the PSD emissions rate averaging time requirements for these same units. Protection of the PSD SO_2 increments requires emission limits with averaging times no longer than the averaging times for the increments. Thus, compliance with a 3-hour SO_2 increment requires an emissions limit averaging time of 3 hours or less. The same logic applies to protection of the 24-hour increments and NAAQS.

However, some NSPS emission limits require SO_2 compliance testing against the existing numerical NSPS limits but requires compliance demonstrations on a continuous basis. Sulfur dioxide emissions would be calculated on a rolling 30-day average basis instead of a short-term (approximately 3-hour) stack test.

On June 11, 1979, EPA promulgated new requirements for electric utility boilers (44 FR 33580, Subpart Da sources). These requirements specified a rolling 30-day average NSPS for SO_2 for new Subpart Da sources. PSD permits, although intended to protect short-term as well as long-term increments, may specify only the rolling 30-day average NSPS as an SO_2 emission limitation.

If already issued PSD permits do not contain or incorporate by reference short-term SO_2 emission limits that are adequate to protect short-term increments and NAAQS, the review agency should take the following action:

1) Reassess short-term impacts for all sources on the basis of maximum anticipated short-term emissions and take these new increment consumption levels into account in future PSD permit analyses.

2) If increment exceedances are predicted by the new analysis, develop a revision to the SIP to prevent such exceedances.
3) Develop and implement a policy or regulation requiring short-term limits in PSD permits that adequately protect short-term increments.

3.4.6 Additional Impacts (Class I Areas)

The additional impacts analysis portion of PSD permits examines a project's secondary economic impacts, the effect on soils and indigenous flora, and visibility impacts on Class I areas. Techniques for estimating these impacts are described in the PSD workshop manual. One facet of the additional impacts analysis not covered in the workshop manual is the type of analysis required if a project is expected to affect a designated Class I area.

The Federal Land Manager is routinely notified by EPA or by the state upon receipt of a permit if the major source is located near (usually within 100 km of) a Class I area or if the facility would violate increments or affect the air quality related values at the Class I area. Air quality related values (AQRVs) include visibility, odor, flora, fauna, geological resources, archeological, historical, and other cultural resources, and soils or water quality resources (Christiano, 1985; p.3).

Applications for new or sources impacting Class I areas should contain: a) a complete flora and fauna inventory of the subject area, b) vegetation/habitat maps of the subject area, c) a listing of the Federal and state endangered and threatened species, d) a listing of soil types of the subject area, and e) water chemistry data of open water bodies in the subject area. This information and the following types of studies are used to determine the presence of AQRVs and the potential for adverse impacts: a) examination of flora and fauna for sensitive species, b) examination of flora and fauna for bioindicator species, c) field evaluation of the sensitive bioindicator species for presence of current injury symptoms, d) determination of locations and sensitive species in relation to the proposed air pollution source, e) determination of potential for injury to endangered and threatened species, f) determination of sensitivity of soil types, g) calculations of loadings of pollutants in the subject area in relation to natural inputs and buffering capabilities of subject ecosystems. The PSD applicant is expected to put this information together (Christiano, 1985; p.5).

3.4.7 Multiphase BACT Determinations

One additional problem that often crops up in PSD permitting involves review of multi-phase project BACT determinations. According to the Code of Federal Regulations (40 CFR 52.21(j)(4), for phased construction projects, determination of BACT should be reviewed or modified at the latest reasonable time occuring no later than 18 months prior to the start of construction of each independent phase of a project. At that time, the owner or operator of the source may be required to demonstrate the adequacy of any previous BACT determination for the source (40CFR 52.21(j)(4)).

Approval becomes invalid if construction has not begun within 18 months after reciept of such approval, if construction is discontinued for 18 months or more, or if construction is not completed within a reasonable time. The Administrator may extend the 18-month period upon a satisfactory showing that an extension is justified. However, this provision does not apply to the time period between construction of the approved phases of a phased construction project; each phase must start construction within 18 months of the projected and approved commencement date (40CFR 52.21(r)(2)).

Draft 1
1/22/6

REFERENCES

OTHER CHEMICALS

NAME	CAS NUMBER
Acrylamide	79-06-1
Acrylonitrile	107-13-1
Adiponitrile	111-69-3
Ammonia	7664-41-7
Aniline	62-53-3
Bromine	7726-95-6
Carbon disulfide	75-15-0
Chloroform	67-66-3
Cumene	98-82-8
Cyclohexylamine	108-91-8
Epichlorohydrin	106-89-8
Ethylene oxide	75-21-8
Formaldehyde	50-00-0
Hydrochloric acid	7647-01-0
Hydrogen peroxide	7722-84-1
Hydrogen sulfide	7783-06-4
Hydroquinone	123-31-9
Isopropanol	67-63-0
Methanol	67-56-1
Methyl bromide	74-83-9
Nitrobenzene	98-95-3
Phosgene	75-44-5
Propylene oxide	75-56-9
Sulfur dioxide	7446-09-5
Tetramethyl lead	75-74-1
Vinyl acetate monomer	108-05-4

APPENDIX C

KNOWN, PROBABLE, AND POTENTIAL HUMAN CARCINOGENS

LIST OF TABLES

APPENDIX C-1. KNOWN HUMAN CARCINOGENS[1]
(Radian Corp, 1985b)

Substance/Process	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
4-Aminobiphenyl[c]	92-67-1	No current commercial use in U.S. Formerly used as a rubber antioxidant and a research chemical.	
Arsenic Arsenic trioxide[d] Arsenic pentoxide Sodium arsenate Sodium arsenite	7440-38-2 1327-53-3 1303-28-2 7631-89-2 15120-17-9 7784-46-5	Used in pesticides, glass, ceramics, paints, dyes, and the preservation of hides. Used as a desiccant for cotton and as a wood preservative. Arsenic occurs in number of ores (particularly copper, lead and zinc) and in food. About 70 million pounds are produced in the U.S., primarily from copper and lead ore smelting.	4.29×10^{-3}
Asbestos Chrysotile[e] Amosite Anthophyllite Crocidotile	1332-21-4	Used in more than 5000 products, such as roofing, thermal and electrical insulation, cement pipe and sheet, flooring, gaskets, friction materials, coatings plastics, textiles and paper products. About 200 million pounds were produced in 1979.	9.5×10^{-3}
Auramine Manufacture (Basic Yellow 2)	492-80-8	Used as a dye or dye intermediate for coloring inks, textiles, wool, paper and leather. Auramine is not domestically produced, but 165,000 lb were imported in 1979.	
Azathioprine[g] (Purine)	446-86-6	Used as an immunosupressive drug to suppress rejection of transplanted organs.[h]	

---

[1] The three tables in Appendix C were taken from Final Work Products Supporting the Development of a Toxic Air Pollutant Regulation for the State of Maryland, prepared by Radian Corp., Research Triangle [redacted] [redacted] ark [redacted] NC and [redacted] SCF, Incorporated, Washington, D.C. for US EPA Region III and Maryland Air Management [redacted] These ta[redacted] li[redacted]ne known, [redacted]ab[redacted]nd [redacted]nti[redacted]uma[redacted].rc[redacted]ns[redacted]t h[redacted] bee[redacted] [redacted] [redacted]

APPENDIX C-1. KNOWN HUMAN CARCINOGENS[1] (Continued)
(Radian Corp. 1985b)

Substance/Process	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Benzene	71-43-2	Used as a solvent in the chemical and drug industries, as a starting material and intermediate in the synthesis of numerous chemicals, and as a gasoline additive. Eighty percent is used in the production of ethylbenzene, cumene, and cyclohexane. About 12 billion pounds were produced in 1979.	6.9×10^{-6}
Benzidine	92-87-5	Used as an intermediate in the production of azo dyes, sulfur dyes, fast color salts, naphthols, and other dyeing compounds. About 500 pounds per year are produced.	
N,N-Bis (2-chloroethyl)-2-naphthylamine (chlornaphazine)[c]	494-03-1	Drug used in the treatment of cancer. It is not currently produced in the U.S.	
Bis (chloromethyl) ether, and Chloromethyl methyl ether	542-88-1 107-30-2	Used in the synthesis of other chemicals and in the manufacture of plastics and ion exchange resins.	
Boot and shoe manufacture and repair[g]			
1,4-Butanediol dimethanesulphonate[g]	55-98-1	Used as inhibitor for growth and spread of neoplasms.	
Chlorambucil[e]	305-03-3	A drug used in the treatment of cancer. All of this drug used in U.S. is imported. Workers are exposed while formulating the tablets.	

APPENDIX C-1. KNOWN HUMAN CARCINOGENS[1] (Continued)
(Radian Corp. 1985b)

Substance/Process	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Chromium and certain chromium compounds:	7440-47-3	Metal used: in metal alloys such as stainless steel; as protective coatings on metal; on magnetic tapes; as pigments for paints, cement, paper, rubber, composition floor covering, and other materials; as oxidants in organic chemical synthesis; in photochemical processing; in industrial water treatment; and in medicine as an astringent and antiseptic. The 1980 production of chromium and 10 major chromium compounds was over 152 million pounds; sodium dichromate made up 554 million pounds.	1.2×10^{-2} (Hexavalent)
Sodium dichromate	10588-01-9		
Calcium chromate	13765-19-0		
Lead chromate	7758-97-6		
Sintered calcium chromate	8012-75-7		
Zinc chromate	13530-65-9		
Strontium chromate	7789-06-2		
Sintered chromium trioxide	1333-82-0		
Lead chromate oxide	18454-12-1		
Cobalt-chromium alloy	11114-92-4		
Coal gasification	--	Certain exposures in older retort houses provide evidence that these processes are carcinogenic to humans.	
Coke oven emissions		Complex mixture that is composed of coal and coke particles, vapors, gases and tars. These emissions result from the destructive distillation of carbonization of coal to produce coke.	6.2×10^{-4}
Combined chemotherapy for lumphomus (including Moff)[g]			
Conjugated olestrogens[g]			
Cyclophosphamide[c]	50-18-0	Drug used in the treatment of cancer. it is not produced in the U.S., but 1300 pounds are imported annually.	

APPENDIX C-1. KNOWN HUMAN CARCINOGENS[1] (Continued)
(Radian Corp. 1985b)

Substance/Process	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Diethylstilbestrol (DES)[c]	56-53-1	This synthetic hormone had been used as a growth promoter for cattle and sheep and as a treatment for estrogen-deficiency disorders in animals. In humans, DES has been used to prevent spontaneous abortions and to treat hormonal imbalances. Its use is now limited to the treatment of neoplastic disease in humans.	
Furniture manufacture[g]			
Hematile underground mining		- - -	
Isopropyl alcohol manufacture (strong acid process)	67-63-0	It is not clear which substances in the strong acid process are carcinogenic. The annual production of isopropyl alcohol is about 750 million pounds.	
Melphalan[c]	148-82-3	Drug used in the treatment of cancer. It is not produced in the U.S., but 3000 pounds were imported in 1979.	
Methoxsalen with ultraviolet A therapy[g]	298-81-7	Methoxsalen is used as a suntan accelerator and sunburn protector.[h]	
Mustard gas[c]	505-60-2	Mustard gas was used as a chemical warfare agent during World War I. It is not currently manufactured or used in the U.S.	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
1,2-Dichloroethane (EDC) (Continued)		plastics and rubbers; as an ore flotation compound; and as an extractant in certain food processes.	
Dienoestrol[f]	84-17-3	Used as an estrogenic hormone.[h]	
Diepoxybutane	1464-53-3	Used primarily in research and experimental work as a curing agent for polymers, as a cross-linking agent for textile fabrics, and in preventing microbial spoilage. Used commercially in pharmaceuticals. This chemical was not produced or imported commercially in 1979-1980. It was imported for research.	
Di(2-ethylhexyl)phthalate	117-81-7	Most commonly used as an additive to polyvinyl chloride resins for fabricating flexible products such as pacifiers, squeeze toys, and balls, vinyl upholstery, shower curtains, raincoats, etc. It is also used in adhesives, resins, polymeric coatings, paper and paperboard, defoaming agents, food containers, animal glue, surface lubricants, and medical gloves and iv bags. Production was estimated to be about 260 million pounds in 1980. The chemical is widely distributed in the environment.	
Diethyl sulfate[f]	66-67-5	Used as an ethylating agent in organic synthesis.[h]	
3,3'-Dimethoxybenzidine	119-90-4	Used primarily as an intermediate in the production of azo dyes. The dyes are used for rubber, plastics, paper, leather, and textiles	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
4-Dimethylaminoazobenzene	60-11-7	Used for coloring polishes and other wax products, polystyrene, and soap. Also used as a chemical indicator.	
3,3'-Dimethylbenzidine	119-93-7	Over 75 percent of DMB is used as a dye or as an intermediate in dye and pigment production. The chemical is also used in the production of polyurethane-based elastomers, coatings, and rigid plastics. Also used in chlorine test kits for water companies and in test tapes in clinical laboratories. Most of the DMB used in the U.S. is imported.	
Dimethylcarbamoyl chloride	79-44-7	This chemical is used as an intermediate in the production of pharmaceuticals, pesticides, rocket fuels, and dyes.	
Dimethyl sulfate	77-78-1	An industrial chemical used primarily as an alkylating agent for converting compounds such as phenols, amines, and thiols to the corresponding methyl derivatives. It is also used in polyurethane base adhesives. About 48 million lb/yr are produced in the U.S.	
1,4-Dioxane	123-91-1	Used in chlorinated degreasing solvents and as a solvent for lacquers, plastics, varnishes, paints, dyes, fats, greases, waxes, and resins. Residues have been found in consumer products including detergents, shampoos, and certain pharmaceutical chemicals. Also produced as a byproduct of	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
1,4-Dioxane (Continued)		reactions based on condensing ethylene oxide or ethylene glycol. About 7.7 million lb/yr are produced in the U.S.	
Direct Black 38	1937-37-7	Used to dye fabric, leather, cotton, cellulosic materials, and paper, which are then used in consumer products. Production in 1980 was over 5000 lbs, and the chemical was also imported. Use of Direct Black 38 is declining, as it is being replaced with non-benzidine-based dyes.	
Direct Blue 6	2602-46-2	May be used by artists and as a dye for fabric, leather, cotton, cellulosic materials, and paper, which are then used in consumer products. In 1979 production was reported to be 5000 pounds, but no production was reported to USITC in 1980. It is being replaced by non-benzidine based dyes.	
Direct Brown 95[f]	16071-86-6	Used to dye cellulosic fibers.[h]	
Epichlorohydrin[f]	106-89-8	Used as a raw material for epoxy and phenoxy resins; the manufacture of glycerol; coring propylene-based rubbers; solvent for cellulose esters and ethers; high wet-strength resins for paper industry.[h]	1.2×10^{-6}
Ethinyloestradiol[f]	8056-51-7	Used as an estrogenic hormone.[g]	
Ethylene oxide[f]	75-21-8	Used in manufacture of ethylene glycol and higher glycols; surfactants; acrylonitrile; ethanolamines; petroleum demulsifier; fumigant; rocket propellant; industrial sterilant; and fungicide.[g]	1.0×10^{-4}

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Ethylene thiourea	96-45-7	Used in the vulcanization of various elastomers including neoprene and polyacrylate rubber. Trace amounts are present in the cured products. Neoprene is used in industrial and commercial products. Ethylene thiourea is also used as an intermediate in manufacturing antioxidants, insecticides, fungicides, dyes, pharmaceuticals, and synthetic resins, and as a constituent of electroplating baths. Residues are present in fruit and vegetable crops. In 1979, about 375,000 lbs were produced in the U.S.	
Formaldehyde	50-00-0	About 65-70 percent is used for production of phenolic, urea, melamine, and acetal resins with wide usage in the construction, automotive, and appliance industries. Also used in products such as textiles, embalming fluids, fungicides, bactericides, air fresheners, cosmetics, medicinals, and toothpastes. Production estimated at 6 billion lbs in 1980.	6.1×10^{-6}
Hexachlorobenzene[c]	118-74-1	Used as a fumigant on grains, as an intermediate in the manufacture of dyes and other organic chemicals, and as a wood preservative. Formed as an impurity during the production of herbicides and pesticides. Production of this chemical in the U.S. ended in 1976, and it is no longer imported; however, it is a widespread contaminant in the environment.	4.9×10^{-4}

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Hydrazine and hydrazine sulfate	302-01-2 10034-93-2	Hydrazine is used primarily as an intermediate in the production of rocket fuel. It has also been used as an oxygen scavenger in water boiling and heating systems. Hydrazine is used as an intermediate in the production of agricultural chemicals, spandex fibers, and antioxidents; as a polymerization catalyst; as a blowing agent; for plating metals on glass and plastics; and in fuel cells, solder fluxes, and photographic developers. Hydrazine sulfate is used in refining rare metals, in analytical blood tests, and as a biocide.	
Hydrazobenzene	122-66-7	Hydrazobenzene is used in the dye industry as a precursor to the dye imtermediate benzidine. It is also used as an intermediate in the production of phenylbutazone, an arthritis treatment. Annual production has been estimated at 370,000 lbs, but this may be declining as benzidine-based dyes are being replaced with non-benzidine-based dyes.	
Iron dextran complex	9004-66-4	Used for treatment of iron-deficiency anemia in humans and baby pigs. Manufactured at two U.S. plants.	
Iron and Steel Founding[f]		Evidence suggests that occupational exposures are probably carcinogenic to humans.	
Kepone [c]	143-50-0	Used as an insecticide. Not manufactured or used in the U.S. since 1978. Kepone is a degradation product of the	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Kepone [c] (Continued)		insecticide mirex, and has been found in soil, water, and vegetation and in municipal waste where it was previously manufactured.	
Lead Acetate and lead phosphate	301-04-2 7446-27-7	Lead acetate is used in cotton dyes; in lead coating of metals; in paints, varnishes, and pigment inks; in medicinals such as astringents; and as a color additive in hair dyes. Lead phosphate is used as a stabilizer in styrene and casein plastics.	
Lindane and other hexachlorocyclohexane isomers	58-89-9	About 95 percent of lindane and its isomers are used in agricultural applications, as an insecticidal treatment for lumber, seed grains, livestock, fruit and vegetable crops. The remainder is used by industry. Commercial production ceased in the U.S. in 1976. Annual imports are estimated at 1 million pounds.	
Manufacture of Magenta[f]		- - - -	
Mestranol[f]	72-33-3	Used in oral contraceptives.[i]	
4,4'-Methelenebis(2-chloroaniline) (MOCA)	101-14-4	MOCA has been used as a curing agent in urethane and epoxy resins, which are used to make products such as semi-rigid foams, urethane rubber moldings, and industrial tires. It is also used in the manufacture of gun mounts, jet engine turbine blades, radar systems, and home appliances. One U.S. company currently produces MOCA.	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
4,4'-Methylenebis (n,n'-dimethyl) benzenamine	101-61-1	Used as an intermediate in dye production and as an analytical reagent in the determination of lead. Residual levels may be present in consumer products.	
Metronidazole[f]	443-48-1	Used as an antiprotozal.[i]	
Michler's ketone	90-94-8	Used as an intermediate in the synthesis of dyes and pigments, especially auramine derivatives. Residual levels may be present in consumer products. Domestic production was about 37,000 lbs in 1979, and 40,000 lbs were imported in 1980.	
Mirex [c]	2385-85-5	Mirex was used extensively in the Southeast to control the fire ant. It was also marketed as a flame retardant. It is no longer produced in the U.S., and its registration for technical products was cancelled in 1977. Residues have been found in soil, water, food, beverages, and human tissues.	
Nickel	7440-02-0	Nickel is used to make coins, as a chemical catalyst, in storage batteries, ceramics, electric circuits, coloring glass, petroleum refining, and in the hardening of edible oils. It is emitted from nickel refining facilities, coal- and oil-fired boilers, coke ovens, diesel-fuel burning, gray iron foundries, and other facilties producing or using nickel and nickel compounds.	3.3×10^{-4}
Nickel subsulfide	12035-72-2		
Nickel oxide	1313-99-1		
Nickel carbonate	3333-67-3		
Nickelocene	1271-28-9		
Nickel carbonyl	13463-39-3		

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Nitriloacetic acid	139-13-9	Used in detergents as an alternative to phosphates, also used as a boiler feedwater additive, and for water treatment, textile treatment, metal plating and cleaning, and pulp and paper processing.	
Nitrogen Mustard[f]	51-75-2	Used in medicines and as a military poison gas.[h]	
5-Nitro-o-anisidine	99-59-2	Used primarily as an intermediate in the production of dyes such as C.I. Pigment Red 23. This dye is used in printing inks, paints, rubber, plastics, floor coverings, paper coatings, and textiles. 1980 production was over 15,000 lbs.	
N-Nitrosodi-n-butylamine	924-16-3	Primarily used as a research chemical. May have limited use as an intermediate in the synthesis of n-butylhydrazine. Annual production is approximately 725 lbs. Trace amounts have been found in tobacco smoke, cooked meat products, animal feed, and soybean oil.	
N-Nitrosodiethanolamine	1116-54-7	No evidence of commercial production or use. The chemical is a contaminant of various cosmetics, cutting fluids, pesticides, and tobacco.	
N-Nitrosodiethylamine	55-18-5	Predominantly used as a research chemical. Minor uses include use in plastics, as a lubricant additive, and as an antioxidant. Production is about 725 lb/yr. Certain foods and beverages are also contaminated with this chemical.	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
N-Nitrosodimethylamine	62-75-9	Used prior to 1976 in manufacturing rocket fuels, as a solvent in the plastics industry, as an antioxidant, as a softener of copolymers, and as an additive to lubricants. It is not currently manufactured or used except for research purposes. It may be a byproduct of pesticide and rubber production, and is found in soil, water, and food.	
p-Nitrosodiphenylamine	86-30-6	Used as a chemical intermediate in dye and pharmaceutical production, and in the manufacture of vinyl chloride.	
N-Nitroso-n-propylamine	621-64-7	This chemical has been found as a contaminant in chemical factory wastewater, cheese, alcoholic beverages, and certain pesticides. U.S. production was estimated to be 350 lbs in 1979.	
N-Nitroso-n-ethylurea	759-73-9	Produced in small quantities (360 lb/yr) for research purposes. Widely dispersed in the environment as a contaminant.	
N-Nitroso-n-methylurea	684-93-5	Used for research purposes. No commercial production or use.	
N-Nitrosomethylvinylamine	4549-40-0	Use is limited to laboratory research. No commercial production. This chemical has been found as a contaminant in brandy.	
N-Nitrosomorpholine	59-89-2	Not produced or used commercially in the U.S. although patents have been issued for various uses. Has been detected as a contaminant in analytical grade dichloromethane, chloroform, and morpholine. May be emitted during rubber processing.	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
N-Nitrosonornicotine	16543-55-8	Does not have any commercial use, but may be synthesized for research purposes. It is released during tobacco curing and is found in cigarette smoke.	
N-Nitrosopiperidene	100-75-4	Has been used in the production of epoxy resin for electrical leads and for cardiovascular implants. It is produced in small quantities for laboratory research. Low concentrations are found in tobacco smoke, meat and fish products, and other foods. It may be emitted during rubber processing.	
N-Nitrosopyrrolidine	930-55-2	No evidence of commercial use. It has been found as a contaminant of meats and other food products and in tobacco smoke. It may be emitted during rubber processing.	
N-Nitrososarcosine	13256-22-9	Not used or produced commercially in the U.S. It is an environmental contaminant and is found in meat and other food products.	
Norethisterone[g]	68-22-4	Medicinal use as an orally-active progestin. Not produced in the U.S.[k]	
Oestradiol-17 beta[f]	50-28-2	Used as an estrogenic hormone.[h]	
Oestrone[f]	53-16-7	Used as an estrogenic hormone.[h]	
Oxymethalone [c]	434-07-1	Not produced in the U.S. on a commercial scale. It is imported and used as a drug to treat osteoporosis caused by old age.	
Phenacetin	62-44-2	Used as an analgesic and antipyretic drug. It has also been used in hair bleaching preparations. Domestic production was about	

[redacted]

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Phenazopyridine and phenazopyridine hydrochloride	94-78-0 136-40-3	Phenazopyridine hydrochloride is used as an analgesic drug. It is manufactured in the U.S.	
Phenoxyacetic acid herbicides (occupational exposure to)[f]	122-59-8	- - - -	
Phenytoin and sodium salt of phenytoin	57-41-0 630-93-3	Phenytoin is used as a drug to treat epilepsy and Parkinson's disease. It is imported, but it is uncertain whether it is currently manufactured in the U.S.	
Polybrominated biphenyls [c] (PBB)	36355-01-8	PBBs were widely used as flame retardant additives to synthetic fibers and molded plastics used in a variety of commercial products. PBB production and use was ended in the late 1970's.	
Polychlorinated biphenyls [c] (PCB)	1336-36-3	PCBs were used in transformer cooling liquids, heat transfer and hydraulic fluids, vacuum pump fluids, lubricants, plasticizers, fillers in casting waxes, surface coatings and sealants, pesticide extenders, and for copy papers. By 1974, uses were confined to closed systems. Except for limited research purposes, PCBs are no longer produced, imported, or used in the U.S. Environmental contamination is widespread.	
Procarbazine and procarbazine hydrochloride	671-16-9 366-70-1	Procarbazine hydrochloride is used as a drug to treat Hodgkin's disease and oat-cell carcinoma of the lung. It is manufactured in the U.S.	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Progesterone[f]	57-83-0	Used an an oral contraceptive and laboratory reagent.[h]	
beta-Propiolactone [c]	57-57-8	Over 85 percent of this chemical was used in the production of acrylic acids and esters. It was also used as a sterilant in medicinal uses and as a vapor-phase disinfectant. Production at the sole U.S. commercial manufacturer was reportedly halted in 1973.	
Propylthiouracil	51-52-5	Used as medicine (thyroid inhibitor).[h]	
Reserpine	50-55-5	Used in medicinal preparations as a tranquilizer or sedative. It has also been added to animal feeds. It is produced in the U.S.	
Saccharin	80-17-2	Saccharin is used as a sweetening agent in soft drinks and other foods and beverages. One U.S. plant currently produces saccharin, and it is also imported.	
Safrole	94-59-7	This compound has been used to flavor beverages and foods and as a pesticide ingredient. It may also be used in soap manufacture, perfume, sleep aids, and sedatives. About 2 million lbs were produced in the U.S. in 1977. Safrole is no longer used in pesticides or foods, so production has probably declined since 1977.	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Selenium sulfide	7446-34-6	Used in shampoos to treat dandruff, and in drugs to treat dermatitis. The chemical is imported, but is probably not produced in the U.S.	
Sequential oral contraceptives[f]			
Streptozotocin [c]	18883-66-4	This chemical has not been used commercially but is produced in small amounts for research.	
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	1746-01-6	Used only as a test chemical in basic research. The total estimated release in the U.S. is about 80 lb/yr. Sources include pesticide spraying, cigarette smoke, and combustion of gasoline, diesel fuel, and wood.	
Thioacetamide [c]	62-55-5	Used as an analytical chemical in laboratories. Commercial applications include use as a solvent in the leather, textile, and paper industries; use in the vulcanization of rubber; and as a stabilizer in motor fuel. No evidence has been found that this chemical is currently produced in the U.S. or imported.	
Thiourea	62-56-6	This chemical is used in animal glue liquifiers and silver tarnish removers, in the production of flame retardant resins and as a vulcanization accelerator. It is not produced in the U.S., but is imported.	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
o-Toluidine and o-Toluidine hydrochloride	95-53-4 636-21-5	o-Toluidine hydrochloride is used in the manufacture of a large number of commercial dyes. Residues may be present in dyed textiles. In 1977, 1000 lbs were produced and 25,000 lbs were imported.	
Toxaphene	8001-35-2	About 85 percent of the toxaphene produced in the U.S. was used to control cotton insect pests. The remainder is used to control insects on other crops and livestock. In 1982, EPA published a notice of intent to cancel or restrict registration for toxaphene-containing products.	
2,4,6-Trichlorophenol	88-06-2	This chemical has been used as a wood preservative, a glue preservative, an anti-mildew treatment for textiles, a bacteriacide, a herbacide, and a defoliant. Production has been limited in recent years due to the high costs of removing toxic chlorinated dibenzo-p-dioxins.	
Tris(aziridinyl)-para-benzoquinone[f] (Triaziquone)	68-76-8	Used in organic synthesis.[h]	
Tris(1-aziridinyl)phosphine sulfide	52-24-4	Only one U.S. company produces this drug, and it is used in chemotherapy for cancer patients.	
Tris(2,3-dibromopropyl) phosphite [c]	126-72-7	This chemical has not been produced in the U.S. since 1978. It was widely used as a flame retardant in synthetic textiles and in plastics.	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Uracil Mustard[f]	66-75-1	Used as a drug that inhibits the formation of tumors.[h]	
Urethane	51-79-6	Used as an intermediate in the production of amino resins, pharmaceuticals, insecticides, and fungicides; and in research. It is believed that current production is small and that it is used mainly for research.	

---

[a] American Chemical Society Chemical Abstract Service Registry Number. Source used here: Registry of Toxic Effects of Chemical Substances, NIOSH, 1978 Edition.

[b] Probability of contracting cancer if exposed to 1 ug/m^3 of a carcinogen for 70 years. Source: Personal communication, Mary Ann Baviello to Mike Dusetzina, EPA/OAQPS/PAB, March 1985. These factors are subject to change and should be confirmed with EPA Carcinogen Assessment Group before use.

[c] Probability of being emitted into the ambient air is low.

[d] Beryllium compounds of commercial importance.

[e] Source: Maryland Toxic Substances Registry System-Office of Environmental Programs-Science and Health Advisory for State of Maryland- Chemical Inventory 1983-Quantity by Chemical.
(Blanks indicate the substance was not included in 1983 Survey).

[f] Listed by IARC but not by NTP.

[g] Listed by NTP but not by IARC.

[h] Source: The Condensed Chemical Dictionary, Tenth Edition, Van Nostrand Reinhold Company, New York, 1981.

[i] Source: The Merck Index, Ninth Edition, Merck and Co., Rathway, N.J., 1976.

[k] Source: IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. International Agency for Research on Cancer.

Source (unless otherwise noted): Third Annual Report on Carcinogens: Summary, National Toxicology Program, U.S. Department of Health and Human Services, September 1983.

APPENDIX C-3. POTENTIAL HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS Number[a]	End Uses/Processes/Production	Unit Risk Factor[b]
o-Aminoazotoluene[f]	97-56-3	Used in dyes and medicine.[e]	
2-Amino-5-(5-nitro-2-furyl)-1,3,4-thiadiazole[f]	712-68-5	Used in medicine for treating gastroenteritis.	
Azaserine[f]	115-02-6	Antibiotic produced naturally by the fungus, <u>Streptomyces fragilis</u>. Also produced for commercial use in biochemical research.	
Benz(a)anthracene	56-55-3	Polycyclic aromatic hydrocarbon formed as a result of incomplete combustion. It is present in cigarette smoke condensate, automobile exhaust, gas, soot, emissions from coal- and gas-fired electric plants, mineral oil, commercial solvents, waxes, petrolatum, creosote, coal tar, petroleum asphalt, and coal tar pitch. This substance is a contaminant that has no commercial use.[d]	
Benzo(b)fluoranthene	204-99-2	Polycyclic aromatic hydrocarbon formed as a result of incomplete combustion. It is present in coke oven emissions, coal tar, soot, and cigarette smoke condensate.	
Benzo(j)fluoranthene[f]	205-82-3	A product of incomplete combustion. Also found in fossil fuels, cigarette smoke, marijuana smoke, urban air, various coal emissions, coal tar, smoked and broiled fish, surface water, rainwater, and sludge.	

APPENDIX C-3. POTENTIAL HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS Number[a]	End Uses/Processes/Production
Benzo(k)fluoranthene[f]	207-08-9	A product of incomplete combustion; found in fossil fuels, cigarette smoke, motor oils, lubricting oils, coal tar, crude oils, surface water, rainwater, effluent discharge, and sludge.
Benzye Violet 4B[f]	1694-09-3	Produced in U.S. and Europe for commercial use. Used as a dye and biological stain.
B-Butyrolactone[f]	3068-88-0	Used as an intermediate for the synthesis of butyric acid compounds. Also a solvent for acrylate and styrene polymers; and an ingredient of paint removers and textile assistants.[e]
4-Chloro-ortho-phenylenediamine[f]	95-83-0	Used as a dye intermediate in hair dyes.
Citrus Red No. 2[f]	6358-53-8	Used for coloring the skins of oranges not intended or used for processing.
Daunomycin[f]	20830-81-3	An antibiotic.[e]
N,N-diacetylbenzidine[f]	613-35-4	Used in chemical production.
4,4-diaminodiphenye ether[f]	101-80-4	Used to produce resins.
4,4-diaminodiphenyl ether (4-4Diaminodiphenyl = Benzidiene)		Used as an intermediate in the of dyeing compounds. Formerly produced in large amounts in the U.S.--in 1977, 1.4 million lbs. produced nationally, while 76,300 lbs. were imported.[d]

APPENDIX C-3. POTENTIAL HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS Number[a]	End Uses/Processes/Production
Dibenz(a,h)acridine	226-36-8	Limited used in biochemical and cancer research. It has been detected in the air emissions from coal combustion, petroleum refineries, incinerators, automobile exhausts, and cigarette smoke condensate.[d]
Dibenz(a,j)acridine	224-42-0	Used in biochemical and toxicological research. It has been detected in the air pollution from coal combustion, petroleum refinery incinerators, automobile exhausts, and cigarette smoke condensate.[d]
Dibenz(a,h)anthracene	53-70-3	Polycyclic aromatic hydrocarbon formed as a result of incomplete combustion. It is present in cigarette smoke condensate; gasoline engine exhaust; soot; smoke; coke and coal tars; various smoked, barbecued, or charcoal-broiled meats and fish; and certain-vegetables and vegetable oils.[d]
7H-Dibenzo(c,g)carbazole	194-59-2	Formed as a result of incomplete combustion. It is found in cigarette tar and is produced as a research chemical.
Dibenzo(a,e)pyrene[f]	192-65-4	Found as a product of incomplete combustion; in fossil fuels; in tobacco smoke; and in gasoline engine exhaust.
Dibenzo(a,h)pyrene	189-64-0	A product of incomplete combustion. It is found in coal tar pitch, engine exhaust, and cigarette tar. Workers and the general public may be exposed

APPENDIX C-3. POTENTIAL HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS Number[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Dibenzo(a,h)pyrene (Continued)		to DB(a,h)P from asphalt volatiles, coal tar pitch volatiles, coke oven emissions, and the combustion of fuel oil, diesel fuel, kerosene, and wood.[d]	
Dibenzo(a,i)pyrene	189-55-9	Formed as a result of incomplete combustion. It is found in emissions from coal and refuse buring, in exhaust from diesel powered vehicles, in coke oven emissions, in tobacco smoke, and in asphalt volatiles and coal tar pitch volatiles.[d]	
Dibenzo(a,l)pyrene[f]	191-30-0	A product of incomplete combustion, also in fossil fuels, cigarette smoke, and products of coal gasification.	
3,3-Dichloro-4,4'-diaminophenyl ether[f] (4,4'methylene bis (2-chloroaniline))	28434-86-8	Used as a curing agent for polyurethanes and epoxy resins.[e]	
1,2-Diethylhydrazine[f]	1615-80-1	No commercial production but evaluated experimentally as high powered rocket fuel.	
Dihydrosafrole[f]	94-58-6	Produced as an intermediate in insecticides.	
trans-2[(dimethylamino) methylimino]-5-[2-(5-nitro-2-furyl)vinyl]-1,3,4-oxadiazole[f]	55738-54-0	Used as a pharmaceutical.	

APPENDIX C-3. POTENTIAL HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS Number[a]	End Uses/Processes/Production	Unit Risk Factor[b]
1,1-Dimethylhydrazine[f]	57-14-7	Component of jet and rocket fuels; chemical synthesis; stabilizer for organic peroxide fuel additives; absorbant for acid gases; photography; plant growth controlling agent.[e]	
1,2-Dimethylhydrazine[f]	540-73-8	No commercial production or use.	
Ethyl methanesulphonate[f]	62-50-0	Produced for research purposes only.	
2-(2-formyehydrazino)-4-(5-nitro-2-furyl)thiazole[f]	3570-75-0	No commercial production or use.	
Glyciadaldehyde[f]	765-34-4	Not used commercially in the U.S. but in the U.K. is used as an agent in finishing wool, tanning of leather, and can be used in veterinary medicine.	
Gryomitrin[f]	16568-02-8	Not used or produced commercially. A natural substance found in the false morel (*Gyromitra ascerlenta*) mushroom.	
Hexamethylphosphoramide[f]	680-31-9	Ultraviolet inhibitor in polyvinyl chloride; chemosterilant for insects; promoting stereospecific reactions; solvent.[e]	
Indeno[1,2,3-cd]pyrene	193-39-5	A by-product of incomplete combustion which is released from refuse burning, coal furnaces, diesel powered vehicles, wood burning, and coke ovens. Also found in coal tar pitch, asphalt, and cigarette smoke. Contained in low levels in sausages and edible oils.	

APPENDIX C-3. POTENTIAL HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS Number[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Isosafrole		This compound has been used to flavor beverages and foods and as a pesticide ingredient. Also used in soap manufacture, perfumery, sleep aids and sedatives. In 1977, a reported 2 million lbs. were produced and imported to the United States.[d]	
Lasiocarpine[f]	303-34-4	Naturally produced by the plant *Heliotropium*, used medicinally in India, Greece, and the Mediterranean.	
Merphalan[f]	---	Used in human medicine for treatment of malignancies.	
2-methylaziridine[f]	75-55-8	Used as a chemical intermediate.	
Methylazoxymethanol and its acetate[f]	592-62-1		
5-methylchrysene[f]	3697-24-3	Found in tobacco and marijuana smoke; gasoline engine exhaust.	
4,4methylene bis (2-methylaniline[f]	838-88-0	Used in chemical manufacturing and dye synthesis.	
Methyl iodine[f]	74-88-4	Organic synthesis; microscopy; testing for pyridine.[e]	
Methyl methanesulphonate[f]	66-27-3	Produced for research purposes only.	
2-methyl-1-nitroanthraquinone[f] (of uncertain purity)	129-15-7	Used an an intermediate in the production of chemicals and dyes.	
N-methyl-n'-nitro-n-nitrosoguanidine[f]	70-25-7	Produced only as a research chemical.	

APPENDIX C-3. POTENTIAL HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS Number[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Methylthiouracil[f]	56-04-2	Used in medicine for treating hyperthyroidism.	
Mitomycin C[f]	50-07-7	Antibiotic derived from Streptomyces; stated to be effective against tumors.[e]	
Monocrotaline[f]	315-22-0	Extracted from the seeds of plant genera Crotalaria. Used medicinally and as a dye. (Not used commercially in the U.S.)	
5-(morpholinomethyl)-3 [(5-nitrofurfurylidene) amino]-2-oxazolidinone[f]	139-91-3	Used in veterinary medicine.	
Nafenopin[f]	3771-19-5	Produced only as an investigative drug.	
Niridazole[f]	61-57-4	An effective medicine used as an amoebicide, it has largely been superceded by alternative drugs.	
5-nitroacenaphthene[f]	602-87-9	In Japan, used as a chemical intermediate to produce whiting agents and paper dye.	
Nitrofen	1836-75-5	Nitrofen is a herbicide used on a variety of food and ornamental crops. Direct crop use in 1980 was 882,000 lbs., but in August 1980, the sole U.S. manufacturer of nitrofen recalled all existing stocks of the chemical.[d]	
1-[5-nitrofurfurylidene) amino]-2-imidazolidinone[f]	555-84-0	Formerly marketed as an antibacterial agent.	

APPENDIX C-3. POTENTIAL HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS Number[a]	End Uses/Processes/Production	Unit Risk Factor[b]
N-[4-(5-nitro-2-furyl)-2-thiazolye]acetamide[f]	531-82-8	Used in veterinary medicine.	
Nitrogen mustard N-oxide[f]	126-85-2 or 302-70-5	Used in medicines and in military gas.[e]	
2-Nitropropane[f]	79-46-9	Solvent especially for vinyl and epoxy coatings; chemical synthesis rocket propellant; gasoline additive.[e]	
N-nitrosomethylethylamine[f]	10595-95-6	Not produced or used commercially.	
N-nitroso-N-methylurethane[f]	615-53-2	Produced as a research chemical.	
Oil Orange SS[f]	2646-17-15	Trade name for petroleum dye used to color gasoline.[e]	
Panfuran S[f]	794-93-4	Formerly used in Japan as an antibacterial agent. Not used or produced in U.S. or Europe.	
Phenoxybenzamine and its hydrochloride[f]	63-92-3	Used in human medicine.	
Ponceau MX[f]	3761-53-3	Used as a textile and leather dye. Also used to colour inks, paper, pigment, and wood stains.	
Ponceau 3R[f]	3564-09-8	Used in dying wool and as a biological stain.[e]	
1,3-Propane sultone[f]	1120-71-4	Used as a chemical intermediate.	
Sodium Saccharin[f]	128-44-9	Used as a non-nutritive sweetener in foods.[e]	

APPENDIX C-3. POTENTIAL HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS Number[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Sterigmatocystin[f]	10048-13-2	Not produced or used commercially. Produced in laboratory from fungus cultures.	
Sulfallate	95-06-7	Used as a herbicide on vegetable and fruit crops and ornamentals. Production in 1980 was over 5000 lb/yr.[d]	
Testoterone and its esters[f]	58-22-0	An androgenic steroid, used in medicine and biochemical research.[e]	
4,4-Thiodianiline[f]	139-65-1	Used as a chemical intermediate in the production of dye.	
Trp-P-1[f]	68808-54-8	Not used or produced commercially. Found in broiled foods.	
Trp-P-2[f]	62450-07-1	No commercial production or use. Found in broiled sardines.	
Trypan Blue[f]	72-57-1	Used for dying textiles, leather, and paper; as a biological stain; and as a treatment for sleeping sickness.	
Zinc beryllium silicate[f]	39413-47-3	Used in luminescent materials.	

---

[a] American Chemical Society Abstract Service Registry Number. Source used here: Registry of Toxic Effects of Chemical Substances, NIOSH, 1978 edition.

[b] Probability of contracting cancer if exposed to 1 ug/m^3 of a carcinogen for 70 years. Source: Personal Communication, M.A. Baviello to Mike Dusetzina, EPA/OAQPS/PAB. March 1985. These factors are subject to change and should be confirmed with EPA's Carcinogen Assessment Group before use.

[c] Source: Maryland toxic Substances Registry System--Office of Environmental Programs, Science and Health Advisory Group, Chemical Inventory 1983, Quantity by Chemical for State of Maryland. (Blanks indicate the substance was not included in 1983 survey.)

[d] Source: Third Annual Report on Carcinogens: Summary, National Toxicology Program, U.S. Department of Health and Human Services, September 1983.

[e] Source: The Condensed Chemical Dictionary, Tenth Edition, Van Nostrand Reinhold Company, New York, 1981.

[f] ~~Listed by IARC but not by NTP.~~

Source: (unless otherwise noted) IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans: Vol. 1-34. International Agency for Research on Cancer.

APPENDIX D

SOURCE CATEGORIES BY SIC CODE AND ASSOCIATED POTENTIAL TOXIC POLLUTANTS

APPENDIX D. SOURCE CATEGORIES BY SIC CODE AND ASSOCIATED POTENTIAL TOXIC POLLUTANTS[a]

SIC Code[b]	Description	Potential Pollutants
0723	Crop preparation services	Ethylene dibromide
0724	Cotton ginning	Arsenic
1099	Lithium mining	Lithium
1411	Dimension stone, marble, mica, granite, limestone	c
1422	Crushed/broken limestone	c
1423	Crushed/broken granite	c
1429	Crushed/broken stone	c
1442	Sand and gravel	c
1446	Industrial sand	c
1449	Mica	c
1475	Phosphate rock	Radionuclides, fluorides
1612	Highway/street construction	Asbestos, POM

---

[a] This table is taken from North Carolina Air Toxics Survey, Identification of Pollutants of concern and Potential Emissions Sources and was prepared by Radian Corporation, Research Triangle Park, NC for the US EPA Region IV and the NC Division of Environmental Management. Since this table was derived only from source categories found in North Carolina, it does not include all possible sources of this air pollutants found throughout the U.S.

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
1622	Bridge, tunnel construction	c
2011	Meat packing	e
2013	Sausage and meat products	e
2015[f]	Poultry	e
2016	Poultry	e
2026	Fluid milk	e
2031[f]	Fish	e
2032	Canned specialties	e
2033	Canned vegetables, fruit	e
2034	Dehydrated fruit	e
2035	Pickled fruit, vegetables	e
2041	Flour/grain mill	e

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2042[f]	---	e
2046	Wet corn milling	e
2048	Prepared feed for animals, nec	Acrolein, e
2070[f]	Fats and oils	Ethylene dichloride, e
2071[f]	---	e
2075	Soybean oil	e
2077	Animal/marine fat and oil	Ethylene dichloride
2079	Shortening, table oil, margarine	e
2082	Malt beverages	e
2085	Distilled liquors	e
2091	Canned/cured fish and seafood	Hydrogen sulfide, e
2092	Fresh/frozen fish and seafood	e

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2093	Fresh/frozen fish and seafood	e
2094	---	e
2099	Food preparation, nec	e
2110[f]	---	
2111	Cigarettes	Methyl chloroform, benzene, toluene, chloroform, perchloroethylene, formaldehyde, methylene chloride
2131	Tobacco and snuff	e
2141	Tobacco stemming and redrying	e
2211	Broad woven fabric mills, cotton	
2221	Broad woven fabric mills, man-made fiber and silk	Chloroform, vinylidene chloride, acrylonitrile, benzene, dioxane, formaldehyde, aziridine, perchloroethylene, carbon disulfide, hydrogen sulfide
2231	Broad woven fabric mills, wool (includes dye and finish)	Bis(chloromethyl) ether, methylene chloride, chloroform, 1,4-dichlorobenzene, benzidine, formaldehyde, aziridine, dioxane, perchloroethylene, trichloroethylene, benzene
2241	Small wares mills, cotton, wool, silk, man-made fiber	Chloroform, vinylidene chloride, benzene, dioxane, formaldehyde, aziridine, perchloroethylene

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2251	Womens hosiery (includes dye and finish)	Acrylonitrile, chromium, vinylidene chloride, benzene, benzidine, bis(chloro methyl) ether, chloroform, aziridine, POM, perchloroethylene, 1,4-dichlorobenzene, methylene chloride, dioxane, formaldehyde
2252	Hosiery except womens (includes dye and finish)	Acrylonitrile, POM, vinylidene chloride, benzene, benzidine, bis(chloro methyl) ether, chloroform, aziridine, perchloroethylene, 1,4-dichlorobenzene, methylene chloride, dioxane, formaldehyde
2253	Knit outerwear mills	Dioxane, vinylidene chloride, acrylonitrile, benzene, perchloroethylene, formaldehyde, aziridene
2254	Knit underwear mills	Dioxane, formaldehyde, aziridine, perchloroethylene, vinylidene chloride, acrylonitrile, benzene
2256[f]	---	
2257	Circular knit mills (including dye and finish)	POM, acrylonitrile, vinylidene chloride, benzene, benzidine, bis(chloromethyl) ether, chloroform, aziridine, perchloroethylene, 1,4-dichlorobenzene, methylene chloride, dioxane, formaldehyde
2258	Warp knit fabric mills	Degreasing solvents[d]
2259	Knitting mills, nec	Formaldehyde, aziridine, perchloroethylene, vinylidene chloride, acrylonitrile, benzene, dioxane
2261	Finishers of broad woven fabrics	POM, acrylonitrile, vinylidene chloride, benzene, benzidine, bis(chloromethyl) ether, chloroform, aziridine, perchloroethylene, 1,4-dichlorobenzene, methylene chloride, dimethyl sulfate, dioxane, formaldehyde

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2262	Finishers of man-made and silk fibers	POM, vinylidene chloride, benzene, benzidine, bis(chloromethyl) ether, chloroform, aziridine, perchloroethylene, 1,4-dichlorobenzene, methylene chloride, dioxane, formaldehyde, acrylonitrile
2269	Finishing of textiles, nec	POM, vinylidene chloride, benzene, benzidine, bis-(chloromethyl) ether, chloroform, aziridine, perchloroethylene, 1,4-dichlorobenzene, methylene chloride, dioxane, formaldehyde, acrylonitrile, vinyl chloride, hydrazine
2272	Tufted carpets and rugs	Acrylonitrile, benzene, dioxane, formaldehyde, aziridine, perchloroethylene
2281	Yarn spinning mills; cotton, silk, man-made fibers	d
2282	Yarn texturizing, twisting, winding	d
2283	Yarn mills, wool	d
2284	Thread mills	d
2292	Lace goods	Methylene chloride, POM, vinylidene chloride, benzidine, bis(chloromethyl) ether, chloroform, 1,4-dichlorobenzene
2293	Padding, upholstery filling	Acrylonitrile, benzene, dioxane, formaldehyde, aziridine, perchloroethylene
2295	Coated fabrics, not rubberized	Dioctyl phthalate, POM, vinylidene chloride, benzene, benzidine, bis(chloromethyl) ether, chloroform, aziridine, perchloroethylene, 1,4-dichlorobenzene, ethylene dichloride, nitrosomorpholine, toluene, methylene chloride, dioxane, formaldehyde, acrylonitrile, asbestos, hexachlorocyclopentadiene

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2296	Tire cord and fabric	POM, vinylidene chloride, benzene, benzidine, bis(chloromethyl) ether, chloroform, aziridine, perchloroethylene, 1,4-dichlorobenzene, ethylene dichloride, toluene, methylene chloride, dioxane, formaldehyde, acrylonitrile, asbestos, hexachlorocyclopentadiene
2297	Non-woven fabrics	Acrylonitrile, bis(chloromethyl) ether
2321	Mens shirts and nightwear	d
2322	Mens underwear	d
2327	Mens trousers	d
2329	Mens clothing, nec	d
2334[f]	---	d
2339	Womens clothing, nec	d
2341	Womens underwear, nightwear	d
2369	Girls' clothing, nec	d
2380	Miscellaneous apparel	d
2389	Apparel and accessories, nec	d
2391	Curtains/drapes	d
2392	House furnishings, except curtains	d
2394	Canvas and related products	d

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2399	Fabricated textiles, nec	d
2421	General sawmills, planing mills	Acetaldehyde, dioxins, formaldehyde, manganese, arsenic, nickel, cadmium, chromium, POM (wood combustion)
2426	Hardwood dimension/ flooring mills	Acetaldehyde, dioxins, formaldehyde, manganese, arsenic, nickel, cadmium, chromium, POM (wood combustion)
2431	Millwork	Methylene chloride, carbon tetrachloride, toluene, xylene
2432[f]	---	
2433[f]	---	
2434	Wood kitchen cabinets	Methylene chloride, carbon tetrachloride, toluene, xylene

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2435	Hardwood veneer and plywood	Formaldehyde, perchloroethylene
2436	Softwood veneer and plywood	Formaldehyde, perchloroethylene
2439	Structural wood members, nec	Methylene chloride, carbon tetrachloride, toluene, xylene
2441	Nailed and lock corner wood boxes	Methylene chloride, carbon tetrachloride, toluene xylene
2442[f]	---	Methylene chloride, carbon tetrachloride, toluene xylene
2443[f]	---	Methylene chloride, carbon tetrachloride, toluene xylene
2448	Wood pallets and skids	Methylene chloride, carbon tetrachloride, toluene xylene
2449	Wood containers, nec	Methylene chloride, carbon tetrachloride, toluene, xylene
2451	Mobile homes	
2491	Wood preserving	Arsenic, chromium, dioxins, cresols, pentachlorophenol
2499	Wood products, nec	Methylene chloride, carbon tetrachloride, toluene xylene

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2511	Wood household furniture, except upholstered	Methylene chloride, methyl chloroform, trichloroethylene, perchloroethylene, toluene, xylene, carbon tetrachloride, methyl ethyl ketone, methyl isobutyl ketone
2512	Wood household furniture upholstered	Methylene chloride, methyl chloroform, trichloroethylene, perchloroethylene, toluene, xylene, carbon tetrachloride, methyl ethyl ketone, methyl isobutyl ketone
2514	Metal household furniture	Toluene, xylene, methyl ethyl ketone, methyl isobutyl ketone
2515	Mattresses, bed springs	d
2519	Household furniture, nec	d
2521	Wood office furniture	d
2522	Metal office furniture	d
2531	Public building furniture	d
2541	Wood partitions, fixtures	d
2551[f]	---	
2599	Furniture and fixtures, nec	d

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2611	Pulp mills	Chloroform, hydrogen sulfide
2612[f]	---	
2621	Paper mills, except building paper	Chloroform, hydrogen sulfide, carbon disulfide
2631	Paperboard mills	Chloroform, formaldehyde
2641	Paper coating and glazing	Dioctyl phthalate, toluene, xylene, methyl ethyl ketone
2645	Die cut paper, paperboard, cardboard	Benzidine, d
2647	Sanitary paper products	Benzidine, d
2649	Converted paper and products, nec	Benzidine, d
2651	Folding paperboard and boxes	Benzidine, d
2653	Corrugated and solid fiber boxes	Benzidine, d
2654	Sanitary food containers	Benzidine,
2661	Building paper and board mills	Benzidine, POM, asbestos, d
2675[f]	---	
2714[f]	---	
2741	Miscellaneous publishing	Benzidine
2751	Commercial printing letter press and screen	Benzidine, d
2754	Commercial gravure printing	Solvents

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2789	Bookbinding and related work	Benzidine, d
2795	Lithographic platemaking and services	Solvents
2812	Alkalis and chlorine	Benzene, mercury
2813	Industrial gases	Carbon tetrachloride, ethylene oxide
2816	Inorganic pigments	Hydrazine, dioxane, chloroform, methylene chloride, dimethyl sulfate
2818	---	
2819	Industrial inorganic chemicals, nec	Nitrobenzene, beryllium, cadmium, chromium, manganese, mercury, nickel, aluminum, lithium
2821	Plastic materials, synthetic resins, nonvulcanizable elastomers	Phenol, vinylidene chloride, hexachlorocyclopentadiene, acrylonitrile, benzene, bis(chloromethyl) ether, cresols, ethylene dichloride, maleic anhydride, methylene chloride, dioxane, epichlorohydrin, formaldehyde
2822	Synthetic rubber	Perchloroethylene, aniline, acrylonitrile, benzidine, n-nitrosodimethylamine, nitrosomorpholine
2824	Synthetic organic fibers	Hydrazine, acrylonitrile, trichloroethylene, vinyl chloride, vinylidene chloride, ethylene dichloride
2833	Medicinal chemicals, botanicals	Benzene, dimethyl sulfate, hydrazine, aniline, toluene, carbon tetrachloride, methylene chloride, ethylene dichloride
2834	Pharmaceutical preparations	Benzene, dimethyl sulfate, hydrazine, toluene, carbon tetrachloride, methylene chloride, ethylene dichloride, aniline, nitrobenzene
2841	Soap and detergents	Nitrosomorpholine, perchloroethylene, solvents
2843	Surface active agents	Toluene, ethylene oxide
2844	Perfumes, cosmetics	Dimethyl sulfate, formaldehyde, toluene
2851	Paints, varnishes, [illegible]	Perchloroethylene, toluene, xylene, aniline, carbon [illegible]

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2861	Gum and wood chemicals	Cresols, dioxins
2865	Coal, tar crudes, dyes, organic pigments	Benzidine, cresol, cadmium, chloroform, degreasing solvents, dimethyl sulfate, dioxane, hydrazine, aniline
2869	Industrial organics, nec	Benzene, benzidine, benzyl chloride, bis(chloromethyl) ether, carbon tetrachloride, chlorobenzene, chloroform, methylene chloride, perchloroethylene, trichloroethylene, acetaldehyde, acrolein, acrylonitrile, 1,4-dichlorobenzene, ethylene dichloride, methylene chloride, dimethyl sulfate, dioxane, epichlorohydrin, ethylenediamine, ethylene oxide, formaldehyde, hexachlorocyclopentadiene, maleic anhydride, nitrobenzene, n-nitrosodimethylamine, phenol, PCB, POM, toluene, methyl chloroform, xylene
2871[f]	---	
2872[f]	---	
2873	Nitrogenous fertilizers	
2874	Phosphatic fertilizers	
2875	Fertilizer mixing only	
2879	Pesticides, ag chemicals, nec	Dimethyl sulfate, dioxins, hexachlorocyclopentadiene, hydrazine, n-nitrosodimethylamine, arsenic, carbon tetrachloride, chlorobenzene, chloroform, ethylene dibromide
2881[f]	---	
2892	Explosives	

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
2899	Chemicals and chemical preparations, nec	Benzene, benzidine, benzyl chloride, bis(chloromethyl) ether, carbon tetrachloride, chlorobenzene, chloroform, methylene chloride, perchloroethylene, trichloroethylene, acetaldehyde, acrolein, acrylonitrile, 1,4-dichlorobenzene, ethylene dichloride, methylene chloride, dimethyl sulfate, dioxane, epichlorohydrin, ethylenediamine, ethylene oxide, formaldehyde, hexachlorocyclopentadiene, maleic anhydride, nitrobenzene, n-nitrosodimethylamine, phenol, PCB, POM, toluene, methyl chloroform, xylene
2911	Petroleum refinery	Toluene, xylene, benzene, cresols, formaldehyde, phenol,
2951	Paving mixtures and blocks	Beryllium, cadmium, chromium, manganese, nickel, asbestos, POM, benzene, toluene, xylene, arsenic formaldehyde, cresol
2952	Asphalt felts and coatings	Asbestos, beryllium, cadmium, chromium, manganese, nickel, asbestos, POM, benzene, toluene, xylene, arsenic, cresols
2992	Lubricating oils, greases	Methyl chloroform, methylene chloride, dimethyl sulfate, dioxane, nitrobenzene, n-nitrosodimethylamine, perchloroethylene, trichloroethylene, benzene, carbon tetrachloride, chlorofluorcarbons, chlorobenzene, chloroform, ethylene dichloride
2999	Products of petroleum, coal, nec	Radionuclides, toluene, POM, arsenic, benzene, beryllium, cadmium, chromium, cresols, dioxins, formaldehyde, manganese, mercury, nickel, nitrobenzene
3011	Tires, inner tubes	Benzidine, n-nitrosodimethylamine, 1,3-butadiene, acrylonitrile, nitrosomorpholine, perchloroethylene,

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
3021	Rubber and plastic footwear	Perchloroethylene, chloroprene, acrylonitrile, benzidine, n-nitrosodimethylamine, methylene chloride, dioxane, nitrosomorpholine
3041	Rubber, plastic hose, belts	Methyl chloroform, chloroprene, 1,3-butadiene, perchloroethylene, acrylonitrile, benzidine, n-nitrosodimethylamine, methylene chloride, dioxane, nitrosomorpholine, toluene
3069	Fabricated rubber products, nec	Methyl chloroform, chloroprene, benzidine, n-nitrosodimethylamine, acrylonitrile, nitrosomorpholine, perchloroethylene, toluene
3079	Miscellaneous plastic products	Acrylonitrile, dioctyl phthalate, styrene, vinyl chloride
3111	Leather tanning finishing	Chromium, benzidine
3121[f]	---	
3211	Flat glass	Arsenic
3221	Glass containers	Fluorides
3229	Pressed and blown glass, nec	Fluorides
3231	Glass products made of purchased glass	
3239[f]	---	
3241	Hydraulic cement	Chromium, nickel

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
3253	Ceramic wall, floor tile	Asbestos, beryllium
3254[f]	---	
3255	Clay refractories	
3264	Porcelain electrical supplies	
3269	Pottery products, nec	
3271	Concrete block and brick	Beryllium, cadmium, chromium, manganese, nickel
3272	Concrete products, except block and brick	Beryllium, cadmium, chromium, manganese, nickel, asbestos
3273	Ready-mixed concrete	Beryllium, cadmium, chromium, manganese, nickel
3275	Gypsum products	c
3281	Cut stone and stone products	c
3291	Abrasive products	c

SIC Code	Description	Potential Pollutants
3292	Asbestos products	Asbestos, chromium
3295	Minerals, earths; ground or treated	c
3296	Mineral wool	Fluorides
3299	Non-metallic minerals, nec	
3312	Blast furnaces, steel work, rolling mills	Radionuclides, toluene, POM, arsenic, benzene, beryllium, cadmium, chromium, cresol, dioxins, formaldehyde, mercury, nickel
3321	Gray iron foundries	Arsenic, nickel, chromium, manganese, beryllium
3334	Primary production of aluminum	Aluminum
3339	Primary smelting and refining of nonferrous metals, nec	Manganese, mercury, nickel, arsenic, beryllium, cadmium
3341	Secondary smelting and refining, nonferrous	Nickel, arsenic, cadmium, chromium, manganese, chromium
3352[f]	—	
3354	Aluminum extended products	Solvents
3355	Aluminum rolling and drawing, nec	Solvents

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
3357	Drawing and insulating nonferrous wire	Cresols
3361	Aluminum foundries, casting	Aluminum
3362	Brass, bronze, copper castings	Arsenic, beryllium, chromium, cadmium, manganese, nickel
3392[f]	---	
3399	Primary metal products, nec	d
3400	Fabricated metal products, except heavy equipment	d
3411	Metal cans	d
3423	Hand and edge tools, except machine tools and hand saws	d
3429	Hardware, nec	d
3432	Plumbing fixture fitting, brass trim	d
3433	Heating equipment except warm air and electric furnaces	d
3440	Fabricated metal products	
3441	Fabricated structural metal	d
3442	Metal doors sash frames	d
3443	Fabricated plate work	d
3444	Sheet metal work	d

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
3448	Prefabricated metal buildings and components	Arsenic, chromium, mercury, beryllium, cadmium, d
3461[f]	---	
3469	Metal stamping, nec	d
3471	Electroplating, anodizing	Nickel, chromium, d
3479	Coating, engraving and allied services, nec	d
3481[f]	---	
3491[f]	---	
3494	Valves and pipe fittings except plumbers brass goods	d
3496	Miscellaneous fabricated wire products	d
3499	Fabricated metal products, nec	d
3511	Steam gas and hydraulic turbines and generators	d
3519	Internal combustion engines	Manganese, nickel, radionuclides, toluene, xylene, benzene, ethylene dibromide, ethylene dichloride, dioxins, formaldehyde, POM
3522[f]	---	
3523	Farm machinery and equipment	d
3531	Construction equipment	d
3532	Mining machinery, except oil field equipment	d

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
3535	Conveyors and conveying equipment	d
3537	Industrial trucks, tractors	d
3545	Machine tool accessories	d
3548[f]	---	
3552	Textile machinery	d
3553	Woodworking machinery	d
3559	Special industry machinery, nec	d
3561	Pumps	d
3562	Ball bearings	d
3564	Blowers, exhaust fans	d
3566	Gears, speed changers	d
3573	Electronic computing equipment	Phosphine, formaldehyde, tetrahydrofuran, d
3585	Air conditioning/ heating equipment	d
3589	Service industry machines, nec	d
3599	Machinery, except electrical, nec	d
3612	Power distributors	PCBs, d
3613	Switches, switchboard apparatus	d
3621	Motor generators	d

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
3622	Industrial controls	d
3624	Carbon and graphite products	
3629	Electrical industrial apparatus, nec	d
3631	Household cooking equipment	d
3634	Electric housewares and fans	d
3639	Household appliances, nec	d
3641	Electric lamps	d
3643	Current carrying wiring devices	d
3648	Lighting equipment, nec	d
3661	Telephone and telegraph apparatus	d
3662	Radio/TV	d
3675	Electronic compactors	d
3676	Resistors	d
3679	Electronic components	Tetrahydrofuran, phosphine, d
3691	Storage batteries	Nickel, cadmium, d
3692	Primary batteries, wet and dry	d
3699	Electrical equipment, nec	d
3713	Truck, bus bodies	Chromium, nickel, d

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
3714	Motor vehicles parts and accessories	Chromium, nickel, cadmium, d
3731	Ship building and repairing	Asbestos
3732	Boat building and repairing	d
3743	Railroad equipment	Chromium, nickel, d
3791[f]	---	
3799	Transport equipment, nec	d
3821[f]	---	
3841	Surgical/medical instruments	Ethylene oxide, d
3842	Surgical supplies and equipment	Ethylene oxide
3843	Dental supplies and equipment	Ethylene oxide
3861	Photographic equipment and supplies	d
3931	Musical instruments	d
3944	Childrens' games, except dolls and bikes	d
3949	Sporting goods	d
3955	Carbon paper and ink ribbons	d
3991	Brooms, brushes	Toluene, xylene
3993	Signs, display advertising	d

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
3995	Caskets	d
3999	Manufacturing industries, nec	Formaldehyde, d
4521	Air transport, noncertified carriers	POM, d
4911	Electric services (generator, transmit, distribute)	Arsenic, benzene, beryllium, cadmium, chromium, cresols, dioxins, formaldehyde, manganese, mercury, nickel, PCBs, POM, radionuclides, degreasing solvents
4953	Refuse systems (incinerators, dumps, ash, acid waste)	Arsenic, beryllium, cadmium, chromium, cresols, dioxins, formaldehyde, manganese, mercury, POM, nickel, degreasing solvents
5052	Coal and other minerals and ores, wholesale	Arsenic, chromium, nickel, beryllium, manganese
5093	Scrap and waste material	d
5153	Grain	Ethylene dibromide, e
5171	Petroleum bulk stations, terminals	Xylene, benzene, ethylene dichloride, POM, toluene, ethylene dibromide, formaldehyde
5331	Variety stores, retail	e
5812	Eating places	e
5999	Miscellaneous retail stores	e
7011	Hotels	
7216	Dry cleaners	Perchloroethylene, chlorofluorocarbons
7261	Funeral services, crematories	Formaldehyde, mercury, POM

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
7534	Tire retread and repair	d
8051	Nursing homes	
8061[f]	---	
8062	General hospitals	Ethylene oxide, d, e
8063	Psychiatric hospitals	
8069	Specialty hospitals, except psychiatric	Ethylene oxide
8071	Medical laboratories	Ethylene oxide, d
8211	Elementary/secondary schools	d
8221	Colleges, universities	d, e
8222	Junior colleges	d, e
8281[f]	---	

APPENDIX D. Continued

SIC Code	Description	Potential Pollutants
8922	Non-commercial scientific, research organizations	d
9711	National security	Degreasing solvents, asbestos, chromium, arsenic, beryllium, nickel, manganese, POM, benzene, cadmium, dioxins, formaldehyde, radionuclides, mercury

[b] SIC Code, from NCDEM data.

[c] Trace metals may be contained in stone, gravel, and could be emitted. Metals would probably be bound in ores.

[d] Solvents: carbon tetrachloride, chlorofluorocarbons, chlorobenzene, ethylene dichloride, methylene chloride, perchloroethylene, methyl chloroform, trichloroethylene, methyl ethyl ketone, methyl isobutyl ketone, benzene, toluene, xylene.

[e] May emit toxic air pollutants associated with fuel combustion, if facility has boiler.

[f] SIC Code not listed in SIC Code Manual.

[g] Reference 10.

APPENDIX C-1. KNOWN HUMAN CARCINOGENS[1] (Continued)
(Radian Corp. 1985b)

Substance/Process	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
2-Naphthylamine[c]	91-59-8	It has been used as an intermediate in the manufacture of dyes and as an oxidant in the rubber industry, but is now used for research purposes only.	
Nickel refining		- - -	
Rubber industry[d]		- - -	
Soots, tars and mineral oils		These substances are the by-products of fossil fuel processing technology such as coal carbonization and from incomplete combustion of other carbonaceous materials. Coal tars are used as chemical intermediates for such products as creosote, pitch, timber preservatives, pesticide formulations, benzene, toluene, xylene and napthalene. Petroleum and mineral oils are used in the manufacture of pharmaceuticals, in protective coatings on fruits and vegetables, and in bakery products. In 1975, about 35 million pounds of coal tar and 2 million pounds of coal tar neutral oil were used in the U.S. In 1976, about 948 million pounds of cresote were produced.	
Thorium dioxide[c]	1314-20-1	It was used in the development of nuclear reactors, in electrodes for arc welding and in X-ray procedures. The current use of this chemical has been restricted by several government agencies.	

APPENDIX C-1. KNOWN HUMAN CARCINOGENS[1] (Continued)
(Radian Corp. 1985b)

Substance/Process	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Treosulfan[g]	299-75-2	Produced only in Denmark since 1969. Used in human medicine for treating ovarian cancer.	
Vinyl chloride	75-01-4	Used in the production of plastics, and the synthesis of other chemicals. Vinyl chloride - vinyl acetate copolymers are used in the manufacture of vinyl asbestos floor tiles. Annual production is about 7 billion pounds for the monomer and 5 billion pounds for the homopolymer.	4.1×10^{-6}

---

[a] American Chemical Society Chemical Abstract Service Registry Number. Source used here: Registry of Toxic Effects of Chemical Substances, NIOSH, 1978 edition.

[b] Probability of contracting cancer if exposed to 1 ug/m^3 of a carcinogen for 70 years. Source: Personal Communication, M.A. Baviello to Mike Dusetzina, EPA/OAQPS/PAB. March 1985. These factors are subject to change and should be confirmed with EPA`s Carcinogen Assessment Group before use.

[c] Probability of being emitted into the ambient air is low.

[d] Source for 97 percent of all arsenic products.

[e] Represents 94 percent of U.S. consumption.

[f] Source: Maryland Toxic Substances Registry System - Office of Environmental Programs, Science and Health Advisory Group, Chemical Inventory 1983, Quantity by Chemical for State of Maryland. (Blanks indicate the substance was not included in 1983 survey.)

[g] Listed by IARC but not by NTP.

[h] Source: The Condensed Chemical Dictionary, Tenth Edition, Van Nostrand Reinhold Company, New York, 1981.

[i] Source: The Merck Index, Ninth Edition, Merck and Company, Rathway, New Jersey, 1976.

Source: (Unless otherwise noted) Third Annual Report on Carcinogens: Summary, National Toxicology Program, U.S. Department of Health and Human Services, September 1983

APPENDIX C-2. PROBABLE HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
2-Acetylaminofluorene [c,g]	53-96-3	Less than 20 pounds/year are used for cancer research.	
Actinomycin D[f]	50-76-0	Used as an antibiotic.[h]	
Acrylonitrile	107-13-1	Used in the manufacture of synthetic fibers, resins, plastics, elastomers, and rubber for a variety of consumer goods such as textiles, dinnerware, automotive parts, small appliances, and telephones. About 1.5 billion pounds are produced annually.	6.8×10^{-5}
Adriamycin[f]	23214-92-8	Used as an antibiotic drug effective against leukemia and cancers of the breast and bladder.[h]	
AF-2:[2-(2-Furye)-3-(5-Nitro-2-Furye)Acrylamide][f]	3688-53-7	Used as a food preservative in Japan. Withdrawn from the market in 1974.	
Aflatoxins	1402-68-2	Naturally occurring toxins that are formed by fungi on food when high temperatures and high humidity exist.	
Aluminum Production[f]		Certain exposures in the production industry are probably carcinogenic to humans.	
2-Aminoanthraquinone	117-79-3	Used as a dye intermediate.	
1-Amino-2-methylanthraquinone	82-28-0	Used as a dye intermediate.	
Amitrole (aminotriazole)	61-82-5	An herbicide whose domestic production is limited to about 4000 lb/yr.	
Analgesic mixtures containing Phenacetin[g]	62-44-2	Used as an analgesic and antipyretic drug. It is used alone or with aspirin and caffeine for relief of muscle pain. Also used in hair bleaching preparations. In 1979, Phenacetin production in the U.S. was approximately 550,000 lbs and imports equaled 240,000 lbs.	

APPENDIX C-2. PROBABLE HUMAN CARCINOGENS
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
2-Acetylaminofluorene [c,g]	53-96-3	Less than 20 pounds/year are used for cancer research.	
Actinomycin D[f]	50-76-0	Used as an antibiotic.[h]	
Acrylonitrile	107-13-1	Used in the manufacture of synthetic fibers, resins, plastics, elastomers, and rubber for a variety of consumer goods such as textiles, dinnerware, automotive parts, small appliances, and telephones. About 1.5 billion pounds are produced annually.	6.8×10^{-5}
Adriamycin[f]	23214-92-8	Used as an antibiotic drug effective against leukemia and cancers of the breast and bladder.[h]	
AF-2:[2-(2-Furye)-3-(5-Nitro-2-Furye)Acrylamide][f]	3688-53-7	Used as a food preservative in Japan. Withdrawn from the market in 1974.	
Aflatoxins	1402-68-2	Naturally occurring toxins that are formed by fungi on food when high temperatures and high humidity exist.	
Aluminum Production[f]		Certain exposures in the production industry are probably carcinogenic to humans.	
2-Aminoanthraquinone	117-79-3	Used as a dye intermediate.	
1-Amino-2-methylanthraquinone	82-28-0	Used as a dye intermediate.	
Amitrole (aminotriazole)	61-82-5	An herbicide whose domestic production is limited to about 4000 lb/yr.	
Analgesic mixtures containing Phenacetin[g]	62-44-2	Used as an analgesic and antipyretic drug. It is used alone or with aspirin and caffeine for relief of muscle pain. Also used in hair bleaching preparations. In 1979, Phenacetin production in the U.S. was approximately 550,000 lbs and imports equaled 240,000 lbs.	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
o-Anisidine and o-Anisidine hydrochloride	90-04-0 134-29-2	Used in the synthesis of dyes. Imports of o-Anisidine in 1980 were 2.4 million pounds. Domestic production is unknown.	
Aramite [c]	140-57-8	A pesticide. It is probably not available in the U.S. today.	
Auramine[f]	492-80-8	Used as yellow dye for paper, textiles, leather; also an antiseptic; fungicide.[h]	
Benzo(a)pyrene	50-32-8	A polycyclic aromatic hydrocarbon formed as a result of incomplete combustion. An estimated 1.8 million lb/yr are released from: coal refuse piles, outcrops, abandoned coal mines, residential external combustion of bituminous coal and anthracite coal, and coke manufacture.	
Benzotrichloride[f]	98-07-7	Used in synthetic dyes and organic synthesis.[h]	
Beryllium	7440-41-7	Used in the manufacturing of electrical components, chemicals, ceramics and X-ray tubes. Domestic production was 406,000 lb in 1977. It is emitted from coal and oil fired burners, and from beryllium-copper alloy production. Total emissions are estimated at 5500 lb/yr.	7.4 × 10^{-4}
Beryllium-aluminum alloy	12270-50-2		
Beryl ore [d]	1302-52-9		
Beryllium chloride	7787-47-5		
Beryllium fluoride	7787-49-7		
Beryllium hydroxide	13327-32-7		
Beryllium sulfate [d]	13510-49-1		
Beryllium oxide [d]	1304-56-9		
Beryllium carbonate	13106-47-3		
Beryllium phosphate	13598-15-7		
Beryllium silicate	15191-85-2		
Zinc beryllium silicate	39413-47-3		
Bischloroethyl nitrosourea[g]	154-93-8	Used in medicine as treatment for Hodgkins lymphoma, multiple myeloma, and brain tumors. Currently only produced by one U.S. company.[k]	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Cadmium Cadmium oxide Cadmium sulfide Cadmium sulfate	7440-43-9 1306-19-0 1306-23-6 10124-36-4	Used in electroplating, alloys, soldering, plastic stabilizers, batteries, fungicides, television tubes, inks, artists' colors, glass ceramics, jewelry, silversmithing, textiles, and paper. In 1980, domestic production of cadmium and eight cadmium compounds was 17 million pounds (10 million pounds was cadmium oxide). Cadmium is a component of zinc ores and it is emitted from smelters.	2.3×10^{-3}
Carbon tetrachloride	56-23-5	Used in the production of Freons 11 and 12, in industrial degreasing operations, as a general solvent and as a grain fumigant. In 1979, 730 million pounds were manufactured. There is a downward consumption trend because of its toxicity.	1.5×10^{-5}
Chloramphenicol[f]	56-75-7	Used as an antibiotic and antifungal agent.[h]	
1-(2-Chloroethyl)-3-Cyclohexyl-1-nitrosourea[g]	13010-47-4	Used in medicine for treatment of Hodgkin's disease and various solid tumors.[k]	
Chloroform	67-66-3	Used as an intermediate in the production of fluorocarbon compounds, dyes, drugs, and pesticides; as a solvent in the extraction and purification of some antibiotics, vitamins, and flavors; as an industrial solvent in photography and drycleaning; and as a heat transfer medium. In 1977, domestic production was reported as 176 million pounds.	1.0×10^{-5}

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
Chlorophenols[f] (occupational exposure to)		Used primarily as an intermediate in organic synthesis of products such as dyes, pharmaceuticals, herbicides, and pesticides.[h]	
Cisplatin[g]	15663-27-1	Used in medicine for the treatment of a variety of malignancies.[k]	
Combined oral contraceptives[f]			
p-Cresidine	120-71-8	Used as an intermediate in the production of azo dyes and pigments.	
Cupferron	135-20-6	Used to separate tin from zinc, and copper and iron from other metals. Annual production has been estimated as 37,000 pounds.	
Cycasin	14901-08-7	Occurs naturally in the seeds, roots, and leaves of cycad plants which are found in the tropics and subtropics. It is not used or produced commercially.	
Dacarbazine[f]	4342-03-4	Used in inhibiting or preventing growth and spread of neoplasms.[i]	
DDT[f]	50-29-3	Used as an insecticide. It is not biodegradable and was banned in the U. S. for agricultural used in 1973. It is manufacture for export is still permitted.[h]	
2,4-Diaminoanisole sulfate	39156-41-7	Used as a component of oxidation hair- and fur-dye formulations.	
2,4-Diaminotoluene	95-80-7	Used as an intermediate to produce toluene diisocyanate, which is used in the production of polyurethane. A lesser use is in the production of dyes for textiles, leathers, furs, wood, and bio[illegible]al [illegible]s. [illegible]uct[illegible] was	

APPENDIX C-2: PROBABLE HUMAN CARCINOGENS (Continued)
(Radian Corp., 1985b)

Substance	CAS No.[a]	End Uses/Processes/Production	Unit Risk Factor[b]
1,2-Dibromo-3-chloropropane	96-12-8	This chemical was used as a soil fumigant to control nematodes on a variety of crops. In 1979, EPA suspended all end uses except use on pineapples in Hawaii. The chemical may be emitted during pesticide manufacturing and application. The chemical has also been detected in vegetables that were treated with it.	
1,2-Dibromoethane (EDB)	106-93-4	About 85 percent of the EDB produced is used as a gasoline additive. Other uses include use as a solvent in the chemical industry, use as a fumigant in agricultural insecticide formulations, and use in the production of certain dyes, drugs, and vinyl bromide. In 1977, about 300 million pounds of EDB was produced, but production has declined since consumption of gasoline lead additives has declined and EPA has suspended some uses.	
3,3,'-Dichlorobenzidine	91-94-1	Used in the manufacture of pigments for printing ink, textiles, and plastics. Trace levels may be present in dyes, pigments, and final consumer products.	
1,2-Dichloroethane (EDC)	107-06-2	Used as a leaded gasoline additive and in the production of vinyl chloride and other chemicals. Minor uses as an insect fumigant on stored grains; a soil fumigant in orchards; as a solvent in cleaning and degreasing operations; in production of	7.0×10^{-6}