KENNETH H. CHASE, MD, FACPM
PETER G. SHIELDS, MD

MEDICAL SURVEILLANCE OF HAZARDOUS WASTE SITE WORKERS EXPOSED TO POLYCHLORINATED BIPHENYLS (PCBs)

Kenneth H. Chase, MD, FACPM
Washington Occupational Health Associates, Inc. (WOHA)
Washington, DC

Peter G. Shields, MD
Laboratory of Human Carcinogenesis
National Cancer Institute
Bethesda, Maryland

Reprint requests to:
Kenneth H. Chase, MD, FACPM
Washington Occupational Health Associates, Inc.
1120 19th Street, NW, Suite 410
Washington, DC 20036

Polychlorinated biphenyls (PCBs) are chlorinated organic compounds comprising 209 isomers among 10 different congeners. Because of their fire-resistant and dielectric properties, PCBs were used extensively in electrical equipment such as transformers and capacitors. Less commonly, they were used in pesticides, carbonless copier paper, fluorescent light ballast, and other products. Commercial PCB mixtures produced in the United States were sold by Monsanto under the trade name of Aroclors.

PCBs are relatively resistant to biodegradation and, at low levels, are ubiquitous within the environment. Measurable levels have been reported in animals and fish around the world. Under the Toxic Substances Control Act (TSCA), the United States Congress banned further manufacture of PCBs beyond 1979.

A potential for occupational exposure to PCBs still exists within the electrical utility industry, especially where PCB-containing equipment has been serviced. PCBs can also be found at hazardous waste sites, in sewage sludge, and in soot from transformer fires. Absorption of PCBs in workers exposed to large amounts of PCBs occurs mainly through the skin,[1] although the potential for dermal absorption exists in other groups as well.[3] Consumption of PCB-contaminated fish is a major source of nonoccupational exposure.[20] As PCBs are relatively nonvolatile, inhalation is usually not a significant route of absorption.[26]

OCCUPATIONAL MEDICINE: State of the Art Reviews—
Vol. 5, No. 1, January–March 1990. Philadelphia, Hanley & Belfus, Inc.

HEALTH EFFECTS

The health effects of PCBs have been recently reviewed by Kimbrough.[19] Clinical manifestations in workers with documented exposure to PCBs are limited to skin disorders such as chloracne and transient dermatitis.[12,30,36,39] Laboratory abnormalities of unknown clinical significance include alterations in liver-associated enzymes.[7,12,30] One report suggested an increased prevalence of enlarged livers,[30] but this has not been confirmed in numerous other studies.[7,13] An association between serum PCBs and lipid levels has been reported.[7,11,25] While it was originally believed that PCB exposure affected lipid metabolism,[3,38] more recent analyses suggest that the association is more likely to represent partitioning of PCBs in serum.[11,15,25] Alterations reported include a positive correlation of the PCB blood level with serum triglycerides and total cholesterol[3,7,25,38] and increased correlation with high density lipoproteins.[38] However, results have not been consistent.

Other effects associated with PCB exposure have been sporadically reported. These include hypertension, reported in one study,[21] a finding later characterized as uncertain by the author and not identified in numerous other studies;[7,13,30,40] altered pulmonary function studies,[43] which were not correlated with clinical findings and later established as normal in that same and other populations;[12,24] headaches and various constitutional complaints, which, when formally controlled for, lose their statistical significance;[13,14] and accelerated drug metabolism by the liver reported in one study2 and normal metabolism in another.[12]

Mortality studies of populations with occupational PCB exposure have not shown a consistent increase in rates for total deaths, cancer, or atherosclerotic cardiovascular disease. Brown reported an increased rate of death from cancer of the liver, biliary tract, and gallbladder as a group.[5] Interpretation of these reported associations is difficult, since Brown reports hospital and pathological reports that conflict with the diagnoses provided by the corresponding death certificates. Further, no evidence of a dose-response relationship or appropriate latency is provided. Bertazzi studied capacitor workers in Italy and reported an increased incidence of hematological and gastrointestinal tumors.[4] However, many of the reported cases had only brief exposure and latency. Gustavsson, in a study of Swedish capacitor workers, did not find any statistically significant increases in mortality.[16]

In 1968 and 1978, occurrences in Japan and Taiwan, respectively, led to the ingestion of rice oil contaminated with PCBs, polychlorinated dibenzofurans (PCDFs), terphenyls and quaterphenyls. Multiple skin findings, respiratory ailments, neurological findings, altered immune system testing, and other constitutional complaints were reported.[8,9,27,28,37,42] These two incidents are commonly referred to as Yusho and YuCheng. It has been shown, however, that the likely etiological agents were PCDFs and contaminants other than PCBs.[17,18,22,31,35,41]

BIOLOGICAL MONITORING

PCB levels can be measured in the blood, fat, and other tissues. The levels of PCBs in blood and fat have been correlated to duration of exposure.[7,13,45] PCBs are more highly concentrated in fat than in blood, owing to their lipophilia.

It is imperative when performing biological monitoring that the clinical laboratory be carefully chosen. The variability of assays, methods, expertise, and interpretation can be great.[23] While most laboratories utilize packed column gas chromatography and report results as a total amount of PCBs matched to Aroclor type, the method can be subject to considerable error.[6,34] Problems arise

in extraction techniques, clean-up procedures, and with interfering substances such as chlorinated pesticide residues. In our practice, we have performed quality control analysis by submitting PCB-spiked blood specimens to various laboratories for analysis. These specimens can be obtained from the Bureau of National Standards.

Research laboratories have expended considerable effort in improving sensitivity and analysis based upon isomer configuration.[34] Animal studies reporting differences in toxicity for different isomers might suggest that such an analysis is also appropriate for humans. High resolution gas chromatography (capillary column) coupled with electron capture detection (ECD) or mass spectroscopy allows for such an analysis.[34] The ECD detection system is recommended by EPA.[10] The availability of chlorobiphenyl congener standards has aided research efforts. Computer-assisted analysis and computation of retention times for various isomers has been proposed in lieu of producing and measuring 209 isomer standards.[33,34] As human studies have not corroborated structure-toxicity relationships, the clinical interpretation of isomer-specific analysis is severely limited and cannot be recommended on a routine basis.

PCB blood levels in nonoccupationally exposed persons are generally below 30 parts per billion.[7,13,20] Fat levels are generally less than 3 parts per million.[7,15] A nationwide program, the National Human Adipose Tissue Study (NHATS), sponsored by the Environmental Protection Agency, has suggested that the number of persons with levels above 3 ppm is declining, whereas the number of persons with detectable levels is increasing.[29] Persons with occupational exposure to PCBs can have blood levels as high as 3.3 ppm and fat levels as high as 33 ppm.[13,38]

MEDICAL SURVEILLANCE

Medical surveillance for hazardous waste site workers exposed to PCBs should identify potential health effects caused by excess exposure as well as indicate who is at greater risk of disease due to co-existent illness. Equally important, surveillance needs to determine if workers are medically qualified to use protective equipment such as respirators and barrier suits. This latter reason strongly influences the nature of medical surveillance in this population. The performance of a thorough baseline history and physical examination will address these issues as well as identify persons with pre-existing exposures.[32] The recommended protocol in Table 1 assumes only a PCB exposure risk at a hazardous waste site. Additional exposures will dictate modifications of the

TABLE 1. Baseline Examination

1. Complete history, including detailed occupational, recreational, family, and social history
2. Complete physical examination (specific attention to skin)
3. Pulmonary function tests
4. Chest radiograph
5. Complete blood count
6. Blood chemistries including liver and lipid profiles
7. Electrocardiogram if over age 40 or if clinically indicated
8. PCB blood level (plasma or serum)

TABLE 2. Follow-up Examination

1. Interval history
2. Physical examination
3. Pulmonary function tests
4. Complete blood cound
5. Blood chemistries
6. PCB blood level (plasma or serum)

protocol. Table 2 lists a suggested protocol for follow-up examinations to be performed yearly or more frequently if exposure is high.

Similar recommendations have been published for hazardous waste site workers exposed to a variety of compounds including PCBs.[32] Every effort should be made to send baseline and follow-up blood studies to the same clinical laboratory. Variability in methods and reporting of normals occurs for PCB analysis as described above as well as for blood counts and chemistries.

REFERENCES

1. Acquavella JF, Hanis NM, Nicolich MJ, Phillips SC: Assessment of clinical, metabolic, dietary, and occupational correlations with serum polychlorinated biphenyl levels among employees at an electrical capacitor manufacturing plant. J Occup Med 28:1177–1180, 1986.
2. Alvares AP, Fischbein A, Anderson KE, Kappas A: Alterations in drug metabolism in workers exposed to polychlorinated biphenyls. Clin Pharmacol Ther 22:140–146, 1977.
3. Baker EL, Landrigan PJ, Glueck CJ, et al: Metabolic consequences of exposure to polychlorinated biphenyls (PCB) in sewage sludge. Am J Epidemiol 112:553–563, 1980.
4. Bertazzi PA, Riboldi L, Pesatori A, et al: Cancer mortality of capacitor manufacturing workers. Am J Ind Med 11:165–176, 1987.
5. Brown DP: Mortality of workers exposed to polychlorinated biphenyls—An update. Arch Environ Health 42:333–339, 1987.
6. Burse VW, Needham LL, Korver MP, et al: Assessment of methods to determine PCB levels in blood serum: Interlaboratory study. J Assoc Off Anal Chem 66:40–45, 1983.
7. Chase KC, Wong O, Thomas D, et al: Clinical and metabolic abnormalities associated with occupational exposure to polychlorinated biphenyls (PCBs). J Occup Med 24: 109–114, 1982.
8. Chen R, Tang S, Miyata H, et al: Polychlorinated biphenyl poisoning: Correlation of sensory and motor nerve conduction, neurologic symptoms, and blood levels of polychlorinated biphenyls, quaterphenyls, and dibenzofurans. Environ Res 37:340–348, 1985.
9. Chia L, Chu F: A clinical and electrophysiological study of patients with polychlorinated biphenyl poisoning. J Neurol Neurosurg Psychiatry 48:894–901, 1985.
10. Cooper SD, Moseley MA: Development and Standardization of Methods for Analysis of Biological Tissues for PCBs. Washington, DC, Environmental Protection Agency, 1984, pp 1–252.
11. Emmett EA: Polychlorinated biphenyl exposure and effects in transformer repair workers. Environ Health Perspect 60:185–192, 1985.
12. Emmett EA, Maroni M, Jefferys J, et al: Studies of transformer repair workers exposed to PCBs. II. Results of clinical laboratory investigations. Am J Ind Med 14:47–62, 1988.
13. Emmett EA, Maroni M, Schmith JM, et al: Studies of transformer repair workers exposed to PCBs. I. Study design, PCB concentrations, questionnaire, and clinical examination results. Am J Ind Med 13:415–427, 1988.
14. Fischbein A, Wolff MS, Lilis R, et al: Clinical findings among PCB-exposed capacitor manufacturing workers. Ann NY Acad Sci 703–715, 1979.
15. Guo YL, Emmett EA, Pellizzari ED, Rohde CA: Influence of serum cholesterol and albumin on partitioning of PCB congeners between human serum and adipose tissue. Toxicol Appl Pharmacol 87:48–56, 1987.
16. Gustavsson P, Hogstedt C, Rappe C: Short-term mortality and cancer incidence in capacitor manufacturing workers exposed to polychlorinated biphenyls (PCBs). Am J Ind Med 10:341–344, 1986.

17. Kashimoto T, Miyata H, Kunita N: The presence of polychlorinated quaterphenyls in the tissues of yusho victims. Food and Cosmetics Toxicology 19:335-340, 1981.
18. Kashimoto T, Miyata H, Kunita S, et al: Role of polychlorinated dibenzofuran in yusho (PCB poisoning). Arch Environ Health 36:321-326, 1981.
19. Kimbrough RD: Human health effects of polychlorinated biphenyls (PCBs) and polybrominated biphenyls (PBBs). Ann Rev Pharmacol Toxicol 27:87-111, 1987.
20. Kreiss K: Studies on populations exposed to polychlorinated biphenyls. Environ Health Perspect 60:193–199, 1985.
21. Kreiss K, Zack MM, Kimbrough RD, et al: Association of blood pressure and polychlorinated biphenyl levels. JAMA 245:2505-2509, 1981.
22. Kunita N, Kashimoto T, Miyata H, et al: Causal agents of yusho. Am J Ind Med 5:45-58, 1984.
23. Lawton RW, Brown JF Jr. Ross MR, Feingold J: Comparability and precision of serum PCB measurements. Arch Environ Health 40:29-37, 1985.
24. Lawton RW, Ross MR, Feingold J: Spirometric findings in capacitor workers occupationally exposed to polychlorinated biphenyls (PCBs). J Occup Med 28:453–456, 1986.
25. Lawton RW, Ross MR, Feingold J, Brown JF Jr: Effects of PCB exposure on biochemical and hematological findings in capacitor workers. Environ Health Perspect 60:165–184, 1985.
26. Lees PSJ, Corn M, Breysse PN: Evidence for dermal absorption as the major route of body entry during exposure of transformer maintenance and repairmen to PCBs. Am Ind Hyg Assoc J 48:257-264, 1987.
27. Lu Y, Wong P: Dermatological. medical, and laboratory findings of patients in Taiwan and their treatments. Am J Ind Med 5:81-115, 1984.
28. Lu Y-C, Wu Y-C: Clinical findings and immunological abnormalities in yusho patients. Environ Health Perspect 59:17–29. 1985.
29. Mack GA, Mohadjer L: Baseline Estimates and Time Trends for Beta-benzene Hexachloride, Hexachlorobenzene, and Polychlorinated Biphenyls in Human Adipose Tissue 1970-1983. Washington, DC, United States Environmental Protection Agency, Office of Toxic Substances, Exposure Evaluation Division, 1985, pp i-A-30.
30. Maroni M, Colombi A, Arbosti G, et al: Occupational exposure to polychlorinated biphenyls in electrical workers. II. Health effects. Br J Ind Med 38:55-60, 1981.
31. Masuda Y, Yoshimura H: Polychlorinated biphenyls and dibenzofurans in patients with yusho and their toxicological significance: A review. Am J Ind Med 5:31–44, 1984.
32. Melius JM: Medical surveillance for hazardous waste workers. J Occup Med 28:679-683, 1986.
33. Mullin MD, Filkins JC: Analysis of polychlorinated biphenyls by glass capillary and packed-column chromatography. In Keith LH (ed): Advances in Identification and Analysis of Organic Pollutants in Water. Ann Arbor, MI, Ann Arbor Science Publishers, 1981, p 187.
34. Mullin MD, Pochini CM, Safe SH, Safe LM: Analysis of PCBs using specific isomer high resolution capillary gas chromatography. In D'Itri FM, Kamrin MA (eds): PCBs: Human and Environmental Hazards. Boston, Butterworth Publishing, 1983, pp 165-176.
35. Nagayama J, Masuda Y, Kuratsune M: Determination of polychlorinated dibenzofurans in tissues of patients with yusho. Food and Cosmetics Toxicology 15:195-198, 1977.
36. Ouw HE, Simpson GR, Siyali DS: Use and health effects of Aroclor 1242, a polychlorinated biphenyl, in an electrical industry. Arch Environ Health July/August:189-194, 1976.
37. Shigematsu N, Ishimaru S, Saito R, et al: Respiratory involvement in polychlorinated biphenyls poisoning. Environ Res 16:92-100, 1978.
38. Smith AB, Schloemer J, Lowry LK, et al: Metabolic and health consequences of occupational exposure to polychlorinated biphenyls. Br J Ind Med 39:361-369, 1982.
39. Stark AD, Costas K, Chang HG, Vallett HL: Health effects of low-level exposure to polychlorinated biphenyls. Environ Res 41:174-183, 1986.
40. Stehr-Green PA, Welty E, Steele G, Steinberg K: Evaluation of potential health effects associated with serum polychlorinated byphenyl levels. Environ Health Perspect 70:255-259, 1986.
41. Takamatsu M, Oki M, Maeda K, et al: PCBs in blood of workers exposed to PCBs and their health status. Am J Ind Med 5:59-68, 1984.
42. Urabe H, Asahi M: Past and current dermatological status of yusho patients. Am J Ind Med 5:5-12, 1984.
43. Warshaw R, Fischbein A, Thornton J, et al: Decrease in vital capacity in PCB-exposed workers in a capacitor manufacturing facility. Ann NY Acad Sci 277–283, 1979.
44. Webb RG, McCall AC: Quantitative PCB standards for electron capture gas chromatography. J Chromatogr Sci 11:366, 1973.
45. Wolff MS, Thornton J, Fischbein A, et al: Disposition of polychlorinated biphenyl congeners in occupationally exposed persons. Toxicol Appl Pharmacol 62:294-306, 1982.