VIII. REFERENCES

1. Walker JF: Formaldehyde. Huntington, NY, Robert E. Krieger, 1975

2. Walker JF: Formaldehyde, in Kirk-Othmer Encyclopedia of Chemical Technology, ed 2 rev. New York, Interscience Publishers, 1966, vol 10, pp 77-99

3. Commercial Solvents Corporation: Technical Data Sheet OC Series. TDS No. 5, Formaldehyde. New York, Commercial Solvents Corporation, 4 pp

4. Stickney RN: Engineering, safety, and control for the proper handling of formaldehyde. Presented at Formaldehyde Seminar and Plant Tour held by The Borden Chemical Company, Fayetteville, NC, March 11, 1958

5. Hercules Formaldehyde, Uninhibited, Product Data No 290-3. Wilmington, Del, Hercules Incorporated

6. Properties and Essential Information for Safe Handling and Use of Formaldehyde--Chemical Safety Data Sheet SD-1 Washington, DC, Manufacturing Chemists Association Inc, 1960

7. Fishbein L, Flamm WG, Falk HL: Chemical Mutagens--Environmental Effects on Biological Systems. New York, Academic Press, 1970, pp 206-11, 223-29

8. Hofmann AW: Contributions to the history of methylic aldehyde. Proc R Soc London 16:156-59, 1867

9. Brunnthaler J: [The toxic effects of formaldehyde.] Aerztl Sachverstaendigen Zeitung 19:142-46, 1913 (Ger)

10. Blum F: [Formaldehyde as a hardening agent.] Z Wiss Mikrosk 10:313-14, 1893 (Ger)

11. Benedicenti: [On the effect of formaldehyde on proteins.] Arch Anat Physiol, Physiol Abt, pp 219-57, 1897 (Ger)

12. Sollmann T: The combination of formaldehyde with Witte's peptone. Am J Physiol 7:220-42, 1902

13. Kendall AI: The relaxation of histamine contractions in smooth muscle by certain aldehydes. J Infect Dis 40:689-97, 1927

14. Gubareff E, Bystrenin A: [Formaldehyde reactions with glycine.] Z Biochem 254-55:92-102, 1932 (Ger)

15. Zipf K, Bartscher E: [Inactivation of biogenic amines by formaldehyde.] Arch Exp Pathol Pharmakol 171:592-602, 1933 (Ger)

16. Balson EW, Lawson A: CLXXX. The potentiometric determination of polypeptides and amino acids. Biochem J 30:1257-63, 1936

17. Levy M, Silberman DE: The reactions of amino acids and imino acids with formaldehyde. J Biol Chem 118:723-34, 1937

18. Stewart GN: The condition that underlie the peculiarities in the behaviour of the coloured blood-corpuscles to certain substances. J Physiol 26:470-96, 1901

19. Wiley HW: General Results of the Investigations Showing the Effect of Formaldehyde Upon Digestion and Health, circular 42. US Dept of Agriculture, Bureau of Chemistry, 1908, 16 pp

20. March GH: Formalin poisoning--Recovery. Br Med J 2:687, 1927

21. Ely, F: Formaldehyde poisoning. JAMA 54:1140-41, 1910

22. Kline BS: Formaldehyde poisoning. Arch Intern Med 36:220-28, 1925

23. Bower AJ: Case of poisoning by formaldehyde. JAMA 52:1106, 1909

24. Earp SE: The physiological and toxic actions of formaldehyde--With a report of three cases of poisoning by formalin. NY Med J 104:391-92, 1916

25. Vinson PP, Harrington SW: Cicatricial stricture of the stomach without involvement of the esophagus following the ingestion of formaldehyde. JAMA 93:917-18, 1929

26. Levison LA: A case of fatal formaldehyde poisoning. JAMA 42:1492, 1904

27. Böhmer K: [Formalin poisoning.] Dtsch Z Gesamte Gerichtl Med 23:7-18, 1934 (Ger)

28. Rathery F, Piedelieure R, Delarue J: [Death by absorption of formalin.] Ann Med leg crimiru, Police Sci 20:201-209, 1940 (Fre)

29. Krans EW: Effects of fumes during the moulding of certain types of plastics. Ind Med Surg 4:10-11, 1935

30. Bernstein F: [Cutaneous sensitivity to formalin (solution of formaldehyde) as an occupational disease.] Dermatol Wochenschr 95:1683-86 1932 (Ger)

31. Chajes B: [Formalin eczema from paste.] Zentralbl Gewerbehyg Unfallverhuet 10:136-38, 1922 (Ger)

32. Chajes B: [On industrial formaldehyde dermatitis and eczema.] Dermatol Wochenschr 74:417-21, 1922 (Ger)

33. Gougerot M, Poulain M: [Eczema-formaldehyde sensibilization.] Bull Soc Fr Dermatol Syphilligr 38:1472-73, 1931 (Fre)

34. Lutz G: [Formalin eczema among printers.] Zentralbl Gewerbehyg Unfallverhuet 7:266-68, 1930 (Ger)

35. Rosenbaum E: [On sensitization in a case of formalin-novocaine eczema.] Med Klin (Munich) 19:462-63, 1923 (Ger)

36. Sachs O: [On acute dermatitis caused by vapors of carbolic acid, formaldehyde and ammonia in the production of synthetic resins.] Wien Klin Wochenschr, No 29, p 356, 1921 (Ger)

37. Sachs O: [Industrial dermatitis.] Dermatol Wochenschr 76:582-615, 1923 (Ger)

38. Gegenbauer: [Studies on the disinfectant action of aqueous formaldehyde solutions.] Arch Hyg 90:239-53, 1921 (Ger)

39. Croner: [About the influence of the disinfectant effect of formaldehyde with the aid of methylalcohol and subsequent conclusions drawn about the room disinfection by formaldehyde.] Z Hyg 78:541-54, 1914 (Ger)

40. Galewsky: [On occupational formalin paronychia and dermitides.] Muench Med Wochenschr 52:164-66, 1905 (Ger)

41. Chajes B: Formaldehyde, formalin, in Occupation and Health: Encyclopedia of Hygiene, Pathology and Social Welfare, International Labour Office. Geneva, Noirclerc et Fenetrier, 1930, pp 806-10, vol I

42. Bourne HG, Seferian S: Formaldehyde in wrinkle-proof apparel produces--Tears for milady. Ind Med Surg 28:232-33, 1959

43. Kratochvil I: [The effect of formaldehyde on the health of workers employed in the production of crease resistant ready made dresses.] Pr Lek 23:374-75, 1971 (Cze) (Abstr in Eng)

44. Ettinger I, Jeremias M: A study of the health hazards involved in working with flameproofed fabrics. NY State Dep Labor Div Ind Hyg Mon Rev 34:25-27, 1955

45. Hovding G: Occupational dermatitis from pyrolysis products of polythene. Acta Derm Venereol 49:147-49, 1969

46. Sim VM, Pattle RE: Effect of possible smog irritants on human subjects. JAMA 165:1908-13, 1957

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

48. Zannini D, Russo L: [Consequences of acute intoxications due to gaseous irritants of the respiratory system.] Lav Um 9:241-53, 1957 (Ita)

49. Glass WI: An outbreak of formaldehyde dermatitis. NZ Med J 60:423-27, 1961

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

51. Zaeva GN, Ulanova IP, Dueva LA: [Materials for revision of the maximal permissible concentrations of formaldehyde in the inside atmosphere of industrial premises.] Gig Tr Prof Zabol 12:16-20, 1968 (Rus)

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

53. Miller BH, Blejer HP: Report of an Occupational Health Study of Formaldehyde Concentrations at Maximes, 400 E. Colorado Street, Pasadena, Calif, study number S-1838. Los Angeles, State of California Health and Welfare Agency, Dept of Public Health, Bureau of Occupational Health, 1966

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

55. Rathery F, Piedelivre R, Delarue J: [Death by absorption of formol.] Ann Med Leg 20:201-06, 1940 (Fre)

56. Roy M Jr, Calonje MA, Mouton R: Corrosive gastritis after formaldehyde ingestion--Report of a case. N Engl J Med 266:1248-50, 1962

57. Melekhina VP: Hygienic evaluation of formaldehyde as an atmospheric air pollutant, 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 9-17 (NTIS TT64-11574)

58. Shipkovitz HD: Formaldehyde vapor emissions in the permanent-press fabrics industry, Report No. TR-52. Cincinnati, US Dept of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, Environmental Control Administration, Sept 1968

59. Porter JAH: Acute respiratory distress following formalin inhalation. Lancet 1:603-04, 1975

60. Yonkman FF, Lehman AJ, Pfeiffer CC, Chase HF: A study of the possible toxic effects of prolonged formaldehyde ingestion. J Pharmacol Exp Ther 72:46, 1941 (Abstr)

61. Heffernon EW, Hajjar JJA: Corrosive gastritis after formaldehyde ingestion. Lahey Clin Found Bull 13:293-96, 1964

62. Bartone NF, Gricco RV, Herr BS: Corrosive gastritis due to ingestion of formaldehyde. JAMA 202:104-05, 1968

63. Saury A, Ravault MP, Vincent V: [Optic atrophy due to exposure to formol vapors.] Bull Med Leg 8:466-69, 1965 (Fre)

64. Schuck EA, Stephens ER, Middleton JT: Eye irritation response at low concentrations of irritants. Arch Environ Health 13:570-75, 1966

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

66. Roth WG: [Tylotic palmar and plantar eczema caused by steam ironing clothes containing formaldehyde.] Berufs-Dermatosen 17:263-67, 1969 (Ger)

67. O'Quinn SE, Kennedy CB: Contact dermatitis due to formaldehyde in clothing textiles. JAMA 194:593-96, 1965

68. Rostenberg A, Bairstow B, Luther TW: A study of eczematous sensitivity to formaldehyde. J Invest Dermatol 19:459-62, 1952

69. Berrens L, Young E, Jansen LH: Free formaldehyde in textiles in relation to formalin contact sensitivity. Br J Dermatol 76:110-15, 1964

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

71. Lazar P: Reactions to nail hardeners. Arch Dermatol 92:446-48, 1966

72. Keil H, Van Dyck LS: Dermatitis due to nail polish--A study of twenty-six cases with the chief allergenic component toluene sulfonamide formaldehyde resin and related substances. Arch Dermatol Syphilol 50:39-44, 1944

73. Danto JL: Allergic contact dermatitis due to a formaldehyde fingernail hardener. Can Med Assoc J 98:652, 1968

74. Sneddon IB: Dermatitis in an intermittent haemodialysis unit. Br Med J 1:183-84, 1968

75. Logan WS, Perry HO: Contact dermatitis to resin-containing casts. Clin Orthop 90:150-52, 1973

76. Peck SM, Palitz LL: Sensitization to facial tissues with urea-formaldehyde resin (wet-strength). JAMA 160:1226-27, 1956

77. Fisher AA, Kanol NB, Biondi EM: Free formaldehyde in textiles and paper. Arch Dermatol 86:753-56, 1962

78. Guyot JD: Report of a case of formalin urticaria. South Med J 14: 115, 1921

79. Horsfall FL: Formaldehyde hypersensitiveness--An experimental study. J Immunol 27:569-81, 1934

80. Shellow H, Altman AT: Dermatitis from formaldehyde resin textiles. Arch Dermatol 94:799-801, 1966

81. Marcussen PV: Dermatitis caused by formaldehyde resins in textiles. Dermatologica 125:101-11, 1962

82. Frenk E: [Pruriginous eruptions of epidemic character in a foundry using synthetic resins.] Dermatologica 129:436-39, 1964 (Fre)

83. Skogh M: Axillary eczema in women, a syndrome. Acta Derm Venereol 39:369-71, 1959

84. Harris DK: Health problems in the manufacture and use of plastics. Br J Ind Med 10:255-68, 1953

85. Marcussen PV: Contact dermatitis due to formaldehyde in textiles 1934-1958--Preliminary report. Acta Derm Venereol 39:348-56, 1959

86. Kamchatnov VP Gayazova SS: Temperature Asymmetry in workers exposed to formaldehyde vapor. Hyg and San 36, 286-87, 1971

87. Kachlik Z: Mass outbreak of occuational skin disorders in clothing plant when processing materials with crease-resistant finish. Pr Lek, 20: 154-8, 1968

88. Schwartz L, Birmingham DJ, Campbell PC, Mason HS: Skin hazards--In the manufacture and use of cashew nut shell liquid-formaldehyde resins. Ind Med 14:500-06, 1945

89. Gaul LE: Absence of formaldehyde sensitivity in phenol-formaldehyde resin dermatitis. J Invest Dermatol 48:485-86, 1967

90. Conrad AH, Ford LT: Allergic contact dermatitis caused by Melmac Orthopedic Composition. JAMA 153:557, 1953

91. Malten KE, van Aerssen RGL: Contact eczemas in shoemakers and shoe-wearers due to glue substances. Berufs-Dermatosen 10:264-68, 1962

92. Freeman HG, Grendon WC: Formaldehyde detection and control in the wood industry. For Prod J 21:54-57, 1971

93. Fel'dman YG, Bonashevskaya TI: On the effects of low concentrations of formaldehyde. Hyg Sanit 36:174-80, 1971

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

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

96. Schwartz L, Peck SM, Dunn JE: Dermatitis from resin glue in war industries. Public Health Rep 58:899-904, 1943

97. Markuson KE, Mancuso TF, Soet JS: Dermatitis due to the formaldehyde resins--Prevention and methods of control. Ind Med 12:383-86, 1943

98. Schwartz L: Dermatitis from synthetic resins and waxes. Am J Public Health 26:586-92, 1936

99. Pohl J: [On the oxidation of methyl and ethyl alcohol in the mammalian organism.] Arch Exp Pathol Pharmakol 31:281-302, 1893 (Ger)

100. Lutwak-Mann C: Alcohol dehydrogenase of animal tissues. Biochem J 32:1364-74, 1938

101. Kendal LP, Ramanathan AN: Liver alcohol dehydrogenase and ester formation. Biochem J 52:430-38, 1952

102. Malorny G, Rietbrock N, Schneider M: [The oxidation of formaldehyde to formic acid in the blood, a contribution to the metabolism of formaldehyde.] Naunyn Schmiedebergs Arch Exp Pathol Pharmakol 250: 419-36, 1965 (Ger)

103. Williams RT: Detoxication Mechanisms--The Metabolism and Detoxication of Drugs, Toxic Substances and Other Organic Compounds, ed 2. New York, John Wiley & Sons, 1959, pp 88-90

104. Egle JL: Retention of inhaled formaldehyde, propionaldehyde, and acrolein in the dog. Arch Environ Health 25:119-24, 1972

105. Sawicki E, Hauser TR, Stanley TW, Elbert W: The 3-methyl-2-benzothiazolone hydrazone test--Sensitive new methods for the detection, rapid estimation, and determination of aliphatic aldehydes. Anal Chem 33:93-96, 1961

106. Hauser TR, Cummins RL: Increasing sensitivity of 3-methyl-2-benzothiazolone hydrazone test for analysis of aliphatic aldehydes in air. Anal Chem 36:679-81, 1964

107. Skog E: A toxicological investigation of lower aliphatic aldehydes--I. Toxicity of formaldehyde, acetaldehyde, propionaldehyde, and butyraldehyde--As well as of acrolein and crotonaldehyde. Acta Pharmacol Toxicol 6:299-318, 1950

108. Iwanoff N: [On some aldehydes of practical importance.] Arch Hyg 73:307-19, 1911 (Ger)

109. Carpenter CP, Smyth HF, Pozzani UC: The assay of acute vapor toxicity and the grading and interpretation of results on 96 chemical compounds. J Ind Hyg Toxicol 31:343-46, 1949

110. Murphy SD, Davis HV, Zaratzian VL: Biochemical effects in rats from irritating air contaminants. Toxicol Appl Pharmacol 6:520-28, 1964

111. Altshuller AP, Cohen IR, Meyer ME, Wartburg AF: Analysis of aliphatic aldehydes in source effluents and in the atmosphere. Anal Chim Acta 25:101-17, 1961

112. Salem H, Cullumbine H: Inhalation toxicities of some aldehydes. Toxicol Appl Pharmacol 2:183-87, 1960

113. Amdur MO: The physiological response of guinea pigs to atmospheric pollutants. Int J Air Pollut 1:170-83, 1959

114. Amdur MO: The response of guinea pigs to inhalation of formaldehyde and formic acid alone and with a sodium chloride aerosol. Int J Air Pollut 3:201-20, 1960

115. Amdur MO, Mead J: Mechanics of respiration in unanesthetized guinea pigs. Am J Physiol 192:364-68, 1958

116. Elkins HB: The Chemistry of Industrial Toxicology, ed 2. New York, John Wiley & Sons, 1959, pp 118, 190-91, 251, 339-43

117. MacDonald WE: Formaldehyde in air--A specific field test. Am Ind Hyg Assoc Q 15:217-19, 1954

118. Murphy SD, Ulrich CE: Multi-animal test system for measuring effects of irritant gases and vapors on respiratory function of guinea pigs. Am Ind Hyg Assoc J 25:28-36, 1964

119. Davis TRA, Battista SP, Kensler CJ: Mechanism of respiratory effects during exposure of guinea pigs to irritants. Arch Environ Health 15: 412-19, 1967

120. Altshuller AP, Miller DL, Sleva SF: Determination of formaldehyde in gas mixtures by the chromotropic acid method. Anal Chem 33:621-25, 1961

121. Coon RA, Jones RA, Jenkins LJ, Siegel J: Animal inhalation studies on ammonia, ethylene glycol, formaldehyde, dimethylamine, and ethanol. Toxicol Appl Pharmacol 16:646-55, 1970

122. Horton AW, Tye R, Stemmer KL: Experimental carcinogenesis of the lung--Inhalation of gaseous formaldehyde or an aerosol of coal tar by C3H mice. J Nat Cancer Inst 30:31-40, 1963

123. Goldman FH, Yagoda H: Collection and estimation of traces of formaldehyde in air. Ind Eng Chem 15:377-78, 1943

124. Tye R, Graf MJ, Horton AW: Determination of benzo(a)pyrene in complex mixtures--Use of catalytic iodination on activated alumina. Anal Chem 27:248-53, 1955

125. Gofmekler VA: Effect on embryonic development of benzene and formaldehyde in inhalation experiments. Hyg Sanit 33:327-31, 1968

126. Boucot KR, Weiss W, Seidman H, Carnahan WJ, Cooper DA: The Philadelphia pulmonary neoplasm research project--Basic risk factors of lung cancer in older men. Am J Epidemiol 95:4-16, 1972

127. Frankel LS, McCallum KS, Collier L: Formation of bis(chloromethyl) ether from formaldehyde and hydrogen chloride. Environ Sci Technol 8:356-59, 1974

128. Kallos GJ, Solomon RA: Investigations of the formation of bis-chloromethyl ether in simulated hydrogen chloride-formaldehyde atmospheric environments. Am Ind Hyg Assoc J 34:469-73, 1973

129. Shadoff LA, Kallos GJ, Woods JS: Determination of bis(chloromethyl) ether in air by gas chromatography-mass spectrometry. Anal Chem 45:2341-44, 1973

130. Collier L: Determination of bis-chloromethyl ether at the ppb level in air samples by high-resolution mass spectroscopy. Environ Sci Technol 6:930-32, 1972

131. Marceleno T, Wallingford R, Proud J, Zeller D: Survey of Burlington Industries Inc--Burlington House Finishing Plant, Form Fabrics Plant, Durham Domestics Plant, Brookneal Finishing Plant. Cincinnati, US Dept of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Division of Field Studies and Clinical Investigations, Environmental Investigations Branch, 1974

132. Tou JC, Kallos GJ: Possible formation of bis (chloromethyl) ether from the reactions of formaldehyde and chloride ion. Anal Chem 48: 958-63: 1976

133. Schiff H: [A new series of organic diamines, second part.] Ann Chem 140:92-137, 1866 (Ger)

134. Kersey RW, Maddocks JR, Johnson TE: The determination of small amounts of formaldehyde in air. Analyst 65:203-06, 1940

135. Barnes EC, Speicher HW: The determination of formaldehyde in air. J Ind Hyg Toxicol 24:10-17, 1942

136. Blaedel WJ, Blacet FE: Colorimetric determination of formaldehyde in the presence of other aldehydes. Ind Eng Chem, Anal Ed 13:449-50, 1941

137. Chemical Profile--Formaldehyde, rev 3. Schnell Publishing Co, 1972

138. Morgan GB, Golden C, Tabor EC: New and improved procedures for gas sampling and analysis in the national air sampling network. J Air Pollut Control Assoc 17:300-04, 1967

139. Altshuller AP, Bellar TA, McPherson SP: Hydrocarbons and Aldehydes in the Los Angeles Atmosphere. Presented at the Air Pollution Control Association Annual Meeting, May 2, 1962, Chicago, Ill. Cincinnati, US Dept of Health, Education, and Welfare, Division of Air Pollution, Public Health Service, 1962

140. Rayner AC, Jephcott CM: Microdetermination of formaldehyde in air. Anal Chem 33:627-30, 1961

141. Lyles GR, Dowling FB, Blanchard VJ: Quantitative determination of formaldehyde in the parts per hundred million concentration level. J Air Pollut Control Assoc 15:106-08, 1965

142. Yunghans RS, Munroe WA: Continuous monitoring of ambient atmospheres with the Technicon autoanalyzer, in Automation in Analytical Chemistry, Technicon Symposia 1965. New York, Mediad, 1966, pp 279-84

143. Cantor TR: Experience with the determination of atmospheric aldehydes, in Automation in Analytical Chemistry, Technicon Symposia 1966, New York, Mediad, 1967, pp 514-15

144. Cares JW: Determination of formaldehyde by the chromotropic acid method in the presence of oxides of nitrogen. Am Ind Hyg Assoc J 29:405-10, 1968

145. Altshuller AP, Leng LJ, Wartburg AF: Source and atmospheric analyses for formaldehyde by chromotropic acid procedures. Int J Air Water Pollut 6:381-85, 1962

146. Renzetti NA, Bryan RJ: Atmospheric sampling for aldehydes and eye irritation in Los Angeles smog--1960. J Air Pollut Control Assoc 11:421-24, 427, 1961

147. Thomas JF, Sanborn EN, Mukai M, Tebbens BD: Identification of aldehydes in polluted atmospheres and combustion products. Arch Ind Hyg 20:420-28, 1959

148. Hauser TR: Determination of aliphatic aldehydes--3-methyl-2-benzothiazolone hydrazone, hydrochloride (MBTH) method, in Selected

Methods for the Measurement of Air Pollutants, No. 999-AP-11. US Dept of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, Interbranch Chemical Advisory Committee, 1969, pp F-1 to F-4

149. Cohen IR, Altshuller AP: 3-Methyl-2-benzothiazolone hydrazone method for aldehydes in air--Collection efficiencies and molar absorptivities. Anal Chem 38:1418, 1966

150. Smith RG, Bryan RJ, Feldstein M, Levadie B, Miller FA, Stephens ER, White NG: Tentative method of analysis for formaldehyde content of the atmosphere (MBTH--colorimetric method--applications to other aldehydes). Health Lab Sci 7:173-78, 1970

151. Elfers LA, Hochheiser S: Estimation of Atmospheric Aliphatic-Aldehyde Concentration by Use of a Visual Color Comparator. US Dept of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, 1969

152. Sawicki E, Carnes RA: Spectrophotofluorimetric determination of aldehydes with dimedone and other reagents. Mikrochim Acta, No 1, pp 148-59, 1968

153. Smith RG, Bryan RJ, Feldstein M, Levadie B, Miller FA, Stephens ER, White NG: Tentative method of analysis for low molecular weight aliphatic aldehydes in the atmosphere. Health Lab Sci 9:75-78, 1972

154. Levaggi DA, Feldstein MF: The determination of formaldehyde, acrolein, and low molecular weight aldehydes in industrial emissions on a single collection sample. J Air Pollut Control Assoc 20:312-13, 1970

155. American Conference of Governmental Industrial Hygienists, Committee of Recommended Analytical Methods: Manual of Analytical Methods Recommended for Sampling and Analysis of Atmospheric Contaminants. ACGIH, Cincinnati 1958, pp 1-3

156. Hanson NW, Reilly OA, Stagg HE (eds): The Determination of Toxic Substances in Air. Cambridge, England, W Heffer and Sons Ltd, 1965, pp 131-133

157. Lugg GA, Wright AS: The Determination of Toxic Gases and Vapours in Air, ed 2. Defense Standards Laboratories, circular 14, Maribyonong, Victoria, Australia, 1955, pp 26-27

158. Rapid methods for the determination of organic substances in the air, 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 10, pp 80-82 (NTIS TT64-11761)

159. Altshuller AP, McPherson SP: Spectrophotometric analysis of aldehydes in the Los Angeles atmosphere. J Air Pollut Control Assoc 13:109-11, 1963

160. Knight H, Tennant RWG: Comparison of five methods for the estimation of formaldehyde in mixtures of formaldehyde and air. Lab Pract 22: 169-73, 1973

161. Braymen DT, Songer JR: Methods for quantitating formaldehyde gas in air. Appl Microbiol 19:1021-22, 1970

162. Sawicki E, Stanley TW, Pfaff J: A comparative study of various methods for the detection of formaldehyde. Chemist-Analyst 51:9-11, 1962

163. Ruch W (ed): Chemical Detection of Gaseous Pollutants. Ann Arbor, Science Publications, 1966, pp 95-97

164. Koivusalo M: Studies on the metabolism of methanol and formaldehyde in the animal organism. Acta Physiol Scand 39 (Suppl 131): 1-103, 1956

165. Ackerbauer CF, Lebowich RJ: A simple and reliable method for the determination of methyl alcohol and formaldehyde in the air. J Lab Clin Med 28:372-77, 1942

166. Zhdanov VM: Quantitative determination of formaldehyde in the air, in Levine BS (trans): USSR Literature on Air Pollution and Related Occupational Diseases--A Survey. Springfield, Va, Dept of Commerce, National Technical Information Service , vol 8, 0055-59 (NTIS TT63-11570)

167. Brewer LW (ed): Analytical Procedures for the Environmental Health Laboratory. Albuquerque, N Mex, Sandia Corp, 1968

168. Frankel LS, Madsen PR, Siebert RR, Wallisch KL: Selective retention by porous polymer adsorbents. Anal Chem 44:2401-02, 1972

169. Davies JE, Hillman DE: Improved selectivity of chemical colour reactions by simple gas chromatographic separation. Talanta 16:421-22, 1969

170. Sawicki E, Hauser TR, McPherson S: Spectrophotometric determination of formaldehyde and formaldehyde-releasing compounds with chromotropic acid, 6-amino-1-naphthol-3-sulfonic acid (J acid), and 6-anilino-1naphthol-3-sulfonic acid (phenyl J acid). Anal Chem 34:1460-64, 1962

171. Gladchikova YN, Shumarina NI: Chromotropic acid method for the determination of formaldehyde in air, in Levine BS (trans): USSR Literature on Air Pollution and Related Occupational Diseases, Springfield, Va, US Dept of Commerce, National Technical Information Service, 1960, vol 1, pp 202-05 (NTIS TT60-21049)

172. Gage JC: Gases, vapors, mists and dusts, in Page C, Stolman A (eds): Toxicology--Mechanisms and Analytical Methods, vol II. New York, Academic Press, 1961, p 46

173. Belman S: The fluorimetric determination of formaldehyde. Anal Chim Acta 29:120-26, 1963

174. Sawicki E, Stanley TW, Pfaff J: Spectrophotofluorimetric determination of formaldehyde and acrolein with J acid--Comparison with other methods. Anal Chim Acta 28:156-63, 1963

175. Sawicki E, Stanley TW, Johnson H, Fox FT: Sensitive new test for formaldehyde and pyruvaldehyde with 2-hydroxycarbazole. Mikrochim Acta No. 1, pp 741-45, 1962

176. Bailey BW, Rankin JM: New spectrophotometric method for determination of formaldehyde. Anal Chem 43:782-84, 1971

177. Zhitkova AS: Some Methods for the Detection and Estimation of Poisonous Gases and Vapors in the Air--A Practical Manual for the Industrial Hygienist. SI Kaplun (ed), JB Ficklen (trans). West Hartford, Conn, Service to Industry, 1936, pp 130-32

178. Eegriwe E: [Reactions and reagents for the proof of organic compounds, 4th communication.] Z Anal Chem 110:22-25, 1937 (Ger)

179. Smith RG, Bryan RJ, Feldstein M, Levadie B, Miller FA, Stephens ER, White NG: Tentative method of analysis for formaldehyde content of the atmosphere (colorimetric method). Health Lab Sci 7:87-91, 1970

180. National Institute for Occupational Safety and Health, Division of Laboratories and Criteria Development: Formaldehyde in Air--Physical and Chemical Analysis Branch, in NIOSH Manual of Analytical Methods, HEW publication No. (NIOSH) 75-121. Cincinnati, US Dept of Health, Education, and Welfare, Public Health Service, Center for Disease Control, NIOSH, 1974, pp 125-1 to 125-9

181. West PW, Gaeke GC: Fixation of sulfur dioxide as sulfitomercurate (II) and subsequent colorimetric determination. Anal Chem 28:1816-19, 1956

182. Bennett HP: Report on formaldehyde. J Assoc Off Agric Chem 32: 504-05, 1949

183. Boos RN: Quantitative colorimetric microdetermination of methanol with chromotropic acid reagent. Anal Chem 20:964-65, 1948

184. Boyd MJ, Logan MA: Colorimetric determination of serine. J Biol Chem 146:278-87, 1942

185. Bricker CE, Roberts KH: Determination of end unsaturation in organic compounds. Anal Chem 21:1331-34, 1949

186. Daughaday WH, Jaffe H, Williams RH: Chemical assay for "cortin"--Determination of formaldehyde liberated on oxidation with periodic acid. J Clin Endocrinol 8:166-74, 1948

187. Ozburn EE: A rapid method for determining methyl alcohol in the blood and body fluids. US Nav Bull 46:1170, 1946

188. Sleva SF: Determination of formaldehyde--Chromotropic acid method, in Selected Methods for the Measurement of Air Pollutants, number 999-AP-11. US Dept of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, Interbranch Chemical Advisory Committee, pp H-1 to H-5, Cincinnati, 1969

189. Nash T: The colorimetric estimation of formaldehyde by means of the Hantzsch reaction. Biochem J 55:416-21, 1953

190. West PW, Sen B: A new spot test for formaldehyde. Anal Chem 27:1460-61, 1955

191. Campbell EE, Wood GO, Anderson RG: Development of Air Sampling Techniques LASL Project R-059, report LA-5164-PR. Los Alamos, N Mex, Atomic Energy Commission, 1973

192. Wood GO, Anderson RG: Air sampling of formaldehyde with a solid sorbent tube. Presented at American Industrial Hygiene Conference, Mineapolis, June 1975

193. Otvos I, Palyi G, Balthazar Z, Bartha B: Gas chromatographic analysis of waste gases from a formaldehyde plant. J Chromatogr 60:422-23, 1971

194. Jones K: Analysis of aqueous formaldehyde solutions--Evaluation of new solid supports. J Gas Chromatogr 5:432-34, 1967

195. Szymanska JB: [Case of gastric and esophageal formalin burns.] Pol Tyg Lek 12:1620-22, 1957 (Pol)

196. Wennstrom A, Samuelsson G: A new method for determination of trace amounts of formaldehyde by gas chromatography. Odontol Revy 23:79-83, 1972

197. Wennstrom A, Samuelsson G: Investigation of formaldehyde content in some dental base materials by gas chromatography. Odontol Revy 23: 85-91, 1972

198. Properties and Essential Information for Safe Handling and Use of Paraformaldehyde--Chemical Safety Data Sheet SD-6. Washington, DC, Manufacturing Chemists Association, 1960

199. Formaldehyde, Hygienic Guide Series. Am Ind Hyg Assoc J 26:189-92, 1965

200. Zurlo N: Formaldehyde and derivatives, in Encyclopedia of Occupational Health and Safety. Geneva, International Labour Office, 1972, June 4-10, 1968, Occupational Safety and Health Series No. 20, Geneva, International Labour Office, 1972

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

202. American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems, Z9.2-1971. New York, American National Standards Institute, Inc, 1971, 63 pp

203. Cleary WM: Thermoplastic resins decomposition. Ind Med 39:129-31, 1970

204. USA Standard--Acceptable Concentrations of Formaldehyde, USAS Z37.16-1967. New York, American National Standards Institute Inc, 1967

205. Fassett DW: Aldehydes and acetals, in Patty FA (ed): Industrial Hygiene and Toxicology, ed 2 rev; Toxicology (Fassett, DW Irish, DD, eds). New York, Interscience Publishers, 1963, vol 2, chap 43

206. American Conference of Governmental Industrial Hygienists: Documentation of the Threshold Limit Values for Substances in Workroom Air. Cincinnati, ACGIH, 1971, pp 118-19

207. Henderson Y, Haggard H: Noxious Gases and the Principles of Respiration Influencing Their Action. New York, The Chemical Catalog Company Inc, 1927

208. Czechoslovak Committee of MAC: Documentation of MAC in Czechoslovakia. Prague, The Committee, 1969, pp 83-84

209. Vigliani EC, Zurlo N: [Observations of Clinica del Lavoro with several maximum operating position concentrations (MAK) of industrial poisons.] Arch Gewerbepathol Gewerbehyg 25:528-34, 1955 (Ger)

210. Permissible Levels of Toxic Substances in the Working Environment--Sixth Session of the Joint ILO/WHO Committee, Occupational Health and Safety Series, Title 20, Sixth Session. Geneva, International Labour Office, 1970, pp 190, 201, 213, 219, 235, 242, 288, 290, 292, 295, 296, 306, 333, 348

211. American National Standard Practices for Respiratory Protection, Z88.2-1969. New York, American National Standards Institute Inc, 1969, 31 pp

212. Fiegl F: Spot Tests in Organic Analysis, ed 7. New York, American Elsevier Publishing Company, 1966, p 434

213. Weast RC, Selby SM (eds): Handbook of Chemistry and Physics--A Ready Reference Book of Chemical and Physical Data, ed 48. Cleveland, Chemical Rubber Co, 1967, p C-326

214. Milby TH, Key MM, Gibson RL, Stokinger HE: Chemical hazards, in Gafafer WM (ed): Occupational Diseases, publication No. 1097. US Dept Health, Education, and Welfare, Public Health Service, 1964

215. Jennings BH: Hazardous Vapors and Dusts in Industry. Chicago, Ventilating and Air Conditioning Contractors Association of Chicago, 1957

216. Lawrence WJC: Soil Sterilization. London, George Allen & Unwin Ltd, 1956, chap 17, pp 137-40

217. Fisher AA: Contact Dermatitis, ed 2. Philadelphia, Lea & Febiger, 1973, pp 47-48, 143-46

218. Formaldehyde--Its Toxicity and Potential Dangers, supplement number 181 to the Public Health Rep. Industrial Hygiene Research Laboratory, National Institutes of Health, US Public Health Service, 1945

219. Dietert HW: Foundry Core Practice, ed 3. Des Plaines, Ill, American Foundrymen's Society, 1966

220. Gottshalk HR: Studies on sensitivity to formaldehyde treated starch. Arch Dermatol Syphilol 56:468-70, 1947

221. Rowley J: The Art of Taxidermy. New York, D Appleton & Company, 1898, pp 68-70

222. American Conference of Governmental Industrial Hygienists: TLVs--Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1973. ACGIH, 1973, p 49

IX. APPENDIX I
SAMPLING OF FORMALDEHYDE IN AIR

Sampling

Air samples are collected to represent the breathing zone of employees by drawing air through two all-glass midget impingers in series, each containing 20 ml of distilled water. (If other aldehydes are present, use 20 ml of 1% sodium bisulfite solution.) Under certain conditions, it may be possible to attach the impingers to employees clothing. A personal sampling pump may also be worn by the employee. In other instances, employee movements may make sampling in this manner impractical, but samples should be collected as close to the breathing zone as possible. A prefilter assembly should be used when dusty or smoky conditions prevail and should be connected to the impinger using a minimum amount of tubing. The air being sampled should not pass through any other tubing or equipment before entering the impinger. Sampling is performed for at least 30 minutes at a rate of 1 liter/minute. The flow rate, with the impingers on line, should be checked as a minimum precaution before and after the sample is taken.

Two impingers must be used in series, because under conditions of sampling the collection efficiency of only one impinger is approximately 80% [179]. With two impingers in series, the total collection efficiency is 95% [179]. The contents of each impinger may be analyzed separately if relatively high concentrations are suspected, or may be combined and analyzed as a single sample. If each impinger is analyzed separately and the second impinger is found to contain more than about 30% of the amount

collected in the first impinger, appreciable loss of sample has most likely occurred, and resampling is required to obtain an adquate value.

After sampling, the impinger stems can be removed and cleaned, first tapping the stem gently against the inside wall of the impinger bottle 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 impinger flask. The impinger flask is then sealed tightly with a hard, nonreactive stopper, preferably Teflon, but never with rubber. If shipping the impinger flasks with the stems in, is preferred, the outlets of the stem should be sealed with Parafilm or equivalent nonrubber covers, and the ground glass joints sealed, usually by means of plastic tape. Care should be taken to minimize spillage or loss by evaporation at all times. If analysis cannot be done within a day, samples should be refrigerated to prevent sample loss due to polymerization. Whenever possible, hand delivery of the samples is recommended, or special impinger shipping cases should be used to ship the samples. 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 can be no greater than the accuracy of the volume of air which is measured, the accurate calibration of a sampling device is essential. The frequency of calibration required depends on the use, care, and handling to which the pump 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. Under certain conditions of heavy usage, more frequent calibration may be necessary.

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 is dependent on the type of instrument used as a reference. The choice of calibration instrument will depend largely upon where the calibration is to be performed. For laboratory testing, a 1-liter buret or wet-test meter is recommended, although other standard calibrating instruments such as spirometer, Marriot bottle, or drygas meter can be used. The actual set-up should be the same for any of the instruments mentioned above. The calibration instrument should be connected in sequence to the sampling train which will be followed by the sampler pump. In this way, the calibration instrument will be at atmospheric pressure. If the personal sampler pump is used, each pump must be calibrated separately. If the buret is used, it should be set up so that the flow is toward the narrow end of the unit.

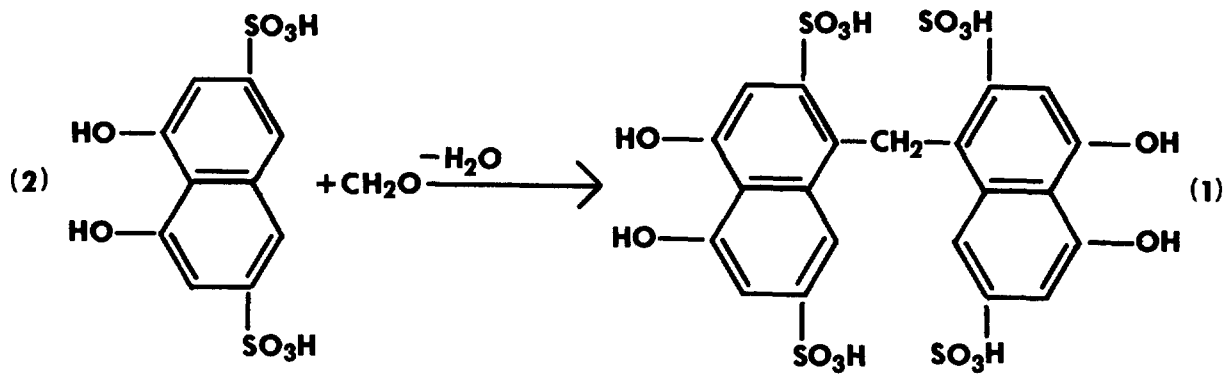
Care must be exercised in the assembly to ensure that seals at the joints are airtight and that the length of connecting tubing is kept at a minimum. Calibration should be performed under essentially the same conditions of pressure and temperature under which it is anticipated the sampling will be performed. The calibrated pump rotameter should be used to set the flow rate in the field.

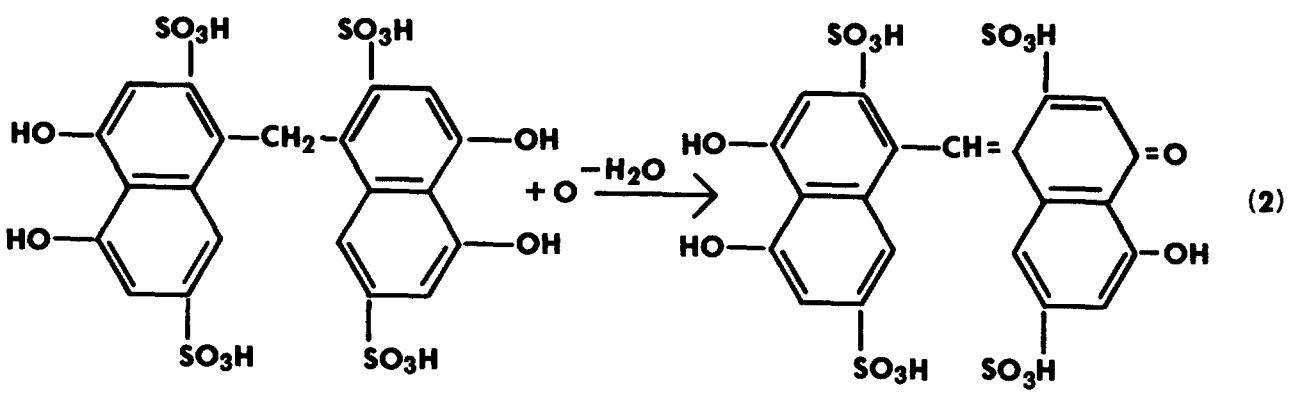
X. APPENDIX II

ANALYTICAL METHOD FOR FORMALDEHYDE IN AIR

Principle of the Method

Formaldehyde reacts with chromotropic acid-sulfuric acid solution to form a purple monocationic chromogen. The absorbance of the colored solution is read in a spectrophotometer at 580 nanometers (nm) and is proportional to the amount of formaldehyde in the solution. The chemistry of this color reaction is uncertain. Fiegel [212] proposed that the chromogen is formed as follows:





Range and Sensitivity

From 0.1 μg/ml to 2.0 μg/ml of formaldehyde can be measured in the 10-ml final volume of solution.

A concentration as low as 0.16 ppm of formaldehyde can be determined in a 25-liter air sample based on an aliquot of 4 ml from 20 ml of absorbing solution and a difference of 0.05 absorbance unit from the blank.

Interferences

The chromotropic acid procedure has very few interferences [179] from other aldehydes. Saturated aldehydes give less than 0.01% positive interference [179], and the unsaturated aldehyde acrolein results in a few percent positive interference [179]. Ethanol and higher molecular weight alcohols and olefins in mixtures with formaldehyde are negative interferences [179]. However, concentrations of alcohols in air are usually much lower than formaldehyde concentrations and, therefore, do not usually cause a serious interference with the estimation of formaldehyde [179].

Phenols result in a 10-20% negative interference [179] when present at an 8:1 excess over formaldehyde. They are, however, ordinarily present in the atmosphere at lesser concentrations [179] than formaldehyde and, therefore, usually do not cause serious interference with the method.

Ethylene and propylene in a 10:1 excess over formaldehyde result in a 5-10% negative interference, and 2-methyl-1,3-butadiene in a 15:1 excess over formaldehyde showed a 15% negative interference [179]. Aromatic

hydrocarbons may produce a negative interference [188]. It has recently been found that cyclohexanone causes a bleaching of the final color [179].

Precision and Accuracy

The method was checked for reproducibility by having three different analysts in three different laboratories analyze standard formaldehyde samples. [179,180] The results listed in Table X-1 agreed within ±5%.

TABLE X-1

COMPARISON OF FORMALDEHYDE RESULTS FROM THREE LABORATORIES

Formaldehyde	Absorbance		
Micrograms	Lab. 1	Lab. 2	Lab. 3
1	0.057	0.063	0.061
3	0.183	0.175	0.189
5	0.269	0.279	0.262
7	0.398	0.381	0.392
10	0.566	0.547	0.537
20	1.02	0.980	1.07

Apparatus

(a) Sampling Equipment

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

(1) Two graduated midget impingers containing distilled water.

(2) A pump capable of delivering a flow rate of 1 liter/minute. The sampling pump is protected from splashover or water condensation by an absorption tube loosely packed with a plug of glass wool and inserted between the exit arm of the impinger and the pump.

(3) An integrating volume meter such as a dry-gas or wet-test meter, or a calibrated rotameter.

(4) Thermometer.

(5) Manometer.

(6) Stopwatch.

(b) Spectrophotometer

An instrument capable of measuring the absorbance of a colored solution at 580 nm.

(c) Associated laboratory glassware for use with a spectrophotometer.

Reagents

(a) Chromotropic acid reagent

Dissolve 0.10 g of 4,5-dihydroxy-2,7-naphthalenedisulfonic acid disodium salt in water and dilute to 10 ml. Filter if necessary and store

in a brown bottle. Make up solution weekly, but discard if solution turns yellow or brown.

(b) Concentrated sulfuric acid

(c) Formaldehyde standard solution "A" (1 mg/ml)

Dilute 3.0 ml of 37% formalin solution to 1 liter with distilled water. This solution must be standardized as described below. The solution is stable for at least a 3-month period. Alternatively, sodium formaldehyde bisulfite can be used as a primary standard. Dissolve 4.4703 g in distilled water and dilute to 1 liter.

(d) Formaldehyde Standard Solution "B" (10μg/ml)

Dilute 1 ml of standard solution "A" to 100 ml with distilled water. Make up solution daily.

(e) Iodine, 0.1 N (approximate)

Dissolve 25 g of potassium iodide in about 25 ml of water, add 12.7 g of iodine and dilute to 1 liter.

(f) Iodine, 0.01 N

Dilute 100 ml of the 0.1 N iodine solution to 1 liter. Standardize using either sodium thiosulfate or arsenic trioxide.

(g) Starch solution, 1%

Make a paste of 1 g of soluble starch and 2 ml of water and slowly add the paste to 100 milliliters of boiling water. Cool, add several milliliters of chloroform as a preservative, and store in a stoppered bottle. Discard if a mold growth is noticeable.

(h) Sodium carbonate buffer solution

Dissolve 80 g of anhydrous sodium carbonate in about 500 ml of water. Slowly add 20 ml of glacial acetic acid to give a final pH of 9.6, and dilute to 1 liter.

(i) Sodium bisulfite, 1%

Dissolve 1 g of sodium bisulfite in 100 ml of water. It is best to prepare a fresh solution weekly.

Procedure

(a) Cleaning of equipment

Care must be exercised to ensure the absence of probable contaminants like organic materials that can be charred by concentrated sulfuric acid. After normal cleaning with detergent solution, glassware should be soaked for 1 hour in a 1:1 mixture of nitric and sulfuric acids, followed by thorough rinsing with doubly deionized water to remove all possible organic contaminants.

(b) Collection and shipping of samples

Pour 20 ml of the absorbing solution (distilled water) into each graduated midget impinger and collect formaldehyde from air and prepare samples as described in Appendix I.

(c) Analysis of samples

(1) Transfer the sample from each impinger to either a 25-ml or 50-ml graduate. Note the volume of each impinger solution.

(2) Pipet a 4-ml aliquot from each of the sampling solutions into glass stoppered test tubes. A blank containing 4 ml of distilled water must also be run. If the formaldehyde content of the aliquot exceeds the limit of the method, use a smaller aliquot diluted to 4 ml with distilled water. Alternatively, aliquots from each impinger can be combined for a single analysis

(3) Add 0.1 ml of 1% chromotropic acid reagent to the solution and mix.

(4) Into the solution from step 3, pipet slowly and cautiously 6 ml of concentrated sulfuric acid. The heat produced by the addition of the sulfuric acid is required to promote the reaction, but the acid should be added sufficiently slowly to prevent loss of sample because of boiling and spattering.

(5) Allow to cool for 20 minutes. Read absorbance at 580 nm in a suitable spectrophotometer using a 1-cm cell. Determine the formaldehyde content of the sampling solution from a curve previously prepared from standard formaldehyde solutions.

(6) During the analysis, it is good practice to group together the two impingers from each sampling series and label them as "A" and "B". The formaldehyde content calculated in "A" is added to that calculated in "B" to give the total amount of formaldehyde collected by the impingers in series.

Calibration and Standards

(a) Standardization of formaldehyde solution

(1) Pipet 1 ml of formaldehyde standard solution "A" into an iodine flask. Into another flask, pipet 1 ml of distilled water. This second flask serves as the blank.

(2) To each flask, add 10 ml of 1% sodium bisulfite and 1 ml of 1% starch solution.

(3) Titrate with 0.1 N iodine to a dark blue color.

(4) Destroy the excess iodine with 0.05 N sodium thiosulfate.

(5) Add 0.01 N iodine until a faint blue end point is reached.

(6) The excess inorganic bisulfite is now completely oxidized to sulfate, and the solution is ready for the assay of the formaldehyde bisulfite addition product.

(7) Chill the flask in an ice bath and add 25 ml of chilled sodium carbonate buffer. Titrate the liberated sulfite with 0.01 N iodine, using a microburet, to a faint blue end point. The amount of iodine added in this step must be accurately measured and recorded.

(8) One milliliter of 0.00100 N iodine is equivalent to 0.15 mg of formaldehyde. Therefore, since 1 milliliter of formaldehyde standard solution was titrated, the milliliter of 0.01 N iodine used in the final titration multiplied by the factor, 0.15, gives the formaldehyde concentration of the standard solution in mg/ml.

(9) The factor 0.15 must be adjusted or determined in accord with the exact normality of the iodine solution.

(b) Preparation of Standard Curve

(1) Pipet 0, 0.1, 0.3, 0.5, 0.7, 1.0, and 2.0 ml of standard solution "B" into glass stoppered test tubes.

(2) Dilute each standard to 4 ml with distilled water.

(3) Develop the color as described in the analysis procedure under Section (C).

(4) Plot absorbance against micrograms of formaldehyde in the color developed solution. Note that the microgram concentration of the

formaldehyde is determined based on the standardization value obtained for solution A.

Calculations

(a) Convert the volume of air sampled (V) to the volume of air at standard conditions (Vs) of 760 mm of mercury and 25 degrees C, using the correction formula:

$$Vs = \frac{V \times P \times 298}{760(T + 723)}$$

where:

Vs = volume of air in liters at standard conditions

V = volume of air sampled in liters

P = barometric pressure in mm of mercury

T = temperature of sample air, C

(b) Determine the total concentration (Ct) of formaldehyde present in the two sample impingers in series, A and B.

$$Ct = Ca \times Fa + Cb \times Fb$$

where:

Ct = total μg of formaldehyde in the sample

Ca and Cb = respective formaldehyde concentration in μg of the sample aliquots taken from impingers A and B as determined from the calibration curve

Fa and Fb = respective aliquot factor; $\frac{\text{sampling soln. vol. in ml}}{\text{ml aliquot used}}$

(c) The concentration of formaldehyde in the sampled atmosphere may be calculated by using the following equation, assuming standard conditions are taken as 760 mm of mercury and 25 degrees C:

$$\text{ppm (volume)} = \frac{Ct \times 24.47}{Vs \times M.W.}$$

where:

Vs = liters of air sampled at standard conditions

M.W. = molecular weight of formaldehyde (30.03)

24.47 = μl of formaldehyde gas in one micromole at 760 mm Hg and 25 degrees C.