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Occurrence, sources, and cancer risk of polycyclic aromatic hydrocarbons and polychlorinated biphenyls in agricultural soils from the Three Gorges Dam region, China

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Abstract: Eighty agricultural topsoil samples were collected near the Three Gorges Dam region of Yangtze River, China, to investigate concentrations, distribution patterns, and possible sources and potential cancer risks of polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) in this area. Total PAHs concentrations in agricultural topsoil ranged from 277.79 to 3,217.20 ng g⁻¹ (ppb) with a mean concentration of 1,023.48 ± 815.31 ng g⁻¹. Total concentrations of seven carcinogenic PAHs (C-PAHs) were between 45.85 ng g⁻¹ and 1,147.45 ng g⁻¹, accounting for 6% to 49% of the total PAHs. Total PCBs concentrations varied from 18.56 to 183.90 ng g⁻¹ with a mean concentration of 35.28 ± 41.01 ng g⁻¹. Positive linear correlations were found between total PAHs and total PCBs, showing these compounds may originate from common sources. Isomer ratios analysis indicated that atmospheric deposition was the main common source for PAHs and PCBs. The incremental lifetime cancer risk (ILCR) of PCBs in agricultural topsoil near the Three Gorges Dam region were all below 10⁻⁶, indicating no cancer risk, whereas ILCR of PAHs were between 10^{-6} and 10^{-4} ; special attention needs to be paid to PAHs in the study area.

Key words: agricultural topsoil—polychlorinated biphenyls (PCBs)—polycyclic aromatic hydrocarbons (PAHs)—Three Gorges Dam region

Polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) are important and ubiquitous classes of persistent organic pollutants. PAHs and PCBs can be found in the dust, soils, sediments, and atmospheric environment (Larsen and Baker 2003). PAHs are of particular concern, and 16 priority PAHs are regulated by the US Environmental Protection Agency (USEPA). Several PAHs are known carcinogens, such asbenz[a]anthracene (BaA), (Chr), benzo[b]fluoranthene chrvsene (BbF), benzo[k]fluoranthene (BkF), benzo[a] pyrene (BaP), dibenz[a,h]anthracene (DBA), and indeno[1,2,3-cd]pyrene (InP) (Ma et al. 2009). Seven PCBs (PCB28, PCB52, PCB101, PCB118, PCB138, PCB153, and PCB180) were defined as indicative monomers by the United Nations GEMS/ Food (Food and Agricultural Organization of the United Nations Global Environment Monitoring System) to monitor the PCBs

pollution in soil and food (Faroon et al. 2003). Soil is the primary steady reservoir for PAHs and PCBs because PAHs and PCBs are readily absorbed by organic matter in soil and hardly degrade (Wild and Jones 1995). In addition, recycling of PAHs and PCBs from contaminated soils into the atmosphere is another pollution source to the environment (Harner et al. 2001).

The Three Gorges Dam region is located from Badong County to Yichang City, Hubei Province, China, along the Yangtze River. Recently many reports on PAH and PCB pollution of the Three Gorges Reservoir have been published (Xu et al. 2007; Zhao et al. 2007; Luo et al. 2010; Li et al. 2012). However, these studies mainly focused on the persistent organic pollutants of the water body, sediments, and water-level-fluctuating zone of the Three Gorges Dam region; agricultural soils of this area were less noticed. In fact, serious pollution by PAHs and PCBs is often found in agricultural soil in China (Tao et al. 2004; Song et al. 2006; Wang et al. 2012; Zhu et al. 2014). It is well known that PAHs and PCBs from contaminated soils could pose significant risks to aquatic ecosystems, especially through surface run off and soil erosion (Luo et al. 2013). Hence, it is important to investigate the pollution of PAHs and PCBs in agricultural soils near the Three Gorges Dam region, China.

The objectives of this study were (1) to investigate the concentrations of PAHs and PCBs, (2) to identify the sources of PAHs and PCBs in agricultural soils, and (3) to evaluate the possible carcinogenic risk of PAHs and PCBs near the Three Gorges Dam region, China. In addition, the study could also provide useful information for agricultural soil management in the Three Gorges Dam region.

Materials and Methods

Sample Collection. A total of 80 agricultural topsoil samples were collected in March of 2013 at 16 sites near the Three Gorges Dam region along the Yangtze River (figure 1). Five 0 to 20 cm (0 to 7.87 in) subsamples were randomly taken within a range of 200 m² (2,153 ft) at each sampling site. All soil samples were collected in agricultural fields. All samples were lyophilized, ground, and then passed through a 100-mesh (0.149 mm [0.006 in]) stainless steel sieve.

Reagents and Standards. PAHs (1,000 mg L^{-1} [ppm]) and PCBs (10 mg L^{-1}) standard solution were purchased from AccuStandard, New Haven, Connecticut, United States.

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PAHs standard solution includes acenaphthylene (Acy), acenaphthene (Ace), fluorene (Fl), phenanthrene (Phe), anthracene (Ant), fluoranthene (Flu), pyrene (Pyr), BaA, Chr, BbF, BkF, BaP, DBA, benzo[ghi]perylene (BgP), and indeno[1,2,3-cd]pyrene (InP). PCBs standard solution includes PCB-28, PCB-52, PCB-101, PCB-118, PCB-153, PCB-138, and PCB-180. Dichloromethane and n-hexane are of chromatographic grade (Fisher Scientific, United States). Other chemicals (carbon [C]18, anhydrous sodium sulfate [Na₂SO₄], and copper [Cu] powder) are of analytical reagent grade.

Sample Extraction, Cleanup, and Analysis. PAHs and PCBs were extracted following the modified matrix solid-phase dispersion extraction method (Rallis et al. 2012). Two grams (0.07 oz) of soil samples were blended thoroughly with 3 g (0.1 oz) C_{18} as dispersion sorbent in a glass mortar for five minutes using a glass pestle to obtain a homogeneous mixture. The mixture was completely transferred by using a funnel into a syringe barrel-column (10 mL [0.34 oz]) with a 0.22 µm membrane filter. One gram (0.035 oz) of anhydrous Na₂SO₄, 1 g of Florisil, 1 g of silica gel, and 1 g of activated Cu powder were placed into the column from bottom to top. After the mixture was transferred into the column, another membrane filter was added on the top of the column. The column was compressed with the syringe plunger for air removal and then 20 mL (0.67 oz) dichloromethane (CH₂Cl₂) was used to elute the column. The eluent was collected into a conical tube. The extract was concentrated to 100 µL under a gentle high purity nitrogen (N) stream after 100 µL of isooctane was added as solvent keeper. A known quantity of pentachloronitrobenzene (PCNB) was added as an internal standard prior to gas chromatograph-mass spectrometer/electron capture detection (GC-MS/ECD) analysis.

Gas Chromatograph/Mass Spectrometer/ Electron Capture Detection Analysis. Qualitative and quantitative analysis was carried out with an Agilent 7890A gas chromatography equipped with an electron capture detector (GC-ECD) and a Model 5975 mass spectrometer (MS) using electron-ionization ion source (EI) in the selected ion monitoring (SIM) mode. An aliquot of 1 µL of the sample extracts was automatically injected into an HP-5 capillary column (30 m [98.4 ft] \times 0.25 mm [0.01 in] \times 0.25 µm). Helium (He) gas was used as the

Figure 1



carrier gas at 1 mL min⁻¹ (0.034 oz min⁻¹) under the constant flow mode. The injector and the detector were operated at 250°C and 300°C (482°F and 572°F), respectively. The ion source and interface temperatures were set to 300°C and 280°C (536°F), respectively.

The GC oven temperature for PCBs was programmed as follows: initial temperature was maintained at 70°C (158°F) for two minutes and then programmed at 25°C (45°F) min⁻¹ to 150°C (302°F), at 3°C (5.4°F) min⁻¹ to 200°C (392°F), 8°C (14.4°F) min⁻¹ to 280°C (536°F), and holding the final temperature for 10 minutes. The GC oven temperature for PAHs was programmed as follows: initial temperature was maintained at 50°C (122°F) for 3 minutes and then programmed at 10°C (18°F) min⁻¹ to 200°C, at 5°C (9°F) min⁻¹ to 280°C, and holding the final temperature for 10 minutes. The data were acquired and processed with Chemstation software (Agilent, Santa Clara, California, United States).

Quality Assurance and Quality Control. Average PAH and PCB recoveries and relative standard deviations (RSDs) were first obtained to evaluate the method performance by multiple analyses of 10 soil samples spiked with PAHs and PCBs standards. A solvent blank and matrix blank were ana-

lyzed through the entire procedure prior to and after every 10 samples. Each sample was analyzed in triplicate. The average recoveries of PAHs were 85% to 93% and PCBs were 72% to 86%. The limits of detection (LODs) of PAHs and PCBs were defined as three times the signal-to-noise ratio (S/N). The LOD for PAHs ranged from 10 to 500 pg g⁻¹ and PCBs from 1 to 50 pg g⁻¹, respectively. All the results were corrected for the recoveries in this study.

Cancer Risk Assessment. Incremental lifetime cancer risk (ILCR) was employed to evaluate the potential risk for PAHs and PCBs in agricultural soils near the Three Gorges Dam region for human health based on the USEPA standard models (USEPA 1989; Chen and Liao 2006). The ILCRs for adults through direct ingestion, dermal contact, and inhalation were calculated using the following equations (Peng et al. 2011):

$$ILCRs_{Ingestion} = \frac{CS \times CSF_{Ingestion} \times \sqrt[3]{BW/70 IR}_{Ingestion} \times EF \times ED}{BW \times AT \times 10^6} , \quad (1)$$

$$LCRs_{Dermal} = \frac{CS \times CSF_{Dermal} \times \frac{1}{8}BW/70 \times SA \times AF \times ABS \times EF \times ED}{BW \times AT \times 10^6}, \text{ and} \qquad (2)$$

$$ILCRs_{Inhulation} = \frac{CS \times CSF_{Inhulation} \times \sqrt[3]{BW/70} \times IR_{Inhulation} \times EF \times ED}{BW \times AT \times PEF}, (3)$$

Compounds	Type of PAHs	TEF	Mean	Median	Range	SD	25%	75 %
Nap	2-rings	0.001	334.51	183.93	63.78 to 1,755.20	501.56	79.47	290.36
Асу	3-rings	0.001	1.51	1.16	0.21 to 6.42	1.44	0.86	1.55
Ace	3-rings	0.001	2.94	2.21	0.33 to 8.84	2.44	1.47	4.47
FI	3-rings	0.001	46.28	46.04	2.28 to 80.01	17.78	34.99	56.20
Phe	3-rings	0.001	145.68	119.16	60.95 to 443.96	92.71	83.45	194.81
Ant	3-rings	0.01	135.28	110.47	55.99 to 414.39	86.75	77.10	181.25
Flu	4-rings	0.001	84.85	27.03	0.11 to 736.33	181.30	0.77	66.51
Pyr	4-rings	0.001	10.20	1.96	0.03 to 89.29	22.18	0.65	12.98
BaA	4-rings	0.1	3.99	3.96	3.94 to 4.26	0.10	3.94	4.05
Chr	4-rings	0.01	24.10	9.01	0.00 to 135.57	36.68	0.00	36.13
BbF	5-rings	0.1	6.09	6.04	6.01 to 6.78	0.19	6.01	6.06
BkF	5-rings	0.1	104.35	55.31	8.97 to 439.38	134.70	10.91	133.99
BaP	5-rings	1	62.22	14.65	4.72 to 576.08	141.82	5.20	40.57
DBA	5-rings	1	38.24	10.79	10.65 to 283.38	28.18	5.64	15.21
InP	6-rings	0.1	16.89	5.75	5.63 to 115.75	71.55	10.73	32.75
BgP	6-rings	0.01	6.34	7.22	0.00 to 7.33	2.48	7.21	7.27
Total C-PAHs			255.89	120.48	45.85 to 1,147.45	326.39	63.22	278.25
Total PAHs			1,023.48	623.97	277.79 to 3,217.20	815.31	461.39	1,706.56

thracene. Flu = fluoranthene. Pyr = pyrene. BaA = asbenz[a]anthracene. Chr = chrysene. BbF = benzo[b]fluoranthene. BkF = benzo[k]fluoranthene. BaP = benzo[a]pyrene. DBA = dibenz[a,h]anthracene. InP = indeno[1,2,3-cd]pyrene. BgP = benzo[gh]perylene.

where CS is the sum of converted PAH and PCB concentrations based on the toxic equivalency factor (TEF) as shown in table 1; CSF is carcinogenic slope factor ([mg kg⁻¹ $d^{-1}]^{-1};\ CSF_{Ingestion},\ CSF_{Dermal},\ and\ CSF_{Inhalation}$ of PAHs were 7.3, 25, and 3.85 [mg kg^{-1}] d⁻¹]⁻¹, respectively [Wang et al. 2007]; and $\text{CSF}_{\text{Ingestion}}, \text{CSF}_{\text{Dermal}}$ and $\text{CSF}_{\text{Inhalation}}$ of PCBs were 2, 2, and 0.57 [mg kg⁻¹ d⁻¹]⁻¹, respectively [USEPA 1997]); BW is body weight (kg; 70 kg [154.3 lb]); AT is the average life span (y; 70 y); EF is the exposure frequency (d y⁻¹; 350 d y⁻¹); ED is the exposure duration (y; 30 y); IR $_{lngestion}$ is the soil intake rate (mg d⁻¹; 0.001 mg d⁻¹ [0.35 × 10⁻⁷ oz day⁻¹]); $IR_{Inhalation}$ is the inhalation rate (m³ d⁻¹; 20 m³ d^{-1} [5,283 gal day⁻¹]); SA is the dermal surface exposure (cm² d⁻¹; 5,000 cm² day⁻¹ [775 in² d⁻¹]); AF is the dermal adherence factor (kg cm⁻²; 0.00001 kg cm⁻² [0.1422 psi]); ABS is the dermal adsorption fraction (0.1); and PEF is the particle emission factor (m³ kg⁻¹; $1.32 \times 10^9 \text{ m}^3 \text{ kg}^{-1} [2.11 \times 10^{10} \text{ ft}^3 \text{ lb}^{-1}]).$

Results and Discussion

Polycyclic Aromatic Hydrocarbons and Polychlorinated Biphenyls Concentrations. Concentrations of PAHs and PCBs in all agricultural topsoil samples are presented in table 1 and table 2. Sixteen priority PAHs were all detected in agricultural topsoil samples. Total concentrations of the PAHs ranged from 277.79 to 3,217.20 ng g⁻¹ with a mean concentration of $1,023.48 \pm 815.31$ ng g-1. The higher concentrations (figure 2a) of PAHs were observed at sampling sites S4 (1,127.72 ng g⁻¹), S11 (1,797.18 ng g⁻¹), S12 (2,134.33 ng g^{-1}), S14 (1,706.56 ng g^{-1}), S15 (1,149.15 ng g⁻¹), and S16 (3,217.20 ng g⁻¹), respectively. These sampling sites were located around different point pollution sources, such as the vehicle repair plant (S4), gas station (S15), scenic spots (S11 and S12), and chemical plants (S16). Total concentrations of PAHs in seven sampling sites (S1, S2, S3, S6, S8, S9, S10, and S13) were below the median values of 623.97 ng g⁻¹. Concentrations of PAHs at S5 and S7 were in a moderate level.

Seven PAHs(BaA, Chr, BaP, BbF, BkF, InP, and DBA) are known as potentially C-PAHs, as it has been reported in several literatures (Sprovieri et al. 2007; Tian et al. 2013). As shown in figure 2a, total concentrations of seven C-PAHs ranged from 45.85 to 1,147.45 ng g⁻¹ with a mean concentration of 255.89 \pm 326.39 ng g⁻¹. Among the seven C-PAHs, BkF, accounting for 41% of the total C-PAHs (figure 3a), showed the largest percentage, followed by BaP (24%), DBA (15%), Chr (9%), InP (7%), BaA (2%), and BbF (2%). The contents of seven indicative PCBs are shown in table 1 and figure 2b. The highest concentration of total PCBs was observed at sampling site S16 (183.9 ng g⁻¹) and the lowest appeared at sampling site S1 (7.86 ng g⁻¹). In general, PCB-52 showed the highest concentration (18.56 ng g⁻¹), accounting for 53% of the total PCBs (figure 3b). PCB-153 exhibited the lowest concentration (1.50 ng g⁻¹), accounting for 4% of the total PCBs.

Cancer Risk Assessment. The total ILCR values of PAHs in agricultural topsoil near the Three Gorges Dam region ranged between 10^{-6} and 10^{-4} with an average of 10^{-5} (table 3), indicating a potential cancer risk. Generally, ILCR values higher than 10^{-6} and 10^{-4} indicated a potential cancer risk (USEPA 1993). The cancer risk values of PAHs through ingestion and dermal contact ranged from 10^{-8} to 10^{-4} in all soil samples, about 10^{3} to 10^{8} more than the cancer risk level via inhalation, which varied from 10^{-12} to 10^{-11} . This result was in accordance with the study of exposure to PAHs in urban surface dust of Guangzhou (Wang et al. 2011).

ILCR values of PCBs were all below 10^{-6} (table 3), indicating no potential cancer risk. For different exposure pathways, the increasing trend in cancer risks for PCBs was as follows: ICLR_{Dermal} > ICLR_{Ingestion} > ICLR_{Inhalation}.

Compounds	Type of PCBs	TEF	Mean	Median	Range	SD	25%	75%
PCB-28	Tri-CBs	0.000002	4.82	2.36	0.42 to 43.22	10.28	1.58	2.99
PCB-52	Tetra-CBs	0.000005	18.56	10.95	2.55 to 126.20	29.30	6.82	17.00
PCB-101	Penta-CBs	0.00003	2.66	2.15	1.46 to 6.03	1.19	1.93	3.27
PCB-118	Penta-CBs	0.00003	2.39	2.44	0.49 to 4.63	1.20	1.48	3.30
PCB-138	Hexa-CBs	0.00001	2.95	1.85	0.23 to 15.32	3.69	0.88	4.12
PCB-153	Hexa-CBs	0.00002	1.50	1.31	0.16 to 4.54	1.36	0.37	1.91
PCB-180	Hepta-CBs	0.00001	2.39	0.24	0.07 to 12.76	3.95	0.19	2.75
Total PCBs			35.28	23.24	7.86 to 183.90	41.01	21.77	21.47

Table 2

Mean concentrations of (a) the carcinogenic polycyclic aromatic hydrocarbons (C-PAHs) and total PAHs and (b) total polychlorinated biphenyls (PCBs) in the agricultural topsoil near the Three Gorges Dam region.



Source Apportionment of Polycyclic Aromatic Hydrocarbons and Polychlorinated Biphenyls. Positive linear correlations were found between total PAHs and total C-PAHs (r = 0.762; p < 0.01; figure 4a), total PAHs and total PCBs (r = 0.737; p < 0.01; figure 4b), and total C-PAHs and total PCBs (r = 0.670; p < 0.05; figure 4c). Therefore, PAHs and PCBs in agricultural topsoil samples near the Three Gorges Dam region may be from multiple sources.

The isomer ratios of Ant/(Ant + Phe), BaA/(BaA + Chr), Flu/(Flu + Pyr), and InP/(InP + BgP) were used to distinguish between petrogenic and pyrolytic sources (Zhang et al. 2006). The ratio of Ant/(Ant + Phe) < 0.1 shows a petroleum source, while the ratio >0.1 indicates a combustion source. Furthermore, Flu/(Flu + Pyr) < 0.4 indicates a petroleum source (liquid fossil fuel, vehicle, and crude oil), between 0.4 and 0.5 implies liquid fossil fuel combustion, and a ratio >0.5 is the characteristic of biomass and coal combustion (Yunker et al. 2002).

In the present study, the values of Ant/ (Ant + Phe) ranged from 0.47 to 0.49 and Flu/(Flu + Pyr) values varied from 0.11 to 0.98, suggesting a mixed source of combustion and traffic emission. Sources can be classified into three distinct groups. As shown in figure 5, S8 and S9 exhibited the typical characteristic of petrogenic sources. S1 and S12 showed the signature of petroleum combustion (liquid fossil fuel, vehicle, and crude oil). The other 12 sampling sites suggested a source of biomass and coal combustion. As a result, the primary PAHs in the agricultural topsoil samples near the Three Gorges Dam region can be thought of as combustion. This result agreed with the

study that combustion was the major contributor of the soils PAHs in Midway Atoll (Yang et al. 2014).

Principal component (PC) analysis has been widely used to distinguish the pollutant sources (Liu et al. 2014). Three principal components (PC1, PC2, and PC3) had been extracted with eigenvalues greater than one and represented 78.46% of the total variance of PAHs in the agricultural topsoil samples. PC1 (table 4; 45.6% of total variances) associated with high molecular weight PAHs, including Phe, Ant, Ace, Flu, BkF, BaP, InP, Pyr, Chr, DBA, and BaA, which represented the influence of diesel combustion. The diesel emissions were characterized by Pyr, BaA, Chr, BbF, BkF, InP, and DBA (Lee and Dong 2010; Hou et al. 2013; Wang et al. 2013). PC2 (table 4) explained 20.11% of total PAHs and indicated coal or biomass burning. Major

Percentage of individual congener of (a) carcinogenic polycyclic aromatic hydrocarbon (C-PAH) and (b) polychlorinated biphenyl (PCB).



compounds in PC2 were Phe, Acy, Ace, Fl, Ant, and BgP. Among them, Acy and Ace are typically emitted from coal or fossil fuel combustion (Khalili et al. 1995; Wang et al. 2013). Phe, Ace, and Ant were also associated with PC1, suggesting that these compounds not only derived from coal or fossil fuel combustion, but also from diesel emission. Overall, PC1 and PC2 related to petroleum combustion, regardless of the types of oil (gasoline, diesel, heavy oil, etc.). This result is in accordance with the consumption of petroleum as an energy source. Thousands of ships on the Yangtze River need lots of petroleum as energy support. In addition, with the construction of the Three Gorges Dam, many tourists visit, and the increase in traffic (number of vehicles) also enhances the PAHs pollution in the agricultural soils. This result can also explain why specific compounds showed high levels at S4, S11, S12, S14, S15, and S16. Main pollutants at S4 were Phe, Ant, and BkF; at S11, S12, and S15 were Phe and Ant; at S14 were naphthalene (Nap), Phe, Ant, and Flu; and at S16 were Nap, Phe, Flu, BkF, and BaP. PC3 contributed 12.75% of the PAHs data with the highest loading from Nap and BbF. Nap was recognized as a major marker of coke production (Yang et al. 2010; Wang et al. 2013).

PCB distribution profiles in the agricultural topsoil (figure 3b) showed that low chlorinated congeners (PCB-28 and PCB-52) accounted for 67% of the total PCBs, espe-

Table 3

Incremental lifetime cancer risks (ILCRs) assessment for polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs).

Compounds		ILCRs _{Ingestion}	ILCRs _{Dermal}		Total ILCRs
PAHs	Minimum	2.96 × 10 ⁻⁰⁸	5.07 × 10 ⁻⁰⁶	2.37 × 10 ⁻¹²	5.10 × 10 ⁻⁶
	Maximum	1.05 × 10 ⁻⁰⁶	1.79 × 10 ⁻⁴	8.36 × 10 ⁻¹¹	1.80×10^{-4}
	Median	5.65 × 10 ⁻⁰⁸	9.67 × 10 ⁻⁰⁶	4.51 × 10 ⁻¹²	9.23 × 10 ⁻⁶
	Mean	5.65 × 10 ⁻⁰⁸	3.10 × 10 ⁻⁰⁵	1.45 × 10 ⁻¹¹	3.12 × 10 ⁻⁵
PCBs	Minimum	6.20 × 10 ⁻¹³	3.10 × 10 ⁻¹³	3.54 × 10 ⁻¹²	4.47 × 10 ⁻¹²
	Maximum	4.40 × 10 ⁻¹²	2.20 × 10 ⁻¹²	2.51 × 10 ⁻¹¹	3.17 × 10 ⁻¹¹
	Median	1.26 × 10 ⁻¹²	6.30 × 10 ⁻¹³	7.19 × 10 ⁻¹²	9.08 × 10 ⁻¹¹
	Mean	1.51 × 10 ⁻¹²	7.54 × 10 ⁻¹³	8.60 × 10 ⁻¹²	1.09 × 10 ⁻¹¹

cially at S16 (PCB-28 and PCB-52 accounted for 91% of the total PCBs). In general, the low chlorinated PCBs were correlated with papermaking progress and chemical plants wastewater discharge (Wang et al. 2005). Considering the positive correlation between TOC and PCBs, atmospheric deposition and industrial wastewater discharge were the two sources for PCBs pollution.

Summary and Conclusions

The mean concentrations of PAHs and PCBs in the agricultural topsoil samples near the Three Gorges Dam region were 1,023.48 ng g^{-1} and 35.28 ng g^{-1} , respectively. PAHs in this area had a potential cancer risk to human health. Positive linear correlation between PAHs and PCBs indicated these compounds may originate from multiple source input. The isomeric ratios analysis showed that PAHs were likely derived from combustion of fossil fuels in this study area. PCBs mainly originated from atmospheric deposition and industrial waste. The present study provides valuable PAH and PCB pollution records in the soil and a foundation for decision-making regarding PAH and PCB pollution in the soil. Some measures must be carried out to prevent further deterioration of the environment.

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Positive correlation between (a) polycyclic aromatic hydrocarbons (PAHs) and carcinogenic polychlorinated biphenyls (C-PCBs), (b) PAHs and PCBs, and (c) C-PAHs and PCBs.



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The isomeric ratios of anthracene/(anthracene + phenanthrene) (Ant/[Ant + Phe]) versus fluoranthene/(fluoranthene + pyrene) (Flu/[Flu + Pyr]) in the agricultural topsoil samples.



Table 4

Principal component analysis (PCA) of polycyclic aromatic hydrocarbons (PAHs).

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Compound	PC1	PC2	PC3	
Nap	-0.09	-0.19	0.52	
Асу	-0.01	0.55	0.06	
Ace	0.87	0.43	-0.13	
FI	0.37	0.51	0.04	
Phe	0.75	0.52	0.09	
Ant	0.75	0.52	0.09	
Flu	0.87	0.33	-0.17	
Pyr	0.63	-0.32	0.01	
BaA	0.73	-0.62	0.15	
Chr	0.61	-0.61	-0.01	
BbF	0.04	-0.19	0.66	
BkF	0.93	0.16	-0.16	
BaP	0.92	0.02	0.01	
DBA	0.88	-0.06	-0.14	
InP	0.74	-0.57	0.08	
BgP	-0.42	0.71	-0.24	
Eigenvalues	7.30	3.22	2.04	
Variance (%)	45.60	20.11	12.75	
Cumulative (%)	45.60	65.71	78.46	

Notes: Nap = naphthalene. Acy = acenaphthylene. Ace = acenaphthene. FI = fluorine. Phe = phenanthrene. Ant = anthracene. Flu = fluoranthene. Pyr = pyrene. BaA = asbenz[a]anthracene. Chr = chrysene. BbF = benzo[b]fluoranthene. BkF = benzo[k]fluoranthene. BaP = benzo[a] pyrene. DBA = dibenz[a,h]anthracene. InP = indeno[1,2,3-cd]pyrene. BgP = benzo[ghi]perylene.

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