Determination and identification of flame retardants in soil collects from E-waste industries and End of Life vehicles (ELV) from major cities of South India

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1. Aim

Polychlorinated biphenyls (PCBs) are a group of commercially synthesized and widely used in numerous industrial applications, such as chemical stability, high thermal conductivity, and electrical insulation properties. Totally 209 PCB congeners are manufactured, classified based on the number of chlorine substituent's, and position of chlorine atoms PCBs are stable under extreme temperature and pressure. Hence, PCBs are used as additives in dielectric fluids in transformers and capacitors, heat transfer fluids and hydraulic fluids in partially closed-industrial systems, furthermore, this can be used as additives in lubricants, casting waxes, surface coatings, adhesives, plasticizers, and inks (UNEP, 1999; WHO, 2000; Erikson and Kaley II,2011). Higher usage of PCBs were released into the environment and that had been found in the environmental matrices, including air, indoor dust, soil, sediment, biota, food, water, and biological samples from Vietnam (Takahashi et al.,2017; Tue et al.,2013; Wang et al.,2016; Tri et al.,2016; Romano et al.,2013). Further, PCBs had been found in human samples, such as breast milk, and blood (Minh et al.,2004; Tue et al.,2010a). PCBs are not produced in the Vietnam, but the level of PCBs in atmosphere was higher than that in Asia and Europe. This might be due to release of PCBs from old electrical equipment, traffic and industrial activities, waste processing and recycling activities (Wang et al.,2016; Jaward et al.,2004; Jaward et al.,2005; Hoai et al.,2010; Toan et al.,2017; Hue et al.,2016; Anh et al.,2018b,Eguchi et al.,2015; Takahashi et al.,2017; Tue et al.,2013).

As like that of PCBs, polybrominated diphenyl ethers (PBDEs) are flame retardants have 1 to 10 bromine atoms. Further, PBDEs have been varied known as "congeners". Almost 209 PBDE congeners are manufactured, but only few numbers of congeners had been found in commercial mixtures. The commonly found congeners are penta-BDE (4 to 5 bromine congeners, Ex: BDE-47, -99, and -100), octa-BDE (7 to 8 bromine congeners, Ex: BDDE-194 to BDE-205), and deca-BDE (10 bromine congeners, Ex: BDE-209). The above mentioned congeners are used in furniture, mattresses, carpet padding, and automobile seats (penta-BDE), acrylonitrile-butadiene-styrene (ABS) plastic in electric and electronic devices (octa-BDE), textiles, certain building materials (octa-BDE) (USEPA, 2010). Wide application of these compounds can eventually released into the environment and persistent for long time. Because, PBDEs are not chemically bound with the products, so it can easily released during production and on usage. Dispose and recycle of PBDEs containing products eventually released the associated compounds into the environment. This results in the ubiquitous presence of PBDEs in food products, house dust, indoor and outdoor air, sediments, soil, sludge, marine species, terrestrial animals and also in humans (Law et al.,2006; Darnerud et al.,2001; De Wit CA, 2002; Gill et al.,2004; Hites et al.,2004; McDonald, 2005; Hazrati etal.,2006; Chen et al.,2007). Presence of PCBs and PBDEs in the environment will enter into the organism and persistent for long time. Many scientist reported the presence of PBDEs in environmental matrices and even in human samples from Vietnam. Major reason for PBDEs contamination was dumping of municipal waste, e-waste recycling and end-of-life vehicles (ELVs) processing in Vietnam (Eguchi et al.,2013; Anh et al.,2017; Takahashi et al.,2017; Tue et al.,2013; Ramu et al.,2007; Eguchi et al.,2015). Fast urbanization was associated with the increasing trend of PBDEs level (Wu et al.,2015).

ELVs are categorized as motor vehicles that had been discarded as waste after they reached their life technically/economically. According to IFCAR, (2012) around 84 millions of ELVs were produced all over the world. Moreover, in European Union about 5.3 million of ELVs produced in 2017, this had been comparatively lesser ELVs produced in 2009 (7.7 million) and 2010 (6.2 million). The main for reduced ELVs in 2017 could be reuse and recovery of ELVs to manufacture hybrid vehicles. Besides, in 2020 the number of ELVs production was increased to 80 million units (WRME, 2014).ELVs had numerous hazardous chemicals which was released from the wastes. Many research peoples found hazardous chemicals released from ELVS, such as heavy metals, persistent organic pollutants (POPs- PCBs, PBDEs, organotin stabilizers), etc. Many literatures reported the variety of hazardous substances found in concerning levels in ELVs, in which approximately 90 million ELV units had been produced in all over the world in 2014 only (Niinipuu, 2013; Korea Statistical Information Service, 2015). Among those variety of hazardous substances, PBDEs are become great concern in international community, because of its persistence and toxicity in the environment (Gearhart and Posselt, 2006; Sakai et al.,2006; lagalante et al.,2011; Jiang and Li, 2016).

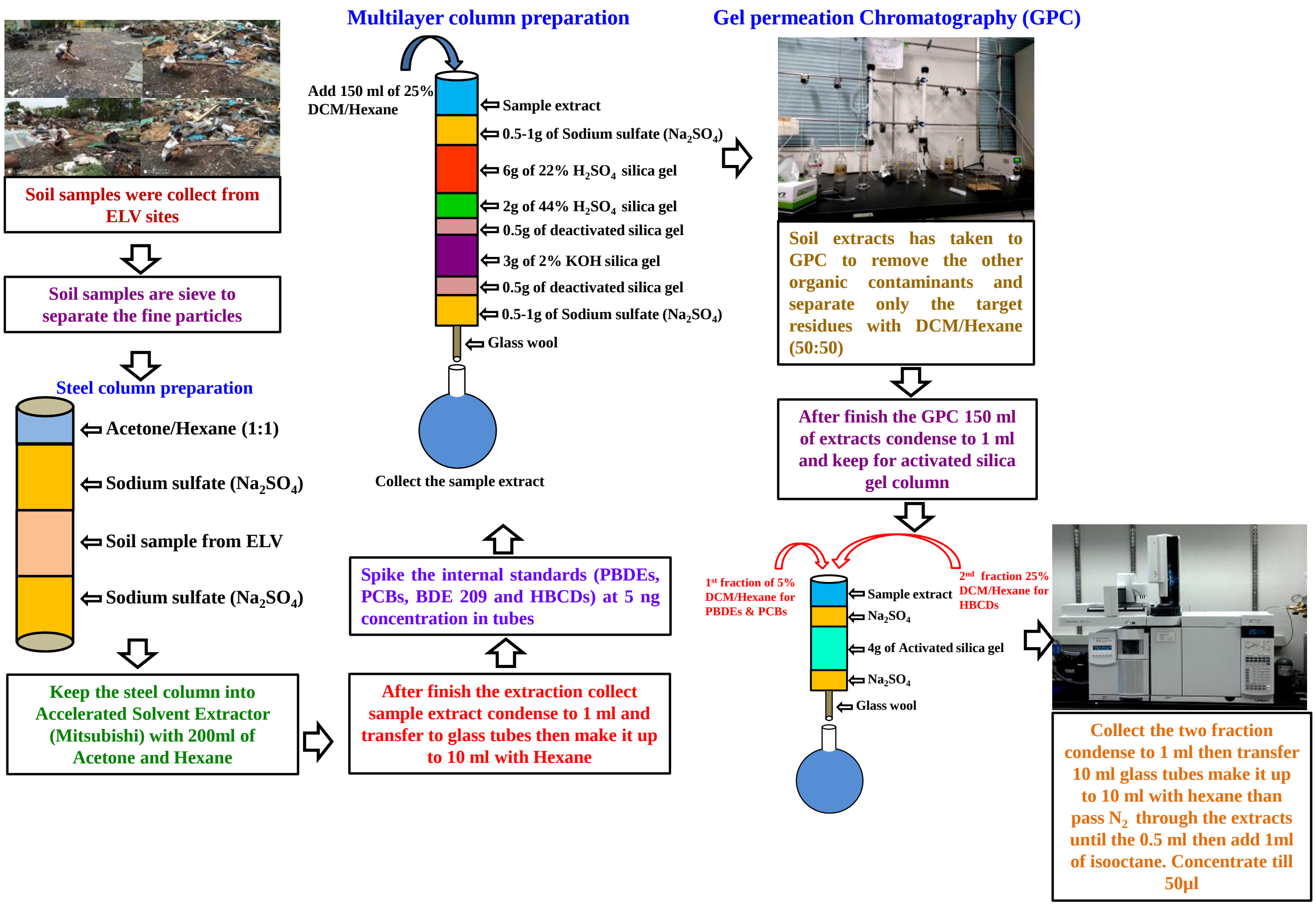
The present study has revealed to determine and quantify PCBs, PBDEs and their biotransformation products in soil samples of ELV sites from major cities (Chennai, Coimbatore and Tiruchirappalli) of Tamil Nadu state in India. The current study was focused on the levels of PCBs and PBDEs in soils from ELV sites and their distribution based on the activity at particular site locations. Numerous studies reported the presence of PCBs and PBDEs in diffrent countries. But, this is the first report of PCBs and PBDEs level in End of Life Vehicle sites in India specifically in South India (Tamil Nadu).

2. Objectives

- ✓ To collect the background data and main sources of PBDEs and PCBs in E-waste industry, and End of Life Vehicles (ELVs).

- ✓ To find the distribution and concentration of PBDEs and PCBs in E-waste and End of Life Vehicles (ELV) in soils samples from various locations and also to find out the hotspots of PBDEs and PCBs contaminated sites.
- ✓ To evaluate the PBDEs and PCBs using the already available data on environmental levels from the study area and the data to be obtained in this study.

3. Methodology for PBDEs and PCBs extraction in soil samples



4. Result and Discussion

4.1. Concentration of PBDEs in ELV sites

Total concentration of PBDEs in the ELV sites were ranged from not detected to 565.2 ng/g dw. PBDEs concentration was higher in Coimbatore (13.1- 565.2 ng/g dw) followed by Chennai (9.4-160 ng/g dw) and Tiruchirappalli (39.5-162.2 ng/g dw) (Table1). Scraping of truck engines and dismantling results in the huge level of PBDEs in CB5 and CB2, further engine oils could be the main source for higher PBDEs concentration in these sites. Tyre removal and storage site in Tiruchirappalli (TPJ1) also influence in higher PBDEs level, because PBDEs are used to prevent tyre from high temperature and some kind of tyres were manufactured by textiles for easy handling. PBDEs can be released from seat foam, rigid insulation, automobile trim, insulations, carpet foam pads, cable insulation, textile coating, headliners and stereos. Hence, the automobile residues releases large amount of PBDEs in environment (Jeff Gearhart and Hans Posselt, 2006). In the present study, engine dismantling and scraping sampling sites showed higher level of PBDEs than those of other ELV sites. The present study was not corroborate with other research reports, because of lack of information about PBDEs released by automobile engines.

PBDEs concentration in automobile shredded residues (ASR) (218 to 2710 mg/kg) were reported by Choi et al. (2017). The author found PBDEs in seat fabrics (25158 to 65842 mg/kg) and other interior components (interior light cover, floor cover, and headliner and seat belt (<1 to 10865 mg/kg). Automobiles releases PBDEs into the environment in their life cycle, which approximately 627 ton. The released PBDEs enter into the domestic market through manufacturing (1743 tons), export (119 tons) and import (74 tons). During the life cycle of automobile it releases about 7748 tons of PBDEs and 28 tons at the ELV stage. Incineration of ELVs leads to around 208 tons PBDEs emission and 23 tons of PBDEs during energy recovery. Dumping of ELVs may results in release of 16 tons of PBDEs. Kajiwara et al. (2014) reported PBDEs in interior materials, and this study was conducted in Japan. The author found PBDEs in cabin dust of ELV sites (5500-7800 mg/kg), seat foam (5200 mg/kg) and interior components (6600-8200 mg/kg). These reports showed the higher PBDEs level in seat fabrics and polyurethane foam (PUF) (Sweden) (13-2200 ng/g) (Niinipuu, 2013). Deca-BDE was the predominant congener in PUF among others. These findings revealed that tetra and deca-BDE were predominantly used in the foam production.

BDE-209 was the major congener among other congeners in all the sampling sites. For as, BDE-209 in samples from Coimbatore (CB5- 460.5 ng/g dw) was higher than that of Chennai (CH3- 132.2ng/g dw) and Tiruchirappalli (TPJ1- 138.6 ng/g dw), respectively. Similarly, BDE-99 was higher in all the sampling sites (CB1, CB2, and CB4) except CB3 and CB5. Concentration of BDE-209 was comparatively higher than BDE-99. Due to the abundant usage of BDE-209 in automobiles results in higher distribution pattern than other congeners. An another study also reported increased level of BDE-209 (62-8200 ng/g) and total PBDEs concentration (68-9200 ng/g) in soil samples from e-waste recycling workshops in Bui Dau, Hung Yen province (Matsukami et al.,2015). Seat fabrics and ASR also showed higher level of BDE-209 and BDE-206 among other congeners (Choi et al.,2017). Floor dust from the household (280 ng/g) and ELV workshops (1500 ng/g) were found contamination of PBDEs. Lower brominated congeners (BDE-47, BDE-15, BDE-17, BDE-28) were frequently found in road dust from urban and industrial areas of northern Vietnam (Anh et al.,2018). Higher BDE-209 was found in road dust collected from urban (12-52 ng/g) and industrial areas (2.2-8.6 ng/g) , however these concentration was lower than in the current study as well as reported in China, Pakistan, Australia and some developed countries (Khan et al.,2016; McGrath et al.,2016; Tang et al.,2016; Xu et al.2015). Lower PBDEs level in the northern Vietnam showed reduced utilization of PBDEs containing products. Tetra- and penta-BDE level had been higher in house dust from Bui Dau (Tue et al.,2013). On the other hand, a study reported extreme contamination of BDE-209 (560,000 ng/g) in dust from TV set in Japan (Takigami et al.,2007). These studies illustrated that higher production of PBDEs; especially deca-BDE had been manufacture largely and longer usage.

4.2. Concentration of PCBs in ELV sites

Total PCBs concentration in soil samples from Chennai, Coimbatore and Tiruchirappalli was ranged from not detected to 18901 ng/g dw (Table 2). Highest PCBs concentration was found in Coimbatore (CB5) (1.6-18901 ng/g dw) followed by Chennai (CH3) (61.9-5429.6 ng/g dw) and Tiruchirappalli (TPJ2) (5.2-127.6 ng/g dw), respectively. Coimbatore showed higher PCBs level, due to the presence of PCB containing materials, like electrical capacitors and transformers. Further, usage of PCBs in closed system influence on the raised contamination level, such as heat transfer fluids in transformers, capacitors, and fluorescent light ballasts, and application in plasticizers, hydraulic fluids, lubricants and miscellaneous uses. In Chennai truck engines were dismantled, which possess to higher PCBs concentration at CH3. PCBs concentration was depend on the kind of activity followed in the ELV sites. For example, CB1 site was used to store the engine parts and vehicle spares, hence level of PCB could be lower.

Soil samples collected in Hanoi (urban area) showed higher level of PCBs, due to the presence of several automobile workshops, busy road crossing and chaotic bus station (Anh et al.,2019). In this study PCBs concentration in soil samples from urban and industrial area were 15-190 ng/g (Toan et al.,2007), 18-104 ng/g (Hue et al.,2016), these were comparatively very low than that in the present study. Similarly, PCBs were found in house dust from urban and suburban areas (Hanoi) were ranged between 5.6-85 ng/g and 3.6-20 ng/g, respectively. Penta and hexa-CBs were found highest level than other congeners in indoor dust of urban and sub-urban area from the Hanoi. Due to the presence of informal recycling sites, however, Trang minh and Bui dau showed highest tri-PCBs in air samples. Northern Vietnam was previously contaminated by higher usage of transformer oil containing PCBs (Minh et al.,2008). Another source of PCBs in Vietnam were Aroclor 1016, 1242 and Kaneclor 300, 400 (Takasuga et al.,2006). Takahashi et al. (2016) reported PCBs (19-2200 ng/g) in floor dust collected from informal ELV recycling site in northern Vietnam, this reveals the presence of PCB containing materials in workshops. The author also found PCBs in dust samples from industrial (14 ng/g), urban (11 ng/g), and rural areas (0.25 ng/g). Urban area (northern Vietnam) showed higher level of PCBs contamination than that of rural areas.

Some of the congeners were found higher level, concentration of CB-28 was highly detected in all the sampling sites. In Chennai, 50 PCB congeners were found out of 56 congener (1904.1 ng/g dw), followed by 51 out of 56 congeners in Coimbatore (5096.3 ng/g dw) and 20 out of 56 congeners in Tiruchirappalli (30.68 ng/g dw). Next to PCB-28, the highly detected compound were PCB-37, PCB-70 and PCB-52 in Chennai and Coimbatore. Di and tetra CBs were found in house dust near to e-waste recycling sites, which illustrate the discharge of electrical wastes. Similarly, tri- and tetra PCBs were higher in the industrial samples than urban and rural areas, which consistent with the present study. Urban areas had been found higher chlorinated PCBs (penta-PCBs and octa-PCBs), due to presence of diesel engine manufacturing company, central area of park, numerous factories results in significant amount of PCBs. Klees et al. (2015, 2017) reported higher PCBs concentration in street dust in the surrounding of e-waste recycling, industrial sites in North Rhine- Westphalia, Germany. Likewise, tetra-PCBs were found in the street dust collected from Thai Nguyen, Essen- Kray, Germany. These PCBs concentration was several order of magnitude higher than the present study. Although, tri and tetra-PCBs levels in dust samples were not corroborate with the present study (Takahashi et al., 2017; Tue et al., 2013).

The reported PCBs level in the present was corroborate with Anh et al. (2019), who reported PCB-28 and PCB-52 level was abundant in the industrial street dust collected from Thai Nguyen, and urban samples were found penta-PCBs to octa-PBCs at higher level. Furthermore, PCB-28 was the major compound in indoor dust from Guangzhou and Hong Kong, China (Wang et al.,2013). The reason for PCBs contamination was oil leakage in electric equipment and lubricating oil in motor vehicles. (Hoi et al., 2010; Toan et al., 2007). According to Cetin, (2016) and Chakraborty et al.(2016) the six lightly chlorinated congeners (PCB28, PCB52, PCB44, PCB70, PCB49 and PCB74) were emitted from metallurgical plants in industrial area and the PCBs were used as heat transfer and insulating fluids in electrical transformers, capacitors and plasticizers (Takasuga et al.,2006; Cachada et al.,2009). Another study reported the abundance of tetra, penta and hexa-CBs in informal e-waste recycling sites in Chennai, which contribute almost two third of the total PCBs concentration. Tetra-CBs were frequently found in the street dust from Mambakkam as an industrial zone (Chennai, India) (**Chakraborty et al.,2016**). The author also reported that ferrous scrapping activity also influence on the tri-CBs, specifically PC-28. Dismantling of electrical wastes results in higher concentration of tri- and terta-CBs (Cachada et al.,2009). The possible source of PCB-28 may due to nearby sources and emission of from the industries, etc (Wang et al., 2013; Klees et al., 2015; Klees et al., 2017; Sohail et al., 2018).

Table 1 **Total concentration, Maximum, Minimum, Mean and median of PBDEs in ELV site soils from Tamil Nadu, India**

Locations	**Chennai**					**Coimbatore**					**Tiruchirappalli**			
Sample sites	C1	C2	C3	C4	C5	MP1	MP2	MP3	MP4	MP5	TPJ1	TPJ2	TPJ3	TPJ4
ΣPBDEs (ng/g d.w.)	141	19	160	25	9.4	58.2	171.6	13.1	98.7	565.2	162.2	50.7	60.9	39.5
Maximum	123.4	14.6	132.6	19.1	8.2	49.5	100.2	2	63.2	460.5	138.6	34	30	11.5
Minimum	0.04	0.01	0.02	0.02	0.01	0.02	0.05	0.02	0.003	0.14	0.03	0.06	0.09	0.14
Mean±SD	7±27.4	1.2±3.7	10±32.7	1.4±4.4	0.7±2.3	2.8±10.7	6.9±20.2	0.5±0.5	3.3±11.5	24.6±95.3	7.7±30	2.7±7.6	2.3±5.6	1.4±2.3
Median	0.5	0.2	0.9	0.2	0.1	0.2	0.9	0.3	0.5	0.8	0.5	0.8	0.8	0.5

Table 2 Total concentration, Maximum, Minimum, Mean and median of PCBs in ELV site soils from Tamil Nadu, India

Locations	**Chennai**					**Coimbatore**					**Tiruchirappalli**		
Sample sites	C1	C2	C3	C4	C5	MP1	MP2	MP3	MP4	MP5	TPJ2	TPJ3	TPJ4
ΣPCBs (ng/g d.w.)	798.3	1243.9	5429.6	159.5	61.9	1.6	3.6	464.8	676.6	18901.4	127.6	6.3	5.2
Maximum	123.5	228.8	1448.7	43.5	14.9	0.2	0.8	71.9	124.5	5043.3	30.7	0.8	1
Minimum	0.1	0.1	0.1	0.3	0.1	0.04	0.1	0.05	0.04	0.5	0.2	0.3	0.2
Mean±SD	23.5±37	31.1±47.7	110.8±234.8	5.7±8.6	2.1±3.2	0.1±0.1	0.3±0.2	13.7±21.5	16.9±26	385.7±817.5	4.4±6.6	0.5±0.2	0.5±0.3
Median	4.4	17	11.7	1.7	0.6	0.1	0.2	2.6	9.2	40.9	1.2	0.4	0.5

Table.3 Background activity of Soils samples in different ELV sites

S.No	ELV sites	Sample ID	Sources of scrapped vehincels	Date of collection
1	Chennai	CH1	Engine dismantle and dumped	17.09.2018
2		CH2	Lorry engine dismantle and storage	
3		CH3	Large types of truck engine dismantle and oil spilied noticed	
4		CH4	Bus engines was dismantle and spares was dumped	
5		CH5	Bus and Van body scrapped and burned (soil contained some ash)	
6	Coimbatore	MP1	Bunk of car engines are stored	26.08.2018
7		MP2	Car bodies are scraped and dumpped	
8		MP3	Vehicle interior spares are dumped	
9		MP4	Car bodies dismantle and storage	
10		MP5	Truck engines are dismantled and scraped	
11	Tiruchirappalli	TPJ1	Tyres are removed and dumped	16.092018
12		TPJ2	Vehicle interior spares are dismantle	
13		TPJ3	Alloy wheel dismantle and storage	
14		TPJ4	Car engines are dismantled and scraped	

5. List of publication and Conference presentation

5.1 Publications:

1. **Vimalkumar K,** Arun E, Nikhil NP, Mayilsamy M, Babu-Rajendran R. Synthetic Musks in surface water and fish from the rivers in India: Seasonal distribution and Toxicological risk assessment Journal of hazardous Materials. 2021. (**IF 9.038**). https://www.sciencedirect.com/science/article/pii/S0304389421005215 (accepted).

2. Praveenkumarreddy Y, **Vimalkumar K**, Ramaswamy BR, Kumar V, Singhal RK, Basu H, Gopal CM, Vandana KE, Bhat K, Udayashankar HN, Balakrishna K. Assessment of non-steroidal anti-inflammatory drugs from selected wastewater treatment plants of Southwestern India. Emerging Contaminants. 2021 Jan 1; 7:43-51 **(IF 1.976)**.

3. **Vimalkumar K,** Seethappan S, Pugazhendhi A. Fate of Triclocarban (TCC) in aquatic and terrestrial systems and human exposure. Chemosphere. 2019 Sep 1; 230:201-9. (**IF 5.108**).

4. Babu-Rajendran R, Preethi G, Poopal RK, Nikhil NP, **Vimalkumar K**, Subramanian A, Krishna-Kumar S. GC–MS determination of phthalate esters in human urine: A potential biomarker for phthalate bio-monitoring. Journal of Chromatography B. 2018 Mar 15; 1079:15-24. (**IF 2.813**).

5. **Vimalkumar K,** Arun E, Krishna-Kumar S, Poopal RK, Nikhil NP, Subramanian A, Babu-Rajendran R. Occurrence of triclocarban and benzotriazole ultraviolet stabilizers in water, sediment, and fish from Indian rivers. Science of the Total Environment. 2018 Jun 1; 625:1351-60. (**IF 5.589**).

6. Sampath S, Selvaraj KK, Shanmugam G, **Vimalkumar K**, Chakraborty P, Ramaswamy BR. Evaluating spatial distribution and seasonal variation of phthalates using passive air sampling in southern India. Environmental Pollution. 2017 Feb 1; 221:407-17. (**IF 5.714**).

5.2 Book Chapter:

1. Nikhil Nishikant Patil, S. Krishna Kumar, **K. Vimalkumar**, E.Arun, Babu Rajendran, R. Organochlorine pesticide contamination in the Kaveri (Cauvery) river, India: A review on distribution profile, status, and trends. In: Water Challenges and Solutions on a Global Scale (Ed. Satinder Ahuja), ACS Books, Washington, DC, 2015: 447p.

5.3 Presentation:

1. **Vimalkumar K***, Tue Minh Nguyen, Shin Tanabe and Tatsuya Kunisue entitled Contamination levels of PCBs and PBDEs in fresh water fish from Chennai and Bangalore cities in India and their toxicological risk. 39th International Symposium on Halogenated Persistent Organic Pollutants (DIOXIN 2019). (26th – 30th, August 2019) at Kyoto International Conference Center, Kyoto, Japan.

2. Babu Rajendran R, **Vimalkumar K**, Patil Nikhil Nishikant, Arun E and Poopal RK entitled Perfluorinated compounds (PFCs) in Indian environment. 27th Symposium on Environmental Chemistry. (22-25, May 2018) at Okinawa, Japan.

3. **Vimalkumar K*,** Srimurali S, Krishna Kumar S, Govindaraj S, Paromita C, BabuRajendranRentitled Spatial Distribution and Seasonal Variation of Phthalates from atmospheric air using Passive Air Sampler in Southern India. International conference on Biodiversity and Sustainable Resource Management (ICBSRM 2018) (12th – 13th March, 2018) at Madras University, Chennai.

4. **Vimalkumar K***, E. Arun,S. Krishna Kumar, Nikhil NishikantPatil, RK. Poopal and R. BabuRajendranentitled Determination of Triclocarban (TCC) and Benzotriazole UV stabilizers (BUVSs) in surface water from South Indian Rivers. 19th International Conference Symposium on "Pollutant Responses in Marine Organisms" (PRIMO 19). (30th July – 3rd June, 2017) at Ehime University, Matsuyama, Japan.

5. **Vimalkumar K*,** E. Arun,S. Krishna Kumar, Nikhil NishikantPatil, RK. Poopal and R. BabuRajendranentitled Toxicity of metal and metal oxide nanoparticles to the Asian common Toad *DuttaphrynusMelanostictus*. 19th International Conference Symposium on "Pollutant Responses in Marine Organisms" (PRIMO 19). (30th July – 3rd June, 2017) at Ehime University, Matsuyama, Japan.

6. Subramanian A, BabuRajendran R, Takafumi Matsushita, **Vimalkumar K***, Tatsuya Kunisue and Shinsuke Tanabe entitled PCDD/Fs, DL-PCBs and PBDEs in the dumping site soils of Tiruchirappalli town, South India. 19th International Conference Symposium on "Pollutant Responses in Marine Organisms" (PRIMO 19). (30th July – 3rd June, 2017) at Ehime University, Matsuyama, Japan.

7. **Vimalkumar K***,Govindaraj, S. Krishna Kumar, S. Srimurali, Nikhil NishikantPatil, E. Arun and R. BabuRajendranentitledNonsteroidalanti inflammatory drugs (NSAIDs) in major rivers of Tamilnadu, India**.** International Conference on "Recent Trends in Bioscience". (07th – 09th February, 2016) at Alagappa University, Karaikudi, Tamilnadu, India.

8. **Vimalkumar K***, Bhuvaneswari R, Govindraj S, Arun E and BabuRajendran R entitled Human and Environmental Risk Assessment of Organochlorine pesticides in Water and Fish from River Cauvery, Tamilnadu. Two days workshop on "Micro pollutants in water and their hazards" (12th – 13th January, 2015) at IIT, Madras, Tamil Nadu, India.

9. **VimalkumarK***, Srimurali S, Krishna Kumar S, Govindaraj S, BabuRajendran R entitledDetermination of PCDDs, PCDFs and dioxin like PCBs in bovine milks and ash samples by using CALUX Assay in Tamilnadu, India. International Symposium on Halogenated Persistant Organic Pollutants (IEEP-2014) (January 16-17 2014) at CSIR-NEERI, Nehru Marg, Nagpur, Maharashtra, India.

10. **Vimalkumar.K*** present paper entitled "Study on effect of elevated CO_2 on growth and nutrient accumulation in important indigenous tree species" in International Symposium on Environmental Risk Assessment at Department of Zoology, School of Life Sciences, Bharathiar University, Coimbatore, Tamil Nadu, India (17th – 19th October, 2011)**.**

***Presenter**