EXECUTIVE SUMMARY

BENZO[a]PYRENE AS A TOXIC AIR CONTAMINANT

Prepared by the Staffs of
the California Air Resources Board
and the Office of Environmental Health Hazard-Assessment

APPROVED BY THE SCIENTIFIC REVIEW PANEL APRIL 1994

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Preface

This report was developed in response to the provisions of Health and Safety Code, sections 39650-39662, which became effective January 1984. This legislation requires a two-phase process which separates risk assessment (identification) from risk management. During the identification phase, a report is developed which considers whether there are adverse health effects of a substance which may be, or is, emitted in California. However, in January 1993, AB 2728 was enacted and the procedure for toxic air contaminant (TAC) identification of federal hazardous air pollutants (HAPs) was changed. Pursuant to the new legislation, the state Air Resources Board (ARB/Board) was required to identify, by regulation, any substance listed as a federal HAP a TAC. Although this report was developed under Health and Safety Code, sections 39650-39662, benzo[a]pyrene (BaP) is within the group of chemicals known as Polycyclic organic matter which is listed as a HAP and, therefore, was identified as a TAC on April 8, 1993.

This report, "Benzo[a]pyrene as a Toxic Air Contaminant," was the basis for the Scientific Review Panel (SRP) review of exposure, the cancer potency number for benzo[a]pyrene, four potencies provided under Proposition 65 (California Safe Drinking Water and Enforcement Act of 1986), and potency equivalency factors (PEFs) for 20 other Polycyclic aromatic hydrocarbons (PAHs) which were also identified as TACs at the April 8, 1993, Board hearing. On April 18, 1994, the SRP approved the benzo[a]pyrene cancer potency number, the expedited potencies, and PEFs, and since BaP was identified by the Board as a TAC, they may now be used in the development of control measures.

No control measures were proposed in this report. If measures are proposed for benzo[a]pyrene during the risk management phase, they will be developed and adopted only after full public participation following a staff evaluation of the need for control.

In preparing this report, staff reviewed pertinent literature published through July 1993.

EXECUTIVE SUMMARY

Introduction

This report was developed in response to provisions of state law (Health and Safety Code sections 39650-39662), which became effective in January 1984. This legislation requires a two-phase process which separates risk assessment (identification) of toxic air contaminants (TACs) from risk management (control). During the identification phase, a report is developed which considers whether there are adverse health effects of a substance which may be, or is, emitted in California. After conducting a public hearing, the California Air Resources Board (ARB/Board) decides whether or not the substance should be identified as a TAC. If identified, the substance is listed by regulation as a TAC in the California Code of Regulations and enters the control phase.

With the adoption of the AB 2728 legislation (signed by the Governor in September 1992 and effective in January 1993), the procedure for identification of federal hazardous air pollutants (HAPs) as TACs was changed. Pursuant to the new legislation, the Board is required to identify, by regulation, all HAP s as TACs. Benzo[a]pyrene is within the group of chemicals known as Polycyclic organic matter (POM) which is listed as a HAP and, therefore, was identified as a TAC by regulation at a Board hearing on April 8, 1993.

What is Contained in This Report?

This report summarizes the emissions, exposure, and atmospheric persistence and fate of benzo[a]pyrene in California. It also describes the potential health effects of benzo[a]pyrene which includes an estimate of the cancer potency number. The Scientific Review Panel (SRP) evaluated the entire report including a review of the data, and on April 18, 1994, approved the cancer potency number. Once the cancer potency number was approved by the SRP, it became available for use in the development of control measures for benzo[a]pyrene.

This report contains several parts. Part a, developed by the ARB staff which contains information on exposure to benzo[a]pyrene in California. As part of the analytical method for measuring benzo[a]pyrene, the ARB has also collected ambient data for five other Polycyclic aromatic hydrocarbons (PAHs). These are: benzo[b]fluoranthene, benzo[k]fluoranthene, dibenz[a,h]anthracene, benzo[g,h,i]perylene, and ideno[1,2,3-c,d]pyrene.

Part B. developed by the Office of Environmental Health Hazard Assessment (OEHHA), contains information on the health effects of benzo[a]pyrene. It also contains a discussion of four potencies provided under Proposition 65 (California's Safe Drinking Water and Toxic Enforcement Act of 1986) and the potency equivalency factors (PEFs) for 20 other PAHs.

What is a Toxic Air Contaminant?

Toxic air contaminants is a legal term referring to 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" (California Health and Safety Code section 39655). The current list of TACs also includes the substances designated as HAPs pursuant to section 7412 of Title 42 of the United States Code (California Health and Safety Code section 39657).

What is Benzo[a]Pyrene?

Benzo[a]pyrene is a five ring Polycyclic aromatic hydrocarbon (PAH) found in small (<1 μm) combustion-generated respirable particles collected from such sources as motor vehicle exhaust, smoke from residential wood combustion, fly ash from coal-fired power plants (not in California), and other combustion related processes. As a class, PAHs have a characteristic structure of fused aromatic rings. Benzo[a]pyrene comprises less than five percent of the total

amount of PAHs present in the atmosphere. The International Agency for Research on Cancer (IARC) considers benzo[a]pyrene a known animal carcinogen and a probable human carcinogen (Group 2A). Benzo[a]pyrene has been evaluated by the ARB and OEHHA under the state law AB 1807.

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Benzo[a]pyrene

Why was Benzo[a]Pyrene Evaluated as a TAC?

The staffs of the ARB and the OEHHA have reviewed the available scientific evidence on the presence of benzo[a]pyrene in the atmosphere of California and its potential adverse effects on public health. The ARB staff has determined that benzo[a]pyrene is emitted from a variety of sources, can be detected in the ambient air throughout California, and ifs highly mobile in the environment.

The United States Environmental Protection Agency (U.S. EPA) classified benzo[a]pyrene as a "possible human carcinogen" (Group B2) and the IARC classified benzo[a]pyrene as a "probable human carcinogen" (Group 2A). Benzo[a]pyrene is part of a larger group of complex mixtures (soots, tars and oils) designated by IARC as Group 1 known human carcinogens. Although there are several studies in which benzo[a]pyrene was measured as an indication of exposure to the mixture of compounds in soots, tars, and oils, the epidemiological data were

considered inadequate to evaluate the carcinogenicity of benzo[a]pyrene itself. The OEHHA staff have concluded that at ambient concentrations, benzo[a]pyrene may cause or contribute to an increase in mortality or serious illness and may therefore pose a potential hazard to human health.

What are the Sources of Benzo[a]pyrene?

Although there are natural sources of benzo[a]pyrene emissions (e.g., volcanic activity), anthropogenic sources are the most important to air pollution. Benzo[a]pyrene is a product of incomplete combustion and its major sources in California are vegetative materials burning, mobile sources, rubber tire wear, residential combustion of wood, and combustion of coal. Vegetative materials and other waste burning is responsible for the majority of statewide benzo[a]pyrene emissions from stationary sources. Vehicles that are not equipped with catalytic converters are the major source of benzo[a]pyrene emissions from mobile sources. Diesel exhaust is currently being considered for identification under the state law AB 1807.

The major indoor sources of airborne benzo[a]pyrene are residential wood combustion and tobacco smoking. The operation of combustion appliances can also contribute to indoor levels.

How much Benzo[a]Pyrene is Emitted into the Air in California?

The ARB staff estimates approximately 8-13 tons per year of benzo[a]pyrene are emitted into the air in California. Vegetative materials and other waste burning are responsible for 50 percent of the total statewide emissions of benzo[a]pyrene. Other sources of benzo[a]pyrene such as residential wood combustion, coal combustion, and residual oil combustion are responsible for about 15 percent of the total statewide emissions. Mobile sources contribute more than 35 percent of the total benzo[a]pyrene emissions. Within this category, light duty vehicles are responsible for 30 percent of benzo[a]pyrene emissions while heavy duty vehicles contribute approximately 10 percent.

Are Emissions of Benzo[a]pyrene Expected to Change in California

Most of the benzo[a]pyrene emissions in California are from combustion sources including vegetative materials burning or combustion-related processes. The staff does not expect an increase in process rates from fuel or vegetative materials burning or from other industrial processes such as oil refining. Because benzo[a]pyrene emissions are directly proportional to the amount of fuel or waste burned or material processed, the staff expects benzo[a]pyrene emissions from fuel combustion or combustion-related processes to remain the same.

The benzo[a]pyrene emissions from motor vehicles are directly proportional to the number and types of motor vehicles powered by petroleum-derived fuels. Before the introduction of catalytic converters, mobile sources were the major contributor of benzo[a]pyrene emissions. Most gasoline powered light duty spark-ignition vehicles manufactured after 1974 and operated in the United States are equipped with catalytic converters. As the pre-1974 vehicles grow older, they are taken out of service. Therefore, as the number of older vehicles decrease, benzo[a]pyrene emissions from this source will also decrease. The introduction of the transitional low emission vehicles (TLEV), low emission vehicles (LEV) and clean fuels, which are part of the California's Motor Vehicle Program, will lead to a significant reduction of ROG (reactive organic gases) and POM emissions. As a result, benzo[a]pyrene emissions are likely to be reduced as well.

Since stationary source emissions are not expected to change, and motor vehicle (both light and heavy-duty) emissions are expected to decline, the ARB staff expects a net decrease in benzo[a]pyrene emissions in California.

What are the Ambient Air Concentrations of Benzo[alpyrene?

Benzo[a]pyrene is routinely monitored by the statewide ARB tonics monitoring network. Mean annual concentrations ranged from a minimum of 0.11 nanograms per cubic meter at Chula Vista to a maximum of 1.48 nanograms per cubic meter at Fresno.

According to Table IV-3 on page a-34 (Part a), population-weighted exposures range from as low as 0.18 nanograms per cubic meter in the South Central Coast Air Basin to 1.39 nanograms per cubic meter in the Sacramento Valley Air Basin. Therefore, outdoor ambient exposure risks may vary according to location. For example, over two million people living in the San Joaquin Valley Air Basin and the Sacramento Valley Air Basin are exposed to benzo[a]pyrene concentrations almost two times higher than the statewide average. The statewide population-weighted exposure is estimated to be 0.53 nanograms per cubic meter. The population-weighted exposure is based on 20 million people represented by the tonics monitoring network (out of a total California population of 30 million).

Are there Elevated Exposures Near Sources of Benzo[a]pyrene in California?

Yes, elevated exposures have been measured at approximately ten times higher than general ambient levels. Residential areas where wood and vegetative materials are burned have the potential for elevated ambient Benzo[a]pyrene concentrations. To investigate this, the ARB staff analyzed benzo[a]pyrene concentrations in archived PM10 filters collected from the ARB PM10 monitoring network. These filters were collected from November 1988 through February 1989 in the two mountain communities of Quincy and Mammoth Lakes. The study showed that the mean benzo[a]pyrene concentrations during the winter months were 2-17 times higher than the annual statewide population-weighted estimate of 0.53 nanograms per cubic meter.

Is there Evidence of Indoor Air Exposure to Benzo[a]pyrene?

The major sources of indoor benzo[a]pyrene in California are tobacco smoking, woodburning in fireplaces and woodstoves, and infiltration of polluted outdoor air into homes. Tobacco smoking indoors raises benzo[a]pyrene concentrations by the greatest magnitude compared to other indoor sources. In two recent California studies, smoking raised indoor levels up to several times the concentrations in nonsmokers' homes and several times outdoor levels as well. Average concentrations of 2.2 nanograms per cubic meter have been reported in smoker's homes, compared to a level of 0.83 nanograms per cubic meter in a "no source" home. Woodburning also raises benzo[a]pyrene levels indoors; however, the newer, more efficient airtight stoves appear to emit less then the older leakier woodstove models. In a recent California study of woodburning homes, fireplace and woodstove use raised average benzo[a]pyrene levels to about twice the levels found in homes with no obvious combustion sources.

Two recent California studies found infiltration of polluted outdoor air to be a major source of benzo[a]pyrene pollution in the home. Woodsmoke in the outdoor air in woodburning communities was an especially significant contributor to indoor benzo[a]pyrene levels.

Are there Non-inhalation Routes of Exposure to Benzo[a]pyrene?

Yes. In addition to inhalation of benzo[a]pyrene, exposure can also occur from dermal absorption and the ingestion of water and food. Benzo[a]pyrene is also found in foods, particularly meats, which are smoked, grilled over an open flame, or cooked at high temperatures; this pollutant is also found in foods grown in polluted environments. The levels of benzo[a]pyrene measured in various foods range from 0.1 to 60 micrograms per kilogram wet weight. Preliminary data suggest that benzo[a]pyrene can accumulate in road and house dust and is a potential source of exposure through ingestion, especially for toddlers. Investigators reported

a range of 1.5 to 41 ppm benzo[a]pyrene in an eight-home study in Ohio with an average concentration of 9.6 ppm. There are insufficient data to estimate exposure to benzo[a]pyrene through drinking water in California.

How Long Does Benzo[a]pyrene Remain in the Atmosphere?

There are two dominant removal processes for benzo[a]pyrene: a) physical loss processes for the particles on which benzo[a]pyrene resides, and b) adsorbed phase reactions of benzo[a]pyrene on the particles. Considering only its physical removal processes, the lifetime of benzo[a]pyrene due to particle dry deposition is expected to be about ten days. However, in the adsorbed phase the chemical reactions include photolysis and reaction with O3, SO2, NO2 and/or HNO3, and N2O5. It is difficult to estimate an atmospheric lifetime for benzo[a]pyrene due to chemical reactions and/or photolysis. However, based on available information, the atmospheric lifetime of benzo[a]pyrene is on the order of a few hours in polluted urban atmospheres during the summer months. This may explain the low concentrations of benzo[a]pyrene measured in the ambient air during the summer season.

What is the Mutagenicity of Benzo[a]Pyrene and other PAHs?

Besides benzo[a]pyrene, other PAHs are emitted or formed in the atmosphere which account for additional mutagenicity. Gas-phase reactions can convert volatile and semi-volatile PAHs to nitro-PAHs and nitro-PAH lactones, some of which are strong “direct-acting" mutagens (do not require addition of metabolizing enzymes in the Salmonella tvphimurium bacterial assay known as Ames test). Recent evidence indicates that it is likely that the presence of nitro-PAH lactones formed in the atmosphere contribute significantly to the mutagenicity of ambient air.

Mutagenicity is the ability of a chemical compound to induce mutations in DNA and in living cells. Benzo[a]pyrene is a *promutagen* (as are other biologically-active PAHs), i.e., it must

be metabolized before it can induce mutation. Nitro derivatives of certain PAHs including benzo[a]pyrene and some nitropyrenes are strong direct mutagens (i.e. they do not need to be metabolized to be biologically active) and are formed during combustion or through atmospheric reactions with NOX emissions. The contribution to carcinogenicity of nitro derivatives of benzo[a]pyrene has not been extensively studied; however, PEFs have been derived for some of them.

Several products of benzo[a]pyrene formed during the reaction with ozone are strong mutagens. a major contributor has been identified as benzo[a]pyrene-4,5-oxide, an animal metabolite, known to be a strong direct mutagen.

What are the Health Effects of Exposure to Benzo[a]Pyrene?

The OEHHA staff agrees with the IARC classification of benzo[a]pyrene (IARC Group 2A) as a probable human carcinogen based on sufficient evidence for carcinogenicity in animals and limited evidence in humans. Benzo[a]pyrene has the ability through its metabolites to arylate DNA, cause gene mutations in both prokaryotic and eukaryotic cells, induce sister chromatic exchanges in mammalian cells, end produce unscheduled DNA synthesis in mammalian cells. Several types of malignant tumors have been induced in rodents by benzo[a]pyrene. Epidemiological evidence for human cancer from exposure to benzo[a]pyrene is found in studies of roofers, tar distillers, patent-fuel workers, and creosote-exposed brickmakers. Certain complex mixtures such as soots, tars and oils are in the IARC Group 1 (sufficient evidence for carcinogenicity in humans) based on epidemiological studies. However, in these studies the benzo[a]pyrene was only one component of a mixture of PAHs and therefore a precise exposure assessment was not made.

Acute and chronic exposure to benzo[a]pyrene leads to reproductive system toxicity and bone marrow toxicity; however, the OEHHA staff has concluded that it is unlikely that

noncarcinogenic adverse health effects would be caused by the levels of benzo[a]pyrene currently found in the ambient air.

What is the Risk Assessment for Ambient Exposure to Benzo[a]Pyrene?

The inhalation unit risk is the calculated, theoretical upper limit possibility of contracting cancer when exposed to benzo[a]pyrene at a concentration of one microgram per cubic meter of air for a 70 year lifetime. Since several unit risks can be obtained depending on the cancer incidence data available and analysis of the data, a range of values can be obtained. From this range a “best” value is selected which, in the judgement of the OEHHA, has the strongest scientific support.

Since there are inadequate epidemiological studies regarding the carcinogenicity of benzo[a]pyrene to humans, data from animal bioassays must be extrapolated to estimate the human cancer risk. After reviewing available studies on benzo[a]pyrene carcinogenicity, the OEHHA staff estimates the range of unit risk for continuous exposure to benzo[a]pyrene over a 70-year lifetime to be from 1.1×10^{-3} to 3.3×10^{-3} per microgram per cubic meter. The staff of the OEHHA recommends that the unit risk of 1.1×10^{-3} per microgram per cubic meter be considered the "best" value for inhalation exposures because it is based on an inhalation study (in hamsters) (see Part B. Sections 5.3.1 and 7.2.6). This value is 30 percent lower than the U.S. EPA cancer unit risk value of 1.7×10^{-3} per microgram per cubic meter.

Using the OEHHA's range of risk numbers and the statewide population-weighted exposure of 0.53 nanograms per cubic meter, exposure to benzo[a]pyrene could result in 0.6 to 1.7 potential cancer cases per million people exposed. Such an exposure could result in a cancer burden of 17 to 52 potential excess lifetime cancers (upper 95 percent confidence limits) among the 30 million residents of California.

Using the OEHHA's “best” value, exposure to benzo[a]pyrene could result in 0.6 potential cancer cases per million with a cancer burden of 17 among the 30 million residents of California. This estimate represents the upper range of plausible excess cancer risk; however, the actual number of career cases-may be significantly lower. Table 1 shows a comparison of benzo[a]pyrene potency with other compounds the Board has identified as TACs.

What is the Cancer Risk from Indoor Exposure?

In poorly ventilated indoor environments, environmental tobacco smoke and other combustion sources such as woodburning raise people's exposure to benzo[a]pyrene. Using the OEHHA's best estimate of risk, and average indoor concentrations in California homes where smoking occurred, exposure to benzo[a]pyrene in smoking environments is estimated to result in 0.5 to 2.4 potential cancer cases per million people exposed for most of their day.

What is the Potential for Acute or Chronic Non-carcinogenic Health Effects from Exposure to Ambient Concentrations of Benzo[a]Pyrene?

The OEHHA staff concluded that it is unlikely that *noncarcinogenic adverse health effects* would be caused at the levels of benzo[a]pyrene currently found in the ambient air.

What are the Uncertainties Associated with the Risk Assessment?

The estimates of risk values result from several sources of uncertainty, including the choice of mathematical model used to estimate risk, extent of absorption of benzo[a]pyrene by various routes, variability of response to benzo[a]pyrene in different species, the choice of the extrapolation model, and the large range of extrapolation (five orders of magnitude) from the benzo[a]pyrene concentrations used in the animal experiments to current ambient levels.

TABLE 1

UNIT RISKS APPROVED BY THE SCIENTIFIC REVIEW PANEL COMPARED TO UNIT RISK OF BENZO[a]PYRENE
(in decreasing order of cancer potency)

Compound	Unit Risk per microgram per cubic meter	Unit Risk parts per billion volume
Dioxins	3.8×10^{1}	Particulate Matter
Chromium VI	$1.4 \times l0^{-1}$	Particulate Matter
Cadmium	$4.2 \times l0^{-3}$	Particulate Matter
Inorganic Arsenic	3.3×10^{-3}	Particulate Matter
Benzo[a]pyrene	1.1×10^{-3}	Particulate Matter
Nickel	$2.6 \times l0^{-4}$	Particulate Matter
1,3-Butadiene	1.7×10^{-4}	3.7×10^{-4}
Ethylene Oxide	8.8×10^{-5}	1.6×10^{-4}
Vinyl Chloride	7.8×10^{-5}	2.0×10^{-4}
Ethylene Dibromide	7.1×10^{-5}	5.5×10^{-4}
Carbon Tetrachloride	4.2×10^{-5}	2.6×10^{-4}
Benzene	2.9×10^{-5}	9.3×10^{-5}
Ethylene Dichloride	2.2×10^{-5}	8.9×10^{-5}
Formaldehyde	6.0×10^{-6}	7.0×10^{-6}
Perchloroethylene	5.9×10^{-6}	4.0×10^{-6}
Chloroform	5.3×10^{-6}	2.6×10^{-6}
Acetaldehyde	2.7×10^{-6}	4.8×10^{-6}
Trichloroethylene	2.0×10^{-6}	1.1×10^{-6}
Methylene Chloride	1.0×10^{-6}	3.5×10^{-6}
[Asbestos	1.9×10^{-4} per 100 fiber/m^3]	

Is there a Threshold Level for Benzo[a]pyrene?

The OEHHA staff is unable to identify a threshold for benzo[a]pyrene carcinogenicity. There is compelling evidence of benzo[a]pyrene genotoxicity. Benzo[a]pyrene is mutagenic, its metabolites bind to DNA, and it can act as an initiator of tumorigenesis. Thus, based on current cancer theory, the OEHHA staff treats benzo[a]pyrene carcinogenesis as a nonthreshold phenomenon.

Is there Evidence of Adverse Health Effects Associated with Other PAHs?

The OEHHA has compiled a list of 24 PAHs and PAH-derivatives known to be carcinogenic in animals, and a list of others with limited evidence of potential carcinogenicity in animals. The OEHHA has developed a scheme for evaluating the potential carcinogenicity of 20 of these PAHs and PAH derivatives so that the effects of airborne PAHs can be evaluated in regulatory programs. The PEFs for these chemicals were developed by comparing the cancer activity of the chemicals relative to benzo[a]pyrene. In addition, OEHHA staff developed expedited potency factors for the other four PAHs and PAH-derivatives (dibenz[a,h]anthracene, 7,12 dimethyl benzanthracene, 3-methylcholanthrana, and 5-nitroacenaphthene) under Proposition 65 (California's Safe Drinking Water and Toxic Enforcement Act of 1986). It is assumed that the unit risk for inhalation have the same relative activities as cancer potencies for oral intake.

The expedited potencies and PEFs are presented in Tables 2 and 3 of this Executive Summary, Section 7 and Appendix a of hart B of this report. Certain of these, e.g., 7,12-dimethyl benzanthracene and 1,6-dinitropyrene are significantly more potent than benzo[a]pyrene.

Based on the ambient concentrations and PEFs for benzo[b]fluoranthene, benzo[k]fluoranthene, indeno[1,2,3-c,d]pyrene, and dibenz[a,h]anthracene, the combined risk from exposure to these four PAHs is approximately one-third of benzo[a]pyrene.

TABLE 2

COMPARISON OF UNIT RISKS OF BENZO[A]PYRENE TO OTHER PAHs

PAH	Unit Risk $(\mu g/m^3)^{-1}$
Benzo[a]pyrene	1.1×10^{-3}
Dibenz[a,h]anthracene	3.9×10^{-4}
7,12-dimethyl benzanthracene	2.4×10^{-2}
3-methylcholanthrene	2.1×10^{-3}
5-nitroacenapthene	1.1×10^{-5}
$\mu g/m^3$: microgram per cubic meter	

TABLE 3

POTENCY EQUIVALENCY FACTORS for PAHs

PAH or derivative	IARC Classification	PEF
benzo[a]pyrene (index compound)	2A	1.0
benz[a]anthracene	2A	0.1
benzo[b]fluoranthene	2B	0.1
benzo[j]fluoranthene	2B	0.1
benzo[k]fluoranthene	2B	0.1
chrysene	3	0.01
dibenzo[a,j]acridine	2B	0.1
dibenzo[a,h]acridine	2B	0.1
7-H-dibenzo[c,g]carbazole	2B	1.0
dibenzo[a,e]pyrene	2B	1.0
dibenzo[a,h]pyrene	2B	10.0
dibenzo[a,i]pyrene	2B	10.0
dibenzo[a,l]pyrene	2B	10.0
1,6-dinitropyrene	2B	10.0
1,8-dinitropyrene	2B	1.0
indo[1,2,3-c,d]pyrene	2B	0.1
5-methylchrysene	2B	1.0
6-nitrochrysene	2B	10.0
2-nitrofluorene	2B	0.01
1-nitropyrene	2B	0.1
4-nitropyrene	2B	0.1
dibenz[a,h]anthracene[a]	2A	0.4[c]
7,12-dimethylbenzathracene[a]	b	21.8[c]
3-mehtylcholanthrene[a]	b	1.9[c]
5-nitroacenapthene[a]	2B	0.01[c]

[a] An inhalation unit risk factor has been developed for this PAR for purposes of implementing Proposition 65.

[b] Not classified by IARC

[c] PEF determined by dividing the inhalation unit risk factor for that PAH by the inhalation unit risk factor for benzo[a]pyrene.

What is the Staff Recommendation?

The staff recommends that the OEHHA's cancer potency number for benzo[a]pyrene, the potency equivalency factors and the expedited potencies for other PAHs be approved by the SRP and that benzo[a]pyrene be considered a compound with no identifiable threshold.

What are the findings of the Scientific Review Panel?

Findings of the Scientific Review Panel on
THE REPORT ON BENZO[A]PYRENE
as Adopted at the Panel's April 18, 1994 Meeting

Pursuant to the Health and Safety Code section 39661, the Scientific Review Panel (SRP) has reviewed the report Identification of Benzo[a]Pyrene as a Toxic Air Contaminant by the staffs of the Air Resources Board (ARB or Board) and the Office of Environmental Health Hazard Assessment (OEHHA) on the public exposure to, and health effects of, benzo[a]pyrene (BaP). The SRP also reviewed the public comments received on this report. Based on their review the SRP makes the following findings pursuant to Health and Safety Code section 39661:

1. BaP is within the group of chemicals known as particulate Polycyclic organic matter (POM) which is listed as a federal hazardous air pollutant and, therefore, was identified as a toxic air contaminant by the Board on April 8, 1993.

2. Based on epidemiological evidence, the International Agency for Research on Cancer (IARC) has classified certain complex mixtures such as soots, mineral oils, shale-oils, and coal tars which contain BaP in Group 1 - carcinogenic to humans. The United States Environmental Protection Agency (U.S. EPA) classified BaP as a possible human carcinogen (Group B2) on the basis of sufficient evidence in animals and no adequate data in humans. The IARC classified BaP as a Probable human carcinogens (group 2A) based on sufficient evidence in animals and inadequate evidence in humans.

3. BaP is a product of incomplete combustion; it is present on the surface of respirable, submicron size particles. Its major sources in California are open burning of vegetative materials, mobile sources, rubber tire wear, and residential combustion of wood. The sources of ambient outdoor BaP are estimated to emit approximately 8-13 tons per year. Other sources include coil combustion and residual oil combustion.

4. Based on air monitoring data collected by the ARB, the statewide population-weighted ambient exposure is estimated to be 0.53 nanograms per cubic meter. The mean near source

BaP concentrations in residential areas where wood and vegetative materials burned during the winter months were 2-17 times higher than the annual statewide population-weighted estimate.

5. Before the introduction of the catalytic converter, mobile sources with spark ignition and diesel engines were the major contributor of BaP emissions. After 1974, in the United States, vehicles were manufactured and operated with catalytic converters. As the pre 1974 vehicles grow older and are taken out of service, BaP emissions will decrease as the number of older vehicles decrease. Reductions in BaP emissions are also expected as a result of decreases in reactive organic gases (R0G) and respirable POM from the introduction of transitional low emission vehicles (TLEV), low emission vehicles (LEV), and “clean" fuels. Respirable combustion products (soot) from non-controlled spark-ignition and diesel engines continue to be a significant source of BaP emissions.

6. There are two dominant removal processes for BaP: a) physical loss processes for the particles on which BaP resides, and b) adsorbed phase reactions of BaP on the particles. The lifetime of BaP due to particle dry deposition is expected to be about 10 days. The lifetime of BaP due to chemical reactions and/or photolysis is on the order of a few hours in polluted urban atmospheres during the summer months. Relatively little is known of the carcinogenicity, or lack thereof, of, reaction products, an area warranting expanded exposure and health effects studies.

7. The major sources of indoor BaP in California are tobacco smoking woodburning in fireplaces and woodstoves, and infiltration of polluted outdoor air into homes. Tobacco smoking indoors raises BaP concentrations by the greatest magnitude compared to other indoor sources. Average concentrations of 2.2 ng/m^3 hate been reported in smoker's homes, compared to a level of 0.83 ng/m^3 in a “no source” home. Preliminary data indicates that BaP can accumulate and persist in house dust. For example, investigators reported a range of 1.5 to 41 ppm BaP in an eight-home study in Ohio with an average concentration of 9.6 ppm.

8. In addition to inhalation of BaP, exposure can also occur from dermal absorption and the ingestion of water and food. The levels of BaP measured in various foods range from 0.1 to 60 micrograms per kilogram wet weight. There are insufficient data to estimate the dose of BaP through drinking water exposure in California.

9. Epidemiological evidence for human cancer from exposure to polycyclic aromatic hydrocarbons (PAHs) in complex mixtures is found in studies of roofers, tar distillers, and coke oven workers. Furthermore, human exposure to PAHs such as those found in mainstream cigarette smoke. environmental tobacco smoke, soots and diesel exhaust, may

also increase cancer risk. Certain complex mixtures such as soots, tars and oils are in the IARC Group 1 (sufficient evidence for carcinogenicity in humans) based on epidemiological studies. However, in these studies BaP was only one component of a mixture of PAHs and therefore a precise exposure assessment was not made. Consequently, BaP risks are based on animal studies.

10. Exposure to BaP alone results in animal carcinogenicity including cancers of the respiratory tract, gastrointestinal tract, and skin. BaP has the ability through its metabolites to arylata DNA, cause gene mutations in both prokaryotic and eukaryotic cells, induce sister chromatic exchanges in mammalian cells, and produce unscheduled DNA synthesis in mammalian cells.

11. Based on available studies on BaP animal carcinogenicity the range of unit risk for continuous exposure to BaP over a 70 year lifetime is estimated to be from 1.1×10^{-3} to 3.3×10^{-3} per microgram per cubit meter. The "best" upper 95 percent confidence limit value for unit cancer risk is 1.1×10^{-3} per microgram per cubic meter, and is based on the strongest inhalation study reporting respiratory tract tumors in hamsters.

12. The estimates of risk include several sources of uncertainty, including the choice of mathematical model used to estimate risk, extent of absorption of BaP by various routes, variability of response to BaP in different species, the choice of the animal-to-human scaling fact oral the choice of the extrapolation model, and the large range of extrapolation (five orders of magnitude) from the BaP concentrations used in the animal experiments to current ambient levels.

13. Based on the chests value for potential unit cancer risk of 1.1×10^{-3} per microgram per cubic meter and the mean annual statewide population-weighted exposure of 0.53 nanograms per cubic meter, there could be 0.6 potential cancer cases per million over a 70 year lifetime. Based on a population of 30 million California residents, such an exposure could result in a cancer burden of 17 potential cancer cases. Risks to individuals around "hot spots" are substantially higher.

14. Using the OEHHA's "best" estimate of risk, and average indoor concentrations in California homes, exposure to BaP in smoking environments is estimated to result in 0.5 to 2.4 potential cancer cases per million people exposed for most of their day.

15. Table 1 compares the "best" value of upper bound unit cancer risk for BaP with those of other compounds reviewed by the SRP. These 95 percent upper-bound lifetime risk estimates are health-protective estimates; the actual risk may be much lower.

16. BaP is the most studied PAN. However, many other PAHs present with BaP in complex mixtures, such as tobacco smoke and diesel exhaust, are also potential carcinogens. In order to address the carcinogenicity of PAHs in ambient air as a class, potency equivalency factors

(PEFs) for some PAHs relative to BaP have been developed using carcinogenesis studies in experimental animals. Table 2 lists 24 additional PAHs and PAN derivatives, their IARC classifications, and their PEFs.

17. Based on the ambient concentrations and PEFs for benzo[b]fluoranthene, benzo[k]fluoranthene, indeno[1,2,3-c,d]pyrene, and dibenz[a,h]anthracene, the combined risk from exposure to these four PAHs is approximately one-third that of BaP.

18. The report also includes inhalation unit risks for four PAHs (dibenz[a,h]anthracene, 3.9×10^{-4} per microgram per cubic meter; 7,12-dimethyl benzanthracene, 2.4×10^{-2} per microgram per cubic meter; 3-methylcholanthrene, 2.1×10^{-3} per microgram per cubic meter; 5-nitroacenaphthene, 1.1×10^{-5} per microgram per cubic meter. These unit risks were developed from Expedited risk assessments for implementing Proposition 65. It is assumed that the unit risks for inhalation have the same relative activities as cancer potencies for oral intake. Table 3 lists the comparison of unit risks and the risk per million for BaP and these four PAHs.

19. Based on available scientific information, a threshold could not be identified.

I certify that the above is a true and correct copy of the findings adopted by the Scientific Review Panel on April 18, 1994.

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James N. Pints, Jr.
Chairman, Scientific Review Panel

TABLE 1

UNIT RISKS APPROVED BY THE SCIENTIFIC REVIEW PANEL COMPARED TO UNIT RISK OF BENZO[a]PYRENE*

(in decreasing order of cancer potency)

Compound	Unit Risk $(\mu g/m^3)^{-1}$	Unit Risk $(ppbv)^{-1}$
Dioxins	3.8×10^{1}	Particulate Matter
Chromium IV	1.4×10^{-1}	Particulate Matter
Cadmium	4.2×10^{-3}	Particulate Matter
Inorganic Arsenic	3.3×10^{-3}	Particulate Matter
Benzo[a]pyrene	1.1×10^{-3}	Particulate Matter
Nickel	2.6×10^{-4}	Particulate Matter
1,3-Butadiene	1.7×10^{-4}	3.7×10^{-4}
Ethylene Oxide	8.8×10^{-5}	1.6×10^{-4}
Vinyl Chloride	7.8×10^{-5}	2.0×10^{-4}
Ethylene Dibromide	7.1×10^{-5}	5.5×10^{-4}
Carbon Tetrachloride	4.2×10^{-5}	2.6×10^{-4}
Benzene	2.9×10^{-5}	9.3×10^{-5}
Ethylene Dichloride	2.2×10^{-5}	8.9×10^{-5}
Formaldehyde	6.0×10^{-6}	7.0×10^{-6}
Perchloroethylene	5.9×10^{-6}	4.0×10^{-5}
Chloroform	5.3×10^{-6}	2.6×10^{-5}
Acetaldehyde	2.7×10^{-6}	4.8×10^{-6}
Trichloroethylene	2.0×10^{-6}	1.1×10^{-5}
Methylene Chloride	1.0×10^{-6}	3.5×10^{-6}
Asbestos	1.9×10^{-4} per 100 fiber/m^3	

$\mu g/m^3$: microgram per cubic meter
ppbv: part per billion volume

*Listed in order of unit risk $(\mu g/m^3)^{-1}$.

TABLE 2

POTENCY EQUIVALENCY FACTORS for PAHs

PAH or derivative	IARC Classification	PEF
benzo[a]pyrene (index compound)	2A	1.0
benz[a]anthracene	2A	0.1
benzo[b]flouranthene	2B	0.1
benzo[j]flouranthene	2B	0.1
benzo[k]flouranthene	2B	0.1
chrysene	3	0.01
dibenz[a,j]acridine	2B	0.1
dibenz[a,h]acridine	2B	0.1
7H-dibenzo[c,g]carbazole	2B	1.0
dibenzo[a,e]pyrene	2B	1.0
dibenzo[a,h]pyrene	2B	10.0
dibenzo[a,i]pyrene	2B	10.0
dibenzo[a,l]pyrene	2B	10.0
1,6-dinitropyrene	2B	10.0
1,8-dinitropyrene	2B	1.0
ideno[1,2,3-c,d]pyrene	2B	0.1
5-methylchrysene	2B	1.0
6-nitrochrysene	2B	10.0
2-nitrofluorene	2B	0.01
1-nitropyrene	2B	0.1
4-nitropyrene	2B	0.1
dibenz[a,h]anthracene[a]	2A	0.4[c]
7,12-dimethyl benzanthracene[a]	b	21.8[c]
3-methylcholanthrene[a]	b	1.9[c]
5-nitroacenapthene[a]	2B	0.01[c]

[a] An inhalation unit risk factor has been developed for this PAH for purposes of implementing Proposition 65 (See Finding #18).

[b] Not classified by IARC

[c] PEF determined by dividing the inhalation unit risk factor for that PAH by the inhalation unit risk factor for benzo[a]pyrene.

TABLE 3

COMPARISON OF UNIT RISKS AND RISK PER MILLION FOR BENZO[A]PYRENE AND OTHER PAHs

PAH	Unit Risk $(\mu g/m^3)^{-1}$	Mean Concentration $(\mu g/m^3)$	Risk per Million
Benzo[a]pyrene	1.1×10^{-3}	0.00063	0.69
Dibenz[a,h]anthracene	3.9×10^{-4}	0.00026	0.10
7,12-dimethyl benzanthracene	2.4×10^{-2}	(no data)	--
3-methylcholanthrene	2.1×10^{-3}	(no data)	--
5-nitroacenapthene	1.1×10^{-5}	(no data)	--

$\mu g/m^3$: microgram per cubic meter
ppbbv: part per billion volume