VII. COMPATIBILITY WITH OTHER STANDARDS

The Environmental Protection Agency has not classified cadmium as a hazardous pollutant and neither emission nor ambient air standards have been issued.

EPA has not promulgated solid waste regulations for cadmium. However, it has reaffirmed the 1962 PHS drinking water standard of 0.01 mg/liter[279] as an interim primary drinking water regulation, applicable to community water supplies (*Federal Register* 40:59570, December 24, 1975). While this standard is for community water supplies, and thus is not directly applicable to discharge of cadmium into streams, it seems clear that disposal of cadmium waste, liquid or solid, should be in a manner not leading to its introduction into drinking water.

VIII. REFERENCES

1. Friberg L, Piscator M, Nordberg GF, Kjellstrom T: Cadmium in the Environment, ed 2. Cleveland, CRC Press Inc, 1974, 248 pp
2. Friberg L, Kjellstrom T, Nordberg G, Piscator M: Cadmium in the Environment—III. A Toxicological and Epidemiological Appraisal. EPA-650/2-75-049. US Environmental Protection Agency, Office of Research and Development, 1975
3. Riihimaki V: Cadmium—Occurrence and effects. Work Environ Health 9:91-101, 1972
4. World Health Organization-International Agency for Research on Cancer: IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man. Vol 2: Some inorganic and organometallic compounds. Lyon, IARC, 1973, pp 74-99
5. Scientific and technical assessment report on cadmium, EPA-600/6-75-003, March 1975, US Environmental Protection Agency, Office of Research and Development, Office of Program Integration, 1975
6. Fleischer M, Sarofim AF, Fassett DW, Hammond P, Shacklette HT, Nisbet ICT, Epstein S: Environmental impact of cadmium—A review by the panel on hazardous trace substances. Environ Health Perspect, Experimental issue No. 7, May 1974, pp 253-323
7. Fulkerson W, Goeller HE (eds): Cadmium, The Dissipated Element. ORNL NSF-EP-21. Oak Ridge National Laboratory, 1973
8. Chizhikov DM: Cadmium. New York, Pergamon Press, 1966, 263 pp
9. Remy H: Second sub-group of the periodic system: Zinc, cadmium, and mercury, in Treatise on Inorganic Chemistry. New York, Elsevier Publishing Co, 1956, vol 2, pp 445-56
10. Weast RC (ed): Handbook of Chemistry and Physics—A Ready-Reference Book of Chemical and Physical Data, ed 56. Cleveland, CRC Press Inc, 1975, pp B-1, B-3, B-79, B-80
11. Ashley BE: Cadmium, in Minerals Yearbook 1970—Vol I: Metals, Minerals, and Fuels. US Dept of the Interior, Bureau of Mines, 1973, pp 245-51
12. Davis WE and Associates: National Inventory of Sources and Emissions—Cadmium, nickel and asbestos—1968—Cadmium, Section 1, PB 192250. US Dept of Health, Education, and Welfare, National Air Pollution Control Administration, 1970, 44 pp
13. Athanassiadis YC: Air Pollution Aspects of Cadmium and Its Compounds, PB 188086. US Dept of Health, Education, and Welfare, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, 1969, 80 pp
14. Schroeder HA, Balassa JJ: Cadmium—Uptake by vegetables from superphosphate in soil. Science 140:819-20, 1963
15. Schroeder HA, Nason AP, Tipton IH, Balassa JJ: Essential trace metals in man—Zinc—Relation to environmental cadmium. J Chronic Dis 20:179-210, 1967
16. Schroeder HA, Balassa JJ: Abnormal trace metals in man—Cadmium. J Chronic Dis 14:236-58, 1961
17. Essing H-G, Schaller K-H, Szadkowski D, Lehnert G: [Usual cadmium burden from food and drink.] Arch Hyg Bakteriol 153:490-94, 1969 (Ger)
18. Kropf R, Geldmacher-von Mallinckrodt M: [Cadmium content of foods and daily cadmium intake.] Arch Hyg Bakteriol 152:218-24, 1968 (Ger)
19. Rautu R, Sporn A: [Contribution to the determination of the cadmium supply of foodstuffs.] Nahrung 14:25-31, 1970 (Ger)
20. Fox MRS, Jacobs RM, Fry BE Jr, Harland BF, Story AH: Comparative effects in quail of cadmium supplied by oysters and cadmium. Summary Abstracts, IXth International Congress of Nutrition Mexico City, 1972, p 137
21. US Environmental Protection Agency, Division of Atmospheric Surveillance: Air Quality Data for 1968 from the National Air Surveillance Network and Contributing State and Local Networks, Publication No. APTD-0978. US EPA, Office of Office of Air Programs, 1972
22. Lee RE Jr, Patterson RK, Wagman J: Particle-size distribution of metal components in urban air. Environ Sci Technol 2:288-90, 1968
23. Durum WH, Hem JD, Heidel SG: Reconnaissance of Selected Minor Elements in Surface Waters of the United States, October, 1970. Geological Survey Circular 643. US Dept of the Interior, 1971, 49 pp
24. Taylor FB: Significance of trace elements in public finished water supplies. J Am Water Works Assoc 55:619-23, 1963
25. McCabe LJ, Symons JM, Lee RD, Robeck GG: Survey of community water supply systems. J Am Water Works Assoc 62:670-87, 1970

26. Murthy GK, Rhea US: Cadmium, copper, iron, lead, manganese, and zinc in evaporated milk, infant products, and human milk. J Dairy Sci 54:1001-05, 1971

27. Murthy GK, Rhea U: Cadmium and silver content of market milk. J Dairy Sci 51:610-13, 1968

28. Murthy GK, Rhea U, Peeler JT: Levels of antimony, cadmium, chromium, cobalt, manganese, and zinc in institutional total diets. Environ Sci Technol 5:436-42, 1971

29. Tipton IH, Stewart PL: Analytical methods for the determination of trace elements—Standard man studies, in Hemphill DD (ed): Trace Substances in Environmental Health—III. Proceedings of University of Missouri's 3rd Annual Conference on Trace Substances in Environmental Health (1969). Columbia, Mo, University of Missouri, 1970, pp 305-30

30. Meranger JC, Smith DA: The heavy metal content of a typical Canadian diet. Can J Public Health 63:53-57, 1972

31. Duggan RE, Corneliussen PE: Dietary intake of pesticide chemicals in the United States (III), June 1968-April 1970. Pestic Monit J 5:331-41, 1972

32. Food and Agriculture Organization/World Health Organization: Evaluation of Certain Food Additives and the Contaminants Mercury, Lead, and Cadmium—Sixteenth Report of the Joint FAO/WHO Expert Committee on Food Additives, WHO Tech Rep Ser No. 505, FAO Nutrition Meetings Rep Ser No. 51, 1972. Geneva, 32 pp

33. Menden EE, Elia VJ, Michael LW, Petering HG: Distribution of cadmium and nickel of tobacco during cigarette smoking. Environ Sci Technol 6:830-32, 1972

34. Bonnell JA: Emphysema and proteinuria in men casting copper-cadmium alloys. Br J Ind Med 12:181-97, 1955

35. Sovet: [Poisoning caused by powder used in the cleaning of silver: severe symptoms: acute gastroenteritis; dysentery episodes, antidotes; antiinflammatory products; ipecac; chemical analysis.] Presse Med Belge 10:69-70, 21 Feb 1858 (Fre)

36. Christensen FC, Olson EC: Cadmium poisoning—Report of a fatal case, with discussion of pathology and clinical aspects. Arch Ind Health 16:8-13, 1957

37. Fairhall LT: Industrial Toxicology, ed 2. Baltimore, Williams & Wilkins Company, 1957, pp 30-33

38. Nicaud P, Lafitte A, Gros A: [Symptoms in chronic poisoning by cadmium.] Arch Mal Prof 4:192-202, 1942 (Fre)

39. Kobayashi J: Relation between the "Itai-Itai" disease and the pollution of river water by cadmium from a mine. Presented at 5th International Water Pollution Research Conference, San Francisco, July-August, 1970, 7 pp

40. Shigematsu I, Hasegawa Y: Itai-Itai (ouch-ouch) disease and cadmium pollution in Japan. Presented at Conference on the Effects of Environmental Trace Metals on Human Health, US-Japan Cooperative Science Program, Feb 1-5, 1971, Honolulu, Hawaii, pp 49-64

41. Tsuchiya K: Environmental pollution by cadmium and its health effect in Japan. Working paper for Conference on the Effects of Environmental Trace Metals on Human Health, US-Japan Cooperative Science Program, Feb 1-5, 1971, Honolulu, Hawaii, pp 65-89

42. Zavon MR, Meadows CD: Vascular sequelae to cadmium fume exposure. Am Ind Hyg Assoc J 31:180-82, 1970

43. Townshend RH: A case of acute cadmium pneumonitis—Lung function tests during a four-year follow-up. Br J Ind Med 25:68-71, 1968

44. Beton, DC, Andrews GS, Davies HJ, Howells L, Smith GF: Acute cadmium fume poisoning—Five cases with one death from renal necrosis. Br J Ind Med 23:292-301, 1966

45. Huck FF: Cadmium poisoning by inhalation—Report of a case. Occup Med 3:411-14, 1947

46. Heath D, Gillund TD, Kay JM, Hawkins CF: Pulmonary vascular disease in honeycomb lung. J Pathol Bacteriol 95:423-30, 1968

47. Blejer HP, Caplan PE: Occupational Health Aspects of Cadmium Inhalation Poisoning with Special Reference to Welding and Silver Brazing, ed 2. Berkeley, State of California Department of Public Health, Bureau of Occupational Health and Environmental Epidemiology, 1971, 36 pp

48. Blejer HP, Caplan PE, Alcocer AE: Acute cadmium fume poisoning in welders—A fatal and a nonfatal case in California. Calif Med 105:290-96, 1966

49. Paterson JC: Studies on the toxicity of inhaled cadmium—III. The pathology of cadmium smoke poisoning in man and in experimental animals. J Ind Hyg Toxicol 29:294-301, 1947

50. Kleinfeld M: Acute pulmonary edema of chemical origin. Arch Environ Health 10:942-46, 1965

51. Barrett HM, Irwin DA, Semmons E: Studies on the toxicity of inhaled cadmium—I. The acute toxicity of cadmium oxide by inhalation. J Ind Hyg Toxicol 29:279-85, 1947

52. Barrett HM, Card BY: Studies on the toxicity of inhaled cadmium—II. The acute lethal dose of cadmium oxide for man. J Ind Hyg Toxicol 29:286-93, 1947

53. Lane RE, Campbell ACP: Fatal emphysema in two men making a copper cadmium alloy. Br J Ind Med 11:118-22, 1954

54. Kazantzis G, Flynn FV, Spowage JS, Trott DG: Renal tubular malfunction and pulmonary emphysema in cadmium pigment workers. Q J Med, New Series 32:165-92, 1963

55. Friberg L: Health Hazards in the Manufacture of Alkaline Accumulators with Special Reference to Chronic Cadmium Poisoning—A Clinical and Experimental Study. Stockholm, Ivar Haeggstroms Boktryckeri AB, 1950, 124 pp (Also published as supplement CCXL to Acta Med Scand, vol 138)

56. Friberg L: Chronic cadmium poisoning. Arch Ind Health 20:401-07, 1959

57. Friberg L: Injuries following continued administration of cadmium—Preliminary report of a clinical and experimental study. Arch Ind Hyg Occup Med 1:458-66, 1950

58. Baader EW: Chronic cadmium poisoning. Ind Med Surg 21:427-30, 1952

59. Holden H: Cadmium fume. Ann Occup Hyg 8:51-54, 1965

60. Chowdhury P, Louria DB: Influence of cadmium and other trace metals on human α_1-antitrypsin—An in vitro study. Science 191:480-81, 1976

61. Suzuki S, Suzuki T, Ashizawa M: Proteinuria due to inhalation of cadmium stearate dust. Ind Health 3:73-85, 1965

62. Princi F: A study of industrial exposures to cadmium. J Ind Hyg Toxicol 29:315-20, 1947

63. Tsuchiya K: Proteinuria of workers exposed to cadmium fume—The relationship to concentration in the working environment. Arch Environ Health 14:875-80, 1967

64. Hammer DI, Finklea JF, Creason JP, Sandifer SH, Keil JE, Priester LE, Stara JF: Cadmium exposure and human health effects, in Hemphill DD (ed): Trace Substances in Environmental Health—V. A Symposium. Columbia, Mo, University of Missouri, 1972, pp 269-83

65. Potts CL: Cadmium proteinuria—The health of battery workers exposed to cadmium oxide dust. Ann Occup Hyg 8:55-61, 1965

66. Piscator M: Proteinuria in chronic cadmium poisoning—I. An electrophoretic and chemical study of urinary and serum proteins from workers with chronic cadmium poisoning. Arch Environ Health 4:607-21, 1962

67. Vigliani EC: The biopathology of cadmium. Yant Memorial Lecture. Am Ind Hyg Assoc J 30:329-40, 1969

68. Davis JS, Flynn FV, Platt HS: The characterisation of urine protein by gel filtration. Clin Chim Acta 21:357-76, 1968

69. Berggard I, Bearn AC: Isolation and properties of a low molecular weight β-globulin occurring in human biological fluids. J Biol Chem 243:4095-4103, 1968

70. Piscator M: [Effects of cadmium on the health of the population.] Staub-Reinhalt Luft 33:457-59, 1973 (Ger)

71. Adams RG, Harrison JF, Scott P: The development of cadmium-induced proteinuria, impaired renal function, and osteomalacia in alkaline battery workers. Q J Med 38:425-43, 1969

72. Bonnell JA, Kazantzis G, King E: A follow-up study of men exposed to cadmium oxide fume. Br J Ind Med 16:135-47, 1959

73. Smith JC, Wells AR, Kench JE: Observations on the urinary protein of men exposed to cadmium dust and fume. Br J Ind Med 18:70-78, 1961

74. Piscator M: Proteinuria in chronic cadmium poisoning—III. Electrophoretic and immunoelectrophoretic studies on urinary proteins from cadmium workers, with special reference to the excretion of low molecular weight proteins. Arch Environ Health 12:335-44, 1966

75. Clarkson TW, Kench JE: Urinary excretion of amino acids by men absorbing heavy metals. Biochem J 62:361-72, 1956

76. Ahlmark A, Axelsson B, Friberg L, Piscator M: Further investigations into kidney function and proteinuria in chronic cadmium poisoning, in Proceedings of the 13th International Congress on Occupational Health, 1960. New York, 1961, pp 201-03

77. Axelsson B: Urinary calculus in long-term exposure to cadmium, in Proceedings of the 14th International Congress on Occupational Health, Madrid, 1963. Amsterdam, 1964, vol III, pp 939-42

78. Adams RG, Crabtree N: Anosmia in alkaline battery workers. Br J Ind Med 18:216-21, 1961

79. Tsuji T, Nagata M, Ito Y, Takigawa H: [Cadmium exposure in zinc refinery workers—1. Summary and evaluation—Preliminary examination.] Jpn J Hyg 27:316-25, 1972 (Jap)

80. Prodan L: Cadmium poisoning—II. Experimental cadmium poisoning. J Ind Hyg Toxicol 14:174-96, 1932

81. Hardy HL, Skinner JB: The possibility of chronic cadmium poisoning. J Ind Hyg Toxicol 29:321-24, 1947

82. Carroll RE: The relationship of cadmium in the air to cardiovascular disease death rates. JAMA 198:267-69, 1966

83. Perry HM Jr, Schroeder HA: Comparison of the concentration of several trace metals in the urine of treated and untreated malignant hypertensive patients as compared with normal individuals. Circulation 12:758-59, 1955

84. Schroeder HA: Cadmium as a factor in hypertension. J Chronic Dis 18:647-56, 1965

85. Schroeder HA: The water factor. New Engl J Med 280:336-38, 1969

86. Morgan JM: Tissue cadmium concentration in man. Arch Intern Med 123:405-08, 1969

87. Szadkowski D, Schaller K-H, Lehnert G: [Relation between renal cadmium excretion, age, and arterial blood pressure.] Z Klin Chem Klin Biochem 7:551-52, 1969 (Ger)

88. Schroeder HA: Cadmium, chromium, and cardiovascular disease. Circulation 35:570-82, 1967

89. Tsuchiya K: Causation of ouchi-ouchi disease (Itai-Itai Byo)—An introductory review—Part I. Nature of the disease. Keio J Med 18:181-94, 1969; Part II. Epidemiology and evaluation. Ibid pp 195-211

90. Barthelemy P, Moline R: [Chronic intoxication by cadmium hydrate—Early symptoms of yellow tooth.] Paris Med 1:7-8, 1946 (Fre)

91. Parizek J: The destructive effect of cadmium ion on testicular tissue and its prevention by zinc. J Endocrinol 15:56-63, 1957

92. Parizek J, Zahor Z: Effect of cadmium salts on testicular tissue. Nature 177:1036-37, 1956

93. Favino A, Candura F, Chiappino G, Cavalleri A: Study on the androgen function of men exposed to cadmium. Med Lav 59:105-10, 1968

94. Smith JP, Smith JC, McCall AJ: Chronic poisoning from cadmium fume. J Pathol Bacteriol 80:287-96, 1960

95. Tsvetkova RP: [Materials concerning an investigation of the effect of cadmium compounds on the generative function.] Gig Tr Prof Zabol 12:31-33, 1970 (Rus)

96. Kipling MD, Waterhouse JAH: Cadmium and prostatic carcinoma. Lancet 1:730-31, 1967

97. Lemen RA, Lee JS, Wagoner JK, Blejer HP: Cancer mortality among cadmium production workers. Ann NY Acad Sci 271:273-79, 1976

98. Holden H: Cadmium toxicology. Lancet 2:57, 1969

99. Humperdinck K: [Cadmium and lung cancer,] Med Klin, 63:948-51, 1968 (Ger)

100. Winkelstein W Jr, Kantor S: Prostatic cancer—Relationship to suspended particulate air pollution. Am J Public Health 59:1134-38, 1969

101. Kolonel LN: An Epidemiological Investigation of Cadmium Carcinogenesis, Ph.D. thesis. Berkeley, University of California, Graduate Division, 1972, 109 pp

102. Kolonel LN: Association of cadmium with renal cancer. Cancer 37:1782-87, 1976

103. Morgan JM: Cadmium and zinc abnormalities in bronchogenic carcinoma. Cancer 25:1394-98, 1970

104. Malcolm D: Potential carcinogenic effect of cadmium in animals and man—Effects of cadmium on the genito-urinary tracts of animals. Ann Occup Hyg 15:33-36, 1972

105. Levy LS, Roe FJC, Malcolm D, Kazantzis G, Clack J, Platt HS: Absence of prostatic cancer changes in rats exposed to cadmium. Ann Occup Hyg 16:111-18, 1973

106. Levy LS, Clack C: Further studies on the effect of cadmium on the prostate gland—I. Absence of prostatic changes in rats given oral cadmium sulphate for two years. Ann Occup Hyg 17:205-11, 1975

107. Levy LS, Clack D, Roe FJC: Further studies on the effect of cadmium on the prostate gland—II. Absence of prostatic changes in mice given oral cadmium sulphate for eighteen months. Ann Occup Hyg 17:213-20, 1975

108. Lufkin NH, Hodges FT: Cadmium poisoning. Nav Med Bull 43:1273-76, 1944

109. Baker TD, Hafner WG: Cadmium poisoning from a refrigerator shelf used as an improvised barbecue grill. Public Health Rep 76:543-44, 1961

110. Berman E: Determination of cadmium, thallium and mercury in biological materials by atomic absorption. At Absorpt Newsl 6:57-60, 1967

111. Bui T-H, Lindsten J, Nordberg GF: Chromosome analysis of lymphocytes from cadmium workers and Itai-Itai patients. Environ Res 9:187-95, 1975

112. Shiraishi Y, Yosida TH: Chromosomal abnormalities in cultured leucocyte cells from Itai Itai disease patients. Proc Jpn Acad 48:248-51, 1972

113. Shiraishi Y, Kurahashi H, Yosida TH: Chromosomal aberrations in cultured human leucocytes induced by cadmium sulfide. Proc Jpn Acad 48:133-37, 1972

114. DeKnudt G, Leonard A: Cytogenetic investigations on leucocytes of workers from a cadmium plant. Environ Physiol Biochem 5:319-27, 1975

115. Friberg L: Deposition and distribution of cadmium in man in chronic poisoning. Arch Ind Health 16:27-29, 1957

116. Vorob'yeva RS: [Investigation of the functional state of the nervous system in workers exposed to cadmium oxide.] Nevropat Psikhiat 57:385-88, 1957 (Rus)

117. Nandi M, Slone D, Jick H, Shapiro S, Lewis GP: Cadmium content of cigarettes. Lancet 2:1329-30, 1969

118. Lewis GP, Lyle H, Miller S: Association between elevated hepatic water-soluble protein-bound cadmium levels and chronic bronchitis and/or emphysema. Lancet 2:1330-33, 1969

119. Rahola T, Aaran R-K, Miettinen JK: Retention and elimination of cadmium-115m in man, paper no. 78. Second European Congress on Radiation Protection, Budapest, 1972

120. Lehnert G, Schaller KH, Haas T: [The determination of cadmium in serum and urine by atomic absorption spectrometer.] Z Klin Chem Klin Biochem 6:174-76, 1968 (Ger)

121. Imbus HR, Cholak J, Miller LH, Sterling T: Boron, cadmium, chromium, and nickel in blood and urine—A survey of American working men. Arch Environ Health 6:286-95, 1963

122. Friberg L: Further investigations on chronic cadmium poisoning—A study on rabbits with radioactive cadmium. Arch Ind Hyg Occup Med 5:30-36, 1952

123. Axelsson B, Piscator M: Serum proteins in cadmium poisoned rabbits—With special reference to hemolytic anemia. Arch Environ Health 12:374-81, 1966

124. Smith JC, Kench JE, Smith JP: Chemical and histological post-mortem studies on a workman exposed for many years to cadmium oxide fume. Br J Ind Med 14:246-49, 1957

125. Baader EW: [Chronic cadmium poisoning.] Dtsch Med Wochenschr 76:484-87, 1951 (Ger)

126. Kazantzis G: Respiratory function in men casting cadmium alloys—Part I. Assessment of ventilatory function. Br J Ind Med 13:30-36, 1956

127. Buxton RSJ: Respiratory function in men casting cadmium alloys—II. The estimation of total lung volume, its subdivisions, and the mixing coefficient. Br J Ind Med 13:36-40, 1956

128. King E: An environmental study of casting copper-cadmium alloys. Br J Ind Med 12:198-205, 1955

129. Smith JC, Kench JE, Lane RE: Determination of cadmium in urine and observations on urinary cadmium and protein excretion in men exposed to cadmium oxide dust. Biochem J 61:698-701, 1955

130. Tsuchiya K: Proteinuria of cadmium workers. J Occup Med 18:463-66, 1976

131. Piscator M, Adamsson E, Elinder C-G, Pettersson B, Steninger P: Studies on cadmium-exposed women. Paper presented at the XVIIIth International Congress on Occupational Health, Brighton, England, 1975

132. Kjellstrom T, Evrin P-E, Rahnster B: Dose-response analysis of cadmium-induced tubular proteinuria—1. A study of urinary β_2-microglobulin excretion among workers in a battery factory. Submitted to Environ Res, 1976

133. Lauwerys RR, Buchet JP, Roels HA, Brouwers J, Stanescu D: Epidemiological survey of workers exposed to cadmium—Effect on lung, kidney, and several biological indices. Arch Environ Health 28:145-48, 1974

134. Lauwerys R, Buchet J-P, Roels H: [A study of pulmonary and renal function in workers exposed to cadmium.] Paper presented at the XVIIIth International Congress on Occupational Health, Brighton, England, 1975 (Fre)

135. Materne D, Lauwerys R, Buchet JP, Roels H, Brouwers J, Stanescu D: [Investigations on the risks resulting from exposure to cadmium in two production plants and two plants using cadmium.] Cahiers Med Trav 12:3-76, 1975 (Fre)

136. Skog E, Wahlberg JE: A comparative investigation of the percutaneous absorption of metal compounds in the guinea pig by means of the radioactive isotopes—^{51}Cr, ^{58}Co, ^{65}Zn, ^{110m}Ag, ^{115m}Cd, ^{203}Hg. J Invest Dermatol 43:187-92, 1964

137. Wahlberg JE: Percutaneous toxicity of metal compounds—A comparative investigation in guinea pigs. Arch Environ Health 11:201-04, 1965

138. Decker LE, Byerrum RU, Decker CF, Hoppert CA, Langham RF: Chronic toxicity studies—I. Cadmium administered in drinking water to rats. Arch Ind Health 18:228-31, 1958

139. Fitzhugh OG, Meiller FH: The chronic toxicity of cadmium. J Pharm Exp Ther 72:15, 1941 (abst)

140. Spivey Fox MR, Fry BE Jr: Cadmium toxicity decreased by dietary ascorbic acid supplements. Science 169:989-91, 1970

141. Friberg L: Iron and liver administration in chronic cadmium poisoning and studies of the distribution and excretion of cadmium—Experimental investigations in rabbits. Acta Pharmacol Toxicol 11:168-78, 1955

142. Kench JE, Gubb PJD: The activity of certain enzymes in cadmium-poisoned chicks—Proceedings of the Biochemical Society. Biochem J 120:27-28, 1971

143. Dalhamn T, Friberg L: Dimercaprol (2,3-dimercaptopropanol) in chronic cadmium poisoning. Acta Pharmacol Toxicol 11:68-71, 1955

144. Lawford DJ: Serum changes in the rat following oral administration of cadmium. Nature 190:815, 1961

145. Jacobs RM, Spivey Fox MR, Aldridge MH: Changes in plasma proteins associated with the anemia produced by dietary cadmium in Japanese quail. J Nutr 99:119-28, 1969

146. Perry HM Jr, Erlanger M: Hypertension and tissue metal levels after intraperitoneal cadmium, mercury, and zinc. Am J Physiol 220:808-11, 1971

147. Perry HM Jr, Erlanger M, Yunice A, Schoepfle E, Perry EF: Hypertension and tissue metal levels following intravenous cadmium, mercury, and zinc. Am J Physiol 219:755-61, 1970

148. Perry HM Jr, Erlanger MW: Elevated circulating renin activity in rats following doses of cadmium known to induce hypertension. J Lab Clin Med 82:399-405, 1973

149. Perry HM Jr, Erlanger MW: Prevention of cadmium-induced hypertension by selenium. Fed Proc 33:357, 1974 (abst)

150. Thind GS: Vascular smooth muscle characteristics in cadmium-induced hypertension. Fed Proc 33:436, 1974 (abst)

151. Fischer GM, Thind GS: Tissue cadmium and water content of normal and cadmium hypertensive rabbits. Arch Environ Health 23:107-10, 1971

152. Porter MC, Miya TS, Bousquet WF: Cadmium and vascular reactivity in the rat. Toxicol Appl Pharmacol 34:143-50, 1975

153. Fowler FA, Jones HS, Brown HW, Haseman JK: The morphologic effects of chronic cadmium administration on the renal vasculature of rats given low and normal calcium diets. Toxicol Appl Pharmacol 34:233-52, 1975

154. Singhal RL, Merali Z, Hrdina PD: Aspects of the biochemical toxicology of cadmium. Fed Proc 35:75-80, 1976

155. Mason KE, Brown JA, Young JO, Nesbit RR: Cadmium-induced injury of the rat testis. Anat Rec 149:135-47, 1964

156. Sangalang GB, O'Halloran MJ: Cadmium-induced testicular injury and alterations of androgen synthesis in brook trout. Nature 240:470-71, 1972

157. Webb M: Protection by zinc against cadmium toxicity. Biochem Pharmacol 21:2767-71, 1972

158. Kar AB, Das RP, Mukerji FNI: Prevention of cadmium induced changes in the gonads of rat by zinc and selenium—A study in antagonism between metals in the biological system. Proc Natl Inst Sci India 26B (Suppl):40-50, 1960

159. Mason KE, Young JO, Brown JE: Effectiveness of selenium and zinc in protecting against cadmium-induced injury of the rat testis. Anat Rec 148:309, 1964 (abst)

160. Mason KE, Young JO: Effectiveness of selenium and zinc in protecting against cadmium-induced injury of the rat testis, in Muth OH (ed): Symposium—Selenium in Biomedicine. Westport, Conn, Avi Publishing Co Inc, 1967, chap 23, pp 383-94

161. Gunn SA, Gould TC, Anderson WAD: Protective effect of thiol compounds against cadmium-induced vascular damage to testis. Proc Soc Exp Med Biol 122:1036-39, 1966

162. Nordberg GF: Effects of acute and chronic cadmium exposure on the testicles of mice—With special reference to protective effects of metallothionein. Environ Physiol 1:171-87, 1971

163. Nordberg GF, Piscator M: Influence of long-term cadmium exposure on urinary excretion of protein and cadmium in mice. Environ Physiol Biochem 2:37-49, 1972

164. Piscator M, Axelsson B: Serum proteins and kidney function after exposure to cadmium. Arch Environ Health 21:604-08, 1970

165. Madlafousek J, Hlinak Z, Parizek J: Sexual behaviour of male rats sterilized by cadmium. J Reprod Fertil 26:189-96, 1971

166. Kar AB, Das RP, Karkun JN: Ovarian changes in prepuberal rats after treatment with cadmium chloride. Acta Biol Med Ger 3:372-99, 1959

167. Parizek J, Ostadalova I, Benes L, Pitha J: The effect of a subcutaneous injection of cadmium salts on the ovaries of adult rats in persistent oestrus. J Reprod Fertil 17:559-62, 1968

168. Kaul DK, Ramaswami LS: Effect of cadmium chloride on the ovary of the Indian desert gerbil, *Meriones hurrianae* Jerdon. Indian J Exp Biol 8:171-73, 1970

169. Parizek J: Vascular changes at sites of oestrogen biosynthesis produced by parenteral injection of cadmium salts—The destruction of placenta by cadmium salts. J Reprod Fertil 7:263-65, 1964

170. Parizek J, Ostadalova I, Benes I, Babicky A: Pregnancy and trace elements—The protective effect of compounds of an essential trace element—selenium—against the peculiar toxic effects of cadmium during pregnancy. J Reprod Fertil 16:507-09, 1968

171. Chernoff N: Teratogenic effects of cadmium in rats. Teratology 8:29-32, 1973

172. Barr M Jr: The teratogenicity of cadmium chloride in two stocks of Wistar rats. Teratology 7:237-42, 1973

173. Mulvihill JE, Gamm SH, Ferm VH: Facial formation in normal and cadmium-treated golden hamsters. J Embryol Exp Morphol 24:393-403, 1970

174. Ishizu S, Minami M, Suzuki A, Yamada M, Sato M, Yamamura K: An experimental study of teratogenic effect of cadmium. Ind Health 11:127-39, 1973

175. Gale TF, Ferm VH: Skeletal malformations resulting from cadmium treatment in the hamster. Biol Neonate 23:149-60, 1973

176. Ferm VH: Developmental malformations induced by cadmium—A study of timed injections during embryogenesis. Biol Neonate 19:101-07, 1971

177. Ferm VH, Carpenter SJ: The relationship of cadmium and zinc in experimental mammalian teratogenesis. Lab Invest 18:429-32, 1968

178. Ferm VH, Carpenter SJ: Teratogenic effect of cadmium and its inhibition by zinc. Nature 216:1123-24, 1967

179. Wills JH, LeFevre R, Benitz K-F, Dougherty W, Talley WH, Coulston F: Chronic and multi-generation toxicity of cadmium for the rat and the rhesus monkey. Accepted for publication by Environ Qual Safety, 1976

180. Epstein SS, Arnold E, Andrea J, Bass W, Bishop Y: Detection of chemical mutagens by the dominant lethal assay in the mouse. Toxicol Appl Pharmacol 23:288-325, 1972

181. Gilliavod N, Leonard A: Mutagenicity tests with cadmium in the mouse. Toxicology 5:43-47, 1975

182. Gunn SA, Gould TC, Anderson WAD: Specific response of mesenchymal tissue to cancerigenesis by cadmium. Arch Pathol 83:493-99, 1967

183. Haddow A, Roe FJC, Dukes CE, Mitchley BCV: Cadmium neoplasia—Sarcomata at the site of injection of cadmium sulphate in rats and mice. Br J Cancer 18:667-73, 1964

184. Kazantzis G: Induction of sarcoma in the rat by cadmium sulphide pigment. Nature 198:1213-14, 1963

185. Kazantzis G, Hanbury WJ: The induction of sarcoma in the rat by cadmium sulphide and by cadmium oxide. Br J Cancer 20:190-99, 1966

186. Heath JC, Daniel MR, Dingle JT, Webb M: Cadmium as a carcinogen. Nature 193:592-93, 1962

187. Heath JC, Daniel MR: The production of malignant tumours by cadmium in the rat. Br J Cancer 18:124-29, 1964

188. Gunn SA, Gould TC, Anderson WAD: Effect of zinc on cancerogenesis by cadmium. Proc Soc Exp Biol Med 115:653-57, 1964

189. Gunn SA, Gould TC, Anderson WAD: Cadmium-induced interstitial cell tumors in rats and mice and their prevention by zinc. J Natl Cancer Inst 31:745-53, 1963

190. Roe FJC, Dukes CE, Cameron KM, Pugh RCB, Mitchley RCV: Cadmium neoplasia—Testicular atrophy and Leydig cell hyperplasia and neoplasia in rats and mice following the subcutaneous injection of cadmium salts. Br J Cancer 18:674-81, 1964

191. Schroeder HA, Balassa JJ, Vinton WH Jr: Chromium, cadmium and lead in rats—Effects on life span, tumors and tissue levels. J Nutr 86:51-66, 1965

192. Kanisawa M, Schroeder HA: Life term studies on the effect of trace elements on spontaneous tumors in mice and rats. Cancer Res 29:892-95, 1969

193. Bionetics Research Labs Inc: Evaluation of Carcinogenic, Teratogenic, and Mutagenic Activities of Selected Pesticides and Industrial Chemicals--Vol I: Carcinogenic Study. Springfield, Va, US Dept of Commerce, National Technical Information Service, 1968 (PB-223 159)

194. Margoshes M, Vallee BL: A cadmium protein from equine kidney cortex. J Am Chem Soc 79:4813-14, 1957

195. Kagi JHR, Vallee BL: Metallothionein—A cadmium- and zinc-containing protein from equine renal cortex. J Biol Chem 235:3460-65, 1960

196. Kagi JHR, Vallee BL: Metallothionein—A cadmium and zinc-containing protein from equine renal cortex—II. Physicochemical properties. J Biol Chem 236:2435-42, 1961

197. Pulido P, Kagi JHR, Vallee BL: Isolation and some properties of human metallothionein. Biochemistry 5:1768-77, 1966

198. Nordberg GF, Nordberg M, Piscator M, Vesterberg O: Separation of two forms of rabbit metallothionein by isoelectric focusing. Biochem J 126:491-98, 1972

199. Shaikh ZA, Lucis OJ: Cadmium and zinc binding in mammalian liver and kidneys. Arch Environ Health 24:419-25, 1972

200. Shaikh ZA, Lucis OJ: Isolation of cadmium-binding proteins. Experientia 27:1024-25, 1971

201. Shaikh ZA, Lucis OJ: The nature and biosynthesis of cadmium binding proteins. Fed Proc 30:238, 1971, abst no. 254

202. Nordberg GF, Piscator M, Lind B: Distribution of cadmium among protein fractions of mouse liver. Acta Pharmacol Toxicol 29:456-70, 1971

203. Shaikh ZA, Lucis OJ: Induction of cadmium-binding protein. Fed Proc 29:298, 1970, abst no. 301

204. Webb M: Binding of cadmium ions by rat liver and kidney. Biochem Pharmacol 21:2751-65, 1972

205. Grasso P: —And last, but not least, cadmium. Food Cosmet Toxicol 13:470-72, 1975

206. Nordberg GF, Goyer R, Nordberg M: Comparative toxicity of cadmium-metallothionein and cadmium chloride on mouse kidney. Arch Pathol 99:192-97, 1975

207. Fluharty AL, Sanadi DR: On the mechanism of oxidative phosphorylation—IV. Mitochondrial swelling caused by arsenite in combination with 2,3-dimercaptopropanol and by cadmium ion. Biochemistry 1:276-81, 1962

208. Jacobs EE, Jacob M, Sanadi DR, Bradley LB: Uncoupling of oxidative phosphorylation by cadmium ion. J Biol Chem 223:147-56, 1956

209. Mustafa MG, Cross CE: Pulmonary alveolar macrophage—Oxidative metabolism of isolated cells and mitochondria and effect of cadmium ion on electron- and energy-transfer reactions. Biochemistry 10:4176-85, 1971

210. Barron ESG, Kalnitsky G: The inhibition of succinoxidase by heavy metals and its reactivation with dithiols. Biochem J 41:346-51, 1947

211. Harkonen M, Kormano M: Acute cadmium-induced changes in the energy metabolism of the rat testis. J Reprod Fertil 21:221-26, 1970

212. Singhal RL, Merali Z, Kacew S, Sutherland DJB: Persistence of cadmium-induced metabolic changes in liver and kidney. Science 183:1094-96, 1974

213. Rutman JZ, Meltzer LE, Kitchell JR, Rutman RJ, George P: Effect of metal ions on in vitro gluconeogenesis in rat kidney cortex slices. Am J Physiol 208:841-46, 1965

214. Sutherland DJB, Tsang BK, Merali Z, Singhal RL: Testicular and prostatic cyclic AMP metabolism following chronic cadmium treatment and subsequent withdrawal. Environ Physiol Biochem 4:205-13, 1974

215. Ribas-Ozonas B, Dean-Guelbenzu M, Santos-Ruiz A: Inhibitory effect of cadmium on alkaline phosphatase of kidney and prostate of guinea-pig, in Mills CF (ed): Trace Element Metabolism in Animals. Proceedings of WAAP/IBP International Symposium, Aberdeen, Scotland, July 1969. Edinburgh and London, E & S Livingstone, 1970, pp 173-76

216. Supplee WC: Production of zinc deficiency in turkey poults by dietary cadmium. Poult Sci 41:827-28, 1961

217. Cotzias GC, Borg DC, Selleck B: Specificity of zinc pathway in the rabbit—Zinc-cadmium exchange. Am J Physiol 201:63-66, 1961

218. Cotzias GC, Borg DC, Selleck B: Virtual absence of turnover in cadmium metabolism—Cd^{109} studies in the mouse. Am J Physiol 201:927-30, 1961

219. Hill CH, Matrone G, Payne WL, Barber CW: In vivo interactions of cadmium with copper, zinc and iron. J Nutr 80:227-35, 1963

220. Bunn CR, Matrone G: In vivo interactions of cadmium, copper, zinc and iron in the mouse and rat. J Nutr 90:395-99, 1966

221. Lease JG: Effect of graded levels of cadmium on tissue uptake of ^{65}Zn by the chick over time. J Nutr 96:294-302, 1968

222. Parizek J, Benes I, Kalouskova J, Babicky A, Lener J: Metabolic interrelations of trace elements—The effect of zinc salts on the survival of rats intoxicated by cadmium. Physiol Bohemoslov 18:89-93, 1969

223. Petering HG, Johnson MA, Stemmer KL: Studies of zinc metabolism in the rat—I. Dose-response effects of cadmium. Arch Environ Health 23:93-101, 1971

224. Starcher BC: Studies on the mechanism of copper absorption in the chick. J Nutr 97:321-26, 1969

225. Evans GW, Majors PF, Cornatzer WE: Mechanism for cadmium and zinc antagonism of copper metabolism. Biochem Biophys Res Commun 40:1142-48, 1970

226. Gunn SA, Gould TC, Anderson WAD: Protective effect of estrogen against vascular damage to the testis caused by cadmium. Proc Soc Exp Biol Med 119:901-05, 1965

227. Gunn SA, Gould TC, Anderson WAD: Mechanisms of zinc, cysteine and selenium protection against cadmium-induced vascular injury to mouse testis. J Reprod Fertil 15:65-70, 1968

228. Parizek J, Benes I, Ostadalova I, Babicky A, Benes J, Lener J: Metabolic interrelations of trace elements—The effect of some inorganic and organic compounds of selenium on the metabolism of cadmium and mercury in the rat. Physiol Bohemoslov 18:95-103, 1969

229. Holmberg RE Jr, Ferm VH: Interrelationships of selenium, cadmium, and arsenic in mammalian teratogenesis. Arch Environ Health 18:873-77, 1969

230. Ithakissios DS, Ghafghazi T, Mennear JH, Kessler WV: Effect of multiple doses of cadmium on glucose metabolism and insulin secretion in the rat. Toxicol Appl Pharmacol 31:143-49, 1975

231. Ghafghazi T, Mennear JH: The inhibitory effect of cadmium on the secretory activity of the isolated perfused rat pancreas. Toxicol Appl Pharmacol 31:134-42, 1975

232. Nomiyama K, Sugata Y, Yamamoto A, Nomiyama H: Effects of dietary cadmium on rabbits—1. Early signs of cadmium intoxication, Toxicol Appl Pharmacol 31:4-12, 1975

233. Axelsson B, Piscator M: Renal damage after prolonged exposure to cadmium—An experimental study. Arch Environ Health 12:360-73, 1966

234. Sporn A, Dinu I, Stoenescu L: Influence of cadmium administration on carbohydrate and cellular energetic metabolism in the rat liver. Rev Roum Biochim 7:299-305, 1970

235. Ginn JT, Volker JF: Effect of cadmium and fluorine on the rat dentition. Proc Soc Exp Biol Med 57:189-91, 1944

236. Leicester HM: The effect of cadmium on the production of caries in the rat. J Dent Res 25:337-40, 1946

237. Occupational Exposure to Inorganic Arsenic (New Criteria-1975): Criteria for a Recommended Standard. US Dept of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, 1975

238. Neumann AJ: Toxic hazards in industry as illustrated by cadmium. Can J Public Health 52:443-45, 1961

239. Fitzgerald JJ, Detwiler CG: Optimum particle size for penetration through the Millipore filter. Arch Ind Health 15:3-8, 1957

240. Lindeken CL, Petrock KF, Phillips WA, Taylor RD: Surface collection efficiency of large-pore membrane filters. Health Phys 10:495-99, 1964

241. Lippmann M: Filter media for air sampling, in American Conference of Governmental Industrial Hygienists: Air Sampling Instruments for Evaluation of Atmospheric Contaminants, ed 4. Cincinnati, ACGIH, 1972, pp N-2 to N-15

242. Thompson RJ, Morgan GB, Purdue LJ: Analysis of selected elements in atmospheric particulate matter by atomic absorption. At Absorpt Newsl 9:53-57, 1970

243. Balzer JL: Inertial and gravitational collectors, in American Conference of Governmental Industrial Hygienists: Air Sampling Instruments for Evaluation of Atmospheric Contaminants, ed 4. Cincinnati, ACGIH, 1972, pp 0-2 to 0-9

244. Lippmann M, Kydonieus A: A multi-stage aerosol sampler for extended sampling intervals. Am Ind Hyg Assoc J 31:730-37, 1970

245. Hosey AD, Kusnetz HL: General principles in evaluating the occupational environment, in Powell CH, Hosey AD (eds): The Industrial Environment—Its Evaluation and Control—Syllabus, PHS publication No. 614. US Dept of Health, Education, and Welfare, Public Health Service, Bureau of Occupational Safety and Health, 1965, pp B-1-1 to B-1-8

246. Cholak J, Hubbard DM: Determination of cadmium in biological material—Spectrographic, polarographic, and colorimetric methods. Ind Eng Chem, Anal Ed 16:333-36, 1944

247. Broadhead J, Hills GJ: Polarography, in Browning DR (ed): Electrochemical Methods. London, McGraw-Hill Publishing Co Ltd, 1969, chap 5

248. American Standards Association: American Defense Emergency Standard—Allowable Concentration of Cadmium, Z37.5-1941. New York, American Standards Association, 1941, 6 pp

249. Saltzman BE: Colorimetric microdetermination of cadmium with dithizone—With improved separation of interfering metals. Anal Chem 25:493-96, 1953

250. Lener J, Bibr B: Determination of traces of cadmium in biological materials by atomic absorption spectrophotometry. J Agric Food Chem 19:1011-13, 1971

251. Beyer M: Preparation of metallic air pollutants for atomic absorption analysis. At Absorpt Newsl 8:23-24, 1969

252. Matson WR, Griffin RM, Schreiber GB: Rapid sub-nanogram simultaneous analysis of Zn, Cd, Pb, Cu, Bi and Tl, in Hemphill DD (ed): Trace Substances in Environmental Health—IV. Columbia, Mo, University of Missouri, 1971, pp 396-406

253. Schroeder HA: Cadmium, Zinc and Mercury, Air Quality Monograph No. 70-16. Washington, DC, American Petroleum Institute, 1972, 40 pp

254. Pulido P, Fuwa K, Vallee BL: Determination of cadmium in biological materials by atomic absorption spectrophotometry. Anal Biochem 14:393-404, 1966

255. Cadmium in Air—Tentative Method of the Physical and Chemical Analysis Branch, P&CAM 151. Cincinnati, US Dept of Health, Education, and Welfare, Public Health Service, National Institute for Occupational Safety and Health, 1972

256. Lehnert G, Klavis G, Schaller KH, Haas T: Cadmium determination in urine by atomic absorption spectrometry as a screening test in industrial medicine. Br J Ind Med 26:156-58, 1969

257. Vigil TS: Industrial hygiene aspects of a vacuum metalizing operation with cadmium. Am Ind Hyg Assoc J 32:203-08, 1971

258. American Conference of Governmental Industrial Hygienists, Committee on Industrial Ventilation: Industrial Ventilation—A Manual of Recommended Practice, ed 14. Lansing, Mich, ACGIH, 1974

259. American National Standards Institute Inc: Practices for Respiratory Protection, ANSI Z88.2-1969. New York, ANSI, 31 pp

260. American National Standards Institute Inc: Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.2-1971. New York, ANSI, 1972, 63 pp

261. American National Standards Institute Inc: Acceptable Concentrations of Cadmium Fume and Cadmium Dusts, Z37.5. New York, ANSI, 1970, 11 pp

262. Special Reports—Threshold Limit Values for 1956, Adopted at the 18th Annual Meeting of the Americal Conference of Governmental Industrial Hygienists, Philadelphia, Pa, April 21-24, 1956. Arch Ind Health 14:186-89, 1956

263. American Conference of Governmental Industrial Hygienists: Threshold Limit Values for 1965, Adopted at the 27th Annual Meeting of the American Conference of Governmental Industrial Hygienists, Houston, Texas, May 2-4, 1965. Cincinnati, ACGIH, 1965, pp 7, 12

264. American Conference of Governmental Industrial Hygienists: Threshold Limit Values for 1967—Recommended and Intended Values, Adopted at the 29th Annual Meeting of the American Conference of Governmental Industrial Hygienists, Chicago, Illinois, May 1-2, 1967. Cincinnati, ACGIH, 1967, p 7

265. American Conference of Governmental Industrial Hygisnists: Threshold Limit Values of Airborne Contaminants and Intended Changes, Adopted by ACGIH for 1970. Cincinnati, ACGIH, 1970, p 7

266. American Conference of Governmental Industrial Hygienists: Threshold Limit Values for Chemical Substances in Workroom Air, Adopted by ACGIH for 1973. Cincinnati, ACGIH, 1973, pp 12,36

267. American Conference of Governmental Industrial Hygienists: Threshold Limit Values for Chemical Substances in Workroom Air, Adopted by ACGIH for 1974. Cincinnati, ACGIH, 1974, pp 12, 37

268. American Conference of Governmental Industrial Hygienists: Threshold Limit Values for Chemical Substances in Workroom Air, Adopted by ACGIH for 1975. Cincinnati, ACGIH, 1975, pp 12, 37, 40-41

269. American Conference of Governmental Industrial Hygienists: Documentation of Threshold Limit Values—Supplements for Those Substances Added or Changed Since 1971. Cincinnati, ACGIH, 1974, p 292

270. American Conference of Governmental Industrial Hygienists: Documentation of the Threshold Limit Values for Substances in Workroom Air, ed 3. Cincinnati, ACGIH, 1971, pp 35-36

271. Bonnell JA: Cadmium poisoning . Ann Occup Hyg 8:45-50, 1965

272. National Board of Occupational Safety and Health: Limit Values—Directions concerning limit values for air contaminants at places of work—Directions No. 100. Translation issued by the National Board of Occupational Safety and Health, Sweden, October 1974, p 15

273. Roschin AV, Timofeevskaya LA: Chemical substances in the work environment—Some comparative aspects of USSR and US hygienic standards. Ambio 4:30-33, 1975

274. Permissible Levels of Toxic Substances in the Working Environment —6th Session of the Joint ILO-WHO Committee on Occupational Health, Geneva, June 4-10, 1968, Occupational Safety and Health Series No. 20. Geneva, International Labour Office, 1970, pp 189, 194, 212, 217, 223, 230

275. Evrin P-E, Peterson PA, Wide L, Berggard I: Radioimmunoassay of β_2-microglobulin in human biological fluids. Scand J Clin Lab Invest 28:439-43, 1971

276. Sevier ED, Reisfeld RA: Semi-automatic solid-phase double-antibody radioimmunoassay for β_2-microglobulin. Immunochemistry 13:35-37, 1976

277. Piscator M: Cadmium toxicity—Industrial and environmental experience. Paper presented at the 17th International Congress on Occupational Health, Buenos Aires, Argentina, 1972

278. American Industrial Hygiene Association-American Conference of Governmental Industrial Hygienists: Respiratory Protective Devices Manual. Ann Arbor, Michigan, Braun and Brumfield Inc, 1963, 162 pp

279. Public Health Service Drinking Water Standards, 1962, PHS Publication No. 956. US Dept of Health, Education, and Welfare, Public Health Service, 1962, pp 29-31

280. Henry RJ, Sobel C, Segalove M: Turbidimetric determination of proteins with sulfosalicylic and trichloroacetic acids. Proc Soc Exper Biol Med 92:748-51, 1956

281. Meulemans O: Determination of total protein in spinal fluid with sulphosalicylic acid and trichloroacetic acid. Clin Chim Acta 5:757-61, 1960

282. McGarry E, Sehon AH, Rose B: The isolation and electrophoretic characterization of the proteins in the urine of normal subjects. J Clin Invest 34:832-44, 1955

283. Piscator M: Proteinuria in chronic cadmium poisoning—2. The applicability of quantitative and qualitative methods of protein determination for the demonstration of cadmium proteinuria. Arch Environ Health 5:325-32, 1962

284. Piscator M: Proteinuria in Chronic Cadmium Poisoning. Stockholm, K L Beckmans Tryckerier AB, 1966, 29 pp

285. Peterson PA, Evrin P-E, Berggard I: Differentiation of glomerular, tubular, and normal proteinuria—Determinations of urinary excretion of β_2-microglobulin, albumin, and total protein. J Clin Invest 48:1189-98, 1969

286. Mancini G, Carbonara AO, Heremans JF: Immunochemical quantitation of antigens by single radial immunodiffusion. Immunochemistry 2:235-54, 1965

287. Evrin P-E, Wibell L: The serum levels and urinary excretion of β_2-microglobulin in apparently healthy subjects. Scand J Clin Lab Invest 29:69-74, 1972

IX. APPENDIX I

AIR SAMPLING METHOD

Apparatus

(a) A cellulose ester membrane filter of nominal pore size 0.8 μm is recommended.

(b) The filter should be mounted in a holder with a cover to protect it during sampling. One or more holes of approximately 4 mm in diameter must be provided in the cover for airflow during sampling (eg, a Millipore Field Monitor in which the inlet plug has been removed).

(c) Connections between the filter holder and the sampling pump must be made in a manner to prevent leakage.

(d) The air sampling pump must be equipped with a means of indicating flow, either directly by a rotameter or indirectly by a suitably geared motor revolution counter.

(e) The air sampling pump should be calibrated so that flow may be determined to within 5%. A spirometer, wet-test meter, bubble meter, or the equivalent, can be used for calibration (see discussion of calibration). A rotameter may be used as flow indicator but should not be used for calibration of pumps with pulsating flow.

(f) Battery-operated pumps must be capable of at least 4 and preferably 8 hours of continuous operation without recharging.

Sampling Procedure for Determining Worker Exposure

(a) Samples should be taken within 50 cm of the worker's nose and mouth.

(b) Each sample for TWA concentration estimation should be taken for 2 or more hours and combined to obtain a TWA concentration for an entire shift. The most meaningful results will be obtained by combining four 2-hour samples (for an 8-hour shift). A single full-shift sample (8-10 hours), two 4-hour samples, or other combinations of full-shift consecutive samples, are also acceptable.

(c) Partial-period consecutive or intermittent samples, for example a number of 15-minute samples for estimation of TWA and ceiling concentrations, are acceptable if they adequately represent full-shift exposure.

(d) Air samples for TWA determinations should have sample volumes of at least 50 liters. A sampling rate of 1.0-2.0 liter/min for personal samples is recommended. Personal samples may be taken at rates of 0.5-3.0 liters/min.

(e) For each air sample, there should be a record of: the date, time, and place of sampling; the operation(s) being carried out during the sampling; the device used to obtain the sample; the sampling rate and sampling period; the name of the person collecting the sample; and other relevant information. Each sample must be clearly labeled for identification.

Sampling Procedure for Determining Control Effectiveness or Need for Personal Protection

(a) Area samples may be taken with the apparatus used for determining worker exposure, or with electrostatic precipitators.

(b) The sample should be taken at a site representative of the area being contaminated. The site should be identified for future sampling.

Calibration of Sampling Trains

The accurate calibration of a sampling pump is essential for the correct interpretation of the volume indicator. The necessary frequency of calibration is dependent on the use, care, and handling to which the pump has been subjected. In addition to the normally scheduled calibration, pumps should be recalibrated if they have been subjected to misuse, just received from a manufac-

turer, or just repaired. If the pump receives hard usage, more frequent calibration may be necessary.

Ordinarily, pumps should be calibrated in the laboratory before they are used in the field and at frequent intervals if they are used to collect numerous field samples. The accuracy of calibration is dependent on the type of calibrating instrument used as a reference. The choice of calibrating instrument may depend largely upon where the calibration is to be performed. For laboratory testing, a 1- or 2-liter buret or a wet-test meter is recommended, although other standard calibrating instruments, such as a spirometer, Marriott's bottle, or dry-gas meter, can be used.

Instructions for calibration with the soapbubble flowmeter follow. However, if an alternative calibration device is selected, equivalent procedures should be used. The calibration setup for personal sampling pumps with a cellulose filter is shown in Figure XIV-1. Since the flowrate indicated by the flowmeter of the pump is dependent on the pressure drop across the sampling device, a membrane filter with appropriate backup pad, the pump flowmeter must be calibrated while operating with a representative filter and backup pad in the line.

(1) While the pump is running, the voltage of the pump battery is measured with a voltmeter to assure that the battery is charged adequately for calibration.

(2) Place the cellulose membrane filter with backup pad in the filter cassette.

(3) The calibration setup is assembled as shown in Figure XIV-1.

(4) The pump is turned on and the inside of the soapbubble meter is moistened by immersing the buret in the soap solution and drawing bubbles up the tube until they are able to travel the entire length of the buret without bursting.

(5) The pump is adjusted to provide a flowrate of 2.0 liters/min.

(6) The water manometer is checked to ensure that the pressure drop across the sampling train does not exceed 13 conventional inches of water (3.23 kPa) at 2 liters/min.

(7) A soapbubble is started up the buret and the time it takes the bubble to travel a minimum of 1.0 liter is measured with a stopwatch.

(8) The procedure in (7) above is repeated at least three times, the results are averaged, and the flowrate is calculated by dividing the volume between the preselected marks by the time required for the soapbubble to travel the distance.

(9) Data recorded for the calibration should include the volume of air measured, elapsed time, pressure drop, air temperature, atmospheric pressure, serial number of the pump, date, and name of the person performing the calibration.

X. APPENDIX II

ENVIRONMENTAL ANALYSIS

Determination of Cadmium in Air Samples by Atomic Absorption Spectroscopy

(a) Principle of the Method

Airborne cadmium dust and fume samples are collected on cellulose ester membrane filters or other collection systems as described in Appendix I. The filter samples are wet-ashed, using nitric acid. Analysis is performed by aspiration of the ashed sample solution into the flame of an atomic absorption spectrophotometer, and comparing the instrument response to that of a standard.

(b) Range and Sensitivity

The sensitivity in conventional flame atomic absorption may be 10-25 ng Cd/ml/0.0044 absorbance units, with detection limits as low as 1 ng Cd/ml, depending on operating conditions and instrumental variations. Using a sensitivity of 20 ng Cd/ml with an air sample of 100 liters (eg, 100 minutes at 1 liter/min) and a final liquid volume of 5 ml, the sensitivity is 1 μg Cd/cu m. For these same air and liquid volumes, the linear response range extends up to 100 μg Cd/cu m (final liquid concentration of 2 μg Cd/ml). Samples may be diluted to provide cadmium concentrations in this range.

(c) Interferences, Precision, and Accuracy

Interferences with this method are not normally encountered in the analysis of air samples. The precision for spiked samples has been determined to be 4% relative standard deviation; a larger deviation could be expected for "real" samples, using a similar method.[255] The accuracy has not been determined; however, recoveries of 90% were reported, using 20 replicates.[251] Collaborative testing has not been performed. The dependability of a similar procedure has been tested[255] and is discussed in Chapter IV.

(d) Advantages and Disadvantages of the Method

Analysis can be performed quickly and accurately by a technician experienced in trace analysis. Atomic absorption instrumentation, although not available in all laboratories, is becoming increasingly popular. The speed of the analysis by this method is a distinct advantage.

(e) Reagents and Apparatus

American Chemical Society (ACS) reagent grade chemicals or materials of similar quality are required.

(1) Concentrated nitric acid: redistilled or of trace metal quality. Use in subsequent steps where nitric acid is designated.

(2) Water: double distilled or distilled deionized.

(3) Standard cadmium solution: 1000 μg/ml. Dissolve 1.000 g of metallic cadmium in nitric acid and dilute to 1 liter in a volumetric flask with sufficient water and nitric acid to yield a solution containing 10% nitric acid. This solution is commercially available.

(4) Atomic absorption apparatus with a cadmium hollow cathode lamp, readout accessory, and gas supply system. Operating conditions recommended by the manufacturer should be followed for gas flow rates and other instrumental variables. The resonance line for cadmium is 2,288 Angstroms.

(5) Hot plate, capable of 300 C.

(f) Quality Control

Establishment and maintenance of total analytical quality control systems to assure continued precision and accuracy of laboratory reports include, as appropriate, these requirements:

(1) Each test must be checked on each day of use.

(2) At least one standard (it may be an instrument standard) and one control sample (working value established and run through the entire analytical procedure) should be included with each run of unknown samples. Where the

control sample is not subject to the interferences in the unknown samples, a previously run unknown should be included as a blind check sample. A blank sample (no added amount of the constituent being determined) should also be run to aid in detecting reagent contamination and other problems important near the lower limit of operation of the method.

(3) If the results on the standard, control, blank, or recycle samples are not within acceptable limits, the entire batch of analyses must be repeated and consideration should be given to the nonacceptance of samples where there is only enough material for a single analysis. There may be situations where this policy is waived. Consideration of the consequences of reporting results when the analytical system is apparently "out of control" should minimize such waivers.

(g) Procedure

(1) Trace Analysis Precautions

All glassware should be thoroughly cleaned and rinsed. Cleaned glassware should be soaked overnight in 10% nitric acid or one-half hour in 50% nitric acid prior to use. Glassware taken from routine laboratory use should be checked for cadmium leachability before it is integrated into the trace analysis system. Note that it is sometimes the case that previous use will make glassware unsuitable for trace analysis.

Analysts are cautioned concerning the potential for contamination of samples by smoking. Hands should be washed and smoking forbidden in the trace analysis facility.

(2) Standardization

Standards are prepared from the 1,000 μg/ml standard solu- tion by serial dilution with 1% nitric acid. Because of the loss of trace metals to glassware or plastic, dilute standards should be made daily unless in-house data show no depletion when compared with fresh standards. Standards are prepared in the 0.02 to 2 μg/ml range; standards should preferably bracket the samples. Aspirate the standards into the flame and record the instrument response. Prepare a graph of the results by plotting the absorbance vs concentration for each standard. Other instrumental output, such as percent absorption, may be used over a narrow range of concentrations. Instruments with devices that read directly in terms of concentration are also suitable.

(h) Analysis of Samples

Sample, control sample (working value previously established by carrying through entire analytical procedure), and blank are placed in suitable acid-washed vessels. For personal samplers employing 37 mm or similar filters, 50-ml Griffen beakers are suitable. Next, 3 ml of concentrated nitric acid is added and the vessel is covered with a watch glass. Each sample is heated on a hot plate in an exhaust hood until the volume of nitric acid is reduced to approximately 0.5 ml and is pale yellow or water white. Further additions of nitric acid may be necessary for complete oxidation of the filter. The cooled sample is transferred to a suitable volumetric vessel, after rinsing the watch glass. A 5-ml graduated cylinder has been employed successfully. The transfer and volume adjustment are effected with 1% nitric acid solution.

The resulting blank, control and sample solutions are aspirated into the flame of the instrument and the instrument response recorded. Samples may be diluted or concentrated to correspond to the standards. If concentration is necessary, the aspiration flow rate should be checked to assure that it is comparable to those for the standards.

(i) Calculations

Absorbances of sample and blank solutions are converted to concentration values by comparison with a curve of absorbance vs concentration prepared from the standards. The blank, which represents the level of contamination in the system, is subtracted from the sample value. The concentration of cadmium in the environmental sample is determined by the following formula:

$$\mu\text{g Cd/cu m} = \frac{\text{Cd} \times \text{S}}{\text{V}}$$

where Cd = Sample concentration minus blank concentration from standard curves, in μg Cd/ml

S = Solution volume, in ml

V = Volume of air sample, in cubic meters