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



Office of the Assistant Secretary

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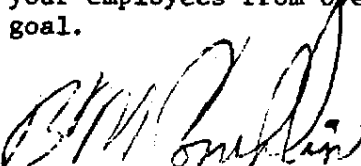
Dear Sir:

The nature of work at your establishment indicates to the Occupational Safety and Health Administration (OSHA) that benzene may be used in your operations. As you know, the present permissible exposure limits to benzene are an 8 hour time-weighted average concentration of 10 parts per million (ppm) and a ceiling concentration of 25 ppm except for a maximum peak up to 50 ppm for a maximum duration of 10 minutes in an 8 hour shift, or limits set by a state agency whenever a state administered Occupational Safety and Health Plan is in effect. If the employee exposure is found to be in excess of the permissible limits, you must implement feasible engineering or administrative controls or maintain an effective respiratory protection program should such controls be found infeasible. The National Institute for Occupational Safety and Health has recommended that the permissible exposure limit for benzene be lowered to a 2 hour time-weighted average concentration of 1 ppm in air. This recommendation is currently being considered by OSHA.

As an interim measure until such time as a complete standard is promulgated we are forwarding herewith recommended guidelines for protection of your employees against the risk of disease or injury resulting from exposure to benzene. These recommendations involve preventive steps of monitoring employee exposure levels, medical surveillance, employee training, respiratory protection, protective clothing, good personal hygiene, and fire and safety precautions which should ensure a reduced health risk for those of your employees who engage in operations involving benzene. The issuance of these guidelines does not alter our intention to continue our compliance activities.

The toxic and flammable properties of benzene plus its wide use in our nation's industries combine to make benzene a major occupational health hazard. Therefore, voluntary compliance with the enclosed nonmandatory guidelines would further the overall objective of the Occupational Safety and Health Act - to assure so far as possible, safe and healthful working conditions.

Your cooperation in this matter is greatly appreciated. Protection of your employees from overexposure to benzene is, I am confident, our common goal.


Bert M. Concklin
Deputy Assistant Secretary

SAL 000018983

Guidelines for Control of Occupational Exposure to Benzene

In accordance with the Occupational Safety and Health Administration's (OSHA) standard for air contaminants (29 CFR 1910.1000, Table Z-2) employee exposure to benzene shall not exceed the permissible exposure limits of an 8 hour time-weighted average concentration of 10 parts per million (ppm) and a ceiling concentration of 25 ppm, except for a maximum peak up to 50 ppm for a maximum duration of 10 minutes in an 8 hour shift, or a limit set by a state agency whenever a state administered Occupational Safety and Health Plan is in effect.

The first mandatory requirement is that employee exposure to benzene above the permissible exposure limits be eliminated through the implementation of feasible engineering controls. Such controls must be implemented even if they do not completely reduce exposure to permissible exposure limits. After all such controls are implemented and if they do not sufficiently reduce levels of benzene to or below those listed in Table Z-2, each employer must rotate his employees to the extent possible in order to reduce exposure. Only when all feasible engineering or administrative controls have been implemented, and the level of benzene still exceeds permissible exposure limits, may an employer rely on a respirator program pursuant to the mandatory requirements of 1910.134. In addition to 1910.1000 and 1910.134 the following standards must be met where employees are exposed to benzene: If skin or eye contact with benzene may occur, the requirements of 1910.132 and .133 must be met. Where employees wear protective clothing, clean change rooms shall be provided in accordance with 1910.141 (e). No employee shall be allowed to consume food or beverages in any area where airborne concentrations of benzene are above the permissible exposure limits in accordance with 1910.141(g)(2). Inasmuch as benzene is a Class IB flammable liquid, storage and handling practices must meet the requirements of 1910.106. Locations where benzene may be present in quantities sufficient to produce explosive or ignitable mixtures are considered Class I Group D and must conform to the requirements of 1910.309. If there is no standard which addresses a recognized hazard, which is likely to cause death or serious physical harm to employees, Section 5(a)(1) of the Act, the general duty clause, may apply.

In August 1976, the National Institute for Occupational Safety and Health (NIOSH) announced that it considers the accumulated evidence from clinical and epidemiological data to be conclusive at this time that benzene is leukemogenic. On the basis of this evidence, NIOSH recommended that, for regulatory purposes, benzene be considered carcinogenic in man and that exposure to benzene be lowered to a two hour time-weighted average concentration of 1 ppm in air, as determined by an air sample collected at one liter per minute for two hours. Due to the information supplied by NIOSH, OSHA strongly recommends that exposure to benzene in air not exceed an eight hour time-weighted average concentration of 1 ppm in any eight hour shift of a 40 hour week.

The following recommendations are made to ensure that employee exposure to benzene is controlled to a time-weighted average concentration of 1 ppm. However, the mandatory OSHA requirements remain in effect and must be met. In these guidelines the mandatory requirements are identified by the applicable OSHA regulation number.

1. MONITORING

- a. Each employer who has a place of employment in which benzene is occupationally produced, reacted, released, packaged, repackaged, transported, stored, handled, or used should inspect each workplace and work operation to determine if any employee may be exposed to benzene at or above a time-weighted average concentration of 1 ppm or to repeated skin contact with liquid benzene. As soon as the areas of benzene exposure have been identified, the employer should limit as much as possible the number of people entering these areas. Indicators that an evaluation of employee exposure should be undertaken would include:
 - (i) Any information or observations which would indicate employee exposure to benzene;
 - (ii) Any measurement of airborne concentrations of benzene above a time-weighted average concentration of 1 ppm.
 - (iii) Any employee complaints of symptoms which may be attributable to exposure to benzene; and
 - (iv) Any production, process, or control change which may result in an increase in the airborne concentration of benzene, or whenever the employer has any other reason to suspect an increase in the airborne concentrations of benzene.
- b. Air Monitoring
 - (i) Employee exposure measurements should represent the actual breathing zone exposure conditions for each employee. Any appropriate combination of long-term or short-term samples would be acceptable, but total sampling time should not be less than 7 hours when determining the time-weighted average exposure of employees
 - (ii) Accuracy of Measurement. The method of monitoring and analysis should have an accuracy, to a confidence level of 95%, of not less than plus or minus 15% for concentrations of benzene equal to or greater than a time-weighted average concentration of 1 ppm (One method of analysis meeting this accuracy requirement is available in the NIOSH Manual of Analytical Methods, Government Printing Office Stock No. 1733-00041). For preliminary range finding tests, NIOSH certified detector tubes with an accuracy of plus or minus 25% may be used.

- (iii) Frequency of Monitoring. Where the employer has determined that employees are exposed to benzene in excess of a time-weighted average concentration of 1 ppm, monitoring should be repeated quarterly. If biological monitoring is done, it should be scheduled to coincide with air monitoring.

2. MEDICAL SURVEILLANCE

Each employer should institute a medical surveillance program for all employees who are or will be exposed to benzene above a time-weighted average concentration of 1 ppm. The employer should provide each employee with an opportunity for medical examination, performed by or under the supervision of a licensed physician, during the employee's normal working hours or at specifically assigned hours designated on the basis of physician availability, without cost to the employee.

a. Medical Examination

- (i) Each employer should provide a medical examination which includes a complete medical history and physical examination, a complete blood count, urinary phenol evaluation, and serum bilirubin evaluation to each employee exposed to benzene in excess of a time-weighted average concentration of 1 ppm.
 - (a) A complete history should include past work exposures to benzene or any other hematologic toxins, a history of blood dyscrasias including genetically related hemoglobin alterations, bleeding abnormalities, abnormal function of formed blood elements, a history of renal or liver disfunction, alcoholic intake and systemic infections.
 - (b) A complete blood count should include: hematocrit, hemoglobin determination, mean corpuscular volume, white blood cell count including a differential count, and a platelet estimation of the differential slide.
- (ii) Medical examinations should also be made available:
 - (a) To employees prior to their assignment to areas in which airborne concentrations of benzene are above a time-weighted average concentration of 1 ppm;
 - (b) At least biannually for each employee exposed to airborne concentrations of benzene above a time-weighted average concentration of 1 ppm at any time during the preceding six months;
 - (c) Immediately, upon notification by the employee that the employee has developed signs or symptoms commonly associated with chronic exposure to benzene.
 - (d) At least monthly for each employee who shows alterations in components of the blood. This schedule should continue for at least three months or until there is evidence of a return to normal values.

(iii) Where medical examinations are performed, the employer should provide the examining physician with the following information:

- (a) The reason for the medical examination requested;
- (b) A description of the affected employee's duties as they relate to the employee's exposure;
- (c) A description of any personal protective equipment used or to be used;
- (d) The results of the employee's exposure measurements, if available;
- (e) The employee's anticipated or estimated exposure level;
- (f) Upon request of the physician, information concerning previous medical examination of the affected employee.

b. Biological Monitoring. Biological monitoring should be scheduled to coincide with air monitoring. By so doing, the route of entry and/or the source of exposure to benzene may be indicated if not already apparent.

(i) Recommended Method

Urinary phenol analysis should be the method of biological monitoring used. According to presently available literature, the urinary phenol evaluation is a method to determine dose when exposure to benzene is in the range of a time-weighted average concentration of 10 ppm or greater. Since the literature supporting this opinion is limited, OSHA also recommends the use of this method where exposure levels are in excess of a time-weighted average concentration of 1 ppm. Data generated by such testing may clarify the effectiveness of the urinary phenol evaluation as an indicator of exposure to benzene. A method of analysis for phenol in urine is described in the Annals of Occupational Hygiene, 1970, Volume 13, pp. 125-146. An automated method which determines total phenol in urine and allows for the analysis of a large number of samples per day is described in the American Industrial Hygiene Association Journal, June 1972, pp. 378-381.

For the analysis, 100 milliliters of urine having a specific gravity of at least 1.010 should be collected as close to the end of the working day as possible. For the best assessment of the work related absorption of benzene, the following factors should be considered since they can contribute to a high urine phenol level:

- (a) The foods or beverages consumed which are likely to increase the total bodily production of phenol, such as but not limited to foods or beverages of the grape family.
- (b) Any medications or drugs, especially phenobarbital, taken within the previous 24 hour period.
- (c) Non-work related exposures to benzene which occurred within the previous 24 hour period.
- (d) Recent exposure to biphenyls.

(ii) Frequency of Monitoring

- (a) If possible, a urine sample should be obtained of all employees prior to assignment to areas where benzene in air concentrations exceed a time-weighted average concentration of 1 ppm.
- (b) For employees exposed to more than a time-weighted average concentration of benzene in air of 1 ppm, urine sampling and analysis should be done every three months.
- (c) Each employee whose urinary phenol level exceeds 75 milligrams per liter should be provided, within one week of the receipt of the results, with two follow-up urinary phenol evaluations performed on two samples taken on the same day, one as close to the beginning and one as close to the end of the working day as possible. If the original elevated finding is confirmed and appears to be due to occupational exposure to benzene, the employee's exposure to benzene should be reduced.
- (d) Each employee whose urinary phenol level exceeds 75 milligrams per liter should be examined by a physician as soon as practicable after such absorption is demonstrated and confirmed, and at least monthly thereafter or more frequently as deemed necessary by the physician until the urinary phenol levels have returned to below 75 milligrams per liter.

iii) Elevated Group Levels

- (a) The results of employee urine sampling should also be considered as a group exposure by area of assignment and/or by job description. Elevated group urinary phenol levels should be a cause for review of operational practices, process controls, and a change in either or both to reduce employee exposure.
- (b) If several employee urine samples from the same area of assignment indicate excessive urinary phenol levels, corrective action in the area should be started by the employer immediately.

c. Physician's Written Opinion

- (i) The employer should obtain and furnish the employee with a written opinion from the examining physician containing the following:
 - (a) The signs or symptoms of benzene exposure manifested by the employee, if any;
 - (b) The physician's opinion as to whether the employee has any detected medical condition which would place the employee's health at increased risk of impairment from exposure to benzene or other substances or which would directly or indirectly aggravate any detected medical condition;
 - (c) Any recommended limitation upon the employee's exposure to benzene or other substances or upon the use of personal protective equipment and respirators; and
 - (d) A statement that any medical condition which has been discovered as a result of the examination has been called to the employee's attention for further examination or treatment.
- (ii) The written opinion obtained by the employer should not reveal specific findings or diagnoses unrelated to occupational exposure to benzene or other substances.

- (iii) If the employer determines, on the basis of the physician's written opinion, that any employee's health would be materially impaired by maintaining the existing exposure to benzene or other substances, the employer should place specific limitations, based on the physician's written opinion, on the employee's continued exposure to benzene or other substances.

3. TRAINING

- a. Each employer should provide a training program for employees assigned to workplace areas where benzene is produced, reacted, released, packaged, repackaged, transported, stored, handled, or used.
- b. The training program should be provided at the time of initial assignment and at least annually thereafter.
- c. The employer should:
 - (i) Inform employees who work or will be working with benzene of potential health hazards;
 - (ii) Advise employees of the signs and symptoms of exposure to benzene described in the appendix and instruct employees to advise the employer of the development of such signs or symptoms.
 - (iii) Inform employees of the specific nature of operations which could result in exposure to benzene above a time-weighted average concentration of 1 ppm, as well as safe work practices where benzene is produced, reacted, released, packaged, repackaged, transported, stored, handled or used;
 - (iv) Instruct employees in proper housekeeping practices;
 - (v) Inform employees of the correct emergency procedures to be followed in case of spills, leaks, or fire, and the personal protective equipment necessary in emergencies;
 - (vi) Inform employees of measures necessary to protect them from exposures in excess of the permissible exposure limit. The wearing and turning in of protective clothing should be stressed;
 - (vii) Instruct employees as to the purpose of respirators.
 - (viii) Provide employees with a description of and explain the purpose for the medical surveillance program;
 - (ix) Inform employees where written procedures and hazard information are available on the premises.
- d. Pursuant to 1910.134(b)(3) the users of respirators shall be trained in their proper use and limitations.

4. RESPIRATORY PROTECTION

- a. Respiratory Protection Program. Engineering controls shall be used to maintain employee exposure to benzene within the permissible exposure limits in Table Z-2. (1910.1000(e)) While engineering controls are being implemented or when employee exposure to airborne concentrations of benzene cannot be fully reduced by feasible engineering or administrative controls, an employer shall utilize a program of respiratory protection to protect every employee exposed. (1910.134(a) and 1910.1000(e))

b. Respirator Selection and Usage

- (i) When respirators are used their use shall comply with the requirements of 1910.134. (1910.1000(e)) Only those respiratory protective devices which have been approved by the Bureau of Mines, the Mining Enforcement and Safety Administration or the National Institute for Occupational Safety and Health under the provisions of 30 CFR Part 11 shall be used. (1910.134(b)(11))
 - (ii) The employer should select and provide an appropriate respirator from the table on the next page.
 - (iii) A respirator specified for use in higher concentrations of airborne benzene may be used in atmospheres of lower concentrations.
 - (iv) Employees experiencing frequent or continuous breathing difficulty while using respirators should be evaluated by a physician to determine the ability of the worker to wear a respirator.
 - (v) Employees who wear respirators in a hot environment should be allowed to leave work areas to wash the face and respirator facepiece to prevent potential skin irritation associated with respirator use.
 - (vi) When employees are exposed to other toxic substances in addition to benzene, appropriate combinations of respiratory protection shall be provided. (1910.134(b)(2))
- c. There should be an established in-plant procedure and means and facilities provided to issue respiratory protective equipment, to return used, contaminated equipment, to decontaminate and disinfect the equipment, and to repair or exchange damaged equipment.

5. PROTECTIVE CLOTHING

- a. Employers shall provide and require employees to wear protective clothing and gloves, or any other appropriate protective equipment deemed necessary to prevent skin contact from repeated spills, splashes, or sprays of liquid benzene. (1910.132(a)) It is recommended that such equipment be impervious to benzene.
- b. The employer shall provide and require employees to use splash proof safety goggles where eye contact with benzene sprays or splashes may occur. (1910.133(a)(1))
- c. The employer should provide and require employees to use full length face shields (eight inch minimum) where the employee's face may be splashed with liquid benzene.
- d. Employers should ensure that any permeable clothing heavily contaminated with benzene be removed immediately and not reworn until the benzene is removed from the clothing.
- e. The employer should launder, maintain, and/or dispose of all heavily contaminated protective clothing or heavily contaminated personal clothing discarded by employees.

RECOMMENDATIONS FOR RESPIRATOR USAGE AT BENZENE CONCENTRATIONS GREATER
THAN 1 PPM

Concentration of Benzene
or Condition of Use

Respirator Type

Less than or equal
to 10 ppm

- (1) Chemical cartridge respirator with organic vapor cartridges and half mask.
- (2) Any supplied air respirator with half mask.

Less than or equal
to 50 ppm

- (1) Chemical cartridge respirator with organic vapor cartridges and full facepiece.
- (2) Any supplied air respirator with full facepiece.
- (3) Any organic vapor gas mask.
- (4) Any self-contained breathing apparatus with full facepiece

Less than or equal
to 1000 ppm

- (1) Supplied air respirator with half mask in positive pressure mode.

Less than or equal
to 2000 ppm

- (1) Supplied air respirator with full facepiece helmet or hood in positive pressure mode.

Less than or equal
to 10,000 ppm

- (1) Supplied air respirator and auxillary self-contained breathing apparatus with full facepiece in positive pressure mode.
- (2) Open circuit self-contained breathing apparatus with full facepiece in positive pressure mode.

Entry into unknown
concentrations or
Fire Fighting

- (1) Open circuit self-contained breathing apparatus with full facepiece in positive pressure mode.

Escape Only

- (1) Any organic vapor gas mask.
- (2) Any self-contained breathing apparatus with full facepiece.

6. PERSONAL HYGIENE FACILITIES AND PRACTICES

- a. All food, beverages, tobacco products, and unapplied cosmetics should be prohibited in areas where airborne concentrations of benzene are above a time-weighted average concentration of 1 ppm.
- b. Where the eyes of an employee may be exposed to liquid benzene, suitable equipment for drenching or flushing the eyes with water should be provided in the immediate work area for emergency use.
- c. The employer should ensure that an employee whose face or extremities become wet with liquid benzene promptly washes to remove any benzene from the skin.
- d. Where the body (other than face or extremities) of an employee may become wet with liquid benzene, the employer should provide showers.
- e. When feasible, an eyewash fountain and emergency shower should be available in the same location for emergency use.
- f. Where employees wear protective clothing, clean change rooms shall be provided in accordance with 1910.141(e).

7. FIRE AND SAFETY

- a. Liquid benzene is classified as a Class IB flammable liquid and its vapor may form explosive mixtures in air. Sources of ignition such as smoking or open flames shall be prohibited where benzene is used or stored. (1910.106(b),(d),(e),(f),(g) and (h))
- b. Benzene should be stored in tightly closed containers in a cool area.
- c. Benzene storage areas shall be well ventilated. (1910.106(b),(d),(e), and (f))
- d. Benzene containers should be grounded prior to opening.
- e. Benzene containers shall be electrically interconnected to the receiving container prior to pouring. (1910.106(e),(f), and (h))
- f. Non-sparking tools shall be used when opening or closing benzene containers. (1910.106(b),(e), and (h))
- g. High exposures to benzene can occur when transferring the liquid from one container to another. Such operations shall be well ventilated (1910.106(f)) and good work practices should be established to avoid spills.
- h. Spills of benzene should be cleaned up immediately after eliminating potential sources of ignition and providing available ventilation.
- i. Large amounts of water should be used to flush the areas where spills have occurred.
- j. Liquid benzene shall not be allowed to enter a confined space such as a public sewer, because of the possibility of explosion. (1910.106(b),(e),(f),(g) and (h)) Sewers designed for chemical waste are permitted.
- k. Large volumes of benzene should be disposed of by atomizing it in a suitable combustion chamber or by absorbing it in dry sand or earth and disposing it in a sanitary land fill.
- l. Rags contaminated with benzene should be temporarily stored in tightly closed containers.
- m. The local fire department should be informed of the exact location of the storage areas and the hazards in case of fire.

8. EMERGENCY SITUATIONS

a. A written plan for emergency situations should be developed for each operation where there is a possibility of a massive release of benzene or where extensive skin contact may occur.

b. The plan should require:

- (i) Employees engaged in correcting emergency conditions to be provided with the appropriate protective clothing and respiratory protective devices.
- (ii) Employees not engaged in correcting the emergency to be restricted from the area, and normal operations in the affected area(s) not to be resumed until the emergency is abated.
- (iii) A local alarm system to be installed and maintained to promptly alert employees that an emergency situation exists.
- (iv) Equipment for quick drenching or flushing be available for employees who have splashed benzene in their eyes.
- (v) Employees who have had a large amount of benzene spilled on their clothing or skin to remove any contaminated clothing and to immediately wash the exposed skin with large amounts of soap and water. Contaminated clothing should be washed before wearing again.
- (vi) Employees who have inhaled benzene at high concentrations to be removed at once to fresh air. If breathing has stopped, artificial respiration or oxygen should be used, if indicated.

APPENDIX

CHARACTERISTICS OF BENZENE

I. Physical and Chemical Data

- A. Synonyms: Benzol, benzole, coal naptha, cyclohexatriene, phene, phenyl hydride, pyrobenzol. (Benzin, petroleum benzin, and benzine do not contain benzene).
- B. Formula: C_6H_6
- C. Appearance and odor: Benzene is a clear, colorless liquid with a pleasant, sweet odor. The odor of benzene does not provide adequate warning of its hazard.
- D. Boiling Point: (760 mm Hg): $80.1^{\circ}C$
- E. Melting Point: $5.5^{\circ}C$ ($42^{\circ}F$)
- F. Specific Gravity (water=1): 0.879
- G. vapor Density (air=1): 2.7
- H. Vapor Pressure at $20^{\circ}C$ ($68^{\circ}F$): 75 mm Hg
- I. Solubility in Water: .06% - .08%
- J. Evaporation Rate (ether=1): 2.8

II. Fire and Explosion Hazard Data

- A. Flash Point (closed cup): $-11^{\circ}C$ ($12^{\circ}F$)
- B. Autoignition Temperature: $580^{\circ}C$ ($1076^{\circ}F$)
- C. Flammable Limits in Air, % by Volume:
Lower: 1.3% Upper: 7.1%
- D. Benzene is classified as a class IB flammable liquid for the purpose of conforming to the requirements of 29 CFR 1910.106. Class IB includes liquids having a flashpoint below $73^{\circ}F$ ($22.8^{\circ}C$) and having a boiling point at or above $100^{\circ}F$ ($37.8^{\circ}C$).
- E. A benzene concentration exceeding 3250 ppm is considered a potential fire or explosion hazard. Benzene vapors are heavier than air; thus the vapors may travel along the ground and be ignited by open flames or sparks at locations remote from the site at which benzene is handled. Locations where benzene may be present in quantities sufficient to produce explosive or ignitable mixtures are considered Class I Group D for the purposes of conforming to the requirements of 29 CFR 1910.309.

- F. Extinguishing Media: Carbon dioxide, dry chemical or foam.
- G. Special Fire Fighting Procedures: Do not use solid stream of water, since stream will scatter and spread fire. Water spray can be used to keep fire exposed containers cool.

III. Health Hazard Data

- A. Route of Entry: Inhalation and skin absorption. Although absorption via the skin is minimal compared to absorption via inhalation, skin contact should nonetheless be avoided.
- B. Biological Effects:

Benzene is primarily an inhalation hazard which can cause both acute and chronic effects. Systemic absorption causes depression of the hematopoietic system and according to the NIOSH evaluation of epidemiological studies, prolonged exposure leads to the development of leukemia. Persons with existing blood disorders may therefore be more susceptible to the effects of benzene. Inhalation of high concentrations can affect central nervous system function. Aspiration of small amounts of liquid benzene causes immediate pulmonary edema and hemorrhage of pulmonary tissue. Liver dysfunctions likely to inhibit the biotransformation and detoxification reactions will tend to promote the toxic actions of benzene. Precautions should be considered before exposing persons with impaired liver function to benzene vapors. Benzene is known as a kidney toxin and the importance of the kidney in the elimination of toxic substances and metabolites justifies special consideration for those with possible impairment of renal function.

The defatting action of benzene may produce primary irritation upon repeated or prolonged contact with the skin. Persons with preexisting skin disorders may be more susceptible to this effect of benzene.

High concentrations of benzene are irritating to the mucous membranes of the eyes, nose, and respiratory tract.

- C. Signs and Symptoms

Benzene is poorly absorbed through the skin, however direct contact may cause erythema or blistering. Repeated or prolonged contact may result in drying, scaling, dermatitis, or precipitate development of secondary skin infections. Exposure to high concentrations of benzene vapor may cause irritation of the nose and respiratory tract and a smarting sensation in the eye. Droplet contamination of the eye by benzene causes a moderate burning sensation, but only slight transient injury of the epithelial cells, with the eye recovering rapidly.

Inhalation of high concentrations of benzene (acute exposure) may have an initial stimulatory effect on the central nervous system characterized by exhilaration, nervous excitation, and/or giddiness, followed by a period of depression, fatigue, or vertigo. There may be a sensation of tightness in the chest accompanied by breathlessness and ultimately the victim may

lose consciousness. Convulsions and tremors occur frequently, and death may follow from respiratory paralysis or circulatory collapse in a few minutes to several hours following severe exposures.

Prolonged exposure to small quantities of benzene vapor (chronic exposure) is of extreme importance due to the irreversible effects on the blood-forming system. The development of such effects is insidious as they have been noted to occur at concentrations of benzene which may not cause irritation of mucous membranes or any unpleasant sensory effects. Early signs and symptoms of benzene morbidity are varied, vague, and not specific for benzene exposure. Subjective complaints of headache, dizziness, and loss of appetite may precede or accompany clinical symptomatology. Bleeding from the nose, gums, or mucous membranes and the development of purpuric spots may occur as the condition progresses. Rapid pulse and low blood pressure in addition to a physical appearance of anemia may accompany a subjective complaint of shortness of breath. Clinical evidence of leucopenia and anemia are the most common abnormalities reported, however, macrocytosis and thrombocytopenia are also frequently present. The bone marrow may appear normal, aplastic, or hyperplastic and may not in all situations correlate with peripheral blood findings indicating hypo- or hyper-activity of blood forming tissues. There are great variations in the susceptibility to benzene morbidity which prohibit the identification of a "typical" blood picture. The effects of prolonged benzene exposure may appear several weeks or years after the actual exposure has ceased.

RECOMMENDED METHOD OF BIOLOGICAL MONITORING

The recommended method of biological monitoring is a urine analysis to determine the concentration of phenol and its conjugates, sulfate and glucuronide, in urine. It also determines orthocresol and meta and paracresols. Urine is hydrolyzed with perchloric acid at 95°C, and the phenols and cresols are extracted with isopropyl ether and determined by gas chromatography.

I. Collection of urine samples

"Spot" urine specimens of about 100 milliliters (ml) are collected as close to the end of the workday as possible.

After thoroughly washing their hands with soap and water, workers should collect urine samples from single voidings in clean, dry specimen containers having tight closures and at least a 120 ml capacity. Collection containers may be glass, wax-coated paper, or other disposable types if desired. Following collection of urine specimens, 1 ml of a 10% copper sulfate solution is added to each sample as a preservative and samples are immediately stored under refrigeration, preferably at 0-4 °C.

Refrigerated specimens will remain stable for approximately 90 days. If shipment of samples is necessary to perform analysis, the most rapid method available shall be employed utilizing acceptable packing procedures as specified by the carrier. Proper identification of each specimen shall include as a minimum, the worker's name, date, and time of collection.

II. Analytical

A. Principle of the Method

Urine samples are treated with perchloric acid at 95°C to hydrolyze the phenol conjugates, phenyl sulfate and phenyl glucuronide, formed as detoxification products following benzene absorption. The total phenol is extracted with diisopropyl ether and the phenol concentration is determined by gas chromatographic analysis of the diisopropyl ether extract.

B. Apparatus

1. Gas chromatograph with a flame ionization detector and equipped with a 5 foot x 3/16 inch column packed with 2% w/w polyethylene-glycol adipate on Universal "B" support. Operating conditions are as follows:

Column temperature 150°C
Detector. Flame ionization, 250°C
Injection point temperature 200°C
Carrier gas Nitrogen
Carrier gas flowrate 60 ml/min

2. Water bath at 95°C.
3. Glass-stoppered, 10 ml volumetric flasks
4. 1 ml, 2 ml, and 5 ml volumetric pipets
5. 5 microliter (ul) syringe

C. Reagents

1. Phenol
2. 15% Perchloric acid (Perchloric acid can probably be replaced with hydrochloric acid. The use of perchloric acid should be avoided if at all possible.)
3. Diisopropyl ether
4. Distilled water

D. Procedure

1. Hydrolysis of phenol conjugates

Pipet 5 ml of urine into a 10 ml, volumetric flask. Add 2 ml perchloric acid, mix by swirling, and transfer the lightly stoppered flask to a water bath at 95°C. After 2 hours remove the flask and allow to cool at room temperature.

2. Diisopropyl ether extraction of phenol and cresols

Pipet 1 ml of diisopropyl ether into the flask and adjust the volume to 10 ml with distilled water. Shake vigorously for one minute to extract the phenol and cresols. Allow the aqueous and ether layers to separate.

3. Gas chromatographic analysis for phenol

Inject 5 microliters (ul) of the diisopropyl ether layer into the gas chromatograph and record the attenuation and area of the phenol peak. Under the conditions described, phenol is eluted in 100 seconds, o-cresol in 130 seconds, and m- and p- cresols in 320 seconds.

E. Standards Preparation

A 50 mg/liter standard aqueous solution of phenol is prepared. A 5 ml aliquot of the standard solution is then subjected to the hydrolysis, extraction, and gas chromatographic analysis described above.

F. Calculations

Determine the phenol concentration in the urine by comparing the gas chromatographic peak area of the sample with that of the 50 mg/liter standard and adjust the value to a specific gravity of 1.024.

G. Specific Gravity Correction

Due to the magnitude of correction required, samples having specific gravities less than 1.010 should be rejected and another sample obtained.

Corrected Concentration=

$$\frac{\text{Observed Concentration} \times 24}{\text{Last 2 digits of sp gr (eg 1.021)}}$$

Reference:

Sherwood, R.J. and F.W.G. Carter.

The Measurement of Occupational Exposure to Benzene Vapour.

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