criteria for a recommended standard....

OCCUPATIONAL EXPOSURE TO PHENOL

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
July 1976

HEW Publication No. (NIOSH) 76-196

PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and safety of workers exposed to an ever-increasing number of potential hazards at their workplace. The National Institute for Occupational Safety and Health has projected a formal system of research, with priorities determined on the basis of specified indices, to provide relevant data from which valid criteria for effective standards can be derived. Recommended standards for occupational exposure, which are the result of this work, are based on the health effects of exposure. The Secretary of Labor will weigh these recommendations along with other considerations such as feasibility and means of implementation in developing regulatory standards.

It is intended to present successive reports as research and epidemiologic studies are completed and as sampling and analytical methods are developed. Criteria and standards will be reviewed periodically to ensure continuing protection of the worker.

I am pleased to acknowledge the contributions to this report on phenol by members of my staff and the valuable, constructive comments by the Review Consultants on Phenol, by the ad hoc committees of the American Conference of Governmental Industrial Hygienists and the American Academy of Occupational Medicine, and by Robert B. O'Connor, M.D., NIOSH consultant in occupational medicine. The NIOSH recommendations for standards are not necessarily a consensus of all the consultants and professional societies

that reviewed this criteria document on phenol. Lists of the NIOSH Review Committee members and of the Review Consultants appear on the following pages.

John F. Finklea, M.D.
Director, National Institute for
Occupational Safety and Health

The Division of Criteria Documentation and Standards Development, National Institute for Occupational Safety and Health, had primary responsibility for development of the criteria and recommended standard for phenol. The Division review staff for this document consisted of Richard A. Rhoden, Ph.D., Chairman, Howard L. McMartin, M.D., and Barry G. King, Ph.D. (consultant). The Department of Environmental and Industrial Health, School of Public Health, University of Michigan, developed the basic information for consideration by NIOSH staff and consultants under contract No. HSM-99-73-31. Earl S. Flowers, Ph.D., had NIOSH program responsibility and served as criteria manager.

REVIEW COMMITTEE
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

John F. Bester, Ph.D.
Safety and Occupational Health Study Section

Herbert J. Brass, Ph.D.
Division of Physical Sciences and Engineering

Paul E. Caplan
Division of Technical Services

Larry K. Lowry, Ph.D.
Division of Biomedical and Behavioral Science

James B. Lucas, M.D.
Assistant to the Associate Director
for Medical Affairs
Cincinnati Operations

Department of Labor Liaison:

William V. Warren
Division of Health Standards Development
Occupational Safety and Health Administration

NIOSH REVIEW CONSULTANTS ON PHENOL

Harold V. Brown, Dr. P.H.
Office of Environmental Health and
Safety, Center for Health Science
University of California
Los Angeles, California 90024

Evan E. Campbell
University of California
Los Alamos Scientific Laboratory
Health Group
Los Alamos, New Mexico 87544

Dennis Chamot, Ph.D.
Council of AFL-CIO Unions for
Professional Employees
Washington, D.C. 20006

Ralph R. Langner, Ph.D.
Dow Chemical, USA
Midland, Michigan 43640

Ted A. Loomis, M.D., Ph.D.
School of Medicine
University of Washington
Seattle, Washington 98195

John C. Lumsden
North Carolina State Board of Health
Raleigh, North Carolina 27602

Thomas R. Madden
Reichhold Chemicals, Inc.
White Plains, New York 10602

Raymond R. Suskind, M.D.
Department of Environmental Health
University of Cincinnati
School of Medicine
Cincinnati, Ohio 45267

Steve Wodka
Oil, Chemical, and Atomic Workers,
International Union
Washington, D.C. 20006

CRITERIA DOCUMENT: RECOMMENDATIONS FOR AN OCCUPATIONAL EXPOSURE STANDARD FOR PHENOL

Contents

Contents

I. RECOMMENDATIONS FOR A PHENOL STANDARD

The National Institute for Occupational Safety and Health (NIOSH) recommends that employee exposure to phenol in the workplace be controlled by compliance with the following sections. The standard is designed to protect the health and to provide for the safety of employees for up to a 10-hour workday, 40-hour workweek, over a working lifetime. Compliance with the standard should prevent adverse effects produced by exposure of employees to phenol. The standard is measurable by techniques that are valid, reproducible, and available. Sufficient technology exists to permit compliance with the recommended standard. The standard will be subject to review and revision as necessary.

These criteria and the recommended standard apply to exposure of employees to the aromatic organic compound C_6H_5OH, hereinafter referred to as phenol. "Phenol" in this recommended standard includes solids, aerosols, vapor, or solutions containing phenol.

"Occupational exposure to phenol" is defined as exposure to phenol at airborne concentrations exceeding one-half the recommended TWA environmental limit. Exposure at lower concentrations shall not require adherence to the following sections except for sections 3, 4(a), 4(b), 5, and 6.

Section 1 - Environmental (Workplace Air)

(a) Concentration

Occupational exposure to phenol shall be controlled so that no employee is exposed to phenol at concentrations greater than 20 mg/cu m in

air determined as a time-weighted average (TWA) concentration for up to a 10-hour workday, 40-hour workweek, or to more than 60 mg phenol/~~cu~~ m ~~of~~ air as a ceiling concentration for any 15 minute period.

(b) Sampling and Analysis

Procedures for calibration of equipment, sampling, and analysis of phenol samples shall be as provided in Appendices I and II, or by any method shown to be equivalent in precision, accuracy, and sensitivity to the methods specified.

Section 2 - Medical

Medical surveillance shall be made available as specified below to all employees occupationally exposed to phenol, except that first-aid services shall be provided to any employee who is exposed to phenol by spills, splashes, or other means of skin or eye contact.

(a) Preplacement and periodic medical examinations shall be made available and shall include:

(1) A comprehensive initial or interim work history.

(2) A medical history which shall cover at least any history of preexisting disorders of the skin, respiratory tract, liver, and kidneys.

(3) A physical examination of at least the cardiovascular system, respiratory tract, liver, kidneys, and skin. Routine blood tests and urine examination and such other biologic tests which are considered necessary by the responsible physician may also be included.

(4) An evaluation of the employee's ability to use negative

or positive pressure respirators.

(5) An initial medical examination shall be made available within six months of the promulgation of a standard incorporating these recommendations.

(6) Periodic medical surveillance should be made available at an interval to be determined by the responsible physician for all employees occupationally exposed to phenol.

(b) Appropriate medical services and surveillance shall be provided to any employee with adverse health effects reasonably assumed or known to be due to exposure to phenol.

(c) Pertinent medical records shall be maintained for all employees occupationally exposed to phenol, and such records shall be kept for at least one year after the termination of employment.

(d) These records shall be available to the designated medical representatives of the Secretary of Health, Education, and Welfare, of the Secretary of Labor, of the employee or former employee, and of the employer.

Section 3 - Labeling and Posting

(a) All containers of phenol with capacity in excess of one kilogram and contents at a concentration of 1% phenol or greater shall bear the following label in addition to, or in combination with, label information required by other statutes, regulations, or ordinances:

4 Extreme Skin and Inhalation Hazard
2 Moderately Combustible
0 Nonreactive

PHENOL
(% Phenol by weight)

May be fatal if absorbed through skin, inhaled, or swallowed.
Rapidly absorbed through skin.
Causes severe burns of eyes and skin.

Do not breathe vapor or aerosol.
Do not get in eyes, on skin, or on clothing.
Do not take internally.

Wear goggles, face shield, gloves, and protective clothing when handling.

FIRST AID CALL A PHYSICIAN AS SOON AS POSSIBLE

In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse.

If inhaled, remove victim to fresh air. Keep warm and quiet. If breathing stops, give artificial respiration.

If swallowed, induce vomiting.

(b) In an area where phenol is used or handled, except in enclosed systems and for systems in which the concentration of phenol is equal to or less than 1%, the following sign shall be posted in readily visible locations at or near all entrances to the area and on or near equipment using or containing phenol:

DANGER!
PHENOL EXPOSURE AREA
Contact with phenol may be fatal.
Avoid any contact with skin or eyes.
Avoid breathing vapor or aerosol.

(c) In any area where there is bulk storage (greater than 55 gallons) of phenol or where phenol is used in a manner presenting the potential or likelihood of overheating or igniting the phenol, the

following shall be added to the sign specified in Section 3(b):

Combustible Substance: Releases severely injurious vapor on overheating or burning.

(d) If respirators are required for protection from phenol, the following statement shall be added in large letters to the sign required in Section 3(b):

RESPIRATORY AND SKIN PROTECTION REQUIRED IN THIS AREA

(e) In any workroom or area where there is likelihood of emergency situations arising from accidental skin, eye, or other excessive exposures to phenol and where signs are required by Section 3(b), they shall be supplemented by additional signs giving: emergency and first-aid instructions and procedures, the location of first-aid supplies and emergency equipment, including respiratory protective equipment, and locations of emergency showers and eyewash fountains.

(f) Signs shall be printed in English and in the predominant language of non-English-reading employees, if any, unless employers use equally effective means to ensure that non-English-reading employees know the hazards associated with phenol and the areas in which there is occupational exposure to phenol. Employers shall ensure that illiterate employees also know these hazards and the locations of these areas.

Section 4 - Personal Protective Equipment and Protective Clothing

Engineering controls and safe work practices shall be used to maintain exposure to airborne phenol at or below 20 mg/cu m, and protective clothing impervious to phenol shall be provided to prevent contact of phenol with the body surface. In addition, employers shall provide protective equipment and clothing to employees when airborne phenol exceeds 20 mg/cu m phenol in air. Emergency equipment shall be located at well-marked and identified stations and shall be adequate to the needs of all personnel to escape from the area or to safely cope with the emergency on reentry.

(a) Eye and Face Protection

(1) Cup-type or rubber-framed chemical safety goggles shall be worn by employees engaged in activities where it is likely that phenol may come in contact with the eye. With airborne phenol at concentrations in excess of 20 mg/cu m, a full-face mask respiratory protective device is required which will also provide adequate eye protection.

(2) Full-length, plastic face shields shall be worn in addition to safety goggles for face protection when working at tasks where contact with phenol is likely.

(3) Eye protection measures and equipment shall conform with the provisions of ANSI Z87.1-1968.

(b) Protective Clothing

(1) Employers shall provide and employees shall be required to wear gloves of neoprene, polyethylene, rubber, or other material impervious to phenol when working with phenol.

(2) Employers shall provide and employees shall be required to wear protective sleeves, aprons, jackets, trousers, caps, and shoes when needed for protection from skin contact with phenol. These garments shall be made of a material impervious to phenol.

(3) In emergencies or other circumstances involving exposure to airborne phenol at concentrations in excess of 20 mg/cu m, full body protective clothing shall be worn in addition to a respiratory protective device. The garments shall be of an impervious material and shall fit snugly about the wrists, neck, waist, and ankles.

(4) Employees handling drums, cans, or other containers of phenol shall wear impervious shoes or boots with safety toe-caps. Leather safety shoes shall be protected from splashes or spills by use of impervious coverings such as rubbers.

(5) In unusual, nonroutine, or emergency circumstances which may involve occasional periods of exposure to airborne phenol at concentrations in excess of 20 mg/cu m, clothing impervious to phenol vapor and aerosol shall be supplied by employers and shall be worn to supplement the required respiratory protection (see paragraph (c) below) in accordance with the requirements in Table I-1.

TABLE I-1

REQUIREMENTS FOR RESPIRATOR USAGE AND SKIN PROTECTION FOR EXPOSURE AT CONCENTRATIONS IN EXCESS OF THE ENVIRONMENTAL LIMIT

Phenol Concentration	Respirator Type	Impervious Clothing
Less than 60 mg/cu m	(1) Chemical cartridge respirator with replaceable organic vapor cartridge with full facepiece. Maximum service life of 3 hours (2) Full-face gas mask, chin-type, with organic vapor canister. Maximum life of 4 hours	Required for any period of exposure over 8 hrs/day
Less than 200 mg/cu m	(1) Chemical cartridge respirator with replaceable organic vapor cartridge with full facepiece. Maximum service life of 3 hours (2) Full-face gas mask, chin-type, with organic vapor canister. Maximum life of 4 hours	Required for any period of exposure over 1.5 hrs/day
Less than 400 mg/cu m	(1) Full-face gas mask, chest- or back-mounted type, with industrial size organic vapor canister. Maximum service life of 2 hours (2) Type C supplied-air respirator, continuous-flow or pressure-demand type (positive pressure) with full facepiece	Required for any period of exposure over 0.5 hr/day
Greater than 400 mg/cu m	(1) Self-contained breathing apparatus with positive pressure in full facepiece (2) Combination supplied-air respirator, pressure-demand type, with auxiliary self-contained air supply (3) Type A supplied-air respirator with full facepiece and with motor-driven or hand-operated blower	Required for any period and for any such exposure

TABLE I-1 (CONTINUED)

REQUIREMENTS FOR RESPIRATOR USAGE AND SKIN PROTECTION FOR EXPOSURE AT CONCENTRATIONS IN EXCESS OF THE ENVIRONMENTAL LIMIT

Phenol Concentration	Respirator Type	Impervious Clothing
Emergency (no concentration limit)	(1) Self-contained breathing apparatus with positive pressure in facepiece (2) Combination supplied-air respirator, pressure-demand type, with auxiliary self-contained air supply	Required for emergency work crew
Firefighting	(1) Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode	Required
Evacuation or escape (no concentration limit)	(1) Self-contained breathing apparatus in demand or pressure-demand mode (negative or positive pressure) (2) Full-face gas mask, front- or back-mounted type, with industrial size organic vapor canister	Not required

(c) Respiratory Protection

Respirators may be used for nonroutine operations, evacuation, or emergencies which may involve occasional brief exposures to phenol at concentrations in excess of 20 mg/cu m. Such exposures may occur during the period necessary to install or test required engineering controls or to take protective actions.

Appropriate respirators as described in Table I-1 may only be used pursuant to the following requirements:

(1) For the purpose of determining the type of respirator to be used, the employer shall measure the airborne phenol concentration in the workplace, initially and thereafter whenever process, worksite, climate, or control changes occur which are likely to increase the airborne concentration of phenol. This requirement does not apply when only positive pressure supplied-air respirators are used.

(2) The respirator and cartridge or canister used shall be of the appropriate class, as determined on the basis of the airborne concentration of phenol. The employer shall ensure that no employee is being exposed to phenol in excess of 20 mg/cu m as a TWA concentration because of improper respirator selection, fit, use, or maintenance.

(3) A respiratory protective program meeting the requirements of 29 CFR 1910.134 shall be established and enforced by the employer.

(4) The employer shall provide respirators in accordance with Table I-1 and shall ensure that the employee uses the respirator properly.

(5) Respiratory protective devices described in Table I-1 shall be those approved under provisions of 30 CFR 11.

(6) Respirators specified for use at greater airborne concentrations of phenol may be used in lesser airborne concentrations of phenol.

(7) Use of chemical cartridges and canisters more than once or for a period of time greater than that indicated in Table I-1 shall be prohibited.

(8) The employer shall ensure that respirators are adequately cleaned, maintained, and stored when not in use, and that employees are instructed on the use of respirators assigned to them and on how to test for leakage.

Section 5 - Informing Employees of Hazards from Phenol

(a) At the beginning of employment, or assignment for work at operations, or in an area which may involve overexposure to phenol, each employee shall be informed of the hazards of such employment and possible injuries due to phenol. He shall be instructed in the proper procedures for the safe handling and use of this compound, in the operation and use of protective systems and devices, and in appropriate emergency procedures.

(b) A continuing education program, conducted by a person or persons qualified by experience or special training, shall be instituted to ensure that all employees have current knowledge of job hazards, proper maintenance procedures and cleanup methods, and that they know how to use respirators correctly. The instructional program shall include a description of the general nature of the medical surveillance procedures

and why it is advantageous to the employee to undergo these examinations. As a minimum, instruction shall include the information in Appendix III, and this information shall also be made available in the work area and kept on file, readily accessible to the employee at all places of employment where overexposure may occur.

(c) Information shall be recorded on a "Material Safety Data Sheet" described in Appendix III or on a similar form required or approved by the Occupational Safety and Health Administration, US Department of Labor.

Section 6 - Work Practices

(a) Appropriate protective clothing and equipment (goggles, face shields, gloves, aprons, suits, or other personal protective equipment), as set forth in Section 4(a), shall be worn by each employee engaged in any operation at which there is the likelihood of splashes, spills, or other circumstances which may result in phenol coming into contact with the skin or eyes of an employee.

(b) Any workplace in which phenol is introduced into the air shall be adequately ventilated by either natural or mechanical means sufficient to control the airborne concentration of phenol to which any employee may be exposed to a value at or below 20 mg/cu m.

(c) Spills and leaks of phenol shall be cleaned up immediately. Employees engaged in such cleanup operations shall wear suitable protective clothing and equipment and respiratory protective devices. The cleanup operations shall be done or directly supervised by employees instructed and trained in the procedures for the safe decontamination or disposal of

equipment, materials, and waste. All other persons shall be excluded from the area of the spill or leak until cleanup is complete and safe conditions have been restored.

(d) Equipment and systems for using, handling, or transferring phenol shall be enclosed to the extent that is feasible for the operation or shall be otherwise designed or controlled to prevent skin or eye contact with, and overexposure to, phenol.

(e) Phenol shall be stored in closed containers in an area which is adequately ventilated to ensure that airborne phenol concentrations do not exceed the limits specified in Section 1(a).

(1) Storage conditions shall be controlled to prevent overheating and pressure buildup in phenol containers. Transfer and storage systems shall be designed and operated to prevent blockage by condensed phenol.

(2) When drums of phenol are heated to melt the contents, the use of open flames is prohibited. Drums shall be placed bung up with the bung loosened so that the internal pressure will be vented. Bungs shall be tightened prior to moving or handling drums.

(3) Bulk storage facilities shall be designed and constructed to contain any leaks or spills.

(4) Storage tanks shall be electrically grounded and bonded to transfer lines.

(5) Storage containers and transfer lines shall be maintained in good condition.

(f) Drums, carboys, or other containers of phenol shall be closed while they are being moved or handled. Transfer from such containers shall

be done carefully in a manner to prevent splashes, spills, or other possible circumstances by which any employee may come into contact with phenol.

(1) Leaking containers shall be isolated in adequately ventilated areas, or the phenol shall be transferred to an intact container. Employees shall wear adequate and appropriate personal and respiratory protective equipment during such operations.

(2) Shipping containers to be recycled shall be completely drained and securely sealed. Phenol shall be cleaned or flushed from the outside surfaces of the container.

(g) The transfer of phenol to or from tank trucks or cars may be done only at facilities designed and designated for such operations. The wheels of the tank vehicle shall be chocked, warning signs shall be displayed, and barriers shall be erected to prohibit entry of unauthorized personnel. Connections of the tank and the transfer system shall be compatible and clearly identified. Only trained, authorized persons may carry out the procedures.

(1) No transfer may be made unless authorized by a responsible supervisor.

(2) Employees authorized to make transfers shall be fully trained and familiar with the use of equipment and procedures.

(3) Open flames and smoking shall be prohibited in the area during transfer operations.

(4) The tank car or truck shall be electrically grounded and bonded to the transfer line and receiving tank.

(5) Employees engaged in sampling shall wear respiratory and body protection adequate to prevent overexposure.

(6) If leaks or spills occur, they shall be cleaned up immediately.

(h) Cleaning, maintenance, and repair of tanks, process equipment, and lines shall be done only by properly instructed and trained employees under responsible supervision. When possible, such work shall be accomplished from the outside of the tank or equipment. Entry into confined spaces, such as tanks, pits, tank cars, barges, process vessels, and tunnels, shall be controlled by a permit system. Permits shall be signed by an authorized representative of the employer certifying that preparation of the confined space, precautionary measures, and personal protective equipment are adequate, and that precautions have been taken to ensure that prescribed procedures have been followed.

(1) Before working on tanks, equipment, and lines, proper steps shall be followed to protect any employee from overexposure. Employees shall avoid contact with phenol-contaminated drainage or flushings which shall be drained to a phenol waste system.

(2) If the tank or equipment is to be entered, it shall be thoroughly ventilated after being cleaned. The air shall be tested to ensure that there is adequate oxygen and that exposure of employees is not in excess of 20 mg phenol/cu m in air.

(3) No employee shall enter any tank or equipment which does not have an entry large enough to admit an employee equipped with safety harness, lifeline, and appropriate respiratory equipment. The employee shall be able to leave the tank or vessel by the same opening.

(4) Employees entering contaminated tanks or equipment shall wear full body protective clothing until inspection and testing provide assurance of safety for personnel in the tank.

(5) An employee shall be stationed at the entry to keep employees in the tank under constant observation and one or more other employees shall be readily available in case of an emergency requiring rescue of any employee. An additional supplied-air or self-contained breathing apparatus with safety harness and lifeline shall be located outside the tank or vessel for emergency use.

(6) Provision shall be made for adequate ventilation of the tank or vessel to provide sufficient breathing air for any employee inside and to remove or purge any airborne phenol vapor in excess of 20 mg/cu m. The atmosphere in the tank or equipment shall be tested by appropriate direct-reading devices to ensure that the oxygen concentration is within safe limits.

(7) Before work in or on any tank, line, or equipment commences, provision shall be made for preventing inadvertent entry of phenol into the work area.

(8) Exterior work on a tank, vent, or equipment which may lead to leaking or ignition of phenol is prohibited until the item has been cleaned of phenol.

(i) Phenol waste and phenol-contaminated materials shall be treated or disposed of by methods which will prevent overexposure.

(j) Emergency showers and eyewash fountains shall be provided and maintained at locations readily accessible and close to all areas where phenol may contact the skin or eyes.

(k) Protective clothing, respirators, goggles, and other personal protective gear which have been contaminated by contact with phenol shall be thoroughly washed or cleaned before reuse by any employee. Contaminated shoes shall be discarded. Employers shall ensure that all such equipment is regularly inspected and maintained and that damaged items are repaired or replaced.

(l) Emergency plans and procedures shall be developed and employees shall be trained to implement the plans effectively.

(1) These procedures shall be reviewed with employees and shall be made available in the work areas.

(2) Appropriate emergency equipment including protective clothing and emergency and rescue breathing apparatus shall be located in a safe area adjacent to places where phenol overexposure could occur.

(3) During emergency situations, all personnel shall be evacuated from the area except for the trained and properly equipped emergency teams.

(m) The employer shall take the necessary steps to ensure that:

(1) Each employee receives adequate instruction and training in safe work practices and emergency procedures, and in the proper use of operational equipment and protective devices.

(2) Each employee annually receives refresher sessions and drills in safe work practices and emergency procedures.

(3) Each employee is informed of the locations of all emergency and first-aid equipment and supplies in the work area.

(4) Each employee is trained in the procedures and informed of his responsibility for reporting any emergency, exposure, or injury.

(5) Each employee is provided personal protective clothing and necessary safety devices.

(6) Each employee is given adequate, responsible supervision to ensure that all safety requirements and practices are followed.

(7) Only properly trained and authorized employees are permitted in areas in which overexposure to phenol is likely.

Section 7 - Sanitation

(a) Eating and food preparation or dispensing (including vending machines) shall be prohibited where phenol is present.

(b) Smoking shall be prohibited in areas where phenol is used, transfered, stored, or manufactured.

(c) Employees who handle phenol or equipment contaminated with phenol shall be instructed to wash their hands thoroughly with soap or mild detergent and water before eating or using toilet facilities.

Section 8 - Monitoring and Recordkeeping Requirements

(a) Workplace areas are not considered to have "occupational exposure" to phenol if airborne concentrations of phenol as determined on the basis of an industrial hygiene survey do not exceed 10 mg/cu m. Records of these surveys, including the basis for concluding that airborne concentrations of phenol do not exceed 10 mg/cu m or 20 mg/cu m as specified in Section 1(a) shall be maintained.

(b) Employers shall maintain records of exposure to airborne phenol based upon the following sampling and recording schedules:

(1) The first workplace environmental sampling shall be completed within six months of the promulgation of a standard incorporating these recommendations.

(2) In all monitoring, an adequate number of samples representative of the exposure in the breathing zone of the employees shall be collected to permit calculation of a TWA concentration exposure for a representative group of employees in every work operation involving phenol. This shall be performed quarterly for a minimum period of one year until it is verified that occupational exposure has not occurred. Thereafter, monitoring shall be performed annually unless there are changes in the production or process. When this occurs, monitoring shall again be conducted to determine each employee's exposure to phenol.

(3) Workplace environmental samples shall be taken within 30 days after installation of a new process or process changes.

(c) Should environmental sampling indicate airborne phenol concentrations between 10 mg/cu m and 20 mg/cu m, samples shall be collected in accordance with Appendix I and analyzed in accordance with Appendix II, or by equivalent or better methods for determination of the airborne phenol concentration.

(d) For work areas in which the phenol concentration exceeds 20 mg/cu m, corrective measures shall be initiated and monitoring shall be repeated on a weekly basis until two consecutive sampling periods have shown that airborne phenol concentrations have been reduced to 20 mg/cu m or below.

(e) Records of all sampling and analyses for phenol shall be maintained for at least one year. Records shall indicate the type of personal protective devices, if any, in use at the time of sampling. Records shall be maintained so that the exposure of each employee can be classified or characterized.

(f) Access to records

(1) All records required to be maintained by this section shall be made available upon request to authorized representatives of the Assistant Secretary of Labor for Occupational Safety and Health or of the Director of the National Institute for Occupational Safety and Health.

(2) An employee's exposure determination and exposure measurement records required to be maintained by this section shall be made available to the employee or his designated representative upon request by the employee to the employer.

II. INTRODUCTION

This report presents the criteria and the recommended standard based thereon which were prepared to meet the need for preventing occupational diseases arising from exposure to phenol. The criteria document fulfills the responsibility of the Secretary of Health, Education, and Welfare, under Section 20(a)(3) of the Occupational Safety and Health Act of 1970 to "...develop criteria dealing with the toxic materials and harmful physical agents and substances which will describe...exposure levels at which no employee will suffer impaired health or functional capacities or diminished life expectancy as a result of his work experience...."

The National Institute for Occupational Safety and Health (NIOSH), after a review of data and consultation with others, formalized a system for the development of criteria upon which standards can be established to protect employees from exposure to hazardous chemical and physical agents. Criteria for a recommended standard should enable management and labor to develop better engineering controls resulting in more healthful work environments, and mere compliance with the recommended standard should not be regarded as a final goal.

The criteria and recommended standard for phenol are part of a continuing series of documents published by NIOSH. The proposed standard applies only to the processing, manufacture, and use of phenol as applicable under the Occupational Safety and Health Act of 1970. The standard was not designed for the population-at-large, and any extrapolation beyond the occupational environment is not warranted. It is intended to (1) protect against injury from phenol, (2) allow measurement

by techniques that are valid, reproducible, and available to industry and governmental agencies, and (3) be attainable with existing technology.

There is sufficient information to develop a recommended standard for phenol, but research on effects produced by prolonged exposure to phenol at small concentrations is needed, either by animal studies or by epidemiologic investigations. Phenol in excess of normal physiologic capacities adversely affects nearly all organs, and an understanding of the mechanism of action would be useful in the prevention of adverse effects and for the development of a specific medical treatment for intoxication. Refinement of sampling and analytical techniques for phenol in workplace air would be useful. Well-controlled experiments regarding carcinogenesis, mutatgenesis, and teratogenesis are needed.

III. BIOLOGIC EFFECTS OF EXPOSURE

Extent of Exposure

The term "phenol" as used in this document refers specifically to monohydroxybenzene, C6H5OH, [1] which is a clear, colorless, hygroscopic, deliquescent, crystalline solid at 25 C. [1,2,3] Impurities may impart a light pink color to phenol samples. [1,2,4] Such impurities were not considered in the development of the recommended standard. Although "phenol" and "phenolics" are terms often used to describe compounds containing one or more hydroxyl groups attached to an aromatic ring, [1] it is not intended here to develop a standard for compounds other than C6H5OH.

The chief chemical and physical properties of phenol are given in Table XII-1. Phenol readily forms aqueous solutions and emulsions with the amount of phenol actually dissolved in an aqueous solution increasing with temperature. [1] In solution, phenol can be oxidized, forming a variety of products including benzenediols, benzenetriols, and diphenyls. Reduction with removal of the hydroxyl group to form benzene occurs on distillation with zinc. [1] Phenol undergoes esterification and can form an ether by reactions characteristic of an alcohol. [1] The hydroxyl group is ortho- or para-directing in nucleophilic substitution reactions of the aromatic ring, [1] and the hydroxyl group participates and is highly reactive in condensation reactions with formaldehyde. The aromatic ring can be nitrated by nitric acid. [1]

In the US, phenol is produced either synthetically or by the fractional distillation of coal tar. [1,5] Synthetic processes are the most significant commercially, and production of phenol may be accomplished

by the following processes: (1) cleavage of cumene hydroperoxide to form phenol and acetone, (2) the sulfonation of benzene followed by the fusion of sodium benzene sulfonate with NaOH to form phenol, (3) hydrolysis of chlorobenzene to form phenol in an aqueous sodium hydroxide solution, or (4) oxidation of toluene to benzoic acid and then to phenol. The 1972 US production capacities by process are listed in Table XII-2. Demand for phenol in the US was 1,900 million pounds in 1972, and demand has been estimated at 2,500 million pounds for 1976. [5]

Phenol is supplied commercially either as a solid or as an aqueous solution. [1,2] The USP [6] specification for phenol requires a phenol content of not less than 98%, but in practice nearly all synthetic phenol has a purity in excess of 99.5%. [1] Commercial grades of phenol obtained from distillation of coal tar are either 90-92% phenol or 80-82% phenol, the remaining constituents being water and cresol. [1,2] Solid phenol is shipped in tank cars, tank trucks, wooden barrels, wooden boxes, aluminum drums, nonreturnable metal drums, and small containers. [2] Phenol solutions are shipped in tank cars, tanks, returnable barrels or drums, nonreturnable metal drums, boxed glass carboys, and small containers for laboratory use. [2]

About 90% of the phenol produced in the US is ultimately used (Table XII-3) in the manufacture of phenolic resins, caprolactam, bisphenol-A, alkylphenols, and adipic acid. [5,7] A more complete list of uses is found in Table XII-4. [8-48] Phenol has also been identified in automobile exhaust [49,50] and in cigarette smoke. [49,51]

Occupations in which employees may encounter exposure to phenol are listed in Table XII-5. The number of employees who may be exposed to

phenol has been estimated by NIOSH to be 10,000. This essentially reflects that population of employees engaged in commercial production, formulation of products, or distribution of concentrated products. A substantial but uncertain number of employees indicated by occupation in Table XII-5 may be intermittently exposed.

Historical Reports

Historical reports, described below essentially in chronologic order, indicate that phenol has long had significant chemical and physical properties of commercial interests. Phenol has been used in numerous products and processes, and applications are expected to continue and to increase. [5] According to Stevens [52] and Wilbert, [53] phenol was discovered by Runge who called it "carbon oil acid." Stevens [52] also reported that in 1841 Laurent synthesized phenol in pure form and called it "hydrate de phenyle," but Gerhardt who prepared phenol from salicylic acid later in the mid-nineteenth century was the first to introduce the name phenol.

Cook [54] reported that Lemaire was the first to use phenol as a disinfectant on wounds. In 1867, Lister [55] reported a new treatment using lint soaked in phenol and applied as a covered dressing for compound fractures. Tissue was eroded by phenol in all of the 11 cases treated, and gas gangrene occurred in 8. One death occurred when the application of phenol damaged tissue sufficiently to rupture a femoral artery. There were no complaints of pain as a result of the progressive tissue degeneration. This was an early report indicating the anesthetic property of phenol.

Lister [55] also used phenol as a spray for disinfecting operating rooms and in solutions for storing catgut sutures.

In 1869, Fuller [56] gave phenol to healthy individuals and to patients suffering from a variety of disorders. Oral doses from 0.5 to 1 g phenol in 48 ml of an aqueous solution containing 8% glycerol administered 3 - 4 times/day produced complaints of coldness and a burning sensation in the throat upon swallowing. In addition, signs of giddiness, profuse perspiration, and a weak pulse were observed in most of the subjects. Urine collected from those tested was greenish. Some individuals, especially those characterized as heavy alcohol drinkers, were able to tolerate phenol at similar doses from solutions containing as much as 2% phenol concentration before these signs were observed or symptoms developed. Female subjects tolerated only about half the dose tolerated by males. Some individuals became faint after inhaling aerosols of phenol aspirated directly from 1-2% aqueous phenol, at which time the subjects were advised to cease inhalation of the aerosol. Fuller's experiments preceded a report of the germicidal action of phenol described by Koch in 1881. [57]

Many of the effects which have been associated with phenol exposures are presented in Table XII-6. In addition to the numerous injurious effects of phenol exposure, repeated application of dressings impregnated with 5-10% solutions of phenol has produced acquired ochronosis, a discoloration of collagenous tissue, which was described in 4 reports. [58-61] The discoloration occurred when phenol dressings were used to treat skin ulcerations associated with the development of varicose veins. The dressings were applied over periods ranging from 3 to 24 years.

Prior to the 1940's, only a few cases of exposure to phenol in the workplace had been reported. [20,29,62-66] Among these were 3 cases of prolonged inhalation of phenol [63-65] with possible additional contact with the spilled liquid in 1 case [64] and 4 cases of contact with spilled liquid on the skin [20,29,62] including 1 fatal exposure. [20]

In 1872, Unthank [63] described the case of a farmer who inhaled phenol vapor at unknown concentrations for 3 hours. The victim had symptoms of giddiness and euphoria followed by convulsions and coma. Additional signs were stertorous breathing, lividity of face and neck, cold extremities, and a weak, irregular pulse. Following treatment and return to consciousness, the patient complained of giddiness, pain in the face and neck, gastric irritation, and a phenol taste. There was a gradual improvement with recovery in 4 days.

Hamilton, [20] in a 1917 report, attributed 2 poisonings, 1 fatal, to the absorption of phenol through the intact skin. The fatality occurred as a result of a chemist accidentally stepping into a phenol waste solution. The victim experienced tinnitus, dyspnea, vertigo, euphoria, and hysteria. The victim was allowed to leave in this condition, but he evidently soon lost consciousness as he was found dead on the road the next morning. Examination of the body revealed a gangrenous leg below the knee.

In 1922, an employee wiping up the fluid spilled as a result of dropping a bushel of crude phenol developed signs and symptoms associated with absorption of phenol. [65] The victim collapsed a few minutes after a brief exposure. Thirty minutes later, the patient was comatose and cyanotic with stertorous breathing, subnormal temperature, cold extremities, slight burns on the right hand, and the odor of phenol on his

breath. After treatment, recovery was complete in 2 days.

A report by McCord and Minster [29] in 1924 described the exposure of a shoe worker to phenol contained in a marking ink spilled on her clothing. Injuries were second-degree burns on the face, neck, and breasts, followed by depression, fatigue, headache, a weak and rapid pulse, and collapse. Recovery was speedy following institution of treatment.

In 1939, Winkler [62] described a case in which a chemical worker was sprayed with a liquid containing 50% phenol, 35% cresol, and 10% xylene. The victim received severe burns of the hands, chest, face, and eyes. Examination of the eyes revealed edematous conjunctivae, corneal opacities, insensitivity to light, and hemorrhaging beneath the conjunctivae. Application of fluorescein dye produced intense coloration. The victim was euphoric, complained of headache, and passed a darkened urine which contained phenol and albumin. Winkler concluded that the patient had suffered transitory kidney damage. The red blood cell count was initially normal but decreased markedly to 2.3 million/cu mm in 10 days. Aside from anemia, Winkler postulated damage to the blood-forming organs based upon an increased bilirubin concentration in the serum, slightly increased leukocyte count of 17,000/cu mm, lymphocytosis, and monocytosis. Blood and kidney abnormalities disappeared upon treatment.

Prior to the early 1900's, phenol taken orally was a popular suicidal agent. [25,67-74] Its popularity declined markedly after 1900 because other poisons were considered to be less painful and were also more accessible. [26] Reid et al [59] noted that, in 1909 in the US, of the 3,376 fatal poisonings in which the agents were known, 1,621 (48%) were due to phenol. Of the 1,621, 1,466 (88%) were suicides. With the decline of

phenol as a suicidal agent since 1900, [26] cases of phenol poisoning by oral exposure have diminished. Since 1940, there have been two reports [75,76] involving three deaths from intentional phenol ingestion.

Effects on Humans

The most frequent adverse effects of phenol reported in humans are those from skin contact. Since the early 1940's, numerous investigators [27,76-99] have reported the injurious effects of phenol following inhalation, [88, 92,95,97,98], ingestion, [75,76] contact with the skin, [76-99] direct contact with the trachea during a tracheotomy, [91] and percutaneous injection. [81] Injurious effects following skin contact with resins containing phenol have been reported. [100-105] These signs and symptoms are listed in Table XII-6.

Early investigators [29,56,58,62,63,68,69,71,106-112] reported certain signs and symptoms which are not found in the more recent literature. These included abortion, [69,109] acquired ochronosis, [58-61] difficulty in swallowing, [56,68,69,71,106,107,111] and tinnitus. [58] Symptoms such as euphoria, delirium, and giddiness are reported as increased excitability by more recent investigators [86,88] while symptoms of depression have been more recently reported as stupor. [75]

Effects not found in earlier reports but noted by current investigators [77,85,89,93] include pigmentary changes in the skin, [93] damage to the pancreas, [84] skin cancer, [89] loss of weight, [92] and leukocytosis. [76] These reports probably reflect changes in medical terminology.

(a) Effects of Inhalation

Aside from Fuller's [56] 1869 report, only 5 reports were found

[88,92,95,97,98] on the inhalation of phenol. In 1971, Piotrowski, [97] in controlled experiments, exposed 7 men, aged 25-42, and 1 woman, aged 30, to phenol vapor at various concentrations either by inhalation or by absorption through the intact skin. The subjects passed a thorough medical examination prior to exposure. In 12 separate experiments, phenol at 6-20 mg/cu m (1.5-5.2 ppm) was inhaled using a face mask connected to a chamber in which airborne phenol was generated dynamically from a vessel heated in a constant temperature bath. During each experiment, the concentration of phenol was determined hourly by sampling air directly from the inhalation and exhalation channels of the exposure masks and analyzing for phenol. The only dermal exposure to phenol during the inhalation studies was inside the masks. Subjects were exposed for 8 hours with 2 breaks of 0.5 hour each, one occurring 2.5 hours and the other 5.5 hours after the start of exposure. A 24-hour urine sample was collected prior to exposure. Urine samples were taken every 2 hours during exposure and ad libitum until the next morning after the exposure ceased.

Skin absorption studies [97] were carried out inside the previously mentioned exposure chambers at phenol concentrations of 4.8-5.3 mg/cu m (1.2-1.4 ppm), 9.3-9.7 mg/cu m (2.4-2.5 ppm), 24.8-25.3 mg/cu m (6.4-6.6 ppm), and 22.3-26.1 mg/cu m (5.8-6.8 ppm), as determined by hourly sampling of chamber air. The subjects were clothed in underwear and denim overalls and placed in hammocks during the first, second, and fourth series of experiments and were naked during the third. In each case, subjects breathed fresh air through a face mask to exclude the inhalation of phenol vapor. Exposures were for 6-hour periods with 1 short break in the middle. Urine samples were collected as in the inhalation experiments. Urine

samples in both series of experiments were analyzed for total phenol using the method of Porteous and Williams [113] as modified by Teisinger et al. [114] Phenol was collected from air, using 0.1 N NaOH in fritted bubblers, and analyzed by distillation of phenol in a manner similar to that used in the analysis of urine. The standard error of a single measurement was $\pm$ 4% of the mean, and phenol recovery from air in 1 bubbler exceeded 95%.

Piotrowski [97] found that individuals exposed by inhalation retained 60-88% of the inhaled dose. This percentage did not vary significantly with airborne phenol concentration but did decrease from about 80% at the beginning of exposure to about 70% at the end. There was a slight tendency for retention of phenol to increase after each 30-minute break in exposure. Urinary excretion increased rapidly during exposure and returned to normal within 16 hours after termination of exposure. Calculations showed that 99 $\pm$ 8% of the inhaled dose was excreted in the urine. Individuals exposed through skin absorption excreted amounts similar to those exposed by inhalation, and excretion rates were about the same by either route of exposure. In the skin absorption experiments, clothed and naked subjects showed about the same excretion rates. The author [97] did not describe any adverse effects for any of the test subjects.

In 1972, Merliss [92] reported a gradual deterioration of the health of a 44-year-old laboratory technician who had been exposed to vapor containing phenol, cresol, and xylenol and who had often spilled phenol on his trousers. Spills resulted in skin irritation. Signs and symptoms noted included loss of appetite, darkened urine, and muscle pain in the legs and arms. He stayed away from his job for several months during which time his health gradually improved. He returned to the laboratory for a

period of 45 minutes and had an immediate recurrence of muscle pain and subsequent darkened urine. He lost weight and exhibited an enlarged liver which was slightly tender to the touch. His urine remained dark for several weeks. His condition gradually improved over the next 3 months. Although his liver size and urine color had returned to normal and he had gained weight, it was reported that he had not completely recovered.

Petrov [88] reported 29 poisonings during a 3-year period in a group of employees who quenched coke with a waste water solution containing 0.3-0.8 g phenol/liter. Concentrations for phenol in air samples collected in work areas ranged from 0.5 to 12.2 mg/cu m (0.1-3.2 ppm). The author felt that phenol at concentrations from 8.8 to 12.2 mg/cu m (2.3-3.2 ppm) may have been implicated in the intoxications. No other measurements were reported in this area, and the nature of the phenol poisoning was not further characterized. The observed conditions were most likely produced by some substance in the effluents from either the waste water or the coking process, but it is inappropriate to assume that these conditions were produced by phenol.

In documenting their Threshold Limit Value for phenol, [95] the American Conference of Governmental Industrial Hygienists cited data given to them as a personnal communication by the Connecticut Bureau of Industrial Hygiene. These data indicated that employees inside a conditioning room for phenol-impregnated asbestos suffered marked irritation of the nose, throat, and eyes when exposed for intermittent periods of 50 minutes to a mixture of phenol at 48 ppm (about 200 mg/cu m) and formaldhyde at 8 ppm. Formaldehyde alone at 8 ppm has been shown to cause such irritation. [115-122]

Ohtsuji and Ikeda [98] measured exposures to airborne phenol and urinary phenol concentrations in samples from a group of Bakelite factory employees. Airborne phenol concentrations ranged from 0 to 12.5 mg/cu m. Samples of phenol in air were obtained at a rate of 2 liters/minute using two midget impingers containing 15 ml of 0.1 M borate buffer (pH 10.0). Total air volumes sampled ranged from 5 to 10 liters. Analyses for phenol were performed using Gibbs reagent. [98,123] Urine samples were collected before and after exposure and analyzed for total, free, and conjugated phenol using the Ikeda modification [124] of the Gibbs method. Urine samples were also analyzed for ethereal glucuronides and sulfates using the method of Bertolacini and Barney [125] as modified by Ohmori and Hara. [126] In addition, the specific gravity and creatinine concentration of urine were measured, the latter by the method of Ikeda and Ohtsuji. [127] Urinary conjugated phenol and total phenol adjusted to an average urine specific gravity of 1.018, due largely to the conjugated phenol fraction, increased with airborne phenol concentrations, but the concentration of free phenol varied little with changes in airborne phenol concentrations. Ethereal sulfates in the urine generally increased with increasing airborne phenol concentrations. These increases were observed during the shift, but decreases in these constituents to preexposure concentrations the following morning suggested that these employees readily conjugated and eliminated the phenol absorbed as a result of their combined inhalation and skin exposures. These results are in agreement with and appear to support similar conclusions made by Piotrowski, [97] who separately investigated the inhalation and skin absorption of phenol vapor.

(b) Effects of Ingestion

Bennett et al [75] reported 2 suicide cases. The first case involved a 50-year-old morphine addict who had swallowed 2 oz (approximately 60 ml) of an 88% aqueous phenol emulsion. Forty-five minutes later, he was stuporous with cold and clammy skin and had a rapid and weak pulse, stertorous breathing with a phenol odor on the breath, constricted pupils which did not react to light, and rales in his lungs. An electrocardiogram showed auricular flutter with a variable auriculoventricular block. Lumbar puncture revealed normal spinal fluid. His urine was greenish with no albumin but, 12 hours later, there was marked albuminuria and cylindruria. Albuminuria persisted for 10 days. The patient responded to treatment except for nausea, vomiting, and diarrhea which continued during the first week. He recovered in 20 days. Constriction of the pupils may have been due to the intravenous injection of 0.5 g of morphine prior to phenol ingestion.

The second case [75] involved a 19-year-old woman who had ingested 15 ml of liquefied phenol. Ninety minutes later, she complained of severe nausea and burning in the throat and epigastrium. Laryngoscopic examination revealed superficial burns and slight edema of the hypopharynx. Despite gastric lavage with olive oil and intravenous saline administration, she continued to be nauseated. One hour later, she began to vomit blood and to have diarrhea, passing copious amounts of blood with clots. She gradually became cyanotic and stuporous. Her blood pressure decreased markedly and her extremities became cold. She experienced periods of relapse and recovery during treatment but died 17.5 hours after the ingestion.

In another report, [76] a woman committed suicide by ingesting 10-20 g of phenol. She became comatose with partial absence of reflexes, pallor of the skin, accelerated respiration, weak and rapid pulse, and dilated pupils which did not react to light. Almost one hour after the ingestion, her heart and respiration stopped and, in spite of repeated attempts at resuscitation for two hours, she died. Autopsy revealed marked hyperemia of the tracheal and bronchial mucous membranes. Histologic examination revealed pulmonary and liver edema as well as hyperemia of the intestines.

(c) Effects of Skin Exposure

The skin represents a primary route of entry for phenol vapor, [97] liquid phenol [76,77,84,86,87,89,90,93,94,96] and solid phenol. [79] Phenol vapor readily penetrates the skin with an absorption efficiency approximately equal to that for inhalation. [97] Skin absorption can occur at low vapor concentrations, [97] apparently without discomfort. [79,96]

Liquid phenol in contact with the skin rapidly enters the bloodstream [77-79,82,84-87] and is responsible for the variety of signs and symptoms listed in Table XII-6. These signs and symptoms can develop rapidly with serious consequences, including shock, [76,82,84,85] collapse, [76,81,85] coma, [77,86] convulsions, [80,128] cyanosis, [76,78,83] and death. [76,79,84,86,87] Damage to internal organs has also been described. [76,79,82,85] In addition, the skin is often a site of contact for production of chemical burns and absorption of solid [79] or liquid phenol. [77-79,82,84-86,90,93,94,96,105] There is no evidence that allergic dermatitis results from exposure to phenol, but exposure to resins containing phenol has produced allergic dermatitis results. [100-105] Such allergic reactions can be caused by other agents such as formaldehyde

in the resins, [100,102] the resin itself, [100,101 103,104] or some other product. [104] Discussions of phenolic resins are included in these criteria only when the resins are used or manufactured in such a way as to release free phenol. In such cases, phenol has been mentioned as the probable cause of the skin irritation. [105]

Gottlieb and Storey [129] have described pathologic findings in a 32-year-old somewhat obese man who accidentally spilled a strong solution of phenol over his scalp, face, neck, shoulders, and back. The authors stated that information on the onset of symptoms was not available but, had it been, in all probability it would not have been reliable. The victim, a chronic alcoholic, died within 10 minutes after contact with phenol. Pathologic findings related to phenol were coagulation necrosis of the skin and left eye, acute dermatitis venenata, acute phenol toxicosis, and acute passive congestion of the lungs, liver, spleen, and kidneys. There was moderate cerebral edema (possibly due to his chronic alcoholism). Other pathologic conditions, including chronic degeneration of the liver, kidneys, and heart, were also described. Samples of blood, brain, and stomach contents were analyzed for phenol. The blood contained 0.073% ethanol and 0.0037% phenol. The concentrations of phenol and ethanol in the stomach contents were nil. Skin and liver tissues were positive for phenol by Millon's test. The authors attributed the cause of death to a phenol toxicosis from absorption of phenol through the intact skin.

Caviness [84] reported the case of a 47-year-old diabetic woman who had been lax in her diet and insulin regimen for over 3 years. She developed an eczema on her toe to which she applied a 5% phenol in iodoform and zinc oxide ointment twice a day under a closed dressing. The toe

showed marked edema and erythema, which soon extended to the ankle. She complained of a throbbing pain. Five days later upon admission to the hospital, she had a fever, and increased respiratory rate, pulse rate, and blood pressure. The toe was blue in some areas and red and edematous in others. Later, gangrene developed, causing severe pain and associated periostitis. Following amputation, the woman recovered.

Noury [81] reported a suspected case of rabies in a 49-year-old man who was given prophylactic inoculations of antirabies vaccine in 5 cc of a 1% phenol solution every day for 15 days. The patient had a history of chronic alcoholism. For the first 10 inoculations, he did not notice any particular effect but, after the 11th, he collapsed. His pupils were constricted, his breathing was stertorous, and his pulse weak. He vomited, lost consciousness, and was taken to the hospital. He regained consciousness after 6 hours and remained in the hospital for 20 days. A permanent partial facial paralysis occurred as a result of the incident, but the author did not provide sufficient information to determine the cause of paralysis.

Satulsky and Halpern [90] described 3 cases of dermatitis venenata caused by the local application of a phenol-camphor ointment. The first case was that of a 28-year-old man who treated a self-diagnosed case of crab lice with a liquid preparation containing camphor and 4.75% phenol. Within two hours he felt a burning pain which increased in severity. The abdominal area was covered with a severe dermatitis with lurid erythema, marked edema, and numerous small, tense, clear vesicles throughout. Desquamation was evident around the umbilicus. The edges of the eruption were clearly marked. Also noted were a marked increase in local body

temperature, profuse serous exudation, maceration, and a tendency towards bullous formation. Covered and uncovered patch tests with the mixture on unaffected areas of the man's skin and on the skin of 2 volunteers elicited a primary irritant response in all cases within 30 minutes. The second case was that of a 26-year-old man who treated himself for tinea corporis on the abdomen with a phenol-camphor solution. In 1 hour, he had severe burning, stinging, and pruritus; all of these symptoms increased in severity until his hospitalization the following day. Severe erythema and serous exudation were present. The edges of the eruption were clearly demarcated and slightly raised. Vesiculation and bullae were also accompanied by the exudation of a thick, white serum. Edema, erythema, and crusting were also present. The third case was that of a 24-year-old man, who treated paronychia on his fingers and toes with a phenol-camphor mixture which caused burning and pain within 45 minutes and lasted for 1-5 hours. Erythema, vesiculation, crusting, fissuring, and oozing were present.

Hubler [78] cited the case of a 30-year-old woman who treated the ringworm between her toes with a camphor-phenol solution which caused marked edema and pain. One week later, her toes showed bilateral edema and a number of deep ulcerations. The patient was totally disabled for about a month.

In 1949, Cronin and Brauer [77] reported the case of a 10-year-old boy who had received first- and second-degree burns over 25-30% of his body surface. After being treated with a 2% phenol solution, he developed signs and symptoms of phenol poisoning, including darkened urine, increased pulse rate and body temperature, severe abdominal pain, stupor, cyanosis, local

tissue necrosis, stertorous breathing, dyspnea, rales, frothing, and "pink mucus arising from the lungs." Two and one-half days after the initiation of treatment, the boy was comatose, with irregular respiration, fever, and increased pulse rate; he died within 3 days. Post-mortem examination revealed burns, a yellow fluid in the pericardium, and spotty, firm, dark brown and red areas on the lungs, which also showed hypostatic pneumonia. Abnormal amounts of mucus were present in the trachea and bronchi, where the mucous membranes were hemorrhagic. The spleen was congested. The liver showed midzonal necrosis. The epithelial cells in the glomeruli of the kidneys showed marked parenchymatous degeneration, with loss of cellular configuration. The gastrointestinal tract showed acute congestion. A similar case was cited by Johnstone. [130]

Watorski [96] reported 2 cases of phenol poisoning in the workplace following skin contact with phenol. In the first case, a laboratory technician suffered burns on both hands after spilling a 97% phenol solution (containing cresol impurities). Shortly after the spill, he washed his hands with 98% methanol and then with 20% sodium thiosulfate solution followed by soap and water. Later, he was treated by topical application of 20% sodium carbonate and a dressing with 30% castor oil ointment. Six hours later, he suffered fatigue, general weakness, and blurred vision. A day later, he had severe pain and continued weakness. Recovery occurred within several weeks of the accident. In the second case, a man died 5-7 minutes after the explosion of a metal container of crystalline phenol which was being heated by a battery of Bunsen burners. Trauma produced by the explosion could have contributed to his death.

Evans [82] reported the case of an industrial employee who was involved in the spraying of weeds with a predominantly phenolic material which was the effluent of a chemical plant. This material contained 43.5% phenol, 20% water, 14% cresols, 11.5% low-boiling organics probably aldehydes, and 11% high-boiling organics--probably resinous material according to the author. The skin of both thighs (7 inch x 4 inch and 6 inch x 2 inch areas, respectively), of the scrotum, and of the penis was exposed to the spray. Washing with large amounts of warm water was started immediately and continued for 30 minutes. This was followed by swabbing with ethanol for 10 minutes. The warm water wash and ethanol swabbing were repeated. The employee developed symptoms of shock within 30 minutes after exposure. He had reduced body temperature, a weak and irregular pulse, an accelerated respiratory rate, stertorous breathing, and constricted pupils which showed a slow response to light and slow accommodation. His left leg had convulsive movements for 30 minutes. There was minimal liver damage, as indicated by an increased serum bilirubin at 1.7 mg% (approximately 1 mg % is normal) and by a positive Van den Berg reaction with a direct/indirect quotient of 40%. Other tests for liver function were normal. Urine was not analyzed for phenol until 4 days after exposure, at which time it was negative. Recovery was complete, and the patient was released from the hospital 7 days later.

Johnstone and Miller [85] described a case of industrial exposure to phenol in an ink-manufacturing plant where an employee spilled phenol on his leg, abdomen, and chest. Following immediate flushing with water, he went to a physician's office where he collapsed and died within 15 minutes. Post-mortem examination revealed extensive first- and second-degree burns

on his body, hyperemia and edema of the lungs, and marked hyperemia and edema of the kidneys, pancreas, and spleen.

Duverneuil and Ravier [86] reported that an employee accidentally spilled 4-5 liters of 78% aqueous phenol on himself. Despite immediate irrigation with alcohol, he became comatose and exhibited superficial skin burns. He died shortly thereafter.

Hinkel and Kintzel [87] observed 2 cases of newborn-babies exposed to phenol. One died 11 hours after the application of a bandage containing 2% phenol to the umbilicus. The other was treated for a skin ulcer with a 30% phenol-60% camphor mixture (Chlumsky's solution) and then experienced circulatory failure, cerebral intoxication, and methemoglobinemia. The infant recovered following a blood transfusion.

Telegina and Boiko [93] reported vitiligoid dermal changes in 12 employees in a motor-oil additives-production plant where concentrations of phenol vapor were 0.055-3.33 mg/cu m, hydrocarbons 3.3-24.6 mg/cu m, hydrogen sulfide 0.11-0.78 mg/cu m, sulfur chloride 0.05-0.28 mg/cu m, and carbon monoxide 3.3-26.6 mg/cu m, and where contact of the exposed skin surfaces of the employees with phenol and other irritating substances was a distinct possibility. One employee had been employed for 2.5 years, 1 for 3 years and 7 months, 9 for 6-10 years, and 1 for more than 10 years; 3 employees were 20-29 years, 6 were 30-39 years, and 3 were 40-49 years of age. In those employees in whom this pigmentation abnormality had existed for 2-5 years, the skin had vitiligoid depigmentation spots on the chest, the waist, and the dorsa of the hands and feet, with the largest spots occurring at skin folds. The edges of the spots were not clearly demarcated. Accompanying these large spots were numerous small white ones

distributed in clusters. In those individuals who had developed this depigmentation more recently, isolated maculae of depigmentation were evident. Pruritus was rarely reported. In dyschromic individuals, eosinophilia, monocytopenia, elevated local tissue temperature, susceptibility to prolonged spasms of the cutaneous capillaries of the hands, extensive prolonged dermographia of the chest, marbleization of the extremities, induration and turgescence of the larger and intermediate blood vessels, and excessive perspiration and cyanosis of the extremities occurred. Furthermore, the author noted that employees over 40 appeared to develop secondary and intercurrent skin diseases more readily than did younger employees. It also has been noted [131-134] that several other phenolic compounds can cause similar depigmentary changes.

Abraham [79] reported that an 18-year-old laboratory assistant developed gangrene of the thumb after a 30-minute exposure to crystals of pure phenol which were present inside a rubber glove. The phenol rendered his thumb insensitive. He did not receive treatment for 41 hours following exposure. A clear demarcation between the gangrenous area and the normal skin appeared 26 days after exposure. The necrotic tissue was removed surgically, and the patient recovered. No systemic disorders were noted.

In 1940, Stevens and Callaway [89] described a case involving an epithelioma with basal- and squamous-cell components which had resulted from the continued self-application of a salve made of phenol and ergot to an area on the back. The man, a 72-year-old druggist, had applied this "secret formula" daily to one area of the back where the eczematoid dermatitis was more resistant to treatment. His skin in the middle of the lower back was loose, wrinkled, and warm, and contained a large fungating

mass, 15 cm in diameter. Borders were rolled and, in some areas, there was deep ulceration. In other areas, epitheliomatous hyperplasia and granulations were evident. The lesion was extremely vascular and bled easily. A biopsy showed a neoplastic, invasive growth. Microscopic examination of the tissue revealed it to be a basal-cell and squamous-cell epithelioma. The authors reported that there was no evidence of metastasis. The patient refused treatment either by radiation or excision. The investigators properly attributed the cancer to the continued irritation of the skin rather than to any specific property of phenol.

(d) Thresholds of Perception

Leonardos et al [135] using an odor panel determined the phenol odor threshold to be 0.047 ppm. This threshold represented the lowest concentration to which all 4 trained panelists, selected from a pool of 15 experienced odor panelists, responded positively. Phenol was so tested for at least 5 different concentrations.

Makhinya [136] measured the phenol odor thresholds of 19 people and the lowest range of concentrations for the detection of phenol by odor was 0.022-0.094 mg/cu m (0.006-0.024 ppm). Phenol at concentrations of 0.016-0.078 mg/cu m (0.004-0.020 ppm) was not perceptible by odor for the group tested. Mukhitov [17] obtained similar results using a group of 14 people. The odor threshold for phenol ranged from 0.022 to 0.184 mg/cu m (0.006-0.048 ppm). The highest concentration of phenol not perceptible by odor was 0.0175 mg/cu m (0.005 ppm).

Six 5-minute inhalation exposures to phenol at 0.0155 mg/cu m (0.004 ppm) produced an increased sensitivity to light ($p < 0.01$) in each of 3 dark-adapted subjects [17] who were selected from an original group of 14,

based upon their minimal odor thresholds of 0.029, 0.073, and 0.184 mg/cu m, respectively. Further tests on the original group revealed that 15-second exposures to phenol at 0.024 mg/ cu m (0.006 ppm) elicited the formation of conditioned electrocortical reflexes in 4 additional subjects. Tests with 0.0155 mg phenol/cu m (0.004 ppm) elicited the latter response in 3 of the 4, while 0.0137 mg/cu m (0.0036 ppm) elicited no response. In these experiments, light was used as the unconditioned reflex stimulator which elicited alpha-rhythm desynchronization as measured on an electroencephalograph. Inhalation of phenol was used as the conditioned stimulator, and desynchronization was the index of reflex elicitation.

(e) Metabolism

Ruedemann and Deichmann, [137] using 1 group of 5 male medical students and 3 other groups made up of volunteers, conducted experiments on skin absorption of phenol. Each group member received 1 or more applications of 50 g calamine lotion containing 1 g of phenol (2% phenol) applied over 75% of the body. The medical students received a single application; the second group received 2 applications, 90 minutes apart; the third group received 3 applications, 90 minutes apart; the fourth group received 4 applications, 90 minutes apart. Blood samples were drawn at 2-hour intervals for 1-3 days and analyzed for phenol using the method of Deichmann and Schafer. [138] From the time of the final application, subjects did not remove their underwear for periods of 24-48 hours, at which time each took a shower and donned clean clothing. After allowing a 2- or 3-week period for their blood values to return to normal, these same subjects were similarily exposed to 1, 2, 3, or 4 1-g doses of phenol contained in 21 g of phenol-camphor-liquid petrolatum (4.75% phenol). In

both tests, preexposure concentrations or free phenol in the blood of all 20 subjects averaged 0.15 mg/100 ml and increased to an average of about 0.4 mg/100 ml during each of the tests. Preexposure concentrations of conjugated (protein-precipitated) phenol in the blood of all subjects averaged 0.35 mg/100 ml in both experiments. Conjugated phenol concentrations in blood increased to averages of 1.1, 1.65, 1.9, and approximately 1.9 mg/100 ml, respectively, for the groups receiving 1, 2, 3, and 4 calamine applications and to averages of 0.9, 1.2, 1.7, and 1.5 mg/100 ml, respectively, in the groups receiving 1, 2, 3, and 4 applications of phenol-camphor-liquid petrolatum. Both the free and the conjugated phenol concentrations in blood returned to preexposure values within 24 hours. The subjects noted a soothing and cooling sensation followed by a feeling of warmth after application of the test formulation. There were no indications of systemic intoxication at any time during or shortly after the tests. The investigators noted from these experiments that phenol readily penetrated the human skin, and that detoxication by conjugation apparently was initiated immediately.

There have been various estimates made of the "normal" concentrations of phenol in blood and urine. (see Table XII-10,11) Aside from the values cited by Ruedemann and Deichmann, [137] estimates of "normal" free phenol in blood ranged from none or traces to 4 mg/100 ml. For conjugated (protein-precipitated) phenol in "normal" human blood, estimates ranged from 0.1 mg/100 ml to 2 mg/100 ml, and for total phenol in "normal" human blood, values range from 0.15 to 7.96 mg/100 ml. [138-150] The concentrations of free and conjugated phenol in the blood of those exposed to dermal applications of 2% and 4.75% phenol lotions overlapped the range

of other reported norms. [137] However, with the exception of two reports, [137,138] data presented in Table XII-10 were reported prior to 1939. Based upon more recent work and the propensity for phenol to combine with protein, [137] one would expect the concentration of free phenol in the blood of unexposed subjects to be lower than the concentration of conjugated phenol. However, several investigators [145-148] have reported the opposite case. The variation in absolute amounts of phenol reported also depend on the analytical method used; however, even with the exclusion of results from dubious analytical methods, [141-146] "normal" blood values cover a considerable range and no precise estimates of normal, free, or conjugated blood phenol concentrations can be made.

Total phenol concentrations in "normal" urine have been found to range from 0.5 to 81.5 mg/liter. [97,128,151-158] The specific gravity used to correct for "normal" urine in the British literature is usually 1.016 g/cu cm, and in the US literature it is usually 1.024 g/cu cm. Some investigators use the average specific gravity for the urine obtained from a test population as "normal" urine. In some reports, there are no indications of which correction factor, if any, might have been used. The variation for urinary phenol concentrations in Table XII-11 can be attributed in part to individual variation between test subjects, variation between analytical methods, and the correction factor used. Single exposures to phenol vapor at up to 6.8 ppm via either inhalation or skin absorption for periods of up to 8 hours produced no more than about 100 mg total phenol/liter of urine. [97] By comparison, industrial exposures to phenol at 10 mg phenol/cu m (2.6 ppm) were reported to result in a urinary phenol concentration of 262 mg/liter. [98] Assuming respiration of 8 cu m

of air during the work shift and 100% absorption (80 mg), excretion of the total amount absorbed in approximately 300 cc of urine would result in the reported concentration. This suggests that phenol is rapidly collected and excreted in urine.

Ikeda and Ohtsuji [127] observed considerable variation in normal urinary phenol concentrations, depending upon the analytical method used. Folin and Denis [151] found differences in urinary phenol excretion between people on high- and low-protein diets and noted [159] that both salicylic acid and aspirin produced an increase in the concentration of phenol in human urine. The latter finding was recently substantiated in a report by Fishbeck et al. [160] Biologic monitoring of urinary phenol concentration as a precise index of exposure to phenol has limited usefulness because of the considerable variation and overlap in the ranges for urinary phenol output in individuals considered to be unexposed as well as in individuals considered to have been exposed. In addition, phenol is a metabolite associated with benzene exposure [161] and would not provide a specific biologic indicator.

Animal Toxicity

(a) Acute Exposure

Acute toxicity studies have been conducted on a variety of species including the cat, [162-164] dog, [162,165-167] goat, [167] guinea pig, [168], pig, [167] rabbit, [163,169-171] and rat. [163,169,172] Results of these studies by species, routes of administration, and conditions of exposure to phenol are summarized in Table XII-12.

In 1915, Macht [162] reported that oral administration of phenol to

cats at doses of from 50 to 100 mg/kg body weight caused death in all animals tested. Intravenous injection of phenol in water at a dose of 50 mg/kg also killed all animals tested. [164] Subcutaneous injections of phenol in 0.9% sodium chloride solution were administered to cats at doses of from 1.2 to 15 mg/kg each day for 5 days. One of 3 cats administered phenol at a dose of 30 mg/kg each day for 3 days died 2 days after the final dose while the surviving cats experienced inappetence and diarrhea. [164] Lesser doses of phenol caused loss of appetite. Phenol at 80 mg/kg administered by subcutaneous injection of 10% phenol in olive oil killed approximately 50% of a test group of cats. [163]

Macht [162] conducted experiments to determine the minimal dose of phenol which would cause death in cats and dogs in from 1 to 2 hours. For cats this dose was from 50-100 mg/kg while for dogs it was about 500 mg/kg. All animals left untreated died at these doses. However, comparisons of immediate treatments by lavage using plain water, a strong solution of sodium sulfate, or a solution of 10% ethanol in water showed that sodium sulfate was most effective, followed in effectiveness by plain water. Treatment with ethanol aggravated the apparent effects and hastened death. The author recommended that use of alcohol to treat cases of phenol ingestion be strongly discouraged.

Bond and Haag [165] found that 300 mg of camphor administered orally to 3 fasted dogs along with doses of phenol at 54 - 64 mg/kg body weight resulted in death for all animals while administration of phenol at doses of 37-83 mg/kg in 3 fasted dogs produced no fatalities. A seventh dog given 300 mg of camphor alone also survived. In a separate experiment using 14 dogs fasted for 24 hours and given a dose of 20 mg of morphine

sulfate, 10 of 11 dogs died when given phenol at doses from 3 to 8 g/kg while 2 of 3 dogs survived when given doses from 1 to 2 g/kg. Haskell et al [166] administered oral doses of liquified phenol at 320-420 mg/kg to healthy adult dogs. The dogs were fasted for the immediately previous 24 hours, but were allowed free access to water. Prior to phenol administration, each dog was given a subcutaneous injection of morphine sulfate. Two dogs survived, and the remaining dogs died in 1-6 days.

Oehme and Davis [167] observed neuromuscular irritability, coma, and convulsions (but no deaths) as toxic effects of phenol given orally at 100 mg/kg to dogs, goats, and pigs. They also reported frequent intravascular hemolysis and darkened urine containing protein, hemoglobin, and bilirubin. The authors considered these findings indicative of kidney damage.

Chassevant and Garnier [168] gave intraperitoneal injections of phenol to 6 guinea pigs at doses of 30-300 mg/kg using a 10% aqueous solution of the sodium salt of phenol. The average dose was 170 mg/kg. At high doses, the guinea pigs died in a few hours but, at low doses, deaths occurred in 1-5 days. A few minutes after injection, there was usually a crisis which began with a generalized shaking that developed into broader movements until the animal could no longer stand. This was followed by a complete muscular atonia. Hypothermia was a constant observation. Autopsies performed immediately after death revealed intense congestion of the visceral and parietal peritoneum, the abdominal viscera, and particularly of the kidneys and adrenals. In another series of experiments, 5 guinea pigs were given intraperitoneal injections of phenol at doses of from 200 to 1000 mg/kg using 10% phenol solution in olive oil. While 2 of the 5 animals survived, the physiologic responses of the guinea

pigs to phenol and the pathologic findings were similar to those for the sodium salt of phenol. [168]

Cosgrove and Hubbard [171] conducted experiments to determine the effects of phenol on the eyes of rabbits and to test the efficacy of decontamination techniques. One drop of phenol at either 87%, 50%, 20%, or 10% in glycerin was applied to the eyes of rabbits. The eyes were completely destroyed by 1 drop of 87% phenol, and applications of one drop of the more dilute solutions of phenol produced similar destructive effects. When the eyes of the test animals were irrigated immediately with either water or 4% sodium sulfate, there was no damage. Immediate irrigations with 25% ethanol in water resulted in some slight permanent opacities. If irrigation with water was delayed for 10 seconds or longer after application, corneas became opaque in 40% of the animals treated with 87% phenol. However, 70% of the animals developed opacities when treated with 50% phenol followed by delayed irrigation. The authors also reported that animals treated with either 20% or 10% phenol had responses similar to those of the animals treated with 50% phenol, but this observation of more opacities produced by weaker solutions was not further explained. Delayed irrigations with 4% sodium sulfate were less effective than water in preventing opacities.

Experiments to establish a range of toxicity were carried out on the rabbit using a variety of oral doses of phenol in water. [173] The studies indicated that there was no difference in the toxicity of phenol when the same amount was administered in either a concentrated or a dilute solution. Administration of phenol at a dose of 620 mg/kg caused death in all rabbits tested. An intraperitoneal (ip) LD50 of 620 mg/kg was found

for rabbits injected with 5% aqueous solutions of phenol, and the intravenous (iv) LD50 for rabbits was approximately 180 mg/kg. [173] In other experiments, the abdominal skin of rabbits was exposed for one hour to aqueous phenol solutions or emulsions under a latex covering. [173] Blood phenol concentrations were determined after exposure using the diazotized p-nitroaniline method of Deichmann and Schafer. [138] The concentration of phenol in blood did not show a proportional increase relative to the amount of phenol contained in the exposure solutions, and phenol concentrations in blood were 1.1-5.2 mg/100 ml using 7% phenol, 1.2-5.1 mg/100 ml using a 75% emulsion of phenol, and 2.2-6.0 mg/100 ml using a 95% emulsion of phenol. In a range-finding experiment, [170] rabbits were clipped of body hair, and the skin of individual rabbits was exposed to phenol at single doses ranging from 10 to 6,400 mg/kg using 1.0, 5.0, or 20% solutions of phenol applied under an impervious cuff and allowed to remain for 24 hours. Large doses involved application of from 70 to 100 ml of solution to each rabbit under the cuff which covered the entire portion of the body between the appendages. Three rabbits receiving doses of 1,600, 3,200, or 6,400 mg/kg of phenol died within two hours of application. Rabbits exposed to phenol at 10 to 800 mg/kg survived.

Deichmann and Witherup [163] conducted experiments on rats, rabbits, and cats to determine the acute effects of phenol. Equal numbers of males and females were used in the individual experiments. The 100% lethal dose for cats given subcutaneous injections of a 10% phenol solution in olive oil was 80 mg/kg. In experiments using rats to determine differences in susceptibility to phenol as a function of age, 10-day-old rats were more susceptible to phenol administered either cutaneously or by ingestion when

compared to 5-week-old or to adult rats. Cutaneous applications of 3,000 mg phenol/kg were lethal to 9 of 20 (45%) adult rats, to 5 of 20 (25%) 5-week-old rats, and to 13 of 20 (65%) 10-day-old rats. Oral administrations of 600 mg phenol/kg were lethal to 12 of 20 (60%) adult rats, to 9 of 30 (30%) 5-week-old rats, and to 18 of 20 (90%) 10-day-old rats. An LD50 for adult rats given 10% phenol in olive oil was found to be 1,500 mg/kg. In several experiments with rabbits, the effects of phenol either by oral intubation, injection into the stomach through the abdominal wall, intravenous injection, or by skin contact were investigated. Oral doses of phenol ranged from 280 to 940 mg/kg as either melted crystals or as solutions containing from 2 to 90% phenol. There was little difference in the toxicity of either dilute or concentrated solutions when administered in similar amounts orally. Lethal effects were generally produced by phenol at a dose of 620 mg/kg and occasionally by phenol at a dose of 420 mg/kg.

Ernst et al [164] dipped the tails of 10 rats in a 4.75% phenol-camphor-liquid petrolatum solution 1 hour/day for 30 of 42 days. Tails were washed and dried after each exposure. Another group of 10 rats was similarly exposed to water. Both groups showed occasional mild hyperemia, which was less noticeable in controls. No other significant difference between the two groups was observed.

Deichmann and Witherup [163] exposed four rabbits to 4.75% phenol-camphor-petrolatum solutions (250 mg/kg) for 5 hours/day, 5 days/week, for 18 days. Two of the rabbits were wrapped in bandages. After each 5-hour period the bandages were removed, and all rabbits were washed with soap and water. A mild hyperemia developed but disappeared after washing. Mild

tremors occurred during the 18-day period. In a continuation of the experiments, 24 rabbits were divided into 6 groups of 4 each and exposed to aqueous solutions containing phenol at 1.18, 2.37, 3.56, 4.75, 5.93, and 7.12% concentrations. These exposures were equivalent to doses of phenol at 64, 130, 190, 250, 320, and 380 mg/kg, respectively. Two of the four rabbits in each of the groups exposed to the four lowest concentrations were bandaged, while no bandages were used in the two highest exposure groups. Rabbits exposed to 1.18% phenol showed no signs of irritation or of systemic effect. The group exposed to 2.37% showed no signs of skin irritation, but occasional mild tremors were observed. Those rabbits exposed to 3.56% and 4.75% phenol had hyperemia and mild tremors which developed one hour after the start of each exposure for all animals in the group. Hyperkeratosis was observed in one of the four animals in the 4.75% group. Those animals exposed to the two higher concentrations of 5.93 and 7.12% phenol had local tissue necrosis and severe tremors. One of the four exposed to 7.12% phenol died after the sixth application.

In 1950, Deichmann et al [169] found that approximately 50% of the rats whose tails were dipped in 6.6% aqueous phenol solutions for 8 hours died; 2.75% phenol in aromatic liquid petrolatum and 12.5% phenol with 10.86% camphor in aromatized liquid petrolatum produced similar results. They also found that tails dipped in 1.78% phenol in liquid petrolatum or in 4.15% aqueous phenol for 8 hours became gangrenous.

In 1970, Conning and Hayes [172] determined the LD50 to be 0.625 ml/kg (670 mg/kg) for percutaneous exposure of rats to liquified phenol (melted at 40 C) by both occlusive and nonocclusive techniques (shorn back). Severe muscle tremors with twitching developed into generalized

convulsions with subsequent loss of consciousness and prostration 5-10 minutes after administration of the dose in all animals. Severe hemoglobinuria developed 45-90 minutes after the application with severity increasing as a function of the administered dose. In addition, all animals developed skin lesions and edema with subsequent tissue necrosis and discoloration. Pathologic examinations revealed evidence of severe kidney damage in all animals. The lowest dose applied was 0.1 ml/kg.

(b) Chronic Exposure

Various investigators have conducted experiments to determine effects produced in animals by chronic exposure to phenol by inhalation, [17,28,174] ingestion, [173] or skin contact. [175-179] Data from these experiments are presented in Tables XII-13-18.

(1) Inhalation

In 1944, Deichmann et al [174] exposed 12 guinea pigs, 6 rabbits, and 15 rats to phenol vapor at concentrations ranging from 100 to 200 mg/cu m (26-52 ppm) for 7 hours/day, 5 days/week. No control animals were used. All animals were exposed in a single 600-liter chamber with phenol vapor generated from 2 gas-washing bottles containing a phenol solution and immersed in an oil-coated, constant-temperature water bath maintained at 25 C. Airborne phenol concentrations were estimated by analysis of grab samples using a colorimetric diazotization procedure. After 20 exposures over a period of 28 days, 5 guinea pigs died and the remaining 7 were killed on the 29th day. Prior to termination of the exposures, some animals showed weight loss, respiratory difficulty, and signs of paralysis. At autopsy, pathologic examinations revealed evidence of extensive necrosis of the myocardium, acute lobular pneumonia, vascular

damage, and hepatic and renal damage. Analysis of blood at autopsy by the method of Deichmann and Schafer [138] showed average free phenol concentrations of 1.0 mg/100 ml, average conjugated phenol concentration of 0.4 mg/100 ml, and average total phenol concentration of 1.4 mg/100 ml.

In a continuation of the inhalation experiments, [174] 6 rabbits exposed 63 times in 88 days did not show signs of distress. After 27 exposures (37 days), average blood concentrations were 0.5 mg free phenol/100 ml, 0.7 mg conjugated phenol/100 ml, and 1.2 mg total phenol/100 ml. When the animals were killed at 88 days, blood phenol analyses were essentially unchanged. Microscopic examinations revealed evidence of lobular pneumonia, chronic purulent bronchitis, degenerative changes in pulmonary blood vessels, myocardial degeneration, and indications of liver and kidney damage. In general, damage was less severe than that found in the guinea pigs.

Rats exposed 53 times in 74 days showed no signs of distress and upon autopsy revealed no evidence of adverse effects. No blood analyses were reported for rats. [174]

In 1961, Sandage [180] exposed 10 monkeys, 50 rats, and 100 mice to phenol at 5 ppm (19 mg/cu m), 8 hours/day, 5 days/week, for 90 days. An equal number of animals of each species, housed in identical chambers, served as controls. Phenol vapor was introduced using sintered glass gas washing bottles maintained at elevated temperature. Phenol vapor air streams were reduced in temperature, and the air saturated with phenol was introduced into the chambers by mixing with fresh air. Phenol concentrations were determined by absorbing the phenol from 2 liters of air in 20 ml of 0.1 N NaOH and analyzing this solution colorimetrically with

diazotized p-nitroaniline and sodium carbonate. Periodically hematology tests, urinalysis, blood chemistry measurements, kidney function tests, stress tests, and measurements of body weight were performed. Pathologic examinations upon autopsy at the termination of exposure showed no differences between exposed and control animals (with 95% confidence) with the exception of a slight weight gain in exposed rats and monkeys and an increased stress test endurance for exposed mice.

(2) Reproduction and Growth

Heller and Pursell [173] reported the results of controlled oral exposures to phenol, in which 10 groups of rats were allowed 0, 100, 500, 1,000, 3,000, 5,000, 7,000, 8,000, 10,000, and 12,000 ppm phenol in their drinking water. For the groups allowed water containing from 0 to 8,000 ppm phenol, volumes of water consumed were noted and food was analyzed for phenol content. Phenol from food represented a significant fraction of dietary phenol intake, especially in the lower exposure groups. Growth, fecundity, and general condition were noted for 5 generations of rats in the groups receiving 100, 500, and 1,000 ppm phenol, for 3 generations in the 3,000- and 5,000-ppm groups, for 2 generations in the 7,000- and 8,000-ppm groups, and for 1 year in the 10,000- and 12,000-ppm groups. All observations were within normal limits in the groups allowed 5,000 ppm or less. The growth of young from the group allowed 7,000 ppm in water was stunted. At concentrations of 8,000 ppm and above, mothers did not provide the ordinary care for their young, and many of the young died. At 10,000 ppm, the offspring died at birth. At 12,000 ppm, there was no reproduction and, in the summer, the older rats allowed 10,000 or 12,000 ppm died sooner than did controls.

Mukhitov [17] exposed 3 groups of 15 rats continuously for 61 days to phenol vapor at approximately 0.011 mg/cu m (0.003 ppm), 0.11 mg/cu m (0.03 ppm), and 5.2 mg/cu m (1.4 ppm), respectively. A fourth group of 15 rats served as controls. Animals were exposed dynamically in 100-liter chambers. The air was sampled once or twice each day. The general condition and the weight of the animals were determined daily, and motor chronaxy, urinary coproporphyrins, and whole blood cholinesterase activities were measured periodically. Animals exposed to phenol at 0.011 mg/cu m were of good general health and their condition was indistinguishable from controls in all categories. Rats exposed to phenol at 0.11 mg/cu m (0.03 ppm) were also in excellent health, but exhibited a slightly shorter extensor muscle chronaxy ($p < 0.01$) and an increase in whole blood cholinesterase activities in comparison with controls. Rats exposed to 5.2 mg phenol/cu m were more sluggish than controls and showed a lower rate of weight gain ($p < 0.05$), had a shortened extensor and lengthened flexor muscle chronaxy ($p < 0.01$), and showed increased whole blood cholinesterase activities ($p < 0.01$).

(3) Skin Cancer

Salaman and Glendenning [175] performed experiments to test the effect of phenol as a sclerosing agent on the production of skin tumors in 4 groups of 20 male mice using "S" strain albinos. Two groups were pretreated by application to the whole back of 0.2 ml of 0.15% 9,10-dimethyl-1,2-benzathracene (DMBA) in acetone. Three weeks after the DMBA application, one of the pretreated groups and one untreated control group were treated with 0.1 ml of 5% phenol in acetone at two alternating sites on the lower back once a week for 32 weeks. The second group receiving

DMBA pretreatment was treated with 0.025 ml of 20% phenol in acetone at four sites on the back in rotation once a week for 24 weeks while a control group was treated with 20% phenol in a similar manner for 32 weeks. All mice were inoculated on the tails with sheep lymph vaccine as a precaution against ectromelia. The hair from the back was clipped before treatment and at intervals when necessary. Throughout treatment, 20% phenol in acetone continued to produce local ulcerations in both the test and the control groups. The ulcerations required almost the entire 4 weeks to heal before the next application scheduled for the site. Tumors began to appear in the group treated with DMBA after 8 applications of 20% phenol in acetone while tumors appeared in the control group after 24 applications of 20% phenol. No tumors developed in the group exposed only to 5% phenol in acetone. The group pretreated with DMBA and exposed to 5% phenol in acetone developed 13 tumors after 13 weeks, and there were 9 tumors on 4 mice out of 14 surviving after 45 weeks. Tumor yields and the experimental conditions are summarized in Table XII-15. The authors [175] concluded that, under the conditions of these experiments, a solution of 20% phenol in acetone produced skin ulcerations and had a strong promoting action on tumor development and a weak carcinogenic action. A solution of 5% phenol in acetone was found to have a moderate promoting action, but no carcinogenic action. No unexposed controls, no controls with DMBA alone, and no controls for application of acetone were reported.

Boutwell and Bosch [176] conducted experiments with one group of albino male mice of the Sutter strain and several groups of albino female mice of the Sutter, Holtzman, CAF1, and CH3 strains to evaluate the skin tumor-promoting potential of phenol following a single application of 9,10-

dimethyl-1,2-benzanthracene (DMBA). Sutter strain mice were selectively bred for three generations for susceptibility to development of tumors after a single application of DMBA followed by croton oil. [181] Benzene solutions of phenol or DMBA were applied to the backs of mice by test group as indicated in Table XII-16, and tumor yields were noted for periods of up to 52 weeks. DMBA was applied in a single application of 75 μg (0.025 ml of a 0.3% solution in benzene) one week prior to initiation of treatments with phenol. For DMBA applications, the fur was shaved from the test area of the back. Because of the possibility of mechanical irritation and damage to papillomas, the mice were not shaved after initiation of phenol exposures. Phenol was applied at concentrations of 5% or 10% in benzene 2 times/week while one group received only DMBA with no subsequent treatment with phenol or benzene and a second group received DMBA pretreatment followed by 0.025 ml of benzene 2 times/week for 20 weeks.

One group receiving treatment with 10% phenol in benzene 2 times/week for 52 weeks did not receive pretreatment with DMBA. Repeated application of 10% phenol in benzene following pretreatment with DMBA caused benign tumors to appear rapidly and in large numbers while carcinomas appeared late. Phenol alone was capable of inducing tumors in females of the DMBA/croton oil-tumor-susceptible Sutter mice, and in female mice of the Holtzman strain. Using female mice of the DMBA/croton-oil-tumor susceptible Sutter strain, Boutwell and Bosch [176] conducted additional experiments in which a single application of 75 μg of DMBA in 0.025 ml of a 0.3% solution in acetone was used as an inititator for tumor formation, and phenol was applied 2 times/week in concentrations from 5% to 20% in various solvents including acetone, 30% ethanol in acetone, benzene, and dioxane.

Tumor yields, survival, duration of observations, and treatment conditions are given in Table XII-17. Tumor yields increased with increasing phenol content of solvents and total amounts of phenol applied. Tumor yields were zero for acetone, benzene, or 30% ethanol in acetone solvent controls using mice pretreated with a single application of DMBA and observed over a 12-week period

Wynder and Hoffmann [177] conducted experiments to compare the tumor promoting action of phenol and phenol derivatives identified in tobacco smoke. The phenol used in their initial test was especially prepared and "chemically pure" while in later experiments, phenol was purified by distillation over zinc dust. Reagent grade acetone was used as a solvent for the administration of either phenol, 3,4-benzo[a]pyrene (BaP), or DMBA. Six-week-old Swiss Millerton mice were used in seven experiments in which acetone containing phenol at either 5% or 10% concentration was applied 2 or 3 times/week to the backs of animals which had been treated with a single application of DMBA one week prior to the start of the phenol tests. The dorsal hairs of the mice were shaved before the single DMBA application.

In other experiments, [176] about 5 μg of BaP at a concentration of 0.005% in acetone was applied 3 times/ week to the backs of 6-week-old-Swiss Millerton mice. On alternate days, 5% phenol in acetone was applied to one group 2 times/week, and 10% phenol in acetone was applied to a second group 2 times/week. No phenol or acetone was applied to a third group maintained as a BaP-exposed control. The dorsal hair of these mice was not shaved to avoid any additional skin irritation. Tumor yields and conditions for these experiments are presented in Table XII-18. With a

single application of DMBA, exposure to phenol increased the yield of tumors and caused an earlier onset of tumors. In addition, tumor yield was greater and tumor onset was earlier for each of the 2 DMBA-exposed groups receiving 10% phenol when compared to a DMBA-exposed group receiving applications of 5% phenol. Applications of phenol caused earlier onset of tumors compared to time of onset in the control group exposed to BaP alone.

Van Duuren et al [178] treated the shaved dorsal skin of 20 female ICR/Ha Swiss mice with 0.3 mg phenol in 0.1 ml acetone 3 times/week for 1 year beginning 4 days after pretreatment with a single application of 150 μg DMBA in 0.1 ml of acetone. Twenty female ICR/Ha Swiss mice serving as controls were subjected to a single application of 150 μg DMBA. Four of the phenol-exposed mice (20%) developed papillomas during the year with observation of the first papilloma after 167 days of exposure. One animal developed a squamous carcinoma after 355 days of exposure. The DMBA controls had two (10%) papillomas, with observation of the first papilloma after 247 days and one carcinoma (5%) observed after 373 days. Results and conditions of these experiments are presented in Table XII-18.

Van Duuren et al [179] reported an additional experiment in which 3 mg of phenol in 0.1 ml acetone and 5 μg of 3.4-benzo(a)pyrene in 0.1 ml acetone were applied 3 times/week over a 460-day period to the backs of female ICR/Ha Swiss mice. When compared to a control group receiving only BaP in acetone, the phenol treatment produced fewer tumors. Tumor yields and conditions for this experiment are also presented in Table XII-18.

(c) Metabolism

Once phenol enters the body, it may be rapidly eliminated in the urine [167,173,182-192] as the conjugated phenylglucuronide [167,173,182-

192] or phenylsulfuric acid products. [167,182,183,187-192] It may also be oxidized to catechols [191], quinones, [191] and carbon dioxide and water, [182,185] or excreted unchanged in the urine, [167,182,183,185,189,190,192] feces, [173,183,193] or exhaled air. [183] Conjugation occurs primarily in the liver, [183,184,190, 191,193-195] but it also occurs in the intestine, [184,193,195] kidneys, [194, 195] spleen, [195] pancreas, [193] and extracellular fluid. [184,193] Oxidation to catechols and quinones occurs primarily in the liver. [191] Deichmann and Keplinger [196] presented two figures (see Figures XII-1 and XII-2) which combine the findings of Deichmann [183] and Parke and Williams [191] to show the respective fates of sublethal and lethal oral doses of phenol in the rabbit.

The extent and nature of the conjugation of phenol have been shown to be functions of diet, [173,184,189,194,197] dose, [183,187], route of entry, [184] degree of animal fatigue, [198] and body temperature. [199] The metabolism of tyrosine [173,184,189,193,197] or metabolism of salicylic acid [160,192] can result in significant endogenous production of phenol. Williams [187] has stated that the extent of conjugation to phenylsulfuric acid decreases rapidly with increasing dose, and he expressed the opinion that the formation of phenylsulfuric acid was largely a function of available sulfate. [187]

In general, signs of intoxication appear only after absorption of phenol in amounts sufficient to overwhelm the capacity of the body to detoxify or otherwise eliminate phenol. The precise dosage at which adverse effects begin to occur is uncertain. Excessive doses of phenol in animals have been shown to depress the vasomotor centers of the brain,

[164,167,172,200,201] producing, in some studies, motor disturbances and blood pressure changes of sufficient magnitude to induce cardiac arrest, respiratory failure, [167,172,185, 190,192] and coma followed by death. [162,163,165,166,169,170,172]

Correlation of Exposure and Effect

Solutions of phenol were shown (see Table XII-6) to rapidly penetrate human skin. [81,86,96,111,202,203] Skin contact by humans with solutions, emulsions, or pure preparations containing 80-100% phenol for as little as 5-20 minutes (see Table XII-6) resulted in death. [96,115,202,204] Exposure of eczematous skin to a phenol solution as dilute as 2.5% caused coma in 3 minutes. [111] Contact with a 43.5% phenol solution for a period of less than 1 minute produced shock despite repeated 30-minute irrigations with copious amounts of water followed by swabbing with ethanol. [81] Seventeen daily dermal applications of a 1% phenol solution resulted in coma in an 82-year-old woman. [128] Exposure of skin contact areas as small as a portion of a thumb for 30 minutes caused gangrene, [79] while contact of "pure carbolic" with a portion of the scalp and cheek caused death in 5-10 minutes. [204] Thus, repeated contact with dilute phenol solutions or even brief contact with concentrated phenol solutions posed a hazard to life, even if the contact area was relatively small.

Chronic skin contact with 5% phenol in oil was reported to have caused acquired ochronosis [58-61] over periods of 3-30 years, [58,59] and death after a period of 12 years. [60] In addition, Stevens and Callaway [89] reported a single case of an invasive squamous cell epithelioma in a

72-year-old man who had applied a salve of phenol and ergot to his back daily for 20 years.

Reports of occupational exposure and of controlled experiments (see Table XII-6) showed that phenol vapor can enter the human body both by inhalation [17,95,97,98,135,136] and through the intact skin [97] (see Table XII-6), and is rapidly detoxified and eliminated by conjugation [95,97,98] and excreted in the urine. [95,97,98] Conjugation has been associated with the formation of ethereal sulfates [95,98] and glucuronides. [98] Ohtsuji and Ikeda [98] reported that concentrations of conjugated phenol in the urine increased following exposure of humans to phenol from as little as 0.6 mg/ cu m (0.16 ppm) to as much as 12.5 mg/cu m (3.3 ppm) without any significant increase in the concentration of free phenol. Piotrowski [97] conducted experiments on inhalation and skin exposure to phenol vapor separately. He found that humans exposed to phenol at vapor concentrations of 6-20 mg/cu m by inhalation showed increased total urinary phenol. Skin exposure to phenol vapor at 5-25 mg/cu m also caused an increase in total urinary phenol. The increase of urinary phenol was about the same for inhalation as for skin exposure. In both cases, urinary phenol concentration returned to normal within 16 hours after termination of exposure. Denim overalls or other clothing did not hinder the absorption of phenol vapor through the skin. [97] No ill effects were reported from the combined skin and inhalation exposures to phenol at 12.5 mg/cu m (3.3 ppm), [98] from inhalation of phenol at 25 mg/cu m (6.8 ppm) phenol, or from skin exposure to phenol at 20 mg/cu m (5.2 ppm) for up to 8 hours. [97]

Skin absorption from human contact with solid phenol produced tissue destruction and gangrene at the site of contact following 30 minutes of direct contact with the solid. [79]

Cosgrove and Hubbard [171] reported that the eyes of rabbits were completely destroyed by 1 drop of 87% phenol in glycerin. If, however, the eyes were irrigated immediately with water, corneas remained clear. If irrigation of the eyes was delayed 10 seconds or longer after application, corneas were damaged in 40% of the animals tested. One drop of 50% phenol in glycerin left in the eyes 10 seconds or longer before irrigation with water resulted in only 30% of the animals recovering and having transparent corneas within 3 or 5 days. Use of 20% or 10% phenol in glycerin gave similar results. In general, if the eyes of treated animals were irrigated immediately with water or 4% sodium sulfate, all animals had transparent corneas. Using 25% ethanol for immediate irrigation resulted in some slight permanent opacities. Delayed irrigations with 4% sodium sulfate were less effective than water in preventing opacities.

Ingestion of phenol by humans caused abdominal pain and numerous signs and symptoms listed in Table XII-6. Principal effects of ingestion included at least one or more of the following: a burning sensation in the throat [68,69,77,205] followed by abdominal pain, increased irritability, headache, absence of corneal reflexes, collapse, convulsions, [68] coma, and death. [70,75,76] The amounts of phenol required to produce such severe reactions in humans were relatively small, and data in Table XII-9 show that ingestion of as little as 4.8 g of pure phenol caused death in 10 minutes. [205] The ingestion of 4.3 g phenol 3-4 times in a single day caused a burning sensation in the throat, giddiness, cold and profuse

perspiration, a weak pulse, and darkened urine, [56] while by contrast a single ingestion of 1.3 g phenol [206] or 0.96 g phenol taken 3-4 times/day [56] produced no immediate ill effects.

No report was found of acute or chronic human exposure to phenol vapor or aerosol by inhalation. No epidemiologic study of an employee population exposed to phenol by inhalation has been reported.

Phenol can be derived from endogenous as well as exogenous sources, and animal experiments provided a more precise definition of the metabolic fate of phenol. As shown in Figure XII-1, subacute doses of phenol were rapidly eliminated largely by conjugation to phenylsulfuric acid and phenylglucuronic acid, by oxidation to catechols and quinones or to carbon dioxide and water, [182,185] or by excretion as free phenol. [167, 182,183,187,189,190,192] Excretion occurred primarily in the urine [167,173,182-192] with small amounts being excreted in the feces [173,183,193] or in exhaled air. [183] When the functional capacity for detoxification was exceeded, vasomotor centers of the brain could be depressed [164,167,172,200,201] producing alteration of blood pressure [200,207,208] and motor disturbances [164,167,172,200,201] capable of inducing cardiac arrest with respiratory failure [172,185,190,192] followed by death. [162-170,172]

The lowest doses producing death in animals as shown in Table XII-12 were 50-100 mg/kg by oral administration [162] and 20 mg/kg by intravenous injection in the cat, [164] 320 mg/kg by ingestion in the dog, [166] 150 mg/kg by intraperitoneal absorption in the guinea pig, [168] 380 mg/kg by skin absorption in the rabbit, [169] and 420 mg/kg by ingestion in the rabbit. [163] The LD50 for the rat through skin absorption is 670 mg/kg.

[172] Deichmann and Witherup [163] reported the lethal dose for approximately 50% of the animals as 80 mg/kg by subcutaneous injection in the cat, 620 mg/kg by subcutaneous injection or 620 mg/kg by intraperitoneal injection in the rabbit; 340 mg/kg by ingestion in the rat, and as 2.75% phenol in petrolatum applied to the skin of a rat for 1 hour/day for 3 days. The lowest doses of phenol to attack the vasomotor center and produce signs were 4.9 mg/kg by intravenous injection [164] and 1.2 mg/kg by subcutaneous injection in the cat, [164] 700 mg/kg by intravenous injection in the dog, [167] 100 mg/kg by intravenous injection in the goat, [167] 150 mg/kg by intraperitoneal injection in the guinea pig, [168] 100 mg/kg by intravenous injection in the pig, [167] 130 mg/kg by skin contact, [169] 280 mg/kg by ingestion, [163] and 26-52 ppm (100-200 mg/cu m) by inhalation in the rabbit, [174] and 107 mg/kg by skin absorption in the rat. [172]

Inhalation exposures (see Table XII-13) of 26-52 ppm (100-200 mg/cu m) phenol 7 hours/day, 5 days/week, produced 5 (42%) deaths in a group of 12 guinea pigs after 29 exposures. [174] Upon autopsy, pathologic examination revealed necrosis of the myocardium, lobular pneumonia, vascular damage, and hepatic and renal damage. Rabbits similarly exposed 63 times in 88 days showed no signs of illness or discomfort but had lobular pneumonia, chronic bronchitis, vascular damage, myocardial degeneration, liver damage, or kidney damage at post mortem examination. [174] Rats exposed at 26-52 ppm (100-200 mg/cu m) phenol 53 times in a period of 74 days showed no microscopic evidence of adverse effects. [174] No controls, however, were used. Monkeys, mice, and rats were exposed to phenol at 5 ppm for 8 hours/day, 5 days/week, for 90 days without any

adverse effects. None of 15 rats receiving 53 exposures showed any signs of illness or discomfort, and no pathologic findings were reported. [180] In contrast, Mukhitov [17] found a significant ($p < 0.01$) decrease in rate of weight gain for rats exposed to phenol at 1.4 ppm (about 6 mg/cu m). Heller and Pursell [173] found that phenol at 7,000 - 12,000 ppm in drinking water adversely affected growth, fecundity, and general conditions of rats.

Odor thresholds for phenol in air in all persons so tested (see Table XII-7) were found to be 0.091 mg/cu m, [136] 0.178 mg/cu m, [135] and 0.182 mg/cu m. Phenol has warning properties by odor at concentrations far below the concentrations at which toxic effects occur. Mukhitov [17] obtained similar results finding an odor threshold for phenol ranging from 0.022 to 0.184 mg/cu m (0.006-0.048 ppm).

Carcinogenicity, Mutagenicity, and Teratogenicity

Heller and Pursell [173] (see Table XII-14) allowed groups of rats to drink water containing phenol at 0-12,000 ppm. The group allowed phenol at 5,000 ppm in water had no adverse effects over 3 generations. Stunted growth was evident in the young of the group exposed to phenol at 7,000 ppm in water over 2 generations. In the group allowed phenol at 8,000 ppm in water for 2 generations, mothers would not care for their young which then died prematurely. The offspring of the rats allowed phenol at 10,000 ppm in water died at birth. The group allowed phenol at 12,000 ppm in water did not reproduce, and many adults died prematurely in hot weather. This study did not indicate any specific teratogenic properties of phenol.

Salaman and Glendenning, [175] Boutwell and Bosch, [176] Wynder and Hoffmann, [177] and Van Duuren et al [178] showed that phenol promotes skin cancer in mice. In addition, Boutwell and Bosch [176] and Wynder and Hoffmann [177] reported that phenol is a weak skin carcinogen in mice. However, all of these studies did not provide for evaluation of effects produced by the solvents used and, in some cases, for the pretreatment of the albino mice with a known carcinogen, either DMBA or BaP. Conditions of these experiments, [175-179] do not reflect industrial experience with phenol, and the studies were carried out with phenol dissolved in various organic solvents, including benzene, acetone, dioxane, and a mixture of 30% ethanol in acetone. Results of these mice studies suggest that phenol functions primarily as a nonspecific irritant and may be capable of promoting tumors. There is no evidence that phenol acts as a specific carcinogen or as a mutagen, particularly at low concentrations within normal physiologic limits.

IV. ENVIRONMENTAL DATA

Sampling and Analytical Methods

Phenol and substituted phenols have commanded the attention of analytical chemists for more than a century, and a large number of publications, in both theoretical and applied research, may be found in the general analytical chemical literature. In 1926 and 1927, Gibbs [209,210] published comprehensive reviews of the literature dealing with tests for phenol and noted that the number of tests exceeded 100. The bibliography to these papers contained references to more than 250 papers, many of them from the German literature in the latter years of the 19th century. However, modern industrial experience with phenol is substantially different, and most of these early reports are only of historical interest.

Almost all of the methods described by Gibbs are colorimetric tests, and virtually all of the spectrophotometric methods in use today are included in his classification scheme. [209,210] In the nearly 50 years since Gibbs' papers, many modifications and improvements in techniques using the reagents he described have been made, but relatively few new methods have been added. Gibbs classified all tests as dye reactions, halogen reactions, reactions with salts of metals, or a final mixed group which consisted of methods not belonging in the first three groups. The majority of the methods in use today would have been classified by Gibbs as dye reactions, which rely on the spectrophotometric determination of a color intensity produced with phenol and a reagent system. In a more recent review of colorimetric methods for determining phenols, Snell and Snell [211] described several reagents useful in phenol analysis and, in

addition, made specific recommendations for analyzing urine, blood, and other biologic samples, as well as air, water, sewage, and various commercial preparations. Feigl [212] also described several color tests suitable as spot tests for phenol. A review of the literature dealing with the analysis of phenol, but not necessarily related to air analysis in the workplace, reveals that the most widely used reagents have been Gibbs' reagents (2,6-dibromoquinonechloroimide), [4,13,97,98,124,213-217] 4-aminoantipyrine, [49,215,216,218-232] diazotized aromatic amines, [138,157,215,220-225,228,233-243] and diaotized sulfanilic acid. [4,13,244-246] Other authors have reported methods based on ultraviolet spectrophotometry [213,215,216, 221,222,247-256] and measurement in both the near-infrared [257] and the conventional infrared [215,258-260] regions. A number of electrometric procedures have also been used to determine phenol, including potentiometric titrations, [261,262] voltametric determinations, [263] and oscillopolarography. [264] Chemiluminescence has also been used as the basis for a method described by Ponomarenko and Amelina [265] in which luminol (3-aminophthalhydrazide) is the chemiluminescent material. Still other investigators have performed photometric titrations, usually in nonaqueous media. [266-268]

Unless there are precautions to separate phenol from other compounds, and in particular from phenol derivatives, most of the above methods are not specific for phenol. For the specific determination of phenol, a preliminary separation is usually required. Depending upon the sample composition, cleanup procedures generally involve separations by extraction and may require use of chromatographic techniques; separations have been performed by means of paper, [252,269-271] thin layer, [217,235,272-276]

and column chromatography. [248-252,277,278] Separation or extraction does not constitute a determination of phenol but must be followed by analysis of phenol by an independent method.

Gas chromatography (GC) is perhaps the most convenient method for separation and simultaneous determination of phenol and phenol derivatives. A variety of GC techniques has appeared in the general literature. [50,152,154,232,252,259,275,279-294] In most of these techniques, isolation and concentration of the phenolic fraction of the samples is necessary to eliminate potential interferences prior to introduction into the chromatograph. Although phenolic compounds may often be separated and analyzed by selected GC procedures without modification or preparation of derivatives, some investigators have prepared methyl aryl ethers, [280,295] phenoldiethylphosphate esters, [294] acyls, or more complex ethers [291] to facilitate separation and analysis.

Numerous analytical procedures are described for the determination of phenol in mixtures with a variety of substances, including hydrocarbon solvents, [296] gasoline, [247] wood smoke, [248] coal tar, [259] whiskey, [252] cigarette smoke, [234,235,275,280,281,295] and, of course, water. [214,215,227,228,231,232,254,279] Analytical methods applied to the analysis of either water or cigarette smoke are particularly useful, as these methods, with appropriate modifications may often be applied to analysis for phenol in workplace air. Standardized methods developed for the analysis of phenol in water have been tested many times and are likely to be quite reliable. The American Society for Testing and Materials (ASTM) recommends several colorimetric and gas chromatographic methods for determining phenolic compounds in water. [232] Similar methods are also

recommended in Standard Methods for the Examination of Water and Wastewater. [279]

Analysis of biologic samples for phenol has also been an area of interest. Phenol and phenol derivatives are naturally occurring substances found in blood, urine, and in a variety of samples of biologic origin, [194,240,297,298] and are related to both normal [267,299] and abnormal metabolism. [267,300] However, most earlier literature and some current studies generally have not been concerned with exposure to phenol in the workplace but instead have attempted to define the roles of phenols in health and disease. [152,241,246,240,288,301] Phenol has long been recognized as a toxic substance, and reports from the forensic toxicology literature contain numerous methods for determination of phenol in specimens obtained from humans. [138,242,302]

In general, most phenol analyses currently performed on biologic samples are intended to show exposure to benzene, rather than to phenol. [303] Exposure to benzene results in increased urinary phenol excretion, and there are numerous methods for the determination of phenols in urine. [152,154,157,230,243,287] In contrast, relatively little interest has been shown in measuring biologic concentrations of phenol in relation to phenol exposure, but several investigators have suggested that such analyses are indeed useful in assessing exposure to phenol [97,98] or phenol derivatives. [304]

Sampling and analysis of air to determine phenol content have been performed in connection with air pollution studies as well as in-plant determinations related to industrial hygiene investigations. Air pollution studies include a number of surveys of atmospheric phenol concentrations,

[49,221-223,238,239,305,306] analyses of vehicular exhaust products, [32, 221,222,225,226,255,271] and analyses of other air-pollution sources. [221,222,294] Many of the methods use colorimetric reagents, including diazotized paranitroaniline, [210] paraaminodimethylaniline sulfate, [49,305] aminoantipyrine, [49,220-226,229,237] chloroparanitrophenol, [237] and piperonyl chloride. [225,306] Ultraviolet spectrophotometric methods have also been used, [221,222,225,255] and a number of GC methods have been described. [32,271,283-286]

After collection of a workroom air sample, most industrial hygiene methods rely on spectrophotometric measurement of a phenol-dye complex using techniques developed for phenol in tissue or liquid samples. Jennings [9] and Zhitkova [307] described the use of Millon's reagent, a mercury-containing mixture which forms a colored compound with phenol, in the analysis for phenol in workplace air samples. Lovelock [244] was among the first to use diazotized sulfanilic acid for determination of phenol in air, and other investigators [4, 245] used a similar analytical procedure in later years. Fukuyama et al [233] used the so-called Moir reaction, utilizing diazotized paranitroaniline to produce a red color, and this reagent was also recommended by subsequent investigators. [308] Other spectrophotometric methods used for the analysis of phenol in workplace air include those based on nitration, [309] the use of several stable diazonium salts, [243,310,311] the Gibbs method, [13,213] and nitroso formation. [312] In addition to procedures involving analysis of a colored complex, ultraviolet absorption measurements have also been used by several investigators. [213,253]

None of the above methods is specific for phenol, and it has been the practice in industrial hygiene to determine "total phenols" or, more accurately, those substances which react with a given reagent rather than to attempt to limit the analysis to phenol. In using such methods, the underlying assumption is that either it is unnecessary to separate phenol derivatives or phenol is the only compound likely to be present.

One of the problems in the determination of phenol in air in contrast to other materials is the method of collecting the sample. It has been shown that phenol can exist in the air as a vapor, an aqueous aerosol, or in association with particulate matter. [221,222] An air sampling method for total phenol must collect all phases. Frequently, phenol is assumed to be present as a vapor and is collected by absorption in water, [9,244,245,307,310,308] alkaline solution, [4,233,243,309] or a bicarbonate solution. Ethanol solutions have also been used. [213] Phenol has also been collected by adsorption onto silica gel. [243] Smith et al [221,222] collected phenol on activated carbon, but this method of sampling was not applied to in-plant atmospheres.

A GC method [313] has been developed for NIOSH. Although this method has not been field-tested, it has been shown to be specific for phenol, subject to certain limitations inherent in all GC procedures. It is suitably accurate and precise for quantitative analysis of phenol.

Control of Exposure

Reported injuries produced by phenol exposures, occupational and otherwise, have primarily resulted from either skin contact or ingestion. The rapid rate at which phenol is absorbed through the skin, resulting in

severe injury or fatal results, is well documented. [81,86,96,112,170,202 204] The eye can be damaged by contact with small quantities of phenol, and this has been amply demonstrated in the rabbit using 10-87% solutions of phenol in glycerin. In some instances, occupational injuries said to have been produced by skin contact with phenol [79,81,86,96,129,202,204] may also have involved vapor inhalation.

Quantitative data on phenol vapor concentrations associated with human effects due to exposure to phenol are scarce, [88,97,98] and the few reports containing quantitative data have involved low concentrations of the vapor. Piotrowski [97] has shown that phenol vapor is readily absorbed through the respiratory membranes and the skin, but absorption of the vapor through the skin is slower than by inhalation. Although there are no reports of severe injuries or fatalities resulting from exposure to phenol vapor in the industrial setting, prolonged skin exposure or inhalation of phenol should nevertheless be prevented.

Equipment, processes, and procedures for handling or using phenol should be designed and engineered to prevent all employee contact with phenol in any form. Total enclosure of processes and materials, with appropriate venting for pressure or vacuum relief, is desirable. When routine operating, servicing, or maintaining of a production system is required, provisions must be made to protect employees by the use of personal protective devices, adequate ventilation, and good work practices including spill prevention, cleanup, and prompt, safe disposal of material wastes. In addition, specific practices to be applied to the handling of phenol are as follows:

(1) Remote control or automation of operations can be used effectively to remove employees from the proximity of operations where contact with phenol or inhalation of vapor would be most likely to occur.

(2) Pure phenol is a solid at 25 C, and all pipelines for transfer of phenol liquid should be steam-traced or otherwise designed and operated to ensure that phenol does not solidify in the lines. Similarly, all vent pipes from tanks and equipment should be steam-traced, [2,314] or designed and operated to prevent solidification.

(3) Personal protective clothing, shoes, and equipment must be used together with good work practices wherever there is a possibility of skin or eye contact with phenol (Chapter I).

Experience has shown that in many instances the concentration of phenol vapor in air is controlled adequately by the usual dilution ventilation of the workplace. Given the amount, method, and rate at which phenol is used in the workplace environment, the volume of air exhausted during the work shift, and the rate at which phenol may be vaporized depending on room temperature, appropriate calculations or air sampling and analysis should be performed to characterize any likely exposures to phenol vapor. At 25 C (77 F), the vapor pressure of phenol is sufficient to produce an equilibrium concentration (saturated air) of 462 ppm, and at 41 C (106 F), the melting point of phenol, the equilibrium concentration is 1,710 ppm. These equilibrium concentrations are not likely to occur in the breathing zone of an employee. However, there is sufficient vapor pressure [314] at temperatures ordinarily encountered in the work environment for the development of concentrations of airborne phenol in excess of the recommended environmental limits, particularly in enclosed or poorly

ventilated spaces.

Increased general dilution ventilation can be used to increase the volume of air and rate of flow, thereby decreasing the concentration of phenol in the workplace to a safe airborne concentration. Where feasible, removal of phenol by local exhaust ventilation close to single or isolated sources of emission is preferred over general dilution ventilation. Properly designed and functioning local exhaust ventilation can capture and prevent contaminants from reaching the breathing zones of employees or from being disseminated throughout the work areas. In employing exhaust ventilation for such control, certain recommended practices [315] and design and operating fundamentals [316] should be followed. Regular inspection and maintenance of the ventilation system are necessary for its continued effectiveness. Local exhaust ventilation should also be used for the control of phenol vapor emissions from hot processes.

V. DEVELOPMENT OF STANDARD

Basis for Previous Standards

The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended an 8-hour TWA concentration of 5 ppm (approximately 19 mg/cu m) as the threshold limit value (TLV) for phenol (with a skin notation). The TLV for phenol was first established at 5 ppm in 1952. A skin notation was added in 1961, and there has been no change in the TLV through 1975. The ACGIH supports its limit in its Documentation of the Threshold Limit Values for Substances in Workroom Air [95] as follows. "Deichmann (1) reported results of animal experimentation in which guinea pigs were severely injured by inhalation for 20 days of phenol vapor at concentrations of from 25-50 ppm. Post mortem evidence of acute toxicity to the lungs, heart, liver, and kidney was found. According to unpublished data from the Connecticut Bureau of Industrial Hygiene (2) intermittent industrial exposure (5-10 minutes per hour) inside a conditioning room for phenol-impregnated asbestos resulted in marked irritation of the nose, throat, and eyes. The average phenol concentration in the room was 48 ppm, although formaldehyde (8 ppm) also was found. Urine sulfate ratios were 79.4 and 86.7 percent. Employees at the same plant, continuously exposed during winding operations, experienced no respiratory irritation, although the odor of phenol was noticeable. The average concentration found was 4 ppm. Urine sulfate ratios averaged 74%. Due in part to its low volatility, phenol does not frequently constitute a serious respiratory hazard in industry. (3) Formerly its use as an antiseptic in surgery resulted in numerous cases of sub-acute or chronic poisoning among surgeons

and their assistants. (4) Urinary excretions of 2 gm per day by patients have been reported. (4) Absorption of 2 gm of phenol could result from 8 hours' inhalation at about 50 ppm. According to Thomas and Back (5), the TLV of 5 ppm provides a sufficiently large factor of safety to prevent systemic poisoning if skin absorption is avoided." (Note: Numbers 1 through 5 in parentheses within the quotation are citations and correspond in the order given to references 174, 317, 308, 196, and 318 in this document. Primary references cited are the animal studies of Deichmann et al, [174] Thomas and Back, [318] and the unpublished human data from the Connecticut Bureau of Industrial Hygiene. [317] The human data include conditions which may have been produced, at least in part, by the high airborne formaldehyde concentration reported to be present).

The present federal standard for phenol based upon the 1968 TLV [319] is an 8-hour TWA of 5 ppm phenol (skin).

Other countries and various states in the United States have established standards for phenol. These are listed in Table XII-19.

The Czechoslovak Committee of MAC, in their Documentation of MAC in Czechoslovakia, [320] present values shown in Table XII-20. The standard is supported in a translation as follows: "We believe on basis of observations in USSR and reports and standards from abroad that no hazard of chronic poisoning threatens in mean MAC and no hazard of acute poisoning in peak MAC. The comparatively small vapour tension of phenol and its distinct smell causes only isolated occupational poisonings by inhalation. The considerable etching effect of phenol on skin and possibly percutaneous resorption require care when handling liquid phenol especially in hot state."

Ryazanov, [8] in supporting the Russian ambient air standard, concludes that the limit of allowable concentration of phenol in the air of work departments of production plants and factories of 5 mg/cu m (1.3 ppm) was not only low enough to prevent chronic poisoning but was also far above the threshold of odor perception.

Basis for the Recommended Standard

To protect the health of employees and to provide a safe working environment, it is essential to prevent skin or eye contact, inhalation, and ingestion of phenol. The recommended standard prohibits skin or eye contact and requires use of protective clothing made of rubber, neoprene, plastic, or other material impervious to phenol. Face shields, chemical safety goggles, or a full facepiece on respirators to provide eye protection are requried. Overexposure by inhalation is prevented by specifying an environmental limit and a ceiling limit for phenol in air which are values not to be exceeded. Exposures in excess of the airborne concentrations of phenol specified in Table I-1 are prevented by the use of appropriate respiratory protective devices. Ingestion of phenol is prevented by work practices which prohibit smoking, drinking, or eating in work areas where phenol is present. In addition, medical surveillance is required for employees who are occupationally exposed to phenol. Occupational exposure has been defined as exposures to phenol at airborne concentrations exceeding one-half the recommended time-weighted average concentration limit.

To protect employees and to reduce the likelihood of injury, employers are required to provide first-aid services including deluge

showers and eyewash fountains in areas where phenol is used.

Crystalline phenol has produced gangrene after 30 minutes of skin contact. [79] Such contact is possible, despite phenol's irritant properties, because of its local anesthetic action. [79] Phenol in solution has been shown to rapidly penetrate human skin. [82,86,96,111,112,202,204] Phenol solutions containing 50-100% phenol (see Table XII-6) have caused death after skin contacts as brief as 5-20 minutes, [96,129,202,204] 2.5% phenol solution applied in a dressing over the human body caused coma in 3 minutes, [111] and a 43.5% phenol solution accidently sprayed on the thighs, scrotum, and penis for a period of less than 1 minute caused shock despite repeated treatments consisting of 30-minute irrigations with copious amounts of water followed by swabbing with ethanol. [81]

Chronic contact with solutions as dilute as 1% phenol caused coma in an 82-year-old woman with eczema after 17 daily applications of phenol in calamine lotion. [129] Daily contact with phenol at an unknown concentration in an ergot salve over a period of 20 years induced a case of invasive epithelioma in an elderly man. [89]

Concentrations as dilute as 5% phenol have been shown to promote cancer in mice after pretreatment with DMBA. [175-178] (see Table XII-15). However, Van Duuren et al [179] found a reduced prevalence of tumors in mice exposed 3 times/week to 3 mg phenol applied concurrently with 5 μg benzo(a)pyrene (BaP) as compared to mice receiving similar doses of BaP without phenol. Boutwell and Bosch [176] and Wynder and Hoffmann [177] produced a single malignancy in groups of 24 and 30 female mice after twice-weekly applications of 10% phenol for 72 and 52 weeks, respectively.

From studies using albino mice, [175-179] no definitive conclusions concerning phenol as a carcinogen or promoting agent can be made. Phenol as a nonspecific irritant may promote development of tumors when applied repeatedly to the skin in large amounts.

Skin contact with either liquid or solid phenol has led to serious consequences in humans, and numerous reports indicate that such contact with phenol in even small amounts represents a serious hazard in the occupational environment. [79,82,86,96,111,112,202,204]

Controlled-inhalation and skin-absorption studies conducted by Piotrowski [97] on 8 human volunteers clearly showed that phenol absorbed by inhalation of vapor at concentrations at or below 20 mg/cu m (5.2 ppm) or by skin exposure at vapor concentrations at or below 25 mg/cu m (6.8 ppm) was completely eliminated within 24 hours, and that there was no sign or symptom of any biologic disorder. In addition, Ohtsuji and Ikeda [98] supported the above findings by showing that employees who received a combined inhalation and skin exposure to phenol vapor at concentrations up to 12.5 mg/cu m (3.3 ppm) readily detoxified the absorbed phenol during their shift. Excretion of conjugated phenol was still apparent in the urine prior to the next shift, but free urinary phenol concentrations remained essentially unchanged and at background levels. These investigators [98] further substantiated Piotrowski's findings [97] in that no ill effects were reported in any of the employees surveyed.

Cosgrove and Hubbard [171] demonstrated that the rabbit eye is completely destroyed by one drop of 87% phenol in glycerin. Corneas remained clear in test animals when there was immediate irrigation with water. However, if irrigation of the eyes was delayed for 10 seconds or more after

application, the cornea became opaque in 40% of the animals tested. By using more dilute solutions of phenol in glycerin (10-50%), a greater percentage of animals developed corneal opacities with delayed irrigation. Therefore, any phenol in the eyes should be regarded as a serious emergency requiring immediate irrigation with copious amounts of water. Eye protection, eyewash fountains, and deluge showers are mandatory.

Studies by Sandage [180] (see Table XII-13) clearly showed no ill effects in monkeys, rats, and mice exposed to phenol vapor at 5 ppm (19 mg/cu m) for 8 hours/day, 5 days/week, for 90 days. Deichmann et al [174] exposed guinea pigs, rabbits, and rats to phenol vapor at 26-52 ppm (100-200 mg/cu m) for 7 hrs/day, 5 days/week (see Table XII-12). Twenty-nine such exposures killed 5 of 12 guinea pigs, and post mortem examination revealed necrosis of the myocardium, acute lobular pneumonia, and hepatic and renal vascular damage. Although none of 6 rabbits receiving 63 such exposures showed any signs of illness or discomfort, they showed similar but less severe changes at autopsy. None of 15 rats receiving 53 exposures exhibited any signs of illness or discomfort, and no pathologic changes were reported. [174]

Ingestion of relatively small amounts of phenol is immediately hazardous to human life (see Table XII-9). Ingestion of as little as 4.8 g of phenol has caused death within 10 minutes. [205] Ingestion of 48 ml of a 1-2% phenol solution (0.5 to 1.0 g of phenol) 3-4 times/day [56] produced a burning sensation in the throat, giddiness, cold and profuse perspiration, a weak pulse, and darkened urine. Although ingestion of either a single dose of 60 ml of a 2% phenol solution (1.2 g) [206] or 48 ml of a 0.2% phenol solution (0.1 g) 3-4 times in a single day produced no

immediate ill effects, [56] only small doses of a few grams were necessary to cause death in humans. [112,205] Therefore, it is recommended that appropriate work practices be used to minimize any phenol exposure by ingestion.

There are no data to suggest a substantial change in the current federal standard, and an environmental limit for phenol at 20 mg/cu m expressed as a TWA concentration for up to a 10-hour workday is recommended. Except for addition of a skin notation in 1961, the threshold limit value for phenol has not been changed since it was established at 5 ppm in 1952. The body burden for exposure to phenol at 20 mg/cu m would have a maximum steady state value of about 50 mg throughout the shift. This amount of phenol is well within the physiologic range for detoxification or elimination. [167,173,182, 192]

Phenol is detectable by odor at a threshold of 0.05 ppm (see Table XII-1) which may be annoying to some people. Fuller [56] found that phenol in large amounts (1-2 g) could be tolerated for short durations several times a day but that the toxic threshold dose for phenol can be only a few grams. [78,205,206] To avoid irritation by phenol and to minimize exposure to large amounts, a ceiling limit of 60 mg phenol/cu m of air based on a 15-minute sampling period has been added to the recommended standard.

Occupational exposure is defined as exposures to phenol at airborne concentrations in excess of one-half the recommended TWA environmental limit, and medical surveillance shall be made available to employees who are thus exposed. This provision is necessary to provide a basis for diagnosis, intervention, treatment, or rehabilitation in cases of potential phenol overexposure and to identify those individuals with preexisting

conditions, such as skin, eye, kidney, liver, heart, or lung disorders, that might place them at increased risk from occupational exposure to phenol. However, first-aid services are recommended in any workplace where phenol is present.

VI. WORK PRACTICES

Employees should be informed that "protective creams" do not afford adequate or acceptable skin protection from contact with phenol. [2]

Phenol tanks and pipelines should not be placed underground [321] as leakage from underground tanks or lines is more difficult to locate and to repair in the event of leakage. Surrounding earth can become sufficiently impregnated with phenol that it may present a hazardous exposure to employees digging to uncover and to repair the leak, and the contamination may extend beyond the leak to expose other individuals.

Food should neither be stored nor eaten in a workplace where phenol is stored or used. [2] Employees should be given warnings strongly emphasizing the serious injury which may result from ingestion of even very small amounts of phenol. Employees should exercise great care that phenol from contaminated gloves, garments, or respirators not be transferred to the eyes, mouth, or skin. Protective clothing should be cleaned and decontaminated after each use.

Washing facilities, showers, and lockers should be provided in conveniently located change rooms. Employees should be urged to practice good personal hygiene by washing and showering after each work shift. They should change work clothes each day. Work clothes should be laundered after each wearing.

Clean and hygienic lunchroom or lounge areas should be provided for the use of employees, but such areas should be separate and protected from exposure to or contamination by phenol. These areas or similarly provided

areas should be used for smoking, drinking, or eating during work breaks.

Smoking must be prohibited in areas of possible phenol exposure to avoid unnecessary sources of ignition and possible increased risk from exposure to toxic products of combustion.

Swabbing the contaminated skin with a 2:1 mixture of polyethylene glycol 300 and industrial methylated spirits is effective for removal of phenol. [172,201,322,323] Recently, Pullin et al [324] used pigs to compare the swabbing technique with deluge showers of water. They concluded that either swabbing or water shower, properly used, was equally effective. Since deluge showers containing anything but water are inappropriate, the recommended method of decontamination of the skin from an exposure to phenol is the use of a water deluge shower. Such showers should be available wherever large volumes of phenol are in use or whenever there is a significant risk of exposure to phenol.

In emergencies or in nonroutine operational situations where either engineering or administrative controls are not capable of maintaining the amount of exposure at or below the recommended TWA environmental limit, the wearing of approved respiratory protective devices (see Chap I, Sect 4) is essential. Because of the sensitivity of the eye to phenol, only full facepiece respiratory protective devices are recommended. [2]

Phenol spills and leaks must be cleaned up immediately and employees engaged in cleanup must wear adequate personal protective garments and respiratory equipment (Chapter I). Employees must avoid skin and eye contact with solids or liquids and also must avoid prolonged breathing of, or exposure to, phenol vapor. Often an adequate cleanup procedure consists of flushing spilled phenol to a drain with an abundant flow of water and

subsequent drainage into an enclosed waste treatment or disposal system. Phenol wastes should not be flushed into a community sewer system unless it has been determined that such action will neither interfere with sewage treatment nor result in contamination of water sources sufficient to violate applicable regulations and ordinances.

Phenol waste must be disposed of or treated in a manner which does not result in prohibited or undesirable contamination of water, air, or land. Phenol can be recovered from waste by adsorption on charcoal, solvent extraction, or steam stripping. [2] Phenol may be destroyed by either chemical or biologic oxidation processes. The latter processes usually involve impounding the waste liquor, in which case precautions are necessary to ensure that seepage does not contaminate ground water.

Phenol is capable of reaching flammable (explosive) vapor concentrations. The lower explosive limit is 1.5% (by volume in air) which is the equilibrium concentration at 75 C (167 F). The closed-cup flash point is 79 C (174 F). [2] High concentrations of phenol in an employee's breathing zone are not likely to occur in a workplace unless phenol is heated. Although inhalation of phenol may not be likely in a particular area where phenol is used, the danger of explosion should be considered, and measures should be taken to maintain the concentrations of phenol vapor and oxidizing agents below the explosive limit and to eliminate ignition sources, particularly in closed systems. Sprinkler systems, alcohol foam, carbon dioxide, and dry chemicals are effective extinguishers for fires involving phenol. [2]

Good work practices, personal hygiene, and proper training of employees are necessary for the control of occupational hazards associated

with exposure to phenol. Employees must be thoroughly trained in all the procedures and equipment required in their employment and in the use of all appropriate emergency procedures and equipment.

Phenol destroys tissue, but it also has a local anesthetic action. Any contact with phenol may result in significant absorption without noticeable pain. The employer should require that each instance of phenol contact with the skin or eye be reported promptly and that appropriate first aid be administered. Review of reports should be carried out at regular intervals (not greater than 6 months) to identify processes, procedures, operations, equipment, job sites, or personnel showing repeated or unusual frequency of contact with phenol. Surveillance and careful attention to prevention of significant contact with solid or liquid phenol, and the elimination of processes involving prolonged or repeated exposure to phenol vapor should be significant factors in reducing occupational exposure and preventing injury. If proper work practices are ignored or carelessness is tolerated, serious injury is likely to occur in spite of protective equipment and systems. Skin contact is a major danger in working with phenol. The effective use of good work practices is entirely dependent on the knowledge and the cooperation of employees and employers.

VII. OCCUPATIONAL RESEARCH PRIORITIES FOR PHENOL

(1) Chronic Effects

The effects of chronic exposure to phenol at low concentrations require investigation. With few exceptions, human experience with phenol by skin contact, inhalation, or ingestion has been by exposures to overwhelming amounts (see Tables XII-7,8, and 9). Epidemiologic investigations of occupational groups are lacking, and information on concentrations of phenol in air and any associated clinical findings would be useful. Chronic exposure of animals to phenol at concentrations in the range of the recommended environmental limit also would be appropriate.

(2) Mechanism of Action and Metabolism

There is uncertainty regarding the normal values for phenol in blood and urine for humans, and research should be conducted on biologic monitoring and determination of normal values. Phenol is a normal metabolite and may be derived from a variety of endogenous sources including proteins and medications. Within physiologic limits, phenol does not appear to produce toxic effects. In excess of these limits, toxic effects are produced in several organs, and research on the mechanism of action might allow development of preventive measures and a specific therapeutic regimen for phenol intoxication.

(3) Monitoring Techniques

Analytical and sampling methods for determination of phenol in workplace air require refinement to provide more adequate personal monitoring techniques. Direct reading devices and continuous monitors suitable for breathing zone determinations would be useful.

(4) Carcinogenic Studies

Well-controlled experiments using several animal species should be conducted to ascertain the carcinogenic, mutagenic, or teratogenic potential of phenol.

VIII. REFERENCES

1. Lederman SJ, Poffenberger N: Phenol, in Kirk-Othmer Encyclopedia of Chemical Technology, ed 2. New York, Interscience Publishers, 1968, vol 15, pp 147-59

2. Chemical Safety Data Sheet SD-4--Properties and Essential Information for Safe Handling and Use of Phenol. Washington, DC, Manufacturing Chemists Association Inc, 1960

3. Weast RC (ed): Handbook of Chemistry and Physics--A Ready-Reference Book of Chemical Data, ed 55. Cleveland, CRC Press, 1974, p C-421

4. Jacobs MB: The Analytical Chemistry of Industrial Poisons, Hazards and Solvents, ed 2. New York, Interscience Publishers, 1949, pp 697-703

5. Chemical Profiles--Phenol, rev 3. New York, Schnell Publishing Co, 1972

6. The United States Pharmacopeia, rev XIX. Rockville, Md, United States Pharmacopeial Convention Inc, July 1, 1975, p 375

7. Faith WL, Keyes DB, Clark RL: Industrial Chemicals, ed 3. New York, John Wiley and Sons Inc, 1965, pp 583-94

8. Ryazanov VA (ed): Limits of allowable concentration of phenol in the atmospheric air of inhabited localities, in Limits of Allowable Concentrations of Atmospheric Pollutants, in Levine BS (trans): USSR Literature on Air Pollution and Related Occupational Diseases--A Survey. Springfield, Va, US Dept of Commerce, National Technical Information Service, 1955, vol 2, pp 65-68 (NTIS 59-21174)

9. Jennings BH: Phenol - C6H5OH, in Hazardous Vapors and Dusts in Industry. Chicago, Ventilating and Air Conditioning Contractors Association of Chicago, 1957, pp 4-153 to 4-154

10. Prahl WH: Chlorinated benzenes--Their ammonolysis and hydrolysis, in Sconce JS (ed): Chlorine--Its Manufacture, Properties and Uses. American Chemical Society Monograph Series. New York, Reinhold Publishing Corp, 1962, pp 435, 437-48, 450-52

11. Encyclopedia of Occupational Safety and Health. Geneva, International Labour Office, 1972, vol II, pp 1043-44

12. Hamilton A, Hardy H: Industrial Toxicology, ed 2. New York, Paul B Hoeber Inc, 1949, pp 284-95

13. Fairhall LT: Phenol, in Industrial Toxicology, ed 2. New York, Hafner Publishing Co, 1969, pp 316-17

14. International Labour Office: Phenol, in Occupation and Health--Encyclopedia of Hygiene, Pathology and Social Welfare. Geneva, Noirclerc et Fenetrier, 1930, vol II, pp 615-20

15. Phenol, Hygienic Guide Series. Detroit, American Industrial Hygiene Association, 1957

16. Williams RT: Detoxication Mechanisms--The Metabolism and Detoxication of Drugs, Toxic Substances and Other Organic Compounds, ed 2 rev. New York, John Wiley and Sons Inc, 1959, pp 278-79

17. Mukhitov B: The effect of low phenol concentrations on the organism of man or animals and their hygienic evaluation, in Levine BS (trans) USSR Literature on Air Pollution and Related Occupational Diseases--A Survey. Springfield Va, US Dept of Commerce, National Technical Information Service, 1964, Vol 9, pp 185-99 (NTIS 64-11574)

18. Moeschlen S: Poisoning--Diagnosis and Treatment. New York, Grune and Stratton, 1965, pp 354-56

19. Schwartz L: Dermatitis in the manufacture of synthetic resins and waxes, in Skin Hazards in American Industry, Part II, Public Health bulletin 229. US Treasury Dept, Public Health Service, 1936, pp 1-12

20. Hamilton A: Industrial poisons encountered in the manufacture of explosives. JAMA 68:1445-51, 1917

21. Adams RM: Occupational Contact Dermatitis. Philadelphia, JB Lippincott Co, 1969, p 168

22. Industrial Health Division, Dept of National Health and Welfare, and Division of Industrial Hygiene, Dept of Health for Ontario: A Guide to the Diagnosis of Occupational Diseases--A Reference Manual for Physicians. Ottawa, King's Printer and Controller of Stationery, 1949, pp 239-41

23. Gonzales TA, Vance M, Helpern M, Umberger CJ: Legal Medicine--Pathology and Toxicology, ed 2. New York, Appleton-Century-Crofts Inc, 1954, pp 728-35

24. Gleason MN, Gosselin RE, Hodge HC, Smith RP: Clinical Toxicology of Commercial Products, ed 3. Baltimore, Williams & Wilkins Co, 1969, pp 189-92

25. Oettinger WF: Phenol and its derivatives--The relation between their chemical constitution and their effect on the organism, National Institutes of Health bulletin No. 190. US Treasury Dept, Public Health Service, 1949, pp 1-397

26. Polson CJ, Tattersall RN: Clinical Toxicology. London, Pittman Medical and Scientific Publishing Co Ltd, 1971, pp 51-76

27. Thienes CH, Haley TJ: Clinical Toxicology. Philadelphia, Lea and Febiger, 1964, pp 226-29

28. Lefaux R: Practical Toxicology of Plastics. Cleveland, CRC Press, 1968, pp 97-99, 159-61, 329

29. McCord CP, Minster DK: Phenol poisoning from ink. JAMA 83:843, 1924

30. Kaiser HE, Bartone JC: The carcinogenic activity of ordinary tea--A preliminary note. J Natl Med Assoc 58:361, 1966

31. Baker TJ, Gordon HL: Chemical face peeling and dermabrasion. Surg Clin North Am 51:387-401, 1971

32. Baker TJ, Gordon HL, Seckinger DL: A second look at chemical face peeling. Plast Reconstr Surg 37:487-93, 1966

33. Ayres S: Superficial chemosurgery--Its current status and its relationship to dermabrasion. Arch Dermatol 89:395-403, 1964

34. Sperber PA: Chemexfoliation for aging skin and acne scarring. Arch Otolaryngol 81:278-83, 1965

35. Aronsohn RB: Complications of chemosurgery. Eye Ear Nose Throat Mon 51:19-25, 1972

36. Dupont C, Ciaburro H, Prevost Y, Coutier G: Phenol skin tightening for better dermabrasion. Plast Reconstr Surg 50:588-90, 1972

37. Brown AM, Kaplan LM, Brown ME: Phenol-induced histological skin changes--Hazards, technique, and uses. Br J Plast Surg 13:158-69, 1960

38. Hansebout RR, Cosgrove JBR: Effects of intrathecal phenol in man--A histological study. Neurology 16:277-82, 1966

39. Nathan PW, Sears TA: Effects of phenol on nervous conduction. J Physiol 150:565-80, 1960

40. Maher RM: Relief of pain in incurable cancer. Lancet 1:18-20, 1955

41. Reid W, Watt JK, Gray TG: Phenol injection of the sympathetic chain. Br J Surg 57:45-50, 1970

42. Liversedge LA, Maher RM: Use of phenol in relief of spasticity. Br Med J 1:31-33, 1960

43. Berry K, Olszewski J: Pathology of intrathecal phenol injection in man. Neurology 13:152-54, 1963

44. Smith MC: Histological findings following intrathecal injections of phenol solutions for relief of pain. Br J Anaesth 36:387-405, 1964

45. Lourie H, Vanasupa P: Comments on the use of intraspinal phenopantopaque for relief of pain and spasticity. J Neurosurg 20:60-63, 1963

46. Gordon RA, Goel SB: Intrathecal phenol block in treatment of intractable pain of malignant disease. Can Anaesth Soc J 10:357-63, 1963

47. Pedersen E, Juul-Jensen P: Intrathecal phenol in the treatment of spasticity. Acta Neurol Scand (Suppl 3) 38:69-77, 1962

48. Mark VH, White JC, Zervas NT, Ervin FR, Richardson EP: Intrathecal use of phenol for the relief of chronic severe pain. N Engl J Med 267:589-93, 1962

49. American Industrial Hygiene Association: Community air quality guides--Phenol and cresol. Am Ind Hyg Assoc J 30:425-28, 1969

50. Hoffmann D, Wynder EL: Studies on gasoline engine exhaust. J Air Pollut Control Assoc 13:322-27, 1963

51. Roe FJC, Salaman MH, Cohen J: Incomplete carcinogens in cigarette smoke condensate--Tumour-promotion by a phenolic fraction. Br J Cancer 13:623-33, 1960

52. Stevens GH: The Manufacture of Synthetic Phenol from Benzol by Sulfonation. Newark, NJ, Geo H Stevens, 1916

53. Wilbert MI: Some fallacies regarding phenol. Public Health Rep 31: 1046-54, 1916

54. Cook AM: Phenolic disinfectants. J Pharm Pharmacol 12:19-28, 1960

55. Lister J: On a new method of treating compound fracture, abscess, etc, with observations on the condition of suppuration. Med Classics 2:28-71, 1937. Reprint of articles originally published in The Lancet, 1867

56. Fuller HW: Carbolic acid--Its doses and medical value. Br Med J 1: 160-61, 1869

57. Koch R: On disinfection, in Cheyne WW: Recent Essays by Various Authors on Bacteria in Relation to Disease. London, New Sydenham Society, 1886, pp 493-518

58. Beddard AP: Ochronosis associated with carboluria. Q J Med 3:329-36, 1909-10

59. Reid E, Osler W, Garrod AE: On ochronosis--Report of a case. Q J Med 1:199-208, 1907-08

60. Pope FM: A case of ochronosis. Lancet 1:24-26, 1906

61. Goldberg SE: Ochronosis--Report of a case of carbolochronosis. Arch Intern Med 43:196-205, 1929

62. Winkler A: [Cauterization of both eyes by phenol and its general sequelae; some remarks about the therapy of eye burns.] Klin Monatsbl Augenheilkd 102:810-15, 1939 (Ger)

63. Unthank RE: Poisoning from the fumes of carbolic acid--Recovery. Br Med J 2:579, 1872

64. Cahn A: [Lysol poisoning with aspiration into the air passages and a consecutive empyema. Phenol cauterization of the respiratory tract with lethal end.] Ther Monatsh 25:428-31, 1911 (Ger)

65. Smith RE: Absorption of carbolic acid through the skin. Lancet 2: 1359, 1922

66. Wainwright JW: Poisoning from the application of carbolic acid to the unbroken skin. Boston Med Surg J 146:361-62, 1902

67. Hayes CF, Horn WS: Adrenal support in carbolic acid poisoning--Report of case, with recovery. Tex State J Med 18:218, 1922

68. Sheppe WM: Treatment of phenol poisoning with methylene-blue. Milit Surg 76:30-32, 1935

69. Stitt-Thomson J: A case of fatal poisoning by carbolic acid. Br Med J 2:194, 1896

70. I'Anson W: Notes on a case of carbolic acid poisoning. Br Med J 2: 756, 1885

71. Hunt R, Gettler AO: Phenol (Carbolic acid), in Peterson F, Haines WS, Webster RW: Legal Medicine and Toxicology, ed 2. Philadelphia, WB Saunders Co, 1923, vol 2, pp 701-08

72. Hodge GE, Scharfe EE: Stricture of the oesophagus. Can Med Assoc J 37:541-47, 1937

73. Clarke TW, Brown ED: The value of alcohol in carbolic acid poisoning. JAMA 46:782-90, 1906

74. Smith AHD: A fatal case of poisoning by a non-arsenical weed-killer. Br Med J 1:714-15, 1928

75. Bennett IL, James DF, Golden A: Severe acidosis due to phenol poisoning--Report of two cases. Ann Intern Med 32:324-27, 1950

76. Stajduhar-Caric Z: Acute phenol poisoning. J Forensic Med 15:41-42, 1968

77. Cronin TD, Brauer RO: Death due to phenol contained in Foille--Report of a case. JAMA 139:777-79, 1949

78. Hubler WR: Ulceration of the feet following single application of camphor-phenol mixture. JAMA 123:990, 1943

79. Lambotte C, Degroote V: [A case of fatal phenol poisoning in a newborn infant.] Ann Med Leg 40:288-90, 1960 (Fre)

80. Abraham AJ: A case of carbolic acid gangrene of the thumb. Br J Plast Surg 25:282-84, 1972

81. Noury M: [Transitory hemiparesis during antirabies therapy using vaccine treated with phenol, case.] Bull Soc Pathol Exot 33:4-5, 1940 (Fre)

82. Evans SJ: Acute phenol poisoning. Br J Ind Med 9:227-29, 1952

83. Kosmodamianskaya DM: Effect of atmospheric pollution upon the population's health. Hyg Sanit 33:265-67, 1968

84. Caviness VS: Phenol gangrene complicating diabetes mellitus. NC Med J 1:219-21, 1940

85. Johnstone RT, Miller SE: The aromatic hydrocarbons and derivatives, in Occupational Diseases and Industrial Medicine. Philadelphia, WB Saunders Co, 1960, pp 195-96

86. Duverneuil G, Ravier E: [Acute toxicity of phenol by cutaneous application.] Arch Mal Prof 23:830-33, 1962 (Fre)

87. Hinkel GK, Kintzel HW: [Phenol poisoning of a newborn through skin resorption.] Dtsch Gesundheitswes 23:2420-22, 1968 (Ger)

88. Petrov VI: Cases of phenol vapor poisoning during coke slaking with phenol water, in Levine BS (trans): USSR Literature on Air Pollution and Related Occupational Diseases--A Survey. Springfield Va, US Dept of Commerce, National Technical Information Service, 1963, vol 8, pp 219-21 (NTIS 63-11570)

89. Stevens JB, Callaway JL: Mixed epithelioma of the back arising from daily application of a phenol and ergot ointment. Am J Cancer 38: 364-66, 1940

90. Satulsky EM, Halpern W: Dermatitis venenata caused by phenol-camphor mixtures. J Med Soc NJ 40:137-39, 1943

91. Buch H, Neurohr O, Pfleter K, Buch U, Hutschenreuter K: [Dangerous mucous membrane lesions due to endotracheal catheter caused by concen-

tration of phenols from a disinfectant.] Anaesthesist 17:204-209, 1968 (Ger)

92. Merliss RR: Phenol marasmus. J Occup Med 14:55-56, 1972

93. Telegina KA, Boiko VI: [Vitiligoid skin changes in employees in phenol-containing additive production.] Vestn Dermatol Venerol 46:31-34, 1972 (Rus)

94. Sielieka L, Maliehiewicz J: [Problems of skin allergies in the chemical industry.] Pol Tyg Lek 13: 795-799, 1958 (Pol)

95. American Conference of Governmental Industrial Hygienists, Committee on Threshold Limit Values: Documentation of the Threshold Limit Values for Substances in Workroom Air, ed 3. Cincinnati, ACGIH, 1971

96. Watorski K: [Fatal and mild phenol poisoning.] Pol Tyg Lek 7:126567, 1952 (Pol)

97. Piotrowski JK: Evaluation of exposure to phenol--Absorption of phenol vapour in the lungs and through the skin and excretion of phenol in urine. Br J Ind Med 28:172-78, 1971

98. Ohtsuji H, Ikeda M: Quantitative relationship between atmospheric phenol vapour and phenol in the urine of employees in Bakelite factories. Br J Ind Med 29:70-73, 1972

99. Fabre R, Regnier MT, Cheramy P: Lecons de Toxicologie. Paris, Hermann & Cie, Editeurs, 1943, pp V-38 to V-46

100. Humperdinck K: [Results of examination of male and female employees when using synthetic resin solutions on the basis of formaldehyde-phenol condensation products.] Arch Gewerbepathol Gewerbehyg 11:519-35, 1942 (Ger)

101. Meneghini CL, Rantuccio F, Ghislanzoni G: [Further observations on experimental sensitization by phenolic and epoxy resins.] Dermatologica 132:99-103, 1966 (Fre)

102. Pirila V, Kilpio O: On dermatitis caused by formaldehyde and its compounds. Ann Med Intern Fenn 38:38-51, 1949

103. Meneghini CL, Rantuccio F, Cozza G: [Experimental sensitizations of an eczematous form caused by contact with DNCB, phenolic resin and epoxy resin.] Dermatologica 132:425-32, 1966 (Ita)

104. Engel HO, Calnan CD: Resin dermatitis in a car factory. Br J Ind Med 23:62-66, 1966

105. Schwartz L: Dermatitis in the manufacture of synthetic resins and waxes, in Skin Hazards in American Industry, Part II, Public Health bulletin 229. US Treasury Dept, Public Health Service, 1936, pp 1-12

106. Wallace J: Symptoms of carbolic acid poisoning by absorption--Discharge of pigments in the urine. Br Med J 1:432, 1870

107. Isaacs R: Phenol and cresol poisoning. Ohio State Med J 18:558-61, 1922

108. Langerhans R: [Changes in the air passages and lungs by phenol poisoning.] Dtsch Med Wochenschr 19:297-71, 1893 (Ger)

109. Schleicher O: [A case of phenol intoxication during parturition.] Dtsch Med Wochenschr 17:9-10, 1891 (Ger)

110. Silbermann O: [Clinical and experimental findings about carbolic acid poisoning and its effect on the respiratory organs.] Dtsch Med Wochenschr 21:681-82, 1895 (Ger)

111. Adams SS: Rapid absorption of carbolic acid by an eczematous skin (case). Arch Pediatr 11:825-27, 1894

112. Lucas RC, Lane WA: Two cases of carbolic acid coma induced by the application of carbolic compresses to the skin. Lancet 1:1362-64, 1895

113. Porteous JW, Williams RT: Studies in detoxication--The metabolism of benzene. Biochem J 44:46-55, 1949

114. Teisinger J, Skramovsky S, Srbova J: Chemiky Methody k Vysetrovani Biologickeho Materialu Prumyslove Toxikologii. Prague, SZN, 1956, pp 70-86

115. Kratochvil I: [The effect of formaldehyde on the health of employees employed in the production of crease resistant ready-made dresses.] Prac Lek 23:374-75, 1971 (Cze)

116. Yefremov GG: [The state of the upper respiratory tract in formaldehyde production employees.] Zh Ushn Nos Gorl Bolezn 30:11-15, 1970 (Rus)

117. Morrill EE: Formaldehyde exposure from paper process solved by air sampling and current studies. Air Cond Heat Vent 58:94-95, 1961

118. Zaeva GN: [Materials for the revision of maximal permissible concentrations of formaldehyde in the inside atmosphere of industrial premises.] Gig Tr Prof Zabol 12:16-20, 1928 (Rus)

119. Blejer HP, Miller BH: Occupational Health Report of Formaldehyde Concentrations and Effects on Employees at the Bayly Manufacturing Company, Visalia, study report number S-1806. Los Angeles, Bureau of Occupational Health, State Dept of Public Health, 1966

120. Miller BH, Blejer HP: Report of an Occupational Health Study of Formaldehyde Concentrations at Maximes, 400E Colorado Street,

Pasadena, California, study report number S-1838. Los Angeles, Bureau of Occupational Health, State Dept of Public Health, 1966

121. Kerfoot EJ, Mooney TF Jr: Formaldehyde and paraformaldehyde study in funeral homes. Am Ind Hyg Assoc J 36:533-37, 1975

122. Shipkovitz HD: Formaldehyde Vapor Emissions in the Permanent-Press Fabrics Industry, report No TR-52. US Dept of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Services, Environmental Control Administration, Occupational Health Programs, 1968

123. Gibbs HD: Phenol tests--The indophenol test. J Biol Chem 72:649-64, 1927

124. Ikeda M: Enzymatic studies on benzene intoxication. J Biochem (Tokyo) 55:231-43, 1964

125. Bertolacini RJ, Barney JE: Colorimetric determination of sulfate with barium chloranilate. Anal Chem 29:281-83, 1957

126. Ohmori S, Hara I: [A rapid colorimetric determination of sulphate in urine with barium chloranilate.] Proc Osaka Prefect Inst, Public Health, Ed Ind Health 3, 1966 pp 32-55 (Jap)

127. Ikeda M, Ohtsuji H: Hippuric acid, phenol, and trichloroacetic acid levels in the urine of Japanese subjects with no known exposure to organic solvents. Br J Ind Med 26:162-64, 1969

128. Light SE: Convulsive seizures following the application of phenol to the skin. Northwest Med 30:232-34. 1931

129. Gottlieb J, Storey E: Death due to phenol absorption through unbroken skin. Maine Med J 27:161-64, 1936

130. Johnstone RT: Aromatic hydrocarbons, in Occupational Medicine and Industrial Hygiene. St Louis, CV Mosby Co, 1948, pp 215-17

131. Gellin GA, Possick PA, Perone VB: Depigmentation from 4-tertiary butyl cathecol--An experimental study. J Invest Dermatol 55:190-97, 1970

132. Lerner AB: On the etiology of vitiligo and gray hair. Am J Med 51: 141-47, 1971

133. Malten KE, Seutter E, Hara I, Nakajima T: Occupational vitiligo due to paratertiary butylphenol and homologues. Trans St Johns Hosp Dermatol Soc 57:115-34, 1971

134. Occupational leucoderma. Lancet 2:879, 1974

135. Leonardos G, Kendall D, Barnard N: Odor threshold determination of 53 odorant chemicals. J Air Pollut Control Assoc 19:91-95, 1969

136. Makhinya AP: Data for the sanitary validation of maximum permissible concentrations of sulfur dioxide in combination with phenol, in Nuttonson MY (ed): American Institute of Crop Ecology Survey of USSR Air Pollution Literature--A Fourth Compilation of Technical Reports on the Biological Effects and the Public Health Aspects of Atmospheric Pollutants. Silver Spring, Md, American Institute of Crop Ecology, 1972, vol 17, pp 6-16

137. Ruedemann R, Deichmann WB: Blood phenol level after topical application of phenol-containing preparations. JAMA 152:506-09, 1953

138. Deichmann W, Schafer LJ: Phenol studies--I. Review of the literature; II. Quantitative spectrophotometric estimation of free and conjugated phenol in tissues and fluids; III. Phenol content of normal human tissues and fluids. Am J Clin Pathol 12:129-43, 1942

139. Haas G, Schlesinger EF: [On the quantitative proof of free phenol and cresol in small amounts of blood and its prognostic significance in cases of poisonings.] Arch Exp Pathol Pharmakol 103:56-72, 1924 (Ger)

140. Becher E, Litzner S, Taglich W: [The content of phenol in the blood under normal and pathological conditions.] Klin Med 104:182-206, 1926 (Ger)

141. Schmidt EG, Schmulovitz MJ, Szczpinski A, Wylie HB: The phenol and imidazole content of the blood. J Biol Chem 120:705-17, 1937

142. Emanuele P, Piero, P: [Further contribution to the determination of phenols in the blood of normal and pathological individuals.] Rev Clin Med 35:55, 1934 (Ita)

143. Marcolongo F: [Clinical and experimental studies of phenols in uremia--II. Clinical analysis of nonvolatile phenols (diphenols and aromatic hydroxy acids) in blood.] Arch Sci Med 63:262-71, 1937 (Ita)

144. Marcolongo F: Richerche cliniche e sperimentali sui fenoli nell'uremia --Tecnica clinica per il dosaggio dei fenoli volatili (eterosolubili ed etero-insolubili) nel sangue. Minerva Med 28:83-91, 1937

145. Banfi R, Lida E, Marenzi AD: [The hourly constancy of carbolemia in man in normal and pathological conditions.] C R Soc Biol 121:358-59, 1936 (Fre)

146. Theis RC, Benedict SR: The determination of phenol in the blood. J Biol Chem 61:67-71, 1924

147. Rakestraw NW: A quantitative method for the determination of phenols in blood. J Biol Chem 56:109-19, 1923

148. Volterra M: [Determination of aromatic substances in blood--New method for the determination of volatile phenols.] Sperimentale 91:13, 1937 (Ita)

149. Nassi L: Contributo al dosaggio dei fenoli volatili del sange. Diag-Tecn Lab 9:161, 1938

150. Theis RC, Benedict SR: Phenols and phenol derivatives in human blood in some pathological conditions. J Biol Chem 36:99-103, 1918

151. Folin O, Denis W: The excretion of free and conjugated phenols and phenol derivatives. J Biol Chem 22:309-20, 1915

152. Dirmikis SM, Darbre A: Gas-liquid chromatography of simple phenols for urinalysis. J Chromatogr 94:169-87, 1974

153. Fukuyama T, Sato T: [Estimation of phenol in air.] Rodo Kagaku 32: 263-64, 1956 (Jap)

154. Van Haaften AB, Sie ST: The measurement of phenol in urine by gas chromatography as a check on benzene exposure. Am Ind Hyg Assoc J 26:52-58, 1965

155. Docter HJ, Zielhuis RL: Phenol excretion as a measure of benzene exposure. Ann Occup Hyg 10:317-26, 1967

156. Brieger L: [On the excretion of phenol with diseases and after use of tyrosin.] Physiol Chem 2:241-58, 1878-79 (Ger)

157. Walkley JE, Pagnotto LD, Elkins HB: The measurement of phenol in urine as an index of benzene exposure. Am Ind Hyg Assoc J 22:362-67, 1961

158. Hensel M: [On the method of determining phenol in urine.] Z Anal Chem 78:373-81, 1912 (Ger)

159. Folin O, Denis W: The relative excretion of phenols by the kidneys and by the intestine. J Biol Chem 22:507-13, 1915

160. Fishbeck WA, Langner RR, Kociba RJ: Elevated urinary phenol levels not related to benzene exposure. Am Ind Hyg Assoc J 36:820-24, 1975

161. Gerarde HW: The aromatic hydrocarbons, in Patty FA (ed): Industrial Hygiene and Toxicology, ed 2 rev; Toxicology (Fassett DW, Irish DD eds). New York, Interscience Publishers, 1963, vol II, chap 30

162. Macht DI: An experimental study of lavage in acute carbolic acid poisoning. Johns Hopkins Hosp Bull 26:98-104, 1915

163. Deichmann WB, Witherup S: Phenol studies--VI. The acute and comparative toxicity of phenol and o-, m-, and p-cresols for experimental animals. J Pharmacol Exp Ther 80:233-40, 1944

164. Ernst MR, Klesmer R, Huebner RA, Martin JE: Susceptibility of cats to phenol. J Am Vet Med Assoc 138:197-99, 1961

165. Bond WR, Haag HB: The synergistic action of camphor in phenol poisoning. J Am Pharm Assoc 14:118-20, 1925

166. Haskell CC, Alley RC, Prillaman PE: Exsanguination-transfusion in treatment of phenol poisoning. J Lab Clin Med 12:313-18, 1927

167. Oehme FW, Davis LE: The comparative toxicity and biotransformation of phenol. Toxicol Appl Pharmacol 17:283, 1970

168. Chassevant A, Garnier M: [Relationships between the chemical structures of substances and their toxicity in the aromatic series (benzene and its derivatives.)] Arch Int Pharmacodyn Ther 14:97-170, 1905 (Fre)

169. Deichmann WB, Miller T, Roberts JB: Local and systemic effects following application of dilute solutions of phenol in water and in camphor-liquid petrolatum on the skin of animals. Arch Ind Hyg 2:454-61, 1950

170. Toxicological information on phenol. Midland, Michigan, Dow Chemical USA, Toxicological Research Laboratory, May 29, 1975 (available on request)

171. Cosgrove KW, Hubbard WB: Acid and alkali burns of the eye. Ann Surg 87:89-91, 1928

172. Conning DM, Hayes MJ: The dermal toxicity of phenol--An investigation of the most effective first-aid measures. Br J Ind Med 27:155-59, 1970

173. Heller VG, Pursell L: Phenol-contaminated waters and their physiological action. J Pharmacol Exp Ther 63:99-107, 1938

174. Deichmann WB, Kitzmiller KV, Witherup BS: Phenol studies--VII. Chronic phenol poisoning, with special reference to the effects upon experimental animals of the inhalation of phenol vapor. Am J Clin Pathol 14:273-77, 1944

175. Salaman MH, Glendenning OM: Tumour promotion in mouse skin by sclerosing agents. Br J Cancer 11:434-44, 1957

176. Boutwell RK, Bosch DK: The tumor-promoting action of phenol and related compounds for mouse skin. Cancer Res 19:413-24, 1959

177. Wynder EL, Hoffmann D: A study of tobacco carcinogenesis--The role of the acidic fractions as promoters. Cancer 14:1306-15, 1961

178. Van Duuren BL, Sivak A, Langseth L, Goldschmidt BM, Segal A: Initiators and promoters in tobacco carcinogenesis. Natl Cancer Inst Monogr 28:173-80, 1968

179. Van Duuren BL, Bazej T, Goldschmidt BM, Katz C, Melchionne S, Sivak A: Cocarcinogenesis studies on mouse skin and inhibition of tumor induction. J Natl Cancer Inst 46:1039-44, 1971

180. Sandage C: Tolerance criteria for continuous inhalation exposure to toxic material, ASD Technical Report 61-519 (I). Kansas City, Mo, Midwest Research Institute, 1961, pp 1-29

181. Boutwell RK, Bosch DK, Baldwin HH: Breeding for susceptibility and resistance to tumor induction by initiation and promotion. Proc Am Assoc Cancer Res 3:8, 1959

182. Baumann E: [On paired sulfuric acids in the organism.] Arch Physiol 13:285-308, 1876 (Ger)

183. Deichmann WB: Phenol Studies--V The distribution, detoxification, and excretion of phenol in the mammalian body. Arch Biochem 3:345-55, 1944

184. Pelkan KF, Whipple GH: The physiology of the phenols--II. Absorption, conjugation, and excretion. J Biol Chem 50:499-511, 1922

185. Salkowski E: [About the effect and the chemical behavior of phenol in the animal organism.] Arch Physiol 5:335-58, 1872 (Ger)

186. Schutz E: [The influence of polyethyleneglycol 400 on the percutaneous resorption of substances.] Arch Exp Pathol Pharmakol 232:237-38, 1957-58 (Ger)

187. Williams RT: Studies in detoxication--I. The influence of (a) dose and (b) o-, m-, and p- substitution on the sulphate detoxication of phenol in the rabbit. Biochem J 32:878-87, 1938

188. DeMeio RH, Arnolt RI: Phenol conjugation--IV. Effect of several inhibitors. J Pharmacol Exp Ther 84:64-66, 1945

189. Bakke OM: Urinary simple phenols in rats fed purified and nonpurified diets. J Nutr 98:209-16, 1969

190. Biebl M: [The pathological anatomy of the acute, subacute, chronic and latent intoxication by the phenol-indol compounds in the animal experiment.] Beitr Pathol 84:257-65, 1930 (Ger)

191. Parke DV, Williams RT: Studies in detoxication--The metabolism of benzene (a) the formation of phenylglucuronide and phenylsulphuric

acid from benzene (b) the metabolism of phenol. Biochem J 55:337-40, 1953

192. Kuster E: [The poisonous properties of phenol during surgical application.] Arch Klin Chir 23:117-55, 1879 (Ger)

193. Dubin H: Physiology of the phenols. J Biochem 26:69-91, 1916

194. Smith MI: The estimation of tissue phenols. Public Health Rep 48: 1487-96, 1933

195. DeMeio RH, Arnolt RI: Phenol conjugation--II. The conjugation by rat and cat tissues in vitro. J Biol Chem 156:577-83, 1944

196. Deichmann WB, Keplinger ML: Phenols and phenolic compounds, in Patty FA (ed): Industrial Hygiene and Toxicology, ed 2 rev; Toxicology (Fassett DW Irish DD, eds). New York, Interscience Publishers, 1963, vol II, chap 33

197. Bakke OM: Urinary simple phenols in rats fed diets containing different amounts of casein and 10% tyrosine. J Nutr 98:217-21, 1969

198. Palladin A, Borshkovski S, Palladina L: [The influence of fatigue on the glutathione of muscles.] Ukr Biokhim Zh 7:7-22, 1934 (Rus)

199. Ito H: The effects of temperature and fever upon the synthesis of ethereal sulfuric and urochloralic acids in the organism. J Biol Chem 26: 301-18, 1916

200. Jung F, Witt P: [Effect of phenol on blood pressure.] Arch Exp Pathol Pharmakol 204:437-38, 1946 (Ger)

201. British Chemical Industry Safety Council: First-aid treatment of phenol splashes on the skin--A new approach. London, British Chemical Industry Safety Council, Chemical Industries Association, 1971

202. Turtle WRM, Dolan T: A case of rapid and fatal absorption of carbolic acid through the skin. Lancet 2:1273-74, 1922

203. Roberts HL: The chloracetic acids--A biochemical study. Br J Dermatol Syphil 38:323-24, 375-91, 1926

204. Gibson W: Clinical cases, death from carbolic acid burn. Queens Med Q 10:133-34, 1905

205. Anderson W: Fatal misadventure with carbolic acid. Lancet 1:179, 1869

206. Leider M, Moser HS: Toxicology of topical dermatologic preparations. Arch Dermatol 83:928-29, 1961

207. Sollmann T, Hanzlik PJ, Pilcher JD: Quantitative studies on the gastrointestinal absorption of drugs--The inhibitory action of phenol on absorption. J Pharmacol Exp Ther 1:409-44, 1909-10

208. Hoppe-Seyler F: [The presence of phenol in the animal body and its influence on blood and nerves.] Arch Physiol 5:470-80, 1872 (Ger)

209. Gibbs HD: Phenol tests--In a classification of the tests and a review of the literature. Chem Rev 3:291-319, 1926-27

210. Gibbs HD: Phenol tests--II. Nitrous acid tests: The millon and similar tests--Spectrophotometric investigations. J Biol Chem 71:445-59, 1927

211. Snell FD, Snell CT: Colorimetric Methods of Analysis, ed 3. Toronto, Van Nostrand Co Inc, 1953, vol 3, pp 104-20

212. Feigl F: Spot Tests--Organic Applications. Amsterdam, Elsevier Publishing Co, 1954, vol 2, pp 132-37

213. American Industrial Hygiene Association: Phenol. AIHA Analytical Abstracts, 1965, 4 pp

214. Beshgetoor AW, Greene LM, Stenger VA: Determining phenols in dilute solutions--Notes on the Gibbs method. Ind Eng Chem 16:694-96, 1944

215. Mohler EF, Jacob LN: Determination of phenolic-type compounds in water and industrial waste waters--Comparison of analytical methods. Anal Chem 29:1369-74, 1957

216. Pellerin F, Bartos J, Pesez M: A Survey of Some Recommended Methods for the Identification and Determination of the Phenol Group, technical report No. 7. Oxford, International Union of Pure and Applied Chemistry, 1973, pp 1-9

217. Crabtree AN, McGill AEJ: Thin-layer chromatography of phenolic compounds. Mikrochim Acta 1:85-87, 1967

218. Emerson E: The condensation of aminoantipyrine--II. A new color test for phenolic compounds. J Org Chem 8:417-28, 1943

219. Syobodova D, Gasparie J: Investigation of the colour reaction of phenols with 4-amino-antipyrine. Mikrochim Acta 1-6:384-90, 1971

220. Inglett GE, Lodge JP: Comparative phenolic spot tests--Application to some air particulate fractions. Anal Chem 31:248-49, 1959

221. Smith RG, MacEwen JD, Barrow RE: The occurrence of phenols in air and combustion products. Am Ind Hyg Assoc J 20:149-52, 1959

222. Smith RG, MacEwen JD, Barrow RE: Sampling and analysis of phenols in air. Am Ind Hyg Assoc J 20:142-48, 1959

223. Khrustalev VA: [Detection of phenol in the atmosphere with 4-aminoantipyrene.] Gig Sanit 10:42-45, 1962 (Rus)

224. Alekseeva MV, Tkachev PG: Methods for the determination of some organic atmospheric air pollutants, in Levine BS (trans): USSR Literature on Air Pollution and Related Diseases--A Survey. Springfield, Va, US Dept of Commerce, National Technical Information Service, 1964, vol 9, pp 203-12 (NTIS 64-11574)

225. Stanley TW, Sawicki E, Johnson H, Pfaff JD: Comparison of methods for the spectrophotometric determination of phenols in automobile exhaust fumes. Mikrochim Acta 1:48-59, 1965

226. Hinkamp JB, Griffing ME, Zutaut DW: Aromatic aldehydes and phenols in the exhaust from leaded and unleaded fuels. Presented at the Symposium on Current Approaches to Automotive Emission Control, American Chemical Society, Los Angeles, March 1971

227. Martin RW: Rapid colorimetric estimation of phenol. Anal Chem 21: 1419-20, 1949

228. Dyatlovitskaya FG: A comparative study of colorimetric methods for the determination of low phenol concentrations in industrial waste water, in Levine BS (trans): USSR Literature on Water Supply and Water Pollution. Springfield, Va, US Dept of Commerce, National Technical Information Service 1962, Vol 7, pp 135-39 (NTIS 62-11103)

229. Intersociety Committee for Ambient Air Sampling and Analysis: Tentative method of analysis for determination of phenolic compounds in the atmosphere (4-aminoantipyrine method). Health Lab Sci 7:182-85, 1970

230. Heistand RN, Todd AS: Automated determination of total phenol in urine. Am Ind Hyg Assoc J 33:378-81, 1972

231. Ettinger MB, Ruchhoff CC, Lishka RJ: Sensitive 4-aminoantipyrine method for phenolic compounds. Anal Chem 23:1783-88, 1951

232. American Society for Testing and Materials: Annual Book of ASTM Standards, Part 31. Philadelphia, American Society for Testing and Materials, 1975, pp 545-58

233. Fukuyama T, Sato T, Kimura H: Estimation of toxic gases in air--I. Phenol. Bull Inst Pub Health 6:10-11, 1957

234. Rayburn CH, Harlan WR, Hanmer HR: Determination of volatile phenols in cigarette smoke. Anal Chem 25:1419, 1953

235. Smith GAL, Sullivan PJ: Determination of the steam-volatile phenols present in cigarette-smoke condensate--II. Determination of phenol, the cresols and guaiacol by thin-layer chromatography. Analyst 89:312-18, 1964

236. Ryazanov VA (ed): Limits of allowable concentrations of atmospheric pollutants, in Levine BS (trans): USSR Literature on Air Pollution and Related Occupational Diseases--A Survey. Springfield Va, US Dept of Commerce, National Technical Information Service, 1960, vol 3, pp 123-25 (NTIS 60-21475)

237. Maslenikov AS: Determination of simultaneously present phenol, cyclohexanone and cyclohexanol, in Levine BS (trans): USSR Literature on Air Pollution and Related Occupational Diseases--A Survey. Springfield, Va, US Dept of Commerce, National Technical Information Service, 1960, vol 1, pp 196-201 (NTIS 60-21049)

238. Lahmann E: Determining phenol in air. Staub 26:24-29, 1966

239. Joszko H: Determination of low atmospheric concentrations of phenol and cresol. Air Conservation 3:31-41, 1969

240. Hanke MT, Koessler KK: Studies on proteinogenous amines--IV. A quantitative method for the separation and estimation of phenols including phenol, o-,m-, and p-cresol, p-oxyphenylacetic, p-oxyphenylpropionic, and p-oxyphenyllactic acids, tyrosine, and tyramine. J Biol Chem 50: 271-88, 1922

241. Gomori G: Laboratory methods--Determination of phenol in biologic material. J Lab Clin Med 36:275-81, 1949

242. Thienes CH, Haley TJ: Clinical Toxicology. Philadelphia, Lea and Febiger, 1964, pp 399-402

243. Buchwald H: The colorimetric determination of phenol in air and urine with a stabilized diazonium salt. Ann Occup Hyg 9:7-14, 1966

244. Lovelock JE: The quantitative estimation of chemical bactericides in very low aerial concentration, number 262. Medical Research Council Special Report Series. London, His Majesty's Stationery Office, 1948, pp 64-68

245. Gurvits SS, Sergeva TI: Phenol determination in the presence of polyatomic phenols in the air during foundry casing pouring, in Levine BS (trans): USSR Literature on Air Pollution and Related Diseases--A Survey. Springfield, Va, US Dept of Commerce, National Technical Information Service, 1962, vol 7, pp 108-13 (NTIS 62-11103)

246. Warshowsky B, Schantz EJ, Rice MW: Determination of phenol and m-cresol in complex biochemical mixtures--Application of countercurrent distribution method. Anal Chem 20:951-52, 1948

247. Murray MJ: Total phenols in gasolines and in cresylic acids--Spectrophotometric determination. Anal Chem 21:941-45, 1949

248. Commins BT, Lindsey AJ: The determination of phenols by chromatography and spectrophotometry of their methyl ethers--I.

Ultraviolet absorption spectra of methyl aryl ethers in cyclohexane. Anal Chim Acta 15:546-50, 1956

249. Commins BT, Lindsey AJ: The determination of phenols by chromatography and spectrophotometry of their methyl ethers--II. The separation and quantitative determination of methyl aryl ethers. Anal Chim Acta 15:551-54, 1956

250. Commins BT, Lindsey AJ: The determination of phenols by chromatography and spectrophotometry of their methyl ethers--III. The determination of phenols in wood smoke. Anal Chim Acta 15:554-56, 1956

251. Kogan IE, Bragilevskaya MM, Neimark: Analysis of phenolic products by partition chromatography and spectrophotometry. J Anal Chem USSR 20:227-31, 1965

252. Masuda Y, Mori K, Hirohata T, Kuratsune M: Carcinogenesis in the esophagus--III. Polycyclic aromatic hydrocarbons and phenols in whiskey. Jpn J Cancer Res 57:549-57, 1966

253. Houghton JA, Lee G, Shobaken MA, Fox A: Practical applications of analysis by the ultraviolet absorbance method. Am Ind Hyg Assoc J 25:380-85, 1964

254. Schmauch LJ, Grubb HM: Determination of phenols in waste waters by ultraviolet absorption. Anal Chem 26:308-11, 1954

255. Gross GP: The Effect of Fuel and Vehicle Variables on Polynuclear Aromatic Hydrocarbon and Phenol Emissions. New York, Society of Automotive Engineers Inc, 1972, pp 1-20

256. Milano MJ, Pardue HL: Evaluation of a vidicon scanning spectrometer for ultraviolet molecular absorption spectrometry. Anal Chem 47:25-29, 1975

257. Goddu RF: Determination of phenolic hydroxyl by near-infrared spectrophotometry. Anal Chem 30:2009-13, 1958

258. Scheddel TR, Kiley LR: Determination of phenol, 2-chlorophenol, 4-chlorophenol, and 2, 4-dichlorophenol in 4-chlorophenol. Anal Chem 30:156, 1958

259. Karr C, Brown PM, Estep PA, Humphrey GL: Identification and determination of low-boiling phenols in low temperature coal tar. Anal Chem 30: 1413-16, 1958

260. Wilson HW: Apparent integrated intensities and absorption coefficients for the 1125/cm to 1230/cm infrared region of phenol in the vapor phase. Anal Chem 46:962-63, 1974

261. Belcher R, Dryhurst G, MacDonald AMG: Submicro methods for the analysis of organic compounds--The determinations of hydroxyl groups. Anal Chim Acta 38:435-45, 1967

262. Fishman GI, Pevzner ID: Analysis of phenol-formaldehyde mixtures by potentiometric titration in a non-aqueous medium. Sov Plast 3:58-60, 1971

263. Feher ZS, Pungor E: The application of hydrodynamic voltammetry in chemical analysis. Anal Chim Acta 71:425-32, 1974

264. Reyes PG, Aroca RM, Morales AB: Oscillopolarographic analysis of phenols. J Electroanal Chem 12:69-73, 1966

265. Ponomarenko AA, Amelina LM: Determination of phenols by a chemiluminescent method. J Anal Chem USSR 18:1075-79, 1963

266. McKinney RW, Reynolds CA: Photometric titration of phenols. Talanta 1:46-54, 1958

267. Hummelstedt LEI, Hume DN: Photometric titration of weak acids in nonaqueous media. Anal Chem 32:1792-97, 1960

268. Williams T, Krudener J, McFarland J: Use of pyridinium bromide perbromide as an analytical reagent. Anal Chim Acta 30:155-62, 1964

269. Crump GB: The paper chromatographic separation and identification of simple phenols. J Chromatogr 10:21-28, 1963

270. Clark IT: Chromatographic separation of phenols on ion-exchange paper. J Chromatogr 15: 65-69, 1964

271. Barber ED, Sawicki E, McPherson SP: Separation and identification of phenols in automobile exhaust by paper and gas liquid chromatography. Anal Chem 36:2442-45, 1964

272. Sherma J, Hood LVS: Thin-layer solubilization chromatography--Phenols. J Chromatogr 15: 307-15, 1965

273. Chafetz L, Kay AI, Schriftman H: Selective detection of o-dihydroxybenzenes and other phenolic compounds on cellulose thin-layer plates. J Chromatogr 35:567-69, 1968

274. Srivastava SP, Gupta RC, Gupta A: Peroxydisulphate oxidations--Identification of aromatic amines and phenols by thin-layer chromatography. Z Anal Chem 262:31-32, 1972

275. Kushnir L, Barr PA, Chortyk OT: An improved quantitative method for volatile phenols. Anal Chem 42:1619-21, 1970

276. Egorova NF, Koltunovskaya AY: Thin-layer chromatography of phenols communication--I. A sensitive method for developing chromatograms. J Anal Chem USSR 21: 1338-39, 1966

277. Fritz JS, Willis RB: Chromatographic separation of phenols using an acrylic resin. J Chromatogr 79:107-09, 1973

278. Grant DW, Meiris RB, Hollis MG: The use of bentone 34 (Trademark) coated supports in column chromatography and their potential application in the field of organic pollution analysis. J Chromatogr 99:721-29, 1974

279. American Public Health Association, American Water Works Association, Water Pollution Control Federation: Standard Methods for the Examination of Water and Wastewater, ed 13. Washington, DC, American Public Health Association, 1971, pp 501-17

280. Commins BT, Lindsey AJ: The determination of phenols by chromatography and spectrophotometry of their methyl ethers--IV The determination of phenols in cigarette smoke. Anal Chim Acta 15:557-58, 1956

281. Spears AW: Quantitative determination of phenol in cigarette smoke. Anal Chem 35:320-22, 1963

282. Merz O: Orientierende Messungen mit Gasprufrohrchen bei Luft- und Ofentrocknung. Staub 31:399-401, 1971

283. Dietz WA: Calibration data for gas chromatographic analysis of phenols. J Chromatogr Sci 10: 423-24, 1970

284. Levaggi DA, Feldstein M: Determination of phenols and trimethylamine in industrial effluents, AIAA Paper No 71-1115. New York, American Institute of Aeronautics and Astronautics, 1971, pp 1-2

285. Aue WA, Teli PM: Sampling of air pollutants with support-bonded chromatographic phases. J Chromatogr 62:15-27, 1971

286. Intersociety Committee for Ambient Air Sampling and Analysis: Tentative method of analysis for phenols in the atmosphere (gas chromatographic method). Health Lab Sci 10:362-66, 1973

287. Sherwood RJ, Carter FWG: The measurement of occupational exposure. Ann Occup Hyg 13:125-46, 1970

288. Wengle B, Hellstrom K: A gas chromatographic technique for the analysis of volatile phenols in serum. Scan J Clin Lab Invest 28:477-83, 1971

289. Chin W. Cullen TE, Stanovich, RP Microdetermination of phenol by mono- and poly-chloroacetylation followed by microcoulometric gas chromatography. J Gas Chromatogr 6:248-50, 1968

290. Styskin El, Tarada: EP, Sharpanova, IK: Comparative evaluation of diatomite carriers in the gas chromatographic analysis of phenols. Ind Lab 37: 1511-13, 1971

291. Seiber JN, Crosby DG, Fouda H, Soderquist CJ: The derivatives for the determination of phenols and phenol-generating pesticides by electron capture gas chromatography. J Chromatogr 73:89-97, 1972

292. Sidorov RI, Borovskaya IS: Gas-liquid-chromatographic identification of phenols in complex mixtures. J Anal Chem USSR 29:491-93, 1974

293. Karasek RW, Smythe RJ, Laub RJ: Preparation of high-capacity high-resolution open-tubular columns. J Chromatogr 97:151-57, 1974

294. Heenan MP, McCallum NK: A new method for the gas chromatographic detection of phenols. J Chromatogr Sci 12:89-90, 1974

295. Commins BT, Lindsey AJ: Some phenolic constituents of cigarette smoke. Br J Cancer 10:504-06, 1956

296. Wetlaufer LA, Van Natta FJ, Quattlebaum HB: Determination of phenols in hydrocarbon solvents. Ind Eng Chem (Anal Ed) 11:438-39, 1939

297. Morris JL: A new salt of uric acid and its application to the analysis of uric acid and phenol. J Biol Chem 25:205-10, 1916

298. Pelkan KF: The physiology of the phenols--I. A quantitative method for the determination of phenols in the blood. J Biol Chem 50:491-97, 1922

299. Folin O, Denis W: A colorimetric method for the determination of phenols (and phenol derivatives) in urine. J Biol Chem 22:305-08, 1915

300. Benedict SR, Theis RC: The colorimetric determination of phenols in the blood. J Biol Chem 36:95-103, 1918

301. Deichmann W, Scott EW: Quantitative estimation of phenol and related compounds in tissues. Ind Eng Chem (Anal Ed) 11:423-24, 1939

302. Limits of allowable concentrations of poisonous gases, vapors and dust in the air of working zones in industrial premises, supplement 3, in Levine BS (trans): USSR Literature on Air Pollution and Related Diseases--A survey. Springfield, Va, US Dept of Commerce, National Technical Information Service, 1961, vol 6, pp 132-34 (NTIS 61-21982)

303. Criteria and Recommended Standard....Occupational Exposure to Benzene, HEW Publication No (NIOSH) 76-137. Rockville, Md, US Dept of Health, Education, and Welfare, National Institute for Occupational

Safety and Health, Public Health Service, Center for Disease Control, 1974, HEW Pub No. 74-137

304. Stoughton RW: A method for the quantitative determination of phenols. J Biol Chem 115:293-98, 1936

305. Braverman MM, Hochheiser S, Jacobs MB: Colorimetric ultramicro determination of phenol in air. Am Ind Hyg Assoc Q 18:132-34, 1957

306. Sawicki E, Miller R, Stanley T, Hauser T: Detection of polynuclear hydrocarbons and phenols with benzal and piperonal chlorides. Anal Chem 30:1130-33, 1958

307. Zhitkova AS: Some Methods for the Detection and Estimation of Poisonous Gases and Vapors in the Air--A Practical Manual for the Industrial Hygienist. West Hartford, Conn, Service to Industry, 1936, pp 149-50

308. Elkins HB: The Chemistry of Industrial Toxicology, ed 2. New York, John Wiley and Sons Inc, 1959, pp 384-85

309. Quantitative determination of phenol in the air, in Levine BS (trans): USSR Literature on Air Pollution and Related Diseases--A Survey. Springfield, Va, US Dept of Commerce, National Technical Information Service, 1963, vol 8, pp 52-54 (NTIS 63-11570)

310. Lugg GA: Stabilized diazonium salts as analytical reagents for the determination of air-borne phenols and amines. Anal Chem 35:899-904, 1963

311. Schaffernicht H, Deicke H: [Continuous personal measurement of phenol and sulphur dioxide on place of employment with the aid of colorimetric methods.] Int Arch Arbeitsmed 33:71-77, 1974 (Ger)

312. Orlovskaya AM, Ol'khovskaya ZK, Shein EM, Nul'man FS: Comparative assessment of the method of determining phenol. Hyg Sanit 36:144-45, 1970

313. Standards Completion Program, National Institute for Occupational Safety and Health, Public Health Service, Center for Disease Control, Rockville, Md (unpublished)

314. Dejarnac: [An occupational dermatitis caused by phenol-formaldehyde resins.] Arch Mal Prof 33:499-501, 1972 (Fre)

315. ACGIH Committee on Industrial Ventilation: Industrial Ventilation--A Manual of Recommended Practices, ed 13. Lansing, Mich, American Conference of Governmental Industrial Hygienists, 1974

316. Fundamentals Governing the Design and Operation of Local Exhaust Systems. ANSI Z9.2-1971. New York, American National Standards Institute, Inc, 1971

317. Connecticut Bureau of Industrial Hygiene Am Conf Govt Ind Hyg, Cincinnati, Ohio

318. Thomas AA, Back KC: The environmental toxicity of space cabin atmospheres. Wright Patterson AFB, Ohio, Aerospace Medical Research Laboratories, 1964, pp 135-42

319. American Conference of Governmental Industrial Hygienists: Threshold Limit Values of Air-borne Contaminants for 1968. Cincinnati, Ohio, ACGIH, 1968, p 11

320. Czechoslovak Committee of MAC: Documentation of MAC in Czechoslovakia. Praha, Czechoslovak Committee of MAC, 1969, pp 1-167

321. Dow Chemical Company: Phenol Handbook. Midland, Mich, Dow Chemical Company, pp 1-17

322. Schutz E: [Measures for the prevention of percutaneous poisoning with phenol anilin.] Berufs-Dermatosen 7(5):266-74, 1959 (Ger)

323. Brown VKG, Box VL, Simpson BJ: Decontamination procedures for skin exposed to phenolic substances. Arch Environ Health 30:1-6, 1975

324. Pullin TG, Pinkerton, MN, Johnston RV, Kilian DJ: Comparison of decontamination procedures for acute dermal phenol exposures in swine. Freeport, Tex, Dow Chemical USA, January 1976 (unpublished)

325. Applied Science Laboratories Inc: Technical Bulletin No 24, Tenax-GC. State College, Pa, Applied Science Laboratories Inc

326. Milby TH, Key MM, Gibson RL, Stokinger HE: Occupational Diseases, in Gafafer Wm (ed): Occupational Diseases--A Guide to Their Recognition, publication 1097. US Dept of Health, Education, and Welfare, Public Health Service, 1964, pp 199-200

327. Taylor WE: Death from accidental poisoning by carbolic acid. Calif State J Med 17:366-67, 1919

328. Falkson R: [Examination of pheno-intoxication and phenol-containing urine as a sequela of the wound-treatment by Lister.] Arch Klin Chir 26:204-40, 1881 (Ger)

329. Soresi AL: Painless incision by the use of pure phenol. JAMA 72: 1288, 1919

330. Montgomery DW: Phenol. J Cutaneous Dis 35:157-62, 1917

331. Miller FG: Poisoning by phenol. Can Med Assoc J 46:615-16, 1942

332. Bill JH: On the application of carbolic acid as a local anaesthetic in surgical operations. Am J Med Sci 60:573-74, 1870

333. Boenninghaus: Dangers of petrolatum vehicle for phenol. Exp Cancer 47:1497, 1921

334. Meltzer SJ: [Carbolic acid poisoning in a child.] Ther Monatsh 4:52, 1890 (Ger)

335. Wachholz L: [Changes in the breathing organs following carbolic acid poisoning.] Dtsch Med Wochenschr 21:146-48, 1895 (Ger)

336. Mosler F: [Healing of intensive carbolic acid poisoning by means of a stomach pump and depletive vein section.] Dtsch Arch Klin Med 10:113-18, 1872 (Ger)

337. de Vries: [A case of carbolic acid poisoning.] Ther Monatsh 4:644, 1890 (Ger)

338. Model A, Berzirksaret K: [Poisoning with concentrated carbolic acid of a child, sick with diphtheria. (Cure)] Ther Monatsh 3:482-85, 1889 (Ger)

339. Schussler OF, Stern MA: Gangrene of finger caused by five per cent phenol ointment. JAMA 57:628, 1911

340. Harrington FB: Carbolic gangrene. Am J Med Sci 120:2-7, 1900

341. Raubenheimer JA: Case of carbolic acid poisoning due to external application. Br Med J 1:1145-46, 1903

342. Herlyn: Die Gefahrlichkeit der Carbolsaure bei Klystieren. Dtsch Med Wochenschr 21:683, 1895

343. Werth: [A case of hemoglobinuria observed during delivery.] Arch Gynaekol 17:122-27, 1881 (Ger)

344. MacLean JA: Contrasted effect of phenol and merthiolate on appendiceal stumps. J Mich Med Soc 32:392-94, 1933

345. Hartigan W: Poisoning by lysol. Br Med J 2:1498, 1900

346. Bernard P: [Grave accident during immunization for rabies using vaccine treated with phenol.] Bull Soc Path Exot 32:799-800, 1939 (Fre)

347. Reese JJ: Manual of Toxicology, JB Lippineott and Co. 1874, pp 342-45

348. Lundell E, Nordman R: A case of infantile poisoning by topical application of Castellani's solution. Ann Clin Res 5:404-06, 1973

349. Permissible Levels of Toxic Substances in the Working Environment. Occupational Health and Safety Series, Title 20, in Report of the 6th Session, Geneva, June 4-10, 1968, Geneva, International Labour Office, 1970, 405 pp

IX. APPENDIX I

SAMPLING OF PHENOL IN AIR

Sampling

Air samples are collected in the breathing zone of employees by drawing air through an all-glass midget impinger containing 15 ml of 0.1 N sodium hydroxide solution. If the work operation allows the impinger to be maintained in a vertical position, it may be possible to attach the impinger to the employee's clothing. A personal sampling pump may also be attached to the employee's clothing. However, a significant amount of bending from the waist may make impinger sampling impractical. Samples should be collected as close to the breathing zone as possible. Air being sampled should not pass through any other tubing or equipment before entering the impinger. The sampling pump is protected from splashover or solvent condensation by a 5-cm long by 6-mm ID glass tube loosely packed with a plug of glass wool and inserted between the exit arm of the impinger and the pump. Sampling is performed for at least 15 minutes at a rate of 1 liter/minute. The flow rate, with the impinger on line, should be checked before and after the sample is taken.

After sampling, the impinger stem can be removed and cleaned, first tapping the stem gently against the inside wall of the sample flask to recover as much of the sampling solution as possible, then washing with a small amount (1-2 ml) of distilled water and adding the wash to the sample flask. The flask is then sealed tightly with a hard, nonreactive stopper, preferably Teflon, but never with rubber. Shipment of sample flasks should be with the stems in, the opening of the stem should be sealed with

Parafilm or equivalent nonrubber covers, and the standard taper joints should be sealed usually by means of plastic tape. Precautions should be taken to minimize spillage or loss by evaporation at all times. Refrigerate samples if analyses cannot be performed within a day in order to minimize chemical reactions which might otherwise occur. Whenever possible, hand delivery of samples is recommended, or special shipping cases should be used. A blank impinger should be handled in exactly the same manner as the other samples (fill, seal, and transport) except that no air is sampled through this impinger.

Calibration

Since the accuracy of an analysis is often limited by the accuracy of the volume of air which is measured, accurate calibration of a sampling device and flowmeters is essential. Frequency of calibration depends on the use, care, and handling to which the sampling system is subjected. Pumps should be calibrated if they have been subjected to abuse or if they have just been repaired or received from a manufacturer. When sampling highly polluted or dusty environments, frequent cleaning and calibration may be necessary because the orifices of flow meters and other equipment may become contaminated.

Ordinarily, pumps should be calibrated in the laboratory both before they are used in the field and after they have been used to collect a large number of field samples. The accuracy of calibration depends highly on the type of instrument used as a reference, and choice of calibration procedure will depend largely upon where the calibration is to be performed. For laboratory testing, a 1-liter buret or a wet-test meter is recommended,

although other standard calibrating instruments, such as spirometer, Marriot bottle, or dry-gas meter, can be used. The actual set-up should be similar for all calibration systems used. The calibration instrument should be connected first in a series to the sampling train which will be followed by the sampler pump. In this way, the calibration instrument will be at atmospheric pressure. If a personal sampling pump is used, each pump must be calibrated separately. If a buret is used for calibration, it should be set up so that the flow is toward the narrow end of the unit.

Care in the assembly of the calibration set-up ensures that seals at the joints are airtight and that the length of connecting tubing is at a minimum. Calibration should be performed at essentially the same conditions of pressure and temperature as those under which it is anticipated that the sampling will occur. A calibrated pump rotameter should be used to establish flow rate in the field.

Apparatus

The sampling unit for the impinger collection method consists of the following components:

(a) A standard glass midget impinger containing the collection medium.

(b) A pump suitable for exhausting at least 1 liter/minute for 100 minutes.

(c) Thermometer.

(d) Manometer.

(e) Stopwatch.

X. APPENDIX II

ANALYTICAL METHOD FOR PHENOL IN AIR

Principle of the Method

A known volume of air is drawn through a midget impinger containing 15 ml of 0.1 N sodium hydroxide as the collection medium. The resulting solution is acidified with sulfuric acid. An aliquot of the collected sample is injected into a gas chromatograph. The area of the resulting trace is determined and compared with similar areas obtained for standards. Use of an internal standard is highly recommended.

Range and Sensitivity

This method [313] was validated over the range of 9.46-37.8 mg/cu m at an atmospheric temperature of 22 C and atmospheric pressure of 760 mmHg, using a 100-liter sample. With a 100-liter sample, the probable useful range of this method is 5-60 mg/cu m at a detector sensitivity that gives nearly full deflection on the strip chart recorder for a 6-mg sample.

Interference

Any compound which has the same retention time and detector response as phenol under the GC operating conditions described in this method may interfere in the analysis. Retention time data on a single column cannot be considered proof of chemical identity. If there is possible interference, separation conditions (column packing, temperature, flow rate, etc) must be changed to circumvent the problem.

Precision and Accuracy

The coefficient of variation for the total analytical and sampling method in the range of 9.46-37.8 mg/cu m was 0.068. This value corresponds to a 1.3 mg/cu m standard deviation at 19 mg/cu m. A collection efficiency of 1.00 $\pm$ 0.01 was determined for the collecting medium.

In general, the analytical results obtained for phenol at concentrations of 5 ppm (19 mg/cu m) using the recommended overall sampling and analytical method averaged 2.6% less than the "true" concentrations for a limited number of laboratory experiments. Since the coefficient of variation is greater than 0.026, any difference between the "found" and "true" concentrations may not represent a bias in the sampling and analytical method, but rather a random variation from the experimentally prepared "true" concentration. Therefore, it should not be necessary to apply a recovery correction to the final result.

Advantages and Disadvantages of the Method

Samples collected in impingers are analyzed by means of a quick, instrumental method. However, under certain work conditions, impingers attached to an employee's clothing and containing sodium hydroxide may not be suitable for breathing zone samples. The GC instrumental method is precise and accurate, but it does require that samples be returned to the laboratory for analysis.

Apparatus

(a) Gas chromatograph (GC) equipped with a flame ionization detector (FID)

(b) Column (4-ft long x 1/4-in OD stainless steel) packed with 35/60 mesh Tenax. [325]

(c) An electronic integrator or some other suitable means for measuring peak areas.

(d) Microl syringes - 10 μl and other convenient sizes for making standards and injecting samples into the GC.

(e) Volumetric flasks - convenient sizes for making solutions.

(f) Pipets - 15 ml and other convenient sizes.

Reagents

(a) Distilled water.

(b) Phenol - reagent grade.

(c) Sulfuric acid - reagent grade.

(d) Sodium hydroxide - 0.1 N solution.

Dissolve 4.0 g of sodium hydroxide in distilled water (carbon dioxide free) and dilute to a final volume of 1 liter.

(e) Purified nitrogen.

(f) Purified hydrogen.

(g) Filtered compressed air.

(h) Standard solutions.

Six standard solutions at each of the three concentrations (0.5x, 1x, and 2x the recommended TWA concentration limit) are prepared by adding 1 mg, 2 mg, or 4 mg of phenol to 15-ml aliquots of 0.1 N sodium hydroxide

contained in 25-ml volumetric flasks. The amounts introduced are equivalent to that present in a 100-liter air sample at multiples of the recommended limit. The solutions are acidified with 0.1 ml of concentrated sulfuric acid and made up to volume with distilled water. The solution should be checked to confirm that the pH is less than 4. A reagent blank is prepared in the same manner, except that no phenol is added. The standards and blank are analyzed in the manner indicated below.

Procedure

(a) Cleaning of equipment

All glassware used for the laboratory analysis should be washed with detergent and thoroughly rinsed with tap water and distilled water.

(b) Analysis of samples

Transfer the solution to a 25-ml volumetric flask. Rinse the impinger twice with 1 ml of distilled water and add the rinses to the flask. Add 0.1 ml of concentrated sulfuric acid to the flask and mix. Check to ensure that the pH is less than 4. Dilute to mark with distilled water and mix. Typical operating conditions for the gas chromatograph are:

(1) 50 ml/min (60 psig) nitrogen carrier gas flow.

(2) 65 ml/min (24 psig) hydrogen gas flow to detector.

(3) 500 ml/min (50 psig) air flow to detector.

(4) 215 C injector temperature.

(5) 225 C manifold temperature (detector).

(6) 200 C column temperature.

The first step in the analysis is injection of the sample into the gas chromatograph. To eliminate difficulties arising from blowback or distillation within the syringe needle, employ the solvent flush injection

technique. The 10-μl syringe is first flushed with solvent several times to wet the barrel and plunger. To increase the accuracy and reproducibility of the injected sample volume, 3 μl of solvent are drawn into the syringe. The needle is removed from the solvent, and the plunger is pulled back about 0.2 μl to separate the solvent flush from the sample with a pocket of air to be used as a marker. The needle is then immersed in the sample, and a 5-μl aliquot is withdrawn taking into consideration the volume of the needle, since the sample in the needle will be completely injected. After the needle is removed from the sample and prior to injection, the plunger is pulled back 1.2 μl to minimize evaporation of the sample from the tip of the needle. Note that the sample occupies 4.9-5.0 μl in the barrel of the syringe. Duplicate injections of each sample and standard should be made. No more than a 3% difference in area is to be expected. An automatic sample injector can be used if it is shown to give reproducibility at least as good as the solvent flush method.

The area of the sample peak is measured by an electronic integrator or some other suitable means of area measurement, and preliminary results are read from a standard curve prepared as discussed below.

Calibration and Standards

It is convenient to express concentration of standards in terms of mg/15 ml of collection medium because samples are collected in this amount of collection medium. Solutions varying in concentration over the range of interest are prepared and analyzed under the same GC conditions and during the same time period as the unknown samples. Curves are established by plotting concentration in mg/15 ml versus peak area. Note that since no internal standard is used in the method, standard solutions must be analyzed at the same time that the sample analysis is done. This will minimize the effect of known day-to-day variations and variations during the same day of the FID response.

Calculations

Read the weight in mg corresponding to each peak area from the standard curve. No volume corrections are needed because the standard curve is based on mg/15 ml collection medium and the volume of sample injected is identical to the volume of the standards injected. Corrections for the blank must be made for each sample.

$$\text{corrected mg} = \text{mg sample} - \text{mg blank}$$

where:

mg sample = mg found in sample impinger

mg blank = mg found in blank impinger

The concentrations of phenol in the air sample can be expressed in mg/cu m.

$$\text{mg/cu m} = \frac{\text{corrected mg} \times 1000 \text{ (liter/cu m)}}{\text{air volume sampled (liter)}}$$

Another method of expressing concentration is ppm.

$$\text{ppm} = \text{mg/cu m} \times \frac{24.45}{MW} \times \frac{760}{P} \times \frac{T + 273}{298}$$

where:

P = pressure (mmHg) of air sampled

T = temperature (degrees C) of air sampled

24.45 = molar volume (liter/mole) at 25 C and 760 mmHg

MW = molecular weight (g/mole) of phenol = 94.11

760 = standard pressure (mmHg)

298 = standard temperature (degrees K)

XI. APPENDIX III

MATERIAL SAFETY DATA SHEET

The following items of information which are applicable to a specific product or material shall be provided in the appropriate block of the Material Safety Data Sheet (MSDS).

The product designation is inserted in the block in the upper left corner of the first page to facilitate filing and retrieval. Print in upper case letters as large as possible. It should be printed to read upright with the sheet turned sideways. The product designation is that name or code designation which appears on the label, or by which the product is sold or known by employees. The relative numerical hazard ratings and key statements are those determined by the rules in Chapter V, Part B, of the NIOSH publication, An Identification System for Occupationally Hazardous Materials. The company identification may be printed in the upper right corner if desired.

(a) Section I. Product Identification

The manufacturer's name, address, and regular and emergency telephone numbers (including area code) are inserted in the appropriate blocks of Section I. The company listed should be a source of detailed backup information on the hazards of the material(s) covered by the MSDS. The listing of suppliers or wholesale distributors is discouraged. The trade name should be the product designation or common name associated with the material. The synonyms are those commonly used for the product, especially formal chemical nomenclature. Every known chemical designation or

competitor's name need not be listed.

(b) Section II. Hazardous Ingredients

The "materials" listed in Section II shall be those substances which are part of the hazardous product covered by the MSDS and individually meet any of the criteria defining a hazardous material. Thus, one component of a multicomponent product might be listed because of its toxicity, another component because of its flammability, while a third component could be included both for its toxicity and its reactivity. Note that a MSDS for a single component product must have the name of the material repeated in this section to avoid giving the impression that there are no hazardous ingredients.

Chemical substances should be listed according to their complete name derived from a recognized system of nomenclature. Where possible, avoid using common names and general class names such as "aromatic amine," "safety solvent," or "aliphatic hydrocarbon" when the specific name is known.

The "%" may be the approximate percentage by weight or volume (indicate basis) which each hazardous ingredient of the mixture bears to the whole mixture. This may be indicated as a range or maximum amount, ie, "10-40% vol" or "10% max wt" to avoid disclosure of trade secrets.

Toxic hazard data shall be stated in terms of concentration, mode of exposure or test, and animal used, ie, "100 ppm LC50-oral-rat," "25 mg/cu m LD50-skin-rabbit," "75 ppm LC man," or "permissible exposure from 29 CFR 1910.93," or, if not available, from other sources of publications such as the American Conference of Governmental Industrial Hygienists or the American National Standards Institute Inc. Flashpoint, shock sensitivity,

or similar descriptive data may be used to indicate flammability, reactivity, or similar properties of the material.

(c) Section III. Physical Data

The data in Section III should be for the total mixture and should include the boiling point and melting point in degrees Fahrenheit (Celsius in parentheses); vapor pressure, in conventional millimeters of mercury (mm Hg); vapor density of gas or vapor (air = 1); solubility in water, in parts/hundred parts of water by weight; specific gravity (water = 1); percent volatiles (indicate if by weight or volume) at 70 degrees Fahrenheit (21.1 degrees Celsius); evaporation rate for liquids or sublimable solids, relative to butyl acetate; and appearance and odor. These data are useful for the control of toxic substances. Boiling point, vapor density, percent volatiles, vapor pressure, and evaporation are useful for designing proper ventilation equipment. This information is also useful for design and deployment of adequate fire and spill containment equipment. The appearance and odor may facilitate identification of substances stored in improperly marked containers, or when spilled.

(d) Section IV. Fire and Explosion Data

Section IV should contain complete fire and explosion data for the product, including flash point and autoignition temperature in degrees Fahrenheit (Celsius in parentheses); flammable limits, in percent by volume in air; suitable extinguishing media or materials; special firefighting procedures; and unusual fire and explosion hazard information. If the product presents no fire hazard, insert "NO FIRE HAZARD" on the line labeled "Extinguishing Media."

(e) Section V. Health Hazard Information

The "Health Hazard Data" should be a combined estimate of the hazard of the total product. This can be expressed as a TWA concentration, as a permissible exposure, or by some other indication of an acceptable standard. Other data are acceptable, such as lowest LD50, if multiple components are involved.

Under "Routes of Exposure," comments in each category should reflect the potential hazard from absorption by the route in question. Comments should indicate the severity of the effect and the basis for the statement, if possible. The basis might be animal studies, analogy with similar products, or human experiences. Comments such as "yes" or "possible" are not helpful. Typical comments might be:

> Skin Contact--single short contact, no adverse effect likely; prolonged or repeated contact, mild irritation and possibly some blistering.
>
> Eye Contact--some pain and mild transient irritation; no corneal scarring.

"Emergency and First Aid Procedures" should be written in lay language and should primarily represent first-aid treatment that could be provided by paramedical personnel or individuals trained in first aid.

Information in the "Notes to Physician" section should include any special medical information which would be of assistance to an attending physician including required or recommended preplacement and periodic medical examinations, diagnostic procedures, and medical management of overexposed employees.

(f) Section VI. Reactivity Data

The comments in Section VI relate to safe storage and handling of hazardous, unstable substances. It is particularly important to highlight instability or incompatibility to common substances or circumstances such as water, direct sunlight, steel or copper piping, acids, alkalies, etc. "Hazardous Decomposition Products" shall include those products released under fire conditions. It shall also include dangerous products produced by aging, such as peroxides in the case of some ethers. Where applicable, shelf life should also be indicated.

(g) Section VII. Spill or Leak Procedures

Detailed procedures for cleanup and disposal should be listed with emphasis on precautions to be taken to protect employees assigned to cleanup detail. Specific neutralizing chemicals or procedures should be described in detail. Disposal methods should be explicit including proper labeling of containers holding residues and ultimate disposal methods such as "sanitary landfill," or "incineration." Warnings such as "comply with local, state, and federal antipollution ordinances" are proper but not sufficient. Specific procedures shall be identified.

(h) Section VIII. Special Protection Information

Section VIII requires specific information. Statements such as "Yes," "No," or "If necessary" are not informative. Ventilation requirements should be specific as to type and preferred methods. Respirators shall be specified as to type and NIOSH or US Bureau of Mines approval class, ie, "Supplied air," "Organic vapor canister," "Suitable for dusts not more toxic than lead," etc. Protective equipment must be specified as to type and materials of construction.

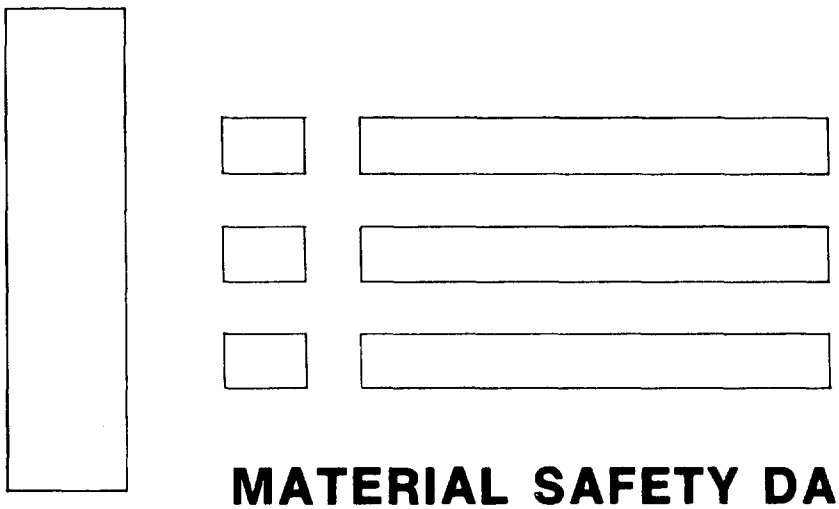
(i) Section IX. Special Precautions

"Precautionary Statements" shall consist of the label statements selected for use on the container or placard. Additional information on any aspect of safety or health not covered in other sections should be inserted in Section IX. The lower block can contain references to published guides or in-house procedures for handling or storage. Department of Transportation markings and classifications and other freight, handling, or storage requirements and environmental controls can be noted.

(j) Signature and Filing

Finally, the name and address of the responsible person who completed the MSDS and the date of completion are entered. This will facilitate correction of errors and identify a source of additional information.

The MSDS shall be filed in a location readily accessible to employees potentially exposed to the hazardous material. The MSDS can be used as a training aid and basis for discussion during safety meetings and training of new employees. It should assist management by directing attention to the need for specific control engineering, work practices, and protective measures to ensure safe handling and use of the material. It will aid the safety and health staff in planning a safe and healthful work environment and suggesting appropriate emergency procedures and sources of help in the event of harmful exposure of employees.



MATERIAL SAFETY DATA SHEET

I PRODUCT IDENTIFICATION	
MANUFACTURER'S NAME	REGULAR TELEPHONE NO. EMERGENCY TELEPHONE NO.
ADDRESS	
TRADE NAME	
SYNONYMS	

II HAZARDOUS INGREDIENTS		
MATERIAL OR COMPONENT	%	HAZARD DATA

III PHYSICAL DATA			
BOILING POINT, 760 MM HG		MELTING POINT	
SPECIFIC GRAVITY (H_2O=1)		VAPOR PRESSURE	
VAPOR DENSITY (AIR=1)		SOLUBILITY IN H_2O, % BY WT	
% VOLATILES BY VOL		EVAPORATION RATE (BUTYL ACETATE=1)	
APPEARANCE AND ODOR			

IV FIRE AND EXPLOSION DATA

FLASH POINT (TEST METHOD)		AUTOIGNITION TEMPERATURE	
FLAMMABLE LIMITS IN AIR, % BY VOL.	LOWER		UPPER	
EXTINGUISHING MEDIA			
SPECIAL FIRE FIGHTING PROCEDURES			
UNUSUAL FIRE AND EXPLOSION HAZARD			

V HEALTH HAZARD INFORMATION

HEALTH HAZARD DATA

ROUTES OF EXPOSURE

INHALATION

SKIN CONTACT

SKIN ABSORPTION

EYE CONTACT

INGESTION

EFFECTS OF OVEREXPOSURE

ACUTE OVEREXPOSURE

CHRONIC OVEREXPOSURE

EMERGENCY AND FIRST AID PROCEDURES

EYES

SKIN

INHALATION

INGESTION

NOTES TO PHYSICIAN

VI REACTIVITY DATA

CONDITIONS CONTRIBUTING TO INSTABILITY

INCOMPATIBILITY

HAZARDOUS DECOMPOSITION PRODUCTS

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION

VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

NEUTRALIZING CHEMICALS

WASTE DISPOSAL METHOD

VIII SPECIAL PROTECTION INFORMATION

VENTILATION REQUIREMENTS

SPECIFIC PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY (SPECIFY IN DETAIL)

EYE

GLOVES

OTHER CLOTHING AND EQUIPMENT

IX SPECIAL PRECAUTIONS

PRECAUTIONARY
STATEMENTS

OTHER HANDLING AND
STORAGE REQUIREMENTS

PREPARED BY

ADDRESS

DATE

XII. TABLES AND FIGURES

TABLE XII-1

CHEMICAL AND PHYSICAL PROPERTIES OF PHENOL

Formula	C_6H_5OH
Molecular weight	94.11
pKa (acid dissociation)	9.9
Melting point	40-41 C
Boiling point	181.75 C
Vapor pressure (25 C)	0.35 mm Hg
Specific gravity:	
Solid (25 C)	1.071
Liquid (25 C)	1.049
Relative vapor density	3.24 (air = 1)
Solubility: (X is mole fraction.) Phenol in water: $-\log x = 0.375 \log(66-T) + 1.15$ Water in phenol: $-\log x = -0.62 \log(66-T) + 0.99$ (T is Celsius temperature.)	Also soluble in ether, alcohol, acetic acid, glycerol, liquid sulfur dioxide, and benzene
Color	Colorless to light pink solid
Odor	Sweet; threshold = 1 ppm
Flashpoint:	
Open cup	85 C
Closed cup	79 C
Ignition temperature	715 C
Light sensitivity	Darkens on exposure to light
Saturated vapor concentration (25 C)	461 ppm

From references 1,2,3,135

TABLE XII-2

1972 PHENOL PRODUCTION IN THE US

Process	Production Capacity	
	Millions of Pounds/Yr	Percentage of Total Capacity
Cumene	2100	85.4
Sulfonation	150	6.1
Chlorobenzene	110	4.5
Toluene	50	2.0
Coal Tar	50	2.0
TOTAL	2460	100.0

From Chemical Profiles [5]

TABLE XII-3

1972 USE PATTERN OF PHENOL

Product	Percentage of Total Used
Phenolic resins	50
Caprolactam	20
Bisphenol-A	10
Alkylphenols	6
Adipic acid	4
All other	10
TOTAL	100

From Chemical Profiles [5]

TABLE XII-4

TYPICAL USES OF PHENOL

Applications	References
Bulk Processes:	
phenolic resins	5,7
caprolactam	5,7,28
bisphenol-A	5,7
alkylphenols	5,7
adipic acid	5,7
Production of:	
pharmaceuticals	8-15
dyes	8-20
metal cleaners	21
disinfectants	9,10,13,14,17,22-24
antiseptics	14,16,17,22-25
photographic chemicals	10,16,19,20,26
preservatives	8,10,11,14,18,27
perfumes	9-11,13,14,17,25
paint removers	9,11,22
varnish removers	9,11,22
paints	8,9,11,17,20,22
lacquers	8,9,11,17,20,22
rubber	8,11,14
agricultural chemicals	10,11,13,16
asbestos products	11
illuminating gas	11
lampblack	11
ink	12,27,29
tanning agents	9,14,17,25
Product Synthesis:	
picric acid	9,12,20,30
salicylic acid	9,14
phenates	1,9
phenactin	9
Medical Uses:	
chemotherapy	31-37
intrathecal injections for the relief of flexor spasms	38-48

TABLE XII-5

SELECTED OCCUPATIONAL GROUPS POTENTIALLY EXPOSED TO PHENOL

Occupational Groups	References
Antiseptic workers	16,17,22,23,25
Aromatic compound synthesizers	8,17
Asbestos makers	11,14
Battery makers, dry	321
Chemical makers	9,14,17
Coal tar workers	11,14,22,25,326
Disinfectant makers	9,13,17,18,326
Drug makers	11,22,326
Dyemakers	8,9,13,14,17,326
Dyers	11,326
Etchers	326
Explosives workers	11,13,17,20,25,326
Fertilizer workers	11
Gas employees, illuminating	11,14,326
Gas purifiers	326
Inkmakers	27,84
Insecticide makers	13
Laboratory workers	79,96
Lampblack makers	11,326
Lubricating oil processors	13,326
Metal cleaners	21
Motor oil workers	93
Paintmakers	8,11,326
Paint-remover makers and users	9,11,22,326
Papermakers	8,11,14
Pentachlorophenol makers	326
Perfume makers	9,11,13,17,25,326
Petroleum workers	11
Pharmaceutical makers	8,9,11,13,17
Phenol workers	13,326

TABLE XII-5 (CONTINUED)

SELECTED OCCUPATIONAL GROUPS POTENTIALLY EXPOSED TO PHENOL

Occupational Groups	References
Photographic material workers	14,326
Picric acid makers	9,326
Plastic makers	9,10,11,13,17
Printers	84
Researchers	79,96
Resin makers	8,9,11,13,17,326
Rubber reclaimers	14,326
Rubber workers	8,11,326
Soapmakers	11
Stillmen, carbolic acid	326
Surgical dressing makers	326
Textile printers	326
Tanning substance makers	9,11,14,17,25
Varnish and lacquer makers	8,326
Weed killer users	326
Wood preserver users	8,11,14,326

TABLE XII-6

ADVERSE EFFECTS PRODUCED BY EXPOSURE TO PHENOL

Effects	References
Via Skin Absorption:	
death	20,29,61,69,77,112 119,123,202,204,327,328
local tissue irritation	20,62,65,77,78,111, 202-204,329-332
local tissue necrosis	61,77,78,111,129 202,204,327,330,331,333,334
irregular pulse	29,69,111,112,129,115,204,328
darkened urine	62,65,66,77,111,129,204,328
stertorous breathing	77,111,112,129,202,204
collapse	29,112,129,202,204,327,331
vomiting	66,69,77,111,112, 129,192,202
cold extremities	65,66,129,202
coma	77,112
pallor	61,62,65
cyanosis	65,77,111
convulsions	112,129,202
reduced body temperature	65,111,112
elevated body temperature	77,129,112
dilated pupils	69,112,129,204
constricted pupils	111,112,129,202,204
absence of corneal reflexes	111,112,202
difficulty in swallowing	69,111
profuse perspiration	66,111,112,129
rales	61,77,111,202,328
odor of phenol on breath	65,77
headache	29,62,112,328
vertigo	66,77,129,331
euphoria	62,111,112
dyspnea	112,129,331
ochronosis (acquired)	58-61
general fatigue	29,66,111,129
local edema	76,115,203
pulmonary edema	331
abdominal edema	77
anuria	66,202
local anesthesia	66,77,111,203,329,330,332

TABLE XII-6 (CONTINUED)

ADVERSE EFFECTS PRODUCED BY EXPOSURE TO PHENOL

Effects	References
Via Skin Absorption (continued)	
albuminura	66
hematuria	202
damage to kidney tissue	62,66,331
abdominal pain	202
anemia	62
depression	29
liver damage	129,202,331
damage to blood-forming organs	62,331
increased irritability	329
loss of appetite	328
diarrhea	328
Via Inhalation:	
death	110,328
local tissue irritation	56,63,110
local tissue necrosis	110
irregular pulse	56,63,65,110
darkened urine	56,65,110
stertorous breathing	63,65,110
collapse	110,328
cold extremities	63,328
coma	63,65,328
cyanosis	71
constricted pupils	328
convulsions	63
reduced body temperature	110
difficulty in swallowing	56
profuse perspiration	56,65
odor of phenol on breath	63
euphoria	110
unusual thirst	328
pulmonary edema	110
abdominal pain	63
giddiness	63

TABLE XII-6 (CONTINUED)

ADVERSE EFFECTS PRODUCED BY EXPOSURE TO PHENOL

Effects	References
Via Ingestion:	
death	64,70,71,107-109, 205,327,335-337
local tissue irritation	68-70,107,109,336,337
local tissue necrosis	68-71,107-109, 205,336-338
irregular pulse	67,68,71,107,109,205,336,338
darkened urine	71,107,109,336
stertorous breathing	109,205,327,336,338
collapse	56,69,71,107,205
vomiting	68,107,108,205
cold extremities	69,71,107,205,336
coma	67-71,107
convulsions	68,71,205
dilated pupils	107,327
constricted pupils	69-71,205
absence of corneal reflexes	69-71,109
odor of phenol on breath	68-71,107,327
reduced body temperature	71,107,337
elevated body temperature	108
difficulty in swallowing	68,71,107
rales	67,68
headache	68
unusual thirst	69,109
increased irritability	68
euphoria	108
dyspnea	71
pulmonary edema	68,107,108
abdominal edema	107
anuria	68
albuminuria	68,107
giddiness	56
delirium	71
hematuria	68,107
abdominal pain	70,107,205
liver damage	107
low blood pressure	68
nausea	68,107
burning sensation in the throat	56,107,69
abortion	69,109

TABLE XII-6 (CONTINUED)

ADVERSE EFFECTS PRODUCED BY EXPOSURE TO PHENOL

Effects	References
Via Contact with Open Wounds:	
death	55,59,60,328
local tissue irritation	55,106,339
local tissue necrosis	55,60,106,339,340
irregular pulse	106
darkened urine	58,59,60,106,112,341
collapse	341
vomiting	106,328,341
coma	341
pallor	58,59,106,112
cyanosis	341
dilated pupils	341
difficulty in swallowing	106
vertigo	58
ochronosis (acquired)	58,59,60
general fatigue	58,341
unusual thirst	112
local edema	58,340
anuria	112
local anesthesia	55
tinnitus	58
loss of appetite	106

TABLE XII-6 (CONTINUED)

ADVERSE EFFECTS PRODUCED BY EXPOSURE TO PHENOL

Effects	References
Via Contact with Mucous Membranes:	
Uterus-	
death	342
local tissue irritation	342,343
collapse	342
local tissue necrosis	342,343
irregular pulse	342
darkened urine	343
absence of corneal reflexes	342
hematuria	343
damage to blood-forming organs	343
anemia	343
diarrhea	342
Peritoneum-	
local tissue irritation	344
local tissue necrosis	344
diarrhea	328
Via Intramuscular Injection:	
death	345
local tissue necrosis	345,346
constricted pupils	345,346
irregular pulse	345,346
collapse	345,346
vomiting	345,346
reduced body temperature	345
stertorous breathing	346

TABLE XII-7

HUMAN RESPONSES TO PHENOL AT VARIOUS DURATIONS AND AIRBORNE CONCENTRATIONS

Concentration		Duration of			
ppm	mg/cu m	Exposure	N	Response	References
48 + 8 ppm HCHO	185 + 9.8 HCHO	5-10 min/hr, 8 hrs/day	?	Marked irritation of the nose, throat, and eyes. HCHO may be primary cause.	95
1.5-5.2	6-20	8 hrs with 2 30-min breaks	8	No ill effects. 60-88% of phenol absorbed by lungs. Rise in urinary excretion of phenol during exposure with a return to preexposure levels within 24 hrs	97
0-3.3	0-12.5	8 hrs/day	?	No ill effect. Rise in urinary phenol	88
2.3-3.2 (in coke quench effluent)	8.8-12.2 (in coke quench effluent)	8 hrs/day	29	"Poisoning"	88
0.047	0.18	Minutes	4	Odor threshold average	135
0.006-0.048	0.022-0.184	"	14	Odor threshold range	17
0.006-0.024	0.022-0.094	"	19	"	136
0.006	0.024	15 sec	4	Conditioned electrocortical reflex in all	17
0.004	0.0155	5 min	3	Increased sensitivity to light in dark adapted people	17

mg/liter of effluent

TABLE XII-8

HUMAN RESPONSES TO SKIN CONTACT WITH PHENOL

Concentration % phenol	Medium	Contact Duration	Circumstances	N	Most Severe Response	References
100	Crystals	30 min	In glove	1	Gangrene	80
100	Liquefied	5-10 min	Spill on cheeks & scalp	1	Death	204
100	"	5-7 min	Explosion	1	"	96
80-100	Water	20 min	Spill on hip, thigh, scrotum	1	"	202
80-100	"	2-4 days	Closed dressings on open wounds	11	1 death, 8 gas gangrene, 11 tissue necrosis	55
97	Cresols & water	Less than 5 min	Broken flask in lab	1	Burns on hands, later fatigue, blurred vision, weakness	96
"Strong"	Water	10 min	Spill on scalp, face, neck, shoulders, and back	1	Death	129
?	Ergot salve	20 yrs	Applied daily on eczematous back	1	Invasive epithelioma	89
90	Water	20 sec 12 min 31 min 1 hr 2 hrs 44 hrs 5-7 days	Self-exposure-- 1 drop on forearm	1	Some local irritation Edema, anesthesia Burning sensation Increasing pain & edema Increased sensitivity to touch Desquamation Crusting & sloughing	203
78	Water	2-5 min	4-5 liter spill on upper body	1	Coma	86
43.5	Waste water (cresols 14%, low boiling organics 11.5%, high boiling organics 11%, water 20%)	1 min	Spill on lower body, irrigation with warm water for 30 min, followed by swabbing with ethanol for 10 min, followed by repetition of procedure	1	Shock	82
20	Lard	1 5 hrs	Covered with impervious dressing	1	Coma	
11	Olive oil	7 wks	Covered dressing	1	Vomiting, dysphagia, dark urine	59
5	Oil	30 yrs	Closed dressing on ulcerated skin	1	Ochronosis (acquired)	59
5	"	12 yrs	"	1	Death	60
5	"	10 yrs	"	1	Ochronosis (acquired)	61
5	"	3 yrs	"	1	"	58
5	Salve	7 days	Closed dressing on cut	1	Gangrene	339
5	Iodoform & zinc oxide	5 days	Closed dressing over rash on toe	1	"	84

TABLE XII-8 (CONTINUED)

HUMAN RESPONSES TO SKIN CONTACT WITH PHENOL

Concentration phenol	Medium	Contact Duration	Circumstances	N	Most Severe Response	References
5	Water	14.5 hr	Phenol soaked compress on thigh abscess	1	Coma	112
5	"	70 min	Phenol soaked compress on broken skin	1	"	112
<5	"	16-20 hrs	Closed soaked dressing on finger	1	Gangrene	340
4.75	Camphor	1- 7 days	Painted on hand, arms, feet, & lower abdomen	3	Local tissue necrosis	90
4	Water + boric acid	16-20 hrs	Applied twice on head, arms, & thighs	1	Cyanotic, rapid pulse, kidney damage	348
4	Water	7.5 hrs	Rubbed on chest, abdomen, & back	1	Coma	66
2.5	"	2 hrs	Legs wrapped in soaked towels	1	"	341
2.5	"	3 min	Stale bread poultice over entire body	1	"	111
2	"	2.5 days	Moist dressing over burns on 30% of body surface	1	Death	77
2	"	11 hrs	Closed bandage on infant umbilicus		"	87
1%	Calamine & zinc lotion	Daily for 17 days	Rubbed on scalp, arms, chest, back, & legs	1	Coma	128
6 4-6 6 ppm	Vapor exposure	5.5 hrs	No inhalation dose, naked	8	Increased urinary phenol, no effects	97
5.8-6.8 ppm	"	"	No inhalation dose, clothed in underwear and denim overalls	8	"	97
2.4-2.5 ppm	"	"	"	8	"	97
1.2-1.4 ppm	"	"	"	8	"	97

TABLE XII-9

HUMAN RESPONSE ON INGESTION OF PHENOL

Concentration % phenol	Dose ml solution	Dose g phenol	N	Time Prior to Treatment	Response	References
100	120	128	1	45 min	Death	69
100	60	64	1	Shortly	"	71
100	60	64	1	1.5 hrs	"	70
88	60	56	1	45 min	Collapse	75
90	40	39	1	1 hr	Death	109
100	30	32	1	Min	"	71
100	30	32	1	50 min	Coma	68
100	30	32	1	15 min	"	75
82	30	26	1	3 min	Death	327
100	15	16	1	1.5 hr	"	75
100	10-20	11-21	1	25 min	"	76
15	30	4.8	1	10 min	"	205
0.9	45 (3-4 times/ day)	0.43 (3-4 times/ day)	Several	---	Burning sensation followed by giddiness, cold, profuse perspiration, weak pulse, green tint to urine	56
2	60	1.3	1	24 hr	No effect	206
0.2	45 (3-4 times/ day)	0.096 (3-4 times/ day)	Several	---	"	56

TABLE XII-10

PHENOL CONCENTRATIONS IN HUMAN BLOOD

Exposure	Route of Entry	Time Prior to Sampling	Phenol Concentration (mg/100 ml) Free	Conjugated	Analytical Method	References
None	____	____	None or traces	0.0-0.8	Millon's reagent	139
"	____	____	None	0.07-0.9	"	140
"	____	____	0.02	____	p-Nitroaniline	141
"	____	____	0.0-0.04	0.155	Millon's reagent	142
"	____	____	0.05-0.8	0.1-0.15	p-Nitroaniline	143 144
"	____	____	____	1.8-5.96 (total phenol)	Bromo-iodometric titration	149
"	____	____	1.36-1.67	0.06-0.3	p-Nitroaniline	145
"	____	____	1-2	0-0.2	"	146
"	____	____	1.8-2.4	0.17-0.8	Phosphotungstic-phosphomolybdic acid color reagent	147
"	____	____	2-4	2.6-6 (total phenol)	Xanthoprotic reaction	148
None	____	____	None	1.87-7.96 (total phenol)	Phosphotungstic-phosphomolybdic acid color reagent	150
"	____	____	0.15	0.35	p-Nitroaniline	137
1-4 g Phenol (2%) in calamine lotion	Dermal application	2-hour intervals, 1-3 days	0.4	1.1-1.92	"	137
1-4 g Phenol (4.75%) as phenol-camphor in liquid petrolatum	Dermal application	2-hour intervals, 1-3 days	0.4	0.9-1.73	"	137

TABLE XII-11

PHENOL CONCENTRATIONS IN HUMAN URINE

Exposure	Route of Entry	Time Prior to Sampling	Phenol Concentration (mg/l) Free	Conjugated	Analytical Method	References
None	----	----	0.04-0.56	1.06-5.18	GLC	152
"	----	----	----	0.5 -30.8 (total phenol)	"	152
"	----	----	----	1.0 -27.0 (total phenol)	Gibbs reagent	152
"	----	----	----	9 (total phenol)	?	153
"	----	----	----	2-18 (total phenol)	GLC	154
"	----	----	----	7.8 (total phenol)	Gibbs reagent	155
"	----	----	----	3.4 -22 (total phenol) (majority-free phenol)	Phosphotungstic-phosphomolybdic acid color reagent	151
"	----	----	----	3-28 (total phenol)	Gravimetric as tribromophenol	156
"	----	----	----	30 (total phenol)	p-Nitroaniline	157
"	----	----	----	60 (total phenol)	Mooser's procedure	158
"	----	----	----	6.0-60.6 6 -63 (total phenol)	p-Nitroaniline	138
"	----	----	----	8.3-81.5 (total phenol)	Gibb's reagent	128
"	----	----	----	4-14 (total phenol)	?	97
18.3 mg/cu m	Inhalation only, 8 hrs	At termination of exposure		100 (total phenol)	?	97
24.4 mg/cu m	Skin only, 6 hrs	"	----	100 (total phenol)	?	98
8.8 mg/cu m	Inhalation, possibly skin	Preshift, 6th day of work	25 mg/g creatinine	90 mg/g creatinine	Gibb's reagent	98
"	"	Postshift, 6th day	30 mg/g creatinine	290 mg/g creatinine	"	98
"	"	Preshift, 2 days no exposure	25 mg/g creatinine	35 mg/g creatinine	"	98
"	"	Postshift, 2 days no exposure	"	180 mg/g creatinine	"	

TABLE XII-12

ANIMAL RESPONSES FOLLOWING ACUTE PHENOL EXPOSURES

Species	Route of Entry	mg/kg	Medium	Time	N	Response	References
Cat	Oral	50-100	Petrolatum	1-2 hrs	?	Death	162
"	iv	30	Water	?	?	All died	164
"	"	1.2-20 (0.5% soln)	0.9% NaCl	10 hrs	4 groups of 2 each; 3 groups of 1 each	1 death at highest dose, chronic convulsion, increased salivation, ataxia, dilated pupils, increased respiratory rate at intermediate doses. No effects at lower doses	164
"	sc	80 (10% soln)	Olive oil	7 days	?	Dose killing approximately 50% of animals	163
"	"	1.2-15 (0.5% soln) 1-5 daily injections-	0.9% NaCl	16 hrs-6 day	5 groups, of 1 to 3 each group	1 death with repeated daily injections at intermediate dose; inappetence and diarrhea at high doses inappentence at low doses	164
Dog	Oral	275	Petrolatum	1-2 hrs	?	Death	162
"	"	37.2-64.2 (24 hr fast)	Water	?	3	Survived	165
"	"	37.2-64.2 (24 hr fast)	Water	?	3	Survived	165
Dog	Oral	320 -430 (20 mg/kg morphine previously)	Liquified	6 days	1 group of 10 1 group of 4	Death of 10 at high dose, in 1 to 6 days; 2 deaths at low dose in 2 - 3 days	166
"	iv	100	Water	?	?	Neuromuscular irritability, convulsions, coma, all survived. Frequent intravascular hemolyst and darkened urine containing protein, hemoglobin, and bilirubin, kidney damage	167
Goat	"	100	"	?	?	"	167
Guinea pig	ip	100-1000 (10% soln)	Olive oil	24 hrs	5	Tremor, convulsions, paralysis at doses of 300 or below, death at each of 3 higher doses	168
"	"	150-400	Water	24 hrs	6	1 death at doses of 400 and 300; tremor, convulsions, and paralysis for 2 animals at a dose of 300, and for 1 animal each at doses of 200 and 150	168
Pig	"	100	"	?	?	"	167

TABLE XII-12 (CONTINUED)

ANIMAL RESPONSES FOLLOWING ACUTE PHENOL EXPOSURES

Species	Route of Entry	mg/kg	Medium	Time	N	Response	References
Rabbit	Eye	1 drop (87% phenol)	Glycerin	Minutes to 3 days	?	Complete destruction of the eye in minutes. Corneal opacities in 40% of animals if water irrigation delayed 10 seconds or more; and no effect if water irrigation performed immediately	170
"	Skin	1600-6400 (20% emulsion)	Water	24 hrs	3	All died	170
"	"	200-800 (20% emulsion)	"	"	3	Survived	170
"	"	50-1600 (3% soln)	"	"	6	"	170
"	"	20-80 (1% soln)	"	"	4	"	170
"	"	5000 (4.75% soln)	Camphor-liquid petrolatum	7 days	3	2 died, 1 showed mild hyperemia	169
"	"	2000 (4.75% soln)	Pure liquid to 10% water emulsion	"	82 (7 groups	30% died on exposure to pure liquid with % deaths increasing inversely to % of phenol in water resulting in 100% deaths with application of a 10% emulsion	163
Rabbit	Skin	64-380 (1.18%-7.12% soln)	Water	" "	24 (6 groups)	1 death and tissue necrosis at highest dose, severe tremor at intermediate doses, and mild hyperemia and mild tremor at lower doses	169
"	"	250 (4.75% soln)	Camphor-liquid petrolatum	"	4	Mild hypermia, tremor, hyperkeratosis in 1	169
"	Oral	280-620	Water	"	34	All 20 at high dose died, 5 out 10 died at a dose of 420, and remaining 4 survived the low dose	163
"	iv	180 (5% soln)	"	"	?	Death in about 30%	
"	sc	620 (5% soln)	"	"	?	"	163
"	ip	620 (5% soln)	"	"	?	"	163
Rat	Skin	670	"	24 hrs	40	Muscle tremors, convulsions	172
"	"	107	Liquified	"	10		172
"	"	(4.75% soln) 1 hr/day, 30 days	Camphor-liquid petrolatum	42 days	10	Increased severity of mild hyperemia compared to controls	169
"		1 hr/day, 3 days					

TABLE XII-12 (CONTINUED)

ANIMAL RESPONSES FOLLOWING ACUTE PHENOL EXPOSURES

Species	Route of Entry	mg/kg	Medium	Time	N	Response	References
Rat	Skin	(2.75% soln) 1 hr/day, 3 days	Petrolatum	7 days	50	Death in about 50%	169
"	"	(6.6% soln) 1 hr/day, 3 days	Water	"	40	"	169
"	"	(4.15% soln) 1 hr/day, 3 days	"	"	5		169
"	"	(1.75% soln)	Petrolatum	"	5	"	169
"	Oral	530-550 (2% soln to 10% soln)	Water	"	45-80 (4 groups)	Death in about 50%	163
"	"	1500 (10% soln)	Olive oil	"	10	"	163
"	"	340 (20% emulsion)	Water	"	45	"	163

TABLE XII-13

DOSE-RESPONSE RELATIONSHIPS FOLLOWING INHALATION OF PHENOL BY ANIMALS

Species	Concentration ppm	Concentration mg/cu m	Time	N	Response	References
Guinea pig	26-52	100-200	7 hrs/day, 5 days/wk	12	29 exposures, 5 deaths Post mortem revealed extensive necrosis of the myocardium, acute lobular pneumonia, and damage to vascular, hepatic, and renal tissue.	174
Monkey	5	19	8 hrs/day, 5 days/wk, 90 days	10	General health, hematology, urinalysis, blood chemistry, kidney function, stress tests, and post mortem pathology and histology same as controls. Weight gain over controls ($p < 0.05$)	180
Mouse	5	19	"	100	General health, hematology, urinalysis, blood chemistry, kidney function, body weight and post-mortem pathology and histology same as controls. Stress tests revealed increased endurance over controls ($p < 0.05$)	180
Rabbit	26-52	100-200	7 hrs/day, 5 days/wk, 63 exposures/ 88 days	6	No signs of illness or discomfort. Post mortem revealed lobular pneumonia, chronic purulent bronchitis, degenerative changes in pulmonary blood vessels, myocardial degeneration, and indications of liver & kidney damage	174
Rat	26-52	100-200	7 hrs/day, 5 days/wk, 53 exposures/ 74 days	15	No signs of illness. Post-mortem showed no pathologic or histologic changes	174
Rat	5	19	8 hrs/day,	50	General health, hematology, urinalysis, cytology same as controls. Weight gain over controls ($p < 0.05$)	180
Mouse	5	19	"	100	General health, hematology, urinalysis, blood chemistry, kidney function, body weight and post-mortem pathology and histology same as controls. Stress tests revealed increased endurance over controls ($p < 0.05$)	180
Rabbit	26-52	100-200	7 hrs/day, 5 days/wk, 63 exposures/ 5 days/wk, 90 days	6	No signs of illness or discomfort. Post mortem revealed lobular pneumonia, chronic purulent bronchitis, degenerative changes blood chemistry, kidney function, stress tests, and post mortem pathology and histology same as controls. Weight gain over controls ($p < 0.05$)	174
"	1.4	5.2	24 hrs/day, 61 days	15	Sluggish, weight changes (p less than 0.01), altered motor chronaxy (p less than 0.01), increased blood cholinesterase activity ($p < 0.01$)	17
"	0.03	0.11	24 hrs/day, 61 days	15	Healthy, no weight changes, motor chronaxy changes ($p < 0.01$), increased cholinesterase activity ($p < 0.01$)	17
"	0.003	0.011	"	15	Healthy, no weight change, unaltered motor chronaxy, no change in cholinesterase activity	17

TABLE XII-14

ANIMAL RESPONSES FOLLOWING ORAL ADMINISTRATION OF PHENOL IN WATER

Species	Dose (ppm)	Medium	Observation Time	N	Response
Rat	0-4,000	Drinking water	5 generations	?	No change
"	3,000-5,000	"	"	"	No significant change
"	7,000	"	2 generations	"	Stunted growth in young
"	8,000	"	"	"	Mothers did not routinely care for young
"	10,000	"	1 year	"	Offspring died at birth
"	12,000	"	"	"	No reproduction, premature death in hot weather

From reference 173

TABLE XII-15

PROMOTION OF SKIN TUMORS BY PHENOL IN MALE "S" ALBINO MICE

N	Initiator	Phenol Concentration & Duration	Tumor Production			Survival	Duration of Observation (wk)
			# with Tumors	# with Carcinoma	Total Tumors		
20	None	0.1 ml 5% phenol in acetone, 1/wk, at 2 sites in rotation, 32 wks	0	0	0	18 at 45 wk	45
20	0.2 ml 0.15% DMBA in acetone (300 μg)	"	? 4	? 2	13 9	Not stated 14	13 45
20	"	0.025 ml 20% phenol 1/wk at 4 sites in rotation, 34 wks	?	?	74 (3)*	13 at 37 wk	45
20	None	0.075 ml 20% phenol	?	?	7 (1)**	11 at 45 wk	45

*Carcinoma
**Hemangioma

From reference 175

TABLE XII-16

PROMOTING ACTION OF PHENOL ON DEVELOPMENT OF SKIN TUMORS IN VARIOUS STRAINS OF ALBINO MICE

Strain	Sex	N	Initiator	Promotor	No. Survivors/ Originals	% Survivors with pa	% Survivors with ca	Duration of (wk)
Sutter	M	23	75 μg (0.025 ml of a 0.3% DMBA in benzene	None	21/23	15	5	42
"	F	23	"	2.5 mg, 2/wk (0.025 ml of 10% phenol in benzene)	22/23	95	73	"
"	"	24	None	"	23/24 14/24	17 35	- -	28 52
"	"	19	75 μg (0.025 ml of a 0.3% DMBA in benzene)	None (0.025 ml benzene 2/wk)	-	0	-	20
"	"	?	"	1.25 mg USP phenol, 2/wk (0.025 ml, 5% phenol in benzene)	-	37	-	20
"	"	?	"	1.25 mg USP phenol, 2/wk (0.025 ml, 5% phenol in benzene)	-	52	-	20
Holtzman	"	30	"	None (0.025 ml benzene 1 wk)	28/30	45 -	- 10	36 52
"	"	30	"	1.25 mg, 1/wk (0.025 ml of 5% phenol in benzene)	28/30 -	77 -	- 45	36 52
"	"	30	75 μg (0.025 ml of 0.39 DMBA in benzene)	2.5 mg. 1/wk (0.025 ml of 10% phenol in benzene)	29/30 -	95 -	- 55	36 52
"	"	22	"	0.025 ml of 0.5% croton oil in benzene	21/22	4	-	36
"	"	30	None	1.25 mg, 1/wk (0.025 ml of 5% phenol in benzene)	30/30	3	-	36
				(0.025 ml of 10% phenol in benzene)	-	-	-	52
"	"	30	"	0.025 ml of 0.5% croton oil in benzene	30/30	20	-	36
CAF1	"	20	75 μg (0.025 ml of a 0.3% DMBA in benzene)	2.5 mg, 2/wk (0.025 ml of 10% phenol in benzene)	-	60	21	52
"	"	20	None	"	-	0	0	52
CH3	"	20	75 μg (0.025 ml of a 0.3% DMBA in benzene)	"	-	43	29	52
"	"	20	None	"	-	0	0	52

*pa--papilloma; **ca--carcinoma

From reference 176

TABLE XII-17

PROMOTING ACTION OF PHENOL ON DEVELOPMENT OF SKIN TUMORS IN FEMALE MICE OF THE SUTTER STRAIN

Initiator	Promotor, 2/wk	No. Survivors/ Original	% Survivors with pa*	% Survivors with ca**	Av. Pa Survivor	Duration of Observation (wk)
75 µg (0.015 ml of 0.3% DMBA in acetone)	5 mg (0.025 ml of 20% phenol in acetone)	21/24	58	5	-	12
"	None (0.025 ml benzene)	12/12	0	0	0	12
"	5 mg (0.025 ml of 20% phenol in benzene)	22/27	64	0	1.50	12
None	None (0.025 ml of benzene)	27/32	11	0	0.15	24
	1.25 mg (0.025 ml of 5% phenol in benzene)	27/33	74	4	1.67	24
"	2.5 mg (0.025 ml of 10% phenol in benzene)	10/33	100	26	3.94	40
"	5 mg (0.025 ml of 20% phenol in benzene)	15/33	100	93	3.70	39
75 µg (0.025 ml of 0.3% DMBA in acetone)	1.25 mg (0.025 ml of 5% phenol in benzene)	25/33	56	70	1.16	38
"	2.5 mg (0.025 ml of 10% phenol in benzene)	19/33	95	12	2.68	40
75 µg (0.025 ml of 0.3% DMBA in acetone)	5mg (0.025 ml of 20% phenol in benzene)	20/33	90	68	2.25	39
None	5 mg (0.025 ml of 20% phenol in dioxane)	16/30	63	0	0.94	12
"	2.5 mg (0.025 ml of 10% phenol in benzene)	24/30	33	29	0.62	28
75 µg (0.025 ml of 0.3% DMBA in acetone)	2.5 mg (0.025 ml of 10% phenol in acetone)	19/20	32	0	0.63	16
"	None (0.025 ml of acetone)	18/20	0	0	0	16
"	2.5 mg (0.025 ml of 10% phenol in benzene)	16/20	88	0	2.62	12
"	None (0.025 ml benzene)	18/20	0	0	0	12
"	"	18/20	0	0	0	20
"	1.25 mg (0.025 ml of 5% phenol in benzene)	13/19	31	8	0.46	20
"	2.5 mg (0.025 ml of 10% phenol in benzene)	12/20	83	8	2.08	20
0.25 µg (0.025 ml of 0.1% DMBA in acetone)	None (0.025 ml of 30% ethanol in acetone)	20/20	0	0	0	14
"	0.025 ml of 9.4% (1m) in 30% ethanol in acetone	19/20	16	0	0.26	14

pa—papilloma; ca—carcinoma

From reference 176

TABLE XII-18

PROMOTION OF SKIN TUMORS BY PHENOL IN FEMALE MILLERTON MICE

N	Initiator	Promotor	Cumulative with pa*	Cumulative with ca**	# surviving	Duration of Observation	References
30	75 μg DMBA in acetone	None	10	7	17	15 mo	177
30	None	5% phenol in acetone 3/wk	-	-	21	"	177
28		10% phenol in acetone 2/wk	7	3	16	"	177
30	75 μg DMBA in acetone	5% phenol in acetone 3/wk	33	10	17	"	177
30	"	10% phenol in acetone 2/wk	87	70	4	"	177
30	"	10% phenol in acetone 3/wk	80	47	3	"	177
40	5 μg Bap, 0.005% in acetone, 3/wk	None	70	68	2	"	177
28	"	5% phenol in acetone 2/wk	83	77	0	12 mo	177
28	"	10% phenol in acetone 2/wk	80	70	0	"	177
20	150 μg DMBA in 0.1 ml acetone	None	2	1		52	178
20	"	3 mg phenol in 0.1 ml acetone, 3/wk, 52 wks	4	1		"	178
20	5 μg BaP in 0.1 ml acetone 3/wk, 460 days	3 mg phenol in 0.1 ml acetone, 3/wk, 460 days	3	1		460	179
20	"	None	8	1		"	179

*pa--papilloma
**ca--carcinoma

TABLE XII-19

EXISTING STANDARDS FOR PHENOL

Country	Standard			References
	mg/cu m	ppm	Type	
USA 1) Federal standard	19	5	TWA (skin)	FR 39 (125) 1974
2) ACGIH recommendation	19	5	TWA (skin)	129
Bulgaria	5	--	Ceiling	349
Czechoslovakia	20	5	"	320
"	40	10	Peak	320
Federal Republic Germany	19	--	Ceiling	349
Finland	19	5	"	349
German Democratic Republic	19	--	"	349
Hungary	5	--	"	349
Poland	5	--	"	349
Rumania	5	--	"	349
USSR	5	--	"	349
Yugoslavia	19	5	"	349
USA - Florida	--	5	"	349
- Mississippi	--	5	"	349
- Pennsylvania	--	5	"	349
- South Carolina	--	5	"	349

TABLE XII-20

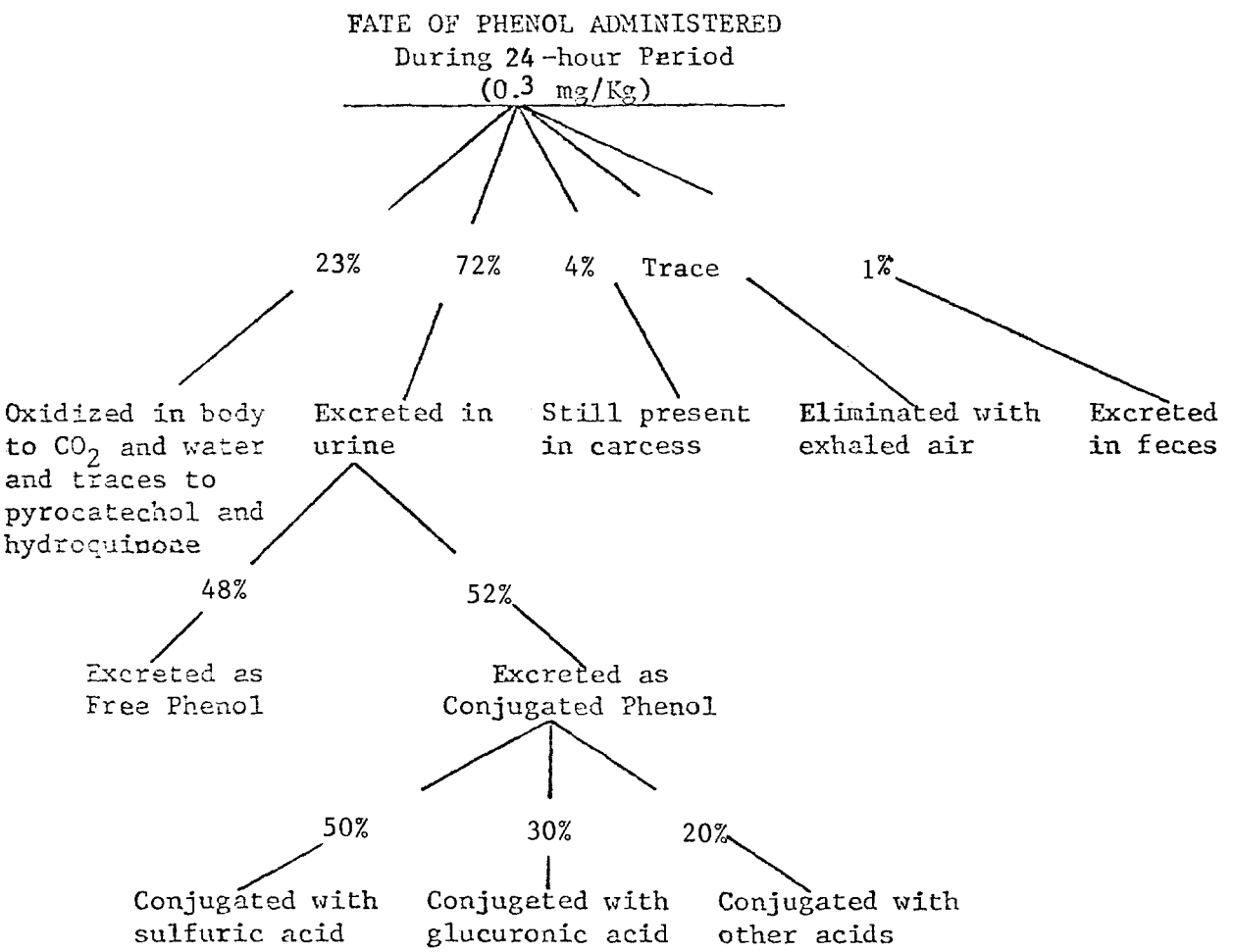
VALUES PRESENTED BY CZECHOSLOVAK COMMITTEE OF MAC

Author	Year	mg/cu m	Basis
Lazareff	1959	4	Smell
Smyth	1956	19	Suggestion for MAC
Bardodej	1960	20-30	Distinct smell; no damage was observed
Patty	1949	29	Smell
Deichmann	1944	100-200	Lung damage in guinea pigs after 20 days, in rabbits after 63 days; no damage noted in rats.

From Documentation of MAC in Czechoslovakia [320]

FIGURE XII-1

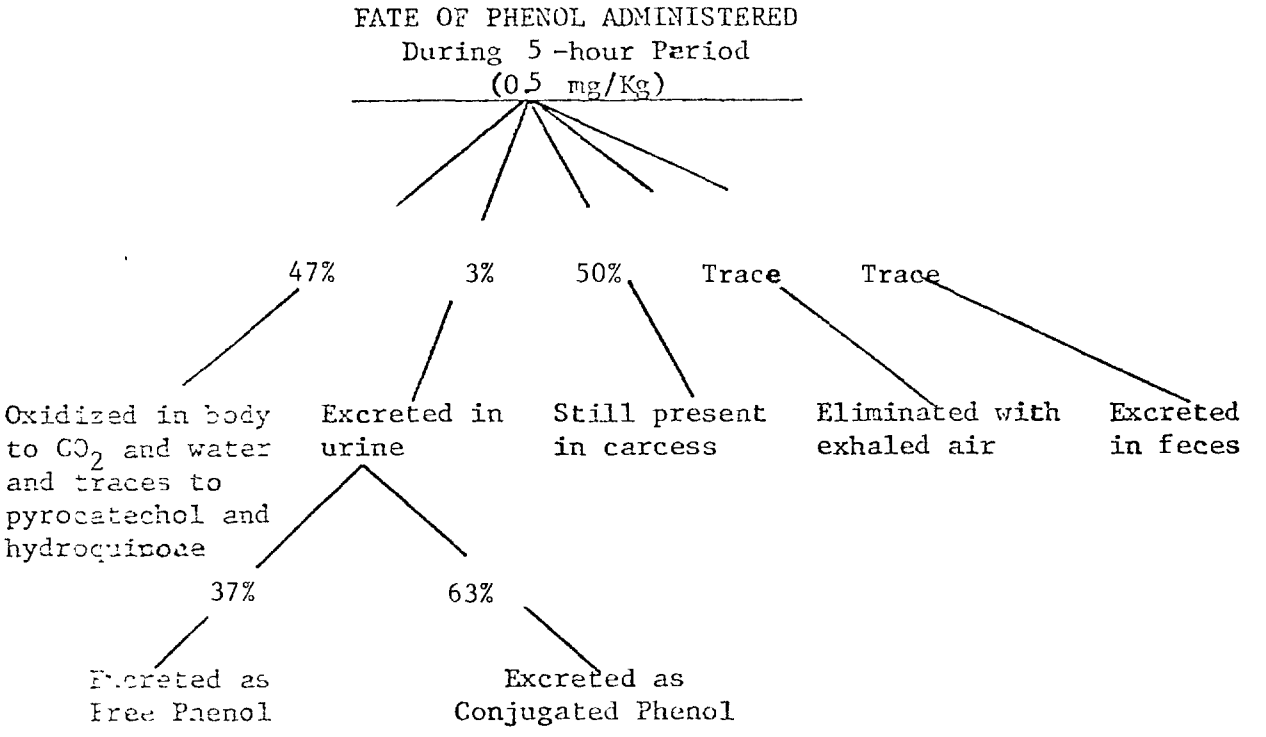
FATE OF PHENOL IN A RABBIT GIVEN A SUBLETHAL ORAL DOSE ADMINISTERED DURING 24-HOUR PERIOD



From Deichmann and Keplinger [196]

FIGURE XII-2

FATE OF PHENOL IN A RABBIT GIVEN A LETHAL ORAL DOSE ADMINISTERED DURING 5-HOUR PERIOD



From Deichmann and Keplinger [196]

☆U S GOVERNMENT PRINTING OFFICE 1977— 757-057/5731

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ROBERT A. TAFT LABORATORIES
4676 COLUMBIA PARKWAY, CINCINNATI, OHIO 45226

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF H.E.W.
HEW 399

HEW Publication No. (NIOSH) 76–196