IV. ENVIRONMENTAL DATA AND BIOLOGIC EVALUATION

Environmental Concentrations

Two reports of workroom air concentrations of PCBs appeared in 1954 [186,190]. Puccinelli [186] studied the concentrations in air of a capacitor factory in Italy, using the methods of Elkins [130], and found concentrations in 500-liter air samples of 5.2-6.4 mg/cu m. Miega et al [190] did not report on the analytical methods they used to determine concentrations of PCBs in the breathing zones of workers exposed when a heat exchange unit in a Connecticut factory leaked. From the description of the factory, it is likely that the exposures were largely to vapors; the concentration found was 0.1 mg/cu m.

In 1959, Elkins [130] reported that over a number of years, PCBs in some Massachusetts plants ranged up to 10.5 mg/cu m of air (Table IV-1).

TABLE IV-1

PCB CONCENTRATIONS MEASURED IN MASSACHUSETTS FACTORIES

Process	PCB Concentrations (mg/cu m)	
	Maximum	Average
Capacitor impregnating	10.5	5.8
"	5.5	4.5
"	0.3	0.2
Capacitor soldering	0.9	0.8
Oil mixing	1.1	0.6
Regulator filling	0.2	0.1

Adapted from reference 130

Of 21 air samples collected in capacitor impregnating operations, Elkins considered that hazardous concentrations (>1 ppm for Aroclor 1242; >0.5 ppm for Aroclor 1254) existed in 15. While the sampling and analytical methods used were not documented, Elkins [130] recommended sampling with either a fritted bubbler or two impingers in series, both containing amyl acetate, and analyzing by the sulfur lamp method.

Occupational environmental studies were conducted in five Japanese plants by Hasegawa et al [191]. Kanechlors 200 (predominantly dichlorobiphenyls), 300 (mostly trichlorobiphenyls), and 400 (mostly tetrachlorobiphenyls) were used or manufactured in the plants. Air samples were drawn through filter paper to collect particulate matter and normal hexane to collect vapors and analyzed by GLC. The data are summarized in Table III-7. In the paired samples, the vapor concentrations exceeded the particulate concentrations. One of the plants was a biphenyl recovery plant where PCBs were not used. In this plant, PCB concentrations were <0.02 mg/cu m. In the PCB manufacturing plant, PCB vapor concentrations were 0.026-0.163 mg/cu m, and particulate PCB concentrations were 0.019-0.037 mg/cu m. Higher PCB concentrations were found in the capacitor plants: 0.095-0.965 mg/cu m of vapors, and 0.20-0.65 mg/cu m of particulates. In one particulate sample collected in a capacitor plant after a spill, the PCB concentration was 6.2 mg/cu m.

Staiff et al [243] in a 1974 report were concerned about emissions from burned-out PCB-containing ballasts in fluorescent fixtures in their laboratory. The investigators collected samples in two midget impingers, containing ethylene glycol and connected in series. The samples were analyzed by GLC. PCB concentrations in the air ranged from 0.012 to 0.166

mg/cu m when the ballasts burned out and were 0.002 mg/cu m 3 days later.

In a 1976 report of a survey of Australian workers exposed to Aroclor 1242, Ouw et al [196] listed breathing zone concentrations ranging from 0.32 to 2.22 mg/cu m before corrective measures were taken, and from 0.08 to 0.75 mg/cu m after installing improved ventilation. Breathing zone samples were collected at 30 liters/minute using Greenburg-Smith impingers containing 75 ml of isopropanol. The concentrations found are shown in Table IV-2.

TABLE IV-2

PCB CONCENTRATIONS IN THE AIR INSIDE A CAPACITOR PLANT BEFORE
AND AFTER IMPROVEMENT OF EXHAUST VENTILATION SYSTEM

Areas in the Impregnation Room	PCB Concentrations mg/cu m	
	Before	After
Area in the unloading tank in front of exhaust register from operator's breathing zone	1.44	0.75
Area in the unloading tank not in front of exhaust register	2.22	0.7
General atmosphere near tank	1.08	0.18
Soldering area	0.32	0.08

Adapted from reference 196

Exposures of electrical and materials technicians during 1976 to PCBs contained in materials they tested were evaluated by Levy et al [197]. Air samples were collected on magnesium silicate "Florisil" at 50 ml/minute for

4-8 hours and analyzed by GLC utilizing electron capture detection. Breathing zone samples were collected on a single day from nine employees for 8 hours. The concentrations in the nine breathing zone samples, which would represent TWA exposure concentrations for the day, ranged from 0.014 to 0.073 mg/cu m. Concentrations of PCBs in nine point source samples collected over 4-8 hours on each of 3 days ranged from 0.013 to 0.264 mg/cu m, and in 19 room air samples collected over 4 hours on each of 3 days, from 0.08 to 0.16 mg/cu m.

A plant manufacturing PCBs in the US was surveyed for worker exposure in July 1976 [244]. Three Aroclors (1016, 1242, and 1254) were made in the PCB production area. To begin the process, biphenyl and chlorine were piped into a chlorinator with a catalyst and allowed to react. Two separate groups of chlorinators were used for Aroclors 1242 and 1254. The product resulting from the reaction passed through a purifying operation, or to a distillation column as in the case of converting Aroclor 1242 to Aroclor 1016, and then on to the storage tanks. Mixing tanks were used to give the desired properties to the final product.

Although the operation was outdoors and theoretically a closed system, potential for employee exposure existed when samples were drawn or leaks occurred. Local exhaust ventilation was used in two operations: (1) while filling 55-gallon drums, hoses were placed near the openings, and (2) when employees tested samples drawn from the chlorinators, their work station was equipped with an exhaust fan and hood.

Eleven personal and seven area air samples were taken in the PCB production area for 6-8 hours at a flow rate of 200 cc/minute [244]. PCBs were collected on Florisil, desorbed with hexane, and analyzed by GLC with

EC detection. Aroclor 1016 was the PCB produced on the sampling dates, and it was used as the standard for quantitating airborne PCBs. Personal air sample concentrations of PCBs reported as Aroclor 1016 ranged from 20 to 86 μg/cu m, while PCBs in area samples ranged from 16 to 55 μg/cu m. The data are presented in Table IV-3.

TABLE IV-3

PCB CONCENTRATIONS FOUND IN A PLANT MANUFACTURING PCBs
ON 2 CONSECUTIVE DAYS (μg/cu m)*

Personal Air Samples Job Title	7/21/76	7/22/76
Premium operator	47	20
Second operator	46	43
Column operator	64	51
Still operator	40	86
Standard operator	-	61
Distribution operator	54	36
Area Air Samples		
Location	7/21/76	2/22/76
Drumming	43	51
Temperature testing	25	52
Chlorinators	55	36
Incinerator burner	16	-

*Total sampling time varied from 409 to 455 minutes and sample volumes varied from 67.6 to 201.6 liters.

Adapted from reference 244

Sato and Hasegawa [32] studied concentrations of PCBs in factories that had discontinued their use in production of pressure-sensitive copying paper 2 years earlier. PCB concentrations in the factories had not been determined when PCBs were being used, but were considered [3] to have been similar to those found by Hasagawa et al [196] in capacitor manufacturing plants. The concentrations found by Sato and Haswgawa [32] at the time of sampling ranged from 0.13 to 4.4 µg/cu m. The PCB concentrations in the outdoor air around the factories were 0.043-0.09 µg/cu m [3].

Another study of contamination in factories after PCB use had been discontinued was reported by Fujiwara et al [33]. These investigators found 0.25 mg/cu m in air of a factory that had previously used PCBs in silk glossing. In addition to air contamination, PCBs were found in the dust around machinery and in the floor boards.

PCB concentrations found in the air of some other factories and their surrounding environments in Japan were summarized in 1976 by Tatsukawa [245]. Concentrations found before 1957 in a factory producing transformers and capacitors ranged from 0.39 to 4.5 mg/cu m. The factory was said to have been old-fashioned with bad ventilation [245]. Concentrations found in warehouses for carbonless copying paper in 1972 ranged from 2 to 70 µg/cu m. In the same year, concentrations of 0.04-0.05 µg/cu m were found in a university laboratory where PCBs were used, and concentrations of 0.006-0.12 µg/cu m were found in areas of mills that recycled paper. Background concentrations found in urban areas of Tokyo, Osaka, and Matsuyama City were <0.002-0.04 µg/cu m.

Background concentrations of PCBs in ambient air over the US have been reported in ng/cu m quantities [26,38]. Average concentrations of

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about 100 ng/cu m were found in Florida and Colorado in 1975 [38].

Control of Exposure

The present primary use of PCBs is as dielectric or insulating fluids for electrical capacitors and transformers. Potential hazards of PCBs in these industries result from inhalation and dermal exposures. It is here that engineering controls, such as local exhaust systems, are necessary.

Local exhaust systems should be designed and operated in conformance with American National Standard Z9.2-1971 Fundamentals Governing the Design and Operation of Local Exhaust Systems [246]. Guidelines for handling capacitor and transformer askarels include the following recommendations from the American National Standards Institute (ANSI) [4]: (1) Enclosed systems of sealed piping, properly gasketed joints, valves, containers, and processing chambers should be used for any portion of the operation where askarel temperatures may exceed 55 C; (2) Enclosure should preferably extend to all other portions of the system insofar as practicable; (3) Operations utilizing PCBs should be isolated from other manufacturing areas to avoid cross contamination; (4) Provision should be made for adequate ventilation and regulation of manufacturing operations to avoid open exposure to askarels; (5) When askarels are used at elevated temperatures (especially 55 C or higher), engineering controls must be applied, either by the use of closed systems or by effective local exhaust ventilation with general workroom exhaust.

Durfee et al [247] cited the following potential sources of air emissions of PCBs in transformer and capacitor manufacturing operations: (1) vapor exhaust from stream jet ejectors; (2) evaporation from accidental

spills; (3) evaporation from hot surfaces as part of flood-filling, inspection, or holding operations; (4) vacuum pump exhausts; (5) evaporation from plant waste water.

There are currently no commercially available fluids which can be considered as totally acceptable substitutes for PCBs in the broad range of AC capacitors, nor are there substitute dielectric systems which would satisfy reliability and safety requirements in most applications [28]. Transformers containing PCBs represent only about 5% of the US transformer market, and are used only where safety and reliability are of prime importance. For new installations, building and installation design provisions could be made to accommodate the use of filled, open dry-type, or sealed dry-type transformers. Major construction changes would be required to compensate for the fire resistance of askarel-filled units if existing askarel-filled transformers are to be replaced with oil-filled units of equivalent electrical ratings [4].

Environmental Sampling and Analytical Methods

(a)   Air Sampling

Before discussing the various methods available for sampling airborne PCBs, it is pertinent to discuss the criteria for an ideal sampling device. NIOSH evaluated an industrial worker's exposure and found that sampling in the breathing zone gives a truer picture of actual exposure than does area sampling. The first criterion for an ideal air sampling device then is that it be amenable to personal sampling. In addition, it should be light, compact, and small enough so that workers can pursue their daily activities without being aware of its presence. The second criterion is that the

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sampling device have a sufficient capacity for PCBs to enable the collection of an air sample representative of a typical workday. Thirdly, recovery of PCBs from the sampling device should be quantitative or, at the least, reproducible. Finally, the sample must be stable in or on the sampling device between the time of sampling and the time of analysis. This latter criterion is hardly of concern here due to the general stability of PCBs.

An air sampling procedure using fritted bubblers or impingers filled with toluene was published by ANSI in 1974 [4]. Neither the sampler capacity nor the sampling efficiency had been experimentally evaluated. Where high sampling flow rates or high capacities were required, additional bubblers or impingers in series were recommended.

Bidleman and Olney [248] used porous polyurethane foam for collecting samples of atmospheric PCBs. They found that the polyurethane foam showed excellent collection efficiency (99% or better) for tri-, tetra-, and pentachlorobiphenyls. The authors [248] did not address the matter of sample recovery from the sorbent.

In an environment where carbonless copy paper was being used, Nishiyama et al [249] collected PCBs by drawing the air through a cooled column filled with Shimalite, a gas chromatographic solid support similar to Chromosorb W. The collection efficiency of the device was 95% and the PCBs were eluted from the column with hexane. Other investigators used 5% glycerol-coated Florisil for collecting organochlorine pesticides and PCBs from air [250]. Collection efficiencies were 90-100% for PCBs.

Harvey and Steinhauer [251] collected ambient air samples of PCBs using 0.25% OV-17 silicone oil coated on ceramic saddles (distillation

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column packing). The collection efficiency of this device was 70%. More recently, Giam et al [252] found that sorbent tubes packed with deactivated Florisil could be used for collecting PCBs and phthalates from air [252]. These compounds were found to be effectively retained by Florisil. The authors did not discuss efficiency of recovery.

In 1976, Laveskog and Lindskog [253] described a stack sampling device for chlorinated hydrocarbons which they used for PCB collection. This device utilized glass wool for the collection of particulates followed by a sorbent, 25-40% Apiezon M on Chromosorb W, to collect vapors. The collection efficiency of the column was 99%, and desorption efficiency with absolute ethanol was 87%. The authors investigated charcoal as a sorbent, but found it unsuitable for their purposes since the PCBs could only be recovered by extraction in a soxhlet apparatus with chloroform which in turn could not be used with electron capture detection.

Occupational Safety and Health Administration (OSHA) workers have used charcoal tubes for personal air sampling for PCBs (RG Kupel, written communication, 1976). While the sampling device would be expected to have good capacity for PCBs, recovery from charcoal is not quantitative. Little other information is known about this method.

A NIOSH Standards Completion Program Report [254] indicated that PCBs with 54% chlorine content were effectively trapped on a fibrous glass filter. However, the presence of PCB vapor either apparently was not addressed or was assumed to be negligible. This may not be a valid assumption, particularly since another report from the same program [255] showed that PCBs with 42% chlorine content have appreciable vapor pressure.

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NIOSH has also investigated the method of Giam et al [252], using Florisil as a sampling medium, in industrial environments. Florisil (30/48 mesh) was placed in a tube similar to that used in the charcoal tube method for solvents, 100 mg in the front section and 50 mg in the back. The retention capacity of this sampling device for PCBs was evaluated under laboratory and field conditions, using various vapor generation techniques. In laboratory experiments, PCBs at 10 μg/liter and 75% relative humidity were sampled through a 100-mg Florisil bed at 0.2 liter/minute with no evidence of breakthrough after 4 hours (48 liters). Of 21 samples collected on Florisil in a capacitor plant, only 6 had PCBs on the backup section and all 6 backup sections contained 1% or less of the total PCBs in the tube. The volumes of air sampled ranged up to 61 liters, and PCB concentrations in air as high as 1.5 μg/liter were measured. Other laboratory experiments showed that PCBs could be desorbed quantitatively from Florisil with hexane. Results from Florisil tube and impinger samples taken side by side in the capacitor plant and analyzed with a single commercial PCB product as a standard were statistically similar.

Impingers are not suitable for personal sampling and are inconvenient to use because they must be recharged with the sampling solvent frequently and must be used in series. The handling of absorber solutions is difficult because of the potential for spillage and leakage of the solvent and samples during transport to and from the sampling site. Solid sorbent sampling devices are well suited for personal sampling since they are relatively small, and personnel wearing the devices quickly become unaware of their presence, enabling more representative sampling. Shipment of these devices is relatively simple.

Of the solid sorbent sampling devices discussed, Florisil-filled tubes are deemed the most advantageous because Florisil has a high capacity for PCBs and can be quantitatively desorbed; field evaluations have shown that Florisil-filled tubes are easier to handle and more convenient than impingers. Therefore, the Florisil-filled tube method is recommended for collection of PCBs from air, as detailed in Appendix I.

(b) Analytical

The chemistry of PCBs was extensively reviewed by Hutzinger et al [1], and PCB analytical chemistry has been reviewed by several authors [256-264] but only references pertinent to selection of an analytical method for determination of PCBs in industrial air samples will be discussed here. Of the analytical techniques available, the one most widely used for determining PCBs is GLC with EC detection. This technique is rapid, precise, and very sensitive. The far greater sensitivity of EC detection compared with that of the flame ionization detector (FID) is demonstrated by comparison of their relative responses to various PCB isomers, shown in Table IV-4 [1].

TABLE IV-4

RELATIVE MOLAR RESPONSES OF ELECTRON-CAPTURE AND FLAME-IONIZATION
DETECTORS TO SOME PCBs

| PCB | Relative Molar Response | |
	Electron Capture	Flame Ionization
2-chloro	1.00	1.00
3-chloro	0.20	0.92
4-chloro	1.10	0.87
2,2'-dichloro	5.16	0.99
2,4-dichloro	17.7	0.86
2,6-dichloro	32.0	0.91
3,3'-dichloro	6.10	0.94
3,4-dichloro	15.2	0.86
4,4'-dichloro	5.97	0.81
2,4,4'-trichloro	135	0.78
2,2'4,4'-tetrachloro	106	0.87
2,2'6,6'-tetrachloro	20.6	0.90
3,3'4,4'-tetrachloro	396	0.87
3,3'5,5'-tetrachloro	320	0.85
2,3,4,5-tetrachloro	367	0.87
2,3,5,6-tetrachloro	259	0.71
2,2'4,4'6,6'-hexachloro	347	
3,3'4,4'5,5'-hexachloro	726	
2,2'3,4'5,5'6,6'-octachloro	1,180	
2,2'3,3'5,5'6,6'-octachloro	1,150	
decachloro	1,410	

Adapted from reference 1

During the GLC-EC detection analysis of PCBs, multicomponent mixtures of various PCBs are almost always encountered. The samples analyzed may or may not resemble a commercial PCB mixture. If so, the appropriate commercial PCB mixture can be used as a standard for quantitation; if not, a commercial mixture should not be used. Quantitation cannot be accurate since it is based on incomplete resolution of PCB isomers. Even if complete resolution were possible, all PCB isomers are not available for standards and the specific EC detection response of each isomer would need

to be known.

Many different methods have been used to "quantitate" or estimate PCBs. Heights or areas of one [263], two [264], three [265], or more [266,267], or of all chromatographic peaks [268-270] of a given sample have been used for comparison with standard commercial PCB mixtures. The chief disadvantage of such methods is that when the chromatogram of the sample does not closely resemble that of the standard the estimates are neither precise nor accurate. An improvement upon these methods is the use of mixed PCB standards, as described by Beezhold and Stout [271]. This procedure involves mixing various proportions of different PCB commercial mixtures, such as Aroclor 1242 and Aroclor 1254, and obtaining sets of chromatograms. The chromatogram most closely resembling the sample is selected and the corresponding mixture is used as the standard.

Sawyer [269], in a collaborative study, evaluated the quantitation of PCBs in chicken fat. He found that the use of the total peak area or the sum total of all peak heights gave better results than did the use of selected peaks. The use of mixed standards gave good results when the composition which best duplicated the response pattern of the sample was used. This was adopted as an official method by the Association of Official Analytical Chemists [272].

Using a different approach to standardization, Rote and Murphy [273] produced a standard response curve using Aroclors 1232, 1242, 1248, 1254, 1260, and 1262. This plot was of the total area responses on the GLC trace divided by the weights of the Aroclors injected versus the average number of chlorine atoms in the molecule. The peaks in each chromatogram were identified as to chlorine content per chlorobiphenyl molecule, and

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each sample could then be quantitated using the response curve. The accuracy of this method is not greater than that of the methods previously mentioned, since it has been shown that the response of EC detection varies greatly with the degree of chlorine substitution and also with the relative position of the chlorine substitution [1].

Risebrough et al [274] and Collins et al [268] used dichlorodiphenyl-dichloroethylene (p,p'-DDE) as a standard and assumed that the response of each chlorobiphenyl isomer was equal to that of p,p'-DDE. This method can only be grossly approximate, since the response of EC detection to individual PCB isomers varies greatly [1].

Risebrough et al [274] also reported the use of microcoulometric detection to determine total chlorine content, using a commercial PCB mixture as a standard. Sawyer [269] compared the EC detection with the microcoulmetric and electrolytic conductivity detectors and found that the latter two detectors are subject to more operational problems than is the EC detection.

An analytical method utilizing a computer for the quantitation of PCBs was described by Zobel [275]. This method would not be of value for routine sample analysis in industrial hygiene laboratories because of the expense or unavailability of a computer.

The method of Webb and McCall [276] involves standardization of an Aroclor mixture whose peak-by-peak composition has been determined as weight percentages of the total. Since the response-to-weight factor is known for each peak, the actual weight equivalent of each peak in the sample can be calculated despite vast differences of overall GLC patterns. To utilize this method as a standard procedure, it is necessary that some

agency serve as a central repository for distribution of the reference materials. Presently, standards for Aroclors 1242, 1254, and 1260 as dilute solutions in iso-octane are available from Webb and McCall [276]. However, a fully characterized standard for the widely used Aroclor 1016 is not available. Potential future sources for these types of standards may be either the Association of Official Analytical Chemists or the US Food and Drug Administration. These organizations currently are interested in this method [277] and are planning to test it collaboratively.

The US Environmental Protection Agency has adopted the method of Webb and McCall [276] as a recommended procedure for quantitation of PCBs in industrial effluents [278]. Other investigators have also concluded that this method is the best available method of quantitation [279].

Berg et al [280] investigated the quantitation of PCBs in terms of derivatives. PCBs could be quantitatively converted by catalytic dechlorination to bicyclohexyl. However the authors [280] found that the relatively low level of sensitivity, because bicyclohexyl had to be determined by GLC with FID, was a marked disadvantage. They [280] found that treatment of PCBs with anitmony pentachloride under elevated temperatures and anhydrous conditions gave good yields (85%) of decachlorobiphenyl which could be determined by GLC with EC detection.

Armour [281] evaluated the perchlorination procedure of Berg et al [280] to determine its utility as a routine method for the confirmatory quantitation of PCBs. It was found necessary to modify that procedure because of observed inconsistencies in the efficiency of conversion of Aroclors 1254 (90-100%) and 1242 (30-70%) to decachlorobiphenyl. Armour [281] attributed this to volatilization of the lower molecular weight PCB

components during solvent evaporation before their reaction with antimony pentachloride. The remedy selected was to end evaporation while a small amount (0.1 ml) of solvent still remained, but this rendered the choice of solvents a more critical matter because of possible interferences during the perchlorination step. Chloroform was the solvent chosen because it minimized volatility and reacted favorably at the selected conditions. The increased pressure produced as a result of this substitution of chloroform required discontinuing use of flame-sealed Carius tubes as recommended by Berg et al [280] for containing the elevated temperature-pressure perchlorination reaction. The recommended substitute was a vacuum hydrolysis tube having the same volume specifications (10 mm O.D. X 150 mm), a tight Teflon sealing valve, and a side venting arm [281].

Other modifications devised by Armour [281] included the addition of methanol to the reaction mixture's extract to produce an azeotrope with the residual chloroform which could then be evaporated to a small volume before dilution, preparatory to determination of decachlorobiphenyl. To determine the feasibility of a shortened reaction time, Armour et al tested iron as a catalyst, but decided that although a reaction time of 6 hours with iron catalyst resulted in quantitative (99% average conversion for six Aroclors) and reproducible (83-110%) conversions, the catalytic modification offered little advantage over the overnight procedure.

Perchlorination has been used for the quantitation of PCBs by others [282,283]. While the sole perchlorination product was usually decachlorobiphenyl, there have been reports of undesired byproducts resulting from contamination of the antimony pentachloride with bromide ions [284,285]. Results of NIOSH investigations indicate that this

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contamination problem can be eliminated by vacuum distillation of the antimony pentachloride. Factors for converting decachlorobiphenyl to Aroclors are presented in Table IV-5.

TABLE IV-5

FACTORS TO CONVERT DECACHLOROBIPHENYL TO AN EQUIVALENT AMOUNT OF AROCLOR

Aroclor	Average Molecular Weight	Q*
1221	188.5	0.38
1232	223	0.45
1242	257.5	0.52
1016	257.5	0.52
1248	292	0.59
1254	326.4	0.65
1260	361	0.72
1262	395.3	0.79

*Calculated by dividing the average molecular weight by 499, the molecular weight of decachlorobiphenyl

Adapted from reference 281

From a review of the literature, NIOSH concludes that the simplest method of PCB quantitation involves standardization of samples with single commercial mixtures of PCBs. Should the composition of a sample not closely resemble that of a single commercial PCB mixture, the most accurate and precise method of quantitation available would be that of

perchlorination, which seems to offer the best approach for determining total PCB content in samples when the initial concentrations of individual PCBs are of little or no concern.

NIOSH recommends desorption of PCBs from Florisil with hexane, analysis by GLC, and quantitation of the sample by comparison with a standard PCB mixture of similar composition (Appendix II). If a PCB mixture with a composition similar to that of the sample is not available as a standard, NIOSH recommends converting the sample PCBs to decachlorobiphenyl for quantitation.

The methodology presented in Appendices I and II has been tested with Aroclor 1016 in the laboratory and in practice. Operating parameters found by NIOSH are presented in the Appendices.

Biologic Evaluation

While there is presently no adequate method for biologically monitoring industrial workers for exposure to PCBs, additional research may make feasible the routine measurement of residues of these compounds in blood or other body fluids.