

The Distribution Characteristics of Polychlorinated Biphenyls in Rural Atmosphere

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Abstract

Atmospheric concentrations of polychlorinated biphenyl (PCB) congeners were measured every two weeks from July, 1999 to January, 2000 at Hankyong University in Ansong, Kyounggi-do. Atmospheric concentrations of Σ_{24} PCB showed a range of 19.8 ~ 71.9 pg/m³. The highest concentration of PCB homolog was tri-CBs (sum of PCB 18, 27, 28, 33, 38) which had a comparatively higher vapor pressure than other homologs. The contribution ratio of lighter PCB homologs (tri-CBs) to total PCBs was 44.5%, and these homologs were the main components of PCBs.

The ratio PCB homologs/deca-CB (PCB 209) suggested that the contribution of vapor phase PCBs increased greatly in summer relative to other seasons. In addition, the regression lines for PCB homologs/deca-CB (PCB 209) and temperature (°C) appeared as an exponential function with high correlation ($R^2 > 0.67$, $p < 0.01$). This suggests that the concentration of vapor phase PCB homologs increases steeply with increasing temperature.

Key words : PCBs, temperature, concentration distribution, PCB homologs/deca-CB

1. INTRODUCTION

Semivolatile organic compounds (SOCs) exist widely due to their high vapor pressure and low reactivity. Polychlorinated biphenyls (PCBs), a kind of SOCs, are circulated in the atmosphere because of its characteristics of persistence and lipophilicity, and thus their atmospheric concentration has recently become a controversial issue. PCBs are managed as toxic materials and they may be bioaccumulated through the food chain. Studies about spacial distribution of PCBs in the atmosphere have been conducted in the polar regions of Canada and Scandinavia, the South Pole, the Indian

Ocean and the Pacific Ocean (Oheme *et al.*, 1996). In addition to these studies, another study about the above compounds was conducted in developing areas (Hoff *et al.*, 1992). PCBs in the atmosphere exist within the cycle of repeated volatilization, deposition, transport and transformation according to changes in the weather such as temperature and wind speed. Recently, primary sources of these PCBs have been dramatically reduced. On the other hand, amounts of PCBs caused by secondary sources, that is, those recondensed and volatilized in soil, plants and the water chain due to temperature changes have fluctuating concentrations. The fluctuation of PCB amounts relative to temperature has been reported for several regions by several researchers in the past few years. Likewise, we have analyzed other

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characteristics of PCBs such as seasonal changes with respect to temperature and long distance transportation.

The purpose of this study is to examine concentration distribution of PCBs and to identify source characteristics of each PCB homolog in rural area.

2. EXPERIMENTAL

2.1 Sampling program

2.1.1 Sampling site

The sampler was installed within a small shelter (above 50 cm height on the ground). The shelter was located at the National Hankyong University campus, which is about 1 km northeast of downtown Ansung, and 10 km west of Kyongbu-express way. Agricultural fields made up 33% of the total area of Ansung. The population is about 130,000. A complex mix of agricultural and industrial regions make up this city located on the south side of Seoul (Fig. 1).

2.1.2 Sampling duration

Atmospheric samples were taken from July, 1999 to January, 2000. A low-volume PUF (polyurethane form) sampler was used to collect the ambient air PCB samples. The overall average volume was about 600 m³ for two weeks sampling. A total of fourteen samples were taken during the sampling period.

2.1.3 Meteorological data

Temperature, wind speed, wind direction and rela-

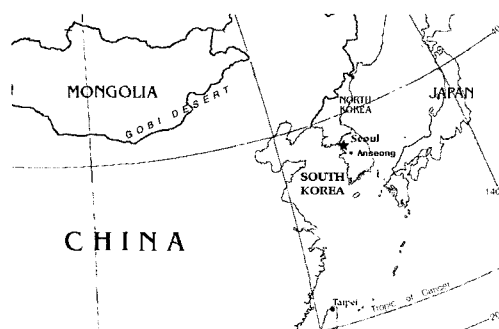


Fig. 1. Sampling site (Ansung, Kyonggi-do).

tive humidity were obtained from a meteorological tower (AWS) installed on top of a building on the Hankyong University campus.

2.2 Chemical analysis

The GFFs (glass fiber filters) were baked in advance at 450°C for 24 hours in loosely wrapped aluminum foil envelopes, and then they were sealed and stored at 4°C until sampling. The PUFs were precleaned by Soxhlet extraction with dichloromethane and dried in a vacuum oven at 70°C and then stored in sealed glassware at 4°C until sampling. After sampling, the GFFs and PUFs were all wrapped in glassware and stored at -26°C until analysis. PUFs were spiked with PCB surrogate standards (¹³C PCB isotopes: PCB 28, PCB 52, PCB 101, PCB 138, PCB 153, PCB 180, PCB 209) prior to sampling for recovery measurement. The internal calibration standards (Ultra Scientific) were prepared with 39 types of PCBs ranging from 1 pg/μl to 100 pg/μl (a total of 7 types).

The samples were extracted in a Soxhlet apparatus with hexane:dichloromethane (9 : 1) for 24 hours. Extracts were concentrated to approximately 2 ml with a rotary evaporator (BUCHI, R-124). For purification, the extract was eluted with 15 ml of hexane, 11 ml of hexane : dichloromethane (1 : 1) and 17 ml of dichloromethane on a silica column packed with 3 g activated

Table 1. GC/MSD operating parameters and conditions for PCBs analysis.

Detector	MSD
Column	HP-5MS capillary column (5% diphenyl & 95% dimethylpolysiloxane) length 30 m 0.25 mm, film thickness 0.25 μm
Inlet	Splitless
Aux temp.	300°C
Injection volume	1 μl
Temp. program	150°C (2 min) $\xrightarrow{30^\circ\text{C}/2\text{ min}}$ 170°C $\xrightarrow{\quad}$ 200°C (13 min) 4°C/min $\xrightarrow{\quad}$ 268°C $\xrightarrow{70^\circ\text{C}/\text{min}}$ 320°C (4.09 min)
Carrier gas	He (99.9999%)
Total run time	45 min.

silica, and sodium sulfate to remove any polar organics that might interfere during analysis. This was eluted again with hexane : dichloromethane (1 : 1) on a GPC (gel permeation chromatography, BUCHI, B-688) column for more clean-up and fractionation. The samples were then concentrated under a gentle stream of purified nitrogen concentrator to 50 μ l by using dodecane (SIGMA, D-4259). PCBs were analyzed using GC/MSD (Hewlett Packard 6890 equipped with HP 5973 detector). The operation parameters and conditions of the GC/MSD are summarized in Table 1.

3. RESULTS AND DISCUSSION

3.1 Quality assurance and quality control (QA/QC)

For quality assurance and quality control of PCBs analyses, a recovery test was conducted and the limit of detection (LOD) and linearity of calibration curve were evaluated. The recovery was measured by the same pretreatment procedure as before, after spiking 5000 pg (100 μ l \times 50 pg/ μ l) of PCB 28, 52, 101, 153, 138, 180 and 209 PCB isotopes (Cambridge Isotope Lab., lot no. ID-091) respectively, in five PUFs and glass fiber filters (Table 2).

Recovery results of low molecular PCBs, PCB 52, especially, showed a low recovery rate (%) compared to high molecular PCBs, for instance, PCB 52 ($77.2 \pm 5.5\%$) and PCB 209 ($116 \pm 13.4\%$). This result indicates the differences in physicochemical properties such as vapor pressure and polarity in each PCB congener. From the analytical calibration using standard PCBs, the correlation coefficients showed good linearity with the range of 0.992–1.000, and the results were appropriate for quantitative analysis. All samples were analyzed due to these calibration results. PCBs QA/QC Protocol published by Lancaster University, England (Lancaster University, 1995) states that the determinant coefficient in each PCBs congener should be more than 0.985. The detection limit was obtained by analyzing the calibration standards at a concen-

Table 2. The results of recovery tests for PCBs.

PCB congeners	Recovery [%]
PCB 28	77.2 ± 5.5
PCB 52	62.9 ± 7.3
PCB 101	78.0 ± 9.2
PCB 153	100.8 ± 9.7
PCB 138	106.1 ± 8.2
PCB 180	116.6 ± 10.2
PCB 209	116.0 ± 13.4

tration of 1–5 times greater than the expected LOD. Analyse it 7 times, the LOD is then calculated as follows : $LOD = \text{mean} + 3 \times S.D$ (Lancaster University, 1995). The detection limit of the PCB standards ranged from 0.011 (PCB 18) to 0.124 pg/ m^3 (PCB 52).

3.2 Distribution of PCB homologs

The distribution of PCB homologs concentrations during the sampling period are represented in Figure 2. In this study, 24 kinds of PCB congeners were detected, such as [tri-(PCB 18, 27, 28, 33, 38), tetra-(PCB 47, 49, 52, 60, 61/74, 66), penta-(PCB 87, 101, 118, 126), hexa-(PCB 138, 153), hepta-(PCB 170, 180/193, 183, 187), deca-CB(PCB 209)]. The average concentration of $\sum_{24}PCB$ (total PCBs) is 19.9 pg/ m^3 ($6.13-71.9$ pg/ m^3).

The tri-CBs (9.29 pg/ m^3) showed the highest concentration, and next by tetra-CBs (5.03 pg/ m^3), penta-CBs (3.51 pg/ m^3), hepta-CBs (1.24 pg/ m^3), hexa-CBs (0.55 pg/ m^3) and deca-CB (0.20 pg/ m^3).

The results showed a trend that the concentrations of PCBs decreased with increasing Cl substitutions. This may be explained by $\log K_{oa}$ (octanol-air partition coefficients), $\log K_{ow}$ (octanol-water partition coefficients), vapor pressure, solubility, and the physical and chemical characteristics of PCBs. Average $\log K_{oa}$, $\log K_{ow}$ and vapor pressure of detected tri-CBs are 8.19, 5.47 and 1.1×10^{-4} mmHg, respectively, 8.68, 5.95 and 1.0×10^{-4} mmHg, respectively, for tetra-CBs, 9.50, 6.34 and 1.1×10^{-5} mmHg, respectively, for penta-CBs, 9.94, 6.75 and 5.5×10^{-6} mmHg, respectively, for hexa, 10.27, 7.06 and 1.3×10^{-6} mmHg, respectively, for hepta-CBs (Harner and Bidleman,

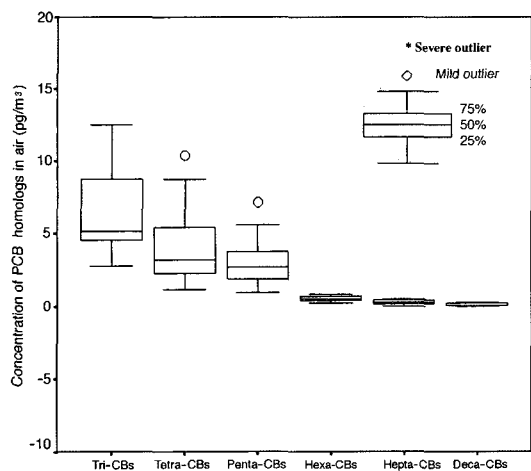


Fig. 2. Distributions of PCB homologs in air.

1996; Brodskyy and Ballschmitter, 1988). As shown in these data, with increasing number of Cl (> penta-CBs), the $\log K_{oa}$ and $\log K_{ow}$ also increased. The PCB homologs (> penta-CBs) easily deposit on plants, soil and layers of water and evaporate less into the atmosphere due to lower vapor pressure than tri- and tetra-CBs. Because PCB homologs with high atmospheric concentration have higher vapor pressure, most of the PCBs in the atmosphere were tri- and tetra-CBs which mostly exists as gases in the atmosphere (Yeo *et al.*, 2001).

3. 3 Seasonal variation

Figure 3 illustrates the ratio of summer to winter concentration in selected PCB congeners which are detected frequently in air. The average temperatures of summer and winter were 26.1°C and -0.5°C, respectively, resulting in more than a 25°C difference. The total concentrations for summer and winter were 36.2 and 17.2 pg/m^3 , respectively, showing summer values almost double that of winter. This maximum concentration in summer was similar with the results of many other researchers (Hoff *et al.*, 1992; Mancheser-Neesvig *et al.*, 1989). In terms of the ratio of summer to winter concentrations for PCB congeners, PCB 28 had the highest level at 2.5 and PCB 153 had the low-

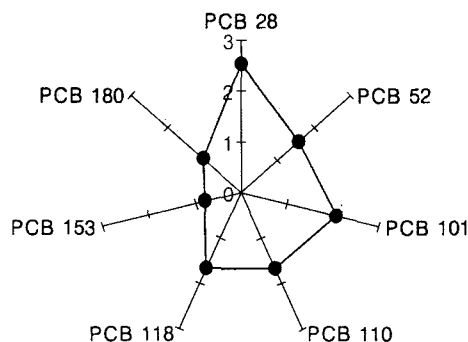


Fig. 3. Summer to winter concentration ratio for PCB congeners.

est level of 0.81. Most of the components had higher concentrations in the summer. However, PCB 153 and PCB 180, which are hexa-, hepta-CBs, respectively, had values less than 1.0.

Figure 4 describes the seasonal contribution of the various PCB homologs. The average contribution of PCB homologs during the sampling period in decreasing order was tri-(44.5%), tetra-(23.6%), penta-(21.6%), hexa-(3.6%), hepta-(5.5%) and deca-CB (1.6%). Since the sum of tri- and tetra-CBs were 68.1%, these were identified as the main components of PCB homologs. Additionally, even though the absolute sum of tri- and tetra-CBs with respect to seasonal concentrations were as follows: summer (23.8 pg/m^3 , 69.8%) > autumn (10.0 pg/m^3 , 66.4%) > winter (6.87 pg/m^3 , 69.5%), it is quite clear that the contributions were almost the same for all seasons. This is a relatively lower contribution compared to the 80% contribution of di- and tri-CBs which were researched at the North Pole from 1992 to 1994 by Stern and his other colleagues.

However, this is most likely due to the fact that the average maximum and minimum temperatures of this area were 3.6°C and -33.4°C, respectively. On the other hand, this study had values of 28.5°C and -1.8°C. That is to say, it appears that the contribution of low atomic PCBs (di-, tri- and tetra-CBs) have higher levels regardless of site, including pole regions. Also,

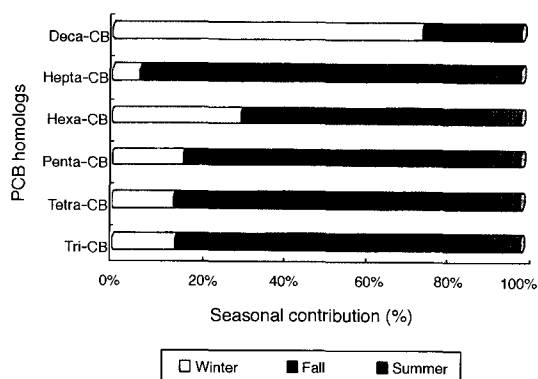


Fig. 4. Seasonal contributions(%) of PCB homologs.

the contributions of tri- and tetra-CBs from July 20 to August 4 were at their minimum level of 47.8%. During this period, the rainfall in our country represented a very high amount of 593mm under the influence of a typhoon. This is because these components (tri-, tetra-CBs) have 5-777 times higher solubility than other high atomic PCBs (>penta-CBs). It appears that the values are being influenced by wet deposition. However, the seasonal contribution of penta-CBs showed maximum (27.8%) in autumn and minimum (18.1%) in winter. On the other hand, that of hepta-

CBs showed maximum (88.8%) in summer and minimum (4.9%) in fall. Finally hexa- and deca-CB showed maximum in winter of 5.2% and 4.3%, respectively, and minimum in summer of 2.0% and 0.2%, respectively.

The reason why PCB homologs have little difference in terms of contribution and concentration by season is thought to be because of the influence of partitioning between gases and particles. Figure 5 demonstrates the correlation between the ratio of [PCB homologs/deca-CB(PCB 209)] with temperature. PCB 209 exists mostly in the particle phase due to lower vapor pressure ($< 2.3 \times 10^{-6}$ mmHg) (Ballschmiter and Wittlinger, 1991). If PCB 209 mostly exists as particles in air, the ratio PCB homologs/deca-CB (PCB 209) would confirm the partition between gas and particle phases for each homolog with respect to temperature. Therefore, to confirm the temperature dependence of PCB 209, we first conducted a regression analysis. As a result, the regression line for PCB 209, [deca-CB] = $2921[1/T(K)] - 11.16$ ($r^2 = 0.75$, $p < 0.01$), showed high negative correlation for concentration in air with temperature. This is thought to be because PCB 209 exists mostly in the particle phase due to its tendency to undergo condensation at low temperatures.

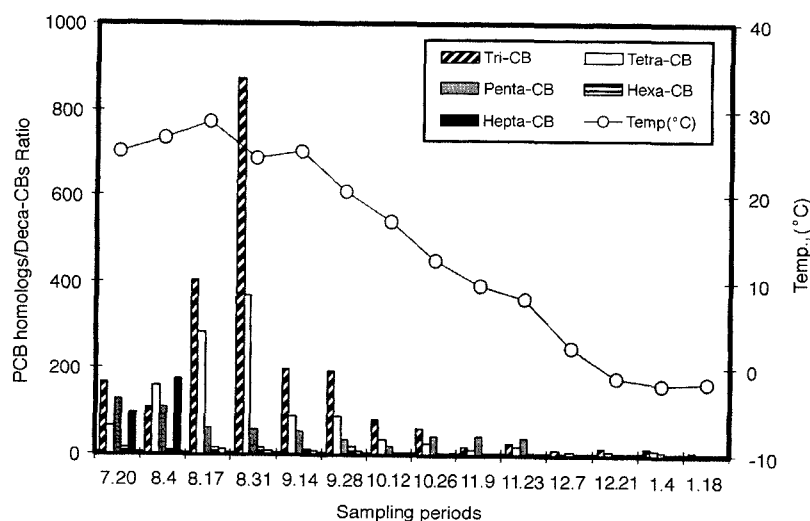


Fig. 5. Correlation of PCB homologs/PCBs ratio and Temp.,(°C)

Table 4. Correlation parameters for PCB homologs (of the form [PCB homologs/PCB 209 ratio = $a e^{mT}$]).

Homologs	a	m	R ²
Tri-CBs	11.8	0.1189	0.85
Tetra-CBs	6.09	0.1228	0.88
Penta-CBs	6.75	0.0096	0.75
Hexa-CBs	1.40	0.0888	0.82
Hepta-CBs	0.43	0.1462	0.67

Eventually, the PCB 209 concentration in air increases dramatically at low temperature. The ratio of PCB homologs versus PCB 209 was quite similar to the change in temperature. This is to be expected since gas/particle phase partitioning progresses to the gas phase with increasing temperature. This tendency is easily found in tri- and tetra-CBs, which have high vapor pressure, and exists mostly in the gas phase in air. Also, the reason why PCB homologs concentration increases in summer is because the contribution of gas phase components becomes bigger.

Table 4 gives some parameter values of the regression line between PCB homologs and PCB 209. As we can see from this table, the ratio of PCB homologs and deca-CB (PCB 209) has a good correlation ($p < 0.01$) with temperature. In particular, the temperature constant (m) of tri-, tetra- and hepta-CBs were 0.1189, 0.1228 and 0.1462, respectively. These homologs were more sensitive to temperature change than the other homologs. Therefore, the concentration of their gas phase component became greater with temperature increase than the other homologs.

3. 4 Regression analysis and concentration with height

From the correlation between temperature and wind speed in air/surface exchange of PCB homologs, it is apparent that temperature has a very significant correlation with most PCB homologs (except deca-CBs). The coefficients (r) of tri-CBs and tetra-CBs was 0.63 and 0.61 ($p < 0.05$) and showed especially close interdependence with temperature. On the other hand, most PCB homologs except deca-CB did not show dependence with wind speed and showed negative correla-

tion. When we look at effect of the above two meteorological factors, the concentrations of PCB homologs dramatically increased when the temperature went up and wind speed decreased and this tendency was seen extensively in summer (average temperature : 26.1°C, wind speed : 0.48 m/s) and fall (average temperature : 15.5°C, wind speed : 0.39 m/s) compared to winter (average temperature : -0.5°C, wind speed : 0.56 m/s). As we can see from the above results, among the PCB homologs, tri- and tetra-CBs showed good correlation with temperature and wind speed. Also, tri- and tetra-CBs have very similar physical and chemical characteristics, so they would be affected by the similar sources. So to realize the causes of this, we conducted a regression analysis and concentration partitioning with height. The regression analysis data for most PCB homologs did not show significant correlation, however, tri-, and tetra-CBs showed quite good correlation ($p < 0.01$; $n = 14$):

$$[\text{Tetra-CBs}] = 0.41 [\text{Tri-CBs}] + 1.29 \quad (R^2 = 0.85) \quad (1)$$

Significant correlation between the two homologs implies that the characteristics of generation of both are very similar regardless of season (Oehme *et al.*, 1996). As mentioned previously, tri- and tetra-CBs, having higher vapor pressure than higher-CBs have more temperature dependence than higher-CBs (> penta-CBs) which have lower vapor pressure. The large correlation between the two homologs is due not only to their relationship with temperature but also to the sensitivity of generation and external inflow. If they are affected by the similar sources, the slope of the regression line is almost 1. However the slope of regression line between two homologs in this study was 0.41. From this, we need to identify the different sources of these two homologs.

Therefore, we plotted the PCB homologs concentration which was obtained for each height (10, 50, 150 and 1500 cm) in Figure 6 ($n = 5$). The lowest value was measured at 10 cm and the highest value at 1500 cm, with very similar values from 10 to 150 cm.

However, except for tetra-CBs, the maximum and

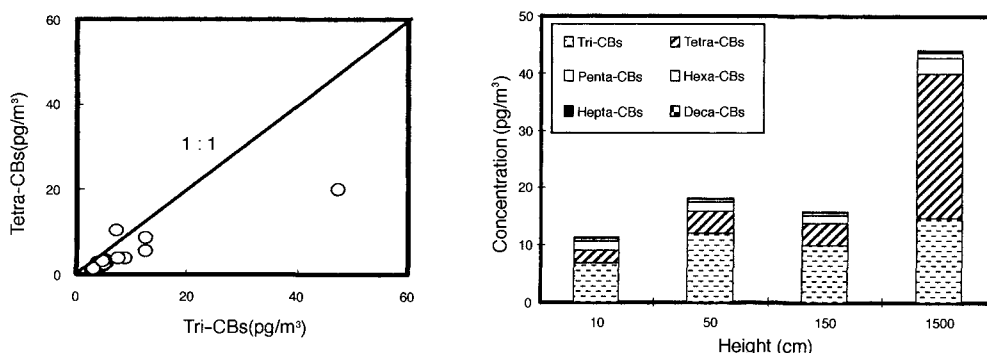


Fig. 6. Regression analysis between tri- and tetra-CBs (left) and comparison of PCB homologs concentrations at each height (right).

minimum height ratio (1500/10 cm) was not much different between PCB homologs, with tri-CBs 2.2, penta-CBs 1.7, hexa-CBs 2.6 hepta-CBs 3.5, and deca-CB 1.8. Tetra-CBs had the largest ratio (6.5) and penta-CBs had the smallest value. The concentration distribution of tetra-CBs with height was quite broad compared to tri-CBs. In the higher layer (1,500 cm), the difference between the two homologs was clearly shown. The reason why the slope of the regression line was as low as 0.41 is because the generation of tetra-CBs are not only from local sources at the surface but also inflow caused by concentration partitioning between the high layer (1,500 cm) and the low layer (< 150 cm). Thus, the tetra-CBs concentration distribution during the sampling period is thought to be a result of both local sources and pollutant inflow from upper layers.

3. 5 Comparison of PCBs concentrations with other studies

Table 5 illustrates the comparison results between PCB concentrations of foreign countries. PCB congeners with a detection frequency of more than 90% and easily found congeners worldwide were selected for comparison. The average concentration \pm standard deviation ($n = 14$) of PCB 28 (Tri-CBs) and PCB 52 (tetra-CBs) were 4.19 ± 2.58 pg/m³ and 1.00 ± 0.53 pg/m³, respectively. PCB 28 was 128 times and PCB

52 was 531 times lower than the average concentration of 557 ± 291 pg/m³ and 531 ± 351 pg/m³, which were measured from 1991 to 1992 by Crispin *et al.* (1995). Comparing with concentrations researched by Wittlinger *et al.* (1986) in the South Indian Ocean of 3.20 pg/m³ and 4.9 pg/m³ respectively, PCB 28 in this study was 1.3 times higher and PCB 52 was 52 times lower than the South Indian Ocean data. In addition, the average concentration of PCB 28 and PCB 52 researched at Lancaster, rural area of England, during March, August and December, 1994 (Crispin *et al.*, 1995), were 24.7 and 18.4 pg/m³ respectively. When we compared our results with these data, PCB 28 in this study was 5.8 times and PCB 52 was 18 times lower. Also, William *et al.* (1995) researched PCB 28+31 and PCB 52 in Chicago and the result were 158 and 123 pg/m³. Comparing with this study, PCB 28 showed a value 37 times higher and PCB 52 showed 123 times higher than our study. Finally, our results were very similar to result (5.79, PCB 28 and 2.26, PCB 52 pg/m³) of Halsall *et al.* (1999) researched at Lake District Park, a rural area of England. As a result, atmospheric levels of PCB 28 and PCB 52 researched in this study showed quite low levels compared to urban areas of foreign countries and similar levels compared to the ocean and rural areas of foreign countries. In the case of penta-CBs, the average concentration \pm standard deviation of PCB 101, 110 and 118

were 2.19 ± 2.96 , 0.38 ± 0.17 and 0.40 ± 0.42 pg/m^3 , respectively. When comparing these results to data which was researched in Esthwaite Water Lake District Park from September, 95 to July, 96 by Halsall *et al.* (1999), PCB 101 concentrations from our study was 2 times higher. On the other hand, PCB 118 was 2 times lower. Additionally, the average concentration of PCB 101 researched in a rural area of England by Robert *et al.* (1999) was 6.5 pg/m^3 , 3 times higher than that of our study and PCB 118 researched in a rural area of the Netherland by Lopez *et al.* (1996) was 3.21 pg/m^3 , 8.5 times higher than that of our study. PCB 110 researched in Lake Baikal in June, 1996 by Laura was 11.3 pg/m^3 and this result was 30 times higher than that of our study. It appears that influences by local sources was quite large for the above case because the lake in this area is severely polluted by PCBs. Average concentrations of PCB 101, 110 and 118 researched in Chicago by William *et al.* (1995) were 100, 78 and 46 pg/m^3 , respectively, which were higher than that of our study. Average concentration of PCB 110 and 118 researched in an urban area of Norway from 1992 to 1995 by John *et al.* (1999) using a high volume PUF sampler were 34.3 ($n = 200$) and 7.5 pg/m^3 ($n = 200$), respectively, and PCB 101 was 15 times and PCB 118 was 18 times higher than that of our study. Overall, the concentration of penta-CBs in our study is quite simi-

lar to that of rural areas but much lower than that of urban areas of foreign countries. In terms of hexa-CBs, the average concentration \pm standard deviation of PCB 153 was $0.28 \pm 0.14 \text{ pg/m}^3$, which was 342 times lower than the 96 pg/m^3 (PCB 153) researched in Chicago by William, 33 times lower than the 9.2 pg/m^3 (PCB 153) measured in Lake Baikal by Laura *et al.* (1996), 121 times lower than the 34 pg/m^3 (PCB 153) researched in the ocean area of Norway by John *et al.* (1999) and 3.5 and 5.6 times lower than the 0.99 and 1.58 pg/m^3 researched in Karvatn and Svanik of north Norway by Oehme *et al.* (1996). The concentration of hexa-CBs (PCB 153) in our study was a little bit lower than for the rural areas and much lower than for urban areas of foreign countries.

4. CONCLUSIONS

PCBs concentrations were measured every two weeks from July, 1999 to January, 2000 in Ansong city. The concentration distribution were investigated of PCBs with temperature was studied, and the source characteristics of PCB homologs.

From the study, it was confirmed that tri-CBs were the main components, making up 44.5% of the total PCB homologs. In terms of seasonal variation, most of

Table 5. Summary of PCBs concentrations [pg/m^3] in other studies.

Site	Period	PCB congeners					
		28	52	101	110	118	153
This study	Jul. '99–Nov. '00	4.27	0.95	1.88	0.39	0.40	0.28
Urban							
Ontario, Canada ^{a)}	Jul. '88–Sep. '89	83.0	180	119			73
Cardiff, U.K. ^{b)}	'91–'92	222	129	91.5	98.3	38.6	32.5
Manchester, U.K. ^{c)}	'91–'92	133	101	84.5	80.7	84.5	32.4
Chicago, US ^{d)}	Feb. '88	158	123	100	78	46 ^{e)}	96
Rural							
Lancaster, U.K. ^{e)}	Aug '95			15		2.7	1.7
Swedish West Coast ^{f)}	Feb. + May '90			9.8		3.0	
Costal Woodland U.K. ^{g)}	Jan. '91–Dec. '92	22.4	4.18	3.59		1.09	2.70
Water Lake District Park, U.K. ^{h)}	Jan. '91–Dec. '92	5.79	2.26	1.10		0.66	0.77

^{a)} Hoff *et al.* (1992), ^{b,c)} Crispin *et al.* (1995), ^{d)} William *et al.* (1995), ^{e)} Lee *et al.* (1998), ^{f)} Brorstrom–Lundon, (1996), ^{g,h)} Halsall *et al.* (1999)

the PCB homologs showed high temperature dependence with maximum levels in summer, fall and minimum levels in winter. In addition, from the results of ratio PCB homologs/PCB 209 (deca-CB), it was appeared that the contribution of gas phase PCBs increase with increasing temperature. From the results of the regression analysis between tri- and tetra-CBs, it was identified that these two components were influenced by the similar sources. However, tetra-CBs were affected much more by the concentration gradient from higher layers to lower layers than tri-CBs. This implies that much of the tetra-CBs was transferred from outside the local area during the sampling period.

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