

**REPORT TO THE SCIENTIFIC REVIEW PANEL  
ON BENZENE\***

Prepared by the Staffs of  
The Air Resources Board and  
The Department of Health Services

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- \* Includes changes pursuant to the October 10, 1984 Scientific Review Panel (SRP) public meeting, as made available to the public and submitted to the SRP on November 15, 1984, and considered by the SRP at its public meeting on November 26, 1984. Also includes changes recommended by the SRP at the November 26, 1984 public meeting and revision of the lower bound of the risk estimate from  $24 \times 10^{-6}/1$  ppb to  $22 \times 10^{-6}/1$  ppb throughout the report, for consistency with the SRP's findings.

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**OVERVIEW**

**I. INTRODUCTION**

Assembly Bill 1807 (Stats. 1983, Ch. 1047; Health and Safety Code Section 39650 et seq., Food and Agriculture Code Section 14021 et seq.), enacted in September 1983, sets forth a procedure for the identification and control of toxic air contaminants (TAC) in California. Staff is proposing, in accordance with the provisions of AB 1807, that benzene be identified as a toxic air contaminant. This overview reviews briefly the ARB's report on the uses of, and the extent of emissions of and public exposure to benzene in California, (Part A of this report) and the DHS' evaluation of the health effects of benzene (Part B of this report). The findings in these reports comprise the rationale for the selection of benzene as a candidate substance for listing as a toxic air contaminant.

AB 1807 defines a "toxic air contaminant" as an air pollutant which may cause or contribute to an increase in mortality or an increase in serious illness, or which may pose a present or potential hazard to human health" (Section 39655).<sup>1/</sup> Under AB 1807, the Air Resources Board (the Board) is responsible for the identification and control of toxic air contaminants, except in their pesticidal use. The Department of Food and Agriculture is responsible for the regulation of toxic air contaminants in their pesticidal use (Sections 39650(g) and 39656; Food and Agriculture Code Section 14021 et seq.). AB 1807 specifies expressly that substances which have been identified by the Environmental Protection Agency as hazardous air pollutants {Section 112 of the Clean Air Act) shall be identified as toxic air contaminants by the Air Resources Board (Section 39655). Benzene has been identified as a hazardous air pollutant by EPA.

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<sup>1/</sup> All statutory references are to the Health and Safety Code unless otherwise indicated.

Included in AB 1807 are the Legislature's findings with respect to substances which may be toxic air contaminants (Section 39650). The Legislature declares:

“That public health, safety, and welfare may be endangered by the emission into the ambient air of substances which are determined to be carcinogenic, teratogenic, mutagenic, or otherwise toxic or injurious to humans.”

The findings also include directives with respect to the consideration of scientific evidence and the basis for regulatory action. With respect to the control of toxic air contaminants, the Legislature declares:

That it is the public policy of this state that emissions of toxic air contaminants should be controlled to levels which prevent harm to the public health.”

The Legislature further declares that, “while absolute and undisputed scientific evidence may not be available to determine the exact nature and extent of risk from toxic air contaminants, it is necessary to take action to protect public health.”

With respect to the evaluation of substances, the Legislature declares that the best available scientific evidence, gathered from both public agencies and private sources, including industry, should be used. The Legislature also finds that this information should be reviewed by a scientific review panel and by members of the public.

The procedures established in AB 1807 implement the Legislature's findings. Specifically, determination by the Board as to whether a substance is a toxic air contaminant includes several steps. First, the ARB staff requests the DHS to evaluate the health effects of a

substance (Section 39660). The evaluation includes a comprehensive review of all available scientific data. Second, upon receipt and in consideration of the DHS evaluation and recommendation, the staff prepares and submits a health effects report to the Scientific Review Panel (SRP) for its review (Section 39661). The report is prepared in a form which may serve as the basis for regulatory action by the Board. The report is also made available to the public, which may comment directly to the SRP. After review by the SRP, the report, with the written findings of the SRP, is considered by the Board in determining whether the substance is a toxic air contaminant. The Board's determination as to whether a substance is a toxic air contaminant must be set forth in a regulation and considered at a noticed public hearing (Section 39662). AB 1807 also includes procedures for the development and adoption of control measures for substances identified as toxic air contaminants (Sections 39665-39667).

## II. EVALUATION OF BENZENE

In accordance with the procedures specified in AB 1807, the ARB and the DHS first prioritized substances for evaluation and regulation as toxic air contaminants” pursuant to Section 39660(f). Briefly, selection of a substance for the Board's consideration is to be based on the risk to the public from exposure to the substance, amount or potential amount of emissions, manner of usage in California, atmospheric persistence, and ambient concentrations. The ARB staff, after consulting the Department of Health Services (DHS), selected benzene as the first substance for the Board's consideration for listing as a TAC. A central factor in its selection was that, as a Hazardous air pollutants designated by the U.S. Environmental Protection Agency (EPA) pursuant to Section 112 of the Clean Air Act, benzene must, according to AB 1807, be identified as a TAC by the Board. In addition, the staff selected benzene because it is a known human carcinogen (the primary basis for EPA's

“hazardous air pollutant” designation), it is ubiquitously emitted by the marketing and burning of gasoline, it is persistent in the atmosphere, and its presence in the atmosphere is well documented. Pertinent data are shown below.

Emissions (California)

Stationary Sources	480 tons/year
Gasoline-related	630 “
Other	15,000 “
Vehicular	

Atmospheric Half-Life

(OH* attack, polluted atmosphere)	12 days
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Ambient Concentration

South Coast Air Basin population-weighted year-round average	4.6 parts per billion (ppb)
South Coast Air Basin range (24 hr. average)	1.2-16 ppb

Pursuant to Health and Safety Code Section 39660, the ARB then requested that the Department of Health Services conduct a health effects evaluation of benzene. The DHS evaluation was conducted in accordance with the provisions of that section, which requires that the DHS consider all available scientific data, including, but not limited to, relevant data provided by the State Board, the Department of Industrial Relations, international and federal health agencies, private industry, academic researchers, and public health and environmental organizations. To facilitate the identification of all available data, the ARE, prior to formally requesting the DHS evaluation, sent a letter to owners of sources of benzene emissions in California and other interested members of the public requesting that they submit any information they considered pertinent to the DHS evaluation. The ARB also received a

reference search on benzene health effects using the MEDLARS II and DIALOG Information Services and included a bibliography from that search in its request for information. The data compiled in the search were provided to the DHS. Also, the DHS report was released to the public upon its completion on July 27, 1984, providing additional time during the ARB's preparation of the report to the SRP for the public's preparation of comments. The DHS report was also provided to the SRP on that date.

Section 39660 specifies that the evaluation shall assess the availability and quality of data on health effects, including potency, mode of action, and other relevant biological factors of the substance. Section 39660 also requires that the evaluation contain an estimate of the levels of exposure which may cause or contribute to adverse health effects, and, in the case where there is no threshold of significant adverse health effects, the range of risk resulting from current or anticipated exposure.

In accordance with these requirements, five major issues discussed in the DHS health effects evaluation of benzene are: 1) Is benzene a human and/or animal carcinogen? 2) Does benzene have a threshold below which cancer does not occur? 3) Are health effects other than cancer expected to occur at usual ambient levels? 4) What is the range of added lifetime cancer risk for populations continuously exposed to California's urban air benzene concentrations? and 5) Is this risk sufficient to recommend listing benzene as a toxic air contaminant? Based on its review of all available scientific data, the DHS evaluation concludes that: 1) benzene is a human and animal carcinogen; 2) benzene should be treated as a substance without a carcinogenic threshold; 3) health effects other than cancer are not expected to occur at usual ambient levels; 4) the added lifetime cancer risk from ambient air benzene exposure ranges from 22 to 170 cases per million per ppb; and 5) benzene should be listed as a toxic air contaminant.

The DHS report finds that epidemiological studies associate exposures to tens to hundreds of parts per million benzene with an increased incidence of leukemia. Also, recent animal cancer bioassays show benzene causes leukemia and a variety of other cancers including lymphoid cancers, cancers of the skin, ovary, oral cavity, lip, tongue, lung, mammary gland, and two uniquely rodent secretory organs, the zymbal and preputial glands. Thus, the DHS concludes that benzene is a human and animal carcinogen.

To determine that a substance has a carcinogenic threshold, the DHS requires strong positive evidence that the substance acts only through mechanisms which ought to have a threshold. No positive evidence exists for this position with respect to benzene. Also, benzene causes many kinds of cancer in animals of which only one - leukemia - is postulated by some experts to act by a mechanism which may have a threshold. Because the statistical and mechanistic arguments for a benzene threshold are not compelling, the DHS concludes that benzene should be treated as a substance without a carcinogenic threshold in humans.

The DHS estimated the low-dose carcinogenic potency of benzene using both animal and epidemiological data. Figure A shows dose-response curves derived from these human and animal studies. Line 1 (Mantel-Bryan) and line 2 (95 percent UCL Multistage) are dose-response curves for the most sensitive site in animals, the preputial gland in mice. Line 1 is based on the Mantel-Bryan model and line 2 is based on the 95 percent upper confidence limit (UCL) for the multistage model. The DHS staff recommends line 2 (95 percent UCL Multistage) for calculating the upper bound of risk.

Line 3 (Mouse Mammary and Ovary) is the dose-response curve for mammary and ovarian cancers in mice based on the multistage model. Lines 4 (Leukemia and Lymphoma in Mice) and 5 (Rinsky) are overlapping. Line 4 is the dose-response curve for leukemia and

lymphoma in mice based on the multistage model. Line 5 is the dose-response curve for the Rinsky re-evaluation of human data from the Infante epidemiologic study. Line 6 (CAG #1) is the dose-response curve for human data from the Infante, Aksoy and Ott epidemiologic studies. Lines 5 and 6 are based on the dose-response model from EPA's Carcinogen Assessment Group (CAG). The DHS staff recommends line 6 for calculating the lower bound of risk. Line 7 (Probit) is the dose-response curve for the preputial gland in mice based on the Probit model. This curve lies far below the others.

The DHS staff suggests that the ARB consider that the dose-response curves that lie between line 6 (CAG #1) and line 2 (95 percent UCL Multistage) constitute the most reasonable estimates of risk from ambient benzene exposure. While less conservative curves can else be defended as reasonable, the DHS staff does not feel that any can be clearly preferred, and the more conservative of equally reasonable elements should constitute the basis for regulation. Using these curves (lines 2 and 6) as grounds for the range of risk, then, the added lifetime cancer risk from exposure to benzene in urban air ranges from 22 to 170 cases per million per ppb.

Using the range of dose-response curves suggested by the DHS, the ARB staff estimates that the added lifetime cancer risk to a population exposed to benzene at the population-weighted average concentration of 4.6 ppb estimated for the South Coast Air Basin is in the range of 101 to 780 cases per million persons exposed. To place this in context, the comparable baseline lifetime risk of all cancers combined (SEER program, 1981, Surveillance Epidemiology and End Results Incidence and Mortality Levels, 1973-77, NCI Monograph #57), can be estimated at 23.7 percent or 237,000 cases per million persons exposed.

### III. ENVIRONMENTAL IMPACTS

The identification of benzene as a toxic air contaminant is not expected to result in any adverse environmental impacts. Rather, in light of the adverse health effects associated with benzene, as described in this report, and, in that, upon the identification of benzene as a toxic air contaminant, the Board will be required to identify and the Board and air pollution control districts will be required to adopt airborne toxic control measures in accordance with the provisions of AB 1807. Therefore, the identification of benzene as a toxic air contaminant is expected to result in environmental benefits. Environmental impacts identified with respect to specific control measures, will be included in the consideration of such control measures pursuant to Sections 39665 and 39666.

**Figure A**

**CANCER RISK FROM BENZENE**

#### IV. RECOMMENDATION

Since the evidence strongly suggests that benzene is a known human carcinogen, since the evidence does not warrant the assumption that carcinogenicity is confined to the dose above any threshold, and since the range of conservative reasonable dose-response curves predicts a range of added lifetime cancer risks which are not negligible, the ARB staff considers available evidence sufficient to recommend listing benzene as a toxic air contaminant.

Furthermore, the staff is recommending listing benzene as a toxic air contaminant because AD 1807 requires that all pollutants identified by EPA as hazardous air pollutants be identified as a toxic air contaminant.