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.