Developments in Environmental Science, Volume 7
A. Li, S. Tanabe, G. Jiang, J.P. Giesy and P.K.S. Lam (Editors)

ISSN: 1474-8177/DOI:10.1016/S1474-8177(07)07013-1

Chapter 13

Persistent Toxic Substances in the Environment of Indonesia

Agus Sudaryanto, Shin Takahashi and Shinsuke Tanabe*

Abstract

Although Indonesia has been using vast amounts of chemicals for accelerating its economic development as well as for combating various vector borne diseases, the state of knowledge on toxic pollutants in the country is not much understood, due to lack of information, limited financial resources etc. Regional and nationwide monitoring studies indicate that the levels of most studied compounds, including classical organochlorines and butyltins in the environment of Indonesia are generally low when compared to global contamination levels and guideline standards. However, there is also a concern on wildlife and human health due to elevated levels of DDTs (the major contaminants) and tributyltin, particularly in the locations which are close to human activities such as ports and harbors, urban centers and areas of intensive agriculture. There is limited information on temporal trends for most contaminants, however, it was found that DDTs and PCBs exhibited declining levels in Indonesian environment with time. New environmental challenges are also emerging in Indonesia, such as contamination of coastal and terrestrial ecosystems by brominated flame retardants (BFRs). Recent investigations on BFRs revealed that PDBEs and HBCDs are widespread in the environment and concentrations may increase in future. Overall, this chapter provides an overview of the levels, occurrences and distributions of PCBs, organochlorine pesticides, BFRs and organotins, and their possible impacts on the environment of Indonesia.

13.1. Introduction

Growth in industrial, agricultural and many other activities caused by increasing human population has resulted in a rapid increase in inputs of anthropogenic chemicals into the environment, including the chemicals that are generally referred to as "persistent toxic substances" (PTS).

*Corresponding author: E-mail: aguss@agr.ehime-u.ac.jp

Substances in this category are diverse. Many of the substances of greatest interest are organic compounds characterized by persistence in the environment, resistance to degradation, and acute and chronic toxicity. In addition, many are subject to atmospheric, aquatic or biological transport over long distances and are, thus, globally distributed, and detectable even in the areas where they have never been used. The lipophilic properties of these compounds cause their bioaccumulation in tissues of living organisms leading to body burdens that pose potential risks of adverse health effects. The persistence and bioaccumulation of PTS may also result in increase over time of concentrations in consumers at higher trophic levels, including humans. Several groups of chemicals are having such properties, including the chemicals traditionally referred to as persistent organic pollutants (POPs), organometalics, heavy metals, and other substances. For several decades, these PTS have been found in a range of environmental media and biota, and their toxic impacts on wildlife and humans is a major issue that gives rise to concerns at local, national, regional, and global scales.

Indonesia is an archipelago located in Asian tropical belt between the Pacific and Indian oceans, and two continents, Asia and Australia. The whole territory consists of 17,508 islands of which ~6000 are uninhabited. The population was around 240 million in 2004 making it the fourth most populous country in the world (after China, India, and the United States). About 60% of the total population live in Java, the fifth largest island of the territory. Presently, Indonesia is experiencing rapid industrialization and high annual economic growth rates, and as a result many chemicals are produced and used for industrial, agricultural, and health purposes. In the last decade there were many evidences on the declining environmental quality resulting in decreasing or even disappearing populations of wildlife and adverse effects on humans (Untung, 1999). In this situation, it seems that the accelerating development of Indonesian economy may have been primarily achieved at the expense of the environment. However, little information exists on levels of toxic contaminants as well as assessment of their potential toxicity to wildlife and human. The aims of this chapter are to overview the levels of selected PTS in the environment of Indonesia comprising areas of various land-based activities from urban to rural areas, the potential sources of contaminants, and the toxicological consequences on the wildlife and human. In this chapter, occurrence and distributions of certain groups of PTS such as organotins (OTs), organochlorines (OCs) including polychlorinated biphenyls (PCBs) and OC pesticides, such as dichlorodiphenyltrichloroethane and its metabolites (DDTs), hexachlorocyclohexane isomers (HCHs), chlordane compounds (CHLs), hexachlorobenzene (HCB), *tris*

(4-chlorophenyl) methane (TCPMe) and new candidates of POPs, polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecanes (HBCDs) in the water, sediment, soil, air, mussel, fish, and human milk in Indonesia are reviewed.

13.2. Historical use, production, and management of POPs

As an agriculture-based tropical country, use of pesticide in Indonesia is very much needed for the national development. The use of pesticides has been increasing very rapidly because of the expansion of area cultivated under food crops and vegetables. In 1979–1980, ~6500 tons of pesticides were used and it became 15,000 tons in 1981–1982 (Soekarna and Sundaru, 1983). The first group of insecticides that were introduced by the government for agriculture was DDT and other OCs in early 1950s, followed by organophosphates and carbamates in the late 1960s (Untung, 1999). According to the reports (UNIDO, 1984; Untung, 1999; Suroso et al., 2000; EMC, 2003), no data on the total amount of DDT used for agricultural are now available. However, information is available for some other OC pesticides. For example, in 1974, total imports and production of aldrin was 30,000 kg, chlordane 20,902 kg, and toxaphene 144 kg. In 1979, 3000 kg of dieldrin and 3720 kg of chlordane were imported and used. The latest recorded data on the use of dieldrin was in 1990 when a total of 3492 kg was imported. Total import and consumption of chlordane in 1990, 1991, and 1992, were 21,072, 25,984, and 37,871 kg, respectively.

Under the laws and regulations of pesticide registration, since 1974, some of the OC pesticides, including aldrin, DDT, endrin, and heptachlor were prohibited for agricultural purposes. However, owing to the unavailability of alternative insecticides, dieldrin, and chlordane remain registered and are allowed restrictedly for use in termite control. Toxaphene 70 EC was specially registered and permitted for use on cotton, but finally was banned in 1980. In 1992, dieldrin 20 EC and chlordane 960 EC were the last group of OCs that were prohibited by the government for agricultural use. Among the POPs, HCB and mirex were never registered; however they were used in Indonesia for agricultural purposes. No data are available on HCHs usage. Currently, the pesticides used in Indonesia belong to different groups, such as organophosphates, carbamates, synthetic pyrethroids, insect growth regulators, and biological pesticides. In efforts to limit and terminate the use of hazardous and persistent pesticides, including chemicals in the POPs list, since 1986 the Government has adopted the Integrated Pest Management (IPM) approach.

By implementing IPM, Indonesia is now reducing the national consumption of pesticides.

Although the use of DDT in agriculture was banned in 1974, this pesticide was officially used until the mid-1990s for eradication of *Culex sp.* and *Anopheles sp.*, the main vector of malaria. In 1952, the government through the Department of Health introduced DDT and dieldrin for malaria control in Java Island. The formulation of DDT used was 75% WDP (Water Dispersable Powder) and it was applied two times a year at a dose of $2\,g\,m^{-2}$. From 1969 to 1974, 8,900,000 houses were sprayed with 5,250,000 kg of DDT 75% WDP. In 1975–1979, the number of house sprayed in Java and Bali increased significantly up to 18,600,000 houses and 13,300,000 kg of DDT was used. At the same time, a total number of 3,400,000 houses in outer islands of Java and Bali were sprayed with 1,600,000 kg of DDT. In the period of 1984–1989, the number of houses sprayed in Java and Bali reduced drastically, down to 1,900,000 houses that were sprayed with 1,200,000 kg DDT, but in outer Java and Bali the number of houses sprayed increased up to 6,200,000 and 2,600,000 kg DDT was applied. The extensive use of DDT for malaria control program was at the period from 1974 to 1982, with annual consumption accounting on an average of 2565.4 tons DDT. In 1992–1993, by the decree of the Ministry of Health, the use of DDT for malaria control was terminated in Java and Bali, and subsequently for the whole country in 1993–1994.

Indonesia is also one of the few countries that produced DDT. In 1984, formulation plant of DDT was built with an annual capacity as much as 7000 tons $year^{-1}$, and the main task was to supply all the DDT of needed by the Department of Health for malaria control program. The rest of the production only was permitted for export aimed to the countries that were using DDT for eradication of diseases, such as Latin America, and other Asian countries. The production was stopped in 1994, after the Department of Health banned the usage of DDT for health purposes. Currently, there is not enough information on the stockpile of these compounds available.

With regard to other POPs, PCBs have not been imported to Indonesia for the last 5 years, and they have been prohibited for use in industrial activities. According to Untung (1999), the Department of Mining and Energy which manage the supply of electrical power for the whole country, and also National Electrical Company, none had any concern or put forth any special instruction on the use of PCBs in electrical appliances including use of PCBs in the insulators, capacitors, and generators. Therefore, PCBs are still present in many electrical appliances, which have been used and distributed widely in the country.

The usage of toxic chemicals such as POPs was generally based on government regulations on environmental management. For example, according to Government Regulation No. 73 of 1973 on the control, distribution, storage, and use of pesticides, every pesticide must be registered at the Ministry of Agriculture through National Pesticide Committee. Based on Presidential Decree No. III/1986, 57 pesticides consisting of 28 active ingredients, including POPs pesticide were banned for controlling targeted organisms in rice fields. In other regulation, Agency for the Environmental Impact Management (BAPEDAL) under Ministry of Environment is responsible for the national management of environmental problems. In accordance with international efforts to reduce and eliminate POPs gradually, which are released either intentionally or unintentionally into environment, Indonesia has signed the Stockholm Convention in 2001 along with 176 countries. Following this, the Government of Indonesia responded to the need for the management of hazardous and toxic substances by passing Regulation Number 74 in 2001, which banned ten chemicals included in the Stockholm Convention list of POPs, i.e. eight chemical pesticides (Aldrin, Dieldrin, Chlordane, DDT, Endrin, Heptachlor, Mirex, and Toxapene) and two industrial chemicals (HCB and PCBs). While Dioxins and Furans are not currently regulated, Decree Number 03/BAPEDAL/09/1995 addresses the technical requirements for hazardous waste management by identifying emission standards for the incinerator process. The Governmental Regulation Number 85/1999 controls the air emission standard and the destruction removal efficiency (DRE) of incineration process for dioxins and furans. Some other related regulations also were stated by Ministry of Agriculture and Ministry of Health. Although some regulations have been stipulated, Indonesia until now does not have set standards for all POPs chemicals, either for human or the environment.

In order to better protect human health and the environment from the hazards of POPs, the Government of Indonesia has developed the National Implementation Plan (NIP). The objective of developing the NIP was not only to adhere to Indonesia's commitment as a signatory of the Stockholm Convention (Article 7) but also to unify the existing POP management strategies and achieve cooperation among all national stakeholders.

In this context, environmental monitoring and inventory study are important as the basis for formulating and development of NIP. Several scientists of the region may have been dealing with POPs monitoring, however not much of the results could be accessed widely. Comprehensive monitoring researches since 1990s to date from the Department of Environment Conservation (currently Center for Marine Environmental

Studies), Ehime University (Japan), contributed much valuable information on the occurrence, fate, and behaviour of POPs in tropical Asian developing countries, including Indonesia. The Ministry of Environment of the Republic of Indonesia is now responsible for carrying out the inventory to determine the actual state of environmental pollution caused by POPs. To strengthen the national capability and to enhance knowledge and understanding among decision makers, managers, industries, and public, to meet the obligations of the Stockholm Convention and implement the elimination of POPs, several international collaboration studies have been conducted. During 1996–1999, under the Asia Pacific Mussel Watch Project coordinated by Professor Shinsuke Tanabe from Ehime University (Japan), cooperative research efforts with scientists from respective developing countries succeeded in ascertaining the status of marine pollution by toxic contaminants in the Asia-Pacific region, including Indonesia. The Ministry of the Environment has also taken an inventory program on POPs under the Global Environment Facility (GEF) project enabling activities to facilitate early action on the implementation of the Stockholm Convention on POPs in Indonesia. Further to this, in 2001, Environmental Management Centre (PUSARPEDAL), Ministry of Environment, Indonesia, in collaboration with United Nations University (UNU), Japan,and Japan International Cooperation Agency (JICA), conducted POPs residues monitoring in the river, seawater, sediments, and soil from several locations that have been considered as hot spots of contamination. All of these efforts, however, are still far from clarifying the status of POPs in Indonesia as much of these data are not published.

13.3. Environmental contamination by organochlorine compounds (OCs)

13.3.1. Contamination by OCs in abiotic compartment (water, sediment, soil, and air)

Available information on concentrations of OCs, particularly OC pesticides in water, sediment, soil, and air has been summarized in Table 13.1. In most cases, larger data sets on OC concentrations in abiotic compartment are from the surveys conducted in recent years (1990s to the middle of 2000s), with particular concern on water and sediment (Table 13.1). A nationwide occurrence of OC pesticides in water and sediment indicate that the two major contaminants in the Indonesian environment are DDTs and HCHs (Table 13.1). Although, there is no report on the usage of HCHs, elevated levels of this compound in water and sediment confirm

Table 13.1. Residue levels of OCs in water, sediment, soil, and air from various locations in Indonesia

Location	Year	*n*	α-HCH	β-HCH	γ-HCH	HCHs	*p,p′*-DDE	*p,p′*-DDD	*p,p′*-DDT	DDTs	PCBs	CHLs	References
River water (ng L^{-1})													
Rungkut River, Surabaya, East Java	2001	2	4.0 (3.3–4.7)	na	4.3 (3.8–4.8)	8.3 (8.0–8.5)	nd	1.9 (0.86–2.9)	2.6 (1.6–3.5)	8.3 (6.9–9.7)	na	na	Ratnaningsih et al., 2002
Rungkut River, Surabaya, East Java	2002–2003	2	8.0 (nd–16)	4.1 (nd–8.1)	6.5 (nd–13)	19 (nd–37)	nd	nd	nd	nd	na	nd	EMC, 2003
Surabaya River, Surabaya, East Java	2001	6	0.73 (nd–2.2)	na	3.4 (2.2–5.6)	4.1 (2.2–7.8)	16 (nd–98)	5.0 (0.75–22)	22 (1.3–120)	71 (7.1–390)	na	na	Ratnaningsih et al., 2002
Surabaya River, Surabaya, East Java	2002–2003	13	120 (nd–390)	4.2 (nd–19)	6.2 (nd–23)	130 (nd–480)	0.19 (nd–2.0)	0.11 (nd–1.1)	0.11 (nd–1.3)	0.54 (nd–4.7)	na	28 (nd–360)	EMC, 2003
Banjir Kanal T, Semarang, Central Java	2001	4	7.9 (7.0–12)	na	10 (2.3–18)	19 (14–23)	0.02 (nd–0.08)	2.3 (0.75–3.9)	nd	5.0 (2.2–8.0)	na	na	Ratnaningsih et al., 2002
Banjir Kanal T, Semarang, Central Java	2002–2003	4	13 (nd–35)	4.3 (nd–17)	25 (nd–76)	43 (nd–110)	nd	nd	0.24 (nd–0.96)	0.41 (nd–0.96)	na	0.63 (nd–1.4)	EMC, 2003
Banjir Kanal B, Semarang, Central Java	2001	4	1.1 (0.38–1.6)	na	3.5 (2.5–4.7)	4.6 (3.0–6.2)	nd	2.2 (0.73–2.8)	1.7 (nd–3.1)	4.7 (3.2–6.3)	na	na	Ratnaningsih et al., 2002
Banjir Kanal B, Semarang, Central Java	2002–2003	4	1.7 (nd–4.0)	0.46 (nd–1.6)	1.6 (nd–4.9)	3.9 (nd–9.2)	nd	nd	nd	nd	na	nd	EMC, 2003
Ciliwung River, Bogor, West Java	1991	1	14	4.2	3.7	22.0	0.073	0.038	0.071	0.19	1.3	0.24	Iwata et al., 1994
Ciliwung River, Bogor, West Java	2001	6	1.4 (nd–4.3)	na	4.1 (1.3–7.3)	5.5 (1.3–12)	0.11 (nd–0.57)	2.0 (0.70–3.3)	1.9 (nd–3.8)	6.8 (3.0–10)	na	na	Ratnaningsih et al., 2002
Ciliwung River, Bogor, West Java	2002–2003	8	2.7 (nd–7.7)	2.2 (nd–11)	1.6 (nd–7.1)	6.6 (nd–22)	0.025 (nd–0.20)	0.20 (nd–1.6)	0.054 (nd–0.43)	0.46 (nd–3.3)	na	1.1 (nd–3.2)	EMC, 2003
Ciliwung River, Jakarta, West Java	1991	2	2.4 (1.7–3.2)	0.66 (0.53–0.78)	1.0 (0.84–1.2)	4.2 (3.1–5.2)	0.65 (0.094–0.12)	0.076 (0.064–0.087)	0.052 (0.016–0.087)	0.24 (0.22–0.27)	2.5 (0.38–2.1)	0.17 (0.071–0.26)	Iwata et al., 1994
Ciliwung River, Jakarta, West Java	2001	4	12 (3.0–23)	na	5.2 (nd–14)	19 (6.9–27)	0.22 (nd–0.68)	1.9 (0.68–3.1)	2.4 (nd–6.2)	8.3 (1.8–14)	na	na	Ratnaningsih et al., 2002

Table 13.1. (*Continued*)

Location	Year	n	α-HCH	β-HCH	γ-HCH	HCHs	p,p'-DDE	p,p'-DDD	p,p'-DDT	DDTs	PCBs	CHLs	References
Ciliwung River, Jakarta, West Java	2002–2003	6	13 (nd–59)	1.2 (nd–7.3)	3.2 (nd–12)	17 (nd–78)	0.25 (nd–0.84)	0.26 (nd–1.6)	1.5 (nd–4.2)	2.0 (nd–4.3)	na	0.73 (nd–2.8)	EMC, 2003
Upper Citarum, West Java	na	21	na	na	400 (nd–910)	na	na	na	180 (nd–750)	na	na	na	Parikesit et al., 2005
Coastal water (ng L^{-1})													
Siak, Riau	1997	na	nd–0.86	nd–0.098	nd–2.1	na	nd–0.24	nd–3.0	nd–0.70	na	na	na	Hutagalung et al., 1997
Kuala Tungkal, Jambi	1997	na	nd–0.24	0.071–0.95	nd–0.020	na	nd–0.34	nd–0.70	0.071–0.42	na	na	na	Munawir, 1997
Musi, Palembang, South Sumatra	1998	na	nd–0.013	nd–0.16	nd–0.20	na	nd–0.13	nd–0.11	nd–0.070	na	na	na	Munawir, 1998
Kuala Jambi, Jambi	1999	na	nd–0.31	nd–1.2	nd–1.2	na	nd–0.49	nd–0.43	nd–0.15	na	na	na	Munawir, 1999
Asahan, North Sumatra	2001	na	nd	nd–0.38	nd–1.3	na	nd–6.7	nd–2.5	nd–3.5	nd	na	na	Munawir, 2001a
Way Kambas, Lampung	2001	na	nd–0.12	nd–0.62	nd–0.93	na	nd	nd–1.2	nd–8.3	na	na	na	Munawir, 2001b
Way Sekampung, Lampung	2001	na	nd–0.16	nd–2.0	0.21–2.7	na	nd–0.97	nd–0.88	nd–5.6	na	na	na	Munawir, 2001b
Coastal, Surabaya, East Java	2001	4	0.33 (nd–1.3)	na	2.7 (1.3–3.9)	3.0 (1.3–5.2)	0.12 (nd–0.48)	1.8 (0.65–3.2)	2.5 (1.3–3.5)	6.3 (2.7–9.6)	na	na	Ratnaningsih et al., 2002
Coastal, Surabaya, East Java	2001	4	0.58 (nd–1.2)	na	3.0 (nd–6.2)	3.4 (nd–7.4)	nd	1.1 (nd–2.8)	1.2 (nd–3.2)	2.9 (nd–6.4)	na	na	Ratnaningsih et al., 2002
Coastal, Semarang, Central Java	2002–2003	1	7.0	8.7	2.0	19	nd	nd	nd	nd	na	nd	EMC, 2003
Coastal, Semarang,, Central Java	2001	4	0.71 (0.09–1.5)	na	4.2 (1.8–7.4)	4.9 (1.9–8.8)	nd	1.9 (0.65–3.3)	2.4 (1.3–3.5)	6.7 (3.2–10)	na	na	Ratnaningsih et al., 2002
Coastal, Jakarta Bay	2002–2003	3	1.3 (nd–4.0)	0.75 (nd–2.2)	3.0 (nd–9.0)	5.3 (nd–16)	nd	nd	0.25 (nd–0.76)	0.73 (nd–2.2)	na	nd	EMC, 2003
Coastal, Jakarta Bay	1994	na	nd–0.015	nd	nd	na	nd–3.5	nd–0.049	nd	nd	na	na	Razak and Munawir, 1994
Arafura, West Papua	2002	na	nd	0.027–0.046	0.006–0.031	na	0.015–0.038	nd–0.009	0.021–0.032	na	na	na	Munawir, 2002
Memberamo, West Papua	2003	12	nd	nd	nd	na	nd	nd	nd	na	na	na	Munawar, 2005

River sediment (ng g^{-1})													
Surabaya River, Surabaya, East Java	2002–2003	12	140 (nd–430)	10 (nd–51)	7.3 (nd–61)	150 (nd–480)	2.3 (nd–12)	2.1 (nd–7.4)	7.0 (nd–51)	12 (nd–51)	na	0.89 (nd–8.7)	EMC, 2003
Bajir Kanal T, Semarang, Central Java	2002–2003	4	7.0 (nd–16)	2.5 (nd–6.2)	5.1 (nd–11)	15 (nd–31)	0.025 (nd–0.10)	nd	6.3 (1.4–8.7)	8.0 (2.7–11)	na	0.20 (nd–0.78)	EMC, 2003
Bajir Kanal B, Semarang, Central Java	2002–2003	4	0.64 (nd–1.8)	1.0 (nd–4.0)	1.4 (nd–2.9)	3.0 (nd–7.4)	0.32 (nd–0.81)	0.042 (0.17)	1.6 (nd–3.0)	2.0 (nd–3.8)	na	0.055 (nd–0.22)	EMC, 2003
Ciliwung River, Bogor, West Java	1991	2	0.001 (nd–0.002)	0.019 (0.018–0.020)	0.033 (0.015–0.051)	0.053 (0.035–0.071)	20 (19–21)	10 (5.5–15)	2.0 (0.86–3.2)	34 (26–42)	180 (140–220)	23 (8.0–38)	Iwata et al., 1994
Ciliwung River, Bogor, West Java	2002–2003	7	35 (nd–210)	0.20 (nd–1.2)	2.1 (nd–6.8)	37 (nd–220)	0.26 (nd–0.86)	0.24 (nd–1.0)	2.1 (0.25–4.3)	2.6 (0.29–5.5)	na	0.36 (nd–1.2)	EMC, 2003
Ciliwung River, Jakarta	1991	2	nd	026 (0.013–0.040)	0.052 (0.045–0.059)	0.078 (0.058–0.099)	2.5 (0.95–4.1)	2.3 (0.94–3.6)	2.8 (1.3–4.4)	8.2 (3.4–13)	42 (5.9–79)	0.32 (0.16–0.49)	Iwata et al., 1994
Ciliwung River, Jakarta	2002–2003	6	51 (nd–200)	10 (nd–54)	7.6 (nd–26)	68 (nd–260)	2.0 (nd–7.6)	0.81 (nd–1.9)	4.1 (nd–14)	6.8 (nd–22)	na	1.5 (nd–7.5)	EMC, 2003
Coastal sediment (ng g^{-1})													
Jakarta Bay	1994	na	nd–0.62	nd–0.21	nd	na	nd–1.5	nd–3.6	nd	na	na	na	Razak and Munawir, 1994
Siak, Riau	1997	na	nd–0.006	nd–2.8	nd–1.4	na	nd–1.2	nd–2.9	nd–5.4	na	na	na	Hutagalung et al., 1997
Kuala Tungkal, Jambi	1997	na	nd–0.18	nd–0.056	nd–1.8	na	nd–0.27	nd–1.2	nd–5.5	na	na	na	Munawir, 1997
Musi, Palembang, South Sumatra	1998	na	nd	nd–0.30	nd–0.064	na	nd–0.61	nd–0.004	nd–0.076	na	na	na	Munawir, 1998
Kuala Jambi, Jambi	1999	na	nd–0.027	nd–0.087	nd–0.52	na	nd–0.59	nd–0.009	nd–2.2	na	na	na	Munawir, 1999
Asahan, North Sumatra	2001	na	nd–1.7	nd–5.5	nd–2.0	na	nd–0.11	nd	nd–0.15	na	na	na	Munawir, 2001a
Way Kambas, Lampung	2001	na	nd–0.075	nd–0.40	0.14—3.0	na	nd–0.16	nd	nd	na	na	na	Munawir, 2001b
Way Sekampung, Lampung	2001	na	nd	nd	0.48–3.1	na	nd	nd	0.56–1.6	na	na	na	Munawir, 2001b
Arafura, West Papua	2002	na	0.009–0.11	0.017–0.051	0.005–0.025	na	0.006–0.022	nd	nd	na	na	na	Munawir, 2002
Mamberamo, West Papua	2003	12	nd	nd	nd	na	nd	nd	nd	na	na	na	Munawar, 2005

Table 13.1. (*Continued*)

Location	Year	*n*	α-HCH	β-HCH	γ-HCH	HCHs	*p,p'*-DDE	*p,p'*-DDD	*p,p'*-DDT	DDTs	PCBs	CHLs	References
Soil (ng g^{-1})													
Surabaya, East Java	2002–2003	11	140 (nd–1300)	1.9 (nd–12)	41 (nd–430)	190 (nd–1700)	3.8 (0.81–7.6)	3.2 (nd–13)	8.8 (nd–39)	16 (1.8–42)	na	0.82 (nd–5.1)	EMC, 2003
Semarang, Central Java	2002–2003	8	1.8 (nd–5.3)	4.2 (nd–26)	1.1 (nd–3.9)	7.2 (nd–30)	1.9 (nd–8.8)	0.24 (nd–1.3)	7.3 (nd–18)	9.5 (nd–21)	na	0.17 (nd–0.68)	EMC, 2003
Bogor, West Java	2002–2003	8	1.3 (nd–2.8)	0.86 (nd–3.0)	0.57 (nd–2.2)	2.7 (nd–6.7)	0.30 (nd–2.0)	0.31 (nd–2.3)	3.9 (nd–6.2)	4.5 (nd–15)	na	0.76 (nd–4.8)	EMC, 2003
Jakarta	2002–2003	6	24 (nd–110)	3.8 (nd–15)	1.5 (nd–5.9)	29 (nd–130)	0.56 (nd–1.4)	1.1 (nd–3.7)	23 (nd–120)	25 (nd–120)	na	1.2 (nd–5.7)	EMC, 2003
Air (pg m^{-3})													
Java Sea	1989–1990	1	56	na	19	75	1.5	na	23	39	36	3.9	Iwata et al., 1993
Celebes Sea	1989–1990	1	95	na	23	120	0.70	na	23	37	22	7.9	Iwata et al., 1993
Indian Ocean	2004	2	0.30–0.50	na	2.8–5.6	3.1–6.1	na	na	18–28	27–33	28–51	1.1–3.8	Wurl et al., 2006

Note: Data of OCs from various literatures were selected based on the similar target compounds; all values of concentrations were normalized into similar unit and rounded to two digits for comparison; nd = not detected; na = no data available.

their usage in Indonesia. DDT has been intensively used in the past for almost three decades in agriculture as well as for health purposes. Geographical distributions of OCs indicate spatial variability of DDTs and HCHs in water from Indonesia. DDT and HCHs were highly present in the aquatic environment from several rivers and coastal areas in Java Island such as Surabaya, Semarang, Bogor, Jakarta, and Citarum than in other parts of Indonesia (Table 13.1). For instance, the occurrence of HCHs and DDTs in western (Sumatra Island) and eastern parts of Indonesia (West Papua) were much lower. DDTs and HCHs were not detected in remote areas such as Memberamo River at West Papua Province (Munawar, 2005). Higher concentration of HCHs and DDTs in several river and coastal areas in Java Island indicate their intensive usage in this island. *p,p′*-DDT was still found as the predominant compound both in river and coastal waters of these areas with concentration around 780 ng L^{-1} in upstream Citarum River. In most cases, higher concentrations of DDTs were found in rivers than those in coastal areas, indicating considerable use of this compound in inland rather than coastal areas.

The profiling of HCHs was also similar to those of DDTs (Table 13.1). Higher proportion of both α-HCH and γ-HCH were observed in various studies that indicate the use of technical HCHs and lindane (purified γ-HCH) in this country. Likewise, there were differences in use of different formulations of HCH among the locations. Higher α-HCH levels in water from some locations in Java may have been due to preferential use of technical HCHs, whereas high concentration of γ-HCH in several rivers and coastal areas in Sumatra Island may indicate the considerable usage of lindane. It has been reported that lindane is commonly used on palm oil tree plantations (Othman and Balasubramanian, 2001). It is plausible that this pesticide is intensively applied on palm oil tree, a common plantation crop in Sumatra Island.

PCBs have been reported only by Iwata et al. (1994) in water from Ciliwung River, West Java. Although there was no considerable variation among the locations in this river, higher concentrations of PCBs were found in river waters across Jakarta City than upstream rural area in Bogor, indicating elevated contribution from urbanized area.

Unlike contamination patterns in water, the OCs residue levels in coastal and riverine sediments revealed less variation between locations nationwide (Table 13.1). Similar pattern has been reported by a larger study in sediments from northern and southern countries in Asia (Iwata et al., 1994). Likewise, this is due to the prevailing high temperatures in these countries including Indonesia throughout the year and hence volatile compounds such as HCHs and DDTs remain for shorter time in the water. Tanabe et al. (1991) in their field study indicated that, more than

90% of HCH applied in a paddy field of tropical India evaporated into atmosphere. Although little variability of OCs was observed in sediment samples, sediments from rivers and coastal areas in Java Island, such as Surabaya, Jakarta, and Semarang seems to accumulate DDT and HCH higher than those in Sumatra Island (Table 13.1). The data obtained from sediment reflects the long-term use of these compounds in Java Island than in Sumatra Island. In the case of PCBs (Table 13.1), similar to those found in water, river sediment in Ciliwung River located in Jakarta City was relatively higher than that in upper stream at Bogor rural area (Iwata et al., 1994), again indicating higher contribution of this compound from the industrialized and urban areas. Furthermore, preliminary results also indicated widespread contamination by PBDEs and HBCDs, relatively new compounds which are commonly used as flame retardants, in sediments along coastal areas of Indonesia (Sudaryanto et al., 2006a). Relatively higher residue levels of these brominated flame retardants (BFRs) were found in sediments collected from Jakarta Bay, indicating similar pattern generally found for PCBs that are higher in populated and industrialized areas.

In contrast to water and sediment, very little information is available on the contamination of soil. OCs were found to be present in soils from river banks in four major cities on Java Island such as Jakarta, Bogor, Semarang, and Surabaya (EMC, 2003). Again, DDTs and HCHs were higher when compared to other target OCs such as CHLs and HCB (Table 13.1). Higher DDTs in soil was observed in riverbank of Ciliwung River located in Jakarta and Surabaya (up to 120 ppb and 42 ppb, respectively). Although, DDT for controlling malaria has been legally banned in 1994, high proportions of *p,p′*-DDT observed in soil collected from these locations, indicate persistency and/or the recent usage of this compound. The higher concentration of DDTs in soil from populated areas such as Surabaya and Jakarta may be due to intensive use of this compound for malaria eradication in these locations as well as for agricultural purposes. Elevated α-HCH was found in soil collected from riverbank in Surabaya (up to 1300 ppb) and Jakarta (up to 110 ppb) indicating favored use of technical mixture of HCHs in these locations. The profile of HCHs in soils and sediments indicate high use of technical HCH in Java Island. However, γ-HCH was also found to be dominant in the soil, particularly in samples from Semarang, suggesting also the use of lindane in this area. As for water and sediment, the profiles of HCHs and DDTs in soil also reflect the intensive and recent use of these two pesticides in Indonesia.

Among the abiotic compartment, atmosphere is known to be an important media for the distribution of volatile compounds in the global environment; however very few studies have reported the contamination of OCs in air in Indonesia (Table 13.1). The atmosphere can be considered as a mobile phase for the long-range transport of POPs towards final sink including the polar regions, where cold condensation of POPs to the ocean occurs. In addition to primary sources, the atmosphere receives input of POPs via evaporation processes from soil and the oceans, which occur intensively in tropical regions. There were two reports indicating the occurrence of POPs in the atmosphere of Indonesia, concerning the oceanic atmosphere (Iwata et al., 1993; Wurl et al., 2006) and/or semi continental (Wurl et al., 2006). In 1990s, Iwata et al. (1993) provided information on the concentrations of PCBs, DDTs, HCHs, and CHLs in air of seas and oceans along southern to northern hemisphere including two locations of Indonesian seas, Java Sea and Celebes Sea, the inland sea located at center and northern parts of this country. Based on available data from this study, distribution of OCs between these two seas was found to be quite similar (Table 13.1). In a subsequent study in 2004, Wurl et al. (2006) carried out studies on regional oceanic atmospheric levels of POPs in Indian Ocean and adjacent areas (Table 13.1). Although, HCHs concentration was lower in the latest study, there has been no change in concentrations of DDT between these two studies. Similar magnitude of pollution was observed more than ten years ago (1989–2004, see Table 13.1), indicating that emission of DDT is still taking place in Indonesia.

13.3.2. Contamination by OCs in biotic environment (mussel and fish)

Information on the occurrence of POPs in biota samples from Indonesia is very scarce and the available data are generally from studies in Asia-Pacific region dealing with low trophic aquatic wildlife such as mussel and fish (Kannan et al., 1995b; Monirith et al., 2003; Ueno et al., 2003b, 2004; Sudaryanto et al., 2005b, 2006a, 2007b), and no data has been reported for higher trophic animals. Table 13.2 shows compiled data of OCs including PCBs, DDTs, HCHs, CHLs, and HCB in biological samples from Indonesia, whereas Fig. 13.1 illustrates the distribution of some OCs. As a part of Asia-Pacific Mussel Watch Project organized by Ehime University, Japan (Tanabe, 2000), a comprehensive monitoring study using mussel as bioindicator reported spatial variability of OCs in coastal environment of Indonesia (Monirith et al., 2003). Similarly, an extended monitoring study, using fish and other aquatic and terrestrial animals also revealed the same distribution pattern (Sudaryanto et al., 2005b, 2006a, 2007b, Fig. 13.1). In all these studies, among OCs, DDTs and PCBs were the predominant compounds in aquatic wildlife (Table 13.2).

Table 13.2. Concentrations of OCs (ng g^{-1} lipid wt.) in mussels and fish from various locations in Indonesia

Location	Year	*n*	Fat (%)	PCBs	DDTs	CHLs	HCHs	HCB	Remark
Mussel[a]									
Belawan, North Sumatra	1998	48	1.4	13	15	5.3	5.3	0.80	Rural
Hurun Bay, Lampung	1998	40	1.1	14	65	15	4.1	<0.90	Rural, mariculture
Lada Bay, Banten	1998	56	1.1	85	110	<0.90	2.4	1.1	Rural, mariculture
Kamal, Jakarta	1998	54	1.3	210	45	13	<0.80	<0.80	Urban, fishing port
Ancol, Jakarta	1998	51	1.9	96	48	7.5	4.9	<0.50	Urban, marina
Cilincing, Jakarta	1998	49	1.7	140	58	7.4	4.7	<0.60	Urban, fishing port
Cirebon, West Java	1998	51	2.0	30	160	16	2.1	1.5	Rural, fishing village
Surabaya, East Java	1998	50	1.2	190	120	<0.80	<0.80	1.2	Urban, industrialized
Maros, South Sulawesi	1998	24	1.8	5.6	6.5	<0.60	<0.60	0.80	Rural, fishing village
Fish[b,c]									
Bogor, West Java	1991	5	3.0	86	930	15	24	1.7	Rural/suburban
Bogor, West Java	2003	8	7.6 (5.3–11)	110 (21–150)	640 (37–1100)	10 (2.0–21)	11 (3.4–24)	1.3 (0.26–2.6)	Rural/suburban
Jakarta Bay	1998	105	2.7 (1.4–5.8)	1400 (530–2700)	340 (73–750)	46 (11–80)	1.5 (0.40–2.6)	1.6 (0.70–1.9)	Urban, industrialized
Jakarta Bay	2003	13	5.3 (2.9–8.0)	690 (260–1100)	190 (110–350)	44 (23–81)	1.8 (1.0–3.7)	8.3 (0.44–28)	Urban, industrialized
Cirebon, West Java	1998	10	2.6 (1.2–5.1)	260 (27–560)	450 (70–880)	5.1 (nd–8.4)	16 (nd–77)	0.90 (0.30–1.5)	Rural, agriculture
Lada Bay, Banten	1998	10	5.0 (4.0–7.1)	170 (32–360)	310 (19–810)	5.9 (4.2–7.1)	2.4 (1.7–3.2)	5.1 (0.90–16)	Rural, agriculture
Lampung Bay, Lampung	2003	10	2.5 (1.1–5.5)	33 (9.7–94)	39 (12–120)	8.5 (0.73–30)	2.6 (0.78–4.2)	1.0 (0.22–2.1)	Rural, marine culture
West Sumatra	1998	5	2.5 (1.1–5.5)	33 (9.7–94)	39 (12–120)	8.5 (0.73–30)	2.6 (0.78–4.2)	1.0 (0.22–2.1)	Offshore (tuna)

Notes: nd = not detected; DDTs = *p,p′*-DDE + *p,p′*-DDD + *p,p′*-DDT; HCHs = α-HCH + β-HCH + γ-HCH; CHLs = *oxy*-CA + *cis*-CA + *trans*-CA + *trans*-nona + *cis*-nona.

[a]Data on mussels were reported by Monirith et al. (2003).

[b]Fish on 1991 by Kannan et al. (1995b).

[c]Fish on 1998 and 2003 by Sudaryanto et al. (2007b).

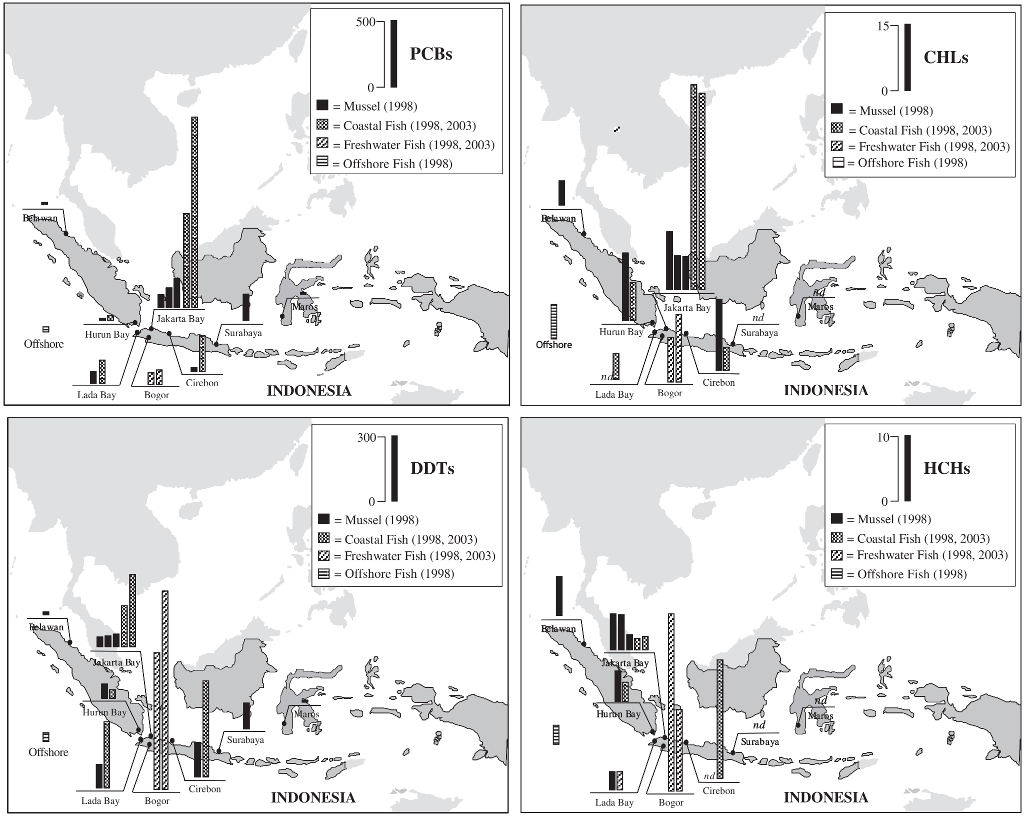

Figure 13.1. Distribution of OCs in mussels and fish from Indonesia.

So far, on lipid weight basis, the maximum concentrations of PCBs and DDTs reported were 210 ng g^{-1} and 160 ng g^{-1} in mussels, and 2700 ng g^{-1} and 1100 ng g^{-1} in fish, respectively (Monirith et al., 2003; Sudaryanto et al., 2005b, 2007b), while HCHs, CHL, compounds, and HCB were one or two order magnitude lower. Concentration patterns of OCs in mussels and fish were generally in the order DDTs > PCBs > CHLs > HCHs > HCB (Kannan et al., 1995b; Monirith et al., 2003; Sudaryanto et al., 2005b, 2007b). Higher concentrations of PCBs and DDTs in biological samples have been suggested as due to the higher bioaccumulative properties of these compounds and continuous discharge into aquatic environment; particularly in the case of DDTs which has been intensively used in agriculture as well as malaria eradication program (Untung, 1999).

A nationwide comparison indicates that elevated levels of OCs were found in the samples collected from Java Island than Sumatra and Sulawesi Islands (Table 13.2; Fig. 13.1). In Belawan (North Sumatra), Hurun Bay (Lampung), and Maros (South Sulawesi) residue levels of OCs were low. Such a pattern is understandable because Java Island is the most populated and industrialized island with intense agricultural activities, and the results could reflect the usage status of OCs in this island. Levels of OCs are still low in remote areas of Sumatra offshore waters as exemplified by less contamination in tuna (Ueno et al., 2003b).

Study conducted by Kannan et al. (1995b) showed the presence of DDT at higher concentration (960 ng g^{-1} lipid wt.) in fish collected in 1991 from Bogor, a rural area located 60 km away from Jakarta. In a survey conducted more than ten years later, DDT was still found to be high in this area (640 ng g^{-1} lipid wt.). Considerable levels of DDTs were also found in fish and mussels from Cirebon and Lada Bay (Monirith et al., 2003, Sudaryanto et al., 2007b). While comparing inland and coastal species, DDTs were apparently higher in freshwater fish (Ciliwung River, Bogor) than in marine fish species (Sudaryanto et al., 2005b, 2007b), indicating higher pollution by DDT in the terrestrial environment. All these results indicate considerable exposure to DDTs in the farming areas in Java Island. This is probably because of their intensive usage in both agricultural activities and malaria control program at those sites. DDTs have been banned since 1974 for agricultural application; however the country used the chemical until very recently for health purposes. Information on the amount of DDT usage in agriculture is not available; however, for disease eradication, Indonesia used DDT as much as 2565.7 ton $year^{-1}$ during 1974–1982 (UNIDO, 1984). For this program, DDT was formulated in Indonesia since 1984 with an annual capacity of as much as 7000 tons $year^{-1}$ (UNIDO, 1984; Untung, 1999).

Interestingly, although DDTs were low in rural areas in Sumatra Island (Lampung Bay), *p,p′*-DDT was relatively prevalent, suggesting recent application of DDT in this region (Sudaryanto et al., 2005b, 2007b). Profiles in abiotic samples also support this hypothesis. Recent monitoring study using human breast milk also indicated that there was possible recent input in specific rural agricultural areas (Burke et al., 2003; Sudaryanto et al., 2006b).

Although, there is little variability of HCHs in mussels, their distribution pattern in fish is relatively similar to DDTs. In fish, higher concentrations of HCHs were found in Ciliwung River (Bogor) and Cirebon coastal area than other locations. Higher levels of HCHs in fish from rural area also indicate their particular usage pattern and reflect recent input of HCH in agricultural sites. While, concentrations of HCHs were relatively low in all the samples, there was difference in the isomer patterns among the locations. Survey in 1991 indicated that γ-HCH was in higher proportion in rural area of Bogor (Kannan et al., 1995b). Similarly, study during 1998–2003 also found γ-HCH as the major contributor to total HCHs in fish from rural areas in Bogor and Lampung Bay (Sudaryanto et al., 2005b, 2007b). Despite lack of available information on their usage, the results in fish also reinforce the finding from abiotic samples and suggest the usage of lindane in Indonesia.

PCBs were particularly higher in the samples from urban sites (Table 13.2; Fig. 13.1). In Jakarta Bay, mussels collected from three locations contained PCBs from 96 to 210 ng g^{-1} lipid wt., that are one or two orders of magnitude higher than other locations. Similarly, an urban area of Surabaya also had elevated levels of PCBs (190 ng g^{-1} lipid wt.) within the range found in mussels from Jakarta Bay. In the samples collected at the same time of sampling as those of mussels, concentrations of PCBs in fish from Jakarta Bay (530–2700 ng g^{-1} lipid wt.) were also one or two orders of magnitude higher than other locations (Sudaryanto et al., 2007b). Survey of fish in 2003 also revealed similar distribution pattern, although PCBs decreased to 260–1100 ng g^{-1} lipid wt. in Jakarta Bay (Sudaryanto et al., 2005b, 2007b). No information is available on PCBs usage and production in Indonesia (Untung, 1999); however, the results indicate that notable contamination by PCBs is associated with a highly industrialized and populated area.

In case of CHLs, although elevated levels in mussel appeared in agricultural sites, notable contamination was also found in fish from Jakarta Bay (Table 13.2; Fig. 13.1). Besides being used as agricultural pesticides, CHLs are also generally used for killing termites in wood building materials and thus it could be a suitable explanation for higher CHLs in populated cities like Jakarta. According to regulation of OC pesticides, CHLs and dieldrin were the last group of OC pesticides that were prohibited by government for agricultural use in 1992 (Untung, 1999). During the period from 1974 to 1991, the amount of usage of CHLs increased from 20,902 to 37,871 tons. Thus, higher CHLs in fish from Jakarta Bay indicate higher usage of these compounds for termite control in urbanized area and reflect continuous input of CHLs in Indonesia.

Distribution of HCB concentrations in fish from Indonesia was rather uniform and the levels were much lower than other OCs (Table 13.2). However, relatively higher concentrations of HCB were observed in fish from Jakarta Bay. Higher concentrations of HCB in fish of the populated city in Jakarta Bay may be because HCB is not only used as a fungicide for crops and in industries, but also generated as a by-product during the production of several agrochemical and industrial chemicals. Furthermore HCB has been released into the environment by waste incineration (van Birgelen, 1998; Bailey, 2001). Therefore, various sources of HCB might be present in the areas that have been populated and industrialized.

To understand the magnitude of contamination in biotic samples from Indonesia, an extensive study on regional comparison of OCs in mussels (Monirith et al., 2003), fish (Kannan et al., 1995b), and tuna (Ueno et al., 2003b) are presented in Fig. 13.2. International comparison of OCs in mussels and fish from Indonesia revealed lower levels in Indonesian samples similar to those in other Southeast Asian countries such as Malaysia, Philippines, Cambodia, and Oceanian countries (Papua New Guinea and Solomon Island). The spatial variability of OC levels in multimedia biological samples suggested the presence of elevated levels of PCBs in Japan and Australia, and HCHs in India and China, which may reflect the high usage of the respective compounds in these countries (Kannan et al., 1995b). PCBs are discharged from Japan, which is a highly developed and industrialized country (Ueno et al., 2004). In case of HCHs, it was estimated that ~575,000 tons was used in India until 1985 (Kannan et al., 1995b). Although, it is believed that DDTs were intensively used in Indonesia for longer periods, global comparison indicates low levels of DDTs in biological samples. Apart from differences in sampling time, this result may suggest a lower accumulation in tropical fish, which could be due to the rapid volatilization of DDTs in the tropical environment (Kannan et al., 1995b). Kannan et al. (1995b) also noted that DDTs levels in tropical fish were ~1–2 orders of magnitude lower than those of United States.

With regard to brominated flame retardants, PBDEs were also reported in various samples including sediment, mussel, freshwater fish, coastal fish, and offshore marine fish (Ueno et al., 2004; Sudaryanto

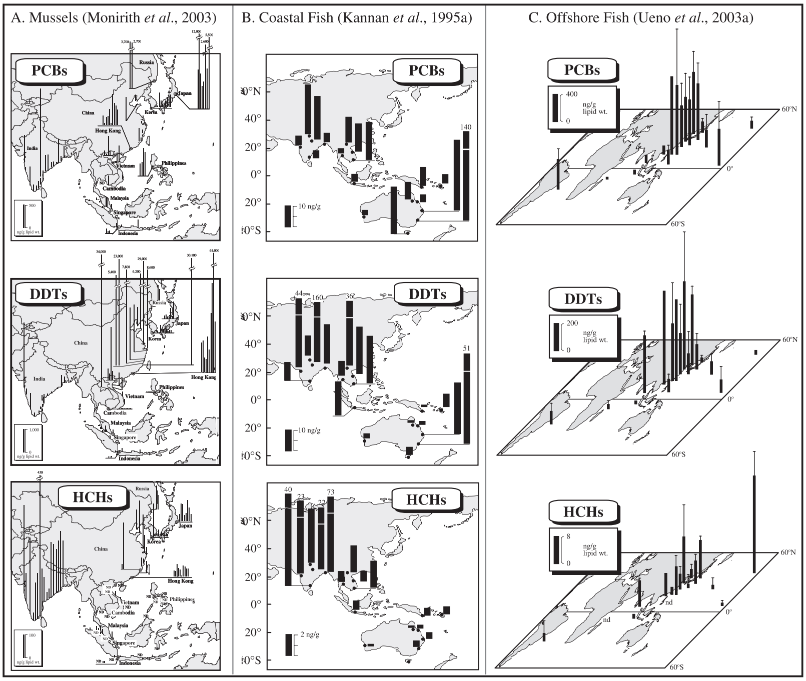

Figure 13.2. Regional distribution of OCs in mussels, fish and tuna in Asia-Pacific region.

et al., 2005b, 2006a; Fig. 13.3), and HBCDs was found in sediment and mussels from coastal waters (Sudaryanto et al., 2006a), suggesting their occurrence in the environment of Indonesia. Concentrations of PBDEs in fish also varied within species and locations. As those in sediment samples, relatively higher residue level of these brominated flame retardants were found in biological samples from urban areas in Jakarta Bay and Surabaya (Fig. 13.3), indicating similar pattern generally found for PCBs which are normally higher in populated and industrialized areas. Low levels of PBDEs and HBCDs were found in samples from remote areas including offshore waters. In comparison with OCs, the levels of PBDEs was the third most abundant pollutant class after DDTs and PCBs followed by CHLs, HCHs, and HCB in freshwater fish, whereas PBDEs ranked fourth in marine fish both from Jakarta Bay and Lampung Bay (Sudaryanto et al., 2005b). This result indicates that PBDEs are becoming chemicals of environmental concern as they frequently occur and are ubiquitous in the environment, similar to OCs, the classical contaminants routinely detected in the environment.

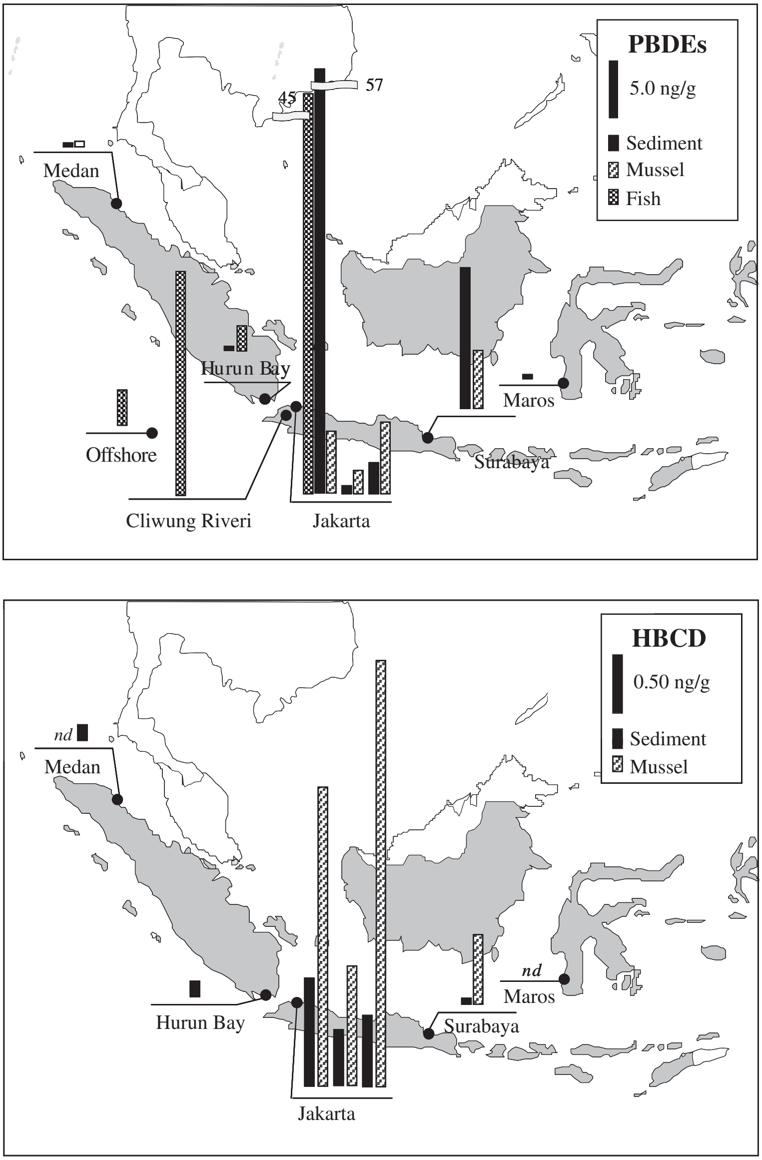

Figure 13.3. Spatial distribution of PBDEs and HBCDs in the environment of Indonesia.

Generally, levels of BFRs in Indonesian samples were considered low when compared worldwide. Ueno et al. (2004) showed regional differences in concentrations of PBDEs in tuna from several Asian countries and revealed low levels in Indonesian samples. The levels in fish were also much lower as compared to fish in North America (Dodder et al., 2002; Rayne et al., 2003) and European countries (Zennegg et al., 2002; Sellstrom et al., 1998; Erdogrul et al., 2005). Various species of fish in North America accumulated PBDEs that ranged from few hundred ppb to ppm level on lipid wt. basis, both in freshwater and marine fish. For example, Hale et al. (2001) reported maximum concentration of total PBDEs in carp from Virginian watershed up to 48,000 ng g^{-1} lipid wt., which is much higher than in carp from Indonesia (24 ng g^{-1} lipid wt.). In European studies, PBDEs were reported in levels ranging from few tens of ppb to ppm levels in various fish species, such as Whitefish and Pike. In Viskin River, Sweden close to several plastics and textile facilities, Sellstrom et al. (1993) found high concentrations of PBDEs in perch (37,000 ng g^{-1} lipid wt.).

13.3.3. Contamination by OCs in foodstuffs

Four studies have indicated the food contamination by OCs in Indonesia (Table 13.3). DDT was detected in vegetables (14–4400 ng g^{-1} wet wt.), chicken muscle (7.1–4000 ng g^{-1} wet wt.), egg (8800 ng g^{-1}), pork (47 ng g^{-1}), and fish (29–700 ng g^{-1}). DDT in chicken tissue and eggs from sprayed villages in Central Java exceeded the MRL of FAO/WHO

Table 13.3. Mean concentrations (ng g^{-1} wet wt.) of OCs in certain foodstuffs from Indonesia[a]

Food item	Location	Year	PCBs	HCHs	DDTs	References
Vegetables	Central Java	1984	na	12	14	Kuwatsuka et al., 1986
Vegetables	Central Java	1987	na	na	4400	Sulistiyono, 2004
Chicken muscle	Central Java	1989	na	na	4000	Noegrohoati et al., 1992
Egg	Central Java	1989	na	na	870	Noegrohoati et al., 1992
Carp fish	Central Java	1989	na	na	700	Noegrohoati et al., 1992
Rice	Bogor	1991	0.34	0.12	0.10	Kannan et al., 1994
Chicken muscle	Bogor	1991	4.5	4.4	7.1	Kannan et al., 1994
Pork fat	Bogor	1991	2.9	0.88	47	Kannan et al., 1994
Squid	Bogor	1991	2.0	0.06	0.66	Kannan et al., 1994
Fish	Bogor	1991	3.9	1.4	29	Kannan et al., 1994

Note: na = no data available.
[a]Values are from pooled individuals of several samples; all values of concentrations were normalized into similar unit and rounded to two digits for comparison.

(Noegrohoati et al., 1992). A greater proportion of *p,p′*-DDT was found in most food samples of animal origin, suggesting possible usage of DDT for malaria vector control. HCH, HCB, and PCB in Indonesian foods were relatively low, as observed in Thailand and other countries. As it has been shown in various abiotic samples and some fish from Bogor (Kannan et al., 1995b) and Lampung (Sudaryanto et al., 2005b, 2007b), levels of γ-HCH were greater than those of other HCH isomers, underlining the use of lindane rather than technical HCH (Kannan et al., 1994). These results indicate that Indonesians are exposed to high levels of DDT via their diet, particularly of animal origin.

13.3.4. Human exposure to OCs

As those in wildlife samples, only very few studies have addressed the accumulation of OCs in human from Indonesia and many of them focused on human breast milk particularly from women living in Java, the most populated island (Noegrohoati et al., 1992; Burke et al., 2003; Sudaryanto et al., 2006b). Except in a study by Sudaryanto et al. (2005a, 2006b) which included PCBs, TCPMe/OH, and PBDEs as target compounds, all the available data from this country are related to OCs pesticides (Noegrohoati et al., 1992; Burke et al., 2003). In an earlier study, Noegrohoati et al. (1992) investigated concentration of DDTs in human breast milk from single population of women who had lived in huts sprayed with DDTs during the malaria control in Central Java Province in 1982. In this study, very high concentrations of the parent compound *p,p′*-DDT (mean = 12,000 ng g^{-1} lipid wt., max = 42,000 ng g^{-1} lipid wt.) and recalcitrant metabolite, *p,p′*-DDE (mean = 16,000 ng g^{-1} lipid wt., max = 55,000 ng g^{-1} lipid wt.) were reported. This information provides an evidence on considerable usage of DDTs during the mid-1980s. A greater proportion of *p,p′*-DDT was also found in chicken muscle, egg, carp fish, and vegetables in this village, suggesting the recent usage of DDT for malaria control. Further study by Burke et al. (2003) attempted to understand spatial variability of OC pesticides by analyzing DDTs, HCHs, and HCB in human milk from women living in two different locations in urban (Jakarta) and rural areas (Puncak, Bogor). In this study, they found no significant difference in concentrations of DDTs, β-HCHs, and HCB between the cohorts, in which mean concentrations ranged between 200 and 460 ng g^{-1} lipid wt., 80–100 ng g^{-1} lipid wt., and 30–40 ng g^{-1} lipid wt., respectively. A more comprehensive data on human exposure conducted by Sudaryanto et al. (2006b) found variable sources and specific exposure routes to these contaminants in the general population of Indonesia. In particular, DDTs were significantly higher

($p < 0.05$) in breast milk from mothers living in suburban (Bogor), rural agriculture (Purwakarta), and rural fisheries (Lampung) than in urban area (Jakarta). Interestingly, based on these two recent studies, it can be concluded that until the early 2000s, some residents were exposed to relatively high levels and/or fresh input of DDTs, particularly in specific areas that have intensive agriculture and malaria eradication program (Burke et al., 2003; Sudaryanto et al., 2006b). For example, elevated level of DDTs (15,000 ng g^{-1} lipid wt.) was found in a woman living in an agricultural area (Purwakarta) located 70 km away from the capital city, Jakarta (Sudaryanto et al., 2006b). Furthermore, a woman, also with a farming background accumulated high level of *p,p*′-DDT (2400 ng g^{-1} lipid wt.) with a low ratio (0.56) of *p,p*′-DDE/*p,p*′-DDT (Sudaryanto et al., 2006b). Similarly, Burke et al. (2003) also reported a considerable proportion of *p,p*′-DDT in some donors from urban (Jakarta) and rural areas (Bogor) with a ratio of *p,p*′-DDE/*p,p*′-DDT as low as 0.20 and 0.50, respectively. Although, according to the regulation, the use of DDT in Indonesia has been totally banned since 1990s, the ratio and residue levels in some specific donors indicate ongoing usage of DDTs. Similar finding in abiotic compartments and fish also reflect the continuous fresh input of DDT. It was reported that after the peak usage from 1986 to 1991, the cumulative factory stock of DDT at the end of 1991 was around 4121 kg. It is possible that the stock of this obsolete DDTs may still be illegally distributed and used in recent years.

Unlike DDTs, Sudaryanto et al. (2006b) found only little spatial variation of PCBs, HCHs, CHLs, and HCB contamination among the above locations. A similar finding was made by Burke et al. (2003) for HCHs and HCB. However, it seems that PCBs were slightly higher in human milk samples from urban area (Jakarta = 33 ng g^{-1} lipid wt.) than suburban and rural areas (Lampung = 27 ng g^{-1} lipid wt., Purwakarta = 24 ng g^{-1} lipid wt., and Bogor = 21 ng g^{-1} lipid wt.), but no such trend was observed for HCHs, CHLs, and HCB, which might be due to the low levels of their accumulation in Indonesian breast milk as well as other environmental matrices. Residue levels of PCBs, HCHs, CHLs, and HCB were reported to be 1–3 orders of magnitude less than those of DDTs.

The bioaccumulation pattern of OCs in human breast milk from Indonesia (DDTs > HCHs > PCBs > CHLs > HCB; Sudaryanto et al., 2006b) was reported to be different with those in mussels and fish (Monirith et al., 2003; Sudaryanto et al., 2005b, 2007b), which showed higher level of PCBs and CHLs compared to HCHs. This may probably be because of differences in exposure route(s), and/or because the intakes of these compounds via seafood by the Indonesian population are not significant. In fact, there is no correlation between OCs levels in breast milk and frequency of seafood consumption either in the studies of Burke et al. (2003) or by Sudaryanto et al. (2006b). These results imply that other foodstuffs may also be responsible for exposure of the Indonesian general population. Indeed, the occurrence of OCs has been reported in vegetables (Kuwatsuka et al., 1986), rice, chicken, egg, pork, pork fat, and squid (Kannan et al., 1995b; Noegrohoati et al., 1992). Further studies using large number of samples and various foodstuffs are needed to clarify human exposure, accumulation levels, and sources of OCs in Indonesia.

With regard to compounds recently identified as endocrine disrupters, TCPMe/TCPMOH, and PBDEs were first reported by Sudaryanto et al. (2005a, c, 2006b, 2007a). Of the total 55 human milk samples, TCPMe was detected in almost all the donors but TCPMOH was found only in 10% of the samples (Sudaryanto et al., 2006b), similar to that seen in some other populations (Kunisue et al., 2003; Minh et al., 2004). The low bioavailability of TCPMOH has been suggested as it is rapidly metabolized and eliminated by humans (Minh et al., 2001). The average concentrations of TCPMe in breast milk from the four locations in Indonesia ranged from 2.8 to 9.3 ng g^{-1} lipid wt., comparable to other populations from Asian developing countries (Kunisue et al., 2003; Minh et al., 2004). Though a variety of sources could be possible (Jarman et al., 1992), accumulation of TCPMe in general population of Indonesia can be suggested to be from technical DDT, as a significant ($p < 0.05$) positive correlation between concentrations of DDTs and TCPMe was observed (Sudaryanto et al., 2006b).

Further to this, using a subset of samples ($n = 30$), a study by the same authors also found ubiquitous contamination by PBDEs in general population of Indonesia (Sudaryanto et al., 2007a). Among the four locations mentioned above, there were no significant differences ($p > 0.05$) in PBDEs concentrations (Sudaryanto et al., 2007a). Because of the short usage history, levels of PBDEs in human breast milk from Indonesia were still 1–3 orders of magnitude lower than PCBs, DDTs, HCHs, and CHLs, but comparable with TCPMe and HCB. PBDEs in breast milk from Indonesia did not correlate with age of mother and parity (number of children of the respective mother), an accumulation kinetics that showed different picture from those of PCBs and DDTs (Sudaryanto et al., 2005a, 2006b, 2007a), the group of compounds having similar properties and structure as PBDEs. Another report by Sudaryanto et al. (2005c) on widespread contamination of PBDEs in human breast milk from Asian countries, such as Japan, Korea, China, Vietnam, Philippines, Cambodia, and India, provided a regional comparison of this compound in general population of Asia. Concentrations of PBDEs in human milk from Indonesia are relatively similar to those in other Asian countries, a distribution pattern different from those of OCs that shows specific regional contamination status. The level of PBDEs in Indonesia was also comparable with some European countries, but still much lower than North America (Schecter et al., 2003), a region with largest consumption of PBDEs in the world.

Among 14 congeners (mono- to deca-BDE) analyzed by Sudaryanto et al. (2007a), BDE-47 and BDE-153 were generally the predominant congeners. However, some higher brominated congeners such as BDE-183 and BDE-209 were also prevalent, and equal to or even higher than BDE-47 in some donors. This is an important observation because it has been hypothesized that these compounds are less bioaccumulative due to their relatively high molecular weight. This study reveals the exposure of certain human population to higher brominated PBDEs, which is different to those observed in fish from Indonesia. The exposure routes are different for BDE-47 and higher brominated congener like BDE-183, i.e., food is the important source for BDE-47 because it is the major contaminant in wildlife, whereas airborne uptake seems to be more noticeable for BDE-183. The results of this study indicate that Indonesian people have been exposed to multiple source(s) and pathways of PBDEs.

13.4. Environmental contamination by OTs

Development of ports, ship construction, increasing shipping, and fishing activities in Indonesia (Soegiarto and Stel, 1998) has become an important issue with possible contamination of OTs in the marine waters (Sudaryanto et al., 2005d). OTs assessment in the environment of Indonesia was a main part of the comprehensive monitoring surveys in Asia–Oceania conducted by Ehime University, Japan (Kannan et al., 1995a; Ueno et al., 2003a; Sudaryanto et al., 2002, 2005d). In an earlier report, Kannan et al. (1995a) provided information on butyltins (BTs) residues in muscle of two species of fish purchased at market from Bogor, but could not give information on from where they were caught. Subsequently, Ueno et al. (2003a) found BTs contamination in liver of five individuals of tuna collected in 1998 from Western Sumatra open sea waters. In the same period on the above study, under the framework of Asia-Pacific Mussel Watch Project (Tanabe, 2000), Sudaryanto et al. (2002) revealed the occurrence of BTs in mussel along the coastal waters of Indonesia and other Asian developing countries. In a large scale survey covering various matrices (sediment, mussel, and fish) and locations, representing different land-based activities such as commercial ports, fishing ports, marinas, mariculture, as well as rural areas, widespread contamination by BTs was made clear in the marine environment of Indonesia (Sudaryanto et al., 2005d).

Figure 13.4 illustrates widespread contamination by BTs in the environment of Indonesia from available references. Concentrations of BTs in mussels, fish, and sediments from coastal waters were reported to be in the range of 3.7 to 64 ng g^{-1} wet wt., 3.3–84 ng g^{-1} wet wt., and 0.51–320 ng g^{-1} dry wt., respectively (Sudaryanto et al., 2005d), whereas in tuna from offshore waters, the values ranged from 13 to 150 ng g^{-1} wet wt. (Ueno et al., 2003a). In this study, it was indicated that maritime activities play a major role as sources of BTs. Usage of BTs on fish culture nets seems to be minimal in Indonesia. Indeed, almost all the mussels, fish and sediments showing higher concentration of BTs were from the areas with intensive maritime activities (Fig. 13.4) such as large commercial harbors or marina and fishing ports (Jakarta Bay, Surabaya, and Belawan). In Tanjung Priok Port, Jakarta, high concentrations (0.022–0.204 ppm) of tributyltin (TBT) were reported in seawater (Budianto, 2000). Nevertheless, concentrations of BTs found in the major marine culture areas (Hurun Bay and Lada Bay) are still low (Sudaryanto et al., 2005d). Among BTs, TBT was substantially higher than the metabolites di- (DBT) and monobutyltin (MBT) in almost all the samples (Fig. 13.5), suggesting recent input of BTs into marine environment. The

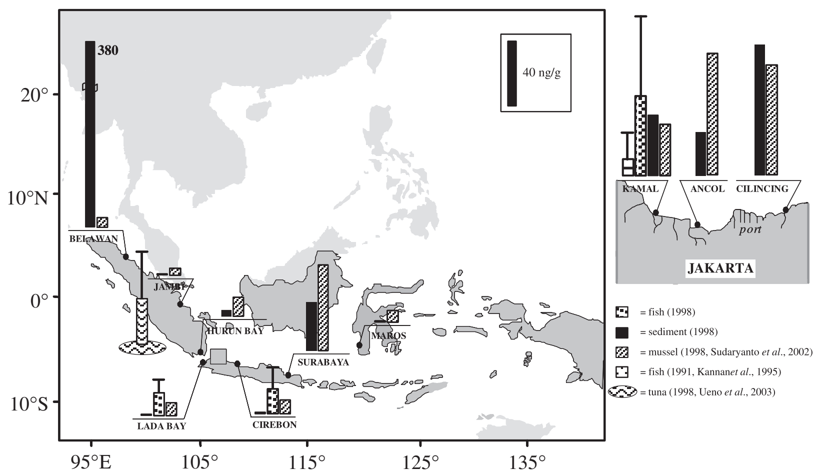

Figure 13.4. Levels and distribution of BTs in the environment of Indonesia.

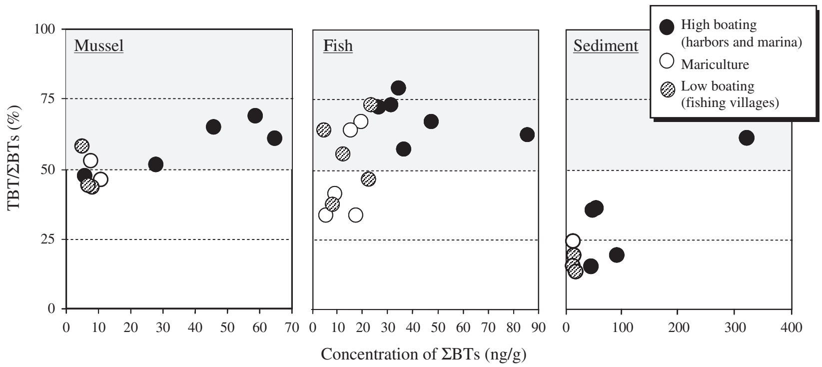

Figure 13.5. Concentrations of BTs and their relation with the proportion of TBT/ΣBTs according to various maritime activities.

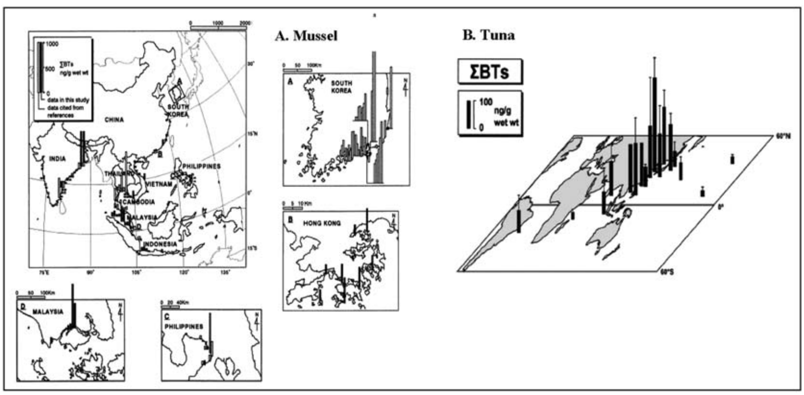

Figure 13.6. Regional distribution of ΣBTs in mussels (A) and tuna (B) from Asia-Pacific region.

composition pattern was similar to those in surrounding Asian developing countries (Sudaryanto et al., 2002), suggesting similar status of TBT usage in this region.

An appropriate regional comparison using similar species and analytical methods (Fig. 13.6) revealed that mussels and tuna from Indonesia contained lower levels of BTs when compared to certain other Asian countries (Sudaryanto et al., 2002; Ueno et al., 2003a). In the study of Sudaryanto et al. (2002), it was reported that, among Asian developing countries, mussel samples from Hong Kong, South Korea, Malaysia, and Thailand showed relatively high levels of BTs. Similarly, Ueno et al. (2003a) using liver of skipjack tuna (*Katsuwonus pelamis*) collected from

Asian offshore waters (off-Japan, the Japan Sea, off-Taiwan, the East China Sea, the South China Sea, off-Philippines, off-Indonesia, the Bay of Bengal, off-Seychelles, off-Brazil) and open seas (the North Pacific) also pointed out a similar pattern found in mussels (Fig. 13.6). Interestingly, the orders of mean and 90th-percentile values of concentrations in mussel agreed well with the per capita gross national product (GNP) of each country (Sudaryanto et al., 2002). Since per capita GNP is an indicator of economic status, butyltin contamination seems to be related to the industrial and human activities. The contamination of BTs may increase in those countries with increasing economic growth rates. Considering the high economic growth rate and the unregulated usage of TBT in many Asian developing countries, including Indonesia and the increasing demand for antifouling paints in Asia and Oceania (Layman, 1995), contamination by BTs in Asian aquatic environments may be expected to become more serious in the future. Thus, continuous monitoring and investigations on BTs contamination are required in Indonesia as well as other Asian developing countries.

Worldwide comparison of BTs in sediment and fish from Indonesia also revealed lower levels in Indonesian samples. The residue levels of BTs found in sediment (0.96–380 ng g^{-1} dry wt.) were lower than those reported in many coastal and harbor areas of various countries including several Asian developing countries, such as Malaysia and Thailand, as well as urbanized industrial nations such as the USA, Europe, Australia, and Japan (see Sudaryanto et al., 2004 and references therein). A similar case was also for fish (Fig. 13.7). Concentrations of BTs in fish from Indonesia were obviously lower than those reported in urbanized developed regions, such as the USA, Japan, Australia, Italy, and Netherland (See Takahashi et al., 1999 and references therein). The levels were also lower than those of the polluted areas of Asian developing countries, including the Malacca Strait, Malaysia (Sudaryanto et al., 2004).

13.5. Temporal variation of contaminations

It has been well known through intensive monitoring efforts that decreasing trends of classical OCs in the environment of developed countries occurred as a consequence of their regulation on use and waste treatment. However, considerably little information is available on their temporal trend in developing countries. In Indonesia, there are only few studies dealing with PTS in the environment (see review above) and no data series from temporal monitoring study are available, thus making it difficult to provide reliable long term trends. However, some findings on

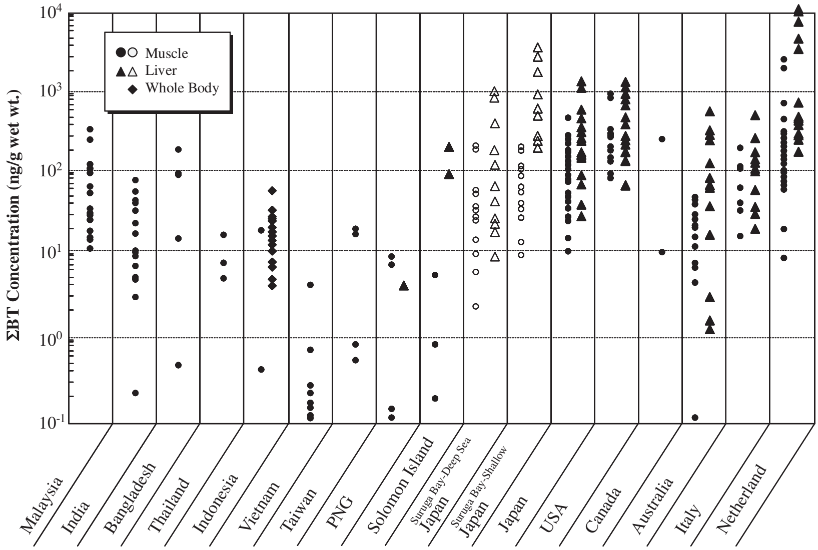

Figure 13.7. Worldwide comparison of ΣBTs in fish.

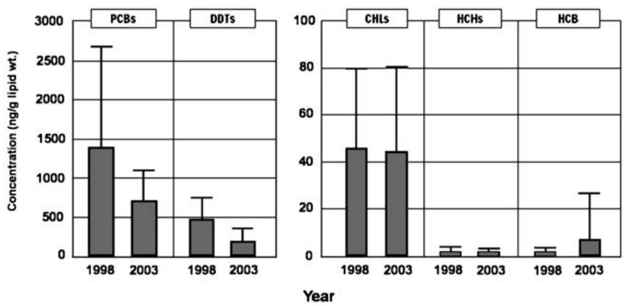

Figure 13.8. Comparison of OCs in fish caught at Jakarta Bay between 1998 and 2003.

PTS in the same sample matrices (mostly OCs in fish) and locations in different years of sampling are available that can explain temporal variation in the environment of Indonesia. Comparing data of OCs in fish caught from Jakarta Bay in 1998 and 2003 (Sudaryanto et al., 2007b) showed that concentrations of PCBs and DDTs have decreased significantly (Fig. 13.8). Similarly, levels of DDTs in freshwater fish collected in 2003 (Sudaryanto et al., 2007b) from Bogor were also significantly lower than those in fish collected in 1991 (Kannan et al., 1995b). DDTs in human breast milk collected during recent years around 2000–2003

(Burke et al., 2003; Sudaryanto et al., 2006b) were also much lower than those in 1991 (Noegrohoati et al., 1992). Based on these data, PCBs and DDT levels may appear to have declined with time in Indonesia. However, there was less temporal variation for other OCs, which could be due to lower background levels in the environment.

In case of BTs, a reduction of TBT contamination was also recorded in many developed countries after the regulation (Champ, 2000). In Indonesia, contamination status of BTs did not seem to improve during 1991 (Kannan et al., 1995a) to 1998 (Sudaryanto et al., 2005d); on the other hand, the contamination relatively increased in the later period, at least in the case of fish. This implies continuous pollution by BTs derived from heavy ship traffic in the busiest ports such as in Jakarta, coming from the countries having no TBT usage regulation. Declining trend of the contamination of TBT were not found in other countries in Asia also, such as India (comparing the data between 1994–1995 and 1998) and South Korea (between 1994 and 1997–1999) (Sudaryanto et al., 2002).

13.6. Ecological and human health risk

Risk of OCs and PBDEs has been estimated based on human dietary intake of OCs via seafood. The average dietary intake of PCBs and DDTs by an Indonesian as well as the data for other countries reported elsewhere are presented for comparison in Table 13.4. The FAO/WHO and Health Canada acceptable daily intake (ADI) as well as dose-response variable for target analytes (US-EPA, 2000) are listed for reference. None of the daily intake values of OCs reached the ADIs recommended by various agencies, indicating minimum risk caused by these pollutants. In case of PCBs, the mean daily intake of 1.2 μg person^{-1} day^{-1} and 0.81 μg person^{-1} day^{-1} via fish in 1998 and 2003, respectively, was only around 2% of the FAO/WHO and Health Canada-suggested maximum of 60 μg person^{-1} day^{-1} (FAO/WHO, 1986; Oostdam et al., 1999) or 10% of the conservative oral reference dose (RfD) proposed by US-EPA (2000). Although, PCBs were reported to be declining during several years before, the present value is higher than the dietary intake of PCBs during the 1991 survey conducted by Kannan et al. (1995b) as average seafood consumption has increased in recent years from 40 ng day^{-1} in 1991 to 57 ng day^{-1} in 2003. Comparing with other countries, the dietary intake of PCBs in Indonesia was lower than in developed countries such as Japan (17 μg person^{-1} day^{-1}) and Australia (3.0 μg person^{-1} day^{-1}) but higher than Cambodia, Thailand, India, and Solomon Island (Table 13.4). In case of DDTs, intake by an Indonesian in 1998 and 2003 was

Table 13.4. Estimated average daily intake (µg person^{-1} day^{-1}) of OCs and PBDEs from fish in Indonesia in comparison with other countries

Country	Fish consumption	PCBs	DDT	HCHs	CHLs	HCB	PBDEs	References
Cambodia (1998)	20	0.007	0.16	0.002	0.002	0.002	na	Monirith et al., 1999
Thailand (1990)	57	0.091	0.35	0.047	0.15	0.014	na	Kannan et al., 1995b
Vietnam (1990)	36	0.36	0.94	0.065	0.004	0.002	na	Kannan et al., 1995b
Australia (1992)	55	3.0	1.2	0.019	2.8	0.23	na	Kannan et al., 1995b
SI (1990)	121	0.44	0.58	0.064	0.069	0.002	na	Kannan et al., 1995b
India (1990)	10	0.036	0.16	0.29	0.025	0.001	na	Kannan et al., 1995b
Japan	90	17	1.4	na	na	na	na	EAJ, 1997
Hong Kong	160	na	2.7	na	na	na	na	Dickman and Leung, 1998
Indonesia (1991)	40	0.11	1.1	0.030	0.018	na	na	Kannan et al., 1995b
Indonesia (1998)	51	1.2	0.54	0.006	0.004	0.004	na	Sudaryanto et al., 2007b
Indonesia (2003)	57	0.81	1.1	0.018	0.010	0.010	0.037	Sudaryanto et al., 2007b
Acceptable daily intake by FAO/WHO		60	1200	na	na	na	na	FAO/WHO, 1986
Acceptable daily intake by Health Canada		60	1200	18	3	17	na	Oostdam et al., 1999
Oral reference dose (RfD)		12	30	18	30	na	na	US-EPA, 2000
LOEL (reduce male fertility & T4 in rat)							60	Kuriyama et al., 2005
LOEL (behavior alteration in mouse)							400	Viberg et al., 2003

Note: na = no data available.

0.54 μg person^{-1} day^{-1} and 1.1 μg person^{-1} day^{-1}, respectively, and accounted less than 1% of FAO/WHO and Health Canada guideline standard. The Indonesian daily intake of DDTs via seafood in recent years is similar to those ten years ago reported in a study conducted by Kannan et al. (1995b), but lower than those for Chinese (Dickman and Leung, 1998). However, the levels were relatively higher than those for other Asian countries (Table 13.4). The dietary intake of CHLs and HCHs was much lower than those of PCBs and DDTs (Table 13.4).

In case of PBDEs, based on data obtained from Sudaryanto et al. (2005b), average Indonesian daily intake via fish was 0.037 μg person^{-1} day^{-1}, which corresponds to the lower end of the estimate for the total PBDE intake by the Nordic consumer (0.2–0.7 μg person^{-1} day^{-1}) (Darnerud et al., 2001) and the maximum daily intake in Switzerland

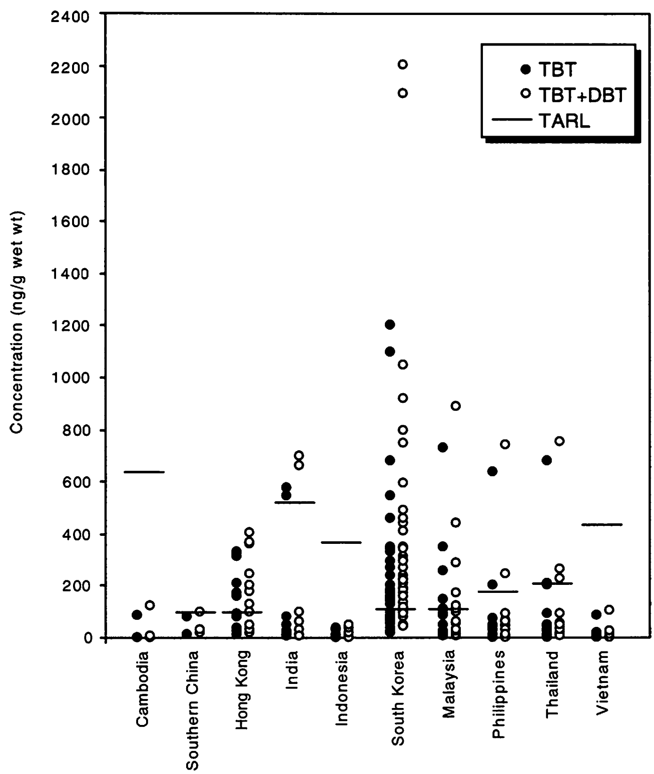

Figure 13.9. Residue levels of TBT and sum of TBT and DBT (TBT + DBT) detected in mussels from coastal waters of Indonesia and some other Asian countries compared with the tolerable average residue levels (TARLs) for seafood in each country.

(0.15 μg person^{-1} day^{-1}) (Zennegg et al., 2002). This value is still well below the experimental body burden associated with various developmental effects in neonatal mice and rats (Kuriyama et al., 2005; Viberg et al., 2003), such as reduced male fertility and T4 in rat (60 μg kg^{-1} day^{-1}) and behavior alteration in mouse (400 μg kg^{-1} day^{-1}). Although a number of limitations are involved in the estimation and interpretation of dietary intake values of OCs and PBDEs, including small number of samples, the use of whole body tissue (instead of fillets), and also not much availability of information on fish consumption pattern and fish dietary intake on each location, this result provide some useful indication of the approximate exposure levels and the need to conduct further studies to determine and/or to control excessive human exposure. Further studies toward clarifying current contribution from various food items to organohalogens intake by an Indonesian are also important. Moreover, in the light of continued use of PBDE in large quantities, monitoring levels of these compounds will continue to be an important issue.

With regard to BTs, the residue levels of TBT in mussels and fish were lower than the levels causing growth retardation in bivalves (Page and Widdows, 1991) and sublethal effect in fish (Rice et al., 1995). However, TBT residues found in some fish, particularly from hot spot areas such as Jakarta Bay (9.7–52 ng g^{-1} wet wt.), and mussels from Jakarta Bay (13–38 ng g^{-1} wet wt.) and Surabaya (28 ng g^{-1} wet wt.) were close to the threshold levels observed in several animals based on laboratory and field studies. For example, Horiguchi et al. (1994) estimated that *Thais clavigera* developed imposex when exposed to a threshold concentration of 10–20 ng TBT g^{-1} wet wt. In the tropical muricid *Thais distinguenda,* the development of imposex was observed when the body burden exceeded 20.4 ng TBT g^{-1} (Bech et al., 2002).

For instance, an extrapolated water TBT concentration (0.21–5.9 ng L^{-1}) based on concentrations of TBT and its bioconcentration factors (5000–10,400 for TBT in mussel and 9400–11,000 in marine fish) (Sudaryanto et al., 2005d) were also close to or above the threshold levels of toxic implications, such as imposex in mollusks and immunotoxicity in mussel (St-Jean et al., 2002). The levels were also near to the criteria established by US-EPA (2003) to protect saltwater aquatic life from chronic toxic effects of TBT (0.0074 μg L^{-1}). Indeed, high incidence of imposex in gastropods has been shown to occur in Indonesia, such as the Ambon coastal area (Ellis and Pattisina, 1990). An evidence of ecotoxicological impact of TBT, imposex incidence is also a usual phenomenon in gastropods in coastal waters of some other Asian countries

(Swennen et al., 1997). These observations suggest that TBT levels in some polluted areas of Indonesia and other Asian countries pose a toxic threat to susceptible mollusks and other marine organisms.

Human health risk assessment by BTs has also been estimated by using tolerable average residue levels (TARLs) for TBT in seafood products (Sudaryanto et al., 2002). TARLs value for seafood in Indonesia was estimated to be 360 ng g^{-1} wet wt. for an average person weighing 60 kg. When compared to TARL value, concentrations of TBT or the sum of TBT and DBT (TBT + DBT) in mussels from Indonesia were below this value (Fig. 13.9), suggesting no immediate public health risk. This situation was similar to those in Cambodia (TARL: 630 ng g^{-1} wet wt.) and Vietnam (435 ng g^{-1} wet wt.) which have low contamination status by organotin in mussels (Fig. 13.9). The higher risk may happen in some other Asian countries which have elevated exposure to BTs. Concentrations of TBT or the sum of TBT and DBT (TBT + DBT) exceeded respective TARL values in some of the mussels from southern China, Hong Kong, South Korea, Malaysia, India, the Philippines, and Thailand (Fig. 13.9). In addition to mussels, consumption of other seafood items such as fish can also contribute to higher exposure.

Although the magnitude of contamination by BTs in coastal waters of Indonesia is low, and no immediate public health problems could be seen, increasing levels of BTs contamination in recent years still causes concern. Information concerning organotin contamination and its potential effects on the ecosystems in Indonesia are still scarce. Continuous monitoring studies are required to observe future trends and to delineate toxicological implications.

13.7. Conclusions and recommendations

Available data searched from literatures revealed widespread contamination by polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs), polybrominated diphenyl ethers (PBDEs), and hexabromocyclododecanes (HBCDs) as well as butyltin compounds (BTs) in Indonesia comprising aquatic and terrestrial environment and biota including human. From several monitoring studies, it is evident that concentrations and the contamination patterns of these compounds varied within specimens and locations. Some locations were considered as hot spots by specific contaminants and part of the population in Indonesia is highly exposed to environmental contaminants, particularly DDTs as the most prominent pollutant. Although, in general, the residual concentrations of PTS are still low when compared to global contamination levels and standards, the occurrence of imposex, an indication of possible toxicity of TBT, has been observed in the mollusks. Moreover, specific residents are still subjected to elevated levels of pesticides—a cause for concern on human health. Estimated infant daily intake of DDTs and HCHs through lactation in some donors also exceeded WHO guideline. Levels of some OCs such as DDTs and PCBs decreased recently; however, recent input and emission into the environment still continue. Fresh TBT input is a common phenomenon in coastal waters and the reduction trend in the environment still did not improved. Altogether, and in line with the various findings on increasing new candidate of POPs (PBDEs and HBCDs) in many environmental matrices (Hites, 2004) including Asia (Kajiwara et al., 2004), and also Asia seems to consume large quantities of BFRs (Watanabe and Sakai, 2003), the present situation highlight the need for continuous monitoring study of the levels of PTS in environment, people, and food, to delineate temporal trend, sources, and their potential effects as well as determining other routes of exposure of these compounds to the general population of Indonesia. The environmental conservation and monitoring under an international cooperation is highly requested in order to prevent subsequent pollution and toxic impacts on aquatic wildlife and humans in Indonesia. Cooperative research effort with scientists from developed countries is needed to strengthen the national capability and to enhance knowledge and understanding amongst decision makers, managers, industries, and public to meet the obligations of the International Conventions regarding the management and elimination of toxic chemical contaminants.

ACKNOWLEDGMENTS

We thank Dr. A. Subramanian, Ehime University, Japan, for critical reading of this manuscript. This research was supported by grants from Research Revolution 2002 (RR 2002) Project for Sustainable Coexistence of Human, Nature, and the Earth (FY 2002) and "21st Century COE Program" from the Japanese Ministry of Education, Culture, Sports, Science and Technology. Financial support was also provided by Grants-in-Aid for Scientific Research (A) (No. 16201014) from Japan Society for the Promotion of Science (JSPS); and the Global Environment Research Fund (RF-064), the Waste Management Research Grants (K1821 and K1836) from the Ministry of the Environment, Japan. The award of JSPS Postdoctoral Fellowships for Foreign Researchers in Japan to A. Sudaryanto (No. P07174) is acknowledged.

REFERENCES

Bailey, R.E., 2001. Global hexachlorobenzene emissions. Chemosphere 43, 167–182.

Bech, M., Strand, J., Jacobsen, J.A., 2002. Development of imposex and accumulation of butyltin in the tropical muricid *Thais distinguenda* transplanted to a TBT contaminated site. Environ. Pollut. 119, 253–260.

van-Birgelen, A.P.J.M., 1998. Hexachlorobenzene as a possible major contributor to the dioxin activity of human milk. Environ. Health Perspect. 106, 683–688.

Budianto, E., 2000. Coastal research programmes at Environmental Management Center (EMC). Coastal Ecology, Nutrient Cycles & Pollution. 2nd UNU-ORI Joint International Workshop for the Marine Environment, Otsuchi, Japan, December 3–8, 2000.

Burke, E.R., Holden, A.J., Shaw, I.C., Suharyanto, F.X., Sihombing, G., 2003. Organochlorine pesticide residues in human milk from primiparous women in Indonesia. Bull. Environ. Contam. Toxicol. 71, 148–155.

Champ, M.A., 2000. A review of organotin regulatory strategies, pending actions, related costs and benefits. Sci. Total Environ. 258, 21–71.

Darnerud, P.O., Eriksen, G.S., Johannesson, T., Larsen, P.B., Viluksela, M., 2001. Polybrominated diphenyl ethers: Occurrence, dietary exposure, and toxicology. Environ. Health Perspect. 109, 49–68.

Dickman, M.D., Leung, K.M.C., 1998. Mercury and organochlorine exposure from fish consumption in Hong Kong. Chemosphere 37, 991–1051.

Dodder, N.G., Strandberg, B., Hites, R.A., 2002. Concentrations and spatial variations of polybrominated diphenyl ethers and several organochlorine compounds in fishes from the Northeastern United States. Environ. Sci. Technol. 36, 146–151.

EAJ-Environmental Agency of Japan, 1997. Chemicals in the environment. Environmental Health Department, Environmental Agency, Japan.

Ellis, D.V., Pattisina, L.A., 1990. Widespread neogastropod imposex: A biological indicator of global TBT contamination? Mar. Pollut. Bull. 21, 248–253.

EMC (Environmental Management Center), 2003. Monitoring of persistent organic pollutants in the coastal hydrosphere of Indonesia 2003. Environmental Monitoring and Governance in the East Asian Hydrosphere. Country report, UNU, Japan. http://landbase.hq.unu.edu/Data.htm

Erdogrul, O., Covaci, A., Schepens, P., 2005. Levels of organochlorine pesticides, polychlorinated biphenyls and polybrominated diphenyl ethers in fish species from Kahramanmaras, Turkey. Environ. Int. 31, 703–711.

FAO/WHO, 1986. Joint FAO/WHO food standards programme. Codex alimentarius commission, codex maximum limits for pesticides residues. Codex Alimentarius, XIII, 2nd ed. Rome, Italy.

Hale, R.C., La Guardia, M.J., Harvey, E.P., Matteson-Mainor, T., Duff, W.H., Gaylor, M.O., 2001. Polybrominated diphenyl ether flame retardants in Virginia freshwater fishes. Environ. Sci. Technol. 35, 4585–4591.

Hites, R.A., 2004. Polybrominated diphenyl ethers in the environment and in people: A meta-analysis of concentrations. Environ. Sci. Technol. 38, 945–956.

Horiguchi, T., Shiraishi, H., Shimizu, M., Morita, M., 1994. Imposex and organotin compounds in *Thais clavigera* and *T. bronni* in Japan. J. Mar. Biol. Assoc. U.K. 74, 651–669.

Hutagalung, H.P., Setiapermana, D., Munawir, K., 1997. Organochlorine, oil and heavy metals in Siak Estuary, Riau, Indonesia. In: Vigers, G., Ong, K.S., Pherson, Mc., Milson, N., Watson, I., Tang, A. (Eds.), Proceeding of the Asean-Canada Technical Conference on Marine Science. Penang, Malaysia, pp. 21–29.

Iwata, H., Tanabe, S., Sakai, N., Nishimura, A., Tatsukawa, T., 1994. Geographical distribution of persistent organochlorines in air, water and sediments from Asia and Oceania, and their implications for global redistribution from lower latitudes. Environ. Pollut. 85, 15–33.

Iwata, H., Tanabe, S., Sakai, N., Tatsukawa, R., 1993. Distribution of persistent organochlorines in the oceanic air and surface seawater and the role of ocean on their global transport and fate. Environ. Sci. Technol. 27, 1080–1098.

Jarman, W.M., Simon, M., Nostrom, R.J., Bruns, S.A., Bacon, C.A., Simaret, B.R.T., Riseborough, R.W., 1992. Global distribution of *tris*(4-chlorophenyl)methanol in high trophic level birds and mammals. Environ. Sci. Technol. 26, 1770–1774.

Kajiwara, N., Ueno, D., Ramu, K., Kamikawa, S., Yamada, T., Chung, K.H., Tanabe, S., 2004. Geographical distribution and temporal trends of polybrominated diphenyl ethers (PBDEs) in cetacean from Asian waters. The third international workshop on brominated flame retardants. June 6–9, 2004. Canada. pp. 187–190.

Kannan, K., Tanabe, S., Iwata, H., Tatsukawa, R., 1995a. Butyltins in muscle and liver of fish collected from certain Asian and Oceanian countries. Environ. Pollut. 90, 279–290.

Kannan, K., Tanabe, S., Tatsukawa, R., 1995b. Geographical distribution and accumulation features of organochlorine residues in fish in tropical Asia and Oceania. Environ. Sci. Technol. 29, 2673–2683.

Kannan, K., Tanabe, S., Williams, R.J., Tatsukawa, R., 1994. Persistent organochlorine residues in foodstuffs from Australia, Papua New Guinea and the Solomon Island: Contamination levels and human dietary exposure. Sci. Total. Environ. 153, 29–49.

Kunisue, T., Someya, M., Monirith, I., Watanabe, M., Tana, T.S., Tanabe, S., 2003. Occurrence of PCBs, organochlorine insecticides, tris(4-chlorophenyl)methane and *tris*(4-chlorophenyl)methanol in human breast milk collected from Cambodia. Arch. Environ. Contam. Toxicol. 46, 405–412.

Kuriyama, S.N., Chris, E., Talsness, Grote, K., Chahoud, I., 2005. Developmental exposure to low dose PBDE 99: 1-effects on male fertility and neurobehavior in rat offspring. Environ. Health Perspect. 113, 149–154.

Kuwatsuka, S., Moon, Y.-H., Ohsawa, K., Yamamoto, I., Hartadi, S., Noegrohoati, S., Sastrohamidjojo, H., Untung, K., Arya, N., Sumiartha, K., 1986. Comparative studies on pesticide residues in soils, water and vegetables in Indonesia and Japan. In: Proceeding of the International Seminar on Comparative Agricultural Studies in Southeast Asia, Denpasar, Bali, Indonesia, January 20–24, pp. 121–133.

Layman, P.L., 1995. Marine coating industry adopts new technology for shifting markets. Chem. Eng. News 1, 23–25.

Minh, N.H., Someya, M., Minh, T.B., Kunisue, K., Iwata, H., Watanabe, M., Tanabe, S., Viet, P.H., Tuyen, B.C., 2004. Persistent organochlorine residues in human breast milk from Hanoi and Hochiminh city, Vietnam: Contamination, accumulation kinetics and risk assessment for infants. Environ. Pollut. 129, 431–441.

Minh, T.B., Watanabe, M., Tanabe, S., Yamada, T., Hata, J., Watanabe, S., 2001. Specific accumulation and elimination kinetics of *tris*(4-chlorophenyl)methane, *tris*(4-chlorophenyl)methanol, and other persistent organochlorines in humans from Japan. Environ. Health Perspect. 109, 927–935.

Monirith, I., Nakata, H., Tanabe, S., Tana, T.S., 1999. Persistent organochlorine residues in marine and freshwater fish in Cambodia. Mar. Pollut. Bull. 38, 604–612.

Monirith, I., Ueno, D., Takahashi, S., Nakata, H., Sudaryanto, A., Subramanian, A., Karuppiah, S., Ismail, A., Muchtar, M., Zheng, J., Richardson, B.J., Prudente, M., Hue, N.D., Tana, T.S., Tkalin, A.V., Tanabe, S., 2003. Asia-Pacific mussel watch: Monitoring contamination of persistent organochlorine compounds in coastal waters of Asian countries. Mar. Pollut. Bull. 46, 281–300.

Munawar, K., 2005. Organochlorine pesticides in water and sediment in the waters of Memberamo Estuarine, Irian Jaya. Oseanologi dan Limnologi di Indonesia 38, 69–78.

Munawir, K., 1997. Kadar pestisida organoklorin di perairan Muara Sungai Kuala Tungkal, Jambi. In: Praseno, D.P., Atmadja, W.S., Supangat, I., Ruyitno, Sudibyo, B.S. (Eds.), Inventarisasi dan Evaluasi Potensi Laut-Pesisir II. Geologi, Kimia, Biologi dan Ekologi. Pusat Penelitian dan Pengembangan Oseanologi, Lembaga Ilmu Pengetahuan Indonesia. pp. 31–37. (In Indonesian language.)

Munawir, K., 1998. Kadar pestisida organoklorin di perairan Muara Sungai Musi, Palembang. In: Praseno, D.P., Atmadja, W.S., Supangat, I., Ruyitno, Sudibyo, B.S. (Eds.), Inventarisasi dan Evaluasi Potensi Laut-Pesisir III. Oseanologi, Lingkungan dan Biologi. Pusat Penelitian dan Pengembangan Oseanologi, Lembaga Ilmu Pengetahuan Indonesia. pp. 27–33. (In Indonesian language.)

Munawir, K., 1999. Kadar pestisida organoklorin di Muara Sungai Kuala Jambi. In: Praseno, D.P., Atmadja, W.S., Supangat, I., Ruyitno, Sudibyo, B.S. (Eds.), Pesisir dan Pantai Indonesia I. Pusat Penelitian dan Pengembangan Oseanologi Lembaga Ilmu Pengetahuan Indonesia. pp. 45–51. (In Indonesian language.)

Munawir, K., 2001a. Kadar pestisida organoklorin di perairan Muara Sungai Asahan Tanjung Balai, Sumatera Utara. In: Atmadja, W.S., Ruyitno, Sudibyo, B.S, Supangat, I., Hutagalung, H.P., Genisa, A.S., Sunarto, Sugiarto, H. (Eds.), Pesisir dan Pantai Indonesia VI. Pusat Penelitian dan Pengembangan Oseanologi, Lembaga Ilmu Pengetahuan Indonesia. pp. 193–201. (In Indonesian language.)

Munawir, K., 2001b. Pestisida organoklorin dalam air dan sedimen Muara Sungai Way Kambas dan Way Sekampung, Lampung. In: Atmadja, W.S., Ruyitno, Sudibyo, B.S, Supangat, I., Hutagalung, H.P., Genisa, A.S., Sunarto, Sugiarto, H. (Eds.), Pesisir dan Pantai Indonesia VI. Pusat Penelitian dan Pengembangan Oseanologi, Lembaga Ilmu Pengetahuan Indonesia. pp. 229–239. (In Indonesian language.)

Munawir, K., 2002. Kadar pestisida organoklorin dalam air dan sedimen di perairan Muara Sungai Digul dan Arafura, Irian Jaya. In: Nuchsin, R., Muchtar, M., Supangat, S. (Eds.), Pesisir dan Pantai Indonesia VII. Pusat Penelitian dan Pengembangan Oseanologi, Lembaga Ilmu Pengetahuan Indonesia. pp. 41–48. (In Indonesian language.)

Noegrohoati, S., Sardjoko, Untung, K., Hammers, W.E., 1992. Impact of DDT spraying on the residue levels in soil, chicken, fish-pond water, carp, and human milk samples from malaria infested villages in Central Java. Toxicol. Environ. Chem. 34, 237–251.

Oostdam, J.V., Gilman, A., Dewailly, E., Usher, P., Wheatley, B., Kuhnlein, H., 1999. Human health implications of environmental contaminants in Arctic Canada: A review. Sci. Total Environ. 230, 1–82.

Othman, A.B., Balasubramanian, K., 2001. The FAO programme for community icpm in Asia, country report-Malaysia. Prepared for the meeting of the Programme Advisory Committee (PAC), Ayutthaya, Thailand, November 2001, pp. 1–11.

Page, D.S., Widdows, J., 1991. Temporal and spatial variation in levels of alkyltins in mussels tissues: A toxicological interpretation of field data. Mar. Environ. Res. 32, 113–129.

Parikesit, Salim, H., Triharyanto, E., Gunawan, B., Sunardi, Abdoellah, O.S., Ohtsuka, R., 2005. Multi-source water pollution in the upper Citarum watershed, Indonesia with special reference to its spatiotemporal variation. Environ. Sci. 12, 121–131.

Ratnaningsih, D., Helmy, M., Bagus, B.E., Nety, W., Heni, P., 2002. A survey on water pollution by endocrine disrupter compounds: Monitoring of organochlorine pesticides, phenols and phthalates in the coastal hydrosphere of Indonesia. Environmental Monitoring and Governance in the East Asian Hydrosphere. Country report, UNU, Japan. http://landbase.hq.unu.edu/Data.htm

Rayne, S., Ikonomou, M.G., Antcliffe, B., 2003. Rapidly increasing polybrominated diphenyl ether concentrations in the Columbia River system from 1992 to 2000. Environ. Sci. Technol. 37, 2847–2854.

Razak, H., Munawir, K., 1994. Kadar pestisida organoklorin di perairan Teluk Jakarta. In: Hutagalung, H.P., Setiapermana, D., Sulistyo (Eds.), Makalah Penunjang Seminar Pemantauan Pencemaran Laut. Pusat Penelitian Oseanografi, Lembaga Ilmu Pengetahuan Indonesia. pp. 37–48. (In Indonesian Language.)

Rice, C.D., Banes, M.M., Ardelt, T.C., 1995. Immunotoxicity in channel catfish, *Ictalurus punctatus*, following acute exposure to tributyltin. Arch. Environ. Contam. Toxicol. 28, 464–470.

Schecter, A., Pavuk, M., Päpke, O., Ryan, J.J., Birnbaum, L., Rosen, R., 2003. Polybrominated diphenyl ethers (PBDEs) in U.S. mothers' milk. Environ. Health Perspect. 111, 1723–1729.

Sellstrom, U., Jansson, B., Kierkegaard, A., de Wit, C., Odsjo, T., Olsson, M., 1993. Polybrominated diphenyl ethers (PBDE) in biological samples from the Swedish environment. Chemosphere 26, 1703–1718.

Sellstrom, U., Kierkegaard, A., de Wit, C., Jansson, B., 1998. Polybrominated diphenyl ethers and hexabromocyclododecane in sediment and fish from a Swedish river. Environ. Toxicol. Chem. 17, 1065–1072.

Soegiarto, A., Stel, J.H., 1998. The Indonesian experience in marine capacity building. Mar. Policy 22, 255–267.

Soekarna, D., Sundaru, M., 1983. The present status of pesticide use in Indonesia. Proceedings of the International Symposium on Pesticide Use in Developing Countries—Present and Future, Kyoto, September 2–4, 1982. Tropical Agriculture Research Center, Tsukuba, Japan, pp. 15–23.

St-Jean, S.D., Pelletier, E., Courtenay, S.C., 2002. Very low levels of waterborne butyltins modulate hemocyte function in the blue mussel *Mytilus edulis*. Mar. Ecol. Prog. Series 236, 155–161.

Sudaryanto, A., Isobe, T., Takahashi, S., Tanabe, S., 2006a. Brominated flame retardants in the environment of Indonesia. Proceedings of 232nd American Chemical Society National Meeting & Exposition, Division of Environmental Chemistry, 46(2), 1160–1165. San Francisco, CA, September 10–14, 2006.

Sudaryanto, A., Kajiwara, N., Iwata, H., Adibroto, T.A., Hartono, P., Muawanah, A., Tanabe, S., 2005a. Geographical distribution of polybrominated diphenyl ethers (PBDEs) in human breast milk from Indonesia. 14th Symposium on Japan Society for Environmental Chemistry, Osaka, Japan, June, 2005, pp. 192–193.

Sudaryanto, A., Kajiwara, N., Iwata, H., Santoso, A.D., Hartono, P., Muawanah, Hayami, R., Omori, K., Tanabe, S., 2005b. Geographical distribution of polybrominated diphenyl ethers and organochlorine compounds in fish from Indonesia. Organohalo. Compd. 67, 598–601.

Sudaryanto, A., Kajiwara, N., Takahashi, S., Muawanah, A., Tanabe, S., 2007a. Distribution and accumulation features of PBDEs in human breast milk from Indonesia. Environ. Pollut., in press, doi: 10.1016/j.envpol.2007.02.016.

Sudaryanto, A., Kajiwara, N., Tsydenova, O., Iwata, H., Adibroto, T.A., Yu, H., Chung, K.H., Subramanian, A., Prudente, M., Tana, T.S., Tanabe, S., 2005c. Global contamination of PBDEs in human milk from Asia. Organohalo. Compd. 67, 1315–1318.

Sudaryanto, A., Kunisue, T., Iwata, H., Adibroto, T.A., Hartono, P., Tanabe, S., 2006b. Specific accumulation of organochlorines in human breast milk from Indonesia: Levels, distribution, accumulation kinetics and infant health risk. Environ. Pollut. 139, 107–117.

Sudaryanto, A., Monirith, I., Kajiwara, N., Hartono, P., Muawanah, Omori, K., Takeoka, H., Tanabe, S., 2007b. Levels and distribution of organochlorines in fish from Indonesia. Environ. Int., in press, doi: 10.1016/j.envint.2007.02.009.

Sudaryanto, A., Takahashi, S., Iwata, H., Tanabe, S., Ismail, A., 2004. Contamination of butyltin compounds in Malaysian marine environment. Environ. Pollut. 130, 347–358.

Sudaryanto, A., Takahashi, S., Iwata, H., Tanabe, S., Muchtar, M., Razak, H., 2005d. Organotin residues and the role of anthropogenic tin sources in the coastal marine environment of Indonesia. Mar. Pollut. Bull. 50, 226–235.

Sudaryanto, A., Takahashi, S., Monirith, I., Ismail, A., Muchtar, M., Zheng, J., Richardson, B.J., Subramanian, A., Prudente, M., 2002. Asia Pacific mussel watch: Monitoring of butyltin contamination in coastal waters of Asian developing countries. Environ. Toxicol. Chem. 21, 2119–2130.

Sulistiyono, L., 2004. Dilema penggunaan pestisida dalam sistem pertanian tanaman Hortikultura. Makalah pengantar ke falsafah sains. Program Pascasarjana/S3. Institut Pertanian Bogor. (In Indonesian Language.)

Suroso, T., Sianturi, B., Pramono, B., 2000. Vector control policy in malaria control programme in Indonesia. Proceedings of Workshop on Sustainable Approaches for Pest and Vector Management and Opportunities for Collaboration in Replacing POPs Pesticides, Bangkok, March 6–10, 2000, UNEP/FAO/WHO.

Swennen, C., Ruttanadakul, N., Ardseungnern, S., Singh, H.G., Mensink, B.P., Ten Hallers-Tjabbes, C.C., 1997. Imposex in sublittoral and littoral gastropods from the gulf of Thailand and Strait of Malacca in relation to shipping. Environ. Technol. 18, 245–1254.

Takahashi, S., Tanabe, S., Takeuchi, I., Miyazaki, N., 1999. Distribution and specific bioaccumulation of butyltin compounds in a marine ecosystem. Arch. Environ. Contam. Toxicol. 37, 50–61.

Tanabe, S., 2000. Asia-Pacific mussel watch: Progress report. Mar. Pollut. Bull. 40, p. 651.

Tanabe, S., Ramesh, A., Sakashita, D., Iwata, H., Mohan, D., Subramanian, A.N., Tatsukawa, R., 1991. Fate of HCH (BHC) in tropical paddy field: Application test in South India. Int. J. Environ. Anal. Chem. 45, 45–53.

Ueno, D., Inoue, S., Takahashi, S., Ikeda, K., Tanaka, H., Subramanian, A.N., Fillmann, G., Nakata, H., Lam, P.K.S., Zheng, J., Muchtar, M., Prudente, M., Tanabe, S., 2003a. Global pollution monitoring of butyltin compounds using skipjack tuna as a bioindicator. Environ. Pollut. 127, 1–12.

Ueno, D., Kajiwara, N., Tanaka, H., Subramanian, A., Fillmann, G., Lam, P.K.S., Zheng, G.J., Muchtar, M., Razak, H., Prudente, M., Chung, K.H., Tanabe, S., 2004. Global pollution monitoring of polybrominated diphenyl ethers using skipjack tuna as bioindicator. Environ. Sci. Technol. 38, 2312–2316.

Ueno, D., Takahashi, S., Tanaka, H., Subramanian, A.N., Fillmann, G., Nakata, H., Lam, P.K.S., Zheng, J., Muchtar, M., Prudente, M., Chung, K.H., Tanabe, S., 2003b. Global pollution monitoring of PCBs and organochlorine pesticides using skipjack tuna as a bioindicator. Arch. Environ. Contam. Toxicol. 45, 378–389.

UNIDO, 1984. Indonesia: Consultation on research and development for pesticide production in Indonesia. Technical Report. United Nations Industrial Development Organization, Vienna. p. 42.

Untung, S., 1999. Status and management of POPs in Indonesia. Proceedings of the Regional Workshop on the Management of the Persistent Organic Pollutants (POPs), Hanoi, Vietnam, 16–19 March 1999.

US-EPA, 2000. Guidance for assessing chemical contaminant data for use in fish advisories, volume 1: Fish sampling and analysis, 3rd ed. EPA 823-B-00-007. United States Environmental Protection Agency, Office of Water, November 2000.

US-EPA, 2003. Ambient aquatic life water quality criteria for tributyltin. U.S. Environmental Protection Agency, Office of Water Office of Science and Technology, Health and Ecological Criteria Division, Washington D.C.

Viberg, H., Fredrikson, A., Erickson, P., 2003. Neonatal exposure to polybrominated diphenyl ether (PBDE 153) disrupts spontaneous behaviour, impairs learning and memory, and decreases hippocampal cholinergic receptors in adult mice. Toxicol. Appl. Pharmacol. 192, 95–106.

Watanabe, I., Sakai, S., 2003. Environmental release and behavior of brominated flame retardants. Environ. Int. 29, 665–682.

Wurl, O., Potter, J.R., Obbard, J.P., Durville, C., 2006. Persistent organic pollutants in the equatorial atmosphere over the open Indian Ocean. Environ. Sci. Technol. 40, 1454–1461.

Zennegg, M., Kohler, M., Gerecke, A.C., Schmid, P., 2002. Polybrominated diphenyl ethers in whitefish from Swiss Lakes and farmed rainbow trout. Chemosphere 51, 545–553.