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AN INVENTORY OF CARCINOGENIC SUBSTANCES RELEASED INTO THE AMBIENT AIR OF CALIFORNIA

VOLUME I - FINAL REPORT

SCREENING AND IDENTIFICATION OF CARCINOGENS OF GREATEST CONCERN

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1.0 INTRODUCTION

Science Applications, Inc. (SAI) and its subcontractor KVB, Inc., are currently conducting a four-task study for the California Air Resources Board (ARB), An Inventory of Carcinogenic Substances Released into the Ambient Air of California. The present volume reports on Task I, Carcinogen Identification and Ranking, and Task III, Assessment of Occupationally Regulated Carcinogens. The overall objective of these two tasks is the identification of the five to ten carcinogens of greatest potential concern as ambient atmospheric pollutants in California. Tasks II and IV, which are a Baseline Emissions Inventory and a Design of a Source Testing Program, respectively, will be covered in a later volume, along with the final reporting for Task III

Task I consisted of a screening of the many known and suspected carcinogenic substances which potentially could be important to the California Air Resources Board (CARB). The screening methodology is presented in Section 3. An initial list of specific compounds and groups of compounds were selected from hundreds of potential candidates by examining published lists and rankings of carcinogens to determine which appeared to be of greatest concern nationwide.* Because no previous inventory of airborne carcinogens in California existed, this national data base had to be the starting point of a California-specific inventory. As part of Task III, 14 substances regulated as occupational carcinogens by California's Department of Industrial Relations were added to the list.

The screening methodology was applied to the candidate substances, with special attention given to production and/or use in California. Many substances were found to have no significant use in the state and were excluded from further consideration. Table 1-1 lists the remaining candidates and the three categories of rejected substances. The remaining candidates were studied in greater detail and were reviewed and discussed by a Panel of Experts convened by SAI. The candidates were ranked by the

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* Some substances considered may actually be precursors or co-carcinogens under certain circumstances. However, if a substance has been unequivocally associated with carcinogenesis, we have considered them as carcinogens in this study. Conditions of emission and exposure, including the presence of co-carcinogens, were factored into the evaluation of each carcinogenic substance where possible. Carcinogenic substances derived from the metabolism of a precursor (as some suspect benzo(a)pyrene to be) were considered as carcinogens. However, ubiquitous substances (e.g., the formation of N-nitrosoamines from secondary amines, nitrous acid, and nitric oxide) which have been hypothesized to be precursors were not considered because of uncertainties in the importance of their link to the carcinogenic compound and the practical considerations demanded by the scope of the study.

Table 1-1

SUBSTANCES REVIEWED IN DETAIL BY SAI

CANDIDATE SUBSTANCES

Arsenic
Asbestos
Benzene
Cadmium
Carbon Tetrachloride
Chloroform
Chromium
1,4-Dioxane
Epichlorohydrin
Ethylene Dibromide
Ethylene Dichloride
Inorganic Lead
Alkyl Lead
Maleic Anhydride
Nickel
Nitrosamines
Perchloroethylene
Phenol
Polycyclic Aromatic Hydrocarbons
Propylene Oxide
Trichloroethylene
Vinyl Chloride

REJECTED SUBSTANCES

General

Acetamide
Aniline
Auramine
Beryllium
Diethyl Sulfate,
  Dimethyl Sulfate
Diphenylamine
Hydrazines
Isonicotinic Acid Hydrazide
Bis(dimethyldithiocarbamato)
  Lead
Nitrobenzene

Occupationally Controlled Carcinogens

2-Acetylaminofluorine
Benzidine
4-Biphenylamine (4-Aminodiphenyl)
Bis(Chloromethyl) Ether,
Chloromethyl Methyl Ether
3,3'-Dichlorobenzidine
4-Dimethylaminoazobenzene
Ethyleneimine
4,4'-Methylene Bis (2-Chloroaniline)
  (MOCA)
α-Naphthylamine, β-Naphthylamine
4-Nitrobiphenyl
β-Propiolactone

Provisionally Rejected Substances

Acrylonitrile
Formaldehyde
Vinylidene Chloride

Panel and by SAI. Finally, considering all the available information, several substances or groups were selected as those airborne carcinogens of most concern to the CARB. These are listed in Table 2-1. Three substances were provisionally rejected -- acrylonitrile and vinylidene chloride because the preponderance of the available evidence indicated that they have no significant use in California and formaldehyde because it appears not to be carcinogenic. However, should new or additional evidence prove the contrary, these substances would take on much greater importance. Indeed, many other substances were rated on the basis of incomplete or conflicting evidence, so that new or additional data could affect the rankings. The ranking methodology used for this study is flexible enough to accomodate new information and to quickly determine the relative importance to the CARB of any hitherto unsuspected carcinogens which may be considered in the future.

This portion of the study required the rapid collection of the most important data for many substances. These data were gathered largely from key reference works and from discussions with manufacturers and users. It was not feasible to intensively study each substance. For this reason, the rating factors required in the screening methodologies were assigned a range of values for some substances to indicate the uncertainty in their evaluation.

Section 2.0 summarizes the conclusions and recommendations reached at this program milestone. Section 3.0 describes the technical approach and results of Task I. Additionally the 14 occupational carcinogens specified for consideration in Task III were screened and evaluated by the Task I approach if they were found to have any significant use in California. Of these carcinogens only the nitrosamines are being carried through to the next stage i.e. Task II - Baseline Emissions Inventory. The substance dossiers for both candidate and rejected substances are presented as Section 4.0. Rationale for each substance rejection is provided where applicable.

Effort will be undertaken in Task II to further quantify the emissions of the highest ranking substances and to identify and map areas of greatest concern. Test plan requirements and strategies will be developed in Task IV for subsequent field monitoring programs for the most important substance/source combintaions where the available data base is considered inadequate.

2.0 INTERIM CONCLUSIONS AND RECOMMENDATIONS

The results of the Task I and III effort have established the focus and direction for the conduct of the remainder of the study. Although final conclusions and recommendations must await program completion, it is useful to summarize our principal findings at this milestone.

Although three alternative approaches were employed (two semi-objective ranking methodologies and the more subjective or Delphi alternative of the Panel), there was relatively little difference among the resulting rankings. We conclude that the numerical ranking approaches were useful in establishing a relevant framework for retrieving and analyzing information and for identifying early those substances to be rejected. The use of an expert panel was of great help in obtaining a perspective on the relative importance of candidate substances and in gathering information on use patterns and trends. The substances which we recommend for further study in the next phase of the project are listed in Table 2-1. Inspection of this list shows that many of the substances are ubiquitous in the environment. Emission sources, except perhaps for those of carbon tetrachloride, are numerous, widely distributed and in several cases highly varied. Task II must therefore closely address the identification and quantification of these sources.

It is notable that five of the substances recommended for further study are contained in leaded gasoline, unleaded gasoline, diesel fuel and/or their combustion products. These are benzene, ethylene dibromide, ethylene dichloride, polycyclic aromatic hydrocarbons, and nitrosamine (suspected to be in diesel emissions). Additional significant sources have been identified for each of these substances. Polycyclic aromatic hydrocarbons (PAH) and nitrosamines are rather large and complex classes of compounds for which identification presents formidable problems and uncertainties.

The dossiers presented in Section 4.0 summarize the relevant features contributing to our appreciation of each substance's emissions sources, environmental pathways and degree of carcinogenic risks. These can be used in combination with the summary of rating factors given in Table 3-7 to assist the reader in understanding the basis of the resultant rankings.

Table 2-1

FINAL SELECTION OF CANDIDATES[a]

Highest Consensus Ranking

- Arsenic
- Asbestos
- Benzene
- Cadmium
- Carbon Tetrachloride
- Chloroform
- Ethylene Dibromide
- Ethylene Dichloride
- Nitrosamines
- Perchloroethylene
- Polycyclic Aromatic Hydrocarbons (PAH)

Highly Ranked But No Inventory Recommended At This Time

- Vinyl Chloride
- Gasoline and Engine Exhaust
- Tobacco Smoke
- Pesticides

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[a] See Section 3.3.4 text for explanation.

It is expected that investigation of the highest ranking substances during Task II, the construction of an emissions inventory, will result in a further understanding of their relative potential to adversely impact the health of the general population. This will assist in the selection of substances and sources for which to develop sampling protocols during Task IV.

3.0 SCREENING OF CARCINOGENIC SUBSTANCES -- TASK I AND TASK III

The purpose of Task I was to identify the five to ten suspected carcinogenic materials or groups which, of the hundreds of potential carcinogens currently under study, are most likely to be of greatest concern as airborne carcinogens to California's general population. The National Institute for Occupational Safety and Health (NIOSH) Suspected Carcinogens Subfile (Christensen et al., 1976) lists 1,905 chemicals which have reported neoplastigenic or carcinogenic effects and 510 which have otherwise received attention for their neoplastigenic potential. The need to derive a list of 5 to 10 substances or groups of substances from such a large number of potential candidates dictated that we devise a rapid screening methodology for eliminating from further consideration the vast majority of the potential candidates.

3.1 First Screening of Potential Candidate Carcinogens

In the past several years, many attempts have been made to classify chemical substances according to various measures of importance to occupational health and safety, environmental impact, or community risk. The purpose of our initial screening was to examine 9 compilations of suspected carcinogens and, from these, to identify about 30 substances which would merit further screening under Task I. Our procedure was as follows.

First, 65 organic carcinogens were selected from a compilation made by the MITRE Corporation (Fuller et al., 1976) for the U.S. Environmental Protection Agency. This study scored 642 industrial organic air pollutants by computing the product of four explicitly defined rating factors: annual U.S. production, fraction of production lost to the environment, volatility, and toxicity. Table 3-1 shows the definitions of these rating factors. The toxicity score consisted of the quotient of the sum of all applicable toxicity ratings and the sum of the maximum possible values of these rating factors. To adapt this work to our purpose, we first selected the 114 substances listed as having carcinogenic potential, i.e., those rated 4 or 5 under MITRE's category "carcinogenicity." We then rated each of these compounds under the criteria "annual U.S. production," "fraction of production lost," "volatility," and "carcinogenicity." Selected for further consideration were those substances which had a product score above 50 or had a carcinogenicity score of 5 and lacked information in one of the other categories.

Table 3-1

MITRE SCORING SYSTEM FOR PRIORITY RANKING OF INDUSTRIAL ORGANIC CHEMICALS

Annual U.S. Production (10^6 lbs)

Range	Score
< 1	0
> 1 ≤ 10	1
> 10 ≤ 25	2
> 25 ≤ 50	3
> 50 ≤ 100	4
> 100	5

Fraction of Production Lost

Range	Score
< 0.01	1
≥ 0.01 < 0.015	2
≥ 0.015 < 0.02	3
≥ 0.02 < 0.03	4
≥ 0.03	5

Volatility (Vapor Pressure in mmHg at Normal Temperatures)

State	Range	Score
Solid	-	1
Liquid	≤ 24	2
Liquid	> 24 ≤ 100	3
Liquid	> 100	4
Gas	-	5

Acute Toxicity I: (LD_{50} in mg/kg)

Range	Score
< 50	5
≥ 50 < 250	4
≥ 250 < 1000	3
≥ 1000 < 5000	2
≥ 5000 < 10,000	1
> 10,000	0

Acute Toxicity II: (LC_{50} in ppm)

Range	Score
< 100	5
≥ 100 < 200	4
≥ 200 < 1000	3
≥ 1000 < 3000	2
≥ 3000 < 5000	1
> 5000	0

Non-Lethal Acute Effects

Type of Effect	Score
Mild	1
Severe	2

Carcinogenicity

Effects Noted or Status	Score
Carcinogenic	5
Produces neoplasm	4
Under test	3
Not studied or negative	0

Mutagenicity

Status	Score
Mutagenic	5
Not studied or negative	0

Teratogenicity

Status	Score
Teratogenic	5
Not studied or negative	0

Occupational Standard (TWA* in ppm)

Range	Score
≤ 5	5
> 5 ≤ 10	4
> 10 ≤ 25	3
> 25 ≤ 100	2
> 100 ≤ 200	1
> 200	0

* TWA - Time weighted average concentration in the air over an 8-hour work day assuming a 40-hour work week.

Source: Fuller et al., 1976.

Through this exercise, we identified 65 potential airborne carcinogens, which we then compared with those of eight other lists (described in Table 3-2). Organic substances or classes of substances common to these lists and to our list of 65 were considered appropriate for further study. To our compilation were added suspected inorganic carcinogens, all of the 14 substances currently regulated as occupational carcinogens by California's Department of Industrial Relations, as well as organics which, in the judgment of experienced SAI staff and consultants, were potentially of concern to the CARB. Examples of these are epichlorohydrin, bis(chloromethyl)ether and hydrazine. Acrylonitrile, a widely-used carcinogen which has just come under OSHA regulation, was also added. This grouping closely resembles all the substances appearing in Table 3-4. The substances were subjected to further screening and ranking as described in the subsequent sections.

Table 3-2

LISTS OF CARCINOGENS USED FOR FURTHER REFINING THE LIST OF 65 SELECTED FROM THE MITRE DATA BASE

Priority Toxicants Listed by U.S. Environmental Protection Agency

The Administrator of EPA has issued a list of 15 substances or substance classes believed to be of primary concern (Lozano, 1977). Included in the list are mercury and "phosphates;" while of general environmental concern, they are not suspected carcinogens (Rogozen and Hausknecht, 1978).

EPA - Air and Hazardous Materials Division - Selected Toxicants For Priority Environmental Assessment

Twenty-six organic hazardous (suspected or confirmed to be carcinogenic, neoplastic, or teratogenic) substances were recommended for routine multimedia ambient monitoring around chemical manufacturing sites in EPA Region VI (USEPA, 1977d). Specific company sites and production rates were identified for the chemicals listed and in some cases, emission efficiencies (lb emission/lb production) are provided for the chemical species and compounds associated with their manufacture.

State of New Jersey - Survey and Ranking Study

The New Jersey Department of Environmental Protection is now conducting a prioritization study of the organic chemicals manufactured and handled in the state. Dr. David Bardin, New Jersey Commissioner for the Department of Environmental Protection, has testified that air monitoring should be conducted for polynuclear aromatic hydrocarbons, chlorinated hydrocarbons, and for carcinogens identified in the vicinity of particular industrial facilities (Bardin, 1976). Finally, arsenic and heavy metals such as lead were identified as potentially important environmental carcinogens.

NIOSH - National Occupational Hazard Survey (NOHS)

This survey of approximately 453 occupations within all major SICs except agriculture, government service and mineral extraction is a large scale effort to delineate occupational hazards to which workers are exposed. Ranking of the most potent industrial chemicals was based upon NOHS and associated program results (Hickey and Kearney, in press). This listing was based strictly upon carcinogenic potential. NIOSH established a separate ranking of the ten most hazardous industrial chemicals, in which consideration was given to potency, amount of exposure and production (Maugh, 1977).

National Cancer Institute Listing and Department of Health, Education and Welfare Memorandum

These documents identify and classify 36 chemicals and mixtures which have been found by direct observation of exposed populations to cause cancer in man. For the purposes of this study interest was focused upon the first, third and fifth of the following substance categories (Warner, 1975):

Table 3-2 (continued)

Category	Definition
I	Controlled or restricted usage. Protection of the population requires technical surveillance.
II	Recognized as carcinogenic. Exposure is largely voluntary.
III	Implicated in human carcinogenesis by epidemiological evidence. Exposure is poorly controlled in spite of carcinogenesis hazard.
IV	Prescribed by physicians or endogenous
V	Utilized in laboratory only.

Certain substances within the remaining categories were considered not to be of interest to the ARB, namely, radioactive pollutants, drug or possible food residues, (e.g., diethylstilbestrol) and naturally occurring carcinogens (e.g., aflatoxin). The remaining 25 substances were classified as either specific chemicals or mixtures.

International Agency for Research on Cancer (IARC) - Monographs of the Evaluation of Carcinogenic Risk of Chemicals to Man

Numerous monographs on specific chemicals and chemical classes have been published. These informative studies indicate in general which substances are of prominent concern. In addition this listing source seems to anticipate, by several years, some of the critical carcinogens of today. Moreover, the IARC has recently published a list of 26 chemicals or processes which appear to be associated with human carcinogenesis (IARC, 1978).

American Conference of Governmental Industrial Hygienists (ACGIH)

The ACGIH (1977) has listed substances in industrial use which have proven carcinogenic in man, or have induced cancer in animals under appropriate experimental conditions.

3.2 Methodology for Refining and Ranking Candidate List

Further screening of the list of carcinogens was done through a semi-objective algorithm based upon numerical rating factors. A previous SAI study (Rogozen, et al., 1976) showed that most screening or ranking systems which claim to be objective fall into one of two categories: additive and multiplicative. Some systems are a combination of the two, while others combine an "objective" approach with subjective evaluation of the results (making the whole process rather subjective). The multiplicative method was used for refining the candidate list down to 22, and then for ranking the remaining 22 substances. The initial multiplicative screening eliminated those substances with no significant production or use in California. The additive method was used independently to rank the substances, and the results of the two methods were then synthesized (Figure 3-1). The rationale for this approach is presented in Section 3.2.3.

3.2.1 Additive Approach

In the additive approach, the user identifies one or more criteria and rates each alternative substance or course of action against each criterion, while simultaneously deciding the relative importance of the criteria. Equation 3-1 shows its mathematical formulation.

$$\text{Rating for pollutant } i = \sum_{j=1}^{m} W_j R_{ij} \tag{3-1}$$

Each criterion, or rating factor (R_j) is assigned a value for each pollutant, and each rating factor is weighted (by W_j) according to its importance relative to the other criteria. The rating given pollutant i with respect to criterion j should be completely independent of the rating with respect to any other criterion. Any numbers could be used as weights, but to have them sum to one is often convenient. The score for pollutant i under criterion j is the product of the rating under that criterion and the corresponding criterion weight. The overall rating for pollutant i is then the sum of the scores under all the criteria. If the weights are assigned so that they sum to unity, then the overall rating is in effect a weighted average of the individual criterion scores.

The additive approach has several virtues, the main one being that it forces the user to make all assumptions explicit. In the process of setting up such a ranking system, new insights into the problem under consideration may be gained. Once the system is set up, it is relatively easy to use. Where data for scoring

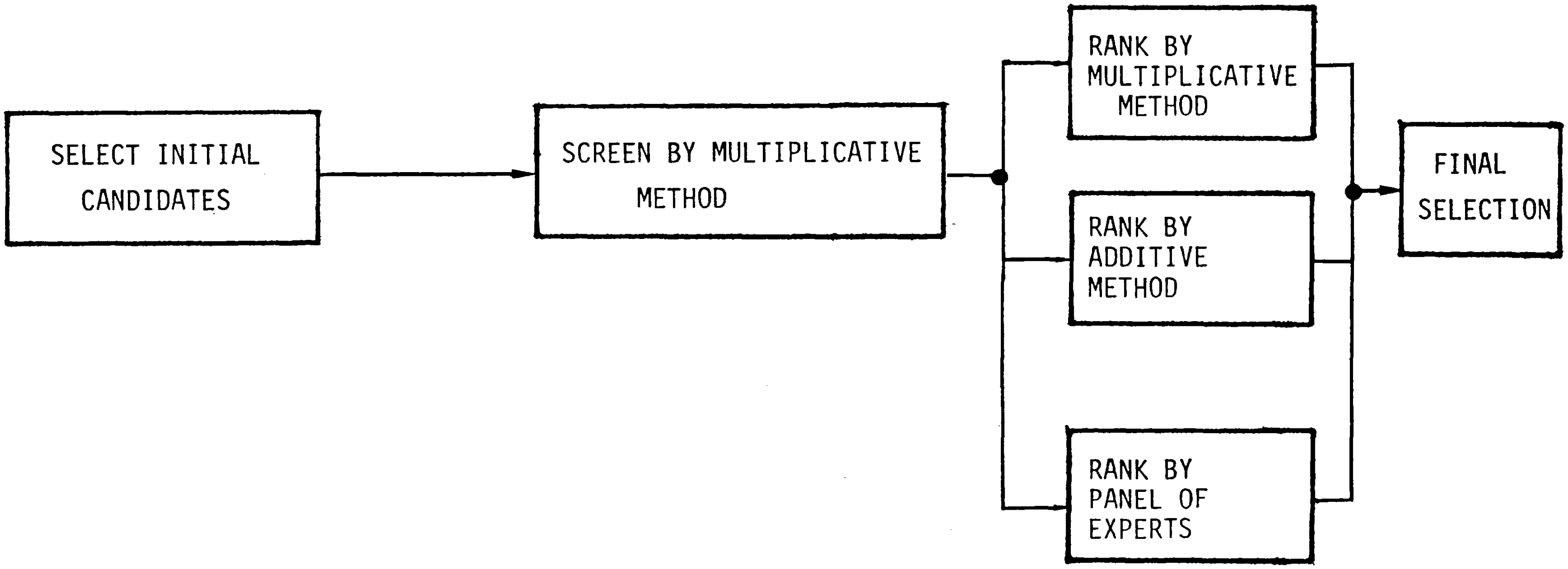

Figure 3-1. Methodology for Refining and Ranking Candidate List

pollutants are unavailable, artificial scales can be constructed to quantify subjective factors. Finally, the sensitivity of the results to the system's subjective aspects may be measured; for example, one can determine the effect of changing criteria weights upon the final pollutant ranking. Similarly, an appreciation may be gained of the significance of the range of uncertainty for a particular required data element by varying rating factor values.

The fundamental problem with the approach is that there is no logical basis for adding the individual scores assigned under the criteria, other than the assumption that this simulates, or even improves upon, the user's thought process. A major operational problem is that of weighting the criteria. A common practice is to give all criteria equal weight, but that is in itself a statement about the relative importance of the criteria.

3.2.2 Multiplicative Approach

In the multiplicative approach, the rating for each alternative is the product of the ratings under each criterion:

$$\text{Rating for pollutant } i = \prod_{j=1}^{m} R_{ij} \qquad (3\text{-}2)$$

A multiplicative approach can have some advantages over additive ones. First, in some cases the ratings can be physical parameters such as concentrations or volatilities; there is then no need to weight the criteria and hence less controversy over subjective judgments. Second, multiplication generally provides a wider range of scores than does addition, allowing clearer discrimination among alternatives. Finally, this approach provides results which are more intuitively acceptable. As an example of this last point, suppose that exposure and "harmfulness" levels for candidate substances are each converted to values on a 0-to-10 scale and that a certain substance is both extremely toxic and extremely rare. An additive approach would give the compound a rating of 0 + 10 = 10, which is equivalent to that of a moderately prevalent substance (rated, say, at 5) which is moderately harmful (rated also, say at 5). A multiplicative approach, on the other hand, would rate the first substance at 0 and the second at 25.

3.2.3 SAI's Approach

Because of the advantage of the multiplicative method just described -- namely, that candidates with a score of zero for any rating factor are rated zero overall -- this method was used to pare the list of possible candidates by rejecting

those having a score of zero for any rating factor. Also considered in this exercise were the initial 14 chemicals regulated as occupational carcinogens by the State. Then the multiplicative and the additive approaches were used independently to score and rank the remaining candidates. Any anomalies peculiar to one method could be balanced by using the other. If the same substance rates highly under both systems, its importance to California is more certain than if only one method were employed. The results of these ratings, along with the ratings made by the Panel of Experts convened by SAI (Section 3.3), were used as aids in deciding which substances should be of greatest concern to California as potential airborne carcinogens.

Rating Factors For The Rating Systems

Both the additive and the multiplicative approaches were based upon the following rating factors:

R_1: Extent of present use in California
R_2: Projected growth in use in California
R_3: Potential for emissions during production and use
R_4: Stability in ambient air
R_5: Dispersion potential
R_6: Evidence of carcinogenicity

Table 3-3 shows how the candidate suspected carcinogens were rated against each rating factor. The range of scores was made the same for each factor so that, in the multiplicative approach, all the factors would have equal weight. In cases for which data were lacking, scientific judgment was used in assigning a score.

R_1: Extent of Present Use in California. Because the purpose of this exercise was to determine the relative importance of the suspected candidate carcinogens, R_1 was scaled to the most heavily used substance. Benzene, with an annual production and usage in California of nearly 10^9 lb, was the most heavily used material considered. Relative to this, materials with a usage under 10^5 lb/yr would be rated zero for R_1 and rejected as a candidate. However, before being rejected by this criterion, whether the substance might be emitted at a very high rate or under site-specific conditions which could result in high population exposures was considered.

Table 3-3
DEFINITIONS OF THE RATING FACTORS USED

R_1: Present Use in California	
100% of max. (10^9 lb/yr)	5
10% of max. (10^8 lb/yr)	4
1% of max. (10^7 lb/yr)	3
0.1% of max. (10^6 lb/yr)	2
0.01% of max. (10^5 lb/yr)	1
< 0.01% of max. ($< 10^5$ lb/yr)	0

R_2: Growth in California Use	
+20%	5
+10% to +20%	4
Positive growth to 10%	3
Stable or unknown	2
Decline	1
Being phased out	0

R_3 : Emission Potential	
Widespread use in consumer products	5
Relatively poor control over emissions	4
Relatively good control over emissions	2
Tightly controlled	1

R_4: Stability in Ambient Air	
Moderate to high stability ($t_{\frac{1}{2}}$ >8 hr)	5
Low to moderate stability ($t_{\frac{1}{2}}$ ∿0-8 hr)	3
Unstable ($t_{\frac{1}{2}}$ ∿few minutes)	0

R_5: Dispersion Potential	
Emitted largely as vapor or fine particulate	5
Emitted largely as coarse particulate	1

R_6: Evidence of Carcinogenicity	
Known or suspected human carcinogen	5
Known mammalian carcinogen	4
Suspected mammalian carcinogen or known mammalian mutagen	3
Ames test positive	2
Precursor or co-carcinogen	1

R_2: Growth in California Use. This factor attempted to take into account that the chemical industry is in continual change. Pollutants of concern today may be phased out, while use of others may rise dramatically, increasing their importance as pollutants. In evaluating the rate of change of consumption of a substance in California, two types of information sources were generally employed. First, publications such as general reference works on industrial chemistry and chemical-specific studies, which are generally more up-to-date than the former, were examined for growth forecasts. In most cases, these forecasts are on a nationwide basis. Occasionally clues are provided which enable one to evaluate potential growth in California relative to the national forecasts. Second, in our many telephone conversations with producer and user representatives, we gathered their views on national and, especially, California growth. Our emphasis was therefore on contacting representatives who are intimately involved in the California market for each substance. In this way, a reasonable estimate of the growth in the use of each substance in California was ascertained. Nevertheless, such estimates are often relatively imprecise. For this reason, broad ranges in growth rate were used in assigning values to R_2. Also when we were aware of developments which could most likely result in a change in the growth rate, this information was factored into the choice of a value for R_2. As an example, asbestos consumption is stable or is declining at quite a slow rate. However, the pending phase-out of asbestos in motor vehicle friction materials will hasten the decline in asbestos consumption, further encouraging the assignment of a value of 1 for R_2.

R_3: Emission Potential. As an initial attempt to account for the likelihood and significance of release into the atmosphere determination of the emissions of substances of most concern to the CARB is part of Task II i.e. the Emissions Inventory. As part of that task emissions potential will be quantified by utilizing process information, site inspecting ,component leakage rates, etc. Because expending a great deal of effort on possible candidate carcinogens which would be eliminated from further consideration would not have been feasible, a surrogate measure of emission potential, based upon knowledge of the substance's manufacture and use, was employed. The highest rating went to substances which, like benzene, are widely used, especially in consumer products. A slightly lower rating went to substances which are routinely emitted from industrial processes during production and use. Volatility and particle size can greatly affect

emissions. Some materials are employed in such a way that emissions are quite low even though tight emission control may not be required by law. This situation exists when processes and chemical reactivities are such that little of a chemical escapes to the atmosphere. Materials in this category were assigned a value of 2 for R_3. Substances which, under federal or state regulations, may not be discharged to the exterior environment but which could be discharged by accident received by the lowest rating.

R_4: Stability in Ambient Air. The stability of a compound in the atmosphere was evaluated on the basis of its propensity to decompose in ambient air. Materials with half-lives of greater than eight hours were considered moderately to highly stable and rated 5. Low to moderate stability was assigned to substances with half-lives between zero and eight hours. Compounds known to exist in air for only a few minutes would be rated zero and rejected as candidates. Even though their oxidation state or anion associations may change in the atmosphere, metals do not degrade and were considered stable; asbestos is likewise stable. Many of the decomposition reactions of organic molecules are mediated by light. Such substances, if released at night, would have several hours to disperse throughout local communities. Even in the daytime, a compound with a half-life of four hours could travel for four hours in local winds and still be present in half the quantity originally emitted. Thus a half-lfie of four hours allows considerable time for dispersion to local communities, even though in other contexts it may be considered brief.

R_5: Dispersion Potential. A rapid way of assessing the relative potential of different substances to spread from the point of release is to note their physical state under normal ambient conditions. Accordingly, we have ranked materials equipped as vapors or fine particulates the highest and coarse particulates the lowest. Intermediate values are possible for varying amounts of fine and coarse particulate emissions from the same source or from different sources.

R_6: Evidence of Carcinogenicity. Research is on-going to establish relative potencies of carcinogens. Much of this research involves in vitro techniques such as the Ames bacterial mutagenicity test. Extrapolating data from these kinds of tests to whole animals and humans is problematic. In a few cases, some measure of the relative potencies of substances in causing cancer in humans exists. However, for most of the substances considered in this study, insufficient potency data of any kind exists. Therefore a less quantitative measure of the carcinogenic potential

of each candidate substance was used. The highest-rated ones would be those for which there is strong evidence of carcinogenesis in humans. Examples are asbestos, which is implicated in mesothelioma; vinyl chloride, which has been identified as the agent for liver cancer in exposed workers; and bis(chloromethyl)ether, shown by epidemiological studies to cause lung cancer in resin workers. The next-highest rated substances are those for which human carcinogenicity is unknown but which have produced cancer on one or more mammalian species in laboratory tests. Next are those which have not been shown to be carcinogens, but which have proven to be mutagenic in test animals. Substances for which the only knowledge of carcinogenic potential is a positive Ames test (producing mutations in histidine-requiring strains of Salmonella) are rated 2. Finally, substances which are implicated only as precursors or co-carcinogens are rated lowest.*

Arguments can be raised regarding the validity of the evidence of carcinogenicity, and the evidence often changes rapidly as chemicals are newly tested and retested and data evaluated and reevaluated. However, to enter into these debates was not within the scope of this study. Conclusions about carcinogenicity drawn by the IARC or the National Cancer Institute were accepted in this study, regardless of dosage or route of administration.

Weighting Factors

In the additive ranking scheme, each rating criterion is weighted according to its importance relative to the other criteria. Little precedent exists for assigning these weights. In SAI's judgement, as generally agreed by the Panel, R_1, R_3 and R_6 are more important than the other criteria; of these, the evidence of carcinogenicity was considered to be the most important. W_1 and W_3 were set at 0.2 ; W_6 was assigned a value of 0.3, and W_2, W_4, and W_5 were set at 0.1. In consideration of the potential sensitivity of the ranking to the weighting factor assignments, the candidates were also ranked using equally weighted criteria (Section 3.3.3).

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* See footnote in Section 1.0.

3.3 Final Selection of Carcinogens

3.3.1 Candidate Substances

Table 3-4 lists the substances which, upon examination by the methods presented in Section 3.2, were deemed worthy for further consideration, along with those which were rejected. The rejected substances were those which rated zero for one or more criteria, leading to an overall rating of zero by the multiplicative approach. The final selection was made from among the "successful" candidates, using inputs from the Panel of Experts and another pass through the methodology presented in Section 3.2.

3.3.2 Panel of Experts

SAI convened a nine-member panel of experienced scientists (Table 3-5) at its Los Angeles office on 24 and 25 October 1978. The Panel -- whose disciplines included organic and physical chemistry, industrial hygiene, toxicology, epidemiology, and regulatory control of toxic substances -- was assembled to provide additional data for the ranking exercise, to discuss our candidate substances and rejections, to suggest possible new substances for consideration, and to rank the candidates independently of SAI's ranking. Panel members received the dossiers on the substances reviewed by SAI two weeks prior to the meeting.

At the start of the meeting, the Panel was given an overview of the study and methodology. Then, the Panel was asked to rate each candidate with a score from zero to five. Next, each candidate was discussed in turn, starting with an overview of the candidate and a description of the critical issues for panel discussions by the responsible SAI participant. Additional information beyond that provided in the dossiers was also provided. Through materials brought to the meeting and its own personal experience, the Panel was very useful in providing information on the candidates and additional insight into the rating criteria used by SAI. As a result of the members' participation, some significant changes were made, the most notable of which was an improved scheme for evaluating dispersion potential. At the end of the two-day session, the Panel again rated the candidates on a zero-to-five scale.

The Panel's initial and final ranking of candidate substances are shown in Table 3-6. A considerable degree of similarity exists between the initial and final rankings, but several noteworthy shifts are also evident. The most dramatic shift was for inorganic lead, which dropped from 5th to 13th place. Other

Table 3-4

SUBSTANCES REVIEWED IN DETAIL BY SAI

CANDIDATE SUBSTANCES

- Arsenic
- Asbestos
- Benzene
- Cadmium
- Carbon Tetrachloride
- Chloroform
- Chromium
- 1,4-Dioxane
- Epichlorohydrin
- Ethylene Dibromide
- Ethylene Dichloride
- Inorganic Lead
- Alkyl Lead
- Maleic Anhydride
- Nickel
- Nitrosamines
- Perchloroethylene
- Phenol
- Polycyclic Aromatic Hydrocarbons
- Propylene Oxide
- Trichloroethylene
- Vinyl Chloride

REJECTED SUBSTANCES

General

- Acetamide
- Aniline
- Auramine
- Beryllium
- Diethyl Sulfate, Dimethyl Sulfate
- Diphenylamine
- Hydrazines
- Isonicotinic Acid Hydrazide
- Bis(dimethyldithiocarbamato) Lead
- Nitrobenzene

Occupationally Controlled Carcinogens

- 2-Acetylaminofluorine
- Benzidine
- 4-Biphenylamine (4-Aminodiphenyl)
- Bis(Chloromethyl) Ether, Chloromethyl Methyl Ether
- 3,3'-Dichlorobenzidine
- 4-Dimethylaminoazobenzene
- Ethyleneimine
- 4,4'-Methylene Bis (2-Chloroaniline) (MOCA)
- α-Naphthylamine, β-Naphthylamine
- 4-Nitrobiphenyl
- β-Propiolactone

Provisionally Rejected Substances

- Acrylonitrile
- Formaldehyde
- Vinylidene Chloride

Table 3-5

PANEL MEMBERS AND OTHER PARTICIPANTS

PANEL MEMBERS

James Beall	Consultant
Bryant Fischback	Dow Chemical
Jeffrey Hahn	California Department of Health
Kim Hooper	University of California, Berkeley
Richard Johnson	Environmental Protection Agency
Bob O'Brien	Portland State University
Lee Pitchforth	Federal Occupational Safety and Health Administration
Duane Reed	California Department of Health
James Unmack	California Division of Industrial Relations, Occupational Cancer Control Unit

OTHER PARTICIPANTS

John Holmes	Air Resources Board
Steve Hui	Air Resources Board
Bob Reynolds	Air Resources Board
Marc Axelrod	Science Applications, Inc.
Larry Margler	Science Applications, Inc.
Jim Payne	Science Applications, Inc.
Michael Rogozen	Science Applications, Inc.
Richard Ziskind	Science Applications, Inc.
Frank Ducey	K.V.B., Inc.
Hal Taback	K.V.B., Inc.

Table 3-6

RANKING OF THE CANDIDATES BY THE PANEL

	INITIAL RANKING	FINAL RANKING
Arsenic	13	9
Asbestos	2	2
Benzene	1	1
Cadmium	16	17
Carbon Tetrachloride	11	8
Chloroform	11	11
Chromium	13	15
1,4-Dioxane	19	19
Epichlorohydrin	19	16
Ethylene Dibromide	8	6
Ethylene Dichloride	7	6
Inorganic Lead	5	13
Alkyl Lead	18	19
Maleic Anhydride	22	22
Nickel	8	12
Nitrosamines	5	5
Perchloroethylene	5	9
Phenol	17	17
PAH	3	2
Propylene Oxide	21	19
Trichloroethylene	13	13
Vinyl Chloride	3	2

noteworthy changes in rank occurred for arsenic, carbon tetrachloride, nickel and perchloroethylene.

3.3.3 Ranking of Candidates Using Additive and Multiplicative Methodologies

Information necessary to evaluate candidate substances against the rating factors listed in Table 3-3 was obtained through a literature search, interviews with producers and users and consultation with the Panel of Experts. Background data and rationale for assignment of scores to the rating factors are found in the substance dossiers, which are presented in Section 4. The rating factors assigned to each candidate are shown in Table 3-7. Rankings resulting from applying the additive approach are shown in Table 3-8. Where a range of scores occurred for a rating factor, the midpoint was used in the ranking procedure. The sensitivity of the rankings to including or omitting the weighting factors is shown in Table 3-8. Most candidates were unaffected in their rankings, whereas several others (carbon tetrachloride, chloroform, chromium, and inorganic lead) changed more than three positions.

Table 3-9 shows the results of ranking the candidates by the multiplicative approach. As in the additive approach, midpoints of rating factor ranges were used. Comparison between Table 3-8 and Table 3-9 demonstrates considerable general similarity, with several notable exceptions. Perhaps the most noteworthy exception is asbestos. The variation in the rank of asbestos is clearly an artifact of the R_2 criterion, "Growth in California Use." The equal weighting of all the criteria permitted the score of 1 for R_2 to cause asbestos to be ranked relatively low. This is obviously inappropriate, for only a slight decline in use was indicated, leaving asbestos consumption practically unchanged for many years. For example, a decline of one percent annually through 1985 is indicated in the dossier on asbestos, and, at this rate, 94 percent of the current asbestos consumption will still occur in 1985. A similar result also occurred for ethylene dibromide. These anomalous rankings emphasize the importance of the judicious use of rapid screening methods. It is particularly useful to consider both ranking methodologies in order to allow identification and integration of similarities and differences in rankings. Clearly any ranking approach should be used only up to a point and then individual and intensive evaluation of candidates should take over.

Table 3-7

RATING FACTOR ASSIGNMENTS

	R_1	R_2	R_3	R_4	R_5	R_6
Arsenic	3	3	4	5	3	5
Asbestos	5	1	5	5	5	5
Benzene	5	3	5	5	5	5
Cadmium	2	3	4	5	5	5
Carbon Tetrachloride	3-4	3	3	5	5	4
Chloroform	3	3	4	5	5	4
Chromium	3	3	4	5	3	5
1,4-Dioxane	2	3	4	3	5	4
Epichlorohydrin	2	3	2	4	5	4
Ethylene Dibromide	3-4	1	5	5	5	4
Ethylene Dichloride	4-5	3	5	5	5	4
Inorganic Lead	4	1	5	5	4	4
Alkyl Lead	3-4	1	5	5	5	3
Maleic Anhydride	3	4	2	2	1	3
Nickel	2	3	4	5	4	5
Nitrosamines	3	3	4-5	3	5	5
Perchloroethylene	4	3	4	5	5	4
Phenol	2-3	3	4	3	5	3
PAH	1-3	4	5	5	5	5
Propylene Oxide	3	3	3	3	5	3
Trichloroethylene	0-2	0-1	5	5	5	4
Vinyl Chloride	5	3	1-4	4	5	5

Table 3-8

RANKING OF CANDIDATES BY THE ADDITIVE APPROACH

	a	b
Arsenic	8	12
Asbestos	2	3
Benzene	1	1
Cadmium	8	7
Carbon Tetrachloride	15	9
Chloroform	13	7
Chromium	8	12
1,4-Dioxane	17	17
Epichlorohydrin	20	20
Ethylene Dibromide	8	9
Ethylene Dichloride	3	2
Inorganic Lead	8	12
Alkyl Lead	16	16
Maleic Anhydride	22	22
Nickel	13	12
Nitrosamines	6	9
Perchloroethylene	6	5
Phenol	19	18
PAH	4	3
Propylene Oxide	20	20
Trichloroethylene	18	18
Vinyl Chloride	5	6

[a] Using rating factors unequally weighted

[b] Using rating factors equally weighted

Table 3-9

RANKING OF CANDIDATES BY THE MULTIPLICATIVE APPROACH

Arsenic	11
Asbestos	8
Benzene	1
Cadmium	10
Carbon Tetrachloride	7
Chloroform	6
Chromium	11
1,4-Dioxane	16
Epichlorohydrin	20
Ethylene Dibromide	14
Ethylene Dichloride	2
Inorganic Lead	15
Alkyl Lead	18
Maleic Anhydride	22
Nickel	13
Nitrosamines	9
Perchloroethylene	4
Phenol	17
PAH	3
Propylene Oxide	19
Trichloroethylene	21
Vinyl Chloride	5

3.3.4 Selection of the Highest-Rated Candidates

The previous two subsections presented the results of the rankings of candidate materials by the Panel and by the additive and multiplicative approaches. In this subsection, an approach for selecting a consensus ranking of top candidates is presented.

Table 3-10 lists alphabetically the highest-ranked candidates according to the three alternative approaches. The additive approach column was developed by averaging the rankings resulting from using and not using weighting factors. The additive listing was truncated at eight.

The highest-ranked candidates, as shown in Table 3-11, are those which appear on at least two of the lists in Table 3-10. Interestingly, this list is nearly identical to the top ten candidates selected by the Panel. These lists have purposefully been presented in alphabetical order rather than indicating thier precise relative rankings since uncertainties in the data base preclude drawing any significance between small differences in the final ordering. The remainder of this program has been designed to develop further insight into the relative importance among these substances.

Note that vinyl chloride could, because of its high score, have been added to this list. It was excluded because no further action on our part should be considered. Vinyl chloride, in addition to already being regulated as an occupational carcinogen, is subject to a U.S. Environmental Protection Agency emissions standard and a California Air Resources Board ambient air quality standard.

Gasoline and tobacco smoke were both appended to the list because each is very widely used and contains several of the candidate substances reviewed in this study, including some which are in the final listing. For example, gasoline contains benzene, ethylene dibromide, ethylene dichloride, and alkyl lead compounds, the last three being in leaded grades only. Gasoline combustion products contain PAH's and diesel emissions may contain nitrosamines. Tobacco smoke contains, among other neoplastigenic substances, nitrosamines, PAH's, nickel, arsenic, cadmium, and other heavy metals. Many individuals are involuntarily and, in may situations, virtually unavoidably exposed to tobacco smoke. Because the sources of gasoline, its combustion

Table 3-10

HIGHEST RANKED CANDIDATES FROM EACH RANKING METHOD[a]

SAI's ALGORITHMS		
Additive	Multiplicative	Panel of Experts
Asbestos	Arsenic	Arsenic
Benzene	Asbestos	Asbestos
Cadmium	Benzene	Benzene
Ethylene Dibromide	Cadmium	Carbon Tetrachloride
Ethylene Dichloride	Carbon Tetrachloride	Chloroform
Nitrosamines	Chloroform	Ethylene Dibromide
Perchloroethylene	Chromium	Ethylene Dichloride
Polycyclic Aromatic Hydrocarbons (PAH)	Ethylene Dichloride	Nitrosamines
	Nitrosamines	Perchloroethylene
	Perchloroethylene	PAH
	PAH	

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[a] See Section 3.3.4 for explanation.

Table 3-11

FINAL SELECTION OF CANDIDATES[a]

Highest Consensus Ranking

- Arsenic
- Asbestos
- Benzene
- Cadmium
- Carbon Tetrachloride
- Chloroform
- Ethylene Dibromide
- Ethylene Dichloride
- Nitrosamines
- Perchloroethylene
- Polycyclic Aromatic Hydrocarbons (PAH)

Highly Ranked But No Inventory Recommended At This Time

- Vinyl Chloride
- Gasoline and Engine Exhausts
- Tobacco Smoke
- Pesticides

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[a] See Section 3.3.4 text for explanation.

products, and tobacco smoke emissions are well known, however, no specific action was recommended for these materials during the emissions-inventory and source-testing-design phases of this study. It was considered informative to call out these substances in order to explicitly reinforce their identification as exposure sources to the general public. Pesticides were included for the same reason, though a detailed examination of pesticides was beyond the scope of this study. Many pesticides are widely used, and some of them are carcinogenic.

Table 3-11 lists the top candidates along with vinyl chloride, gasoline and engine exhausts, tobacco somke and pesticides. The list is alphabetical, avoiding the implications of a ranked order. The actual rank of the candidates varied from one ranking method to another, except in the case of benzene, which was consistently ranked one.

3.4 Occupational Carcinogens -- Task III

The purpose of Task III is to assess the impact of the occupational control of regulated carcinogens on ambient air concentrations. This is done by mandating that these regulated carcinogens are included for consideration in Task I and account be taken of their control procedures. It is important to know if controlling these materials in the workplace adversely affects the ambient air quality. All of the substances controlled by the California Department of Industrial Relations were evaluated as part of Task I. As of February 1979, there are 18 such substances*, plus coke oven emissions. The standard for benzene is still pending. Most of these were rejected early from further consideration when analysis uncovered they are little used, are tightly controlled, and cannot be discharged to the ambient air. This conclusion was not true of several substances, namely, asbestos, vinyl chloride, and nitrosamines. These were carried through the Task I evaluation process and were eventually included in the final selection of candidates (Table 2-1). These substances, excepting vinyl chloride, will be further evaluated, along with the other highest-ranked substances in Table 2-2, in Task II, the purpose of which is to identify and characterize sources, estimate emissions therefrom, and identify geographical areas where emissions would be most important. Significant sources for all the remaining substances will be inventoried regardless of whether they arise from the workplace or other emissions.

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* They are those shown in Table 1-1 plus N-nitrosodimethylamine, asbestos, vinyl chloride, dibromochloropropane (DBCP), and acrylonitrile.

4.0 SUBSTANCE DOSSIERS

4.1 Candidate Substances

ARSENIC

(Various Forms)

Overview: Although arsenic is used as a metal, as a variety of inorganic oxides and salts and in several organic forms, only the inorganic oxides and salts have been implicated in carcinogenesis. Arsenic trioxide (As_2O_3) is produced commercially as a byproduct of metal refining operations, and is the feedstock for the production of other arsenicals such as arsenic pentoxide (As_2O_5) and sodium arsenate ($Na_3AsO_4 \cdot 12H_2O$). About 82 percent of the arsenic trioxide produced in and imported to the U.S. is used in the manufacture of pesticides; 9 percent goes to glass and glassware while industrial chemicals, copper and lead alloys and pharmaceuticals account for the remaining 10 percent (USBM, 1978). Due to the availability of substitutes and their implication in carcinogenesis, inorganic arsenicals are expected to be used less in the future.

1. Present Use in California: Information on arsenic trioxide production is difficult to obtain, since the sole U.S. producer (in Tacoma, Washington) considers such data proprietary. It has been estimated that U.S. demand for arsenic (including, presumably, organic arsenicals) was 4.8×10^7 lb in 1973, 3.9×10^7 lb of which were used in agriculture (USBM, 1975). The Panel stated that roughly 20 percent of the arsenic consumption was in California; the state's share would therefore be 9.6×10^6 lb. Because of this moderately high use rate, we have assigned a score of 3 for R_1.

2. Growth in California Use: Consumption of arsenic has been inhibited by use of alternative materials, such as synthetic organic pesticides. Imports of As_2O_3, which comprise about half of the inorganic arsenic used, declined from 2.70×10^7 lb in 1973 to 8.5×10^6 lb in 1976 (USBM, 1978). Use of inorganic arsenic in pesticides is expected to decrease now that it has been regulated as a carcinogen (Peters, 1978). However, the Panel indicated that California's use of arsenic as a wood preservative has been substantially increasing recently. We therefore assigned a value of 3 to R_2.

3. Emission Potential: While nonferrous smelting is the dominant source of inorganic emissions in the U.S., there are no such facilities in the state. The chief sources of inorganic arsenic emissions (excluding pesticide application) in California are production of arsenical compounds, glass production and assorted other uses such as cotton gins, inorganic chemical manufacture, and wood preservation. Emissions from these sources in 1974 were

estimated at 1.21 x 10^6 lb in the U.S. (USEPA, 1976). In an ongoing investigation, the California Department of Health recently learned that a potential source of arsenic emissions is fireplace logs fabricated from cotton-crop trash (Hahn, 1978). Because pesticide application is beyond the scope of this study, we cannot consider this use in our rating exercise. Factor R_3 was given a value of 4.

4. Stability in Ambient Air: The question of arsenical mobility and transformation in the atmosphere has not been thoroughly addressed. It is believed that most airborne arsenic particulate material consists of inorganic arsenic (III) compounds (arsenic trioxide, arsenites) and perhaps some pentavalent arsenic (arsenic pentoxide, arsenate) (Braman, 1976). Coarse particulate arsenic is removed from the air by settling and rainfall, and atmospheric concentrations do not build up (NRC, 1976). Background concentrations in comparatively nonpolluted locations average about 4 to 6 ng/m^3 of total arsenic (Braman, 1976). Industrial areas (apart from the immediate vicinity of smelters) may have atmospheric arsenic concentrations of about 20 to 90 ng/m^3 (NRC, 1976a). Because arsenic cannot be degraded in air, we have assigned a value of 5 to rating factor R_4.

5. Dispersion Potential: Because inorganic arsenic compounds of interest are emitted as both fine and coarse particulates we have given them a rating of 3 for rating factor R_5.

6. Severity of Carcinogenicity: Arsenic is one of the few substances implicated in human carcinogenesis but not yet convincingly demonstrated to produce cancer in experimental animals (EPA, 1976; Pinto and Nelson, 1976). Because arsenic is a human carcinogen (IARC, 1978), it is assigned 5 for R_6.

ASBESTOS

(Various Mineral Silicates)

Overview: Asbestos is a mineral fiber which has over 2,000 individual uses, including: asbestos cement pipe (25%), flooring products (22%), friction products (11%), paper (11%), roofing products (8%), asbestos cement sheet (7%), packing and gaskets (35%), insulation (1%), textiles (1%) and other uses (11%) (Clifton, 1977). Consumption in the U.S. in 1976 was about 1.45 x 10^9 lb. Asbestos has been identified as a human carcinogen (IARC, 1978), and a number of major commercial sources of airborne emissions are limited by EPA regulations (EPA, 1974b and 1975c). Mesothelioma has been associated with nonoccupational exposures in the neighborhood of asbestos sources.

1. Present Use in California: Production and use in California is considerable. Of the five mine and mill operations in the U.S. in 1976, three were in California (Clifton, 1977). About 70 percent of asbestos products are used in the construction industry; 60,000 construction locations were identified in California in 1976 (AIA, 1976). Roughly 1,000 firms have reported using asbestos in California (Davidson, 1978), but primary users--those producing or using raw asbestos--are far fewer. Assuming that consumption of asbestos in California is 10 percent of the national consumption results in an estimated California consumption of 1.45 x 10^8 lb. However, the Panel indicated that considerably more than 10 percent of the national consumption was consumed in California, indicating a value of 5 for R_1.

2. Growth in California Use: The million tons of asbestos fiber reserve at the Copperopolis deposit are probably economically recoverable, although the future of the millions of tons of short fibers available in the Coalinga area is doubtful because of low demand and environmental costs (Clifton, 1977). Economically feasible substitutes are being pursued, and more synthetic inorganic fibers are becoming available each year. Asbestos use in automobile-related friction materials, for instance, will be phased out in the next few years. National demand is expected to decline at an average annual rate of 1 percent through 1985 (USBM, 1978). With no evidence to indicate that California's experience will differ appreciably from this, R_2 was assigned a value of 1.

3. Emission Potential: Airborne asbestos fibers may be generated in the mining and milling of asbestos ore; manufacture and fabrication of asbestos products, including cement mining and manufacturing; and disposal of solid wastes from these processes. Airborne asbestos fibers may also be generated by natural erosion of asbestos-bearing serpentine rock, which is widely distributed in California. Asbestos fibers are detectable in widespread areas of California, but concern is greater near large emission sources. Although 85 percent of the asbestos is tightly bound in products, some uses result in direct exposure to the general population and consumers, indicating a value of 5 for R_3. Between 1950 and 1972, asbestos was used in spray insulation in buildings. As buildings constructed during this period are demolished, they may become a major

source of environmental discharge (Nicholson et al., 1975).

4. Stability in Ambient Air: Asbestos fibers are extremely resistant to degradation in the environment, usually have negligible gravitational settling properties, and are easily re-entrained at ground surfaces (EPA, 1978c).

Asbestos measurements in the ambient air of California have been made in several studies as follows:

Location in California	Number of Fibers/m^3	References
King City, downwind of a milling plant	6,000 to 1,600,000	John et al., 1976
King City, upwind of a milling plant	200 to 11,000	John et al., 1976
San Jose	0 to 3,500	Murchio et al., 1973
Berkeley	0 to 4,000	Murchio et al., 1973
Los Angeles (Downtown)	0 to 5,700	Murchio et al., 1973
Emeryville, near asbestos manufacturer	238,000	Murchio et al., 1973
White Mountain (desert)	20 to 100	Murchio et al., 1973
Santa Monica Freeway, upwind (at 4th)	700*	Murchio et al., 1973
Santa Monica Freeway, downwind (at 4th)	700*	Murchio et al., 1973
Harbor Freeway, upwind (at 146th)	1,100*	Murchio et al., 1973
Harbor Freeway, downwind (at 146th)	1,600*	Murchio et al., 1973
San Diego Freeway, upwind (at National)	200*	Murchio et al., 1973
San Diego Freeway, downwind (at National)	800*	Murchio et al., 1973
San Diego Freeway, upwind (at 122nd)	900*	Murchio et al., 1973
San Diego Freeway, downwind (at 122nd)	500*	Murchio et al., 1973

ASBESTOS (continued)

Location in California	Number of Fibers/m^3	References
Los Angeles Freeways, upwind (four sites)	800^{**}	Murchio et al., 1973
Los Angeles Freeways, downwind (four sites)	900^{**}	Murchio et al., 1973
San Lucas	1,000,000	Wesolowski, 1975
Berkeley	700,000	Wesolowski, 1975

---

* Mean values

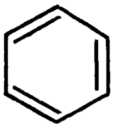
** Mean value of 60 samples

R_4 was assigned a value of 5, indicating high stability.

5. Dispersion potential: Asbestos fibers are emitted in large part as fine particles, indicating a value of 5 for R_5.

6. Severity of Carcinogenicity: Asbestos has been identified as being carcinogenic in humans (IARC, 1978; ACGIH, 1977), indicating an R_6 value of 5. Cigarette smoking enhances the carcinogenic effect of asbestos.

BENZENE



Overview: Benzene is a component of gasoline and is widely utilized in the synthesis of organic chemicals. It appears in consumer products principally as a solvent. Benzene has been linked with leukemia in human studies. Large quantities are known to be discharged to the atmosphere and ambient concentrations are commonly measured. U.S. production of benzene in 1976 was 10^{10} lb (USITC, 1977b).

1. Present Use in California: Benzene is produced at several facilities in California (Mara and Lee, 1978):

Atlantic Richfield	Wilmington	12×10^6 gal/year (capacity)
Shell Oil	Wilmington	20×10^6
Standard Oil	El Segundo	23×10^6
		$55 \times 10^6 = 4.0 \times 10^8$ lb

In addition, benzene emissions are associated with process emissions from petroleum refinery operations. There are approximately 32 refineries in California (Dickerman et al., 1975), the largest being principally clustered in the Los Angeles South Bay Area.

Major California users of benzene as a feedstock in synthesizing organic chemicals have been identified as (Mara and Lee, 1978):

Company	Location	Annual Benzene Emission (10^6 kg)	End Product
Wetco Chem.	Carson	.055	Detergent alkylates
St. Oil Calif.	El Segundo	.011	Cumene
Specialty Organics	Irwindale	.080	Dichlorobenzene
Std. Oil Calif.	Richmond	.025	Phenol
Std. Oil Calif.	Richmond	.220	Detergent alkylates
Ferro Corp.	Santa Fe Springs	0	Phenol*

Coke ovens present a potential source of benzene emissions. Although the Kaiser coking facility in Fontana is not used as a benzene production source, emission rates and population exposure have been estimated.

Benzene is found in solvent operations in a number of industries. The number of plants in California in some of these industries was tabulated as (Mara and Lee, 1978):

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* Although the cited reference lists Ferro Corp. with emissions data as N.A. (not available), consultation with plant personnel indicate no benzene utilization or formation in their phenol production process.

Tires and Innertubes	22 plants
Rubber, Plastic Hose and Belting	8
Rubber and Plastic Footware	3
Plastic Materials; Synthetics	51
Floor Covering Mills	62

Other significant benzene sources are due to its presence in gasoline; these include automobile emissions, general ambient service station emissions, evaporation from gasoline bulk storage, and personal exposure during tank filling at self service stations. Estimates of these emissions are summarized under Emission Potential. The dominant source of benzene to which the general population is exposed is vehicle exhaust. R_1 was assigned a value of 5 to indicate benzene production and usage is roughly 10^9 lb per year.

2. Growth in California Use: Proposed standards for Cal OSHA appear likely to accentuate an existing trend towards decreased usage (ADL, 1977). (The standard will limit the 8-hour TWA concentration to 1 ppm benzene with a 0.5 ppm action level.) However the proposed state standard does not apply to "the storage, transportation, distribution, dispensing, sale or use of benzene as a fuel or gasoline, motor fuel, or other fuels subsequent to discharge from bulk terminals." Therefore, benzene use as a gasoline constituent should be relatively unaffected and total use might be expected to parallel vehicle population growth. Thus, R_2 was given a value of 3 to indicate slow but known annual growth.

3. Emission Potential: The table below (Patterson et al., 1976) estimates the national emissions of benzene.

Source	10^6 lb	(10^6 gal)
Vehicle exhaust	841	(119)
Vehicle evaporative loss	68	(9.5)
Benzene production	58	(8.1)
End product manufacturing	58	(8.1)
Solvent usage	55	(7.7)
Gasoline handling	35	(4.9)
Bulk storage	34	(4.8)
	1,149	(161)

Quite clearly, vehicle emissions represent the largest emission source. SRI estimated the nationwide total exposures of individuals residing in the vicinities of identifiable benzene sources. The total number of people exposed and their annual integrated exposure is as follows (Mara and Lee, 1978):

Source	Number of People Exposed to Benzene Concentrations (ppb)					Comparison Among Sources (10^6 ppb-person-years)
8-hour Worst Case:	2.5-25.0	25.1-100.0	100.1-250.0	>250.0		
Annual average:	0.1-1.0	1.1-4.0	4.1-10.0	> 10.0	Total	
Chemical manufacturing	6,000,000	1,000,000	200,000	80,000	7,300,000	8.5
Coke ovens	300,000				300,000	0.2
Petroleum refineries	5,000,000	3,000			5,000,000	2.5
Solvent operations	poorly known				—	—
Storage & distribution of gasoline	slight				—	—
Automobile emissions - urban	69,000,000	45,000,000			110,000,000	150.0
Gasoline service stations - urban	20,000,000	900,000			21,000,000	12.0
People using self-service gasoline				*	37,000,000	1.6

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* Estimated at 245 ppb for 1.5 hr/yr/person

Factor R_3 was given a value of 5.

4. Stability in Ambient Air: With a half-life of roughly four days, benzene is relatively stable in the atmosphere. The ARB places it in Class I (low reactivity). Recent studies suggest that benzene is converted to phenol in air. Ambient measurements and dispersion calculations (Youngblood, 1977) confirm the stability and high dispersion potential of benzene. A number of ambient air measurements of benzene in Southern California have been made (Altshuller and Bellar, 1963; Mayrsohn et al., 1975; Pellizzari, 1977). Readings range between 13-240 ppb average levels to 360 ppb maximum. An older study (Lonneman et al., 1968) showed average concentrations in the Los Angeles Basin of 14 ppb benzene. R_4 was assigned a value of 5 to indicate benzene's relatively high stability.

5. Dispersion Potential: Benzene is a volatile liquid with a vapor pressure of 76 mm Hg at 20°C. It is emitted as a vapor, indicating a value of 5 for R_5.

6. Severity of Carcinogenicity: The IARC has concluded that there is sufficient evidence to classify benzene as a strongly suspected human carcinogen (IARC, 1978), indicating a value of 5 for R_6.

CADMIUM

(Various Forms)

Overview: Cadmium and its compounds have many uses, including electroplating (55%), plastics stabilizers (20%), pigments (12%), batteries (5%), and miscellaneous (8%) (USEPA, 1978a). Consumption of cadmium in the U.S. in 1977 was approximately 10 million lb (USBM, 1978). Cadmium and several of its compounds have been identified as animal carcinogens (Christensen et al., 1976) and the Clean Air Act Amendments of 1977 require that the U.S. Environmental Protection Agency (EPA) determine whether atmospheric emissions of cadmium are hazardous to public health. Cadmium source categories potentially able to cause measurable ambient levels of cadmium were identified as primary zinc, copper, lead, and cadmium smelters; secondary zinc and copper smelters; municipal incinerators; and iron and steel mills (USEPA, 1978a). An estimated 1000,000 workers in the U.S. are potentially occupationally exposed to cadmium (NIOSH, 1976a).

1. Present Use in California: Measurable levels of cadmium in ambient air may arise from smelters, incinerators, and iron and steel mills. According to the EPA, California has no operating municipal incinerators or primary smelters, but several iron and steel mills and secondary smelters are located in California, with emission rates and estimated population exposures as follows (Coleman et al., 1978):

	Emission Rate (g Cd/sec)	Thousands of Persons Exposed to Concentration Range (ng Cd/m^3)				
		10	5-10	1-5	0.1-1	TOTAL
Iron and Steel Mills						
Carson	7.5×10^{-4}	0	0	0	93	93
Emeryville	7.5×10^{-4}	0	0	0	120	120
Fontana	2.9×10^{-2}	0	18	146	319	483
Union City	1.3×10^{-3}	0	0	0	54	54
Secondary Smelters						
Asarco, Long Beach (Copper)	--	107	183	1838	1279	3407
Asarco, Long Beach (Zinc)	--	0	0	0	40	40
Asarco, San Francisco (Copper)	--	76	171	866	493	1606
	TOTAL	183	372	2850	2398	5803

-- = No data

Thus an estimated total of 5.8 x 10^6 persons are exposed to concentrations of cadmium in the air greater than or equal to 0.1 ng/m^3, and 1.8 x 10^5 persons are exposed to levels greater than 10 ng/m^3 from these sources. However, these estimates are very crude, and the EPA is currently revising the secondary smelter data. The Panel indicated that 50 to 60 secondary smelters are located in California. Also, U.S. Steel (Torrance) and Bethlehem Steel (Vernon) were not included in the EPA's data, and some of the steel plants which are included may no longer be operating (Vreeland, 1978). Assuming that California's consumption of cadmium amounts to ten percent of the national consumption (10^7 lb), a value of 2 for R_1 is indicated.

2. Growth in California Use: Steel production and secondary smelting are expected to increase nationwide (USEPA, 1978a). The national demand for steel is expected to increase at an average annual rate of 2 percent through 1985 (USBM, 1978), with no indication that California experience will differ greatly from this, indicating a value of 3 for R_2.

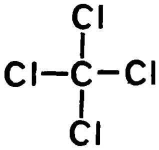
3. Emission Potential: Emissions are not tightly controlled; some sources have no controls, while others use control devices (baghouse, cyclone, electrostatic precipitator, scrubber) to greatly reduce emissions. Even with increased steel production, the increasing application of control devices is expected to result in decreased total emissions from iron and steel mills. But emissions from secondary copper smelting may increase considerably through 1985 (USEPA, 1978a). The overall effect on emissions in California is unknown. Even with controls, emissions cannot be considered tightly controlled, so R_3 was assigned a value of 4.

4. Stability in Ambient Air: Cadmium is emitted as metallic cadmium vapor from hot processes such as steelmaking and smelting. Cadmium in this form is expected to react quickly to form stable compounds such as the oxide, sulfate or chloride. Urban concentrations of cadmium are typically 3 ng/m^3, ranging from 100 ng/m^3 to undetectable (USEPA, 1978a). In California, a total of 304 composite quarterly samples were taken at 18 cities from 1970 through 1974. Of these, 284 (93%) were below the detection limit (0.2 to 0.4 ng/m^3), and of the 20 positive samples, the average was 0.29 μg/m^3, with a maximum value of 0.295 μg/m^3. Discarding this extraordinarily high value lowers the mean composite quarterly sample to 0.015 μg/m^3, the maximum sample then being 0.093 μg/m^3 (Akland, 1976). Particles greater than 50 μm in diameter settle out rapidly, the smaller ones remaining airborne longer and being transported farther (Anon., 1977). Because cadmium cannot be degraded in the atmosphere, R_4 was valued at 5.

5. Dispersion Potential: Cadmium is emitted from steel mills and smelters as a vapor because of its relatively high volatility at high temperatures. (Its melting point and boiling point are 312° and 765°C, respectively.) Thus any high temperature process, such as metallurgical processes, will vaporize cadmium. In the air, this vapor should react rapidly to form the oxide, sulfate or chloride (USEPA, 1978a; Anon., 1977). Thus R_5 is 5, indicating that cadmium will exist largely as fine particulates in ambient air.

6. Severity of Carcinogenicity: Cadmium, its oxide, chloride, sulfate, and other cadmium compounds have been identified as being carcinogenic in mammals (Christensen et al., 1976) indicating a value of 4 for R_6.

CARBON TETRACHLORIDE



Overview: Carbon tetrachloride is a high-production chlorinated hydrocarbon used for making fluorocarbon 12 (52%), fluorocarbon 11 (28%) and other applications (20%) (Lowenheim and Moran, 1975). U.S. production in 1976 was 8.6 x 10^8 lb (USITC, 1977b). Carbon tetrachloride is a confirmed animal carcinogen. An estimated 2 x 10^6 persons are exposed occupationally (NIOSH, 1977a).

1. Present Use in California: Dow Chemical Co. has a production facility at Pittsburg, California, though its output is uncertain. Until recently, Dow's production was purchased by duPont, Inc. at Antioch for making F_{11} and F_{12}, but duPont now imports its carbon tetrachloride from its own plant in Corpus Christi, Texas, except when this plant is not operating (Matthews,1978). In any case, all California production of carbon tetrachloride is done by Dow at Pittsburg, and apparently, essentially all that consumed in California is used for making F_{11} and F_{12} by duPont at Antioch. When demand for its carbon tetrachloride is low, Dow swings production to a different product (Stevens, 1978). The Panel indicated that California likely consumes 5 percent of the national total, or roughly 4 x 10^7 lb per yer. R_1 was assigned a value of 3-4.

2. Growth in California Use: Any decline in F_{11} production for use as aerosol propellants has probably already occurred in California, and use should not decline further (Stevens, 1978). Future growth will likely not be dramatic, indicating a value of 3 for R_2.

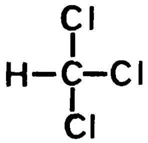
3. Emission Potential: Almost all carbon tetrachloride used in California is for nondispersive uses. Losses during production reportedly amount to 1.5 percent of production (Brown et al., 1975); however, the Panel indicated that producers were much more concerned about losses for economic reasons than were users. For this reason, a value of 3 was assigned to R_3. The atmospheric burden of carbon tetrachloride may also be contributed to by chlorinated water (Singh et al., 1977).

4. Stability in Ambient Air: Carbon tetrachloride is stable in the troposphere and has no degradation products (Barber, 1977). California rural background levels appear to be roughly 0.11 ppb, while levels in Los Angeles average 0.13 ppb. Atmospheric carbon tetrachloride is thought to be largely or solely anthropogenic in origin (Singh et al., 1977). R_4 is 5.

5. Dispersion Potential: As carbon tetrachloride is a volatile liquid with a vapor pressure of 90 mm Hg at 20°C, vapors are readily emitted, indicating a value of 5 for R_5.

6. Severity of Carcinogenicity: Carbon tetrachloride is a confirmed carcinogen in the mouse, hamster and rat (IARC, 1972c), indicating a value of 4 for R_6.

CHLOROFORM


$\mathrm{H-\overset{Cl}{\underset{Cl}{C}}-Cl}$

Overview: Chloroform is a chlorinated hydrocarbon with the following uses (Lowenheim and Moran, 1975): fluorocarbon refrigerants and propellants (52%); fluorocarbon resins (41%); miscellaneous and exports (7%). Its U.S. production in 1976 was 2.9×10^8 lb (USITC, 1977b).

1. Present Use in California: No chloroform is produced in California, and the only significant use of chloroform appears to be in making F_{22} at the El Segundo site of Allied Chemical Corporation (Stevens, 1978; Cardinale, 1978), though the actual amount consumed was not available. Assuming that consumption in California amounts to 5 to 10 percent of the national figure results in a value of 3 for R_1.

2. Growth in California Use: Allied Chemical Corporation at El Segundo recently converted from making F_{11} and F_{12} with carbon tetrachloride to making F_{22} with chloroform. Chloroform consumption apparently increased greatly at that time (Cardinale, 1978), but no further dramatic increase is foreseen, indicating a likely value of R_2 of 3.

3. Emission Potential: An estimated 5.6 percent of the chloroform produced is lost to the environment (NAS, 1978), indicating a value of 4 for R_3. Chloroform is also emitted to the air from chlorinated waters (Barcelona, 1978).

4. Stability in Ambient Air: Chloroform is relatively stable, with a tropospheric half-life of 480-770 days, degrading slowly into phosgene, HCl, and chlorine monoxide (Barber, 1977). The rural background level in California is roughly 0.02 ppb, and urban levels in California average approximately 0.1 ppb. Whether natural sources of chloroform exist is unclear (Singh et al., 1977). R_4 was assigned a value of 5 to indicate its high stability.

5. Dispersion Potential: As a volatile liquid (vapor pressure at 20°C is 160 mm Hg) chloroform is readily emitted as vapor, indicating a value for R_5 of 5.

6. Severity of Carcinogenicity: In National Cancer Institute tests, chloroform was carcinogenic in rats and mice. However, because of the very high doses given and resulting poor health of the test animals, these tests are controversial (Maugh, 1978). R_6 was assigned a value of 4.

CHROMIUM

(Various Forms)

Overview: As one of modern industry's most essential and versatile elements, chromium is used in widely diversified products such as stainless, tool, and alloy steels; heat- and corrosion-resistant materials; special purpose alloys; alloy cast iron; pigments; metal plating; leather tanning; chemicals; and refractories for metallurgical furnaces. These uses are broadly classified as metallurgical, chemical, and refractory (Morning, 1977). The estimated 1976 domestic consumption of chromite ore was 2.0×10^9 lb -- 1.2×10^9 lb metallurgical grade, 4.0×10^8 lb refractory grade, and 4.1×10^8 lb chemical grade -- all of which was imported (USEPA, 1978b).

Sodium dichromate is produced from chromite ore and is the principal intermediate in the manufacture of chromium chemicals. The estimated 1976 domestic production of sodium dichromate was 3.14×10^8 lb by four firms. The major derivatives of sodium dichromate are pigments; metal treatment chemicals; leather tanning chemicals, and textile and dye chemicals. Chromium in these chemicals is largely hexavalent (USEPA, 1978b). Chromium is widely detected in urban air, and hexavalent chromium is strongly suspected of causing cancer in humans via the inhalation route. An estimated 1.5 million persons in the U.S. are potentially occupationally exposed to chromium oxides (NIOSH, 1977a).

1. Present Use in California: Interest in mining chromite deposits along the California-Oregon border has grown since the U.S. embargo against Rhodesian chromium in March 1978 (USBM, 1978). In 1976, a chromite mine in California was reopened and its output exported (USBM, 1978), though this mine may have already ceased productions (Matthews,1978). Individual chromite deposits in California are generally small and relatively unattractive (Matthews,1978).

No plants in California produce chromium alloys or metallic chromium for use in steelmaking (Morning, 1977), though charging chromium is used in California in at least three steelmaking plants -- Kaiser Steel, U.S. Steel, and Bethlehem Steel Corporations (private communications with respective firms) -- all of which are in Southern California. The amount of chromium used by these plants was not revealed.

California has one chromite refractory-making plant, located in Moss Landing (Morning, 1977). The amount of chromite ore used in this plant was divulged in confidence.

Sodium dichromate, the chemical from which practically all other chromium chemicals are derived, is not produced in California but is used in the state in tanning and wood preserving. Chromic acid, potassium dichromate, and chromium

pigments are also used, but not produced, in California (Kuhn, 1978). The annual use of some chromium-containing chemicals in California is shown in the following table:

	10^6 lb
Sodium Dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$)[a],	
Tanning	4
Wood preserving	0.6
Unknown	0.4
	5
Chromic Acid (CrO_3)[a],	
Metal finishing	0.6
Potassium Dichromate ($K_2Cr_2O_7$)[a]	0.2
Yellow Traffic Paint Used by the California Department of Transportation[b]	0.25
	6.0

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[a] Kuhn, 1978

[b] Takasako, 1978

The amount of chromium consumed in steel, refractories, traffic paint and pigments for other uses has not been estimated. The Panel estimated about 10^7 lb/yr of chromium is used in California. On this basis, an R_1 value of 3 was assigned.

2. Growth in California Use: Nationwide demand for chromium is expected to increase at about 3.4 percent per year through 1985 (USBM, 1978). No indications are evident that consumption in California will differ from this relatively low national growth rate. Rating factor R_2 was therefore assigned a value of 3.

3. Emission Potential: Information on emission control was unavailable from California steel producers and refractories, and this type of information seems to be lacking in general in the published literature (USEPA, 1978b). Potential sources of airborne chromium in California include steel mills, tanneries, pigments (traffic and other yellow paints), electroplating,

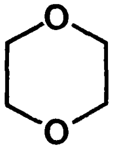
electric arc welding, and cooling towers (corrosion inhibitors). In the case of cooling towers, at least one measurement confirmed the potential for chromium emissions (Unmack, 1978). R_3 was assigned a value of 4, indicating that some, if not all, emissions are not well controlled.

4. Stability in Ambient Air: Because chromium cannot be degraded, even though its oxidation state and ionic associations may change, R_4 was assigned a value of 5.

5. Dispersion Potential: Chromium has a relatively high melting point (1857 ± 20°C) and boiling point (2672°C) and is unlikely to volatilize to a great extent in metallurgical processes. Potential sources of airborne chromium in California include aerosols and solid particles from paint application, paint decay, electroplating, tanning, refractory-making, and steelmaking, though the importance of these sources is unknown. Airborne hexavalent chromium can react with particulate matter and be reduced to trivalent chromium, and it can settle out of the air or be washed out with precipitation. However, the rates of these mechanisms are unknown (USEPA, 1978b). A total of 324 composite quarterly ambient air samples were taken at 18 California cities from 1970 through 1974 as part of EPA's National Air Surveillance Network program (Akland, 1976). Of these, 70 (22%) were below the detection limit (0.6 to 0.8 ng/m^3). The 254 positive samples had a mean of 9 ng Cr/m^3 and a maximum value of 87 ng/m^3. R_3 was given a value of 3, indicating that chromium is emitted as fine and coarse particulates.

6. Severity of Carcinogenicity: Chromite, chromium, and several chromium compounds are suspected or confirmed animal carcinogens (Christensen et al., 1976). Hexavalent chromium is strongly suspected of causing lung cancer in dichromate-manufacturing workers (USEPA, 1978b; IARC, 1978), indicating a value of 5 for R_6.

1,4-DIOXANE



Overview: 1,4-Dioxane is a widely used synthetic organic chemical used mainly as a stabilizer in chlorinated solvents (IARC, 1976c). 1,4-Dioxane is also found in consumer products such as varnishes, paint and varnish removers, cleaners, detergents, and deodorants (Hawley, 1977). However, one manufacturer indicated that uses other than as a stabilizer in chlorinated solvents are uncommon (Stevens, 1978). A review of Chemical Abstracts from 1972 through 1977 revealed many citations dealing with 1,4-dioxane's use as a stabilizer in methyl chloroform (1,1,1-trichloroethane) and no other solvent. In this use, methyl chloroform is prevented from degrading and thus corroding metal parts. Abstracts, mostly of patents, indicated that 1,4-dioxane was generally used in concentrations of 1 to 3 percent mixtures in methyl chloroform. 1,4-dioxane is apparently not used in perchloroethylene for metal degreasing (Sterling, 1978). It appears, therefore, that the major use of 1,4-dioxane is as an inhibitor in methyl chloroform used for metal degreasing. The 1976 production was 1.5 x 10^7 lb (USITC, 1977b).

1. Present Use in California: 1,4-dioxane is apparently not produced in California by any of its four U.S. producers. Total consumption in California is unknown, but a minimum consumption is the 7.5 x 10^5 lb per year which Dow Chemical Company distributes in chlorinated solvents for vapor degreasing (Fischback, 1978). Dow does not market 1,4-dioxane in California (Fischback, 1978), and Union Carbide probably sells under 10^5 lb per year in the state (Gilbert, 1978). R_1 was assigned a value of 2 to indicate moderately low use in California.

2. Growth in California Use: Nationwide growth in the use of 1,4-dioxane was expected to be 4 to 5 percent in 1973, 7 to 8 percent for use only in chlorinated solvents (Anon., 1973). No indications are evident that California's experience will differ appreciably from the nationwide trends for this chemical. Based on this limited information, R_2 was assigned a value of 3 to indicate moderate growth.

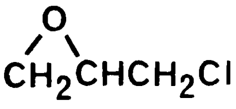
3. Emission Potential: Essentially all of the 1,4-dioxane consumed is reportedly released to environment (Brown et al., 1975), and much of this is likely emitted directly to the atmosphere. The Panel pointed out, however, that 1,4-dioxane, as a preservative, should decompose to a large extent before being emitted. The exhaust from a large methyl chloroform vapor degreasing operation in the Los Angeles area contained 0.3 ppm 1,4-dioxane in the idling mode and 1 ppm while operating (Taback, 1978). R_3 was assigned a value of 4, in view of its routine emission.

4. Stability in Ambient Air: 1,4-dioxane is unstable in air, forming an explosive peroxide (IARC, 1976c). This mechanism may lead to removal of 1,4-dioxane from the air. In chamber experiments, 1,4-dioxane was found to have a half-life of 3-4 hours in air containing nitric oxide in the light (Dilling et al., 1976). No data were available on ambient concentrations of 1,4-dioxane. R_4 was assigned a value of 3.

5. Dispersion Potential: As a volatile liquid (vapor pressure at 20°C is 30 mm Hg), 1,4-dioxane is emitted as a vapor, indicating a value of 5 for R_5.

6. Severity of Carcinogenicity: 1,4-dioxane is carcinogenic in test animals, though administration to mice via inhalation resulted in negative results (IARC, 1976c). R_6 is 4, indicating that 1,4-dioxane is regarded as a confirmed carcinogen in mammals.

EPICHLOROHYDRIN



$\overset{O}{CH_2CH}CH_2Cl$

Overview: The 1973 national use pattern for epichlorohydrin was as follows: (IARC, 1976d): synthetic glycerin (46%), unmodified epoxy resins (39%), elastomers (2%), other products (9%), exports (4%). Domestic production in 1974 was 5.0×10^8 lb (Dorigan et al., 1976).

1. Present Use in California: Epichlorohydrin is not produced in California, but roughly 1.5×10^6 lb per year are used in the state (Stoebner, 1978). The primary user is Diamond Shamrock, Redwood City, which uses epichlorohydrin for production of water treatment resins (Gardner, 1978). A spokesman for Drake and Feld Division of Hercules, Inc. indicated that they no longer use epichlorohydrin for making paper-sizing agent. R_1 was assigned a value of 2.

2. Growth in California Use: Growth in the use of epichlorohydrin in California is likely to be around three to four percent per year, with no change expected (Stoebner, 1978), indicating a value of 3 for R_2.

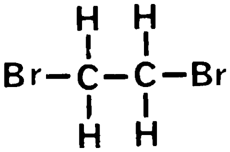
3. Emission Potential: The Panel indicated that epichlorohydrin is very reactive and is likely to be used up in manufacturing processes. Although Diamond Shamrock has relatively good control over emissions, fugitive releases could occur during transfers between storage and reactor vessels, from leaky valves, pumps, or during reactions, depending on operating practices and other reactants (Gardner, 1978). An R_3 value of 2 was assigned to indicate that relatively low emissions are likely.

4. Stability in Ambient Air: Under simulated atmospheric conditions, photodecomposition of epichlorohydrin occurs, resulting in a half-life of 16 hours in the presence of nitric oxide (Dilling et al., 1976). R_4 was given a value of 4 to indicate that epichlorohydrin is relatively stable in the atmosphere.

5. Dispersion Potential: As a volatile liquid (vapor pressure at 20^oC is 12 mm Hg) epichlorohydrin would be emitted as a vapor, indicating a value of 5 for R_5.

6. Severity of Carcinogenicity: Epichlorohydrin is a confirmed animal carcinogen, indicating a value of 4 for R_6. The panel pointed out that some epidemiological evidence implicates epichlorohydrin in human carcinogenesis.

ETHYLENE DIBROMIDE
(1,2-dibromoethane)



Overview: 1,2-dibromoethane (EDB) is a dense, colorless liquid. Almost all ethylene dibromide produced in the U.S. is used as a scavenger in leaded gasoline preparations. The rest is used as a soil and seed fumigant, as an intermediate in the manufacture of dyes and pharmaceuticals, and as a nonflammable solvent for resins, gums and waxes (Lowenheim and Moran, 1975). It is a known animal carcinogen.

1. Present Use in California: U.S. production of ethylene dibromide was 2.0×10^8 lb in 1976 (USITC, 1977b). At this writing we know of no manufacturing plant sites in California. In 1977, 5.2×10^5 lb were used in California as a pesticide (Calif DFA, 1978). Since the major use is in gasoline, it may be assumed that California's share would be roughly proportional to its share of the population, or about 10 percent; use in 1976 would thus be about 2.0×10^7 lb Accordingly, R_1 was assigned a value of 3-4.

2. Growth in California Use: The use of ethylene dibromide in antiknock mixes has been declining since the early 1970s (30 percent from 1973 to 1976) due to the decreased use of tetraethyl lead, and this decline should continue (Lowenheim and Moran, 1975). Assuming that the same trend occurs in California, we assign a value of 1 to rating factor R_2.

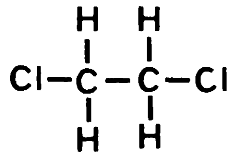
3. Emission Potential: The chief source of EDB emissions would be evaporation from gasoline; emission sources would be dispersed throughout the state. Assuming an emission rate of 1.5 percent (Dorigan et al., 1976), California emissions would be about 3×10^5 lb/yr (210 ton/yr). Because ethylene dibromide is used essentially as a consumer product, it was given a rating of 5 for R_3.

4. Stability in Ambient Air: Ethylene dibromide vapor reacts slowly with oxidizing materials and is subject to photochemical degradation in the atmosphere. It is generally present in ambient air. Levels near groups of gasoline stations and along highways have been measured to be about 1.4 ppb (Going and Long, 1975). Because of its persistence, we have assigned a value of 5 to rating factor R_4.

5. Dispersion Potential: EDB's volatility (11 mm Hg vapor pressure at 20°C) ensures its emission as a vapor, indicating a value of 5 for R_5.

6. Severity of Carcinogenicity: Ethylene dibromide is carcinogenic in rats and mice after oral administration (IARC, 1977). We therefore assigned a value of 4 to R_6.

ETHYLENE DICHLORIDE



$\mathrm{Cl{-}CH_2{-}CH_2{-}Cl}$

Overview: A colorless liquid, ethylene dichloride (EDC) is one of the most heavily used chemicals in the U.S. Its principal use (almost 80 percent) is as an intermediate in the production of vinyl chloride; other chemicals for which it is a feedstock include 1,1,1-trichloroethane, trichloroethylene, perchloroethylene, vinylidene chloride, and ethyleneamines. It is also widely used as an extraction solvent, as a lead scavenger in gasoline, as a solvent for textile cleaning and metal degreasing, in adhesives, fumigants, paint remover, soaps and scouring compounds, wetting and penetrating agents, ore flotation, and as a dispersant for nylon, rayon, styrene-butadiene rubber and other plastics (Bahlman et al., 1978). The National Institute for Occupational Safety and Health (NIOSH) estimates that about two million workers may be occupationally exposed to this chemical (NIOSH, 1978a). Recent laboratory studies have implicated EDC as an animal carcinogen.

1. Present Use in California: Total U.S. production of ethylene dichloride during 1973-1976 was as follows (USITC, 1975, 1976, 1977a, 1977b):

Year	Annual Production (lb)
1973	9.29×10^9
1974	9.17×10^9
1975	7.98×10^9
1976	8.04×10^9

Production in January-May 1978 has been 4.30×10^9 lb (USITC, 1978).

To our knowledge, the only California producer of ethylene dichloride is Stauffer Chemical Co., Long Beach, which is also the only producer of vinyl chloride monomer. This plant has a vinyl chloride production capacity of 1.74×10^8 lb/yr (Milby, 1977), for which about 2.8×10^8 lb/yr of EDC would be needed. Since vinyl chloride production accounts for 80 percent of of EDC use, total use of the latter in California would be about 3.5×10^8 lb/yr. In 1977, 8×10^3 lb were used as a pesticide (Calif. DFA, c 1978). An R_1 value of 4-5 is indicated, reflecting its relatively high use rate in California.

2. Growth in California Use: Specific information on EDC growth trends in California was unavailable as of this writing. As seen above, U.S. production has been variable or in decline. Recent evidence that EDC is an animal carcinogen may have some effect, although a likely substitute for vinyl chloride,

ETHYLENE DICHLORIDE (continued)

EDC's dominant product (and itself a human carcinogen) is not available. We have assigned a value of 3 to rating factor R_2, indicating a position between decline and minor growth.

3. Emission Potential: Atmospheric emissions data for ethylene dichloride are unknown as of this writing. As a moderately volatile liquid (84.4 mm vapor pressure at 25°C), it may enter the air in gaseous form when exposed. The Panel reported knowledge of 25 ppm levels in a vicinity of a plant using EDC. Modelling results predict a concentration of 3,390 ppb (10-minute average) 500 m downwind of a 2.3×10^7 lb/yr production facility; this may be compared to a measured ambient level of 3.7 ppb in Dominguez, California (Barber, 1977). Evaporation of leaded gasoline may also add to atmospheric loading. The EPA estimates total U.S. emissions to be between 1.9 and 4.4×10^8 lb/yr (Barber, 1977). Because of its widespread use in leaded gasoline, EDC was rated 5 for R_3.

4. Stability in Ambient Air: EDC is oxidized very slowly in the troposphere and has a half-life of 10^3 to 10^7 day (Barber, 1977). Because of this high stability, we have assigned a value of 5 to R_4.

5. Dispersion Potential: EDC is emitted as a vapor; therefore R_5 was assigned a value of 5.

6. Severity of Carcinogenicity: Recent tests conducted by the National Cancer Institute show that laboratory animals given oral doses of 1,2-dichloroethane experienced a statistically significant excess of cancer as compared with control animals (NCI, 1978). We have therefore given rating factor R_6 a value of 4.

INORGANIC LEAD

(Various Forms)

Overview: Lead has many uses, but practically all of the lead emitted to the atmosphere in California is from motor vehicle exhaust. (When emitted after combustion, the lead is in inorganic form; precombustion emissions of organic lead are covered in the Alkyl Lead dossier.) Lead is present in the ambient air of California in relatively high concentrations, and some lead salts are demonstrated animal carcinogens.

1. Present Use in California: About 97 percent of the estimated 2.9 x 10^7 lb of inorganic lead emitted to the atmosphere in California in 1977 were emitted by motor vehicles. Other sources of inorganic lead are lawn and utility equipment (1%), heavy duty equipment (1%), and point sources (1%) (Anon., 1978). Identified point sources emitting more than 2,000 lb of lead per year are shown in the following table. These relatively high emissions justify an R_1 value of 4, indicating relatively high usage in California.

LEAD EMISSIONS FROM IDENTIFIED POINT SOURCES IN CALIFORNIA EMITTING MORE THAN ONE TON PER YEAR (Anon., 1978)

	PROCESS	LEAD EMISSIONS, TONS/YEAR
North Central Coast Air Basin		
Monterey County		
PG&E Power Plant, Moss Landing	Oil Combustion	3
San Diego Air Basin		
San Diego County		
San Diego County Gas & Electric Co. 990 Bay Blvd., South Bay	Oil Combustion	2
4600 Carlsbad Blvd., Encinitas	Oil Combustion	2
Naval Air Station, North Island	Oil Combustion	1
Kelco Co., 2145 E. Belt St., San Diego	Oil Combustion	1
University of California, San Diego	Oil Combustion	1
Public Works Center, San Diego	Oil Combustion	1
San Francisco Bay Area Air Basin		
Contra Costa County		
PG&E, Wilbur Ave., Antioch	Oil Combustion	1
Willow Pass Road, Pittsburg	Oil Combustion	3
E.I. Du Pont & Co., Bridehead Road, Antioch	Lead Melting Pots	4
South Central Coast Air Basin		
San Luis Obispo County		
PG&E, Moro Bay	Oil Combustion	2
South Coast Air Basin		
Los Angeles County		
Southern California Edison Co.	Oil Combustion	
7th & Studebaker, Long Beach	(0.91 ppm)	1
1100 Harbor Drive, Redendo Beach	(0.91 ppm)	1
Los Angeles Department of Water & Power	Oil Combustion (9.7ppm)	
12700 Vista Mar, Playa Del Rey	(9.7ppm)	1
Haynes - 7033 Westminster, Long Beach	(9.7ppm)	8
Valley Steam Plant, 9430 San Fernando, Sun Valley	(9.7 ppm)	1
Shell Oil Co., P.O. Box 728, Wilmington	Oil Combustion	1
Los Angeles County Hospital, 1200 N. State St., L.A.	Oil Combustion	1
ARCO, 1801 E. Spulveda, Carson	Oil Combustion	8
U.S. Steel Corp., 840 Van Ness Ave., Torrance	Steel Furnaces	2
R.L. Industries, 2717 Indiana St., L.A.	Secondary Lead Furnaces	3
Bethlehem Steel, 3300 E. Slauson, Vernon	Steel Furnaces	1
Quemetco, Inc., 720 S. 7th Ave., City of Industry	Secondary Lead Furnaces	1
H. Kramer & Co., No. 1, Chapman Way, El Segundo	Brass-bronze & copper smelting	2
General Battery, 13110 Louden Lane, Industry	Battery mfg.	1
ESB, Inc., 5700 E. Olympic Blvd., L.A.	Battery mfg.	1
Gould, Inc. 7040 Motz, Paramount 14500 E. Nelson Ave., City of Industry	Battery mfg.	1
DAELCO, 1629 W. 132nd, Gardena	Battery mfg.	3
Alco Mining Co., 16914 S. Broadway, Gardena		1
San Bernardino County		
Kaiser Steel, 9400 Cherry, Fontana	Waste oil Combustion	28
Orange County		
Elpower, Inc. 2117 S. Anne St., Santa Ana	Battery mfg.	1
Southeast Desert Air Basin		
San Bernardino County		
Riverside Cement Company, Oro Grande	Coal Combustion	2
Imperial County		
Imperial Irrigation District, El Centro	Oil Combustion	2
San Joaquin Valley Air Basin		
Kern County		
ARCO Production Field, 10 mi NW Bakersfield	Oil Combustion	1
Chanslor - Western Oil, P.O. Box N., Fellows, 5 mi NE Bakersfield	Oil Combustion	1
Getty Oil Col, Reed Field, 2 - 6 mi ENE Bakersfield	Oil Combustion	1
Mobil Oil Corp., 10 mi NW McKittrick & 6 mi NW Bakersfield	Oil Combustion	1
Standard Oil of California, 4 mi NE Bakersfield	Oil Combustion	1
Teneco Oil, 2 mi W. Fellows & 5 mi NNE Bakersfield	Oil Combustion	1
Shell Oil, 5 mi NW Fellows	Oil Combustion	1
Getty Oil Co., East Kern Field, 2 - 7 mi N Bakersfield	Oil Combustion	2
Merced County		
Carnation Can Co., 771 Hunt Road, Gustine	Oil Combustion	1

2. Growth in California Use: The lead emitted in motor vehicle exhaust is derived from the alkyl lead anti-knock additive in gasoline. The use of alkyl lead compounds in gasoline is decreasing nationwide and is expected to decline by two-thirds by the year 2000 (Ryan and Hague, 1977). The average lead content of gasoline in California is being phased down from 1.4 g/gal in 1977 to 0.4 g/gal in 1980. This decline in use indicates an R_2 value of 1.

3. Emission Potential: Lead emissions are not tightly controlled, as evidenced by the large amount of lead emitted from motor vehicles and the relatively high ambient concentrations present. R_3 was assigned a value of 5, indicating that the bulk of all lead emissions are from a consumer product -- gasoline.

4. Stability in Ambient Air: Half of the lead emitted from motor vehicle exhaust settles out of the air within several hundred feet of the roadway, leaving the finer particles to disperse throughout the atmosphere (USEPA, 1977b). In 1974, the mean of the annual average lead concentration in 15 California cities was 1.5 $\mu g/m^3$. California has an ambient lead standard of 1.5 $\mu g/m^3$, and the U.S. Environmental Protection Agency has just established a similar national standard. The annual averages for 1974 were generally lower than in 1970, with declines in some cities as great as two-fold (Akland, 1976). Natural background concentrations appear to be roughly 0.001 to 0.03 $\mu g/m^3$ (EPA, 1977b). R_4 was assigned a value of 5, indicating that much of the emitted lead remains airborne.

5. Dispersion Potential: Airborne lead is 90 percent particulate and 10 percent organic vapor. Approximately 40 percent of the lead in gasoline emissions is emitted as coarse particulate and 35 percent as fine particulate, the remainder being deposited in the engine and exhaust system (USEPA, 1977b). R_5 was assigned a value of 4 to indicate that a large portion of the lead emissions are fine particulates.

6. Severity of Carcinogenicity: Lead acetate, lead subacetate, and lead phosphate are carcinogenic in mammalian test species (IARC, 1972b). The major compound present in automobile exhaust is lead bromochloride, though some lead phosphate and other lead compounds are present (USEPA, 1977b). Lead bromochloride apparently has not been tested for carcinogenicity. R_6 was assigned a value of 4, indicating that some lead salts, including at least one found in automobile exhaust, are confirmed animal carcinogens.

ALKYL LEAD

$Pb(CH_2CH_3)_4$ $Pb(CH_3)_4$

Overview: Tetraethyl Lead (TEL) and Tetramethyl Lead (TML) are used almost exclusively as anti-knock additives in gasolines, TML being used preferentially in aviation fuel and premium gasolines (IARC, 1973). These compounds can enter the atmosphere from production, blending with gasoline at refineries and gasoline station operations (USEPA, 1977b; IARC, 1973). 4.8 x 10^8 lb of lead were used in gasoline additives in 1976 nationwide, and use is expected to decline to 1.6 x 10^8 lb by the year 2000 (USBM, 1977b). Tests for carcinogenicity of these compounds have been indeterminate (IARC, 1973).

1. Present Use in California: TEL is produced at Antioch, California by duPont, Inc., though the quantity produced is unknown. This plant emits approximately 7,600 lb of lead per year (CARB, 1978). A rough estimate of the consumption of antiknock lead compounds in California can be obtained from knowing that 2.82 x 10^7 lb of lead were emitted from motor vehicles in California during 1977 (CARB, 1978). Assuming that TEL and TML are used in equal amounts, 2.82 x 10^7 lb of lead would be equivalent to about 2 x 10^7 lb of alkyl lead. Most of this is converted to inorganic lead during combustion, but a small amount may escape in unburned fuel through the exhaust pipe. Alkly lead compounds also escape to the atmosphere directly during the marketing of gasoline, and emissions from this source have been estimated to be 3,000 lb per year in California (CARB, 1978). R_1 was assigned a value of 3-4, due to the prevalence of lead in gasoline.

2. Growth in California Use: The use of alkyl lead compounds in gasoline is decreasing nationwide and is expected to decline by two-thirds by the year 2000 (USBM, 1977b). This trend will be evident in California as well as the rest of the nation. An R_2 value of 1 reflects this decline in California use.

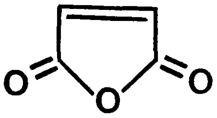
3. Emission Potential: Emissions from California's TEL production plant and from gasoline marketing demonstrate that emissions are not tightly controlled, though gasoline vapor control devices being implemented in California should reduce emissions of TEL and TML in the future. R_3 was assigned a value of 5 because of widespread use of alkyl lead compounds in gasoline.

4. Stability in Ambient Air: TEL and TML decompose photochemically in air (USEPA, 1977b). Whether they are stable in ambient air, where particulates, oxidants, and light are present, is uncertain; however, these compounds are clearly stable enough to remain in the atmosphere in measurable quantities. For example, a two-month average concentration of gaseous organic lead in Los Angeles air was 77 ng Pb/m^3 (IARC, 1973). Thus, R_4 was assigned a value of 5, indicating a moderate to high stability and no major removal mechanisms.

5. Dispersion Potential: The vapor pressures of TEL and TML at 20°C are 0.15 and 22.5 mm Hg, respectively. These compounds can vaporize from gasoline and be found in the atmosphere in the vapor phase. For this reason, both compounds are considered volatile liquids (R_5 = 5), even though TEL has a relatively low vapor pressure.

6. Severity of Carcinogenicity: TEL has been reported to be carcinogenic in animals (Christensen et al., 1976), but the IARC reviews of TEL and TML revealed no strong indications that either was carcinogenic in animals or humans (IARC, 1973). R_3 was assigned a value of 3 to indicate that carcinogenicity tests have been indeterminate.

MALEIC ANHYDRIDE



Overview: Maleic anhydride is used nationwide for making polyester resins (50%), fumaric acid (15%), agricultural pesticides (10%), alkyl resins (5%), and other products (20%) (Lowenheim and Moran, 1975). U.S. production in 1976 was 2.6×10^8 lb (USITC, 1976).

1. Present Use in California: Maleic anhydride is not produced in California, but is used in the state in relatively large quantities. The estimated consumption in California is 3.4×10^7 lb/yr, virtually all of which is used for producing polyester and alkyd resins (Woodyard, 1978). R_1 was assigned a value of 3.

2. Growth in California Use: Maleic anhydride consumption in California should grow with increased production of polyester resins, which is estimated at 12 percent per year (Woodyard, 1978), indicating a value of 4 for R_2.

3. Emission Potential: One percent of consumption is reportedly lost to the environment (Dorigan et al., 1976), potentially resulting in 3.4×10^5 lb of maleic anhydride being emitted annually. A potential additional source of atmospheric maleic anhydride emissions is phthalic anhydride production (Patterson et al., 1976c). Roughly 5 lb maleic anhydride is produced for each 100 lb phthalic anhydride produced (Hill, 1978). Phthalic anhydride is produced by Chevron at Richmond, California and by Allied at El Segundo, California. At both plants, emissions are tightly controlled by incinerating the off-gases from phthalic anhydride production, resulting in virtually no emissions of maleic anhydride (Hill, 1978; Cardinale, 1978). Also, the Panel indicated that, because of its reactivity, maleic anhydride would not likely escape from reactors during the production of resins at elevated temperatures, indicating a value of 2 for R_3.

4. Stability in Ambient Air: Maleic anhydride can undergo a number of reactions including a Diels-Alder reaction with anthracene in the ground state, and in the presence of light it can undergo a photo-addition reaction with benzene. In the presence of water, maleic anhydride can be hydrolyzed to maleic acid. It can also react with other nucleophiles, including alcohols and amines, to form various esters and amides. R_4 was assigned a value of 2 to indicate that maleic anhydride may be relatively unstable in the atmosphere.

5. Dispersion Potential: Maleic anhydride is a solid with a melting point of 53°C and a vapor pressure of 5×10^{-5} mm Hg at 20°C (Verschueren, 1977). Because of its low vapor pressure and its high reactivity in reaction vessels,

maleic anhydride should not be released to the ambient air in appreciable amounts. R_5 was assigned a value of 1 to indicate the possibility of coarse particulate emissions during handling.

6. <u>Severity of Carcinogenicity</u>: Maleic anhydride has been reported carcinogenic in rats when administered subcutaneously (Christensen et al., 1976). Since this was an unconfirmed result, R_6 was assigned a value of 3.

NICKEL

(Various Forms)

Overview: U.S. demand for nickel was estimated at 4.26 x 10^8 lb in 1976, and the use pattern was as follows: chemicals (14.6%), petroleum (8.7%), fabricated metal products (8.7%), transportation (23.2%), electrical goods (12.6%), household appliances (7.1%), machinery (7.6%), construction (9.2%) and other uses (8.3%)(Corrick, 1977). Available evidence indicates an association between human exposure to inorganic nickel and the development of cancer, although complete differentiation of the effects of individual compounds has not been possible (NIOSH, 1977b). An estimated 150,000 persons are exposed to inorganic nickel in their workplaces (NIOSH, 1977a).

1. Present Use in California: The principal end uses of nickel are in the chemical, petroleum, electrical, and aircraft industries, all of which are present in California. The major industrial nickel consumers are located in the eastern U.S., where most nickel components used in California industry are fabricated (Matthews,1978). Direct applications are few. Electroplating operations are spread thinly throughout the state. Also, five or six foundries in California may do precision casting (Matthews, 1978). Measurable ambient air concentrations have been found throughout the state, particularly in urban areas. These levels are not attributable to any particular metallurgic operations. Three general sources have been suggested: automobile and truck exhaust; burning of fuel oil for space heating (California's climate limits this contribution); and the burning of oil for power generation (NRC, 1976b). The burning of coal for power generation, expected to begin in California in the mid to late 1980s, is another minor source of nickel. We assigned a value of 2 for rating factor R_1 to indicate a moderately low usage of nickel in California.

2. Growth in California Use: Estimated national growth in demand is expected to average between 1.8 and 3.5 percent (Corrick, 1977). California use will likely reflect national trends, indicating an R_2 score of 3. However, the Bureau of Mines is continuing research on a process for economically extracting nickel from California laterites, indicating that California may be a significant producer at some time in the future (USBM, 1978).

3. Emission Potential: Data on electroplating's contribution to air pollution are scarce, but the evidence suggests that the greatest problems are due to localized occupational exposures from splashes, fumes, mists and vapors, and not related to emissions to the ambient atmosphere (NRC, 1975). The loss of nickel during the casting of nickel-bearing steels does not result in significant air pollution; the exposure to the air is brief and nickel

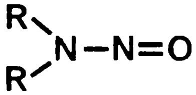
tends to remain with the melt and not be oxidized (NRC, 1975). Flame scarfing of partially rolled surfaces may contribute appreciably to local air contamination (NRC, 1975). Some nickel compounds, such as sulfides, oxides and carbonyl, enter the atmosphere as a result of the combustion of coal, diesel oil and fuel oil. Increased dieselization of California's transportation fleets is predicted; nickel release from diesel automotive exhausts may be appreciable (NRC, 1975). There is also evidence that pure nickel powders and iron-nickel powders (<1 µm in diameter) are deposited as meteoritic dust (IARC, 1976a). Rating factor R_3 was assigned a value of 4.

4. <u>Stability in Ambient Air</u>: Nickel constitutes about 0.03 percent of the particulate matter suspended in the atmosphere (IARC, 1976a). In California, 304 composite quarterly samples were taken at 21 urban sampling sites throughout the state from 1970 through 1974 as part of EPA's National Air Surveillance Network Program. About 46 percent of the quarterly samples had nickel concentrations below the lower detection level (1.2 to 1.9 ng/m^3). Yearly averages in California cities in 1974 ranged from 12.8 ng/m^3 in Santa Ana to 32.1 ng/m^3 in Torrance (Akland, 1976). In the same year, the national urban arithmetic mean atmospheric nickel concentration was 9 ng/m^3 (29 ng/m^3 standard deviation). R_4 was assigned a value of 5 because it cannot be degraded.

5. <u>Dispersion Potential</u>: Nickel is emitted as a fine particulate, as evidenced by the ambient concentrations, but it is also likely emitted to considerable extent as a coarse particulate during grinding and scarfing operations. R_5 was assigned a value of 4 to reflect this.

6. <u>Severity of Carcinogenicity</u>: Inorganic nickel has been recognized as carcinogenic in humans (NIOSH, 1977b and IARC, 1978), leading to a value of 5 for R_6.

NITROSAMINES



Overview: The three major uses for nitrosamines are rubber processing, organic chemicals manufacturing, and rocket fuel manufacturing. Other potential uses (appearing in the patent literature) are in the manufacture of rubber, dyestuffs, gasoline additives, lubricating oils, explosives, insecticides, fungicides, dielectric fluids, acrylonitrile, plasticizers, industrial solvents, and hydrazine. Despite this long list of potential uses, nitrosamines have apparently had relatively little use. Potential or confirmed sources of incidental releases of nitrosamines to the atmosphere include combustion of hydrazine-based rocket fuel, fish meal processing, tobacco smoke, and power plants (USEPA, 1977a). Other sources suggested by the Panel include diesel engines, the cooking of proteinaceous foods, and nitrogen-fertilized soil. Concern is also building over the possibility that nitrosamines may be formed in significant quantities in the atmosphere in reactions between nitrogen oxides and industrially released amines (Pitts et al., 1978). N-nitrosamines, including diethylnitrosamine (DEN) and dimethylnitrosamine (DMN) are potent carcinogens.

1. Present Use in California: No major uses of nitrosamines in California are evident at present. Teledyne-McCormick-Selph built a plant for manufacturing 1,1-dimethylhydrazine (UDMN) for the U.S. Air Force in Hollister, California. This plant was to produce roughly 10^6 lb/yr UDMH, using DMN as an intermediate, for use in the space shuttle, Titan missile, and other Air Force equipment. However, the current outlook is that production for these purposes may not occur, and the company is looking into the feasibility of producing UDMH for other uses. In any case, emissions of both DMN and UDMH will be tightly controlled (Teledyne-McCormick-Selph, 1978). Though nitrosamines appear to have little or no commercial production and use in California, they occur in the atmosphere by direct release from some processes or by formation in the atmosphere from precursors. The amount released or formed in this manner is unknown, but ambient levels indicate appreciable sources of emissions. R_1 was assigned a value of 3 to indicate moderate but unknown sources of airborne nitrosamines.

2. Growth in California Use: Use in California would increase significantly in a discrete step if Teledyne-McCormick-Selph begins production of UDHM. Other sources of nitrosamines should grow along with economic growth, indicating a value of 3 for R_2.

3. Emission Potential: Though nitrosamines appear to have little or no commercial use in California, they are nevertheless found in the state's ambient air. These ambient levels result from direct emissions or by formation in the air from precursors. DMN, for example, has been measured in industrial areas, even though direct sources of DMN have not been identified. If DMN were to be manufactured in California by Teledyne-McCormick-Selph, emissions would be tightly controlled. However, incidental releases from unidentified industrial processes, domestic or commercial cooking, or atmospheric formation are uncontrolled events, indicating a value of 4-5 for R_3.

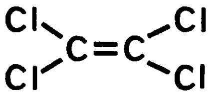
4. Stability in Ambient Air: Nitrosamines have been detected in industrial urban air, implicating their direct emission or formation from precursor pollutants. DEN can be formed photochemically in chambers from triethylamine and NO_x, and, in opposing photochemical reactions, both DMN and DEN are decomposed in light (Pitts et al., 1978). Hanst et al. (1977) found that the half-life of DMN under full sunlight was approximately 30 minutes. Those authors concluded that any DMN detected in the air in the afternoon would likely be the result of direct emissions rather than formation from its immediate precursors.

   Gordon (1977) measured DMN in the ambient air of Southern California. In a sampling program around chemical and petroleum plants, three of the samples were positive -- 0.07, 0.11, and 0.39 $\mu g/m^3$. R_4 was assigned a value of 3, indicating a low to moderate stability in ambient air. Photo-decomposition appears to be the single major removal mechanism of nitrosamines.

5. Dispersion Potential: Even though DEN and DMN have relatively high boiling points (177^o and 152^oC, respectively), they have been described as volatile and very volatile liquids, respectively (IARC, 1972f). Because they may be easily emitted as vapors, R_5 was assigned a value of 5.

6. Severity of Carcinogenicity: Nitrosamines, including DEN and DMN, are considered potent and versatile carcinogens in experimental animals (USEPA, 1977a) and are suspected of being carcinogenic in humans (ACGIH, 1977), indicating a value of 5 for R_6. The potential body retention of DNM from ambient levels similar to those found in California is slightly less than the intake from eating four slices of bacon or smoking a pack of cigarettes daily (Fine et al., 1977). The health effects of intake of this magnitude are unknown.

PERCHLOROETHYLENE
(TETRACHLOROETHYLENE)



Overview: Perchloroethylene, commonly known as perc, is a synthetic organic solvent widely used in dry cleaning (67%), fabric finishing, metal degreasing (15%), and other applications. Nationwide production of perc is 7 x 10^8 lb per year (NIOSH, 1978b). Perc is widely released to the atmosphere and is a confirmed carcinogen in some test animals.

1. Present Use in California: According to spokesmen for Dow Chemical Company, Dow is the only firm producing perc in California (Pittsburg). The total amount of perc used in California has not been identified but is known to be substantial. Emissions of perc in the South Coast Air Basin are shown in the following table (Taback et al., 1978):

Application Category	Emissions (10^6 lb/yr)	% of Total
Petroleum Refining	0.4	1.1
Petroleum Marketing	0.07	0.2
Surface Coating	0.4	0.9
Dry Cleaning	25.7	64.8
Degreasing	11.0	27.8
Other Organic Solvent Applications	0.01	0.4
Chemical	0.05	0.1
Unclassified	2.0	5.1
TOTAL	39.6	100

Dry cleaning and metal degreasing account for 92 percent of the emissions. The very high total emissions in the South Coast Air Basin alone warrant assigning R_1 a usage value of 4.

2. Growth in California Use: The average annual growth rate for perc nationwide is 5.5 percent (Barber, 1977), and growth in California is likely to be similar. However, considering that, because of its carcinogenic potential, perc has been removed from the list of compounds exempted from regulation under the "Recommended Policy on Control of Volatile Organic Compounds" and that control could be sought under the Clean Air Act (Barber, 1977), the future consumption patterns are uncertain. Presently, R_2 should apparently be rated 3.

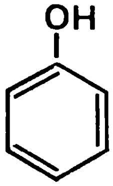
3. Emission Potential: Perc is not a tightly controlled chemical as evidenced by emission data cited above. As a volatile liquid (14 mm vapor-pressure at 20°C), it is released routinely during dry cleaning operations, though the U.S. Environmental Protection Agency is now advocating the recycling of the chemical (Smith, 1978). Rule 442 of the South Coast Air Quality Management District requires that the daily emission of perc by each source be limited to 2,970 lb. R_3 was assigned a value of 4 to indicate that it is routinely emitted during its production and use.

4. Stability in Ambient Air: Perc has a reported half-life in the troposphere of 110-183 days (though the Panel indicated that its half-life in sunlight was only 3 to 4 days), and its degradation products include trichloroacetyl chloride, phosgene, and HCl (Barber, 1977). The rural background concentration in California is around 0.04 ppb, and levels in Los Angeles average approximately 0.7 ppb, with high concentrations of 2 ppb (Singh et al., 1977). R_4 was assigned a value of 5 to indicate that perc is stable enough to result in elevated ambient concentrations.

5. Dispersion Potential: Perc is commonly emitted as vapor when it is used in dry cleaning and metal degreasing operations, indicating a value of 5 for R_5.

6. Severity of Carcinogenicity: Perc has recently been confirmed as being carcinogenic in mice by the National Cancer Institute (NIOSH, 1978b), indicating a value of 4 for R_6.

PHENOL



Overview: Phenol is used in phenolic resins (46%), caprolactum (16%), bisphenol A (14%), adipic acid (3%), exports (3.5%), and in other miscellaneous uses (17.5%) (Lowenheim and Moran, 1975). U.S. production in 1976 was 2.1×10^9 lb (USITC, 1977b). Phenol has been shown to be carcinogenic in at least one animal species (Christensen, 1976) and a number of studies suggest that phenol acts as a co-carcinogen with other compounds (Bachman, 1977). An estimated 10,000 workers may be exposed to phenol during commercial production, formulation of products, or distribution of concentrated products (NIOSH, 1976c).

1. Present Use in California: About 50×10^6 lb of phenol is annually used in California (Gautschin, 1978). The principal manufacturer is Chevron Chemical Company, which manufactures phenol at their Richmond refinery. Productol Company, in Sante Fe Springs, recovers about 2.8×10^6 lb of phenol a year from a waste material obtained from this refinery (Jenkins, 1978). Most of the phenol produced in California is used in the manufacture of phenolic resins for use in the plywood industry (Gautschin, 1978). R_1 was assigned a value of 2-3 to reflect its moderate usage in California.

2. Growth in California Use: Increasing U.S. demand for phenol-derived plastics and specialty chemicals for which phenol is the preferred intermediate is expected (Lowenheim and Moran, 1975). Assuming that California use will reflect the national trend, an R_2 rating of 3 was assigned, based on a projected limited growth.

3. Emission Potential: Brown et al. (1975) estimated that about 0.01 percent of phenol production is emitted to the air and that 1 percent of consumption is released to the environment. Although process control data for California are not available at this time, concentrations of phenol as high as 566 $\mu g/m^3$ have been observed near U.S. industrial plants (Bachman, 1977). The Panel indicated that phenol was routinely emitted during phenol-formaldehyde resin manufacture, indicating a value of 4 for R_3.

4. Stability in Ambient Air: Although little data exist on the atmospheric stability of phenol, the Panel believed that it would be oxidized to quinones, and would have a half-life under several hours, indicating a value of 3 for R_4.

5. Dispersion Potential: Phenol is a crystalline solid with a melting point of 41°C and its vapor pressure at 20°C is 0.2 mm Hg. Although it is a solid, some studies suggest that phenol in the ambient atmosphere is predominantly in vapor phase (Bachman, 1977), and the Panel pointed out that

a vapor pressure of 0.2 mm would permit phenol to exist in air up to 200 ppm. Also manufacture of phenol-formaldehyde resins, although carried out at a fairly low temperature (75° to 100°C) (Kent, 1974), increases the possibility of vapor emissions into the ambient air. R_5 was assigned a value of 5 to indicate that phenol emitted exists in air as a vapor.

6. Severity of Carcinogenicity: Phenol has been shown to be carcinogenic in mice when applied to the skin (Christensen, 1976) and a number of studies suggest that phenol acts as a co-carcinogen with other compounds (Bachman, 1977). However, studies do not reflect the considerable industrial experience with phenol. No evidence exists that phenol acts as a specific carcinogen or mutagen, particularly at low, physiological concentrations. However, phenol does function as a non-specific irritant and may be capable of promoting tumors (NIOS, 1976c). R_6 was assigned a value of 3 to indicate the uncertainty of the carcinogenic potential of phenol.

POLYCYCLIC AROMATIC HYDROCARBONS (PAH)

(Various compounds)

Overview: Polycyclic aromatic hydrocarbons (PAH) are multi-ringed compounds consisting of only carbon and hydrogen. PAH compounds of most environmental interest are in particulate form. Although benzo(a)pyrene (BaP) is often used as an indicator or surrogate for PAH in general, this class of compounds has hundreds of members. Unfortunately, no direct single step analytical techniques exist for ambient air measurements of total PAH although specific compounds or PAH subclasses may be measured by direct or subtractive techniques. In addition, BaP concentrations are not necessarily related to the carcinogenicity of a sample of ambient PAH. Stationary sources account for about 97 percent of the nationwide emissions of BaP (USEPA, 1974a), and include coal refuse fires (34.7%), residential furnaces (33.6%), coke production (19%), vehicle disposal, wood burning, forest and agricultural burning, tire degradation, municipal incineration, petroleum refining, and coal furnaces. Occupational exposure occurs mainly at coke ovens. While BaP is a known animal carcinogen, it is difficult to assess the potential carcinogenicity of the mixture of PAH to which the general public is exposed.

1. Present Use in California: Major PAH emission sources include the Kaiser coking facility in Fontana and petroleum refineries in Southern California and the San Francisco Bay region. Agricultural burning and forest fires are important area sources. Tars, pitches and asphalts, which are used throughout the state, have high PAH contents. Cigarette smoking, which may expose smokers of one pack per day to 1 μg/day of BaP (NAS, 1972) is another known source. An R_1 value of 1-3 was assigned to reflect low to moderate, but unquantified "usage" in California.

2. Growth in California Use: PAH levels in ambient air have been declining since the early 1960s (USEPA, 1974a). The reasons for this decline are unknown. Although tighter emission controls on coke ovens will reduce emissions from a major source, emissions from increasing coal use, dieselization and poorly-tuned automobiles may increase. We therefore assign a value of 4 to R_2.

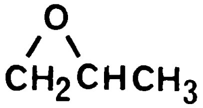
3. Emission Potential: See above for a discussion of sources. PAHs are routinely emitted during certain manufacturing and agricultural processes. The relatively uncontrolled emissions and existence of many small sources, including motor vehicles, indicates a value of 5 for R_3.

4. Stability in Ambient Air: Because of the high melting points and low vapor pressures of most PAHs,these compounds are most likely to be present in the atmosphere as pure particulates or adsorbed to other particulate matter (NAS, 1972). Many PAHs oxidize or photodegrade readily under atmospheric conditions. Some may be converted to more mutagenic products; for example BaP can react with nitrogen dioxide to form 6-nitrobenzo(a)pyrene and a mixture of 1-nitro and 3-nitrobenzo(a)pyrene (Anon., 1978). Recent experimentation has confirmed that directly active mutagens are formed when PAHs are exposed to simulated atmospheres of photochemical smog (Pitts et al., 1978b). In addition many PAHs have been found to be sufficiently stable in the atmosphere to travel long distances (Lunde and Bjørseth, 1977). Annual average ambient BaP concentrations in 12 California cities, as measured in the EPA National Air Surveillance Network program, declined from 1.1 to 2.5 ng/m^3 in 1966 to 0.6 to 1.9 ng/m^3 in 1970 (USEPA, 1975b). During the same period levels at a rural station in Humboldt County decreased from 0.4 to 0.1 ng/m^3. Because of their stability, PAH compounds were given a rating of 5 for R_4.

5. Dispersion Potential: Since PAHs are predominantly in very fine particulate or gaseous form, we have assigned a value of 5 to R_5.

6. Severity of Carcinogenicity: Experimental animals have been exposed to BaP through skin painting, inoculation, oral intake, subcutaneous injection, local implantation, intratracheal inoculation and inhalation (USEPA, 1975b). In general, PAHs in their parent form do not produce major adverse effects; they must be metabolized by the enzyme systems of the body to produce intermediates capable of inducing cancer. BaP is, through its metabolites, a known animal carcinogen. Studies of inhalation of pure PAHs have largely yielded negative results, and no direct evidence exists that inhalation of ambient levels of PAHs leads to cancer in humans. Epidemiological studies are complicated by the existence of other potential carcinogens in the workplace; the general population would not be exposed to the same "mix" of compounds. However, because the IARC (1978) has indicated that soot, tars, and oils are "associated, or strongly suspected to be associated, with cancer induction in humans," R_6 was assigned a value of 5.

PROPYLENE OXIDE



Overview: Propylene oxide was used in the U.S. in 1975 for making flexible polyurethane foams (38%); rigid polyurethane foams (7%); propylene glycol (20%); dipropylene glycol (2%); glycol ethers (2%); and other miscellaneous uses (20%) (USEPA, 1977c). U.S. consumption of propylene oxide was 1.8×10^9 lb in 1976 (USITC, 1977b). Propylene oxide is a suspected animal carcinogen (Christensen et al., 1976). An estimated 4.1×10^7 lb of propylene oxide are released to the environment in the U.S. annually (Dorigan, et al., 1976).

1. Present Use in California: Propylene oxide is not manufactured in California (USEPA, 1977c; Hinge, 1978), but an estimated 10^7 lb/yr are used in the state (Hinge, 1978). The uses for propylene oxide in California appear to be as a surfactant; for making polyether polyols; and in San Diego, for propoxylating kelp used as a food additive (Hinge, 1978). The estimated consumption of propylene oxide in California is roughly 1 percent of the U.S. production and warrants rating R_1 with a value of 3.

2. Growth in California Use: U.S. consumption is predicted to grow by 9 to 10.5 percent per year from 1975 to 1980 (Allport et al., 1977). We have found no indication that California's experience will greatly differ from the national trend, indicating a value of 3 for R_2.

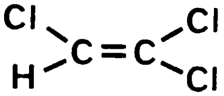
3. Emission Potential: No producers of propylene oxide have been identified in California. Assuming that 1 percent of the propylene oxide consumed is released to the environment (Dorigan et al., 1976), emissions in California are estimated to be 10^5 lb. Because of propylene oxide's high volatility, a large portion of this should be ultimately released to the atmosphere. However, the Panel felt that, considering propylene oxide's use in closed systems and its high reactivity, this rate was too high. An intermediate value of 3 was assigned to R_3.

4. Stability in Ambient Air: If dispersed in the atmosphere, propylene oxide will react with oxidizing materials (IARC, 1976b), including any compound containing active hydrogens such as alcohols, amines, water and acids. Its half-life is probably less than one day (Allport et al., 1977; Radding et al., 1977); it is probably photochemically sensitive as well. R_4 was assigned a value of 3, indicating moderate stability in the ambient air.

5. Dispersion Potential: Propylene oxide is a liquid at room temperature. It has a boiling point of 34°C and a vapor pressure of 596 mm at 25°C, indicating that it is very volatile. A value of 5 was assigned to R_5 to reflect that propylene oxide would be emitted as a vapor.

6. Severity of Carcinogenicity: Propylene oxide was found to be carcinogenic in a limited study in rats in which it was injected subcutaneously, producing local sarcomas (IARC, 1976b). Based on this study, it is considered a suspected animal carcinogen (Christensen et al., 1976) and therefore is assigned an R_6 rating of 3.

TRICHLOROETHYLENE (TRI)



Overview: Trichloroethylene, also known as tri, is a synthetic organic chemical, 90 percent of which is used for vapor degreasing of fabricated metal parts; 6 percent of production is used as a polyvinyl chloride chain terminator (IARC, 1976e). Domestic production of tri was 3.2 x 10^8 lb in 1976 (USITC, 1976). Tri is recognized by the National Academy of Sciences as a confirmed carcinogen in animals (Barber, 1977).

1. Present Use in California: Tri is apparently not produced in California (Fuller, 1976). Because of emission regulations which would usually be prohibitively costly to meet, tri is thought to be used very little in Southern California (Hall, 1978). Tri has been regulated in Los Angeles County since 1966, but regulation is just beginning throughout the rest of the state since the Air Resources Board issued emission regulations. No data on the use of tri outside of Southern California were available. However, the Panel noted that some users are unaware that tri may be present in solvent mixtures obtained from out of state. Based on this information, R_1 should be assigned a value of 0-2, indicating a range of uncertainty regarding use in California.

2. Growth in California Use: The use of tri is declining at an average annual rate of 1.2 percent nationwide (Barber, 1977), and indications are that use in California is largely being phased out because of its photochemical reactivity, indicating a value of 0-1 for R_2.

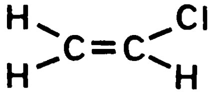
3. Emission Potential: With a vapor pressure of 60 mm Hg at 20 °C, trichloroethylene is considered a volatile liquid. Ninety-five percent of the trichloroehtylene consumed is dispersed to the environment (Brown et al., 1975), much of this ultimately being released to the atmosphere. Rule 442 of the South Coast Air Quality Management District (SCAQMD) requires that emissions of photochemically reactive solvents generally be reduced by a minimum of 95 percent or that emissions not exceed 39.6 lb/day for each source. Compliance with these regulations is normally not economically efficient, resulting in a decline of the usage of tri in the SCAQMD (Hall, 1978). However, as late as 1976, elevated concentrations were measured in Los Angeles. These concentrations average around 0.3 ppb and had a maximum of nearly 2 ppb, indicating a continuing source of emissions. The Panel also called attention to tri's use as a solvent in typewriter correction fluid. R_3 was assigned a value of 5 because of its widespread use in a consumer product.

4. Stability in Ambient Air: Tri is subject to atmospheric degradation and has a half-life in the troposphere of about two days. Degradation products include phosgene (which produces ill effects in man at 500 ppb), HCl, and other compounds (Barber, 1977). Rural background levels in California are about 15 ppt, while urban concentrations average roughly 300 ppt. These levels are thought to be exclusively anthropogenic in origin (Singh et al., 1977). R_4 was assigned a value of 5.

5. Dispersion Potential: As a volatile liquid, tri is emitted to the air as a vapor, indicating a value of 5 for R_5.

6. Severity of Carcinogenicity: Trichloroethylene is a confirmed carcinogen in mice, but tests have failed to demonstrate carcinogenicity in rats, both species being tested by oral administration. Tri is recognized by the National Academy of Sciences as a confirmed carcinogen in animals, indicating a value of 4 for R_6.

VINYL CHLORIDE



Overview: Vinyl chloride (VC), a dense gas at ambient temperature and pressure, is the parent compound of polyvinyl chloride (PVC), a widely-used plastic resin. VC is a known human carcinogen. By far the most important source of VC emissions to the atmosphere is PVC production, which occurs in Long Beach (90 percent) and Saugus (10 percent), California.

1. Present Use in California: Virtually all the vinyl chloride in the U.S. is used for polyvinyl chloride production. PVC is then used to make containers, wrapping film, electrical insulation, pipe, credit cards, and many other consumer and industrial products. (PVC and other vinyl chloride products are not presently considered to represent a carcinogenic risk to man (Milby, 1977).) The only producer of vinyl choride monomer in California is Stauffer Chemical Company, whose Long Beach plant has a capacity of 1.7×10^8 lb/yr. California producers of PVC are (Milby, 1977):

Company	Location	Capacity (10^6 lb)
B.F. Goodrich Co.	Long Beach	32.9
Stauffer Chemical Co.	Long Beach	29.8
Keysor-Century Corp.	Saugus	7.2

Union Carbide, Torrance, California, also uses about 2.5×10^6 lb/yr of vinyl chloride, which is polymerized and included in an emulsion produced by their waterborne coatings material division (Ransom, 1978). We have given vinyl chloride a score of 5 for R_1, based on production and use data cited above.

2. Growth in California Use: Long-term demand for PVC is expected to remain stable, since its uses are firmly established and because there is no material that can readily replace it (Milby, 1977); emissions controls and occupational health criteria are not expected to significantly affect production rates. Milby (1977) estimates an increase from 8.6×10^8 to 1.3×10^9 lb/yr between 1975 and 1980 for the U.S. as a whole. The annual growth rate would be about 8.8 percent. Production in 1975 was estimated to be considerably lower than that of the period 1971-1974, however. If 1971 is used as the base year (8.9×10^8 lb/yr), the annual growth rate would be 4.3 percent. In any event, the R_2 value would be 3.

3. Emission Potential: The U.S. Environmental Protection Agency (USEPA, 1975a) has identified four major sources of vinyl chloride emissions. These are:

VINYL CHLORIDE (continued)

Source	Percent of Total Estimated Emissions, 1974
Ethylene dichloride - Vinyl chloride plants	11
Polyvinyl chloride plants	85
Polyvinyl chloride fabricating plants	1
Miscellaneous	3

Clearly, the most important sources are plants where VC is polymerized to form PVC. Using data from EPA (1975a), we estimated rough VC emission factors (lb VC emitted/lb produced) of 0.0042 and 0.039 for vinyl chloride and polyvinyl chloride production, respectively. Emissions in California would thus be about 76 ton/yr from the one VC plant and 1400 ton/yr from the three PVC plants. The Panel indicated that because the hazards associated with vinyl chloride emissions have been recognized, new regulations may significantly reduce emission levels. Parameter R_3 should be assigned a value of 1-4, reflecting the range of emission potential possible until all sources are in compliance with new standards.

4. Stability in Ambient Air: The chemical behavior of vinyl chloride in ambient air has not been thoroughly characterized. VC has been shown in laboratory photochemical chamber experiments to react with high concentrations of NO_2, O_3, NO and hydroxyl radicals; reaction products include carbon monoxide, formaldehyde, formic acid, formyl chloride and hydrogen chloride (Gay et al., 1976). When potential reactants are at low concentrations or are absent, VC can be quite stable; little potential for autodegradation in sunlight exists. Because of the four-hour half-life indicated by the Panel, R_4 was assigned a value of 4.

5. Dispersion Potential: As a vapor at normal ambient temperatures and pressures, vinyl chloride is automatically assigned a rating of 5 for R_5. In addition, there is evidence that people living in the immediate vicinity of ethylene dichloride-vinyl chloride and polyvinyl chloride plants are generally exposed to average daily concentrations of less than 1 ppm with some 24-hour average excursions of 1 to 3 ppm and peak exposures as high as 33 ppm (EPA, 1975a). The EPA has estimated average exposures to people living within 5 miles of vinyl chloride plants to be 17 ppb, as opposed to a general average population exposure of 0.5 ppb (Kuzmak and McGauhy, 1975). Field studies conducted by the EPA and the California Air Resources Board (EPA, 1978d) showed a median grab sample concentration of about 5 ppb even after installation of a fume incinerator at distances of up to a quarter mile from the Keysor-Century Corporation facility.

6. Severity of Carcinogenicity: "The evidence that vinyl chloride causes angiosarcoma of the liver in humans may be considered conclusive" (Milby, 1977). Vinyl chloride is also strongly suspected to induce brain and lung cancer (IARC, 1978). We therefore assigned a value of 5 to R_6.

GASOLINE AND ENGINE EXHAUST

(Mixture of Many Substances)

The Panel suggested that gasoline deserved recognition as a possible airborne carcinogen of importance to California. It pointed out that gasoline is probably the most used and highly produced suspected carcinogen in the state.

Gasoline is a mixture of relatively volatile hydrocarbons and additives. Gasoline components considered as candidate substances in the current study include benzene, ethylene dibromide, ethylene dichloride, and alkyl lead, as shown in the following table.

Component	Concentration in Liquid Gasoline
Tetraethyl and Tetramethyl Lead[a]	1.5 - 3.2 g/gal
Ethylene dibromide[a]	80 - 150 ppm (v/v)
Ethylene dichloride[a]	150 - 300 ppm (v/v)
Benzene[b]	1.2% (v/v)

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[a] In leaded gasoline only. Source: McDermott and Killiany, 1978.

[b] Source: Runion, 1977.

Control of gasoline vapors is currently being implemented in California to reduce reactive hydrocarbon emissions, not for carcinogen control. One can see from this discussion that reducing gasoline emissions has potential benefits beyond reducing photochemical smog formation. Motor vehicle exhaust also contains many substances which are or may be carcinogenic, including polycyclic aromatic hydrocarbons, inorganic lead compounds, and nitrosamines (suspected to be diesel emissions).

TOBACCO SMOKE

(Mixture of Many Substances)

Concern is growing over the potential health effects of passive smoking (the exposure of nonsmokers to tobacco smoke). That active smokers have a significantly higher risk of cancer than nonsmokers is practically undisputed presently. However, the additional cancer risk, if any, to nonsmokers resulting from passive smoking has not been conclusively demonstrated. Substances reviewed in this report which are components of cigarette smoke include (USDHEW, 1971 and 1976):

β-Naphthylamine
N-Nitrosamines (possible component)
Phenol
PAHs
Cadmium
Chromium
Nickel
Lead

As might be expected, smoke-filled rooms reportedly have elevated levels of PAHs (Brunnemann and Hoffman, 1976). Thus one can see that many individuals are involuntarily and simultaneously exposed to many carcinogens daily from a single source--tobacco smoke.

PESTICIDES

(Mixtures of Pesticides, Solvents, and Carriers)

Many pesticides are in current widespread usage in California, an important agricultural state. Many pesticides are cancer-suspect, several of which were among those substances examined in this study. For example, arsenic, ethylene dibromide (EDB), and ethylene dichloride (EDC) are all used in California as pesticides and are all confirmed animal carcinogens (arsenic is considered a human carcinogen). In 1977, 5.2×10^5 lb were used in the state as a pesticide. Although the assessment of pesticides as airborne carcinogens in California was beyond the scope of this study, the CARB acknowledges the potential for concern in this regard.

4.2 Rejected Substances

4.2.1 Provisionally Rejected Substances

ACRYLONITRILE

Acrylonitrile is a volatile liquid (its vapor pressure at 23.6°C is 100 mm Hg) and a confirmed animal carcinogen with the following uses (Lowenheim and Moran, 1975): acrylic and modacrylic fibers (55%); ABS and SAN plastics (20%); nitrile rubber (5%); exports and miscellaneous (20%). U.S. production in 1976 was 1.5 x 10^9 lb (USITC, 1977b). Acrylonitrile is not produced in California and has quite limited use in the state (Luper, 1978). Reported California users with which the OCCU has communicated have indicated that they are decreasing their use of acrylonitrile (Unmack, 1978). Thus, with little use presently and use apparently declining further, acrylonitrile seems unlikely to be a major airborne carcinogen in California. However, some question exists regarding the magnitude of Japanese imports, which has been difficult for state authorities to elucidate (Unmack, 1978).

FORMALDEHYDE

Formaldehyde is a gas, but is marketed in solution, usually 37 percent HCHO by weight. Its uses are as follows: urea-formaldehyde resins (30%), phenol-formaldehyde resins (24%), acetal resins (9%), pentaerythritol (6%), hexamethylenetetramine (6%), melamine-formaldehyde resins (4%), tetrahydrofuran (3%), chelating agents (3%), acetylenics (3%), miscellaneous and exports (12%) (Lowenheim and Moran, 1975). An estimated 2.5 percent of formaldehyde consumption is lost to the environment, and roughly 1 percent of that is in nondispersive uses (Brown et al., 1975). Borden, Inc. has an 8 x 10^7 lb/yr production capacity in Fremont, California (Patterson et al., 1976b). There is very little evidence that formaldehyde is carcinogenic. The NIOSH Suspected Carcinogens subfile (Christensen et al., 1976) cites a 1954 article in the Japanese Journal of Cancer Research indicating that formadehyde is neoplastigenic. Since then, attempts to demonstrate the carcinogenicity of formaldehyde have failed, and NIOSH (1976a) concluded that there was no evidence that formaldehyde is carcinogenic or that bischloromethylether was formed from formaldehyde in appreciable quantities in industrial environments. The National Cancer Institute has tentatively selected formaldehyde for testing, and should tests demonstrate its carcinogenicity, formaldehyde might then be considered an important airborne carcinogen.

VINYLIDENE CHLORIDE

Vinylidene chloride is a very volatile liquid (vapor pressure at 20°C is 500 mm Hg; boiling point is 31.9°C). It is used in making Saran and methyl chloroform, and annual U.S. production (none of which is in California) is roughly 3 x 10^8 lb (Hushon and Kornreich, 1978). The two domestic producers (Dow and PPG) have indicated that the market for vinylidene chloride in California is very small, with no significant increase foreseen. Vinylidene chloride is considered an animal carcinogen via inhalation and a bacterial mutagen (USEPA, 1978e). Its apparent minor use in California indicates that vinylidene chloride is not likely to be a major airborne carcinogen in the state. However, some question exists regarding the magnitude of Japanese imports, which has been difficult for state authorities to elucidate (Unmack, 1978).

4.2.2 Rejected OCCU Substances

2-ACETYLAMINOFLUORINE

This chemical is used in small amounts in California for calibrating gas chromatographs and for causing cancer in laboratory animals (Unmack, 1978). Its use is too restricted to be of concern to California.

BENZIDINE

Benzidine, a solid with a melting point of 128°C, is a confirmed human carcinogen. Its major use is in producing dyes; however, several chemical manufacturers and users have reported that, because of its status as a regulated occupational carcinogen, they have ceased handling benzidine. Benzidine usage has likewise been reduced to a very low level in California (Unmack, 1978) and is thus precluded from being a major airborne carcinogen in California.

4-BIPHENYLAMINE (4-AMINODIPHENYL)

4-Biphenylamine (solid, melting point = 53°C) is a confirmed human carcinogen, but it is no longer produced in large amounts in the U.S. (IARC, 1972e). It is apparently used only as a laboratory chemical in California (OCCU, 1978). Because of its very limited use in California and tight control on environmental releases, 4-biphenylamine is very unlikely to be important as an airborne carcinogen in California.

BIS(CHLOROMETHYL) ETHER (BCME) AND CHLOROMETHYL METHYL ETHER (CMME)

BCME and CMME are highly volatile liquids used in the production of ion exchange resins (IARC, 1974e). BCME is a known human carcinogen. The only significant use of BCME and CMME in California is at Diamond Shamrock in Redwood City, where emissions are tightly controlled. Because of their isolated use and very tightly controlled emissions, BCME and CMME are not important airborne carcinogens in California.

3,3'-DICHLOROBENZIDINE

3,3'-Dichlorobenzidine, a solid with a melting of 132°C, is used principally in the production of dyes and pigments (IARC, 1974f), though it is used in only very small quantities in California (OCCU, 1978). Its use is too limited to be of major concern to California.

4-DIMETHYLAMINOAZOBENZENE

This chemical, a solid with a melting point of 115°C, is reportedly used in coloring polishes and other wax products, polystyrene production, and other applications (IARC, 1975). Because it is used only in very small quantities in California (OCCU,1978b),it is precluded from being of major concern to California.

ETHYLENEIMINE (EI)

EI, a volatile liquid (its vapor pressure at 20°C is 160 mm Hg), has only one significant user in California. Cordova Chemical Company in Sacramento uses roughly 5×10^5 lb per year in making chemical intermediates. Its emissions are tightly controlled with an ammonium thiosulfate scrubber followed by carbon adsorption, and the spent carbon is disposed of at a Class I landfill. EI is also quite unstable in air (Peters, 1978). Its narrow use, tight control, and instability preclude EI from being a major airborne carcinogen in California.

4,4'-METHYLENE BIS (2-CHLOROANILINE)
(MOCA)

MOCA, a solid with a melting point of 100°C, is used as a curing agent for polymers containing isocyanates and in the production of urethane rubbers. There is probably considerable use in California, though many users appear not to be reporting their use to the OCCU (Unmack, 1978). However, indications are very strong that MOCA is not released to the air in significant quantities (Phillips, 1978; Unmack, 1978); it is therefore unlikely to be a significant airborne carcinogen in California.

ALPHA-NAPTHYLAMINE (α-NA) AND BETA-NAPHTHYLAMINE (β-NA)

The major uses of α-NA and β-NA, both solids, are as intermediates in the production of dyes and antioxidants; α-NA is also used for producing herbicides (IARC, 1974g). β-NA is no longer produced on a large scale, and emissions of α-NA are relatively tightly controlled (Meylan et al., 1976). α-NA and β-NA are used only in very small amounts in California as laboratory reagents (OCCU, 1978), precluding their being significant airborne carcinogens in California.

4-NITROBIPHENYL

4-Nitrobiphenyl is a solid with a melting point of 113°C, whose only known large-scale use is in preparing 4-biphenylamine, though there is no evidence of large-scale production of 4-nitrobiphenyl in the U.S. (IARC, 1974h). Its use in California appears to be limited to small quantities as a laboratory reagent (OCCU, 1978b) precluding it as a significant environmental carcinogen in California.

BETA-PROPIOLACTONE (β-PL)

β-PL is a volatile liquid (vapor pressure at 25°C is 3.4 mm Hg) with very limited use in California. It is likely used only as a research and analytical chemical and perhaps as a sterilizing agent for surgical instruments. It is not used in making acrylic plastics in California. β-PL is also considered to be relatively unstable in the atmosphere, with a half-life measured in minutes or hours, depending on humidity (Unmack, 1978). Its very limited use and instability make β-PL unlikely to be a significant airborne carcinogen in California.

4.2.3 Other Rejected Substances

ACETAMIDE

Acetamide, a solid with a melting point of 81°C, is a confirmed carcinogen in animals (IARC, 1974a). Though acetamide has many possible uses, it appears to be almost exclusively used for making cephalosporins (antibiotics). Heico, Inc., the major manufacturer of acetamide, has indicated that the market for acetamide in California is very small and that none is apparently made in the state (Brinkman, 1978). This, along with its low dispersion potential, indicates that acetamide is not an important airborne carcinogen in California.

ANILINE

Aniline is a non-volatile liquid with a vapor pressure of 0.3 mm Hg at 20°C. Attempts to demonstrate its carcinogenicity have failed (IARC, 1974b), and it is not mutagenic in the Ames test (Auer, 1978b). Aniline has the following published uses (Lowenheim and Moran, 1975): isocyanates, used mainly for making rigid polyurethane foams (40%); rubber chemicals (35%); dyes and intermediates (6%); hydroquinone, for photographic chemicals (6%); drugs (4%); and miscellaneous (9%). Aniline is not produced in California, and it is used very little in the state (personal communication with representatives of the major manufacturers: American Cyanamid Co. and Rubicon Chemicals, Inc.). With no producers and little use in California, low dispersion potential, and undemonstrated carcinogenicity, aniline is not a major concern as an airborne carcinogen in California.

AURAMINE

Auramine, a solid with a melting point of 136°C, is regarded as being carcinogenic in humans. Its published uses include making Solvent Yellow 34 dye and other coloring uses (IARC, 1972d). Auramine appears to be available in California only in 25g or 50g bottles (personal communication with chemical distributors), indicating a quite low level of usage. Its low dispersion potential and low usage in California indicate that auramine is not a significant airborne carcinogen in California.

BERYLLIUM

Beryllium is a non-volatile metal used in nuclear reactors and aerospace applications (39%), as an alloy in electrical equipment (36%), in electronic components (15%), and in other applications (10%) (USBM, 1978). It is carcinogenic in animals (Yung et al., 1977), but is not considered a human carcinogen by the IARC (IARC, 1978). Apparent U.S. consumption of beryllium has declined 86 percent by 1973 to 10^5 lb in 1977, ensuring that annual consumption in California is well under 10^5 lb ($R_1 = 0$). However, consumption is expected to increase at a low rate of 2 percent yearly through 1985. Beryllium ore is mined in the U.S. only in Utah,

and beryllium metal, alloys, and compounds are produced only in Ohio and Pennsylvania (USBM, 1978). Beryllium occurs at low concentrations in the general urban atmosphere. Out of 322 composite quarterly air samples taken at 18 California cities from 1970 through 1974, only five were above the detection limit of 0.04 to 0.08 ng Be/m^3. Three of the positive samples contained 0.2 ng Be/m^3, and the remaining two had 0.3 ng/m^3 (Akland, 1976). The USEPA has established emission limits for certain stationary sources. They are 10g Be/day or 10 ng/m^3 (Yung et al., 1977). Its relatively low usage in California, its low ambient-air levels, and its control by the USEPA indicates that beryllium should not be a major concern in California at present.

DIETHYL SULFATE AND DIMETHYL SULFATE

These confirmed animal carcinogens are nonvolatile liquids (vapor pressure less than 1 mm Hg at room temperatures) and are used as alkylating agents. They could be released in aqueous waste streams, but their rapid hydrolysis would ensure a short lifetime in the general environment (IARC, 1974c). This, along with their low volatility, indicate that they are not significant airborne carcinogens in California.

DIPHENYLAMINE (DPA)

DPA is a solid (melting point = 53°C) with the following published uses (Standen et al., 1963): rubber antioxidant; pharmaceuticals manufacture; explosives stabilizer; and preparation of azo dyes. DPA is not considered a potent carcinogen (Orjelick, 1975); American Cyanamid Co. has reportedly tested DPA and concluded that it was not carcinogenic (Pinto, 1978). 4-biphenylamine is found as a contaminant of DPA, and DPA is treated as a regulated carcinogen if it contains 1,000 ppm or more by weight of 4-biphenylamine; however, commercial DPA contains under 100 ppm and is therefore unregulated (Pinto, 1978). DPA is not produced in California, and its usage in California is likely under 10^5 lb per year (Pinto, 1978); one of the two major manufacturers reported selling no DPA in California (Hines, 1978). Its limited use in California and its low dispersion potential make DPA an unlikely candidate as a major airborne carcinogen in California.

HYDRAZINE; 1,1-DIMETHYL HYDRAZINE (UDMH);
1,2-DIMETHYL HYDRAZINE; MONOMETHYL HYDRAZINE;
AND 1,2-DIETHYL HYDRAZINE

All are volatile liquids and animal carcinogens (carcinogenicity undetermined for monomethyl hydrazine). The major use in California appears to be as an auxiliary power source in the space shuttle and other rockets. There appears to be no production of these chemicals in California presently, though an existing plant may begin production in the future. Because of tight emission controls on potential future production and use of hydrazines, they are unlikely to become important airborne carcinogens in California (see discussion of diethylnitrosamine and dimethylnitrosamine).

ISONICOTINIC ACID HYDRAZIDE (INH)

INH, a solid with a melting point of 171°C, has been used almost exclusively as an antitubercular drug since 1952, and it is a confirmed carcinogen in animals (IARC, 1974d). Its low dispersion potential, low apparent nationwide production; and narrow, non-dispersive use indicates that INH has little potential for being a major airborne carcinogen.

BIS(DIMETHYLDITHIOCARBAMATO)LEAD

Very little information on this chemical has been identified. It has been reported to be neoplastigenic (Christensen et al., 1976) though there is no TLV. Ranked according to the number of times observed in the workplace by the National Occupational Hazard Survey, this chemical was ranked 1,503, the most observed hazard being ranked number one (Seta, 1978). This implies that the chemical is used relatively little in industry and, consequently, that its potential for significant public exposures is slight. This compound was rejected from further consideration because of its apparent obscurity and its undemonstrated carcinogenicity.

NITROBENZENE

Nitrobenzene is a relatively nonvolatile liquid (vapor pressure at 25 °C is 0.3 mm Hg) which apparently has not been tested for carcinogenicity. U.S. production in 1976 was 4.1×10^8 lb (USITC, 1977b). To our knowledge, no nitrobenzene is produced in California (Dorigan and Hushon, 1976b). It is used in aniline production (97%), metal polishes, shoe blackening, soap perfume, dye intermediate, and a combustible propellant (Dorigan and Hushon, 1976b). Since nitrobenzene is not produced in California and since 97 percent of the nitrobenzene produced is immediately converted to aniline (Dorigan and Hushon, 1976b), nitrobenzene is unlikely to be an important airborne carcinogen in California.

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