World Applied Sciences Journal 27 (6): 694-700, 2013
ISSN 1818-4952
© IDOSI Publications, 2013
DOI: 10.5829/idosi.wasj.2013.27.06.7657

Levels of Polychlorinated Biphenyls in Surface and Drinking Waters in Some Egyptian Governorates

[1]*F.I. Eissa,* [2]*Hend A. Mahmoud,* [1]*K.M. Ghanem and* [1]*A.B. Ahmed*

[1]Environment and Bio-agriculture Department,
Faculty of Agriculture, Al-Azhar University, 11884, Cairo, Egypt
[2]Central Agricultural Pesticides Laboratory, Agricultural Research Center, Dokki, Giza, Egypt

Abstract: Eleven polychlorinated biphenyl congeners (PCB28, PCB44, PCB52, PCB70, PCB101, PCB105, PCB118, PCB138, PCB152, PCB180 and PCB192) were monitored in water samples before and after six drinking water treatment stations in three Egyptian governorates (i.e., El-Kalyoubia, Kafr El-Sheikh and Alexandria) from May 2011 to March 2012.Out of 72 surface and drinking water samples collected, 50 were contaminated by PCBs residues representing 69.4%. Among the monitored congeners, PCB180 and 28 were the most abundant and frequently observed congeners in water samples recording 32 and 29%, respectively. On the other hand, PCB70 and 105 were not-detected in all collected samples. In general, the detection of PCBs residues in water samples collected from the six sites tend to be in the following order: El Elkilo40 (100%) >ShoubraElKheima (83.3%) ≥ Metoubes (83.3%) >Mostorod (66.7%) >Elseyouf (50%) >KafrElsheikh (33.3%). However, the levels of PCBs in about 47% of the drinking water samples exceeded the maximum acceptable concentration (MAC) of 0.5 µg/L recommended by EPA. Although their use is presently severely restricted, the results from this study show that, due to their persistence, PCBs contamination is widespread in the aquatic environment of Egypt.

Key words: Water · PCBs · Pollution · Monitoring · Egypt

INTRODUCTION

Water pollution is one of the major threats to public health in Egypt. The access to safe and sufficient water and sanitation are basic human needs and are essential to health and well-being of the human population [1]. It was reported that 80% of all illness in developing countries is related to water and sanitation [2]. Industrialization and urbanization together with intensified agricultural activity have led to increased demands for water on the one hand but to the potential for large scale release of contaminants on the other [3]. With the increasingly degraded water environment, some substances will gradually accumulate in our drinking water source-the surface water and finally threaten drinking water safety when their contents reach a certain amount [4]. Among common and ubiquitous persistent organic pollutants, which may occur in water, are polychlorinated biphenyls (PCBs).

PCBs consist of 209 congeners and have been designated as typical persistent organic pollutants (POPs) by the Stockholm Convention of May 22, 2001 [5]. Commercial PCB formulations have been employed mainly as dielectric fluids in power transformers and capacitors, as heat-exchanger fluids or in hydraulic machinery, vacuum pumps and compressors. Other uses include: lubricants, paints, glues, waxes, carbonless copy paper, inks (including newspapers), solvents for spraying insecticides and cutting oils [6, 7].

PCBs enter the aquatic environment through a variety of sources that include direct deposition from the atmosphere, runoff from the land and industrial and municipal wastewater discharge [8,9]. They are amongst the industrial chemicals banned and included in the list of priority contaminants to be monitored regularly [10]. PCBs have already become one of the important global pollutants and they constitute a serious threat for human

Corresponding Author: Fawzy Eissa, Department of Environment and Bio-Agriculture, Faculty of Agriculture, Al-Azhar University, 11884, Nasr city, Cairo, Egypt.

health due to their considerable environmental persistence, their bioaccumulation in the food chain and their toxic properties [11]. They have been reported to cause a variety of effects including immunologic, teratogenic, carcinogenic, reproductive and neurological problems in organisms [12].

Although the production and usage of PCBs has been banned worldwide since the early 1970s, it is reported that the total global production of PCBs had already exceeded 1.3 million tons [13]. PCBs were never produced in Egypt, but were imported. PCBs are introduced into the Egyptian environment from the discharged waste from chemical and electrical industries and atmospheric deposition [14]. The number of PCB related studies in the Egyptian environment has increased recently thanks to a series of global initiatives on POPs and an increasing concern about the risks that these chemicals pose to human health and the environment. Most of the recent PCB investigations have focused on the assessment of these pollutants in sediments from Egyptian lakes, Mediterranean coastal environment and Nile fish [14-16], while very limited information is available regarding PCBs monitoring studies in drinking water in Egypt.

Thus, the purpose of this study was to analyse water quality before and after six drinking water treatment stations in three Egyptian governorates (i.e., El-Kalyoubia, Kafr El-Sheikh and Alexandria) for polychlorinated biphenyls contamination in order to *(a)* measure its quality *(b)* evaluate the efficiency of purifying treatments; and *(c)* check the compliance with Egyptian and international drinking water standards.

MATERIALS AND METHODS

Chemicals: Eleven PCB congeners i.e., 28, 52, 44, 70, 101, 152, 118, 105, 138, 180 and 192 were selected as the most relevant because of their distribution in the chlorine range. The PCBs reference standards were purchased from Dr. Ehrenstorfer, Augsburg in Germany. All other organic solvents and chemicals were of analytical grade and purchased from standard commercial suppliers.

Sampling Sites: Water samples were collected every two months, during the period from May 2011 to March 2012 from six drinking water treatment stations (before and after treatment) in three Egyptian governorates i.e., Alexandria (Elseyouf and Elkilo40), Kafr El-Sheikh (Kafr El-Sheikh city and Metoubes) and El-Kalyoubia (Mostorod and Shoubra El Kheima). All of these stations near suspected sources of agricultural, urban or industrial pollution. The location of the sampling stations is shown in Fig. 1.

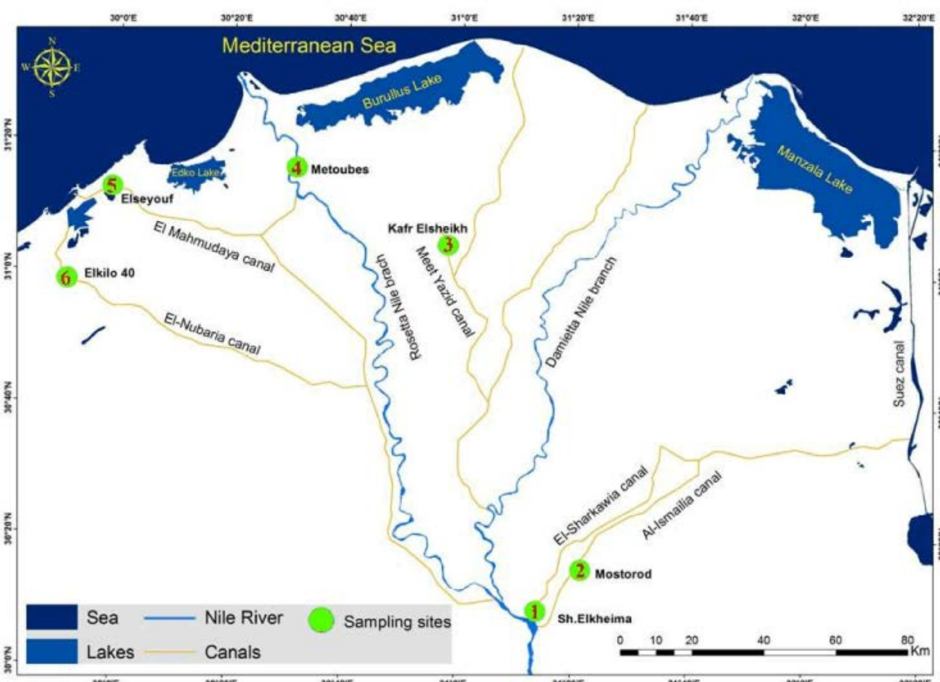

Fig. 1: Sampling sites map for locations from three Egyptian governorates.

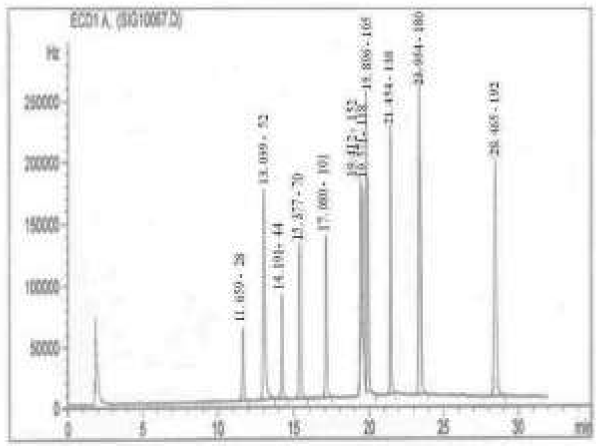

Fig. 2: GC-ECD chromatogram of the standards mixture of 11 polychlorinated biphenyls.

Samples Collection: Seventy-two samples (3 L each) were collected bimonthly in brown glass bottles from surface water (50 cm below water level) and drinking water before and after six treatment stations previously mentioned at different seasonal periods from May 2011 to March 2012. The bottles were covered with screw caps and transported immediately to the laboratory for analysis. Water samples were filtered through a glass fiber filter (GC-50, diameter: 47 mm; pore size: 0.5 ìm, Advantec).

Analytical Procedures

Extraction: Water samples (1 L, each) were partitioned thrice with 50 ml of 15% methylene chloride in n-hexane after addition of 10 ml saturated solution of sodium chloride. Samples were shaked vigorously, the organic layer was takenand combined extracts were dried over anhydrous sodium sulfate and then rotary evaporated to about 1 ml at 30°C.

Clean Up: A 18 mm (i.d.) x 40 cm glass column fitted with a stopcock was used to clean up extracts and was prepared by adding successively a plug of glass wool at the bottom, 20 g of 0.5% deactivated florisil (60-100 mesh) topped with 2 g anhydrous sodium sulfate. The column washed with 50 ml n-hexane, before the sample loaded, then the column eluted by 70 ml of n-hexane. The eluate was evaporated to dryness using rotary evaporator at 35°C and then the residue was dissolved in 2 ml of n-hexane and transferred into autosampler vial for gas chromatography-electron capture detector (GC-ECD) determination.

Quantitative Determination: The concentrated extracts were injected into GC (Aglient 6890) equipped with a ^{63}Ni ECD and a 7683A autosampler. GC analysis was conducted on a HP-5MS (Aglient, Folsom, CA) capillary column of 30 m length, 0.25 mm i.d., 0.25 µm film thickness. The oven temperature was programmed from an initial temperature 160 (2 min hold) to 240°C at a rate of 5°C min^{-1} and was maintained at 240 °C for 20 min. Injector and detector temperature were maintained at 260 and 320°C, respectively. Nitrogen was used as a carrier at flow rate of 3 ml min^{-1}.

Quality Assurance and Control (QA/QC): The QA/QC procedures included analyses of matrix spikes, laboratory blanks and confirmation. As for blank, solvents, florisil and anhydrous sodium sulfate, which used in extraction and clean up of PCBs from water samples were subjected to the same procedures as the examined samples to detect any possible traces of the monitored PCBs and their values were subtracted from the results. Peaks were identified by comparison of samples retention time values with those of the corresponding of pure standard compounds (Fig. 2.) and samples analysed by fullscan GC-MS to confirm the GC-ECD results. The average recovery percentages of the 11 PCB congeners 28, 52, 44, 70, 101, 152, 118, 105, 138, 180 and 192 from fortified clean water samples were 85, 79, 87, 91, 88, 80, 91, 84, 93, 77 and 89, respectively while the repeatability expressed as relative standard deviation (RSD) ranged from 1 to 8%. The detection limits were 1 ng/L for PCBs. All results presented in this paper are the means of triplicate analyses and were corrected with the recovery ratios.

Statistical Analyses: A value of zero was assigned for results below the limit of detection. The data were expressed as Mean ± SE. Statistical analysis was conducted using SPSS 16.0 for windows (SPSS, Chicago, USA).

RESULTS AND DISCUSSION

The individual concentrations of all eleven measured PCB congeners in both surface and drinking water samples collected before and after six drinking water treatment stations from three Egyptian governorates (i.e., El-Kalyoubia, Kafr El-Sheikh and Alexandria) from May 2011 to March 2012 are shown in Table 1, 2 and 3, respectively.

Table 1: Concentration of PCBs congeners (µg/L) detected in surface and drinking water samples collected from El-Kalyoubia governorate

		Sh. ElKheima		Mostorod	
Month	PCB congeners	before	after	before	after
May 2011	152	ND	ND	5.194±1.154	4.35*±0.96
	118	ND	ND	12.91±2.89	11.21*±2.51
	180	6.78±1.92	4.32*±1.22	ND	ND
July 2011	28	8.01±2.7	7.89*±2.8		
	152	3.15±0.69	1.591*±0.35	ND	ND
	180	4.51±1.27	3.15*±0.89		
Sept. 2011	28	2.001±0.5	1.99*±0.7	ND	ND
	180	4.51±1.27	3.15*±0.89		
Nov. 2011	152	ND	ND	3.381±0.75	2.19*±0.48
Jan. 2012	28	ND	ND	0.021±0.005	0.01±0.002
	101	0.781±0.182	0.09±0.02	ND	ND
	180	0.315±0.089	ND	ND	ND
Mar. 2012	28	8.19±2.2	2.15*±0.8	ND	ND
	152	ND	ND	0.121±0.026	0.01±0.002
	180	ND	ND	6.19±1.75	3.19*±0.90

All the values are expressed as means of triplicates ± standard error.

ND: Not detected (below detection limit), *: Exceeded the maximum acceptable concentration (0.5 µg/L).

Table 2: Concentration of PCBs congeners (µg/L) detected in surface and drinking water samples collected from Kafr El-Sheikh governorate

		KafrElsheikh		Metoubes	
Month	PCB congeners	before	after	before	after
May 2011	28	3.15±0.6	1.54*±0.4	ND	ND
	44	ND	ND	2.51±0.75	2.351*±0.70
	118	ND	ND	9.84±2.20	6.51*±1.45
July 2011	101	ND	ND	11.21±2.61	3.94*±0.91
	180			8.11±2.29	6.941*±1.96
Sept. 2011	52	0.871±0.26	0.051±0.015	ND	ND
	44	0.611±0.12	0.29±0.086		
	138	5.87±1.30	4.51*±1.002		
Nov. 2011	101	ND	ND	0.251±0.058	0.081±0.018
	180			0.891±0.25	0.781*±0.221
Jan. 2012	28	ND	ND	0.81±0.3	0.31±0.08
	138			0.51±0.11	0.481±0.1
Mar. 2012	180	ND	ND	5.41±1.53	4.51*±1.27

All the values are expressed as means of triplicates ± standard error.

ND: Not detected (below detection limit), *: Exceeded the maximum acceptable concentration (0.5 µg/L).

Table 3: Concentration of PCBs congeners (µg/L) detected in surface and drinking water samples collected from Alexandria governorate

		Elseyouf		Elkilo 40	
Month	PCB congeners	before	after	before	after
May 2011	28	ND	ND	0.781±0.19	0.341±0.07
	152	1.152±0.25	0.641*±0.14	ND	ND
	180	4.56±1.29	2.91*±0.82	2.351±0.66	1.05*±0.29
July 2011	28	6.35±1.8	4.45±1.6	ND	ND
	52	ND	ND	1.678±0.50	0.02±0.005
	118	ND	ND	3.541±0.79	0.31±0.069
	192	ND	ND	1.121±0.317	0.58*±0.16

Table 3: Continued

		Elseyouf		Elkilo 40	
Month	PCB congeners	before	after	before	after
Sept. 2011	28	ND	ND	0.441±0.14	0.021±0.007
	52			1.678±0.50	0.02±0.005
	138			9.31±2.06	0.09±0.02
	180			4.681±1.32	0.19±0.05
Nov. 2011	52	ND	ND	0.491±0.14	0.251±0.075
	118			0.651±0.14	0.31±0.06
	180			3.11±0.88	0.21±0.05
Jan. 2012	28	ND	ND	0.121±0.04	0.02±0.007
	44	0.511±0.15	0.21±0.062	ND	ND
	101	ND	ND	0.915±0.21	ND
	138	ND	ND	3.521±0.782	ND
	192	ND	ND	0.761±0.215	ND
Mar. 2012	28	ND	ND	0.051±0.02	ND
	101			12.51±2.91	2.94*±0.68
	138			8.13±1.80	6.11*±1.35

All the values are expressed as means of triplicates ± standard error.

ND: Not detected (below detection limit), *: Exceeded the maximum acceptable concentration (0.5 µg/L).

Results demonstrated that, out of 72 surface and drinking water samples collected, 50 were contaminated by PCBs residues representing 69.4%. In other words, 75, 58.3 and 75% of water samples collected from El-Kalyoubia, Kafr El-Sheikh and Alexandria governorates were contaminated by PCBs, respectively.

Concerning samples collected from El-Kalyoubia governorate, the highest concentration of PCBs in surface and drinking water was 12.91 and 11.21 µg/L, while the lowest concentration was 0.021 and 0.01 µg/L, respectively. As for samples collected from Kafr El-Sheikh governorate, the highest concentration of PCBs in surface and drinking water was 11.21 and 6.94 µg/L, while the lowest concentration was 0.25 and 0.05 µg/L, respectively. As regards samples collected from Alexandria governorate, the highest concentration of PCBs in surface and drinking water was 12.51 and 6.11 µg/L, while the lowest concentration was 0.05 and 0.02 µg/L, respectively. Among the monitored congeners, PCB180 and 28 were the most abundant and frequently observed congeners in water samples recording 32 and 29%, respectively. On the other hand, PCB70 and 105 were not-detected in all collected samples. In general the detection of PCBs residues in water samples collected from the six sites tend to be in the following order: El Elkilo 40 (100%) >Shoubra ElKheima (83.3%) ≥ Metoubes (83.3%)> Mostorod (66.7%) > Elseyouf (50%) > KafrElsheikh (33.3%). Moreover, the highest number of PCB congeners was observed in samples that were collected from Alexandria (9) followed by 7 and 5 congeners in Kafr El Sheikh and El-Kalyoubia governorate, respectively. The data also showed that the frequency of PCBs congeners in El-Kalyoubia water samples could be arranged in the following order: 180 > 28 ≥ 152 > 101 ≥ 118, while it was 180 > 28 ≥ 44 ≥ 101 ≥ 138 > 52 ≥ 118 in Kafr El-Sheikh water samples and 28 > 180 > 52 > 138 > 118 > 101 ≥ 192 > 44 ≥ 152 in Alexandria water samples. However, the levels of PCBs in about 47% of the drinking water samples exceeded the maximum acceptable concentration (MAC) of 0.5 µg/L recommended by EPA due to inadequate treatment of the raw water.

The observed PCBs concentrations ranges in surface water samples are comparable to those reported for other surface waters in Egypt [17], but are greater than PCB concentrations reported for surface waters outside of Egypt [18, 19]. It should be noted, however, that a quantitative comparison across reported PCBs data is difficult because of variances in the time of sampling, specific congeners measured in each study and the analytical methods used.

Elevated levels of PCBs observed at Elkilo 40 in Alexandria and Metoubes in Kafr El Sheikh and both sites in El-Kalyoubia are likely due to pollution from the urbanized and industrialized processes in these regions, especially from power plants. It was reported that used electrical equipment and the leakage from the broken transformers and old capacitors were a major anthropogenic source for PCBs transferred into the environment [20]. In many developing countries some old transformers, capacitors and other electrical equipment containing PCB have not disposed of properly and constitute a potential pool of PCBs in many environment compartments [21]. A study by Zhao *et al*. [22] suggested that obsolete transformers and electrical waste are important sources for the emission of PCBs into local environments. In addition, shipping activity is a possible source of PCB emission [23]; as PCB-containing paints were frequently applied to ship hulls in the past [24, 25]. Moreover, potential PCB emission sources include leaks and spills of PCBs, illegal disposal of PCB-containing products, municipal solid waste incineration and historical contamination of bottom sediments [26]. Discharge of untreated effluents from industrial and municipal activities, urban runoff, outflow from agricultural area, chemical spill and atmospheric deposition are consider to be the main sources of polychlorinated biphenyls [14]. In order to determine the sources of the observed contaminants, intense localized sampling and analysis of effluents and runoff patterns would be needed.

CONCLUSION

To our knowledge, this is the first study to report the residue levels of PCBs in drinking water of Egypt and provide baseline data for future research. Based upon the concentration levels of measured PCB congeners in water samples, PCBs are currently posing an unacceptable level of risk to aquatic ecosystem and posing a potential risk to human populations relying on the surface water as a source of domestic water. In addition, sources of PCBs to the water bodies need to be identified and managed. Continuous monitoring of water quality throughout the country both in rural and urban locations and in different seasons must be undertaken. Lastly, industrial wastewater disposal should be strictly monitored and all industries should be forced to adopt wastewater treatment measures.

REFERENCES

1. UN, 2006. African water development report-2006. UN-Water/Africa, Addis Ababa, Ethiopia, pp: 370.
2. Tebutt, T.H.Y., 1998. Principles of water quality control, fifth ed. Butterworth-Heinemann, ISBN 0 7506 3658 0.
3. Holt, M.S., 2000. Sources of chemical contaminants and routes into the freshwater environment. Food and Chemical Toxicology, 38: S21-S27.
4. Shan, W., H. Yue-heng and Z. Dan, 2011. Discussion on parameter choice for managing water quality of the drinking water source. Procedia Environmental Sciences, 11: 1465-1468.
5. Yang, Z., Z. Shen, F. Gao, Z. Tang and J. Niu, 2009. Occurrence and possible sources of polychlorinated biphenyls in surface sediments. Chemosphere, 74: 1522-1530.
6. Webber, I., 1992. PCBs and associated aromatics. In: Encyclopedia of Environmental Science and Engineering, 3rd Edn., Vol. 2 (Edited by J.R. Pfafflin and E.N. Ziegler), pp: 849-898. Gordon and Breach Science Publishers, Langhorne, Pennsylvania.
7. Batterman, S., S. Chernyak, Y. Gouden, J. Hayes, T. Robins and S. Chetty, 2009. PCBs in air, soil and milk in industrialized and urban areas of KwaZulu-Natal, South Africa. Environ Pollut, 157: 654-663.
8. Totten, L.A., M. Panangadan, S.J. Eisenreich, G.J. Cavallo and T.J. Fikslin, 2006. Direct and indirect atmospheric deposition of PCBs to the Delaware River Watershed. Environmental Science Technology, 40: 2171-2176.
9. Davis, J.A., F. Hetzel, J.J. Oram and L.J. McKeeet, 2007. Polychlorinated biphenyls (PCBs) in San Francisco Bay. Environmental Research, 105: 67-86.
10. USEPA, 1996. US Environmental Protection Agency. Method 3630, Revision C. Washington, DC, USA.
11. Eljarrat, E. and D. Barcelo, 2003. Priority lists for persistent organic pollutants and emerging contaminants based on their relative toxic potency in environmental samples. Trends in Analytical Chemistry, 22: 655-665.
12. Nakata, H., M. Kawazoe, K. Arizono, S. Abe, T. Kitano and H. Shimada, 2002. Organochlorine pesticides and polychlorinated biphenyl residues in foodstuffs and human tissues from China: status of contamination, historical trend and human dietary exposure. Arch. Environ. Contam. Toxicol., 43: 473-480.
13. Breivik, K., A. Sweetman, J.M. Pacyna and K.C. Jones, 2002. Towards a global historical emission inventory for selected PCB congeners e a mass balance approach. 1. Global production and consumption. Science of the Total Environment, 290: 181-198.

14. Barakat, A.O., A. Mostafa, T.L. Wade, S.T. Sweet and N.B. El Sayed, 2013. Distribution and ecological risk of organochlorine pesticides and polychlorinated biphenyls in sediments from the Mediterranean coastal environment of Egypt. Chemosphere, 93: 545-554.
15. Barakat, A.O., A. Mostafa, T.L. Wade, S.T. Sweet and N.B. El Sayed, 2012. Assessment of persistent organochlorine pollutants in sediments from Lake Manzala, Egypt. Marine Pollution Bulletin, 64: 1713-1720.
16. Yahia, D. and E.E. Elsharkawy, 2014. Multi pesticide and PCB residues in Nile tilapia and catfish in Assiut city, Egypt. Science of the Total Environment, 466-467: 306-314.
17. Nasr, I.N., M.H. Arief, A.H. Abdel-Aleem and F.M. Malhat, 2009. Persistent Organic Pollutants (POPs) in Egyptian Aquatic Environment. Journal of Applied Sciences Research, 5(11): 1929-1940.
18. Bogdal, C., M. Scheringer, P. Schmid, M. Bläuenstein, M. Kohler and K. Hungerbühler, 2010. Levels, fluxes and time trends of persistent organic pollutants in Lake Thun, Switzerland: combining trace analysis and multimedia modeling. Sci. Total Environ., 408: 3654-3663.
19. Oliveira, T., G. Santacroce, R. Coleates, S. Hale, P. Zevin and B. Belasco, 2011. Concentrations of polychlorinated biphenyls in water from US Lake Ontario tributaries between 2004 and 2008. Chemosphere, 82: 1314-1320.
20. Fu, J.M., B.X. Mai, G.Y. Sheng, G. Zhang, X.M. Wang, P.A. Peng, X.M. Xiao, R. Ran, F.Z. Cheng, X.Z. Peng, Z.S. Wang and W. Tang, 2003. Persistent organic pollutants in environment of the Pearl River Delta, China: an overview. Chemosphere, 52(9): 1411-1422.
21. Hong, H., L. Xu, L. Zhang, J.C. Chen, Y.S. Wong and T.S.M. Wan, 1997. Environment fate and chemistry of organic pollutants in the sediment of Xiamen and Victoria Harbor. Marine Pollution Bulletin, 31: 229-236.
22. Zhao, G., Y. Xu, G. Han and B. Ling, 2006. Biotransfer of persistent organic pollutants from a large site in China used for disassembly of electronic and electrical waste. Environ Geochem Health, 28: 341-351.
23. Hong, S.H., U.H. Yim, W.J. Shim and J.R. Oh, 2005. Congener-specific survey for polychlorinated biphenlys in sediments of industrialized bays in Korea: regional characteristics and pollution sources. Environmental Science and Technology, 39: 7380-7388.
24. Kang, Y.H., G.Y. Sheng, J.M. Fu, B.X. Mai, G. Zhang, Z. Lin and Y.S. Min, 2000. Polychlorinated biphenyls in surface sediments from the Pearl River Delta and Macau. Marine Pollution Bulletin, 40: 794-797.
25. Edge, M., N.S. Allen, D. Turner, J. Robinson and K. Seal, 2001. The enhanced performance of biocidal additives in paints and coatings. Progress Organic Coatings, 43: 10-17.
26. Xia, C., J.C.W. Lam, X. Wu, Z. Xie and P.K.S. Lam, 2012. Polychlorinated biphenyls (PCBs) in marine fishes from China: levels, distribution and risk assessment. Chemosphere, 89: 944-949.