Asian Journal of Chemistry; Vol. 27, No. 3 (2015), 1167-1170

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2015.18726

A Preliminary Investigation of Pentachlorobenzene Amount Created from Municipal Waste Incinerators and Industrial Furnaces at Some Provinces in Northern Vietnam

N.T. HUE*, H. NAM and N.H. TUNG

Institute of Environmental Technology, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet Road, Cau Giay District, Hanoi, Vietnam

*Corresponding author: Fax: +84 4 37911203; Tel: +84 4 37916512; E-mail: nthue2003@gmail.com, nthue2003@iet.ac.vn

Received: 10 September 2014; *Accepted*: 30 October 2014; *Published online*: 19 January 2015; AJC-16748

Pentachlorobenzene is primarily formed from incomplete combustion processes. In this study, pentachlorobenzene amounts in residue ash and cinder from some municipal waste incinerators and industrial furnaces at four provinces in Northern Vietnam, including Hai Duong, Hanoi, Bac Ninh and Thai Nguyen, were preliminary investigated. The pentachlorobenzene amounts from the burners ranged from 0.0013 to 0.0325 mg kg^{-1} and from 0.0016 to 0.0390 mg kg^{-1} for the residue ash and cinder, respectively. The total pentachlorobenzene amounts of the residue ash and cinder in each provinces in 2014 ranged from 0.0070 to 0.0323 mg kg^{-1} and from 0.0016 to 0.0240 mg kg^{-1}, respectively. Specifically, the total amounts of pentachlorobenzene of Hai Duong province, in the period from 2012 to 2014 ranged from 0.0070 to 0.0470 mg kg^{-1} and from 0.0046 to 0.0390 mg kg^{-1} for the residue ash and the cinder, respectively.

Keywords: Pentachlorobenzene, Residue ash, Cinder, Investigation.

INTRODUCTION

Pentachlorobenzene (PeCB) is a kind of unintentional persistent organic pollutants (UPOPs). The threats of this compound to human and the environment have received much worldwide attention due to its toxicity for animals[1-3], persistence in the environment[4,5] and bioaccumulation in animal and human bodies[6,7]. As a result, the Stockholm Convention on persistent organic pollutants was adopted in May 2001 and came into effect in May 2004. This convention aims to control and reduce further environmental exposure of unintentional persistent organic pollutants at local and global levels. For example, the Stockholm Convention states that inventories of unintentional persistent organic pollutants release have to be established and maintained as evidence protection against unintentional persistent organic pollutants.

Pentachlorobenzene is not known to have any commercial use at present[15]. In the past, pentachlorobenzene was one components of a chlorobenzenes mixture used to reduce the viscosity of pentachlorobenzene products and employed for heat transfer[8,9], carriers in the dye process[10] and as a fungicide[11], one of degradation products from quintozene (pentachloronitrobenzene). On the other hand, many studies have shown that pentachloro-benzene is formed in thermal processes[12,13]. Now a days, pentachlorobenzene is emitted into the environment firstly through incinerator waste (waste ash, dust and cinder) and municipal waste and secondly through the waste stream during the processes of pulp and steel or iron powder production, oil additives and active sludge of wastewater treatment equipment. According to statistics, there are three biggest sources of pentachlorobenzene emission into the environment, which are related to the burning processes of biomass (45,000 kg y^{-1}), solid waste (31,600 kg y^{-1}) and coal (11,000 kg y^{-1})[12]. Pentachlorobenzene is formed from uncontrollable combustion processes according to one of three mechanisms as follows: (1) incompletely destroying the burned materials and the existing dioxin and furan in them; (2) formed from metabolism of compounds called precursor substances of dioxin and furan; and (3) created by the carbon particles and inorganic compounds containing chlorine in low-temperature regions (Denovo synthesis)[14]. However, the amount of pentachloro-benzene emission in the combustion process much depends on the combustion conditions and the presence (or not) of catalytic materials. For example, the total amount of chlorobenzenes in the liquefied layer of solid waste incinerators is 20 times higher than in the metal accumulation in the sand[15]. It is estimated that annual pentachlorobenzene emission from waste incinerators[16-18] is about 24-70 kg. In Vietnam, most burners have maximum temperature ranged from 600 to 1200 °C and have gas collecting systems. Nevertheless, pentachlorobenzene is still contained in the waste products, such as cinder and residue ash, due to its unintentional formation during the combustion. Mean weight of burned waste in each burner is approximate 1,500 kg h^{-1} and mean weight of cinder and

residue ash after combustion process are approximate 3,000 kg day^{-1} and 2,000 kg day^{-1}, respectively[19].

The objective of this study is to present the results of a preliminary investigation on pentachlorobenzene amounts from burners at some provinces in Northern Vietnam. Another objective is to describe and discuss the pentachlorobenzene amounts profiles, which may provide useful information for establishing pentachlorobenzene inventories for municipal waste incinerator and industrial furnace.

EXPERIMENTAL

In this study, residue ash and cinder samples were collected from five municipal waste incinerators and three industrial furnaces at four provinces (Hai Duong, Hanoi, Bac Ninh and Thai Nguyen) in Northern Vietnam.

The notations of WI and IF are used for municipal waste incinerator and industrial furnace, respectively. HD1-3, HN and BN are named for sampling sites of municipal waste incinerators from Hai Duong, Hanoi and Bac Ninh, respectively, while TN1-3 is named for sampling sites of industrial furnaces from Thai Nguyen.

Sample extraction and analysis: About 10 g of residue ash or cinder samples were taken for analyzing pentachlorobenzene. The analytical procedure employed was in accordance with US EPA method 8121, in which samples were extracted by soxhlet system with 450 mL of a mixed solvent of hexane and acetone (1:1, v/v) in 16 h. The extracted solution was concentrated up to 1 mL and cleaned up with both copper powder and a silica gel column containing 10 % (w/w) activated coal.

Pentachlorobenzene was determined by gas chromatography electron capture detector (GC ECD). The details of GC ECD conditions were as follows: Model: Shimadzu GC ECD 2010; column: SPB-608TM (30 m length × 0.25 mm diameter × 0.25 μm film thickness); column temperature: 150 °C (isothermal 5 min) to 290 °C (isothermal 8 min), programmed at 8 °C/min; detector temperature: 300 °C; limit of detection: 0.5 μg kg^{-1}; recoveries of spiked 100 μg g^{-1} PCB 209 (Decachlorobiphenyl) in residue ash and cinder for overall analytical procedure were about 81.5 and 90 % at the minimum, respectively.

RESULTS AND DISCUSSION

Amount of pentachlorobenzene in ash samples taken from waste incinerators and industrial furnaces in Northern Vietnam: All samples collected from the incinerators and furnaces at the provinces were analyzed and the results are presented in Table-1. The amounts of pentachlorobenzene were from 0.0013 to 0.0325 mg kg^{-1} and from 0.0016 to 0.0390 mg kg^{-1} for residue ash and cinder samples, respectively.

Table-1 shows that the highest pentachlorobenzene amount in the residue ash was 0.0325 mg kg^{-1} at HN and the lowest: 0.0013 mg kg^{-1} at TN3. For the residue ash of the furnaces, the range of pentachlorobenzene amounts is low, from 0.0013 to 0.0062 mg kg^{-1}, while the range of the pentachlorobenzene amount in the incinerators is high, from 0.0070 to 0.0325 mg kg^{-1}. The pentachlorobenzene content in the residue ash of the industrial furnaces is lower than that in the residual ash from two metal scrap dismantling plants in China (0.0107 and 0.0509 mg kg^{-1}), but the pentachlorobenzene content in the municipal waste incinerator ash is at the same level with these plants[13]. For the cinder, the amount of pentachlorobenzene is highest (0.039 mg kg^{-1}) at HD2 and lowest (0.0016 mg kg^{-1}) at TN1 and TN2. Similarly, the pentachlorobenzene amount range in cinder of the industrial furnaces is low (0.0016-0.0017 mg kg^{-1}), while that of the municipal incinerators is high (0.0016-0.0390 mg kg^{-1}). All burned materials in all burners investigated in this study do not contain pentachlorobenzene. Therefore, the pentachlorobenzene created in both residue ash and cinder as a relation with the combustion conditions and/or the metallic catalyst existed in the materials[15,20].

Total amount of pentachlorobenzene created from burners at some provinces in Northern Vietnam in 2014: The pentachlorobenzene is known as a toxic compound having the long half-life and high toxicity[21] and the essential way of pentachlorobenzene formation is unintentionally created during the combustion process of biomass, solid waste and other materials[12]. However, not many studies have reported the pentachlorobenzene amount in burners, although the sources and environmental concentrations of pentachlorobenzene have been attracting wide attention because of its

TABLE-1
AMOUNTS OF PENTACHLOROBENZENE IN SAMPLES COLLECTED IN WASTE INCINERATORS AND INDUSTRIAL FURNACES AT SOME PROVINCES IN NORTHERN VIETNAM (STUDIED FROM 2012 TO 2014 (mg kg^{-1}))

Sampling site	Type of burner	Province	2012		2013		2014	
			Residue ash	Cinder	Residue ash	Cinder	Residue ash	Cinder
HD1	WI	Hai Duong	ND	ND	0.0160	0.0273	ND	0.0020
HD2	WI	Hai Duong	0.0270	0.0390	0.0310	0.0025	ND	ND
HD3	WI	Hai Duong	ND	ND	ND	ND	0.0070	0.0026
HN	WI	Hanoi	NA	NA	0.0325	ND	0.0323	0.0016
BN	WI	Bac Ninh	NA	NA	NA	NA	0.0225	0.0240
TN1	IF	Thai Nguyen	NA	NA	NA	NA	0.0030	0.0016
TN2	IF	Thai Nguyen	NA	NA	NA	NA	0.0062	0.0016
TN3	IF	Thai Nguyen	NA	NA	NA	NA	0.0013	0.0017
Total HD			0.0270	0.0390	0.0470	0.0298	0.0070	0.0046
Total HN			-	-	-	-	0.0323	0.0016
Total BN			-	-	-	-	0.0225	0.0240
Total TN			-	-	-	-	0.0105	0.0049

ND -Not detected, NA- Not analyzed

inclusion into the Stockholm Convention. In this study, the pentachlorobenzene amount created in Hai Duong, Hanoi, Bac Ninh and Thai Nguyen provinces in Northern Vietnam was preliminarily studied in early 2014. The amount of pentachlorobenzene created in each province was calculated, based on pentachlorobenzene in residue ash and cinder of all burners in this province. Fig. 1 shows that the pentachlorobenzene amounts of the residue ash and the cinder in these provinces range from 0.0070 to 0.0323 mg kg^{-1} and from 0.0016 to 0.0240 mg kg^{-1}, respectively. The highest pentachlorobenzene amounts were 0.0323 mg kg^{-1} for the residue ash of Hanoi and 0.0240 mg kg^{-1} for the cinder of Bac Ninh. In contrary, the pentachlorobenzene amounts in the residue ash and the cinder were lowest for Hai Duong (0.0070 mg kg^{-1}) and Hanoi (0.0016 mg kg^{-1}), respectively.

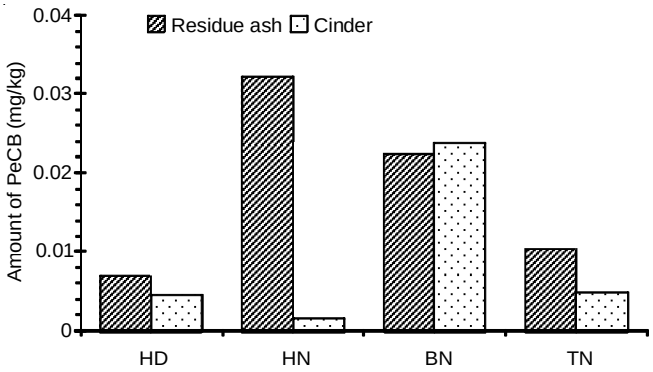

Fig. 1. Total amount of pentachlorobenzene created from waste incinerators and industrial furnaces at some provinces in Northern Vietnam (studied in 2014)

Estimate amount of pentachlorobenzene from municipal waste incinerators in Hai Duong from 2012 to 2014: An initial estimation of pentachlorobenzene amount in municipal waste incinerators in Hai Duong province in the period from 2012 to 2014 is studied. Similar to the total pentachlorobenzene investigation in other provinces in Northern Vietnam, the pentachlorobenzene in the residue ash created from municipal waste incinerators in Hai Duong for 1 year was calculated for the residues ash and cinder samples from all incinerators in this year. A pentachlorobenzene amount change between years is shown in Fig. 2. The total amount of pentachlorobenzene of all municipal waste incinerators varies from 0.0070 to 0.0470 mg kg^{-1} and from 0.0046 to 0.0390 mg kg^{-1} for the residue ash and the cinder, respectively. Accordingly to the result of this study, the pentachlorobenzene amount was highest in 2013 (0.0470 mg kg^{-1}) for the residue ash and in 2012 (0.0390 mg kg^{-1}) for the cinder. On the contrary, pentachlorobenzene amount was lowest in 2014 for the residue ash (0.0070 mg kg^{-1}) and the cinder (0.0046 mg kg^{-1}).

A relation of pentachlorobenzene amounts in residue ash and cinder of burners: The results in Table-1 show that the pentachlorobenzene amounts were different between residue ash and cinder. The higher pentachlorobenzene in the residue ash, the lower pentachlorobenzene in the cinder and vice versa. These results are the similar to those of PCDDs/Fs and PCBs found in fly ash and cinders at nine municipal waste incinerators in Japan[22]. It is suggested that operating conditions

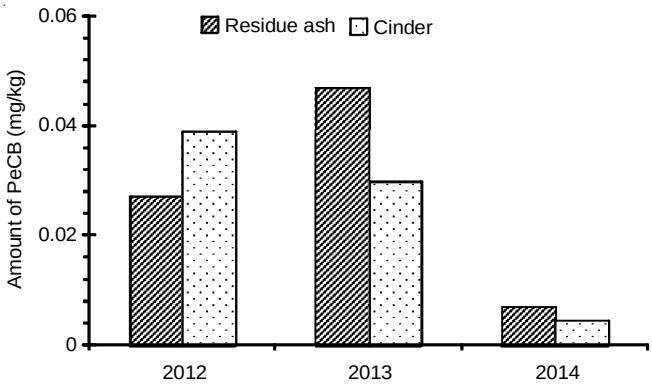

Fig 2. Total amount of pentachlorobenzene of waste incinerators in Hai Duong (studied from 2012 to 2014)

(temperature, oxygen) of burner and/or the presence of metallic catalysts in burned materials may cause the reversible existence of pentachlorobenzene (or POPs) amount between residue ash or cinder[15,20].

Conclusion

The pentachlorobenzene amounts from the residue ash and cinder at burners in Northern Vietnam were quantified. The preliminary investigation results on pentachlorobenzene of this study showed that the pentachlorobenzene content of the residue ash and cinder in municipal waste incinerators is higher than that in industrial furnaces. The pentachlorobenzene in the burners may be created depending on the combustion conditions and catalytic materials. As found in this study, there is a significant difference in pentachlorobenzene amounts between residue ash and cinder. Further investigations on the formation of pentachlorobenzene from burners in Vietnam would be required to prepare a comprehensive pentachlorobenzene inventory for Vietnam in support to the environmental management.

ACKNOWLEDGEMENTS

This study was carried out within the project VAST.CTG.01/13-14 and the authors would like to express special thanks to the president and directorate of the Vietnam Academy of Science and Technology (VAST) for their kind support.

REFERENCES

1. C. den Besten, J.J.R.M. Vet, H.T. Besselink, G.S. Kiel, B.J.M. van Berkel, R. Beems and P.J. van Bladeren, *Toxicol. Appl. Pharmacol*., **111**, 69 (1991).
2. A.R. Carlson and P.A. Kosian, *Arch. Environ. Contam.Toxicol*., **16**, 129 (1987).
3. M.R. Mortimer and D.W. Connell, *Ecotoxicol. Environ. Saf*., **28**, 298 (1994).
4. M. MacLeod and D. Mackay, *Chemosphere*, **38**, 1777 (1999).
5. P. Popp, L. Brüggemann, P. Keil, U. Thuβ and H.Weiβ, *Chemosphere*, **41**, 849 (2000).
6. Y. Chaisuksant, Q. Yu and D.W. Connell, *Water Res*., **31**, 61 (1997).
7. D.J. Hallett, R.J. Norstrom, F.I. Onuska and M.E. Comba, *Chemosphere*, **11**, 277 (1982).
8. Environment Canada, Priority Substances List Assessment Report Pentachlorobenzene (1993).
9. T.L. King, K. Lee, R. Alexander and P. Yeats, *Environ. Contamin. Toxiccol*., **71**, 543 (2003).
10. Cleghorn & Associates and Claude Davis & Associates, Inventory and Technical Study on Pentachlorobenzene and Tetrachlorobenzenes, Report prepared for Environment Canada (2001).

11. J.Ø. Beck and K.E. Hansen, *Pestic. Sci*., **5**, 41 (1974).
12. R.E. Bailey, D. van Wijk and P.C. Thomas, *Chemosphere*, **75**, 555 (2009).
13. Z. Nie, M. Zheng, G. Liu, W. Liu, P. Lv, B. Zhang, G. Su, L. Gao and K. Xiao, *Hazard. Mater*., **215-216**, 259 (2012).
14. J.S. Lighty and J.M. Veranth, The Role of Research in Practical Incineration Systems-A look at the Past and the Future, Twenty-Seventh Symposium (International) on Combustion, Pittsburgh, PA: The Combustion Institute, pp. 1255-1273 (1998).
15. Y. Akimoto, S. Nito and Y. Inouye, *Chemosphere*, **34**, 791 (1997).
16. CPI (Corpus Profile Information), Carbon Tetrachloride (Tetrachloromethane), CPI Product Profiles, Don Mills, Ontario (1990).
17. CPI (Corpus Profile Information), Trichloroethylene (Trichlor), CPI Product Profiles, Don Mills, Ontario (1990).
18. CPI (Corpus Profile Information), Perchloroethylene (Tetrachloroethylene), CPI Product Profiles, Don Mills, Ontario (1990).
19. Ministry of Natural Resources and Environment of Vietnam, Report of National PCBs Inventory and Estimation (2005).
20. M. Yan, X. Li, T. Chen, S. Lu, J. Yan and K. Cen, *J. Environ. Sci.*, **22**, 1637 (2010).
21. J. Liu, *Encyclo. Toxicol*., **3**, 773 (2014).
22. T. Wakimoto and R. Tatsukawa, *Environ. Health Perspect*., **59**, 159 (1985).