Environmental Health Perspectives
Vol. 60, pp. 121-126, 1985

PCB Levels in Breast Milk: Data from the UNEP/WHO Pilot Project on Biological Monitoring and Some Other Recent Studies

by Stuart A. Slorach* and Reggie Vaz*

The levels of polychlorinated biphenyls (PCBs) in human milk provide an index of exposure of the mother to these compounds and enable the intake by the breast-fed child to be estimated. For valid comparisons between different studies, concentrations should be expressed on a milk fat basis.

In a recently completed UNEP/WHO pilot project on monitoring of organochlorine compounds in human milk in ten countries, great emphasis was placed on analytical quality assurance. To obtain comparable data, a common procedure, that of Sawyer, was adopted for quantitation of PCBs, using Aroclor 1260 as standard. In addition, certain criteria (e.g., age and parity) were established for selection of the mothers to be sampled.

In contrast to the situation with *p,p'*-DDT and *p,p'*-DDE, the levels of PCBs in human milk fat were higher in the European countries and Japan than in China, India and Mexico. In fact, PCBs were not detected in human milk in the latter three countries. Although PCBs were detected in some samples in the USA, the median level was below the limit of detection of the method used there (1 mg/kg fat). The median PCB levels reported from Belgium, Israel, Japan and Yugoslavia were 0.81, 0.45, 0.35 and 0.63 mg/kg fat, respectively. Higher median levels were reported from Sweden and the Federal Republic of Germany (0.97 and 2.1 mg/kg fat, respectively). The German samples were not analyzed by the Sawyer method.

Background

Polychlorinated biphenyls (PCBs) are lipophilic and in the human body they are stored mainly in adipose tissue. The levels in blood, hair and urine are relatively low, often below the levels detectable with methodology suitable for use in human monitoring studies. Thus, such studies generally require invasive techniques, using adipose tissue samples collected during surgery or at autopsy. An alternative approach is to use breast milk, which is the major vehicle for excretion of PCBs in lactating women.

In many countries it has been found that, providing the purpose of the study is properly explained, most lactating women are prepared to provide samples of milk for analysis. A large number of studies on the levels of organochlorine compounds (OCCs), including PCBs, in human milk have been carried out since 1950. In some countries, e.g., Japan and Sweden, a large amount of monitoring data is already available and can be compared with newly generated data to detect trends in levels of exposure.

*Research Department, Swedish National Food Administration, Box 622, S-751 26 Uppsala, Sweden.

A disadvantage of the use of breast milk for monitoring exposure of the general population to PCBs is that only a limited age group of one sex can be investigated. However, in addition to providing a measure of the exposure of the mother to PCBs, data from studies on human milk enable the intake of these compounds by the breast-fed infant to be estimated.

Although a number of studies have been carried out on the correlation between PCB levels in human milk fat, adipose tissue fat, blood and plasma it is difficult to define these relationships. This is an area where further research is needed.

When comparing the results from different studies, it is important to remember that many factors may influence the level of PCBs in human milk. PCBs are present in the fat of milk and the fat content can vary widely. For example, it is higher at the end of each feed ("hind-milk") than at the beginning ("fore-milk") and higher during the middle of the day than early in the morning. Colostrum, the milk produced during the first few days of lactation, contains less fat than mature breast milk. Thus, if the PCB levels are expressed on a whole milk basis, wide variations in levels can be found during a feeding, on different feeding occasions, and at different times after parturition. However, the PCB levels

expressed on a fat basis show much less variation and thus comparisons should be made on this basis. Several other factors (e.g., parity, length of previous lactation periods and dietary habits) can affect the levels of PCBs in breast milk: this is discussed below.

Literature Reviews

In 1976 the World Health Organization (WHO) published an environmental health criteria document (*1*) on PCBs, reviewing among other things the available data on PCB levels in human milk. More recently, Jensen (*2*) has made a thorough and extensive review of the published data on chemical contaminants, including PCBs, in human milk. Nearly all the data on PCBs are from industrialized countries.

UNEP/WHO Pilot Project

A UNEP/WHO Pilot Project on Assessment of Human Exposure to Pollutants through Biological Monitoring has recently been completed. It consisted of two parts. One involved measuring the levels of lead and cadmium in human blood and kidney samples and the other the monitoring of organochlorine compounds (mainly *p,p'*-DDT, *p,p'*-DDE, β-HCH and PCBs) in human milk (*3*). Ten countries produced monitoring data on OCCs: Belgium, Federal Republic of Germany, India, Israel, Japan, Mexico, People's Republic of China, Sweden, USA and Yugoslavia. The Swedish National Food Administration served as the co-ordinating institution for the OCCs component of the project and had scientific responsibility for its implementation.

It was recognized from the outset that there was a great need for analytical quality assurance (AQA) in the project. Procedures for sample collection and handling and analysis vary among laboratories, but the purpose of the project was not to standardize such methods. It was agreed that each participating laboratory could use methods of its own choice, provided they produced results acceptable according to the criteria established.

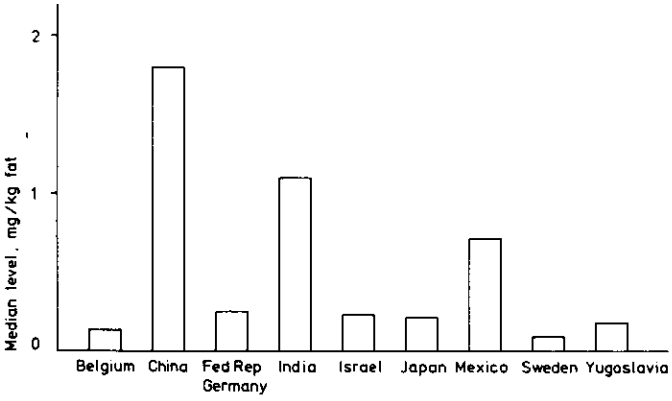

FIGURE 1. Median levels of *p,p'*-DDT in human milk fat in different countries. Data from the UNEP/WHO Pilot Project (*3*). The median level reported by the USA was < 0.1 mg/kg fat (detection limit used there).

The quantitation of PCBs in biological samples presents special problems. The usual approach is to base the calculation on some or all the peaks in the gas chromatogram and comparison with a standard. This is often Aroclor 1254 or 1260 or equivalent technical products, which are highly chlorinated PCB mixtures resembling, but not identical with, the PCB profile usually found in human milk. However, the quantitation is only an approximation because there are differences between the profile of the standard and that in human milk. In the UNEP/WHO project a common procedure, that of Sawyer (*4*), was adopted for quantitation of PCBs, using Aroclor 1260 as standard. However, some laboratories also analyzed the same samples by their usual ("own") method, so that they could compare the results with those found in their earlier studies.

Improvement of the analytical capability of participating laboratories was achieved with the assistance of consultants and by the provision of special training for individual analysts.

The project was divided into two main phases. The first (quality assurance) phase was devoted primarily to training and technical assistance. The second (monitoring) phase was devoted to the actual monitoring of OCCs in human milk, with concurrent AQA. It was agreed that no laboratory should start the analysis of the human milk samples until it had achieved satisfactory results in the quality assurance phase.

In the pre-monitoring phase, three batches of interlaboratory AQA samples (one set of solutions of mixtures of OCCs in isooctane and two sets of spiked cows' milk samples) were analyzed. In addition, each laboratory analyzed five replicates of one spiked cows' milk sample to determine the repeatability of its method. The cows' milk samples were spiked at PCB levels previously reported to occur in human milk in countries with PCB contamination problems. In the monitoring phase, one AQA sample (spiked cows' milk) was analyzed with every five to ten human milk samples as an intralaboratory control. The results of these analyses also gave a measure of the reproducibility of the analytical procedure used. In addition, two sets of interlaboratory AQA samples were analyzed during the monitoring phase. The criterion for acceptance of AQA

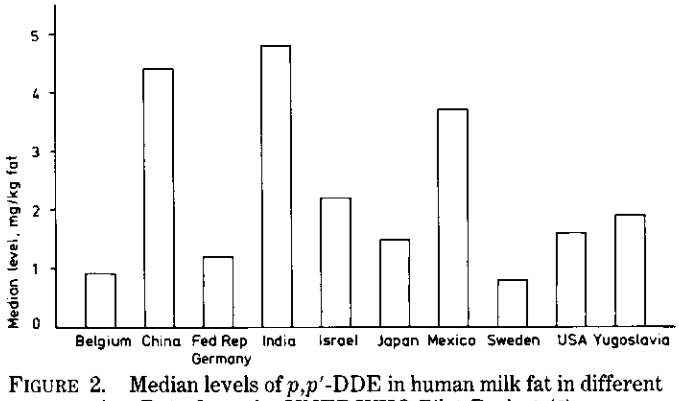

FIGURE 2. Median levels of *p,p'*-DDE in human milk fat in different countries. Data from the UNEP/WHO Pilot Project (*3*).

results was that they should lie within ±30% of the spiked level; in most cases they were within ±20% during the monitoring phase.

In order to improve the comparability of results from the different participating countries, certain criteria were established for selection of the mothers to be sampled, e.g., age and parity. Mothers known to have been occupationally exposed to the OCCs studied were excluded. Samples were collected, mostly during 1981–1982, from at least 50 mothers living in a single geographical area in each country (except for the USA, where samples collected in 22 states in an earlier study were analyzed).

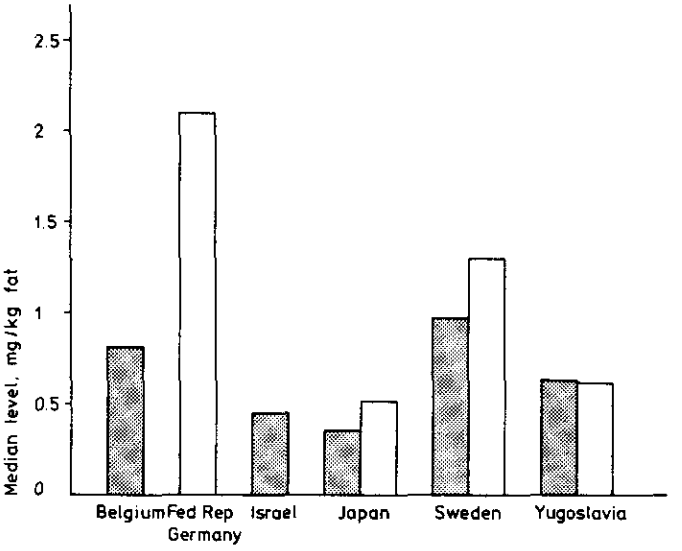

FIGURE 3. Median levels of PCBs in human milk fat determined using the Sawyer method (filled columns) or the laboratory's "own" method (open columns). PCBs were not detected in any samples from China, India or Mexico. The median level reported from the USA was < 1 mg/kg fat (detection limit used there). Data from the UNEP/WHO Pilot Project (*3*).

Data from the project provide an international comparison of the concentrations of certain OCCs in human milk. However, since only a limited number of mothers in a single geographical area in each country have been analyzed, far reaching conclusions concerning intercountry differences in levels cannot be drawn. The results of the quality assurance studies both before and during the actual monitoring provide a measure of the validity and comparability of the results.

In contrast to the situation with *p,p'*-DDT (Fig. 1) and *p,p'*-DDE (Fig. 2), the levels of PCBs in human milk fat were higher in the European countries and Japan than in China, India and Mexico (Fig. 3). In fact, PCBs were not detected in human milk in the latter three countries. In the case of China and India, this was confirmed by analysis of some of the samples in Japan and Sweden. Although PCBs were detected in some samples in the USA, the median level in milk fat was below the level of detection of the analytical method applied there (1 mg/kg fat). The highest PCB levels were reported by the participating institutions in the Federal Republic of Germany and Sweden (median levels 2.1 and 1.3 mg/kg fat, respectively) (Tables 1 and 2).

The data from Osaka in Japan indicate that the levels of PCBs in human milk fat there have decreased slightly during the period 1977–1981. Similarly, the data from Uppsala in Sweden suggest a slight decrease in levels in breast milk fat there between 1978–1979 and 1981. However, the data from Hanau in the Federal Republic of Germany show no indication of a downward trend in PCB levels there, rather the reverse.

The GC pattern of the PCBs found in typical human milk samples collected in the different countries are shown in Figure 4. All the chromatograms were run on the 5% OV 101 column specified in the Sawyer procedure for PCB quantitation (*4*). A chromatogram of the standard (Aroclor 1260) illustrates the numbered peaks

Table 1. Levels of PCBs in the fat of human milk determined by using the Sawyer method and Aroclor 1260 as standard.[a]

	Sample collected			No. of samples			
Country/area	Year(s)	Wks post partum	Mother's age, years	Total	Positive	Fat, % (w/w)	PCBs (Aroclor 1260), mg/kg fat
Belgium (Brussels)	1982	3 (1–37)	26 (17–30)	47	47	2.7 (1.1–6.0)	0.81/1.6 (0.10–2.3)
Israel (Jerusalem)	1981/82	4 (1–16)	26 (19–30)	52	50	3.4 (0.90–7.9)	0.45/1.2 (<0.05[b]–2.1)
Japan (Osaka)	1980/81	13 (5-22)	27 (19–42)	204	204	3.1 (0.89–9.0)	0.35/0.56 (0.10–0.98)
Sweden (Uppsala)	1981	13 (12–15)	27 (21–31)	58	58	2.8 (0.61–5.9)	0.97/1.4 (0.40–1.8)
USA (22 states)	1979	7 (1–75)	28 (19–38)	50	1	2.6 (0.3–6.3)	< 1[b]/< 1[b] (< 1[b]–3)
Yugoslavia (Zagreb)	1981/82	4 (1–22)	26 (18–31)	50	50	3.7 (1.5–7.4)	0.63/0.98 (0.32–1.6)

[a]Medians and ranges are shown and for PCB levels the 90th percentiles. PCBs were not detected in any of the samples from China, India and Mexico.
[b]Limit of detection.

Table 2. Levels of PCBs in the fat of human milk determined using each laboratory's "own" method.[a]

Country/area	Sample collected: Year(s)	Sample collected: Wks post partum	Mother's age, years	No. of samples: Total	No. of samples: Positive	Fat, % (w/w)	PCBs, mg/kg fat
Federal Rep. Germany (Hanau)	1981	1 (1)	25 (15–38)	81	81	3.1 (0.8–6.2)	2.1/4.8 (0.24–10)
Japan (Osaka)	1980/81	13 (5–22)	27 (19–42)	204	204	3.1 (0.89–9.0)	0.51/0.80 (0.16–1.4)
Sweden (Uppsala)	1981	13 (12–15)	27 (21–31)	58	58	2.8 (0.61–5.9)	1.3/1.8 (0.53–2.4)
USA (22 states)	1979	7 (1–75)	28 (19–38)	50	8	2.6 (0.3-6.3)	< 1[b]/2 (< 1[b]–5)
Yugoslavia (Zagreb)	1981/82	4 (1–22)	26 (18–31)	50	50	3.7 (1.5–7.4)	0.62/0.97 (0.30–1.7)

[a]PCBs were not detected in any of the samples from China, India and Mexico. Medians and ranges are shown and for PCB levels the 90th percentiles.
[b]Limit of detection.

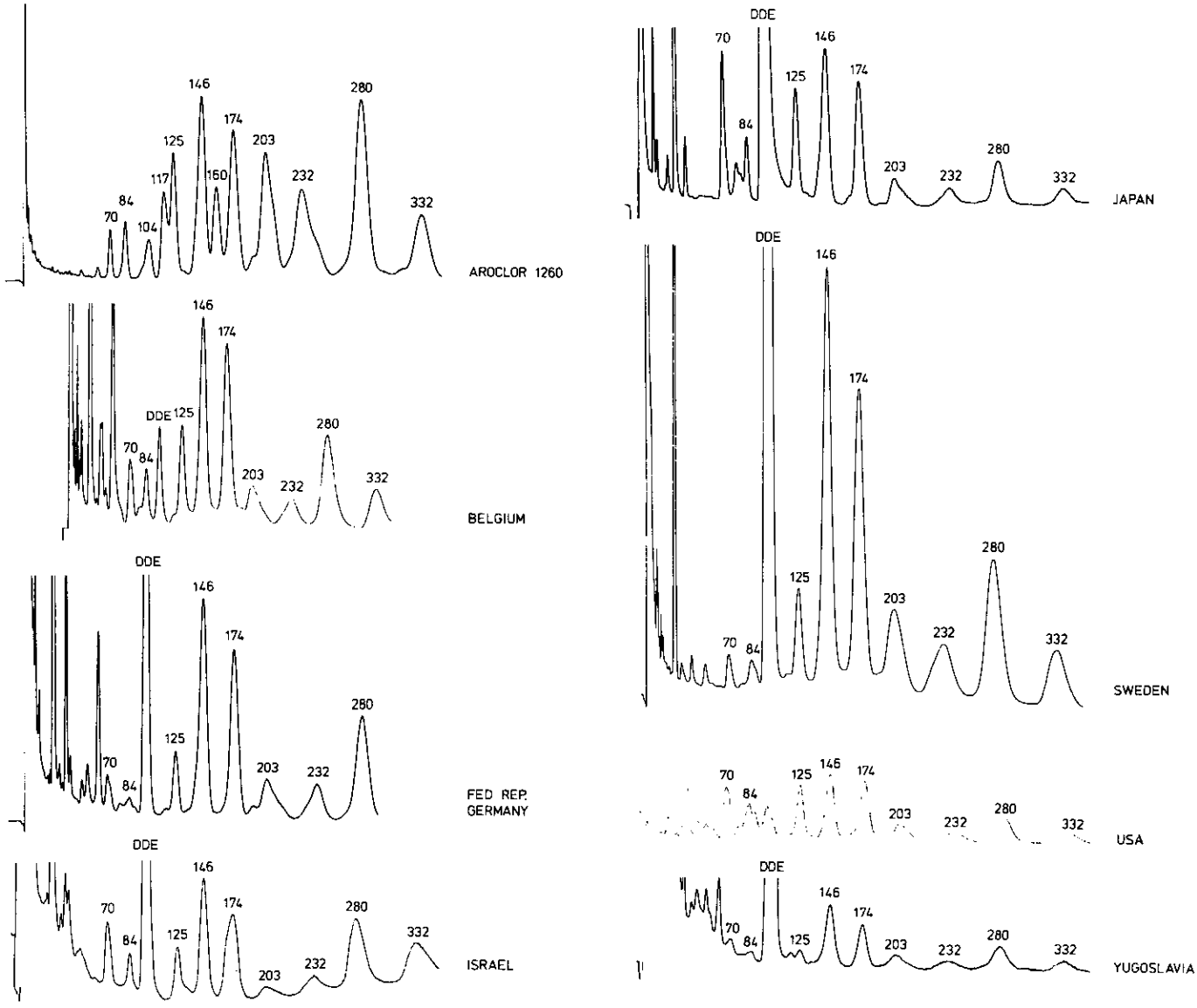

FIGURE 4. Gas chromatograms of Aroclor 1260 standard and PCB fractions from human milk in different countries participating in the UNEP/WHO Pilot Project (*3*). Samples analyzed by the Sawyer method (*4*). Numbered peaks are those used for PCB quantitation. Chromatograms run on 5% OV 101 column.

Table 3. Calculated daily intakes of PCBs by breast-fed infants, assuming a milk consumption of ca. 130 g/kg body weight and a milk fat content of 3.5% (w/w)[a]

		Calculated daily intake, μg/kg body weight					
		Sawyer method			"Own" method		
Country/area	Year	Median	90th percentile	Maximum	Median	90th percentile	Maximum
Belgium (Brussels)	1982	3.6	7.2	10.4	NR[b]	NR[b]	NR[b]
China (Beijing)	1982	NR[b]	NR[b]	NR[b]	<0.45[c]	<0.45[c]	<0.45[c]
Federal Rep. Germany (Hanau)	1981	NR[b]	NR[b]	NR[b]	9.5	22	45
Israel (Jerusalem)	1981/82	2.0	5.4	9.5	NR[b]	NR[b]	NR[b]
Japan (Osaka)	1980/81	1.6	2.5	4.4	2.3	3.6	6.3
Sweden (Uppsala)	1981	4.4	6.3	8.1	5.9	8.1	11
USA (22 states)	1979	<4.5[d]	<4.5[d]	13.5	<4.5[d]	9.0	22.5
Yugoslavia (Zagreb)	1981/82	2.8	4.4	7.2	2.8	4.4	7.7

[a]Results for different methods of PCB analysis shown separately.
[b]Not reported.
[c]PCB level below limit of detection (0.1 mg/kg fat) in all samples.
[d]PCB level below limit of detection (1 mg/kg fat).

that were used to quantify the PCB levels. Inspection of the chromatograms in Figure 4 shows that the PCB profiles in the Aroclor 1260 standard and in the human milk from the different countries are fairly similar. This confirms the suitability of using Aroclor 1260 as a standard in this project. The fact that the GC patterns of PCBs in breast milk samples from different countries are similar is somewhat surprising, since the commercial PCB products released into the environment in different countries differ in composition. In general, the most chlorinated PCBs are the most persistent and most abundant in human tissues. The peaks denoted 146, 174 and 280 dominated in the gas chromatograms shown: these peaks represent heavily chlorinated PCBs.

The intakes of PCBs by the breast-fed infant were calculated assuming that the child consumed 130 g milk/kg body-weight per day and that the milk contains 3.5% (w/w) fat. These assumptions are supported by data from a WHO collaborative study on breast-feeding (*5*). The calculated intakes are shown in Table 3.

Data from Some Other Recent Studies

The results of an extensive study by Norén (*6*) on bulked samples from the Mothers' Milk Center in Stockholm show that the levels of PCBs in human milk fat there have decreased slightly over the period 1978, 1979 and 1980 (median levels 0.88, 0.79 and 0.76 mg/kg, respectively). These levels are somewhat lower than those reported by the same author for bulked samples (not from the Mothers' Milk Center) collected in Stockholm and four other places in Sweden in 1977–1979 (mean PCB levels 1.06 to 1.44 mg/kg fat) (*7*).

The results of a recent 3-cohort study in the Federal Republic of Germany show mean PCB levels of about 2 mg/kg on a fat basis (*8*).

In a longitudinal study on individual mothers, Norén has shown (*9*) that the level of PCBs in the fat of milk of primiparae is higher than that in that of secundiparae. This agrees with results obtained in the UNEP/WHO project and in earlier studies in Japan. This difference is due to the net loss of PCBs that occurs from the mother during lactation and to the second fetus.

In Japan, Sweden, the USA (Michigan) and several other countries, fish is a major source of dietary PCBs. Studies in Sweden (*10*), Japan (*3*) and the USA (*11*) indicate that the levels of PCBs in human milk fat are higher in women who consume large amounts of fish than among vegetarians and others who consume little or no fish.

Studies by Norén (*9*) show that there are only small fluctuations (a slow downward trend) in the level of PCBs in the fat of breast milk during the first few months of lactation. We have found similar results in our own laboratory. Thus the time post partum at which the milk samples are collected has little effect on the PCB levels expressed on a fat basis.

Conclusion

In the light of the above data it is obvious that the analysis of human milk for PCBs can provide valuable information on exposure of both the mother and the breast-fed infant to these persistent environmental contaminants. However, care must be exercised when comparing results from different laboratories where different methods of analysis are used and when different criteria have been used in selecting the mothers to be sampled.

It is also imperative that an adequate quality assurance program be included in each study if valid results are to be obtained.

REFERENCES

1. World Health Organization. Environmental Health Criteria 2. Polychlorinated Biphenyls and Terphenyls. WHO, Geneva, 1976.
2. Jensen, A. A. Chemical contaminants in human milk. Res. Rev. 89: 1–128 (1983).
3. Slorach, S. A., and Vaz, R., Eds. Assessment of Human Exposure to Selected Organochlorine Compounds through Biological Monitoring. Swedish National Food Administration, Uppsala, Sweden, 1983.
4. Sawyer, L. D. Quantitation of polychlorinated biphenyl residues by electron capture gas-liquid chromatography: reference material characterization and preliminary study. J. Assoc. Off. Anal. Chem. 61: 272–281 (1978).
5. World Health Organization. The quantity and quality of breast milk. Report on the WHO collaborative study on breast-feeding. WHO, Geneva, 1983.
6. Norén, K. Organochlorine contaminants in Swedish human milk from the Stockholm region. Acta Paediatr. Scand. 72: 259–264 (1983).
7. Norén, K. Level of organochlorine contaminants in human milk from different parts of Sweden. Ambio 12: 44–46 (1983).
8. Heeschen, W., and Blüthgen, A. Residues of chlorinated hydrocarbons in human milk—three cohort studies. Working paper for Planning consultation on Organohalogen Compounds in Human Milk and Related Health Hazards. WHO Regional Office for Europe, Copenhagen, November 23–6, 1982.
9. Norén, K. Some aspects of the determination of organochlorine contaminants in human milk. Arch. Environ. Contam. Toxicol. 12: 277–283 (1983).
10. Norén, K. Levels of organochlorine contaminants in human milk in relation to the dietary habits of the mothers. Acta Paediatr. Scand. 72: 811–816 (1983).
11. Schwartz, P. M., Jacobson, S. W., Fein, G., Jacobson, J. L., and Price, H. A. Lake Michigan fish consumption as a source of PCBs in human cord serum, maternal serum and milk. Am. J. Publ. Health 73: 293–296 (1983).