POTENTIAL EXPOSURE THREAT TO INDONESIAN ENVIRONMENTAL COMPARTMENTS FROM POLYBROMINATED DIPHENYL ETHERS OF E-WASTE

Suciati F[1], Aviantara DB[1]
[1]Environmental Technology Centre – BPPT, Indonesia, 15314, fuzi.suciati@bppt.go.id

Introduction

Rapid advances and improvements in features and capabilities of electrical and electronic equipment (EEE) have led the acceleration of turnover rate of the EEE globally. As the consequence a worldwide generation of e-waste is hardly to avoid. As the 4th rank of most dense population in the world, it is not surprising that Indonesia is an attracting country for both local importers and foreign exporters, particularly electrical and electronic equipments. Recently, Indonesia reported as the world 9th-ranked in generating e-waste[1]. Approximately 1,274 million tonnes e-waste (equal to 4.92 kg e-waste/capita)[1] was generated three years ago and predicted to reach 1,413.5 million tonnes by the end of 2019.

It has been known that in electronic or electrical devices the use of polybrominated diphenyl ethers (PBDEs) as a flame retardant is not uncommon. The chemical substance is a xenobiotics applied to a wide range of products such as electronics, textiles, building materials, plastics, polyurethane foams, airplanes, motor vehicles, furnishings etc. Therefore PBDEs containing materials are expected ubiquitous in the environment. The use of PBDEs as a flame retardant in a huge number of commercial products has created public concern because of its stability and hard to degrade naturally. The PBDEs may accumulate in the environment as the result of its persistent characteristics and potentially creating chronic exposure problems to living organisms. The PBDEs have been known to reduce the immune system, causing cancer, neurological impairment, behavioural performance disorder and also disrupting thyroid or hormonal system[2,3,4]. This paper describes current PBDEs problem in Indonesia, their existence in environmental matrices as well as potential exposure of PBDEs to human linked to the generated e-waste.

Materials and Methods

Data and information on PBDEs in Indonesia was compiled from many sources such reports, jounals, seminar papers and other literature. An initial evaluation of major source was conducted.

Results

Air contaminated with PBDEs. A study on PBDEs levels in ambient air has been conducted in two locations, i.e. Jakarta City (representing a big city) and Bogor Regency (representing a village)[5]. The study measured nine types of PBDEs congeners that included BDE-17, -28, -47, -66, -99, -100, -153, -154, and -183. Among the nine PBDEs congeners, only BDE-153 and BDE-183 were not detected in Bogor Regency. Total concentration of the detected PBDEs in Jakarta City was 9.77 pg/m^3 and in Bogor Regency was 5.71 pg/m^3. The PBDE congener levels detected in Jakarta City ambient air were in the range 0.13 – 4.12 pg/m^3 meanwhile in Bogor Regency were in the range 0.09 – 2,59 pg/m^3. Although Jakarta City and Bogor Regency demonstrated differences in the levels of detected PBDEs, however, the two have similar PBDE congener type, i.e. BDE-47, that present at the highest level. In addition the maximum ratio and the minimum ratio of PBDEs for Jakarta City against Bogor Regency were similar in the range 1.44 – 1.59. Such a ratio was close to the ratio of population density of Jakarta City to Bogor Regency, i.e. around 1.8[6,7]. This indicated ambient air of Jakarta City was exposed more PBDEs than Bogor Regency as the latter represented less dense in population.

Aquatic and sediment contamination by PBDEs. Report of studies on PBDEs in aquatic environment of Indonesia demonstrated that the hazardous substances have been detected in both surface water and sediment[8,9,10,11,12]. A study focused on 14 types of PBDEs congener typical to be found in commercial products that included BDE-3, -15, -28, -47, -99, -100, -153, -154, -183, -196, -197, -206, -207, -209 demonstrated lipid of both farmed and wild groupers of Lampung Cove contained total PBDEs up to 6.2 ng/g and 1.6 ng/g respectively[8]. Among the assessed congeners the BDE-3, -196, -197, -206, -207 and -209 were not detected. Similar to the aforementioned study of air contamination with PBDEs, in the Lampung Cove study the BDE-47 was found at the highest level.

Another study assessed the potential of PBDEs to biomagnify through four levels foodchain of biota living in Jakarta Bay showed that congeners BDE-47 and BDE-100 had Trophic Magnification Factors (TMF) 1.9 and 1.8 respectively[9]. Value of TMF greater than one indicates a chemical substance may transfer to higher trophic level trough predator-prey relationship. Thus, the apparent environmental fate that congeners BDE-47 and BDE-

100 may proceed with foodweb biomagnification warrant further evaluation to what extent the two congeners may induce deleterious impact to wildlife of Jakarta Bay.

Assessment of Jakarta Bay sediment found contamination by PBDEs in the range 0.15 – 130 ng/g with the higher concentrations of PBDEs within that range were obtained from sampling points close to harbours, industrial and highly populated areas[11]. Differed from results of studies on air and biota contaminated with PBDEs the highest level of PBDE congener found in sediment was BDE-209. This finding indicated that BDE-209 congener was not readily to leach from sediment and may accumulate in the sediment compartment. The levels of organic carbon in the sediment seemed to control the immobility of BDE-209 that made the congener was not labile or less bioavailable. On the other hand evaluation on mussel living in that sediment provided lipid to sediment ratio higher than one for six PBDEs congeners that included BDE-28, -47, -99, -100, -153, -154[11]. Such the ratio value clearly demonstrated transferrable characteristics of those congeners from mussel environment (water and sediment) into lipid of the mussel. As the consequent of bioaccumulative feature of the PBDEs congeners will be posing exposure threat to humans who consume that mussels.

Study of sediments collected from treatment of leachates of two municipal solid waste dumping sites in Benowo – Surabaya City (East Java Province) and Bantar Gebang – Bekasi (West Java Province) reported[10,12] that BDE-209 congener significantly dominated composition of the PBDEs. Meanwhile BDE-47 and BDE-99 congeners dominate PBDEs composition of the treated leachate[12]. Even though results of the study indicated penta-BDE may dominate technical products in the two provinces, nevertheless, a mixture product of octa-BDE and deca-BDE should not be overlooked. This is expected to be the same for other regions of Indonesia.

Soil contaminated with PBDEs. A study on contamination of soils by PBDEs also has been carried out in Surabaya, East Java Province[13]. The study collected soils from three types of road (urban, rural and industrial), municipal dumping site and agricultural area. Results of the study showed PBDEs levels of soils collected from the aforementioned five sampling locations were 1.5 – 22, 0.58 – 6.4, 8.2 – 21, 0.89 – 24 and 0.069 – 0.40 ng/g respectively. Furthermore, evaluation of congener types revealed that summation of concentrations of mono- to hepta-BDEs was less than octa- to nona-BDEs and, except for two sampling points of municipal dumping site, concentration of the BDE-209 congener was the highest to be found. The similarity of findings between sediment and soil studies that showed the BDE-209 was present at the highest level made evident that the congener is less bioavailable and its mobility is could be strongly influenced by the level of organic carbon.

PBDEs in human. The presence of PBDEs in human might be best represented by the measurement of the compounds in breast milk as an indicator of environmental and health problems[14]. Human breast milk study of 30 volunteers who were living in Jakarta (Capital Special Territory), Bogor and Purwakarta (both are located in West Java Province) and Lampung (Lampung Province) revealed the presence of PBDEs at levels in the range 0.70 – 7.5, 1.5 – 4.3, 0.49 – 13 and 0.89 – 2.3 ng/g respectively[15]. The result showed that higher levels of PBDEs were detected in humans who were living in Jakarta than in Bogor. This is in accordance also to the finding of higher levels of PBDEs found in Jakarta ambient air than in Bogor as previously discussed. Therefore, it is suspected that human exposure to PDBEs by way of air pollution might give prominent route of the PBDEs levels found in human body that include breast milk. However, high level of PBDEs found in breast milk of volunteers who lived in Purwakarta Regency (almost twice of the level found in Jakarta City or three-fold of the level found in Bogor Regency) remained unclear. The population density of Purwakarta Regency and Lampung was each approximately one million, far below population density of Jakarta City (± 10 million) or even Bogor Regency (± 6 million)[6,7,16,17]. Thus other important routes may have to be considered in case of PBDEs levels found in breast milk of people living in Purwakarta Regency. The integration of information thus obtained can be seen in Figure 1.

E-waste situation in Indonesia. It is already known that electrical and electronic equipment wastes contain hazardous substances both organic (e.g. POPs) and inorganic (e.g. heavy metals) materials. Typically the PBDEs is added to technical products at rate 5 – 25% by weight3. Thus by the end of 2019, in Indonesia, levels of total PBDEs that present in e-waste will be in the range 70.7 – 353.4 million tonnes. This huge amount of POPs that tend to incrementally increase along the years may pose threat to living organims and the environment.

In developing countries such as Indonesia the generation of e-waste may origin from both domestic and imports activities[18,19]. To the present no formal management of e-waste available in Indonesia as the result of no clearly defined categorized of e-waste according to the regulations in Indonesia, even though, for a certain part of electrical and electronic equipment wastes such used cathode ray tube (CRT), printed circuit board (PCB), discharge lamp, wire rubber have been regulated through Governmental Regulation Number 101/2014 regarding management of hazardous wastes. Nonetheless, informal e-waste collection is existed through the use of conventional technology that may affect health of the workers.

Up to the present the majority of societies in Indonesia still considered the electrical and electronic equipment wastes as general wastes. This perception resulted in a possibility to haphazardly dispose off such the wastes in open dumps, backyards, surface water and landfills. Surprisingly, it is generally difficult to find any e-waste dumped in official final disposal sites or landfills[18,19]. This indicated that an e-waste has economical value[20]. In addition, as the result of e-waste is not properly defined in the national regulation such a loophole created illegal imports of e-waste through manipulated manifest document, e.g. used monitors, telephones, transformers were manifested as metal scrap[20,21].

Potential exposure threat of PBDEs and their impacts. From the results of studies and reports discussed above, it is clear that e-waste may have economical value but also potential deleterious impacts. A leaching study of cathode ray tube (CRT) plastic housings that were exposed to water containing dissoved humic matter demonstrated PBDEs were leached within six hours, irrespective the hydrophobic physicochemical properties of the PBDEs[22]. This result indicated the prominent role of organic compound in controlling PBDEs leaching process. Furthermore, both temperature and pH were also influencing the leaching process of PBDEs[22,23]. Another laboratory study simulated a leaching process of PBDEs from ingested plastics by seabird using artificial digestive liquids[24]. Results of the study demonstrated fish oil and stomach oil capable of leaching PBDEs over 50 and 20 times respectively compare to distilled water, seawater and acidic pepsin solution. In addition, several toxicity studies on animals such as rats, kestrel and fish demonstrated adverse impact of PBDEs[25].

Humans are exposed to low levels of PBDEs through ingestion of food and by inhalation of contaminated dust. Workers associated with manufacturing, recycling and repairing of PBDE-containing products often exposed to high levels of PBDEs[25]. Although a neurodevelopmental disorder in relation to the level of PBDEs concentration in cord blood has been reported in an epidemiologic study, however, confirmation is needed in other longitudinal studies[26].

Conclusion

These studies demonstrated that polybrominated diphenyl ethers (PBDEs), one class of persistent organic pollutants (POPs), may propagate and disperse into the environmental compartments and may pose serious health problems to living organisms including human. Waste electrical and electronic equipment (WEEE) or e-waste is a potential source of PBDEs that may have deleterious impact to living organisms and the inveronment including humans. As to the present, the mandatory to recycle e-waste in Indonesia is still lacking, this resulted in illegal transportation and open burning of e-waste as well as informal recycling that might have released PBDEs to the environment. Chronic exposure to PBDEs may endanger the future life of next generations. Thus, the establishment of appropriate regulation regarding e-waste management and possibly other PBDE containing waste is strongly needed to protect human and the environment.

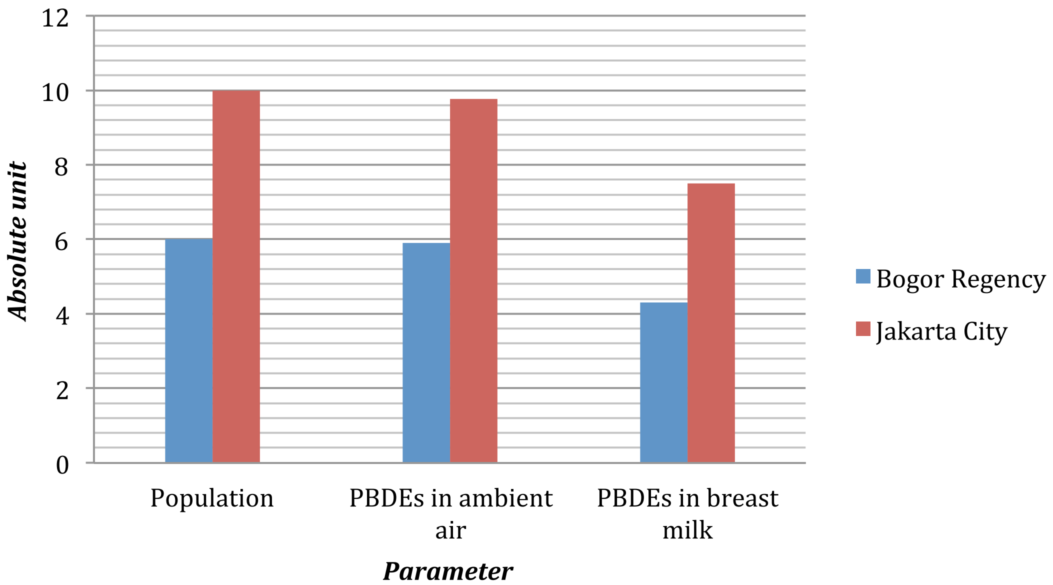

Figure 1. Trend comparison of population (million unit), PBDEs in ambient air (pg/m^3 unit) and PBDEs in human breast milk (ng/g unit). Data taken from references: 5,6,7 and 15

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