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Standard for Occupational Exposure to Benzene

Occupational Safety and Health Administration, Washington, D.C.

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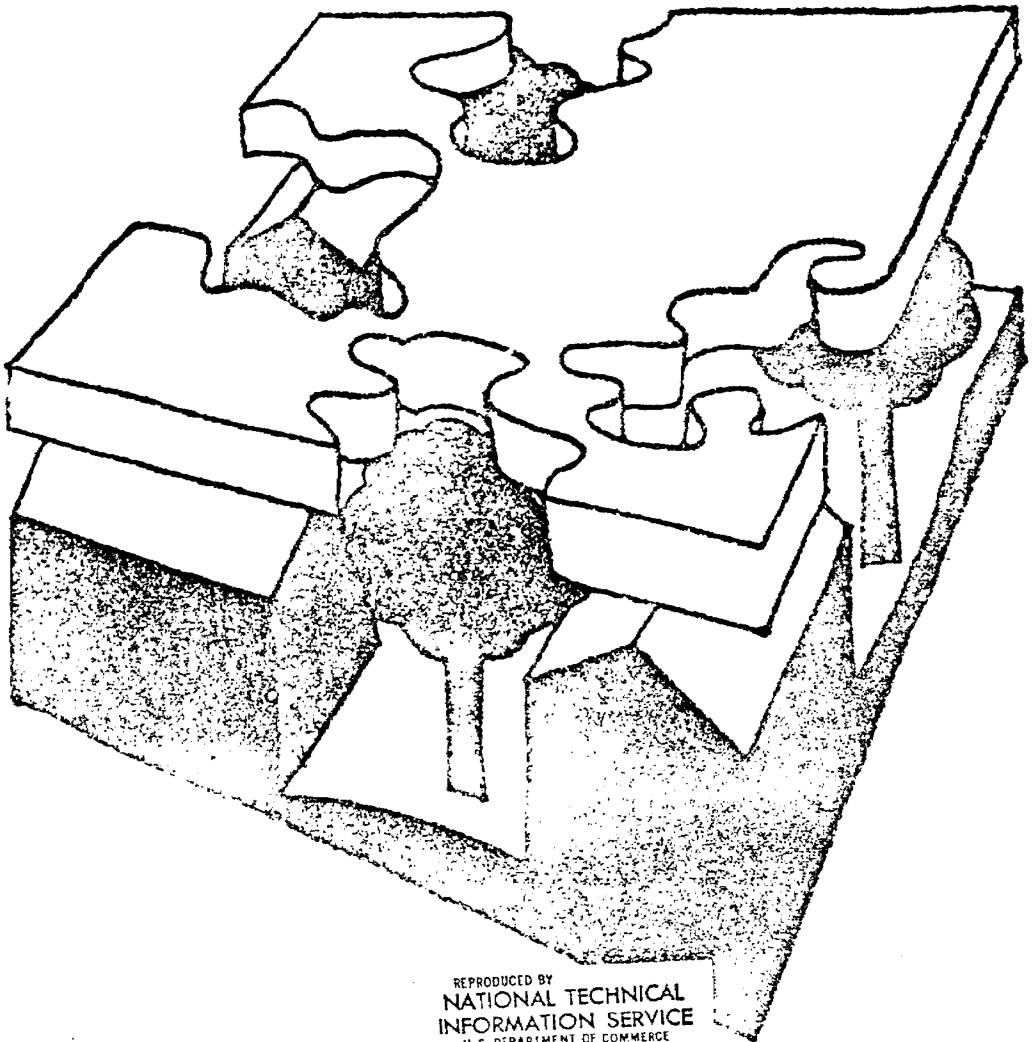
Final Environmental Impact Statement

Benzene

U.S. Department of Labor
Occupational Safety and
Health Administration
January 1978



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Presents information and conclusions developed since draft environmental impact statement in May 1977.

16. Abstract (Limit: 200 words)

Benzene, a chemical compound widely found in nature, is also widely used in industry and industrial operations, causes chromosomal aberrations, blood dyscrasias and other noncancerous abnormalities of the hemopoietic system, and leukemia. Direct skin contact may produce erythema and blistering. OSHA proposed standard would limit employee exposure to 1 ppm/8-hour time-weighted average, with ceiling limit of 5 ppm over a 15-minute sampling period. It would apply to all workplaces in which benzene is produced, reacted, released, packaged, repackaged, stored, transported, handled or used except for operations involving gasoline as a fuel after its discharge from bulk terminals and for mixtures containing 1% or less of benzene. Also reviews: alternatives to proposed standard; beneficial impacts on workplace environment as well as on environment external to workplace; relationship to other federal actions.

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U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration
WASHINGTON, D.C. 20210

JAN 20 1978

FINAL ENVIRONMENTAL IMPACT STATEMENT ON A
STANDARD FOR OCCUPATIONAL EXPOSURE TO BENZENE

The attached final environmental impact statement (FEIS) was prepared in accordance with requirements of the National Environmental Policy Act of 1969 (P.L. 91-190, 42 U.S.C. 4321 et seq.), Guidelines of the Council on Environmental Quality (40 CFR Part 1500) and Occupational Safety and Health Administration (OSHA) regulations (29 CFR Part 1999). This document contains an assessment of the impacts a standard for occupational exposure to benzene may have on the workplace environment and the human environment external to the workplace.

The Environmental Protection Agency (EPA) will publish a notice of the availability of this FEIS in the Federal Register of February 3, 1978. Any correspondence regarding this FEIS on a standard for occupational exposure to benzene should be directed to:

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Environmental Impact Statement on a Standard for Occupational Exposure to Benzene

( ) Draft (X) Final

United States Department of Labor
Occupational Safety and Health Administration
Office of Environmental and Economic Impact
Room N-3673, 200 Constitution Avenue, N.W.
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1. Name of Action: (X) Administrative Action
( ) Legislative Action

2. OSHA intends to regulate employee exposure to benzene by setting a permissible exposure limit of 1 part benzene per million parts of air (1 ppm) as an 8-hour time-weighted average. The proposal also provides for employee exposure measurements, methods of compliance, protective clothing and equipment, medical surveillance, training, signs and labels, employee observation of monitoring, and recordkeeping. The purpose of the proposed standard is to assure, to the extent feasible, that employees are protected from the health hazards associated with occupational exposure to benzene.

3. No significant adverse impacts on the environment external to the workplace are expected as a result of promulgation of the standard. Beneficial impact on the workplace environment is expected in that there will be a reduction in the health effects associated with exposure to benzene. Beneficial impact on the external environment may occur as a result of reduced benzene emissions from the workplace due to improved work practice and engineering controls. Lack of complete data, however, precludes OSHA from quantifying the full extent of any type of environmental impact at this time.

4. Major areas of alternatives considered in the development of the proposed standard include: the scope and application of the regulation, the airborne permissible exposure limit, and the methods of compliance.

5. See Appendix III and Chapter VIII for Federal, State, and local agencies, as well as other interested parties who have submitted comments on the draft environmental impact statement.

6. The draft statement was available to the Council on Environmental Quality and the public on June 10, 1977. The final environmental impact statement was made available to the Environmental Protection Agency and the public on January 27, 1978.

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I. SUMMARY

This final environmental impact statement (FEIS) has been prepared in accordance with the Guidelines of the Council on Environmental Quality (40 CFR Part 1500) and Occupational Safety and Health Administration (OSHA) regulations (29 CFR Part 1999) for the purpose of assessing the environmental impacts which may occur if the proposed standard for occupational exposure to benzene were promulgated as the final OSHA regulation. This document represents information and conclusions developed since the publication of the draft environmental impact statement (DEIS) on benzene in May 1977. The following sections outline the findings contained in this FEIS.

A. Background

Benzene is a chemical which has found wide application in industry and industrial operations as well as being an ubiquitous component of the air, water, plant and animal life of the Earth. A relationship between benzene exposure and blood abnormalities has been established for many years. Evidence of benzene's leukemogenicity has also been growing over the past years. This accumulated data, in addition to more recent information linking benzene with the development of leukemia in workers, prompted OSHA to propose a reduction in permissible exposure levels for employees.

In response to this information, OSHA issued an Emergency Temporary Standard (ETS) for occupational exposure to benzene on May 3, 1977.

This standard replaced the original benzene standard found at 29 CFR 1910.1000 (Table Z-2) for a period of six months, during which OSHA was to propose and promulgate a permanent standard for benzene. OSHA issued its proposal for a permanent standard on May 27, 1977, and it is this proposal which is the subject of this environmental impact statement.

B. Health Effects

Exposure to benzene has been shown to result in both acute and chronic health effects. Among the chronic health effects are chromosomal aberrations, blood dycrasias and other non-cancerous abnormalities of the hemopoietic system, and leukemia. Chapter III of this FEIS discusses these disorders.

C. The Proposed Standard

In keeping with the intent of the Occupational Safety and Health Act of 1970, OSHA has proceeded to develop a new standard that seeks to most adequately assure, to the extent feasible, that no employee will suffer material impairment of health or functional capacity due to occupational exposure to benzene. The proposed standard published May 27, 1977, would limit employee exposure to benzene to an eight-hour time-weighted average of one ppm, with a ceiling limit of five ppm as measured over a 15-minute sampling period. In addition to the permissible exposure limit, the proposal contains provisions regulating employee exposure measurement and monitoring, methods of compliance, respiratory protection, medical surveillance, regulated areas, employee information and training, signs and labels and recordkeping, as well as other items.

The proposed standard would apply to all workplaces in which benzene is produced, reacted, released, packaged, repackaged, stored, transported, handled or used with the exception of operations involved in the storage, transportation, distribution, dispensing or sale of gasoline as a fuel subsequent to its discharge from bulk terminals. Excluded also are operations where the only exposure to benzene is from liquid mixtures containing 1 percent or less of benzene by volume or the vapors released from these liquids. One year from the effective date of the final standard, the proposal states that the level for mixtures would be reduced to 0.1 percent.

D. Alternatives To the Proposed Standard

Four areas of regulatory decision making have been identified as having a potential for affecting the environmental impact of an OSHA standard for benzene: (1) the scope and application of the regulation; (2) the permissible exposure limit (3) the frequency of required exposure measurements and medical examinations, and (4) the method(s) by which compliance must be achieved by the employer.

The alternatives available to OSHA in the area of the scope and application of the final standard involve the inclusion or exclusion of various industrial operations or processes from coverage by the standard as well as determining whether use of mixtures containing small percentages of benzene should be excluded from the standard. Alternatives considered in setting a permissible exposure limit (PEL) include the institution of an action level, PEL's ranging from 0.5 ppm to 10 ppm, institution of a ceiling limit rather than a PEL and setting various PEL's based on feasibility.

Frequency alternatives concern the number of exposure measurements and medical examinations required by the proposal. The area of compliance method alternatives is concerned with the institution of various strategies involving engineering, work practice or respiratory protection controls.

E. Projected Environmental Impacts

The FEIS discusses environmental impacts in the context of two environments: (1) the workplace and (2) the general human environment external to the workplace. The proposed standard is expected to have beneficial impacts on the workplace environment because employee exposures to benzene will be reduced, resulting in a decrease in the incidence of leukemia as well as other blood abnormalities. Benefical effects on the environment external to the workplace may also be anticipated to result from the control of fugitive emissions, although this benefit may not significant.

F. Relationship To Other Federal Actions

The Environmental Protection Agency (EPA), Consumer Product Safety Commission (CPSC) and Department of Transportation (DOT) as well as OSHA are all concerned with the regulation of benzene.

OSHA, together with NIOSH, EPA and the Coast Guard has established a joint federal agency taskforce to coordinate efforts to reduce worker and the general public's exposure to benzene emitted from gasoline vapors in retail automotive service stations, and in certain other aspects of the transportation, storage, distribution and sale of gasoline and other motor fuel, if the facts warrant.

G. Comments

Letters of comment were received in direct response to the DEIS. In addition, all comments, data, evidence and testimony concerning environmental issues, received into the public record of this rulemaking proceeding, have been reviewed prior to the development of this FEIS. The FEIS is intended to serve as an aid in decision-making for the Assistant Secretary prior to publication of a final regulation for occupational benzene exposure.

II. BACKGROUND

A. General

Benzene (C_6H_6) is a clear, colorless, non-corrosive, highly flammable liquid with a strong, rather pleasant odor. Benzene's low boiling point and high vapor pressure cause it to evaporate rapidly under ordinary atmospheric conditions, giving off vapors nearly three times heavier than air.

Benzene is produced primarily by the petrochemical and petroleum refining industries by the process called catalytic reformation, which converts certain lower octane hydrocarbons into higher octane aromatics. The two industries are responsible for 95 percent of the total U.S. production of benzene. Recovery through catalytic reformation, including the benzene formed from the hydrodealkylation of toluene, accounts for almost 80 percent of the total quantity produced. Recovery of coal-derived benzene, primarily as a by-product of the coking process in steel mills, was once the major source of benzene. Today, however, it accounts for only five percent of the total U.S. production.

The production of benzene is rapidly expanding with approximately 11 billion pounds being produced in 1976. (Only 11 other chemicals and only one other hydrocarbon (ethylene) are produced in greater tonnage in the U.S.). Approximately 86 percent of this benzene is used chiefly as an intermediate in the production of other organic chemicals, including styrene, phenol, and cyclohexane. The remaining amount is used primarily in the manufacture of detergents, pesticides, solvents and paint removers.

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Benzene is also present as a component of motor fuels, averaging less than two percent in gasoline.

The first major industrial use of benzene, however, was as a solvent in the rubber industry just preceding World War I. During World War I, benzene production was stimulated greatly by the demand for and resulting production of toluene for use in the manufacture of explosives. The large quantities of benzene which were produced resulted in its more widespread use as a starting point for the manufacture of various organic compounds. This situation led to greatly increased uses of benzene as a solvent in the artificial leather, rubber goods, and rotogravure industries, and as a starting material in organic synthesis.

Industries and processes currently using benzene include chemical production, rubber cements, rubber fabricating, paint removers, adhesives, and petroleum industries. Benzene is also used extensively in laboratories as a solvent and reactant in numerous chemical applications. Where benzene is produced and used in large amounts, it is generally used in enclosed systems, although exposures can occur during liquid transfer operations, from equipment leakage and carryover losses and in maintenance operations.

In addition to its commercial production, benzene is a rather ubiquitous substance found in the volatile portions of numerous plants and natural food stuffs. In fact, benzene has been detected in foods such as roasted peanuts, soybeans, chicken, meat, codfish, tomatoes, pineapples, strawberries and chedder cheese. Benzene has also been measured in the earth's atmosphere, including over nonindustrialized areas, in concentrations ranging from 0.02 to 15 ppb (0.00002 to 0.015 ppm). According to one source, levels between 7 and 14 ppb (0.007 and 0.014 ppm) have been detected over the Amazon jungle while average concentrations over sections of the industrialized U.S. have been in the range of 0.3 to 1.0 ppb (0.0003 to 0.001 ppm).[1]

A team of investigators from the Department of Environmental Health and Institute of Genetics at the University of Lund, Sweden, have reported measurements of benzene concentrations of up to 20 ppb (average 13 ppb) in the breath of individuals not occupationally exposed to the chemical. They stated that such concentrations are probably "a normal background in an urban environment, where they may be in equilibrium with the benzene present in the air" (54 ppb (0.054 ppm) has been measured in a street carrying automobile traffic.)[2]

In his written statement presented at the OSHA rulemaking hearing on benzene, Dr. Herman F. Kraybill stated that intake of benzene

> from cooked meat could be several micrograms per day; from several drinks containing rum, about 30 micrograms per day; and from eggs (assuming 2 eggs per day and a value of 2100 micrograms per kilogram) about 210 micrograms. Thus from known values we have about 250 micrograms per day from diet alone.

Dr. Kraybill estimated that considering daily dietary, water and atmospheric intakes of benzene, a 70 kg man would have exposure to approximately 1.5 milligrams, each day.

B. <u>History of Regulation</u>

Benzene has long been recognized as a toxin affecting the hematopoietic (blood forming) system and a cause and effect relationship between benzene exposure and observed blood abnormalities has been established for man and animals during the last 75 years. The evidence indicating a relationship between benzene exposure and leukemia has been expanding and the international scientific community has increasingly acknowledged that worker exposure to benzene is associated with an increased risk of leukemia.

The present OSHA standard for benzene, found in at CFR 1910.1000, Table Z-2, was adopted in 1971 under the authority of section 6(a) of the Occupational Safey and Health Act (the "Act"), from the American National Standards Institute's (ANSI) Z37.4-1969 standard. That OSHA standard prescribes an eight-hour time-weighted average of 10 ppm with an acceptable ceiling concentration of 25 ppm. In addition, the present standard allows excursions above the ceiling to a maximum peak concentration not to exceed 50 ppm, provided that such exposure occurs for no more than 10 minutes in any eight-hour work period. Neither the ANSI standard nor the resultant OSHA standard were based on the possible leukemia hazard of exposure to benzene.

In 1974, pursuant to section 22(d) of the Act, the Director of NIOSH submitted to the Secretary of Labor a criteria document concerning occupational exposure to benzene which stated that "the possibility that benzene can induce leukemia cannot be dismissed."[4] However, NIOSH recommended retention of the present permissible exposure limit of 10 ppm and ceiling concentration of 25 ppm as measured over a 10-minute period. This recommendation was based on protection from blood dyscrasias, other than leukemia, and not on benzene's potential leukemia hazard.

In a letter to the Secretary of Labor, dated April 23, 1976, the United Rubber, Cork, Linoleum, and Plastic Workers of America urged that an emergency temporary standard regulating occupational exposure to benzene be issued.[5] The request was denied on May 18, 1976 by former Secretary of Labor William J. Usery.[6]

In 1976, the National Academy of Sciences, under contract with the United States Environmental Protection Agency, reviewed the literature concerning health effects of benzene exposures.[7] The Academy concluded that benzene must be considered a suspect leukemogen.

In August 1976, NIOSH submitted to OSHA an updated criteria document which revised its earlier assessment of 1974.[8] On the basis of a review of old studies and new data, NIOSH concluded that benzene was leukemogenic. This report further pointed out that "it is apparent from the literature that benzene leukemias continues to be reported." NIOSH, therefore, recommended that, since no safe level for benzene exposure could be established, "no worker be exposed to benzene in excess of one ppm in air." Following publication of the updated criteria document, the Director of NIOSH recommended to the Assistant Secretary of Labor, by letter dated October 27, 1976, that OSHA publish an emergency temporary standard for benzene establishing the exposure level at one ppm.[9] Based on the information supplied by NIOSH, OSHA issued on January 4, 1977, voluntary "Guidelines for Control of Occupational Exposure to Benzene," recommending that exposure to benzene in air not exceed an eight-hour time-weighted average of one ppm in any eight-hour shift per 40-hour week.[10]

In January 1977, NIOSH informed OSHA that workplace environments had been found in St. Mary's and Akron, Ohio, in which a sufficient number of employees had been exposed to benzene for a number of years to enable the initiation of an epidemiological study of health risks.[11] The worksites were Pliofilm manufacturing plants owned by the Goodyear Tire and Rubber Company. The preliminary conclusions of the NIOSH epidemiological study of Pliofilm workers were transmitted to OSHA on April 15, 1977.[12] NIOSH reported an incidence of leukemia in workers exposed to benzene that was at least five times the expected incidence. NIOSH concluded: "The report shows a statistically significant increase in the risk for developing myelogenous leukemia among workers exposed to benzene. We hope this new information will be of assistance to you in reaching a decision on the most appropriate regulatory action." In his letter of April 15, 1977, transmitting the report on the Goodyear Pliofilm plant, the Director of NIOSH again urged that an emergency standard be issued.

On May 3, 1977, OSHA published an emergency temporary standard (ETS) for control of benzene exposure in the workplace pursuant to sections 6(c) and 8(c) of the Act (42 FR 22516). The ETS, codified as section 1910.1028 and effective on May 21, 1977, applied to all employments in all industries covered by the Act, including "general industry," construction and maritime, with the exception that the standard did not apply to retail automotive service stations or to operations which use liquid mixtures containing one percent or less of benzene by volume. (A copy of the ETS is attached to this final environmental impact statement (FEIS) as Appendix I.)

On May 24, 1977, OSHA published an amendment to the ETS (42 FR 26429). This amendment extended the exemption for automotive service stations to cover the storage, transportation, distribution, dispensing or sale of gasoline as a fuel subsequent to discharge of such gasoline from bulk terminals.

The proposed permanent standard for benzene and the draft environmental impact statement (DEIS) on benzene were published in the Federal Register of May 27, 1977 (42 FR 27452). (The proposed standard is described in detail in Chapter IV.) A copy of the proposed permanent standard is attached to this FEIS as Appendix II.

A public hearing on the proposed standard was held beginning July 19, 1977, at which data and testimony were received into the record of this rulemaking. The hearing record was officially closed on September 22, 1977.

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[1]Memo to J. E. Penick from P. B. Weisz, Mobil Research and Development Corporation, dated May 17, 1977. "Benzene from Natural Sources." (Exhibit #117)*

[2]Berlin, M., K. Fredga, J. C. Gage, V. Lagesson, J. Reitalu and A. Tunek. "Occupational Exposure to Benzene from Motor Fuels." Presented at XVIII International Congress on Occupational Health, September 1975. (Exhibit 2-218)

[3]Kraybill, H.F. "Experimental and Epidemiological Evaluation of Carcinogenic Risk from Exposure to Benzene." Testimony for OSHA Public Hearings on Benzene, July 25-26 1977. (Exhibit 84B-18)

[4]Occupational Exposure to Benzene: Criteria For Recommended Standard. U.S. Dept. of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, 1974.

[5]Letter to William J. Usery, Secretary of Labor from Peter Bommarito, International President, United Rubber Cork, Linoleum and Plastic Workers of America, April 23, 1976.

[6]Letter to Peter Bommarito, International President of United Rubber, Cork, Linoleum and Plastic Workers of America from William J. Usery, Secretary of Labor.

[7]National Research Council. Health Effects of Benzene: A Review. Committee on Toxicology Assembly of Life Sciences, National Academy of Sciences, June 1976.

[8]Occupational Exposure to Benzene: Revised Criteria For A Recommended Standard. U.S. Dept. of Health, Education, and Welfare, Public Health Service, Center For Disease Control, National Institute for Occupational Safety and Health, August 1976.

[9]Finklea, J. F., Director, NIOSH: Memorandum to Assistant Secretary of Labor, OSHA, Dept. of Labor, October 27, 1976.

[10]Guidelines for Control of Occupational Exposure to Benzene. O.S.H.A. Department of Labor, January 14, 1977.

[11]Walk-through Survey of Goodyear Tire and Rubber Co., Cast Film Division, St. Mary's Ohio, NIOSH Survey, January 1977.

[12]Finklea, J. F., Director, NIOSH: Memorandum to Assistant Secretary of Labor, OSHA, Dept. of Labor, April 15, 1977.

*Exhibit numbers refer to the public record of OSHA rulemaking proceedings for benzene (Docket No. H-059). All exhibits are available for examination and copying in the:

OSHA Technical Data Center - Docket Office
Room S6212
200 Constitution Avenue, N.W.
Washington, D.C. 20210

III. HEALTH EFFECTS ASSOCIATED WITH BENZENE EXPOSURE

A. Background

Benzene has been recognized as a toxic substance capable of causing acute or chronic effects since 1900. Inhalation is the primary route of entry of benzene in man. Benzene diffuses rapidly through the lungs and is quickly absorbed into the blood. The rate of absorption is greatest during the first five minutes and thereafter declines significantly. Benzene saturation of the circulating blood may reach as high as 70-80 percent within the first 30 minutes. Relatively complete saturation of the blood may not be attained for two to three days.

The benzene absorbed by the circulating blood is distributed throughout the body where, because of its liposolubility, it tends to accumulate in various body organs in proportion to their fat content.

Upon removal from benzene exposure, the concentration of benzene in the expired breath follows an exponential decay curve, reflecting removal of benzene from various body compartments. Elimination via this route has been estimated to range from 12 to 50 percent of the total amount of benzene absorbed in humans.

A fraction of the absorbed benzene is eliminated in an unchanged form, primarily in the expired air and, to a minimal extent, in the urine. The remainder of the absorbed benzene is metabolized by enzymes contained in the liver and ultimately to derivatives which are more water soluble thereby facilitating their removal by the kidneys. A first intermediate in the biotransformation of benzene is believed to be benzene epoxide, a highly reactive intermediate and one of several candidates suggested as the active agent responsible for benzene's myelotoxic effects. Phenol, and to a lesser extent, hydroquinone, pyrcatechol, and phenyl-mercapturic acid are the primary metabolites of benzene found in urine.

B. Acute Effects

Exposures to high concentrations of benzene produce an almost immediate effect upon the central nervous system. Benzene concentrations of about 20,000 ppm are fatal within minutes, with death occurring from acute circulatory failure or coma, with or without convulsions. Milder exposures produce a period of nervous excitation, euphoria, headache and nausea, followed by a period of depression which can result in cardiovascular collapse and/or unconsciousness. The occurrence of nonspecific nervous disturbance as an after-effect of acute exposures is dependent on duration of unconsciousness and/or severity of circulatory failure. Breathlessness, nervous irritability, and unsteadiness in walking have been observed to persist for a period of several weeks. Inhalation of still lower concentrations (250-500 ppm) yields signs and symptoms of mild poisoning, characterized by vertigo, drowsiness, headache and nausea. Rapid recovery from these symptoms usually occurs following cessation of exposure.

Direct contact with the liquid may cause erythema and blistering. Prolonged or repeated skin contact, even with small quantities of benzene, has been associated with the development of a dry, scaly dermatitis or with secondary infections.

C. Chronic Effects

Benzene exerts a primary toxic effect in the bone marrow, the major blood forming organ. Exposures to concentrations of benzene have been causally related to aplastic anemia (lack of functioning of bone marrow), leucopenia (decrease in leucocytes, the white blood cells), thrombocytopenia (decrease in platelets), or pancytopenia (decrease in all cells in the peripheral blood). More importantly, these conditions may represent a preleukemic phase prior to development of a frank leukemia (an irreversible and fatal disease). An increased risk of leukemia has been observed among workers exposed to benzene in a variety of occupational settings.

The following studies are representative, although by no means all inclusive, of the published literature on the chronic effects in humans of benzene exposure. These studies do, however, illustrate the diversity and variability of effects which dominate the literature on chronic benzene exposure.

(1) Blood dyscrasias. Greenburg and co-workers' 1939 investigation of 332 pressman in three rotogravure printing plants was one of the earliest, comprehensive studies of benzene poisoning.[1] In addition to physical examinations, including medical and occupational histories and laboratory tests, workplace air samples nd chemical analysis of ink solvents and thinners were performed in and attempt to provide a correlation with medical findings. Air samples[1] revealed benzene concentrations ranging from 11 ppm to 1060 ppm for three plants.

Five workers with the most severe benzene poisoning expressed no subjective complaints and physical examination revealed negative findings. The signs of "poisoning" included a reduction in the number of erythrocytes, leucocytes and platelets.

Greenburg stated that: "These findings illustrate the well-known fact that the effects of benzene may be persistent and also suggest that even before blood changes are apparent, processes may have been initiated that will continue to develop even after exposure to benzene has ceased." The authors also reported that individuals varied greatly in susceptibility although data on personal monitoring were not available.

In the same year, Mallory et al. reported post-mortem findings in 19 case studies of workers with a history of chronic exposure to benzene.[2] Exposures varied from six months to 12 years, but no exposure levels were available. The authors indicated that significant changes were found regularly throughout the entire hematopoietic system including bone marrow, liver, spleen and lymph nodes. Of the 19 case studies, six exhibited hypoplasia of the bone marrow (decreased bone marrow function), whereas nine cases showed hyperplasia (overactivity of the bone marrow) and two were diagnosed as leukemia. The authors concluded that exposure to benzene under varying conditions produced diverse reactions and that individual variation was of great importance.

In 1948, Hardy and Elkins investigated an artificial leather plant in Massachusetts in which a man who had been employed as a coating machine operator for 12 years died of what was diagnosed as benzene poisoning.[3] The subject had worked as a coating machine operator in other locations for 18 years. Fifty-two workers were still employed in the leather plant. Benzene concentrations ranged from 40 to 80 ppm with an average concentration of 60 ppm. Blood studies, performed upon all 52 employees, showed abnormalities in more than one blood component in sixteen of the employees. Abnormalities were observed in hemoglobin and both red blood cell and white blood cell counts. There was a wide variation among subjects as to the particular component affected. Six of the 16 employees with blood abnormalities worked in the same coating room as the deceased man. Despite the evidence of blood abnormalities from the laboratory tests, none of the physical examinations revealed any clinical signs or symptoms of overexposure to benzene.

In an epidemiological investigation, Aksoy et al. compared the hematological findings of 100 health male subjects (controls) with those of 217 apparently health males, 95 percent of whom worked with solvents containing benzene in small shoe shops.[4] The shops were considered unhygienic and poorly ventilated. The concentration of benzene in the working environment ranged from 15 to 30 ppm during non-working hours to 210 ppm when adhesives containing benzene were being used. The duration of employee exposures ranged from three months to 17 years. In 51 (23.5 percent) of the 217 employees, hematological abnormalities were found consisting of leucopenia (9.7 percent), thrombocytopenia (1.84 percent), leucopenia associated with thromobocytopenia (4.6 percent) and pancytopenia (2.7 percent). In addition, relative to controls, benzene-exposed workers demonstrated a significant reduction in mean white cell counts and mean platelet counts. The proportion of benzene-exposed workers diagnosed with anemia was increased when compared to controls, however, the presence of iron-deficiency anemia could not be ruled out.

In a French survey of 45 fatal cases of benzene-induced diseases of the blood, covering the years 1947 to 1962, 23 were diagnosed as leukemia and 22 were attributed to aplastic anemia.[5] A similar observation was reported in 1969 by Vigliani and Forni.[6] Of 32 fatal cases of chronic benzene poisoning seen in the Italian provinces of Milan and Pavia, 18 were due to leukemia and 14 due to aplastic anemia. These authors noted that aplastic anemia usually occurs in patients while they are still being exposed to high concentrations of benzene. In a later study, Vigliani reported that among 59 surviving workers with benzene-related aplastic anemia, 11 later died from acute leukemia. The author also reported that he had knowledge of at least 150 cases of leukemia attributed to benzene in Italy alone.[7]

Pancytopenia has been equated with aplastic anemia, although strictly defined aplastic anemia is characterized by pancytopenia and accompanied by a fatty displacement of the bone marrow. In 1976, Viglani and Forni stated:

> In the past two decades, the case records of patients with acute or subacute leukemia, usually with leukopenia at some state of the illness, have become so numerous that they exceed those of acute pancytopenia. This finding led us to suspect that many cases that were considered as acute pancytopenia in the past, prior to the introduction of bone marrow biopsy, may in fact have been examples of acute hemocytoblastic leukemia leucopenic and aleukemic, or with few microhemocytoblasts in the circulating blood, possibly mistaken for lymphocytes.[7]

Unsuccessful at inducing chronic poisoning through inhalation of vapors, Selling in 1916 produced leukopenia in rabbits through subcutaneous injections of commercially pure benzol with olive oil.[8] Selling's findings demonstrated a constant, well defined aplasia of the marrow, characterized by the complete disappearance of leukocytes in the peripheral blood.

Deichman et al. (1963) published results of animal studies which also indicated the great toxicity of benzene vapors for hematopoietic tissue.[9] Eight groups of rats, consisting of 40 animals per group, were exposed to benzene vapors at average concentrations of 831, 65, 61, 47, 44, 31, 29, and 15 ppm, respectively. The duration of exposures was for five hours per day, four days per week, for periods ranging from five weeks to seven months. Exposures to the three highest concentrations resulted in a significant leukopenia after 14 weeks. A moderate, but definite, leukopenia occurred in the rats exposed to 47 and 44 ppm after five to eight weeks of exposure. Exposures to the three lowest benzene concentrations for periods of four, three and seven months, respectively, induced no demonstrable changes in the number of leukocytes.

(2) Chromosomal aberrations. The development of various chromosomal aberrations in peripheral leukocytes and bone marrow cells has also been attributed to benzene exposures. Several investigators characterized these aberrations as both unstable chromosome changes (i.e. including fragments, dicentric, tricentric and ring chromosomes) or stable chromosomal changes (i.e. deletions, translocations, inversions, and trisomies). These types of chromosomal aberrations also occur as the result of exposure to ionizing radiation, which is known to induce leukemia.

Increases in chromosomal aberrations in subjects suffering from benzene hemopathy were investigated by Pollini and Colombi and by Forni and Moreo.[10,11,12]

Forni et al. examined chromosomal changes and their evolution in 25 individuals who had suffered bone marrow impairment of varying severity, one to 18 years previously, as a result of exposure to benzene.[13] Hematologic examinations performed at the time of the cytogenetic study, but subsequent to cessation of exposure and recovery from benzene hemopathy, indicated normal blood values. However, both stable and unstable chromosomal changes were still present. The authors noted: "This finding (persistence of chromosomal aberrations) is similar to that reported in individuals with past exposure to ionizing radiations, both therapeutic and accidental, and suggests that long-lived lymphocytes might maintain chromosome damage even for years."

Chromosomal changes in individuals either no longer exposed to benzene, or exposed intermittently to low levels, and who show no hematological disorders, have also been investigated. After examination of three groups of factory employees who displayed no toxic symptoms, Tough et al. reported that two of these groups exposed on the average of 8 and 15 years, respectively, to similar working environments containing from 25 to 150 ppm benzene, showed a significant increase of structural chromosomal aberrations in lymphcytes over the general population.[14] The third group of workers, from a different kind of factory and exposed to approximately 12 ppm for an average of 13 years, showed a frequency of chromosome aberrations not significantly different from those found in the general population. Tough et al. suggested that their findings may indicate that an interplay between the age of workers and exposure to benzene is responsible for the observed effects.

Induction of chromosomal damage in rabbit lymphocytes by subcutaneous injection of benzene has been reported by Kissling and Speck.[15] During the phase of peripheral pancytopenia the frequency of mitotic figures showing aberrations (mostly gaps and breaks) increased from an initial value of six percent to 58 percent after an average of 18 weeks. Two months later, after the discontinuance of benzene treatment, visible chromosomal damage was still observed in 36 percent of the mitotic cells. Also Philip and Jensen in a preliminary report demonstrated that a single subcutaneous injection of benzene (dose: 2.0 ml benzene/kg body weight) administered to rats is capable of increasing the fraction of marrow cells which exhibit chromosomal abnormalities.[16]

(3) Leukemia. As pointed out, benzene presents a considerable range of health risks to the working population. These include the threat of developing a form of cancer known as leukemia, a fatal and irreversible disease. Robbins defines leukemia by stating:

> Leukemia may best be considered as a neoplasm [cancer] of the white blood cells and is so classified in the International Lists of Causes of Death. It is characterized chiefly by: the appearance of abnormal, immature white cells in the circulating blood; diffuse and almost total replacement of the bone marrow with the leukemic cells; and widespread infiltrates of the liver, spleen and other tissues, analogous to metastatic dissemination of solid tissue cancer.[17]

In 1977, Infante et al. reported a five-fold increased risk of all types of leukemia and a ten-fold increased risk of mylomonocytic leukemia among Pliofilm workers exposed to benzene.[18] This finding is in concert with numerous case reports in the scientific and medical literature over the past several years.

It should be noted that, for many years, many scientists had argued that any substance capable of inducing bone marrow depression or other blood abnormalities should be treated as potential leukemogen. For example, Cronkite stated over twenty years ago that:

> The heart of the problem in the induction of leukemia by industrial hazards rests upon quantitation of the agent and the yield of leukemia. Two agents used in industry have been correlated with an increased incidence of leukemia in human beings. The first, ionizing radiation, is unquestionably able to increase the incidence of leukemia. The second agent, benzol, probably can produce an increased incidence of leukemia, but the data are not as good as fo the former. First, the finger of suspicion must be pointed at any agent which is able to produce an aplasia of the bone marrow, assuming it will probably be able to produce leukemia also. Second, there is no reason to doubt that any agent which will produce a cancer elsewhere in the body will not be able to produce leukemia if the offending agent is tranported to the hemopoietic tissues.[19]

And, as the National Academy of Sciences pointed out in its report of June 1976: "Benzene fits in the former category because it is well documented that it produces aplasia of the bone marrow."[20] Further, Williams et al. notes:

> Any chemical capable of producing myelotoxicity must be regarded as a potential leukemogen, if the findings in radiation-induced leukemia apply which indicate that cell damage with depression of marrow function may produce alterations leading to the transformation of damaged cells into neoplastic ones. The only chemical which has been clearly identified as one which increases the incidence of myeloid leukemias in man is benzene in rather heavy occupational exposure.[21]

The relationship between benzene exposure and leukemia in humans in the past has been based in large part upon clinical observation and to a lesser degree upon epidemiological studies. The clinical evidence of leukemia has been obtained either from a survey of medical records, primarily in various European clinics, or from a canvass of the published literature reporting case histories of individuals diagnosed with leukemia. In lieu of quantitative, individual exposure data, subjective evaluations of intensity of exposure have been utilized. The epidemiological evidence has been derived from either the determination of the frequency of chronic benzene exposure among cases of leukemia or from the determination of frequency of, or mortality from, leukemia among employees of work shops that utilize benzene. In other words, in the first method the leukemia is the constant factor of all case studies and the benzene exposure is the variable; while the second method is the reverse, that is, the benzene exposure is the constant factor while leukemia is the variable.

Vigliani and Saita, in their review of 47 individuals suffering from benzene hemopathy between the period of 1942 and 1963, presented clinical and laboratory accounts of six cases, all of whom were diagnosed as having haemocytoblastic leukemia.[22] The period of exposures of these individuals to either resins, inks, varnishes, or glues containing varying concentrations of benzene ranged up to 19 years. Data on the concentrations of benzene in the workplace environment, with one exception (190-660 ppm) were not available. Although information on previous occupational histories or medical status prior to the final diagnoses were also not available, the authors stated that "attribution of the cases (of leukemia cited) to the exposure cannot be doubted." During the years 1962-1963, when there was sharp rise in the incidence of leukemia among workers exposed to benzene which coincided with an increase in the number of benzene poisoning cases for this period, the risk of acute leukemia was estimated to be about 20 times greater than the risk for the general adult population.

Twelve years following the Vigliani and Saita study, Vigliani and Forni observed that in the rotogravure industry, no new cases of aplastic anemia nor of leukemia were found among workers exposed solely to toluene after this solvent was substituted for benzene in 1964.[6] However, these authors noted in 1974 that cases of benzene-induced leukemia with long latency periods may still be occasionally observed.[23] These investigators also observed that workers exposed to toluene did not exhibit chromosomal aberrations, a finding seen in employees who work with benzene.

Sixteen cases of various forms of leukemia developing from long term exposure to benzene were reported by Tareef et al.[24] The duration of exposure ranged from four to 27 years, however, no exposure concentrations were reported. In contrast to data previously reported in Italy and Turkey, the authors found evidence of chronic leukemia. Acute leukemia accounted for only six of the 16 cases. Three of the six acute leukemias were diagnosed at two, four and five years following cessation of benzene exposure. Four of the acute cases underwent a definite period of hematologic shifts ranging from anemia or leucopenia to aplastic anemia and spanning a period of two to 10 years. Of the 10 chronic cases reported, none of the patients had hemocytopenic changes prior to the onset of leukemia.

Aksoy et al. reported deaths, due to leukemia, of four Turkish shoemakers resulting from their exposure to benzene for periods ranging from six to 14 years.[25] At the time of the study, air concentrations were found to be between 150-210 ppm of benzene. Previous occupational exposure data was not provided. Two of the four patients developed acute leukemia approximately two and three years after the occurrence of aplastic anemia although the other two did not.

Adding eight new cases of leukemia associated with exposure to benzene to 26 previously found, between the years 1967 and 1973, Aksoy et al. observed that with the exception of one case of chronic myeloid leukemia, all had various forms of acute leukemia.[26] A preceding period of pancytopenia was reported present in almost 25 percent of the cases, and the interval between the pancytopenic period and the onset of leukemia varied from six months to six years. Often the clinical findings and blood picture improved considerably before leukemia was diagnosed. During an eight-year period of observation, the incidence of leukemia among shoeworkers chronically exposed to benzene was calculated to be more than twice that experienced by the general population (13.5/100,000 vs. 6/100,000).

Browning tabulated, from published studies, 61 cases of leukemia among workers exposed to benzene at various concentrations.[27] The majority of cases were of the myeloid series. Browning noted that "benzene leukemia is frequently superimposed on a condition of aplastic anemia, but can develop without a preceding peripheral blood picture characteristic of bone marrow aplasia." She also noted that the transition from aplastic anemia to leukemia was not unknown in the ideopathic forms of leukemias.

Based on the hypothesis that the risk of leukemia was higher among workers who were exposed to benzene and medical x-rays, Ishimaru et al. conducted a retrospective epidemiological investigation examining the relationship between occupations and environmental factors, other than A-bomb exposure, and the incidence of leukemia in Nagasaki and Hiroshima between 1945 and 1967.[28] This case-control study compared all cases diagnosed as definite or probable leukemias between 1945 and 1967 and residing, at the time of the onset of the disease, in Hiroshima or Nagasaki. Controls were matched for city, sex, date of birth (± 30 months), distance from the atomic bomb explosion, and residence in either city at the time of the onset of the disease in the patient. Four hundred ninety-two leukemia cases were identified, but matched controls could only be obtained for 413.

Fifteen occupations were selected in which there had been exposure to either medical x-rays or solvents, especially benzene and its derivatives. Three hundred and three adult cases, with the onset of leukemia at age 15 years or over, and their controls were compared. Eleven of the 15 occupations were selected based on whether there had been a history of such occupations by either the leukemia cases or the controls. Considered as a group, the risk of leukemia was found to be significantly higher (about 2.5 times greater) among those with a history of such occupations in which various volatile solvents were used as compared with those without such histories. The relative risk was 1.8 times higher for chronic leukemia and 2.9 times higher for acute. Eighteen of the leukemia cases associated with solvents were located in distant and non-exposed radiation areas and were considered too far from the A-bomb explosion for radiation to have enhanced the increased risk. Accepting the source of error inherent in the method which was used to collect the data, the results of this study nonetheless reinforce the observation that an increase in leukemia existed in that portion of the population exposed to radiation and employed in an occupation where solvents were used, especially benzene or where exposure to medical x-ray occurred.

Thorpe, then Associate Medical Director for the Exxon Corporation, on the other hand, reported that the incidence of leukemia among a population of 38,000 workers having potential exposure to benzene over a 10-year period (1962-1972) was not significantly different when compared with the general population.[29]

This study has been severely criticized by Brown for its relaxed case-finding techniques and the methods of analysis.[30] Thus, the conclusions derived from this study must be viewed in the light of serious methodological problems which were encountered in the collection and treatment of the data. These problems, which were also acknowledged by Thorpe, included: (1) The low incidence of leukemia in the general population; (2) The validity of the diagnoses of leukemia; (3) The quantitative determinations of the extent of exposures; (4) An inadequate follow-up of annuitants and (5) incomplete occupational histories on individuals diagnosed as having leukemia.

In 1977 Infante et al. reported the results of an ongoing epidemiologic study among workers exposed to benzene during the manufacture of Pliofilm, a process unconfounded with mixed solvent exposures.[31] The authors reported a statistically significant excess of leukemia in benzene-exposed workers as compared with the expectations based on the U.S. white male population or on a second population employed in an industry in the same state over the same period of time. Among benzene-exposed workers, a five-fold excess of total leukemia and a 10-fold excess of myelomonocytic leukemias were reported. These findings are consistent with the type of leukemia (acute myelogenous leukemia and its variants) and with the findings reported by Vigliani.

The wide variety of clinical manifestations and hematological disorders observed in humans exposed to benzene, ranging from simple anemia and leukopenia to aplastic anemia have been experimentally induced in animals. However, attempts to demonstrate the development of leukemia in animals exposed to benzene has met with less success. To date, a study by Lignac in 1932 is the only completed animal study known to OSHA in which leukemia has been observed in animals exposed to benzene.[32] Fifty-four mice (28 females, 26 males) were given subcutaneous injections of benzene (0.001 ml in 0.1 ml of olive oil) for 17 to 21 weeks. Nine mice were initially excluded following bacteriological examination and an additional 12 were lost through atrophy of of various organs, especially the spleen. Lignac attributed these deaths to the size of the dose of benzene based upon the findings of a preceding experiment. Eight of the remaining 44 mice developed leukemia or Kundrat's lymphosarcoma and four to 11 months after receiving the first injection. The absence of concurrent controls makes interpretation of the results difficult, and uncertainties as to the strain of the mice studied have frustrated efforts to independently confirm the findings.

Amiel, in 1960, utilized four inbred strains of mice and subjected them to the same experimental program outlined in Lignac's study.[33] No leukemic or aplastic hemopathies were observed. More recently, Ward et al. administered benzene subcutaneously to a species and strain of mice which is responsive to leukemogenic agents.[34] Although they observed a slight increase in the percentage of granulocytic leukemias in the benzene-treated mice as compared with the controls, the authors viewed the increase as not statistically significant.

More recent experimental results indicate the possible development of an animal model indicating a possible leukemic response in rodents subjected to benzene vapors.[35] Two possible leukemias were observed in 2 mice exposed to 300 ppm and 1 rat exposed to 100 ppm. The results of this study are now being examined by the authors.

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IV. DESCRIPTION OF THE PROPOSED STANDARD

The following chapter discusses the significant provisions of the proposed permanent standard for occupational exposure to benzene as published in the Federal Register notice of May 27, 1977 (42 FR 27452).

A. Scope and Application

The proposed standard would apply to all employers and all establishments in which benzene is present, except for two general groups: (1) those engaged in the storage, transportation, distribution, dispensing, or sale of gasoline as a fuel subsequent to the discharge of such gasoline from bulk terminals, and (2) exposures to liquids which contain benzene in amounts of one percent or less by volume. (This exclusion would be reduced to liquids containing 0.1 percent or less by volume after one year).

Although OSHA recognizes the need to develop appropriate control equipment to minimize the loss of gasoline vapors containing benzene and prevent hazardous exposures to employees, OSHA has announced that the final standard will not cover those operations involved in the storage, transportation, distribution, dispensing or sale of gasoline as a fuel subsequent to its discharge from bulk terminals. Rather OSHA is participating in a joint Federal task force with the Environmental Protection Agency (EPA) and the National Institute for Occupational Safety and Health (NIOSH) to coordinate regulatory efforts to reduce both the worker's and the public's exposures to benzene released from gasoline.

At the conclusion of the task force's deliberations, OSHA will decide whether to commence an independent rulemaking proceeding concerning worker exposure to benzene in these operations or to take other appropriate regulatory action in conjunction with EPA.

With regard to liquids containing a certain percentage of benzene, the proposed standard would not apply where the only occupational exposure to benzene was to liquids containing benzene in amounts of one percent or less by volume (0.1% after one year). Benzene is a contaminant as well as an additive in a multitude of industrial substances; for example, benzene is found in toluene, gasoline, xylene, petroleum naphthas, and other hydrocarbon derivatives. The degree of benzene contamination in these and other materials is variable depending upon the practices of individual refineries and the material specifications established by many large volume solvent purchasers.

The Emergency Temporary Standard (ETS) excluded mixtures containing one percent or less benzene by volume based upon OSHA's concern for the feasibility of requiring employers to implement such regulatory activities in so large a number of establishments in a short period of time. Moreover, there was some evidence which indicated that employee exposures to these substances were generally less than one part per million (ppm). However, in the case of a permanent standard, OSHA believed that a more careful consideration of this issue was necessary as there was only limited evidence which served to correlate the potential exposure levels with the amount of benzene contaminant in solvent mixtures. As pointed out in the ETS, there is some indication that exposures resulting from the use of mixtures containing less than one percent benzene will generally be less than one ppm. However, it is not clear that this would always be the case.

The Arthur D. Little study of technological feasibility and economic impact (EIA) prepared for OSHA presented a summary of the data on the benzene content of various solvents and employee exposures that reportedly result from the use of these solvents. For example, within the rubber industry, employee exposure to benzene during tire building operations ranges from one to three ppm on an eight-hour time-weighted average basis. These exposures result from the use of petroleum naptha (white gasoline) which contains benzene in amounts ranging up to four percent by volume.[1]

It is OSHA's belief, based on evidence received in this and other rulemakings, that there is no known safe level for exposure to a carcinogen such as benzene. However, benzene is a widespread contaminant in industrial substances and is present in a large number of workplaces. As noted above, there is limited evidence presently available to predict the exposure that would typically result from the use of many of these substances. OSHA recognizes that the lower the benzene content, generally the lower the worker exposure. Consistent with its general policy of limiting exposure to carcinogens to the lowest feasible level, OSHA intended to exempt from the permanent standard only those substances for which the benzene content has been reduced to the greatest extent feasible. Therefore, OSHA has proposed a stepdown procedure exempting those workplaces in which employee exposure to benzene occurs only from liquids containing benzene of one percent or less, with a reduction of that percentage to 0.1 percent benzene after one year. OSHA believes that the 0.1 percent exemption would result in worker exposures below the permissible exposure limit. The one-year time period was considered necessary to permit reformulation of products containing benzene, and substitution or disposal (perhaps by use) of existing stocks of products already in the channels of trade.

B. Permissible Exposure Limit

The proposed standard has separate permissible limits for airborne exposure and for eye and dermal exposures.

(1) Airborne exposure limits. Considerable scientific opinion supports the regulatory policy that, for carcinogens, no safe level exists for any exposed population. For example, the National Cancer Institute's Ad Hoc Committee on the Evaluation of Low Levels of Environmental Chemical Carcinogens (1970) stated:

> No level of exposure to a chemical carcinogen should be considered toxicologically insignificant for man. For carcinogenic agents, a "safe level for man" cannot be established by application of our present knowledge. (NCI, 1970, p. 1).

Furthermore NIOSH has stated that, "it is not possible at the present time to establish an exposure level at which benzene may be regarded to be without danger," a position which it has consistently taken with regard to other carcinogens.

This regulatory policy is consistent with previous OSHA actions to control employee exposure to carcinogens; see, e.g. the preamble to the carcinogen standards, 29 CFR 1910.1003 et seq. (39 FR 3758); the vinyl chloride standard, 29 CFR 1910.1017 (39 FR 35892) and the coke oven emissions standard, 29 CFR 1910.1029 (41 Fr 46742). Thus, the proposed level of one ppm has been chosen, not as a "safe" or "no effect" level, but on the basis of OSHA's belief, for the reasons set forth in the technical feasibility and economic impact study (EIA) prepared for OSHA by Arthur D. Little Co., that one ppm is the lowest level that generally can be achieved at this time.

(2) Ceiling limit. In addition to limiting eight-hour timeweighted average exposures to one ppm, the proposed standard required that no employee be exposed to benzene in excess of five ppm averaged over any 15-minute period. An employee may be exposed to varying concentrations of benzene during the course of the workday with some periods of exposure above one ppm and corresponding periods below one ppm. OSHA has determined that the peak excursions permitted under the present standard are not appropriate in regulating exposure to benzene--a human leukemia hazard for which no safe level can be determined. For this reason, a 15-minute ceiling limit of five ppm was established to limit the magnitude of brief excursions which might otherwise occur even where the eight-hour time-weighted average was not exceeded.

(3) Dermal and eye exposure limits. The proposed standard prohibited eye and repeated or prolonged skin exposure to liquid benzene. While the

limited studies are not conclusive to indicate whether benzene is or is not readily absorbed through intact skin, it is known direct contact with liquid benzene can cause blistering and breakage of the skin surface.[2,3] Under these circumstances, or where the skin is otherwise broken, prolonged or repeated skin contact may result in significant absorption of benzene.

C. Regulated Areas

When employee exposure is in excess of the permissible exposure limit, the employer would be required to establish a regulated area. The purpose of establishing regulated areas is to limit benzene exposure to as few employees as possible. The burden on the employer was expected to be minimal since the proposed provisions would require the employer merely to identify and control access to regulated areas and to notify the applicable OSHA area office of their existence and the conditions therein.

D. Notification of Use

The proposed standard required employers to notify OSHA of the location of workplaces in which benzene is used and to describe the conditions of use and protective measures in effect.

E. Monitoring of exposure

The proposed standard required employers to monitor each workplace where benzene is present to determine employee exposure. Such determinations may be made by monitoring and measurements which are representative of each employee's exposure to benzene over an eight-hour period. Actual measurements of airborne concentrations of benzene would be required in order to determine employee exposure to benzene. However, employers would not have to measure the exposure of each individual employee.

Where the initial measurements reveal benzene exposure to be above the permissible exposure limit, monthly monitoring would be required. Measurements which reveal levels of exposure to benzene below the permissible exposure limit would require quarterly monitoring.

The results of the exposure measurement program would determine what further action must be taken by the employer. In addition to monthly monitoring, measurement of exposures above the permissible exposure limit would require the employer to institute controls to reduce the exposure to or below the permissible exposure limit.

In establishing the monitoring and measurement requirements of this proposed standard, OSHA has considered the importance of such activities to identifying exposed employees and their levels of exposure so that appropriate protective measures may be taken. OSHA has also considered the question of the feasibility of immediately complying with the monitoring requirements specified.

Performing the required measurements of employee exposure to benzene will generally involve the use of portable battery-powered air sampling pumps worn by the employee during the sampling period, charcoal tubes for absorption of the benzene, and access to appropriate laboratory facilities for subsequent analysis of the charcoal tube samples. The laboratory analysis would usually be performed using gas chromotography, a technique commonly available in analytical laboratories and utilized for the analysis of a wide range of air contaminants found in samples of the workplace environment and general community. The proposed standard provided that the initial sampling be conducted and results obtained within 30 days of the effective date of the standard. The standard did not require a separate measurement for each affected employee. It required only that sufficient measurements be obtained to be representative of the exposure of all affected employees.

OSHA noted that the monitoring requirements would apply principally in the industries engaged in benzene production, gasoline production and related chemical industries. These industries are generally regarded to be at the forefront of all industries with respect to existing industrial hygiene and occupational health programs. Many of the employers in these industries have extensive professional and technical staffs and established employee health programs which include periodic measurement of employee exposure to benzene. Thus these employers were expected to have little difficulty in complying with the monitoring requirements of the proposed standard. Some of these employers have had to acquire much of the apparatus and equipment required for measuring employee exposure to benzene in order to comply with other occupational health standards previously issued by this Agency. For example, those employers engaged in manufacturing or use of vinyl chloride and polyvinyl chloride and employers engaged in the operation of coke ovens--one source of benzene production, will find that much of the effort made earlier in complying with the standards for vinyl chloride and coke oven emissions will be applicable to the requirements under this standard for measuring employee exposure to benzene.

F. Methods of Compliance

The proposed standard would require the employer to institute engineering and work practice controls to reduce employee exposures to or below the permissible limits. In situations where engineering and work practice controls that can be instituted immediately would not reduce exposures to the permissible exposure limit, these controls must nonetheless be used to reduce exposures to the lowest feasible level and be supplemented by respirators. In addition, a compliance program to reduce exposures to within the permissible exposure limits solely by means of engineering and work practice controls must be developed and implemented. Written plans for this program must be developed and be furnished upon request for examination and copying to representatives of the Director or affected employees. These plans must be reviewed and updated periodically to reflect the current status of the program.

Engineering controls are the preferred means of compliance because they reduce exposure hazards in the workplace environment by removing the airborne contaminant. Engineering controls may include the installation of local exhaust ventilation, modification of a process so as to reduce emission of the contaminant into the workplace, or substitution of another substance for benzene. Work practices often are necessary for the effective operation of engineering controls, and, therefore, they are also preferred as a means of control.

Respirators are the least satisfactory means of exposure control because of certain difficulties inherent in their use. Respirators are capable of providing good protection only if they are properly selected for the concentrations of airborne contaminants present, properly fitted to the employee, worn by the employee and replaced when they have ceased to provide protection. While it is theoretically possible for all of these conditions to be met, it is more often the case that they are not. As a consequence, the protection of employees by respirators is not always effective.

G. Medical Surveillance

The proposed standard required employers to institute a program of medical surveillance for all employees exposed to benzene, which included some thorough and sensitive blood tests. OSHA believed that these tests would permit comprehensive evaluation of hematopoietic functions and thereby increase the detection of bone marrow toxicity. In particular, the reticulocyte assay, a sensitive means of estimating changes in red cell production, may indicate impairment of the marrow when other indices appear normal, such as in the case of subtle anemias. Likewise, serum bilirubin tests provide a means of detecting early phases of benzene induced anemia which may be hemolytic in nature. There is not complete agreement as to which parameter of hematologic function is the first indicator of benzene intoxication resulting from chronic low-level exposures to benzene. However, OSHA believed that these blood tests need to be conducted on a quarterly basis. OSHA has accepted this recommendation based upon the Agency's view that this frequency is adequate to detect changes in the components of the blood which indicate benzene intoxication, while not placing an inappropriate burden upon the employer or the employee.

H. Employee Education and Training

Information and training are important to protect employees from workplace cancer hazards. Appropriate training of employees can result in immediate benefits in terms of reduced exposures. To be effective, an employee education system must fully inform the employee of the specific hazards associated with the work environment. For this reason, the employer would be required to inform each employee who is assigned to work in the presence of benzene about the specific operations where benzene exposure may occur and about proper procedures to avoid unnecessary exposure. The required training program must, among other things advise employees of the signs and symptoms of exposure to benzene, the purpose of the medical tests, and the purpose, proper use, and limitations of respirators.

I. Signs and Labels

It is important for the protection of employees that appropriate forms of warning, as necessary, be used to inform employees of the hazards to which they are exposed in the course of their employment. In light of the grave danger posed by exposure to benzene, OSHA believed that signs were necessary, in addition to the periodic training program, for informing employees of the carcinogenic hazard of benzene exposure.

For the same reason, the proposal included a requirement that caution labels be affixed to all containers of benzene and of the products containing benzene, not only because of the hazardous nature of benzene exposure, but because of the related necessity for both the employer and employee to know whether the product contains any benzene. The labeling provision also required the employer to assure that caution labels are affixed to any product containing benzene when such product leaves the employer's workplace. This proposed requirement was designed to protect any other employees who may be handling, transporting, or using this product. Thus both manufacturers and suppliers would be required to affix caution labels. The rationale for this requirement was based on the fact that the manufacturer or supplier is in the best position to know whether a product does contain benzene.

J. Recordkeeping

The proposed standard required the employer to keep written records of employee exposure measurements and medical examinations. Symptoms of leukemia may not appear for many years after the last exposure to benzene. Thus, records of exposure measurements and medical examinations should be retained for a definite period of years even after the employee ceases to work. For this reason, the recordkeeping provisions of the proposal required the employer to retain these records for at least 40 years, or for the duration of employment plus 20 years, whichever is longer.

K. Appendixes

Three appendixes were attached to the proposed standard for informational purposes. These appendixes did not impose any additional requirements on the employer.

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[1] Technology Assessment and Economic Impact Study of an OSHA Regulation for Benzene, prepared for U.S. Department of Labor, Occupational Safety and Administration; Arthur D. Little, Inc., Cambridge, Massachusetts, May 1977.

[2] Conca, G. L. and A. Maltagilati. (Study of the Percutaneous Benzene Adsorption) Med. Lavoro 46:194-98, 1955 (Ital).

[3] Cesaro, A. N. (Is Absorption of Benzene through the Skin Possible? Med. Lavoro 37:151-156, 1946 (Ital).

V. PROJECTED ENVIRONMENTAL IMPACTS OF THE PROPOSED STANDARD

The proposed standard for occupational exposure to benzene has the potential for impacting two environments: the workplace environment and the general human environment external to the workplace. This chapter discusses the projected impacts of the proposal on both of these environments in terms of air quality, water quality, waste disposal (a function of land use, air quality and water quality), energy consumption, human resources, and economic costs, including long-term productivity.

A. Air Pollution Impact

The importance of benzene in air pollution is related to the growing concern for long-term exposure to low levels by large numbers of people. Benzene's participation in the formation of photochemical oxidants is minimal, and as a result, it is generally omitted from control efforts to reduce the formation of photochemical oxidants. However, the evidence regarding the leukemia hazard of exposure to benzene must be taken into account in evaluating the environmental impact of this proposal.

Sampling for air pollutants has been largely concerned with total hydrocarbon levels in the atmosphere. However, several studies as summarized in Table I have been conducted to specifically evaluate benzene levels. These studies were carried out in Los Angeles, Toronto, Zurich and the Netherlands and the data in Table I indicate that ambient benzene concentrations in the urban atmosphere are normally well below 100 ppb (0.1 ppm) and have an average concentration of approximately 16 ppb (0.016 ppm). In the Los Angeles, Toronto and Netherlands studies it was

TABLE I[1]

COMPARISON OF MEASUREMENT RESULTS OF SEVERAL SITES, CONCENTRATIONS IN PPB

		Benzene	
		Maximum	Average
Los Angeles		57.0	15
Toronto		98.0	13
Zurich		74.0	35
Netherlands:	Delft	8.0	1
	The Hague	29.0	9
	Tunnel*	33.2	25

*High traffic area

SOURCE: Modified from: Burghardt, E. and Jeltes, R., "Gas Chromatographic Determination of Aromatic Hydrocarbons in Air Using a Semi-Automatic Preconcentration Method, Atmospheric Environment," Vol. 9, pp. 935-940.

noted that the benzene concentrations found at sampling sites adjacent to major roadways were highly correlated with periods of heavy traffic volume. This suggests that the motor vehicle is a source of benzene in community air as a result of both incompletely combusted exhaust emissions and direct evaporation from vehicle gas tanks.

Although motor vehicles are an important source of benzene emissions, other activities also contribute to ambient concentrations (See Table II). Those which may be affected by the proposed OSHA standard are discussed below.

1. Production. A report prepared by the Mitre Corporation estimates that the quantity of benzene currently lost during commercial production, storage and transport is 79 million pounds.[2] These emissions are largely derived from petroleum cracking facilities which currently contribute approximately 95 percent of the Nation's total output for benzene.[3] A secondary source of benzene is as a by-product of coke production. Emissions from coke ovens are estimated to be greater than those from petroleum refineries (122 million pounds) because coking is not a closed system process. Coke ovens, however, contribute only five percent of total U.S. benzene production.

Emissions from these production sources are related to a variety of operations including equipment repair and maintenance, clean-up of small spills, transfer of materials, and the normal operation of process equipment. Additional emissions result from blow down systems, waste water separators, cooling towers and storage facilities. Fugitive emission sources include leaking pumps and compressor seals, pressure

TABLE II[2]
BENZENE EMISSIONS TO THE ENVIRONMENT -- 1971
(IN MILLIONS OF POUNDS)

Source	Location	Quantity	Media of Entry
Commercial benzene production, storage and transport	Primarily southwest	79.0 (assumed 1% of total production)	Air Water
Commercial benzene usage	Primarily southwest and northeast	658 (based on reaction yields)	Air Water
Oil Spills	Oceans and Rivers	22-24	Water
Motor Vehicle Emissions	Similar to population distribution	1,000	Air
Coke Ovens	Primarily, North Central States and Alabama	122 (1974)	Air

SOURCE: Modified from Walker, P., "Air Pollution Assessment of Benzene; Mitre Technical Report," MTR-7188, Mitre Corporation, McLean, Va., 1976.

relief valves, pipeline valves and flanges, changing pipeline blinds and purging sample lines. The relative magnitude of benzene emissions can be based in part upon the emission factors summarized in Table III. These data are representative of total hydrocarbon emissions, but are pertinent to the evaluation of benzene releases where they constitute a portion of the process stream.

In those industries engaged in the production of benzene either directly or as a by-product, promulgation of a revised standard which lowers the permissible exposure limit (PEL) for benzene will have the effect of reducing overall benzene emissions, because greater control will be maintained over leaking process equipment and fugitive emissions. This may be considered a benefit to both the workplace and ambient air quality.

2. Storage and transportation. Benzene emissions occur during the transportation and storage of benzene (either in pure form or as part of a mixture such as gasoline). Expected means of compliance would include engineering controls such as internal floating roofs on storage tanks, bottom loading assemblies and vapor condensing and/or return equipment, as well as work practice controls and respirators. Table IV illustrates the expected hydrocarbon emission rates (a portion of these amounts are benzene) resulting from storage and transfer operations.[4] Table V indicates employee exposures to benzene occurring during such operations. The application of vapor return or recovery equipment, as well as internal floating roofs and bottom

TABLE III[4]
EMISSION FACTORS FOR PETROLEUM REFINERIES

Type of Process	Hydrocarbons
Fluid catalytic cracking units (FCC	
$lb/10^3$ bbl fresh feed	220.0
$kg/10^3$ liters fresh feed	0.630
Moving-bed catalytic cracking unites (TCC)	
$lb/10^3$ bbl fresh feed	87.0
$kg/10^3$ liters fresh feed	0.250
Blowdown systems	
$lb/10^3$ bbl refinery capacity	
with control	5.0
without control	300.0
$kg/10^3$ liters refinery capacity	
with control	0.014
without control	0.860
Process drains	
$lb/10^3$ bbl waste water	
with control	8.0
without control	210.0
$kg/20^3$ liters waste water	
with control	0.023
without control	0.600
Vacuum jets	
$lb/10^3$ bbl vacuum distillation	
with control	Neg
without control	130.0
$kg/10^3$ liters vacuum distillation	
with control	Neg
without control	0.370
Cooling tower	
$lb/10^6$ gal cooling water	6.0
$kg/10^6$ liters cooling water	0.72
Miscellaneous losses, $lb/0^3$ bbl refinery capacity*	
Pipeline valves and flanges	28 (0.080)
Vessel relief valves	11 (0.031)
Pump seals	17 (0.049)
Compressor seals	5 (0.014)
Others (air blowing, sampling, etc.)	10 (0.029)

*$kg/10^3$ liters shown in parentheses.

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TABLE IV[4]

HYDROCARBON EMISSION FACTORS FOR EVAPORATION LOSSES FROM THE STORAGE OF PETROLEUM PRODUCTS

Type of tank[a]	Units	Type of material stored: Gasoline or finished petroleum product	Type of material stored: Crude oil
Fixed roof			
Breathing loss	lb/day-1000 gal storage capacity	0.4	0.3
	kg/day-1000 liters storage capacity	0.05	0.04
Working loss[b]	lb/1000 gal throughput	11.0	8.0
	kg/1000 liters throughput	1.32	0.96
Floating roof			
Breathing loss	lb/day-tank	140(40 to 210)[c]	100(30 to 160[d]
	kg/day-tank	63.5	45.4
Working loss	lb/1000 gal throughput	Neg	Neg
	kg/1000 liters throughput	Neg	Neg

[a]For tanks equipped with vapor-recovery systems, emissions are negligible.

[b]An average turnover rate for petroleum storage in approximately 6. Thus, the throughput is equal to 6 times the capacity.

[c]140 (63.5) based on average conditions and tank diameter of 100 ft (30.5m); use 40 (18.1 kg) for smaller tanks, 50 ft (15.3 m) diameter; use 210 (95 kg) for larger tanks, 150 ft (45.8 m) diameter.

[d]Use 30 (13.6 kg) for smaller tanks, 50 ft (15.3 m) diameter; use 160 (72.5 kg) for larger tanks, 150 ft (45.8 m) diameter.

TABLE V[3]
EXPOSURE TO BENZENE DURING STORAGE
AND TRANSFER OPERATIONS

Mode of Transportation		Location	Exposure Level (ppm)
Tank Truck			
	1	loading point (upwind)	N.D.*
	2	control house (during hook-up)	<1.0
	3	3-5 feet from connection	0-.9
	4	loading tank truck	30
	5	sampling shipment	30
	6	directly above hatch	400
	7	disconnect lines	75
Tank Car			
	1	25' downwind from loading point	60
	2	50' downwind from loading point	10
	3	hatch opening	104,000
	4	downwind of tank car	100
		downwind of tank car	260
	5	sample shipment	30
Barge/Tank Ship		10-20' from vent stack	7-20
		barge personnel	1
		barge personnel downwind	30
		dock samples	1
		dock house	< 1
		hatchway	100
		8 hour TWA (estimated)	1-5
		dockman's station	trace
		dock manifold before docking	Nil
		dock manifold during hookup	Nil
		walkway downwind from vent	11
		ullage at breathing zone of gauger	130
		making connections	10
		loading tank	12
		at vent line	1400
		ullage port	600
		20' downwind from dock	7
		connecting load line	3
		disconnecting load line	10

TABLE V[3] (cont)

Mode of Transportation	Location	Exposure Level (ppm)
Storage Facilities		
	top of tank	375
	downwind of tank vent	<10
	25' downwind from floating roof tank	0
	gauger	30

SOURCES:

1. American Petroleum Institute
2. OSHA - Survey of Employee Exposure to Benzene During Transfer Oper-tions.

*N.D. = not detectable

loading assemblies, will largely eliminate workplace and ambient emissions, resulting in an environmental benefit. Where respirators are used to protect employees, no benefit will accrue to the external environment.

3. Commercial usage: chemical processing. The chemical process industries utilizing benzene feedstock material were evaluated during the development of the Economic Impact Assessment (EIA).[3] It was determined that these operations were largely in compliance with the previous OSHA standard due to the constraints of closed system operations and the economics of preventing losses of feedstock and products. Possible, though infrequent, over-exposures would be due to non-routine situations such as process upsets or equipment failure.

As with the benzene production facilities, engineering controls may be necessary to comply with a one ppm benzene standard. Controls would be very similar in type and extent to those used in the production facilities to reduce emissions during process operations and from fugitive sources. The reduction in process and fugitive losses may result in a slight reduction in both benzene emissions and those of its process intermediates.

4. Commercial usage: solvent usage. Benzene has been largely removed from solvent applications, often being replaced by toluene, (which, however, does contain a small percentage of benzene), xylene, heptane, petroleum naptha, trichloroethylene or methylene chloride. Benzene is still found in a limited number of specialized low volume applications

such as proprietary adhesives within the rubber industry and in paint remover formulations.

The purpose of solvent materials is simply to provide a vehicle for solid materials to facilitate application procedures. As such, much of the benzene used as solvent is lost by evaporation upon application. Only a limited number of processess within the adhesives and printing industries use vapor recovery equipment as a method of solvent recovery and recycling.

Exposure control of this compound in solvent application involves a variety of alternatives.[3] Primary among the control alternatives would be general dilution and local exhaust ventilation systems or product reformulation to either reduce or remove the benzene component. These alternatives will be discussed separately for their possible environmental impacts.

A common method for protecting workers from solvent vapors is to provide adequate ventilation to both dilute the vapors with fresh air and to carry them out of the worker's breathing zone. This approach to exposure reduction finds widespread application within industries having adhesive and coating solvent exposures. The necessary equipment and design knowledge for spray booth and ventilation-hood installations is readily available for these applications. In many cases, existing equipment can be adapted to achieve lower exposures by increasing the velocity of the fans or reducing the area of the ventilation ducts or booth areas.

Since the purpose of ventilation equipment is to remove vapors from the work environment, once this task is accomplished, the exhausted air, including the vapors, is often emitted directly into the external environment. The vapor concentration in the exhaust is often so low that further treatment is considerably more difficult. When the exhaust air contains large amounts of particulate matter, as from a paint spray operation, or particularly malodorous vapors, air treatment becomes more necessary. Such exhaust treatment is normally accomplished with some form of air filtration (either water spray or fiber beds) or by sending the exhaust air through a burner unit to incinerate the undesirable gases and particles. In summary, when exhaust ventilation is used to remove benzene, the air quality of the worker's environment will be improved. If this exhausted air is then treated as mentioned above, the air quality of the general human environment external to the workplace will also be somewhat improved.

The second general method used to reduce benzene exposures from solvent usage is reformulation. In this approach other solvents may be substituted for either part or all of the benzene or the benzene contamination of other solvents reduced; equipment may be developed to utilize a higher solid content solution (i.e., less solvent per volume of material applied); solvent systems may be completely replaced with water based and hot melt applications; or, in extreme cases, the process involving the solvent may be discontinued entirely. Analysis in the EIA demonstrates examples of each of these reformulation possibilities. The coatings industry is exploring possibilities of high solids and water based coating applications systems.[5] Manufacturers of paint removers are substituting other solvents for benzene. Adhesives manufacturers are beginning to utilize other systems including substitution of solvents such as methyl ethyl ketone, water based systems and new solventless systems that are liquidfied by heat and form the adhesive bond when they cool and solidify ("hot melt" adhesives).[4]

The environmental impacts of reformulation schemes are varied. In the cases of substitution of another organic solvent for benzene, the effective environmental emissions may not be considerably altered. Altering the original photoactive hydrocarbon released into the atmosphere may not effectively alter the impact upon photochemical oxidant formation if the substitute is also photoactive. High solids applications, however, will have positive impacts since the total amounts of solvents needed per application will be reduced. Here positive impacts will be directly proportional to the reduction in solvent content of the coating vehicle. For reformulations entirely removing the organic solvent vehicle such as in water based or hot melt systems, the adverse impacts of atmospheric hydrocarbon emissions, including benzene, will be effectively eliminated.

Once the alternatives of worker exposure control for the solvent applications of benzene are reviewed, it becomes apparent that there is a potential for a variety of ambient air pollution impacts resulting from the proposed OSHA regulation depending on the control technology employed.

OSHA does not currently require the use of specific engineering controls; thus it is difficult to predict and quantify the potential environmental impacts. In cases where conventional ventilation or solvent switching (to another organic solvent) is practiced, the atmospheric impact is not expected to be significant. Where reformulation is practiced to reduce solvent usage, however, the atmosphere will realize a reduction in total hydrocarbon load.

5. Motor vehicle emissions. While this is perhaps one of the most important sources of benzene emissions, it is excluded from this particular rule as the emissions are a result of gasoline combustion after distribution from bulk terminals and thus are not covered by the proposed standard. The proposed standard probably will not affect the quantity or quality of benzene emissions resulting from motor vehicle use.

B. Water Pollution Impact

The relatively moderate water solubility of benzene, compared to other hydrocarbons (1780 mg/l at 25°C), and its vapor pressure (95.2 mmHg at 25°C) are important parameters in the determination of the substance's potential for contamination of water. Because of its moderate solubility in water, benzene may be washed out of the atmosphere with rain. In combination with the evaporation process, this would result in a continuous cycling between air and water.

The three major industrial sectors having emissions which emit benzene to the aquatic environment appear to be: (1) chemical production and processing; (2) coating operations, and (3) storage-transportation. While engineering controls would act to reduce leakage and spills of compounds, work practice controls would tend to emphasize a prompt response to spills with flushing to waste chemical-drains. From chemical drains the materials would proceed to oil separators where the organic materials are recycled to the production system. Some amount of material, however, including benzene, might escape into the water effluent.[6] In comparison to the reduction of leaks and spills expected to result from the regulation, the potential increase in effluent emission due to more efficient work practices is not expected to be significant, and in the long-term an overall reduction in emissions should result.

It is also anticipated that reformulation to water-based systems in industries now using benzene solvents may have some water quality impact due to the necessity for disposal of larger amounts of water containing paint solids, although this impact may not be significant.

C. Solid Waste Impacts

As discussed previously, methods to comply with the proposed benzene regulation are largely aimed at preventing releases to the air and, to a lesser extent, to the water. Since the projected control measures largely involve work practices and the use of durable equipment to either prevent or redirect vapor emissions, impacts of the proposed OSHA standard upon solid waste loads are expected to be minimal, if not completely negligible.

D. Human Resources Impacts

As stated earlier in this document, the intent of the OSHA standard for occupational exposure to benzene is to protect employees from the health hazards associated with such exposures. Health benefits resulting from control of benzene include prevention of blood and bone marrow poisoning as well as lowering the worker's risk of leukemia. Reduced rates of industrial accidents and short term illnesses due to overexposure to benzene are also viewed as the proposed standard's beneficial impacts.

A further impact of the proposal will be an increased demand for professional medical and industrial hygiene resources. As the standard is proposed, some exposure monitoring and medical surveillance requirements are initiated wherever benzene is present. Considering the ubiquitous nature of the substance, this would mean that nearly all establishments with employees, except those excluded by this proposal, would be subject to the benzene standard. The impacts of this standard on medical and industrial hygiene resources are, therefore, expected to be substantial. This impact could be mitigated if an action level provision were included in the final standard (See Chapter VI, Section B for a discussion of the action level alternative.)

E. Energy Impact

Within the scope of the proposed OSHA benzene standard the only activities requiring an increase in energy demand would be increased workplace ventilation and the resulting need to condition greater volumes of make-up air. The EIA estimated that industry's compliance costs for engineering control would result primarily from the tightening up of production processes, and the installation of new hardware (i.e., rupture disks, floating roofs, vapor control systems and mechanical seals).[3] Since engineering control requirements were based upon slight modification to existing inplant systems, the EIA judged increased energy consumption to be "negligible."

No evidence was submitted into the record of this rulemaking which would refute this conclusion.

F. Land Use Impact.

As detailed in the EIA analysis and other material submitted into the public record of this rulemaking, compliance activities for this proposed regulation are expected to consist of modifications to existing control equipment and work practice controls where necessary. These modifications should be easily completed in existing areas and little, if any, additional land usage should result. Thus, the land use impact of the proposal is judged to be insignificant.

G. Economic Impact.

The EIA prepared for OSHA estimated compliance costs for 20 industry sectors engaged in benzene production, benzene transportation, chemical processing, petroleum refining and related activities, production of rubber products and laboratory activities; covering 24,312 facilities and

196,875 employees.[3] The EIA estimated total first-year operating costs for these industries of $124,028,000. Recurring operating costs were estimated to total $74,352,000 while total capital investment was estimated to be $267,331,000.

The EIA's estimates were challenged during the public hearing by several industry witnesses. It was argued that the EIA underestimated the number of employees exposed and that, therefore, monitoring, medical surveillance, training and recordkeeping costs for several industry sectors were severely underestimated.[7] Further, industry criticized the EIA's failure to include downtime costs, i.e. lost production during the installation of controls. The American Petroleum Institute's estimates of cost based on these factors resulted in first-year operating costs and recurring cost figures more than twice those reported in the EIA.

The EIA's economic impact analysis indicated no significant changes in the supply or demand for energy or critical materials. It estimated that compliance costs, if passed on to buyers would raise the price of benzene approximately one percent over the long term. Increased labor costs for compliance activities were estimated at 49.7 thousand manhours for coke producers and 30.0 thousand manhours for petroleum refineries resulting in an average reduction in labor productivity of 1.4 percent and 0.6 percent, respectively.[3]

For the benzene chemical industry, the EIA estimated average price increases of 0.7 to 1.0 percent and projected no changes in market structure or concentration. A 0.5 percent decline in productivity was estimated to result from the increased labor required for compliance.

In the rubber products industry sector, the EIA estimated first years compliance costs would amount to approximately one percent of the value of shipments, while productivity would fall 0.5 percent for tire makers and 1.5 percent for producers of other rubber products.

For laboratory operations using benzene, the proposed standard was estimated to result in an increase in the price of some procedures by as much as five percent, while productivity declines by less than 0.1 percent.

Criticisms of the EIA analysis were confined mostly to methodology, i.e. questioning the scope of the study and the assumptions that were used. No quantitative estimates were presented in rebuttal of the EIA's economic analysis.

In summary, it appears that the major dispute over economic costs centers on the number of employees that will ultimately be included in the final OSHA standard for benzene. The magnitude of impact rests on the scope of the standard, the level to which airborne concentrations will be regulated and whether, and to what levels, mixtures containing benzene will be regulated.

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[1] Burghardt, E. and Jeltes, R.; Gas Chromatographic Determination of Aromatic Hydrocarbons in Air Using a Semi-Automatic Preconcentration Method; Atmospheric Environ., 9, 355-940; 1975.

[2] Walker, P.; Air Pollution Assessment of Benzene; Mitre Technical Report, MTR-7188; Mitre Corporation, McLean, Va.; 1976.

[3]Technology Assessment and Economic Impact Study of an OSHA Regulation for Benzene, prepared for U.S. Department of Labor, Occupational Safety and Health Administration by Arthur D. Little, Inc., Cambridge, Mass., May 1977.

[4]Adapted from: Compilation of Air Pollution Emission Factors (Revised), U.S. Environmental Protection Agency, AP-42; 1972.

[5]Ellerhorst, H.; Energy Crisis; Catalyst for Change; Modern Paint and Coatings, p. 31-33; October 1975.

[6]Communication with Mr. J. L. Goodier, Bio-Enviro Section, Arthur D. Little, Inc., Cambridge, Massachusetts; December 1976.

[7]See testimony and submissions of American Iron and Steel Institute and American Petroleum Institute.

VI. ALTERNATIVES TO THE PROPOSAL

There are four major areas of regulatory decision making which affect the impact of the benzene standard on the environment external to the workplace. These are: (1) the scope and application of the regulation, (2) the airborne permissible exposure limit, (3) the frequency of required exposure measurements and medical examinations, etc., and (4) the methods by which compliance is mandated. The purpose of this chapter is to present the alternatives available to OSHA in setting regulations for the protection of employees from the hazards associated with exposure to benzene.

A. Scope and Application Alternatives

Scope and application alternatives may affect the magnitude of environmental impact in the areas of: (1) the number of employees and workplaces covered by the standard, (2) economic costs of implementing the standard, and (3) human resources (i.e. professional medical and technical personnel needed to conduct the activities required by the standard.

The scope and application section of the proposed standard stated that it applied to the production, reaction, release, packaging, repackaging, storage, transportation, handling or use of benzene, with the exception that the proposal excluded those workplaces involved in the storage, transportation, distribution, dispensing or sale of gasoline as a fuel subsequent to discharge from bulk terminals. Thus, all workers exposed to benzene during gasoline sales and distribution activities would not be covered under this standard. The proposal also contained an exclusion for workplaces in which employee exposure is confined to liquids containing one percent or less benzene by volume, with a lowering of this exemption to 0.1 percent within one year of the effective date of the final standard.

Excluding workplaces from the provisions of the proposed standard has obvious economic advantages for many gasoline industry employers in that few would incur compliance costs as a result of the promulgation of this proposed standard. Further, the liquid mixture percentage exclusion would largely eliminate compliance costs for some other industries, such as the paint and coatings industry. The major disadvantage to the proposed exclusions is that many employees who are exposed to benzene would not be covered by the standard and, consequently, may be at risk of developing benzene-related illnesses which might have been avoided if the standard had applied to their workplaces.

As shown by testimony received into the rulemaking record, for example, there appears to be no necessary correlation between the amount of benzene present in liquid mixtures and the potential concentrations to which employees using such mixtures may be exposed.[1] Other factors, such as size of the work area, air flow through the work area, work practices, etc., are the determinants of employee exposure. Further, data submitted on behalf of the National Paint and Coatings Association, Inc., indicated that current employee exposures, in operations involved with the production production of some paint removing products, are in the range of one to three ppm on an eight-hour average. (This is significant in that benzene usually occurs in these products only because it is present as a contaminant in the aliphatic and aromatic hydrocarbon solvents and certain monomers used in paint remover production. That is, benzene is not currently an intentional ingredient in many paint removers due to industry efforts to eliminate direct use of benzene in its formulations. However, benzene-free grades of many of the alternative solvents used in paint remover production are not commercially available).[2]

As it has been shown that there is little correlation between the amount of benzene present in liquid mixtures and the actual concentrations to which employees are exposed, an alternative for the Assistant Secretary to consider would involve a change in the proposed standard to eliminate the percentage exclusion and to base the requirements of the standard on the actual employee exposure which results from the use of solvent mixtures containing benzene. Such changes would result in increased compliance costs for industry, but OSHA did not attempt to quantify these costs in the EIA and received little quantitative data as to what these additional costs would be. However, even a rough estimate would indicate them to be very high. (Testimony from the American Petroleum Institute, for example, indicated that elimination of the percentage exclusion or exclusion at the 0.1 percent level would at least double their current compliance cost estimates for the petroleum industry.[3]) A mitigating factor which might reduce these costs, however, would be the institution of an action level provision as discussed in sections B and C of this chapter. That is, rather than excluding employees from compliance on the basis of percentage benzene content, employers would have only a few provisions to comply with if employee exposures were below the permissible level but above the action level.

B. Permissible Exposure Limit Alternatives

During the course of this rulemaking hearing numerous PEL alternatives have been suggested. The following sections outline these alternatives.

(1) Institution of an action level. Many of the participants in the benzene rulemaking hearing suggested that an action level be adopted.[4] The action level would be some level, below the permissible exposure limit, at which employers would be required to institute certain minimum monitoring, medical surveillance, training and recordkeeping activities, rather than the full requirements of the standard as now proposed. The major advantage of an action level is that it protects employees from potential exposures in excess of the PEL, by requiring the initiation of certain provisions for monitoring, medical surveillance, etc. before the permissible exposure limit is reached and, probably, exceeded.[5]

(2) PEL 0.5 ppm. Some participants in this rulemaking have recommended that the final OSHA standard limit employee exposure to benzene to a maximum of 0.5 ppm for the oil industry and 1 ppm for other industries.[6] This recommendation is based on the view that, in the absence of information concerning a safe level of exposure to a carcinogen, employee exposures should be reduced to the lowest level feasible. The Oil, Chemical and Atomic Workers (OCAW) stated that 0.5 ppm is feasible for

the oil industry on the basis of monitoring figures presented at the rule-making hearing by that industrial segment.

(3) One ppm PEL/ceiling with an action level of 0.5 ppm. NIOSH has recommended that occupational exposure to benzene be controlled so that no employee will be exposed in excess of one ppm as measured over one hour (the ceiling limit) with an action level of 0.5 ppm.[7] The one-hour sampling time used to determine exposure is one-half of that which was recommended by NIOSH in the 1976 update of the criteria document.[8] This recommendation was based upon current sampling technology which indicates that samples be collected by charcoal tube at one liter per minute for one hour. Because benzene is ubiquitious and occurs naturally in the environment, NIOSH recommended defining "exposure to benzene" as exposure at or above 0.5 ppm. It was NIOSH's opinion that incorporating such a definition of "exposure to benzene" would better define the point at which air monitoring and medical surveillance requirements should be implemented by the employer.

(4) PEL 1.0 ppm/ceiling limit 5.0 ppm. This alternative was presented in the proposed permanent standard for occupational exposure to benzene as published in the Federal Register on May 27, 1977. In the preamble to the proposed standard it was stated that the one ppm PEL was chosen not as a "safe" or "no effect" level, but on the basis of OSHA's view that one ppm was the lowest level that generally can be achieved.

(5) PEL 10 ppm/ceiling limit 25 ppm. The previous OSHA standard for benzene, in effect prior to the issuance of the ETS, prescribed an eight-hour time weighted average (TWA) of 10 ppm with a ceiling

concentration of 25 ppm. In addition, it allowed excursions above the ceiling to a maximum peak concentration of 50 ppm, provided that these peaks occurred for no more than 10 minutes in any eight-hour work period. This standard was based largely on benzene's general toxicity rather than on its leukemia hazard.

A number of parties to this rulemaking proceeding advocated retaining the 10 ppm as an eight-hour TWA on the basis that this level represents a threshold limit below which there is no excess risk of cancer. Some parties have suggested that the threshold for increased risk of leukemia lies substantially above 10 ppm and that a 10 ppm level would provide an adequate safety factor. Other parties have suggested that, in some workplaces or particular operations, 10 ppm may be the limit of feasibility.

(6) Ceiling limit 10 ppm/no TWA. Still another alternative which has been suggested concerns the establishment of a 10 ppm ceiling with no permissible exposure limit specified.[10] Thus, the workers' actual eight-hour exposure would "float" below 10 ppm, but in no case would exceed 10 ppm. Such an alternative would be economically advantageous for many industries.

(7) Different exposure limits based on feasibility. Another regulatory alternative is to adopt different standards for different industries, moderating the degree of regulation as deemed necessary for adequate and feasible protection of workers in the various industries where benzene is present.

C. Frequency Alternatives

The proposed standard requires employers to begin exposure measurement, monitoring, medical surveillance, employee training and related recordkeeping activities whenever benzene is present. The term "present" and its definition directly affect the magnitude of impacts the final standard will have on both the workplace and external-to-workplace environments. Without some limiting definition on the term "present," and considering the ubiquitous nature of benzene in our environment, it is possible that a substantial number of employers would be affected by and required to implement at least some of the provisions of the proposed standard.[9] This would impact on the Nation's professional medical and industrial hygiene resources as well as the long-term productivity of many industries.

As an alternative to the proposed standard's requirements, many participants in this rulemaking have suggested that OSHA adopt an action level.[4] (See Section B of this chapter for a definition of action level.)

D. Methods of Compliance Alternatives

OSHA's regulation, 29 CFR 1910.1000, under which benzene was initially regulated, provided that compliance be achieved first through administrative or engineering controls, whenever feasible, and, when such controls were not feasible, through the use of supplementary protective equipment. The proposed standard would require the institution of engineering and work practice controls supplemented by respirators, if necessary, to reduce exposure to or below the PEL. In addition, the proposal requires that a program be established and implemented to reduce exposures to or below the PEL, solely by means of engineering and work practice controls. Protective clothing and equipment are also required where necessary to prevent eye contact or repeated skin contact.

Engineering controls may include the installation of local exhaust ventilation, modification of a process so as to reduce emissions, or substitution of another substance for benzene. Work practice controls most often consist of actions taken by employees to avoid exposures to benzene, such as standing up-wind of fumes, consciously avoiding situations where benzene may be inhaled, etc.

Alternatives involved in the compliance section of the regulation are primarily concerned with establishing a particular priority among the various types of controls (engineering, work practice, and respiratory protective equipment). Sole reliance on engineering controls or on use of engineering and work practices equally could be required. Another alternative would allow the employer complete freedom in choosing the method of control without any required priority systems. Still another alternative approach would be to specify controls, such as reformulation of products to decrease benzene content, or the preferential use of vapor recovery systems over ventilation.

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[1]See testimony of Robert L. Harris, Jr. Occupational Health Studies Group. (Exhibit 160)

[2]Comments submitted on behalf of National Paint and Coatings Association, Inc., by Royal Brown and Bruce Hamill, July 12, 1977. (Exhibit 41-14)

[3]See American Petroleum Institute testimony and exhibits especially Richard J. Zeckhauser. (Exhibit 115.A.12)

[4]See comments of Beacon Oil Company (Exhibit 6-24) American Trucking Association, Inc. (Exhibit 6-32), Diamond Shamrock Corporation (Exhibit 6-72) and NIOSH (Exhibit 84.A)

[5]Leidel, N.A., K.A. Busch and W.E. Crouse. Exposure Measurement Action Level and Occupational Environmental Variability. U.S. Dept. of HEW, NIOSH, Hew Pub. No. (NIOSH) 76-131, December 1975.

[6]Statement of A.F. Grospiron, OCAW. (Exhibit 111.A)

[7]Occupational Exposure to Benzene: Criteria for Recommended Standard. U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, 1974.

[8]Occupational Exposure to Benzene: Criteria for Recommended Standard. U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, August 1976.

[9]Comment of Motor Vehicle Manufacturer's Association (Exhibit 6-43)

[10]"Benzene Ceiling Level Lowered to Ten PPM," Dow Today, No. 41, July 14, 1977. (Exhibit 82)

VII. RELATIONSHIP WITH OTHER FEDERAL ACTIONS

Workers exposed to benzene during industrial operations constitute that portion of the general population most exposed to its health hazards. Any OSHA standard to limit occupational exposure to benzene is written for their protection. However, since benzene is released to the ambient environment and has impacts on the environment external to the workplace, it is also a matter of concern to the Environmental Protection Agency (EPA) which is responsible for safeguarding air quality under the provisions of the Clean Air Act (as amended, 42 U.S.C. 1857 et seq.) and water quality under the provisions of the Water Pollution Control Act of 1972.

On April 14, 1972, EPA was petitioned by the Environmental Defense Fund to list benzene as an agent of concern under section 112 of the Clean Air Act. On June 8, 1977, EPA published a notice in the Federal Register (42 FR 29332) which added benzene to its list of hazardous air pollutants based on the belief that it may cause or contribute to irreversible or incapacitating adverse health effects. Now that benzene has been placed on the list of hazardous air pollutants, EPA must propose a regulation for its control within 180 days.

EPA is currently preparing reports on the health effects of benzene, an assessment of environmental exposure and a risk assessment to be used in determining what regulatory action should be taken. The Agency is also examining the other legislative authorities it has available, in

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addition to the Clean Air Act, to determine whether any of them may be used to achieve reductions in benzene exposures. In its ongoing process of developing water pollution criteria, EPA is currently evaluating aquatic benzene toxicity. At the present time, benzene effluents are controlled as contributors to the total BOD (biological oxygen demand load of industrial effluents. As such, OSHA regulations resulting in slightly more benzene effluent would not conflict with EPA water effluent standards as long as the total BOD level is controlled. While this relationship in regard to water emissions may change with future standard setting on the part of EPA, it is not expected to alter industry's approach to compliance with OSHA benzene regulations. Since benzene is normally only a portion of the effluent produced by a given industry and it does not offer any unusual problems during water treatment compliance with EPA regulations can be expected to be within industry's capabilities.

The Consumer Product Safety Commission (CPSC) was petitioned on May 8, 1977 by the Health Research Group to ban and recall benzene-containing products by its authority under the Hazardous Substances Act. The Agency is currently working to develop regulations which may result in a ban on household products (such as paint solvents and adhesives) containing benzene. It is anticipated that whatever action CPSC may take on this issue should not conflict with OSHA's regulation of occupational exposure to benzene.

Benzene is classed as a flammable liquid under the Department of Transportation (DOT) regulations (49 CFR 172.5) and, as such, is subject to labeling requirements except where exempted under 49 CFR 173.118 and 173.119. Although the proposed OSHA standard requires labeling of all containers of and products containing benzene, the proposed rule is not expected to conflict with DOT labeling requirements as the OSHA labels would be used in addition to, rather than in place of, any required DOT label. The label requirements of the OSHA proposal are based on benzene's cancer hazard while the DOT requirements are based on its flammability and explosion potential.

OSHA, together with NIOSH, EPA and the Coast Guard has established a joint federal agency taskforce to coordinate efforts to reduce both the worker's and the general public's exposures to benzene emitted from gasoline vapors in retail automotive service stations, and in certain other aspects of the transportation, storage, distribution and sale of gasoline and other motor fuels.

VIII. COMMENTS

Comments on the draft environmental impact statement (DEIS) on the proposed regulation for occupational exposure to benzene were solicited in the Federal Register notice of proposal published May 27, 1977 (42 FR 27452). Letters of comment were received from the following:

John D. Jones, Ph.D
Associate Professor of Biochemistry
Mayo Clinic
Rochester, Minnesota

R. G. Whittle, Jr.
Director
Department of Administration
Division of State Planning
State of Florida
Tallahassee, Florida

David H. Senjem
Safety Coordinator
Environmental Safety Committee
Mayo Clinic
Rochester, Minnesota

Larry E. Meierotto
Deputy Assistant Secretary
U.S. Department of the Interior
Washington, D.C.

Kate Wickes
Deputy Director
Division of Natural Resources
State Planning Office
State of New Mexico
Santa Fe, New Mexico

Office for Planning and Programming
State of Iowa
Des Moines, Iowa

Mrs. Sally Corn
State Clearinghouse Reviewer
Indiana State Clearinghouse
State Budget Agency
Indianapolis, Indiana

Hideto Kono
Director
Department of Planning and Economic Development
State of Hawaii
Honolulu, Hawaii

Sidney L. Willis
State Review Coordinator
Department of Community Affairs
State of New Jersey
Trenton, New Jersey

W. H. Pennington
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U.S. Energy Research and Development Administration
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Charles Custard
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Bruce D. Arkell
State Planning Coordination
Governor's Office of Planning Coordination
State of Nevada
Carson City, Nevada

Gilbert J. Saulter
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Occupational Safety and Health
U.S. Department of Labor
Boston, Massachusetts

T.E. Hornbacker
Director
Illinois State Clearinghouse
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State of Illinois
Springfield, Illinois

John E. Tessieri
Vice President
Research and Technical Department
Texaco, Inc.
Beacon, New York

R. L. Daniel
Chairman
Benzene Issue Management Team
The Dow Chemical Company
Freeport, Texas

The comments received from these parties are attached as Appendix III of this final environmental impact statement (FEIS). In addition to these written comments, all data, information, views, and testimony on environmental impacts, received into the record of the benzene rulemaking proceeding, have been reviewed and considered in the development of this FEIS.