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Chapter 11

Persistent Organic Pollutants in Vietnam: Levels, Patterns, Trends, and Human Health Implications

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Abstract

This chapter provides an overview of the contamination by persistent organic pollutants (POPs) in Vietnam on the basis of the results of extensive monitoring studies conducted in our laboratory during the last two decades. Surveys conducted in the framework of Asia-Pacific Mussel Watch Program during early 1990s indicated widespread contamination by polychlorinated biphenyls (PCBs) and organochlorine (OC) insecticides, particularly DDTs and HCHs in various environmental compartments such as air, water, soils, sediments, and fish collected from different parts of Vietnam. Recent studies have revealed elevated contamination by DDTs in fish, mussels, and birds from Vietnam. Interestingly, DDT residue concentrations in fish and birds from Vietnam are among the highest values reported for the countries in Asia-Pacific region, suggesting the role of Vietnamese environment as a potential emission source of DDTs in this region. Open dumping sites for municipal wastes in some major cities such as Hanoi and Hochiminh City is a matter of concern with regard to environmental pollution, particularly contamination by dioxins (PCDDs) and related compounds such as dibenzofurans (PCDFs) and coplanar PCBs. Soils collected in dumping sites in Hanoi contained higher PCDD/F residues as compared to general soils collected far from dumping sites. PCDD/F concentrations in a few soil samples from Hanoi exceeded the environmental guideline values, suggesting potential health effects on humans and wildlife living near these dumping sites. Daily intakes of DDTs via seafood estimated for Vietnamese general population were among the highest values reported for East Asian countries. In the open dumping sites, intakes of dioxins by residents were significantly greater than those living far from dumping sites. Particularly, the estimated intakes of

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dioxins via soil ingestion and dermal exposure for children were higher than those for adults, suggesting greater risk of dioxin exposure for children in dumping sites. Future studies should be focused on the temporal trends of POPs in biota in Vietnam to predict the future trends of contamination and to understand possible toxic impacts on organisms. In addition, human exposure and possible toxic effects, particularly on children should be considered as priority research as they are the most susceptible group and have higher exposure levels to dioxins.

11.1. Introduction

Global contamination and toxic effects of persistent organic pollutants (POPs) have been an emerging environmental issue and received considerable attention during the past four decades. Although the extent of contamination by POPs has been dominant in industrialized nations, an increasing number of recent investigations have highlighted the role of Asia-Pacific region as a potential source of emission for these chemicals, particularly to pristine areas such as the Arctic and the Antarctic (e.g., see review by Tanabe et al., 1994; Tanabe, 2002).

Vietnam is located at the center of the Southeast Asian region (Fig. 11.1); it has more than 300 km coastal lines and two major agricultural production areas: the Red River Delta in the north and the Mekong River Delta in the south. These two deltas inhabited by approximately more than 30 million people and are two of the most densely populated areas in the world. The Mekong River Delta has recently become one of the most productive agricultural regions of Southeast Asia. Such a strategic geographical position and rapid agricultural development of Vietnam have made this country become an important subject for extensive studies dealing with environmental pollution during the last three decades.

This chapter provides a comprehensive review of the studies dealing with persistent organic substances in Vietnam. Available data of POP contamination in Vietnam were compiled on the basis of various investigations in frame of the Asia-Pacific Mussels Watch Program, the Core University Program supported by Japan Society for the Promotion of Science (JSPS), which were conducted in our laboratory during the last decade. In addition, results from other laboratories were also reviewed to help improve insight into the distribution, transport, and fate, bioaccumulation feature and possible toxic implications for environmental quality and human health. This paper focuses on the organochlorine (OC) insecticides such as 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane (DDTs) and its metabolites

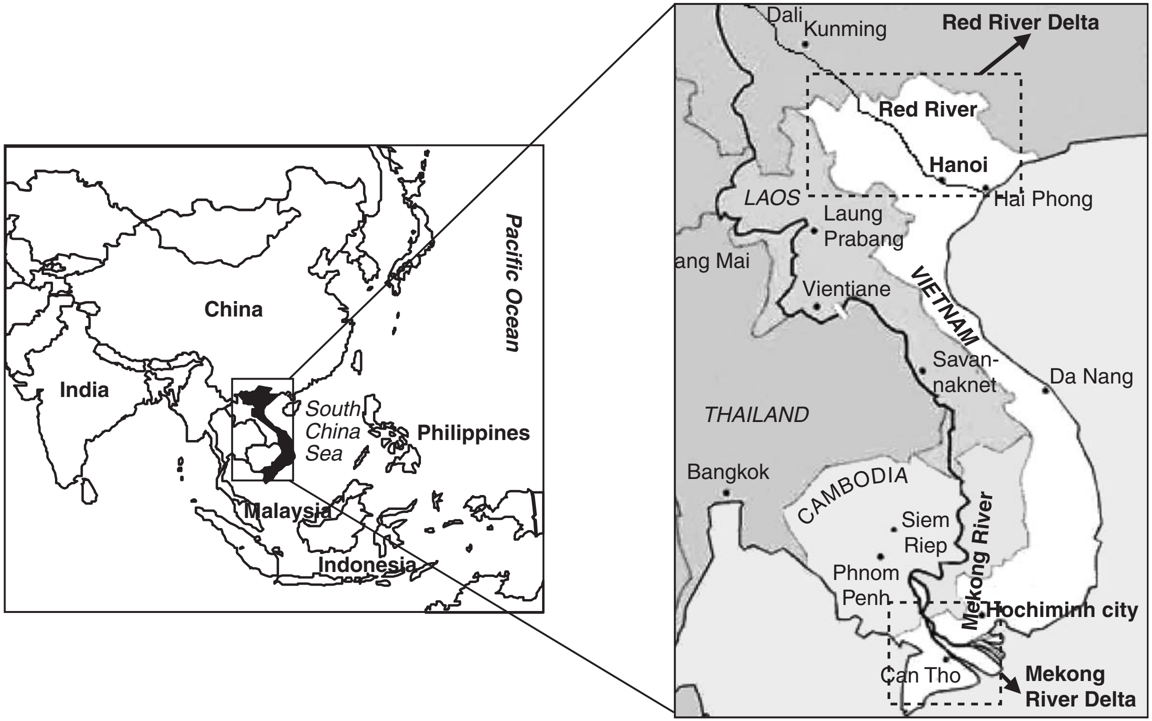

Figure 11.1. Map of Vietnam.

(DDTs), hexachlorocyclohexane isomers (HCHs), chlordane compounds (CHLs) and hexachlorobenzene. Residues levels of industry-derived contaminants such as polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) were also reviewed. Concentrations of these contaminants in different environmental compartments were expressed as unit equivalent to part-per-billion (ppb) level, unless otherwise specified. The cited values of concentrations from various literature sources were rounded to two significant digits for comparison. A number of factors can influence the concentrations in biological samples. Therefore, whenever possible, for biological samples the lipid normalized concentrations were cited for comparison.

11.2. Production and usage of persistent organic pollutants in Vietnam

In general, information on the production and usage of POPs, particularly OC insecticides and PCBs in Vietnam as well as some other developing countries in East Asian region are still limited or obscure. Systematic inventory of toxic man-made chemicals is lacking in these countries due to their limited capacity to conduct comprehensive monitoring surveys. Recently, the United Nations Environment Programs has initiated various monitoring programs for POPs at regional and global levels and the results have been summarized at different workshops. According to the reports, active ingredients for insecticides were not produced in Vietnam. In fact, before 1985, pesticides such as DDT and HCB were imported from former Soviet Union and some socialistic countries with the quantity of ~6500–9000 tons year^{-1} (Sinh et al., 1999). The statistical data showed that the total quality of DDT imported to Vietnam for malaria control from 1957 to 1990 was 24,042 tons. During 1986–1990, approximately 800 tons have been used (Sinh et al., 1999). These amounts are still lower than those in some other countries in region such as Malaysia, Indonesia, and India. DDT usage for malaria control ceased in Vietnam in 1995 and some other chemicals such as pyrethroid compounds have been used as substitutes for DDT (Sinh et al., 1999).

The information about usage of PCBs in Vietnam is still obscure. Statistical data showed that ~27,000–30,000 tons of oils contaminated by PCBs were imported from former USSR, China, and Rumania (Sinh et al., 1999). In addition, electrical equipments like transformer containing PCBs were also imported from Australia until the mid-1980s (Kannan et al., 1995). Other possible source of PCBs in Vietnam could be the weapons which were extensively used during the Indochina War (Thao et al., 1993). Regarding dioxins, the main source in Vietnam in the past was the Agent

Orange and other herbicides sprayed in South Vietnam during the American War. Recently, Stellman and co-workers (Stellman et al., 2003) provided revised estimates on the amounts of herbicides used in Vietnam. During 1961–1971, at least ~45 million liters of Agent Orange were sprayed (Stellman et al., 2003). 2,4,5-T, a constituent of Agent Orange is known to be contaminated with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). However, the combustion-derived sources of dioxins in Vietnam have been unknown. Various kinds of combustion processes may be facilitating the widespread contamination of dioxins and related compounds in Vietnam.

11.3. Widespread contamination

11.3.1. Air, water, sediments, and soils

Comprehensive monitoring surveys have been conducted during the early 1990s to examine the distribution of POPs such as PCBs, DDTs, HCHs, and HCB in air, water, and sediments from estuarine environments from various countries in Asia-Pacific comprising Japan, India, Vietnam, the Philippines, Thailand, Indonesia, Malaysia, the Philippines, and Australia (Iwata et al., 1994). These investigations reported the presence of higher residues of DDTs and HCHs in air and water from coastal and estuarine areas in the developing countries of tropical and subtropical regions (India, Thailand, and Vietnam), rather than developed nations (Japan and Australia). A compilation of available data of POPs in water, soils, and sediment from Vietnam is given in Tables 11.1 and 11.2. The distribution in air, water, and sediments from northern, central, and southern regions of Vietnam showed relatively higher DDT concentrations, indicating a widespread contamination of this insecticide throughout the country. This result suggests extensive use of DDT for agricultural purposes in the past and for malaria control until very recently. Interestingly, in a survey conducted ~10 years later (1998/99) covering an extended area along Red River and Duong River, the two biggest rivers in northern Vietnam, elevated concentrations of DDTs, HCHs, and CHLs were found (Hung & Thiemann, 2002). The levels of DDTs, HCHs, and CHLs in Red and Duong River were apparently higher than those reported in the 1990s surveys. In addition, wastewater collected near to areas having extensive human activities areas such as canals of Tu Liem district, suburb Hanoi (northern Vietnam) and Thi Nghe River, Hochiminh City (southern Vietnam) contained elevated concentrations of DDTs (Table 11.1). It is interesting to note that the levels examined in a recent survey (in suburb Hanoi; Hung &

Table 11.1. Concentrations ($ng\,L^{-1}$) of persistent organochlorines in water from Vietnam

Location	Sample	Year	*N*	DDTs	HCHs	CHLs	PCBs	Reference	Remark
Red River, Hanoi	River water	1990	1	0.68	3.2	0.045	0.84	Iwata et al. (1994)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p′*-DDT; HCHs: sum of α-, β-, and γ-HCH; CHLs: sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane; PCBs: quantified by an equivalent mixture of Kanechlor preparations (KC-300, KC-400, KC-500, and KC-600)
Phu Loc Lake, Hue	Lake water	1990	1	0.29	18	0.21	1.2	Iwata et al. (1994)	
Huong River, Hue	River water	1990	1	1.1	1.9	0.07	1.6	Iwata et al. (1994)	
Nha Be River, Hochiminh City	Estuarine water	1990	1	4.7	31	0.55	2.7	Iwata et al. (1994)	
Gua Canal, Cu Chi	River water	1990	1	0.6	9.5	0.16	1.9	Iwata et al. (1994)	
Long Tau River, Hochiminh City	Estuarine water	1990	1	0.55	5.2	0.13	0.57	Iwata et al. (1994)	
Thi Nghe Canal, Hochiminh City	Estuarine water	1990	1	25	19	1	8	Iwata et al. (1994)	
Red River and Duong River, northern Vietnam	River water	1998/1999						Hung and Thiemann (2002)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, *p,p′*-DDT, *o,p′*-DDE, *o,p′*-DDD, and *o,p′*-DDT; HCHs: sum of α-, β-, γ-, and δ-HCH; CHLs: sum of heptachlor and heptachlorepoxide
Dry season			18	44 (0.55–320)[a]	17 (1.6–83)	21 (0.81–110)	–		
Rainy season			18	56 (8.4–230)	29 (3.1–97)	27 (1.6–130)	–		
Lakes in Hanoi: West Lake, Thuyen Quang Lake	Lake water	1998/1999						Hung and Thiemann (2002)	
Bay Mau Lake and Ba Mau Lake									
Dry season			4	2.1 (0.21–3.6)	0.69 (0.26–2.16)	2.9 (1.1–4.8)	–		
Rainy season			4	5.1 (0.65–15)	32 (0.69–120)	13 (2–51)	–		
Irrigation canal, Tu Liem, suburb Hanoi	River water	1998/1999						Hung and Thiemann (2002)	
Dry season			6	59 (8.2–130)	7.2 (1.6–18)	6.9 (6.0–7.5)	–		
Rainy season			6	50 (11–110)	17 (5.5–26)	15 (1.2–25)	–		
Wells, Gia Lam, suburb Hanoi	Groundwater	1998–1999						Hung and Thiemann (2002)	
Dry season			2	0.17 (0.11–0.23)	0.21 (0.19–0.22)	0.17	–		
Rainy season			2	0.09	0.04	<0.5	–		

[a]Mean (range).

Table 11.2. Concentrations (ng g^{-1} dry wt) of persistent organochlorines in sediments and soils from Vietnam

Location	Sample/sampling site characteristic	Year	*N*	DDTs	HCHs	CHLs	PCBs	Reference	Remark
Phu Da, Hue	Sediment, paddy field	1990	1	0.52	0.43	0.072	0.65	Iwata et al. (1994)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p′*-DDT; HCHs: sum of α-, β-, and γ-HCH; CHLs: sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane; PCBs: quantified by an equivalent mixture of Kanechlor preparations (KC-300, KC-400, KC-500, and KC-600)
A Luoi, Binh Tri Thien	Sediment, municipal sewage	1990	1	68	2.4	0.79	0.18	Iwata et al. (1994)	
Long Giang Canal, Duyen Hai	Sediment, paddy field	1990	1	8	1.1	0.42	3.7	Iwata et al. (1994)	
Lo Giang River, Duyen Hai	Sediment, paddy field	1990	1	1	0.45	0.15	2.2	Iwata et al. (1994)	
Don Canal, Duyen Hai	Sediment, paddy field	1990	1	3.3	0.94	0.21	2.1	Iwata et al. (1994)	
La Canal, Duyen Hai	Sediment, paddy field	1990	1	10	2.3	0.58	9.7	Iwata et al. (1994)	
Ben Nghe Canal, Hochiminh City	Sediment, municipal sewage	1990	1	120	5.2	8.8	140	Iwata et al. (1994)	
Tan Binh, Tay Ninh	Sediment, paddy field	1990	1	7.8	0.7	0.31	–	Iwata et al. (1994)	
Gua Canal, Cu Chi	Sediment, paddy field	1990	1	0.37	0.63	0.24	0.22	Iwata et al. (1994)	
Song Long Tau, Duyen Hai, Hochiminh City	Sediment, paddy field	1990	6	17 (2.1–47)	0.82 (0.5–1.3)	0.26 (0.14–0.46)	6.2 (2.3–8.9)	Iwata et al. (1994)	
Thi Nghe Canal, Hochiminh City	Sediment, municipal sewage	1990	3	530 (360–790)	8.5 (6.0–12)	20 (19–20)	570 (440–630)	Iwata et al. (1994)	
Thinh Liet, Thanh Tri, Hanoi	Soil, paddy field	1990	1	330	18	–	39	Thao et al. (1993)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, *p,p′*-DDT, and *o,p′*-DDT; HCHs: sum of α-, β-, γ-, and δ-HCH; CHLs: sum of cis-chlordane, trans-chlordane, *cis*-nonachlor, *trans*-nonachlor and oxychlordane; PCBs: quantified by an equivalent mixture of Kanechlor preparations (KC-300, KC-400, KC-500, and KC-600)
Vinh Quynh, Thanh Tri, Hanoi	Soil, paddy field	1990	2	76 (31–120)	30 (4–55)	–	11 (5.5–17)	Thao et al. (1993)	
Yen Duyen, Thanh Tri, Hanoi	Soil, paddy field	1990	2	47 (19–74)	1.8 (1.3–2.3)	–	21 (13–28)	Thao et al. (1993)	
Phu Da, Binh Tri Thien	Soil, paddy field	1990	1	38	2.8	–	8.6	Thao et al. (1993)	
Hong Ha, A luoi, Binh Tri Thien	Soil, paddy field	1990	1	23	4.7	–	5.2	Thao et al. (1993)	
Ta Bat, Aluoi, Binh Tri Thien	Soil, paddy field	1990	1	11	1.4	–	2.6	Thao et al. (1993)	
Son Thuy, Aluoi, Binh Tri Thien	Soil, paddy field	1990	1	1300	5.7	–	12	Thao et al. (1993)	
Hong Kim, Aluoi, Binh Tri Thien	Soil, paddy field	1990	1	9.7	0.31	–	0.61	Thao et al. (1993)	
An Hoa, Hue	Soil, paddy field	1990	1	69	5.3	–	5	Thao et al. (1993)	

Table 11.2. (*Continued*)

Location	Sample/sampling site characteristic	Year	*N*	DDTs	HCHs	CHLs	PCBs	Reference	Remark
Phu Loc, Hue	Soil, upland	1990	4	1.9 (0.73–4.4)	0.15 (0.09–0.21)	–	2.1 (1.4–4.0)	Thao et al. (1993)	
Binh Khanh, Duyen Hai, Hochiminh City	Soil, paddy field	1990	2	27 (24–30)	1.5 (1.4–1.5)	–	3.9 (1.6–6.1)	Thao et al. (1993)	
Tan Thuan, Nha Be, Hochiminh City	Soil, paddy field	1990	1	64	4	–	12	Thao et al. (1993)	
My Hung, Cu Chi	Soil, paddy field	1990	1	7.9	0.23	–	1.5	Thao et al. (1993)	
Ba Diep, Hooc Mon	Soil, upland	1990	1	280	0.79	–	130	Thao et al. (1993)	
An Phu, Cu Chi	Soil, upland	1990	3	14 (1.9–37)	2.3 (1.9–2.5)	–	3.7 (3.0–4.2)	Thao et al. (1993)	
Tan Binh, Tan Bien, Tay Ninh	Soil, paddy field	1990	1	5.5	0.15	–	1.6	Thao et al. (1993)	
Thanh Phu, Tan Bien, Tay Ninh	Soil, paddy field	1990	1	350	3.4	–	320	Thao et al. (1993)	
Duong Minh Chau, Tay Ninh	Soil, paddy field	1991	1	1.9	2	–	2.3	Thao et al. (1993)	
Duong Minh Chau, Tay Ninh	Soil, green bean field	1991	1	2.4	0.57	–	1.8	Thao et al. (1993)	
Tan Bien, Tay Ninh	Soil, paddy field	1991	1	6.6	0.78	–	2.3	Thao et al. (1993)	
Hoa Thanh, Tay Ninh	Soil, sugarcane and peanut	1991	1	5.1	1.3	–	1.6	Thao et al. (1993)	
Tan Chau, Tay Ninh	Soil, rubber plantation	1991	1	1.6	1.4	–	1	Thao et al. (1993)	
Tan Chau, Tay Ninh	Soil, sugarcane	1991	1	290	0.27	–	0.45	Thao et al. (1993)	
Tan Chau, Tay Ninh	Soil, harvested crop	1991	5	88 (1.0–270)	0.92 (0.09–2.3)	–	34 (0.95–150)	Thao et al. (1993)	
Tan Bien, Tay Ninh	Soil, paddy field	1991	1	5.7	0.42	–	1	Thao et al. (1993)	
Go Dau, Tay Ninh	Soil, harvested crop	1991	1	130	0.46	–	32	Thao et al. (1993)	
Trang Bang, Tay Ninh	Soil, harvested crop	1991	1	150	0.47	–	38	Thao et al. (1993)	
Duong Minh Chau, Tayninh	Non-cultivated soil	1991	1	1.5	0.8	–	5	Thao et al. (1993)	
Tan Bien, Tay Ninh	Non-cultivated soil,	1991	1	13	1.8	–	92	Thao et al. (1993)	
Tan Chau, Tay Ninh	Non-cultivated soil, US bombed site	1991	1	0.46	0.95	–	25	Thao et al. (1993)	

Tan Bien, Tay Ninh	Non-cultivated soil	1991	6	11 (0.25–38)	0.71 (0.09–1.9)	–	4.8 (0.23–13)	Thao et al. (1993)	
Tan Uyen, southern Vietnam	Non-cultivated soil	1991	2	14 (2.0–26)	1.3 (0.44–2.1)	–	8.0 (3.1–13)	Thao et al. (1993)	
Saigon River, Hochiminh City	River sediment	Q	11	80 (1.8–250)	–	–	220	Phuong et al. (1998)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p′*-DDT; PCBs: sum of 6 congeners
				DS/RS[a]	DS/RS		DS/RS		
Hanoi	Sediment, irrigation canal, northwest Hanoi	1995/1996	1	6.9/13	0.14/0.07	–	4.1/0.98	Nhan et al. (1998)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p’*-DDT; PCBs: quantified by Arochlor 1260; HCHs: γ-HCH only
Hanoi	Sediment, paddy field, southwest Hanoi	1995/1996	1	7.5/14	0.41/0.16	–	6.0/1.3	Nhan et al. (1998)	
Ba Lat Estuary, Red River, northern Vietnam	Sediment	1995/1996	1	7.1/3	0.5/0.05	–	1.1/0.7	Nhan et al. (1998)	
Cua Lan Estuary, Thai Binh coast lines, northern Vietnam	Sediment, intertidal mudflat areas	1995/1996	1	5.8/4.9	0.48/0.025	–	0.87/0.41	Nhan et al. (1998)	
Tra Ly Estuary, Thai Binh coast lines, northern Vietnam	Sediment, intertidal mudflat areas	1995/1996	1	7.3/5.1	0.62/0.13	–	0.36/0.32	Nhan et al. (1998)	
Diem Dien Estuary, Thai Binh coast lines, northern Vietnam	Sediment, intertidal mudflat areas	1995/1996	1	6.2/4.6	0.36/0.11	–	0.23/0.11	Nhan et al. (1998)	
Tra Co beach, Mong Cai, northern coast of Vietnam	Marine sediment, intertidal mudflat areas	1997	1 (pooled)	10	34	–	22	Nhan et al. (1999)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p′*-DDT
Mong Duong, northern coast of Vietnam	Marine sediment, intertidal mudflat areas	1997	1 (pooled)	8.1	4.1	–	0.51	Nhan et al. (1999)	HCHs: sum of α-, β-, and γ-HCH
Ha Long, northern coast of Vietnam	Marine sediment, intertidal mudflat areas	1997	1 (pooled)	7.2	1.8	–	11	Nhan et al. (1999)	PCBs: sum of 13 congeners
Hai Phong, northern coast of Vietnam	Marine sediment, intertidal mudflat areas	1997	1 (pooled)	6.7	1.7	–	18	Nhan et al. (1999)	

Table 11.2. (Continued)

Location	Sample/sampling site characteristic	Year	*N*	DDTs	HCHs	CHLs	PCBs	Reference	Remark
Ba Lat estuary, northern coast of Vietnam	Marine sediment, intertidal mudflat areas	1997	1 (pooled)	6.3	1.2	–	0.33	Nhan et al. (1999)	
Cau Dien, Nhue River, suburb Hanoi	Sediment, canal, densely populated industrial area	1997	2	43 (15–71)	0.34 (0.09–0.58)	–	1.7 (0.97–2.51)	Nhan et al. (2001)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, *p,p′*-DDT, *o,p′*-DDE, *o,p′*-DDD, *o,p′*-DDT, and DDMU; PCBs: sum 13 congeners; HCHs: sum of α-, β-, and γ-HCH; CHLs: sum *cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor
Nhue River, suburb Hanoi	Sediment, canal, rural area	1997	1	8.3	0.78	–	0.74	Nhan et al. (2001)	
Nhue River, suburb Hanoi	Sediment, canal	1997	1	21	0.32	–	18	Nhan et al. (2001)	
Hanoi downtown	Sediment, canal, densely populated industrial area	1997	1	13	0.44	–	5.3	Nhan et al. (2001)	
ToLich River, suburb Hanoi	Sediment, canal, densely populated industrial area	1997	2	59 (36–81)	2.0 (0.85–3.12)	–	29 (24–34)	Nhan et al. (2001)	
Thuong Tin, suburb Hanoi	Sediment, canal, southern Hanoi city	1997	2	37 (24–50)	1.3 (0.59–1.98)	–	20 (16–24)	Nhan et al. (2001)	
Thuong Tin, suburb Hanoi	Sediment, canal, rural area, southern Hanoi city	1997	1	7.4	0.65	–	3.1	Nhan et al. (2001)	
Gia Lam, suburb Hanoi	Sediment, canal, rural area, eastern Hanoi city	1997	1	17	0.46	–	1.9	Nhan et al. (2001)	
Dong Anh, suburb Hanoi	Sediment, canal, rural area, Northern Hanoi city	1997	1	23	0.07	–	1.8	Nhan et al. (2001)	
Ha Long Bay, northern Vietnam	Estuary sediment	1998	–	28	6.1	–	37	Viet et al. (2000)	
Viet Tri, northern Vietnam	Industrial areas	1998	–	5.2	0.68	–	2.3	Viet et al. (2000)	

Hanoi	Soils, municipal dumping sites	1999–2001	7	21 (2.2–58)[b]	0.75 (0.3–2.2)	0.3 (0.08–1.5)	14 (2.2–20)	Minh et al. (2004)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p′*-DDT; HCHs: sum of α-, β-, and γ-HCH; CHLs: sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane; PCBs: quantified by an equivalent mixture of Kanechlor preparations (KC-300, KC-400, KC-500, and KC-600)
Hanoi	Soils, reference areas relative to the Municipal dumping sites	1999–2001	1	6	0.35	<0.03	6.9	Minh et al. (2004)	
Hochiminh City	Soils, municipal dumping sites	1999–2001	7	23 (0.2–93)	0.56 (<0.01–0.9)	1.2 (0.12–2.5)	22 (0.82–40)	Minh et al. (2004)	
Hochiminh City	Soils, reference areas relative to the Municipal dumping sites	1999–2001	3	5.5	0.54	0.2	7.5	Minh et al. (2004)	
Canal, Can Tho, Mekong River, southern Vietnam	Sediment, canals in Cantho city	2003–2004	4	2.8 (1.8–4.3)	0.04 (<0.02–0.11)	0.2) (0.12–0.35	1.8 (0.12–3.7)	Iwata et al. (2004)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p′*-DDT; HCHs: sum of α-, β-, and γ-HCH; CHLs: sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, and *trans*-nonachlor; PCBs: quantified by an equivalent mixture of Kanechlor preparations (KC-300, KC-400, KC-500, and KC-600)
Hau River, Mekong River delta, southern Vietnam	Sediment, river	2003–2004	7	0.96 (0.043–1.9)	<0.02–0.044	0.06 (0.025–0.13)	0.21 (0.12–0.54)	Iwata et al. (2004)	
Canals, Hochiminh city, Saigon River, southern Vietnam	Sediment, canals, densely populated areas	2004	5	37	–	–	81	Minh et al. (2005)	
Saigon River, Hochiminh City	Sediment, river	2004	5	6.9	–	–	8.5	Minh et al. (2005)	
Saigon River, downstream and coastal areas	Sediment, downstream and coastal areas	2004	9	1.2	–	–	0.92	Minh et al. (2005)	

[a]Dry season/rainy season.
[b]Mean (range).

Thiemann, 2002) were even higher than those reported a decade ago (Iwata et al., 1994). Although backgrounds of analytical methods and sampling locations are different among those studies, these observations suggest that the use of DDT for malaria control were relatively extensive until very recently in both northern and southern Vietnam.

Geographical distribution of OCs in sediments from Vietnam showed little variability compared to air and water (Fig. 11.2 and Table 11.2). Consistent results were also observed when considering distribution in Asia-Pacific region (Iwata et al., 1994). A recent survey also indicate rather uniform distribution of DDTs in sediments along the coasts of northern Vietnam, from the sites near the border of China downward to the Red River estuary (Table 11.2, Nhan et al., 1998, 1999). Shorter residence time in water phase and rapid volatilization POPs from sediments of due to the high temperate in tropical region could be reasons for this uniform distribution (Iwata et al., 1994; Tanabe, 2000). However, an interesting result was observed for HCHs, showing relatively higher concentrations in Mong Cai, a site near the border of China than other locations towards the southern areas (Fig. 11.2 and Table 11.2). China has been known as one of the top global HCH users (Li, 1999), and this may be possible reason for such high concentrations in Mong Cai.

As for soils samples, an extensive survey carried out on various soils in northern and southern Vietnam indicated higher concentrations of DDTs in soils from paddy fields than those in soils from upland areas (Table 11.2, Thao et al., 1993). This clearly reflects the status of DDT use as insecticide in the past. Elevated PCB levels were recorded in some specific sites in Tay Ninh, southern Vietnam, where the former US Army Base was located (Thao et al., 1993). A recent survey in soils from the open dumping sites for municipal wastes in Hanoi and Hochiminh City, the two largest metropolitan cities in Vietnam revealed that residue concentrations of DDTs and PCBs in soils collected from dumping sites were much higher than those in paddy field soils collected far from the dumping sites (Fig. 11.3, Minh et al., 2006). PCBs and OC insecticides were likely to be originated from continuous loading of municipal wastes containing residues of these compounds. The open dumping sites therefore, may act as sources of PCBs and OC insecticides.

To understand the magnitude of contamination of POPs in Vietnam, residue concentrations in air, water, and sediments were compared with those in other countries in Asia-Pacific (Fig. 11.4). Higher contamination of DDTs in Vietnamese coastal environments was recorded, again indicating the extensive use of this insecticide in Vietnam. Interestingly, elevated PCB residues were also observed in water and sediments from Mekong River estuary, southern Vietnam; and the levels were comparable to those

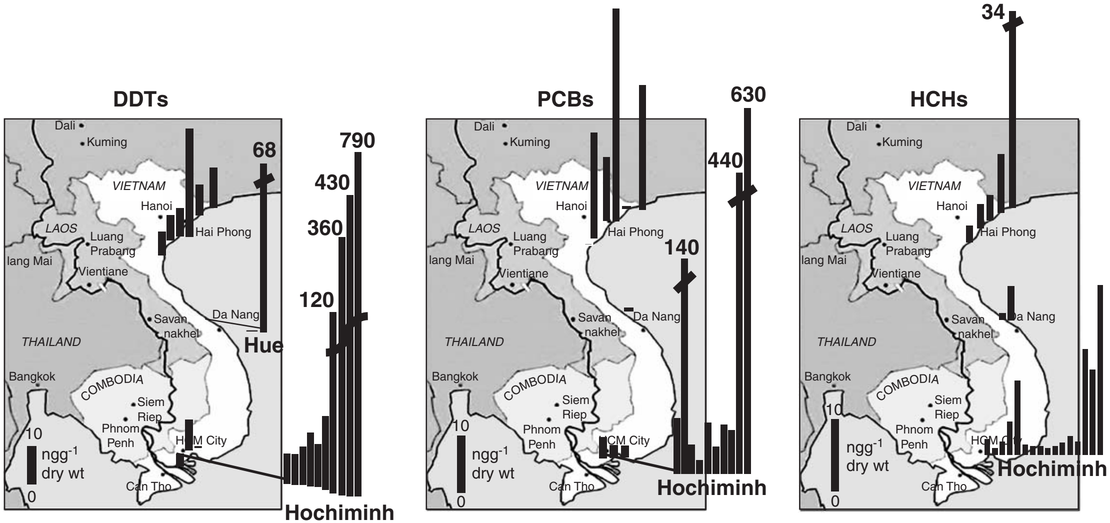

Figure 11.2. Distribution of persistent organochlorines in sediment from various locations in Vietnam.

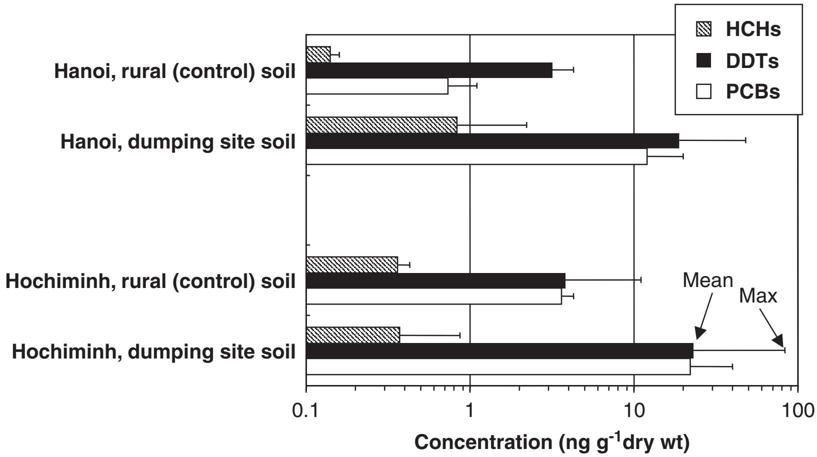

Figure 11.3. Residue concentrations of persistent organochlorines in soils from open dumping sites and rural areas (control sites) in Hanoi and Hochiminh City, the two biggest cities in Vietnam.

reported in some locations in India, Japan, and Australia (Fig. 11.4). High PCB contamination in Vietnam observed during our survey in early 1990s could be derived from both the electrical equipments imported from industrialized nations like former Soviet Union and Australia and the leakages from army weapons extensively used in Indochina War during 1961–1971 (Thao et al., 1993).

Available data on the worldwide comparison for PCBs and OC insecticides levels in open dumpsites are rather scarce. A comparison of PCBs and DDTs residue levels in dumping sites from Vietnam with those in soils from other countries were given in Fig. 11.5. In general, the levels of PCBs in the dumping sites were higher than those in background soils from various countries including industrialized nations such as United States, Russia, Italy, etc, where high contamination of PCBs are commonly reported (Meijer et al., 2003; Minh et al., 2004). Our survey indicated that DDT levels in the dumping site soils were comparable to those found in agriculture soils collected in early 1990s from various countries such as Russia (Iwata et al., 1995), Ireland (McGrath, 1995), and Slovak Republic (Marta et al., 1997), and higher than most of the urban soils recently collected in many countries like Egypt (Ahmed et al., 1998), Korea (Kim & Smith, 2001), and the reference sites in this study (Fig. 11.5). This observation highlights the role of the open dumpsites in Asian developing countries including Vietnam as significant pollution sources of PCBs and DDTs.

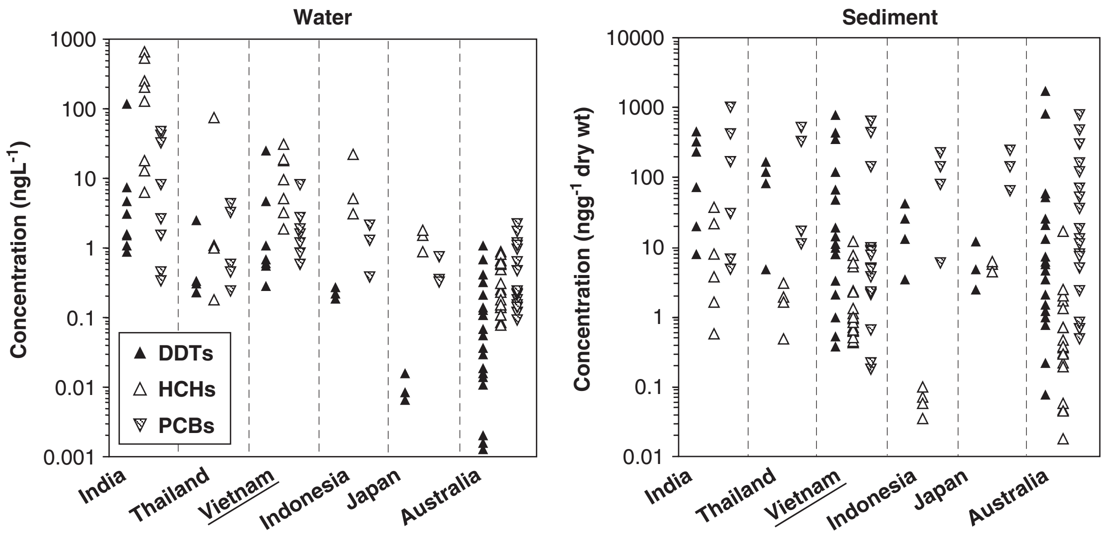

Figure 11.4. Comparison of persistent organochlorine residues in surface water and sediment from different countries in Asia-Pacific.

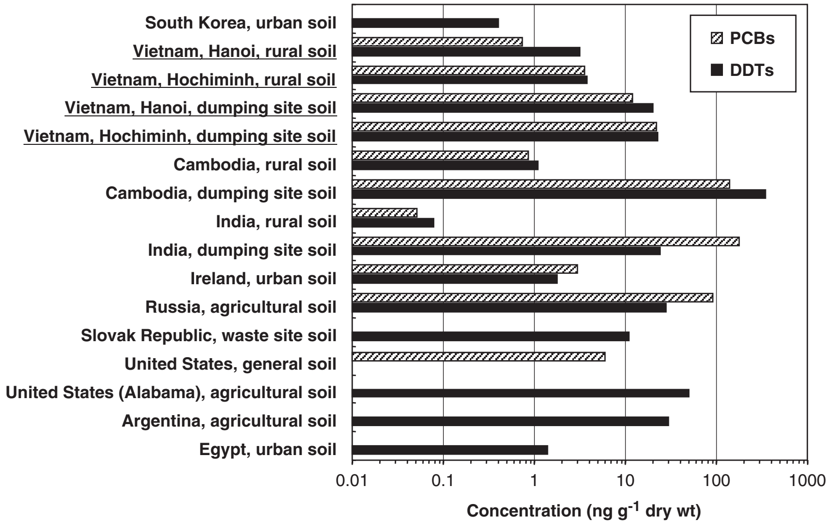

Figure 11.5. Comparison of organochlorine residue levels in soils from different countries in the world.

11.3.2. Biological samples (fish, bivalves, and birds)

Extensive studies on OC contamination in fish and mussels from Asia-Pacific countries including Vietnam were carried out by Kannan et al. (1995) and Monirith et al. (2003). Similar to sediment samples, a relatively uniform distribution of OCs was observed in fish in various countries in the Asia-Pacific region. In Vietnam, residues levels of DDTs were relatively high in both surveys in 1990 and 1997 (Table 11.3). Mussels collected from coastal areas in north and middle of Vietnam contained elevated DDT concentrations (Table 11.3, Monirith et al., 2003). Subsequent surveys conducted by Nhan et al. (1998, 1999) examined OC distribution in clams from different sites along the northern coasts, and results showed a very similar distribution to sediment samples. In particular, residue concentrations of DDTs, HCHs, and PCBs were relatively high in the sites near to the border of China and a decreasing trend was noticed toward southern coastlines (Table 11.3). At the two estuary areas: Hai Phong harbor with extensive human and industrial activities, and Thai Binh province, one of the highest rice production areas in Vietnam, higher concentrations were again observed. In general, the feature of distribution and magnitude of contamination in sediment and biota (fish and bivalves) was very similar in both local and regional scale, which can be characterized by the enhanced

Table 11.3. Concentrations (ng g^{-1} lipid wt) of persistent organochlorines in biological samples from Vietnam

Location	Sample/sampling site description	Year	*N*	Lipid content (%)	DDTs	HCHs	CHLs	PCBs	Reference	Remark
Hanoi	Fish	1990	7	1.9	1900 (680–4000)[a]	120 (47–210)	7.9 (<0.5–17)	580 (270–950)	Kannan et al. (1995)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD and *p,p′*-DDT;
Phu Da, Hue	Fish	1990	6	1.9	1100 (210–2700)	48 (32–74)	8.9 (<0.5–12)	630 (160–1300)	Kannan et al. (1995)	HCHs: sum of α-, β-, and γ-HCH; CHLs: sum of *cis*-
Hochiminh City	Fish	1990	6	1.9	1100 (89–4100)	110 (33–200)	3.2 (<0.5–18)	950 (190–3100)	Kannan et al. (1995)	chlordane, *trans*-chlordane, *cis*-nonanchor, *trans*-
Con Lu Island, Red River Estuary, Northern Vietnam	Fish (*Mugil sp. and Chlorophthalmus sp.*)	1997	10	3.2	4200 (330–8500)	350 (27–210)	110 (29–210)	110 (81–140)	Minh et al. (2002)	nonanchor, and oxychlordane; PCBs: quantified by an equivalent mixture of
Con Lu Island, Red River Estuary	Shrimp	1997	20 (pooled as 1 sample)	2.8	160	150	3.9	100	Minh et al. (2002)	Kanechlor preparations (KC-300, KC-400, KC-500, and KC-600)
Cat Ba Island, Cai Hai Province	Green mussel, floating habitat	1997	38 (pooled as 1 sample)	1.1	530	3.6	14	86	Monirith et al. (2003)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD
Cat Hai Province	Green mussel, floating habitat	1997	34 (pooled as 1 sample)	0.9	300	12	12	20	Monirith et al. (2003)	and *p,p′*-DDT; HCHs: sum of α-,
Cat Hai Province	Green mussel, floating habitat	1997	8 (pooled as 1 sample)	0.7	2500	5.7	24	450	Monirith et al. (2003)	β-, and γ-HCH; CHLs: sum of *cis*-
Cat Hai Province	Green mussel, floating habitat	1997	12 (pooled as 1 sample)	2	420	3	5	110	Monirith et al. (2003)	chlordane, *trans*-chlordane, *cis*-
Lach Truong, Thanh Hoa	Green mussel, aquaculture	1997	33 (pooled as 1 sample)	1.2	610	3.3	13	65	Monirith et al. (2003)	nonanchor, *trans*-nonanchor, and
Ron River Estuary, Ky Anh	Green mussel, fishing village	1997	50 (pooled as 1 sample)	0.6	470	5.5	20	190	Monirith et al. (2003)	oxychlordane; PCBs: quantified by an equivalent
Lang Co, Hue	Green mussel	1997	143 (pooled as 1 sample)	0.9	34000	10	–	380		mixture of

Table 11.3. (*Continued*)

Location	Sample/sampling site description	Year	*N*	Lipid content (%)	DDTs	HCHs	CHLs	PCBs	Reference	Remark
Thi Nai, Binh Dinh	Green mussel, urban, shipping traffic, aquaculture	1997	54 (pooled as 1 sample)	1.1	220	6.3	36	26	Monirith et al. (2003)	Kanechlor preparations (KC-300, KC-400, KC-500, and KC-600)
Phan Ri Estuary, Phan Ri	Green mussel, urban, fishing village	1997	30 (pooled as 1 sample)	1.1	240	2.9	11	80	Monirith et al. (2003)	
Hanoi	Clam (*Hyriopsis*), irrigation canal	1996	15 (pooled as 1 sample)	–	7400	97	–	480	Nhan et al. (1998)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p′*-DDT; HCHs: sum of α-, β-, and γ-HCH; PCBs: sum 13 congeners
Hanoi	Carp (*Cyprinus carpio*), rice field	1996	3 (pooled as 1 sample)	–	22000	370	–	2600	Nhan et al. (1998)	
Balat Estuary, Thai Binh	Shrimp (*Metapenaeus*)	1996	35 (pooled as 1 sample)	–	1000	390	–	490	Nhan et al. (1998)	
Balat Estuary, Thai Binh	Clam (*Meretrix meretrix*)	1996	43 (pooled as 1 sample)	–	830	57	–	220	Nhan et al. (1998)	
Diem Dien Estuary, Thaibinh	Clam (*Mactra quadrangularis*), intertidal mudflat coastal area	1996	13 (pooled as 1 sample)	–	1000	30	–	200	Nhan et al. (1998)	
Tra Co, Mong Cai, northern coast of Vietnam	Clam (*Meretrix meretrix*), intertidal mudflat areas	1997	1 pooled sample	–	1200	2400	–	900	Nhan et al. (1999)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p′*-DDT; HCHs: sum of α-, β-, and γ-HCH; PCBs: sum 13 congeners
Mong Duong, northern coast of Vietnam	Clam (*Meretrix meretrix*), intertidal mudflat areas	1997	1 pooled sample	–	590	400	–	480	Nhan et al. (1999)	
Ha Long, Quang Ninh, northern coast of Vietnam	Clam (*Meretrix meretrix*), intertidal mudflat areas	1997	1 pooled sample	–	660	93	–	470	Nhan et al. (1999)	
Hai Phong, northern coast of Vietnam	Clam (*Meretrix meretrix*), intertidal mudflat areas	1997	1 pooled sample	–	850	77	–	580	Nhan et al. (1999)	

Ba Lat Estuary, Thai Binh, northern coast of Vietnam	Clam (*Meretrix meretrix*), intertidal mudflat areas	1997	1 pooled sample	–	920	71	–	250	Nhan et al. (1999)	
Cau Dien, Nhue River, Hanoi	Freshwater snails (*Angulyagra sp.*), densely populated industrial area	1997	1 pooled sample	–	23000	29	14	720	Nhan et al. (2001)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, *p,p′*-DDT, *o,p′*-DDE, *o,p′*-DDD, *o,p′*-DDT, and DDMU; PCBs: sum 13 congeners; HCHs: sum of α-, β-, and γ-HCH; CHLs: sum *cis*-chlordane, *trans*-chlordane, *trans*-nonachlor, and heptachlor
Cau Dien, Nhue River, Hanoi	Freshwater snails (*Angulyagra sp.*), densely populated industrial area, transformer production	1997	1 pooled sample	–	45000	21	27	2200	Nhan et al. (2001)	
Nhue River, suburb Hanoi	Freshwater snails (*Angulyagra sp.*), rural area	1997	1 pooled sample	–	320	9.8	–	330	Nhan et al. (2001)	
Hanoi downtown	Freshwater snails (*Angulyagra sp.*), densely populated industrial area	1997	1 pooled sample	–	2700	13	1.8	1000	Nhan et al. (2001)	
To Lich River, suburb Hanoi	Freshwater snails (*Angulyagra sp.*), densely populated industrial area	1997	1 pooled sample	–	5300	19	–	3000	Nhan et al. (2001)	
Red River, suburb Hanoi	Freshwater snails (*Angulyagra sp.*), rural area	1997	1 pooled sample	–	910	8.2	2.2	480	Nhan et al. (2001)	
Gia lam, suburb Hanoi	Freshwater snails (*Angulyagra sp.*), rural area	1997	1 pooled sample	–	1000	15	–	340	Nhan et al. (2001)	
Dong Anh, suburb Hanoi	Freshwater snails (*Angulyagra sp.*), rural area	1997	1 pooled sample	–	640	11	1	280	Nhan et al. (2001)	

Table 11.3. (*Continued*)

Location	Sample/sampling site description	Year	*N*	Lipid content (%)	DDTs	HCHs	CHLs	PCBs	Reference	Remark
Mekong River, Can Tho	Catfish (*Pangasianodon hypophthalmus*), common aquaculture	2004	20	3.8 (0.6–7.2)	59 (7.9–150)	0.47 (<0.03–1.5)	0.62 (<0.01–2.6)	7.2 (0.91–27)	Minh et al. (2005)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p′*-DDT; HCHs: sum of α-, β-, and γ-HCH; CHLs: sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane; PCBs: quantified by an equivalent mixture of Kanechlor preparations (KC-300, KC-500, and KC-600)
Can Tho	Catfish (*Clarias sp.*), from a pond near municipal dumping site	2004	5	3.6 (3.2–4.1)	390 (330–700)	2.2 (0.86–5.1)	5.7 (4.2–8.2)	50 (37–77)	Minh et al. (2005)	
Con Lu Island, Red River Estuary, northern Vietnam (250–2400)	Resident birds (including 7 species), wetland wintering grounds	1997	16	1.9–16	6200 (1100–	150 13000)[b]	100 (23–310)	780 (5–550)	Minh et al. (2002)	
Con Lu Island, Red River Estuary, northern Vietnam	Migratory birds (including 17 species), wetland wintering grounds	1997	84	4.1–33	2900 (750–6800)	330 (20–1700)	22 (5.3–130)	530 (82–1600)	Minh et al. (2002)	

[a]Mean (range).

[b]Average concentrations of 7 resident and 17 migratory species.

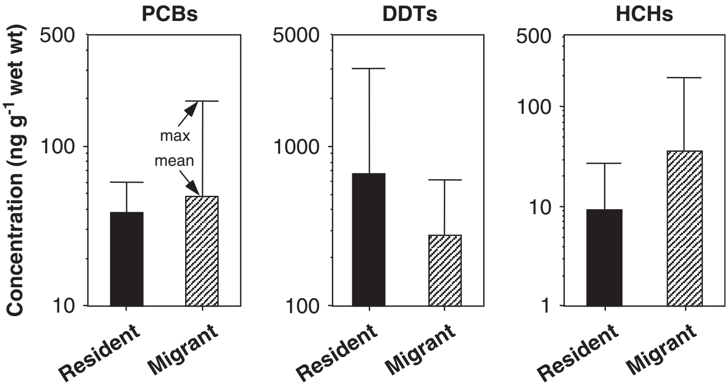

Figure 11.6. Accumulation of persistent organochlorines in birds from Vietnam according to the migratory behavior.

volatilization of semi-volatile organic compounds in high temperature prevailing in tropical ecosystems.

To our knowledge, only few studies have examined OC contamination in higher trophic animals from Vietnam. A survey conducted in 1997 determined OC concentrations in resident and migratory birds from North Vietnam (Minh et al., 2002). Resident birds contained higher concentrations of DDTs than those in migrants (Fig. 11.6). This result indicates recent exposure to DDTs in resident birds from North Vietnam, where elevated DDT contamination is very common as discussed earlier. Interestingly, accumulation of HCHs revealed a contrasting pattern, showing apparently greater concentration in migratory birds (Fig. 11.6). This could be due to accumulation in stopover sites during migration in some polluted areas such as India, southern China, and Japan. The role of these countries as potential sources of HCH accumulation in wintering migratory birds breeding in Lake Baikal, Russia has been also suggested in a recent study (Kunisue et al., 2002). As for PCBs, residue concentrations were similar in residents and migratory species and the levels were relatively low, indicating less prominent sources of PCBs in North Vietnam in recent years. Thus, accumulation pattern of OCs in birds from North Vietnam according to their migratory behavior distinctively reflects the status of contamination of each contaminant. This phenomenon also suggests the suitability of using birds as bioindicators for monitoring POPs in the global environment.

International comparison of OC residues in fish, mussels, and birds from Vietnam indicated relatively higher levels of DDTs in Vietnamese samples (Fig. 11.7). Results of recent surveys in Asia-Pacific Mussel

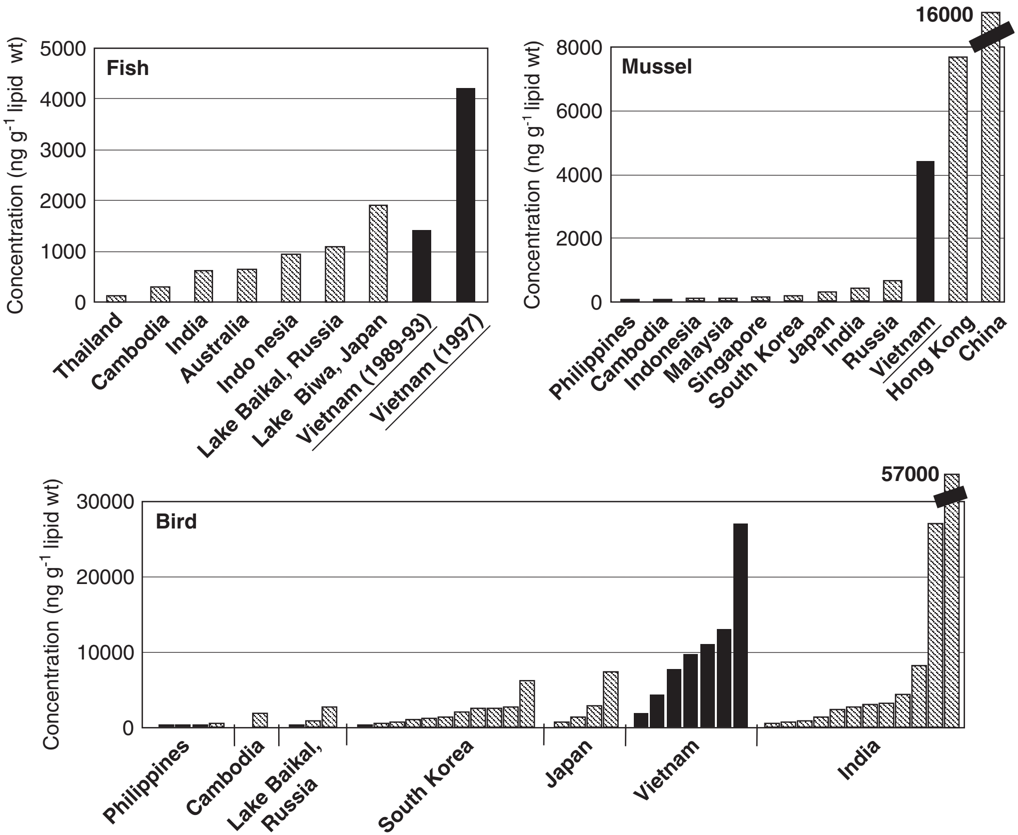

Figure 11.7. Comparison of organochorine residue levels in fish, mussels, and birds in Asia-Pacific countries.

Watch Program showed that DDT levels in Vietnamese mussels were lower than those in mussels from southern China and Hong Kong, but higher than those collected from most of other countries in East Asian region (Fig. 11.7, Monirith et al., 2003). Kannan et al. (1995) reported mean concentration of DDT in fish from Vietnam were higher than India, Thailand, Indonesia, and Australia. Contamination pattern were similar to birds, showing that DDT residue levels in some resident species in Vietnam were among the highest values reported for the Asian countries surveyed (Fig. 11.7, Minh et al., 2002). It is interesting to note that though the recent amounts of DDTs used in Vietnam were lower than those of other countries in the region, the extent of DDT contamination in environmental samples in Vietnam was higher. This observation suggests that the application of DDTs in Vietnam has continued until very recently, resulting in elevated contamination of these compounds in different species occupying low to high trophic levels in food chain.

11.3.3. Human exposure

Available data on human exposure to OC insecticides and PCBs in Vietnamese residents are limited. Preliminary survey by Schecter et al. (1989a) reported very high concentrations of DDTs and HCHs in human breast milk samples from some locations in and around Hochiminh City, southern Vietnam (Table 11.4). DDT levels were higher in both rural and urban areas, ranging from 10,500 to 12,000 ng g^{-1} lipid wt. PCBs levels, however, were relatively low as compared to other countries. A subsequent study conducted in 2000/2001 have provided more extensive data on human exposure and insights into the accumulation kinetics of PCBs and OC insecticides such as DDTs, HCHs, CHLs, HCB, and *tris*(4-chlorophenyl)methane (TCPMe)—a newly detected environmental contaminant which exhibits weak endocrine disrupting properties. Breast milk of 96 nursing women living near the dumping sites of municipal wastes in Hanoi and Hochiminh City, the two biggest metropolitan cities in Vietnam were analyzed for these above contaminants (Table 11.4, Minh et al., 2004). In general, similar degree of exposure to DDTs, CHLs, HCB, and PCBs were observed among samples from Hanoi and Hochiminh City. Interestingly, HCH residues in breast milk of women from Hanoi were significantly greater than those in Hochiminh City, suggesting recent high background levels of HCHs in northern part as compared to southern region. Consistent result was also observed in the survey on sediment and bivalves from various locations along the northern coast of Vietnam, which demonstrated relatively higher residues in sites near the China border (Nhan et al., 1998, 1999). Earlier reports also pointed out similar

Table 11.4. Concentrations of persistent organochlorines in human samples from Vietnam

Locations	Year	Samples/sampling site despcription	Unit	N	DDTs	HCHs	CHLs	HCB	PCBs	Reference	Remark
Me Tri and Tu Liem, Hanoi	2000	Breast milk, primiparas women near municipal dumping sites	ng g^{-1} lipid		2400	69	2.5	4.2	76	Minh et al. (2004)	DDTs: sum of *p,p′*-DDE, *p,p′*-DDD, and *p,p′*-DDT; HCHs:β-HCH only; CHLs: sum of oxychlordane, *trans*-nonachlor, and *cis*-nonanchor; PCBs: quantified by an equivalent mixture of Kanechlor; Preparations (KC-300, KC-400, KC-500, and KC-600)
Me Tri and Tu Liem, Hanoi	2000	Breast milk, multiparas women near municipal dumping sites	ng g^{-1} lipid		1700	46	1.4	3.5	72	Minh et al. (2004)	
Me Tri and Tu Liem, Hanoi	2000	Breast milk, overall near municipal dumping sites	ng g^{-1} lipid	42	2100 (480–6900)[a]	58 (11–160)	2.0 (<0.72–13)	3.9 (0.62–9.5)	74 (26–210)	Minh et al. (2004)	
Vinh Loc and Dong Thanh, Hochiminh City	2001	Breast milk, primiparas women near municipal dumping sites	ng g^{-1} lipid		3020	14	7.8	2.8	88	Minh et al. (2004)	
Vinh Loc and Dong Thanh, Hochiminh City	2001	Breast milk, multiparas women near municipal dumping sites	ng g^{-1} lipid		1500	13	6	2.1	70	Minh et al. (2004)	
Vinh Loc and Dong Thanh, Hochiminh City	2001	Breast milk, overall near municipal dumping sites	ng g^{-1} lipid	44	2300 (440–17000)	14 (4.1–35)	6.9 (1.3–26)	2.5 (1.3–10)	79 (29–200)	Minh et al. (2004)	

Tan Than village, suburb Hochiminh City	1985–1987	Breast milk, rural area	ng g^{-1} lipid	2	10500	25	<2.0	<2.0	49	Schecter et al. (1989a)	DDTs: sum of p,p'-DDE and p,p'-DDT; HCHs: sum of α-, β-, and γ-HCH; CHLs: oxychlordane only; PCBs: sum of CB-138, CB-153, and CB-180
Song Be province, southern Vietnam	1985–1987	Breast milk, rural area	ng g^{-1} lipid	3	12000	37	<2.0	10	28	Schecter et al. (1989a)	
Hochiminh City	1985–1987	Breast milk, urban area	ng g^{-1} lipid	7	11400	250	3	3	84	Schecter et al. (1989a)	
Hanoi, rural area	1994	Serum	ng ml^{-1}	30	12 (1.2–59)	–	–	–	–	Schecter et al. (1997)	DDTs: sum of p,p'-DDE and p,p'-DDT
Hanoi, urban area	1994	Serum	ng ml^{-1}	8	32 (12–68)	–	–	–	–	Schecter et al. (1997)	
Hanoi, breast cancer cases	1994	Serum	ng ml^{-1}	21	16 (1.2–52)	–	–	–	–	Schecter et al. (1997)	
Hanoi, control samples for breast cancer cohort survey	1994	Serum	ng ml^{-1}	21	21 (1.5–88)	–	–	–	–	Schecter et al. (1997)	

[a]Mean (range).

spatial distribution in different kinds of environmental samples, showing higher levels of HCHs in Hanoi compared to Hochiminh City (Thao et al., 1993; Iwata et al., 1994; Kannan et al., 1995). In addition to the influence of the possible transport from China, one of the world leading HCH users, the differences in climate between Hanoi (in the northern part) and Hochiminh City (in the southern part) could be an alternative explanation. The Mekong River delta in the southern Vietnam is characterized by the typical tropical climate with high temperature and heavy rainfall. Rapid volatilization of highly volatile HCH isomers may therefore be enhanced in the environment of southern Vietnam, resulting in lower residues in various environmental and human samples.

Similar to those observed for environmental samples, human exposure to DDTs in Vietnam were very high and among the highest ranks for the developing countries and developed nations (Minh et al., 2004). As discussed earlier, high DDT contamination in Vietnam has been apparent in many environmental samples. This is also the case for humans and this fact raises concern over the possible toxic impacts on human health. This result suggests that Vietnam is a potential source of DDTs in the south Asian region.

11.4. Dioxin contamination

Southern Vietnam has been considered as a well-known region where Agent Orange was extensively sprayed during 1961–1971 in the American War, resulting in severe dioxin contamination in various environmental media and food chain including humans. During the last three decades, Schecter and co-workers have been conducting a number of investigations on the dioxin contamination in southern Vietnam, including sediment, foodstuffs, and particularly, human samples living near the "hot spot" of dioxin contamination (e.g., Schecter et al., 1989a, b, c, 1990, 1995, 2001). In general, the dioxin contamination as a result of Agent Orange can be characterized by the predominant of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), the major contaminants of the herbicide 2,4,5-T, a constituent of Agent Orange. 2,3,7,8-TCDD is one of the most toxic congener and has received wide attention. Researches have shown that this congener can cause adverse health effects in animals (ATSDR, 1998). 2,3,7,8-TCDD was the major component and its concentrations were elevated in foods and human samples including blood, adipose tissues, and breast milk. Recently, Dwernychuk et al. (2002) surveyed soils, sediments, and food items from Aluoi Valley, a "hot spot" of Agent Orange spraying and the former US Army Base sites. The highest concentration of PCDD/Fs in soil were 2200 pg g^{-1} dry wt., which were much higher than those in background levels in many industrialized countries in the world. Of a greater concern, however, are high levels of PCDD/Fs in breast milk, a major dietary intake for breast-fed children. Survey throughout the valley indicates that breast-fed infants of primiparas groups had intake values, 27-fold exceeding the Tolerable Daily Intake proposed by WHO. This fact highlighted a new environmental issue that the first children exposed to high level of contaminants are at higher risk. The breast feeding has been highly recommended by various organizations and scientists due to a number of benefits for children including passing immunological antibody response to the infants, reducing risk of allergic reactions, etc. However, for communities with high exposure to toxic contaminants such as people living near open dumping sites in developing countries, breast feeding has unfortunately become a virtually effective route for the transfer of toxic contaminants to the next generation. Scientific and social efforts are therefore needed to mitigate exposure in order to reduce body burdens of dioxins in both adults and children.

Except for the dioxin problems caused by Agent Orange in southern Vietnam as discussed above, there have been no studies investigating the contamination status, bioaccumulation characteristics, fate and toxic implications of dioxins in a tropical environment in Vietnam until our laboratory reported dioxin contamination in dumping sites for municipal wastes in 2003 (Minh et al., 2003). In recent years, public media have voiced concern regarding the open dumping sites in Asian developing countries where large amount of municipal solid wastes have been dumped. Unfortunately, these open dumping sites are usually located near human habitats; therefore, exposure to various toxic chemicals that originated from dumping sites is of serious concern because of the effects on human health, wildlife and environmental quality. Natural burning for generation of methane gas under anaerobic conditions, combustions by waste pickers scavenging in dumping sites are the favorable factors for the formation of PCDD/Fs in dumping sites. To find an answer for the question of whether open dumping sites are potential source of PCDD/Fs, comprehensive investigations have been conducted to examine residue concentrations of PCDD/Fs in soils and human breast milk from open dumping sites from Philippines, Cambodia, India, and Vietnam (Minh et al., 2003; Kunisue et al., 2004). Concentrations of PCDD/Fs in soils from dumping sites in Hanoi were significantly higher than those in Hochiminh City. Mean and range concentrations in dumping sites from Hanoi were 6100 pg g^{-1} dry wt. (95 pg g^{-1} TEQs), range, 125–50,500 pg g^{-1} dry wt. (0.4–850 pg g^{-1} TEQ) (Minh et al., 2003) (Fig. 11.8).

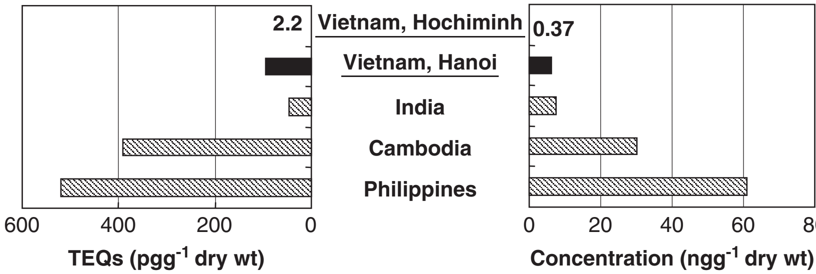

Figure 11.8. Concentrations and TEQs of PCDD/Fs in soils from open dumping sites for municipal wastes in Asian developing countries.

However, in general, dioxin residues in soils from Vietnam were less than those in other Asian countries examined in this study, indicating less dioxin contamination in Vietnam. However, one soil sample contained very high concentration of PCDD/Fs (50 ng g^{-1} dry wt. basis; 850 pg g^{-1} TEQs) (Minh et al., 2003). This level is greater than most of the background levels soils in industrialized countries and even higher than those reported for dioxin-contaminated locations in the world (Minh et al., 2003). In addition, it is interesting to note that PCDD/F levels in soils collected from dumping sites were significantly higher than those in agricultural and resident soils collected far from dumping sites. These results suggest that open dumping sites could be a potential source of dioxins in Vietnam. To understand the degree of human exposure to dioxins in open dumping sites, residue levels of human milk samples were also examined (Kunisue et al., 2004). Mean PCDD/F concentration in breast milk from women living near dumping sites in Hanoi was 52 pg g^{-1} lipid wt. (6.0 pg g^{-1} TEQs), range: 18–120 pg g^{-1} lipid wt. (2.9–9.3 pg g^{-1} TEQs) (Kunisue et al., 2004). These are comparable to those in Philippines and Cambodia, but apparently lower than those in India. Unlike soils, there were no significant differences in PCDD/F residues in milk of women living near dumping sites and far from dumping sites (control sites) (Kunisue et al., 2004).

On the basis of these results, it can be emphasized that the status of dioxin contamination in Vietnam is less pronounced as compared to other countries in East Asian region, but the issue of dioxin pollution in such open dumping site should be considered as one of the priority research in future because of the sporadic evidence of elevated dioxin contamination in dumping sites from Hanoi. Control measures and legislations towards management and mitigation of dioxin emissions in open dumping sites are urgently needed.

11.5. Fate and behavior of dioxins in municipal wastes open dumping sites

Very little information is available regarding the contamination of PCDD/Fs in Asian developing countries. Therefore, fate and behavior of these compounds in developing countries is still obscure. On the basis of the residue concentrations in soils from dumping sites, we estimated the flux of PCDD/Fs to soils to provide insights into the transport and fate of these toxic contaminants (Fig. 11.9, Minh et al., 2003). The estimated fluxes to soils in dumping sites in Asian developing countries including Vietnam were surprisingly higher. Fluxes to soils in Asian dumping sites were higher than those of some other locations in the world, including contaminated areas in the United States and Hong Kong (Fig. 11.9). The loads of PCDD/Fs to the dumping sites were also estimated (Fig. 11.10). Results showed that dumping sites in Philippines and India with a huge area of approximately 23 and 140 ha, could receive the highest annual amount of 3900 and 1400 mg year^{-1} PCDD/Fs (35 and 8.8 mg TEQs year^{-1}), respectively. Dumping site in Hochiminh City, Vietnam, had the lowest loading rate due to the less contamination of PCDD/Fs in soils. As for comparison, total annual fluxes to the Kanto region, Japan, one of the most polluted areas in the world, were estimated and found to range from 50 to 900 g TEQ with a total area of 32,000 km^2 (approximately 3 millions ha) (Ogura et al., 2001). The area of dumping

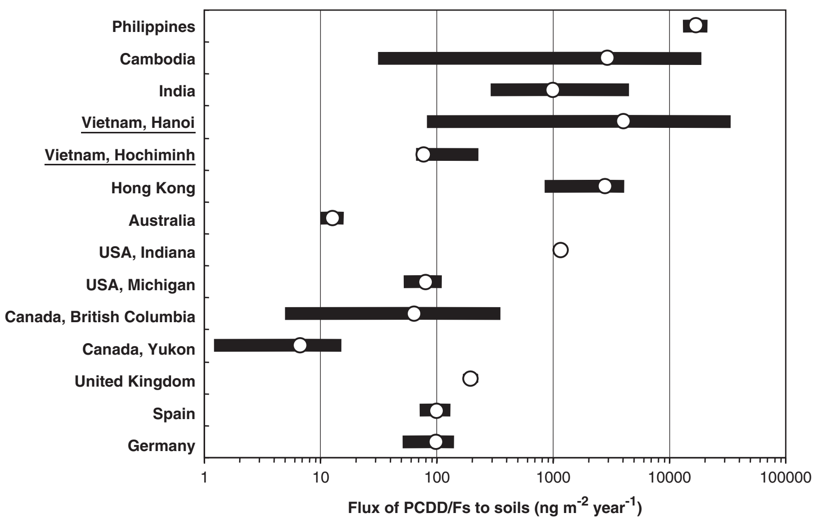

Figure 11.9. Comparison of the fluxes to soils from open dumping sites in Asian countries with those from other locations in the world.

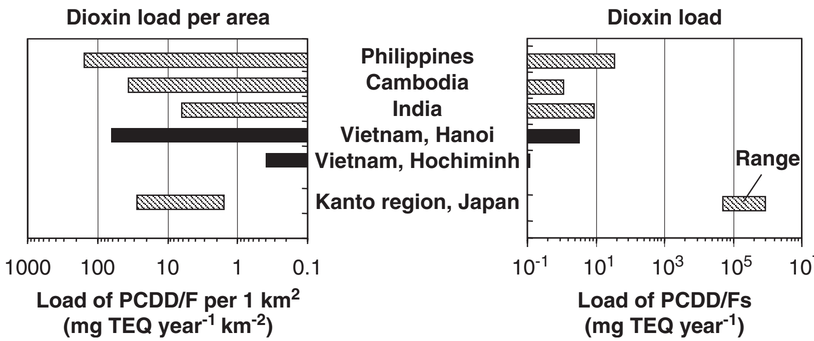

Figure 11.10. Comparison of the load of PCDD/Fs to dumping sites in Asian countries with those in Kanto region, an extensive industrial area in Japan.

sites in India is 140 ha, which is 21,000 times smaller than that of Kanto region, was estimated to receive an amount of 8.8 mg TEQs every year. This data suggest that dumping sites in India and Philippines may be significant reservoirs of PCDD/Fs. Possible impacts on human health and wildlife living near dumping sites are of great concern and warrant further comprehensive studies. On the basis of the results of this study, it is important to note that despite the probable decrease in global pollution by POPs in the future, developing countries may continue to be a potential source of certain compounds, particularly PCDD/Fs.

11.6. Trends of contamination by persistent organic pollutants

Well-designed studies on temporal trends of POP contamination in developing countries are generally limited. This is a common issue in under developed nations, where advanced knowledge, state-of-the-art analytical equipment are still lacking. Therefore, reliable and reproducible data for long-term trends of POP contamination—a key requirement in monitoring program—are limited in these countries, including Vietnam. Nevertheless, studies on temporal trends of contamination are very important, particularly in tropical developing countries. There have been a few reports suggesting the role of the southern Asian region as a possible emission source for the pristine areas such as the Arctic and the Antarctic (Iwata et al., 1993, 1994; Kannan et al., 1995; Kunisue et al., 2002). Despite OCs were banned in most of the developed nations, high consumption of OC insecticides for enhancing food production and eradicating vector-born diseases has been a virtual fact in developing countries. This lends credence that despite rapid decline of OC residues in developed nations, the status of contamination in developing world seemed different with slower rate of decline. Though well-designed studies on the temporal trends of contamination in POP from Vietnam have been limited, trends of OC residues in river water and sediments from Red River estuary and human breast milk from women living in suburb areas of Hanoi and Hochiminh City were investigated along those lines.

Viet et al. (2002) examined residue concentrations of DDTs and γ-HCH (lindane) the two most common insecticides used extensively in Vietnam, in water and sediments from Red River delta. River water and sediments were collected at the same locations annually in both dry and wet season and were examined for the trends of contamination during 1995–2001 (Fig. 11.11). DDT residues in water have declined relatively rapidly during 1995–1998 and remained constant until recent years at the levels below 10 ng L^{-1}. Concentrations in sediments also exhibited a decreasing trend but to a lesser extent. DDT residues in sediments dropped by a factor of 2 during 1997–2000. DDT was officially banned in Vietnam in 1995 (Sinh et al., 1999). The reduction of DDT concentrations in both water and sediments from Red River, northern Vietnam indicate the effect of legislative action in lessening the degree of environmental pollution. Interesting results were observed on the trends of lindane concentrations in sediment, showing peak concentrations in 1997 and lower levels during 1995–1996 and 1999–2001. Recent studies examined HCH residues in sediments from different sites in Red River Delta and estuary showed that HCH concentrations in 1997 survey were higher than in the sampling survey carried out in 1995 (Nhan et al., 1998, 1999). Such a fluctuation of HCH contamination suggests sporadic inputs of this insecticide into the

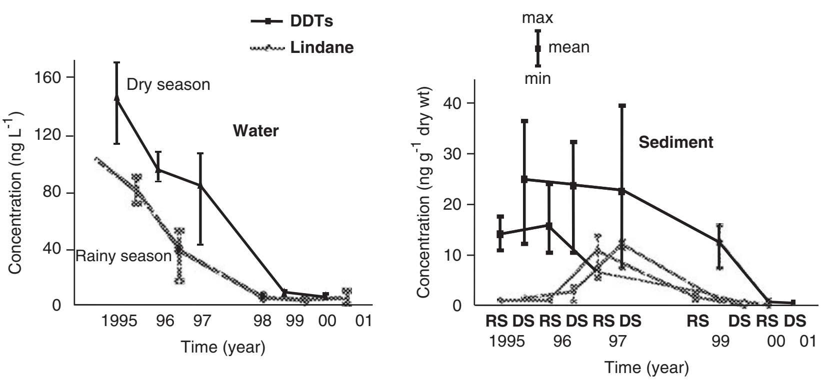

Figure 11.11. Temporal trends of DDTs and lindane in surface water and sediment from Read River Delta, northern Vietnam during 1995–2001.

watershed of Red River. In general, results from water and sediments in recent years indicated a rapid decline of DDTs and HCHs in surface water, but a slow decreasing trend in sediment. There are indeed severe gaps in the monitoring of trends of contamination in biota samples from Vietnam. Temporal monitoring of residue concentrations in biota may provide more realistic hints to understand trends of contamination in the environment. This is because of the fact that the impact of any changes in the environmental input of persistent OCs can be realized relatively slowly in biota samples as compared to those observed for environmental abiotic samples. Similar phenomenon was also seen in the trends of POP pollution in lower and higher trophic animals (Tanabe et al., 2003).

In addition to the studies on the trends of POP levels in the environmental samples, time trends of human exposure is also an important issue for understanding the long-term toxic impacts on general population. Minh et al. (2004) assessed the decline in the rate of human exposure to DDTs and PCBs over the 10 years period (1989 and 2001). A first-order kinetic approach was used to estimate the declining rate of DDTs and PCBs in human breast milk collected from Vietnam. The decrease in the POPs such as DDTs, PCBs, and HCHs in human breast milk was suggested to follow first-order kinetic (Noren & Meironyte, 2000). Another important factor for the assessment is the half-life ($t_{dec1/2}$) defined as the duration in which initial concentrations decrease to a half. On the basis of the residue concentrations of OCs in 1989 reported by Schecter et al. (1989a) and the levels in 2001 obtained by Minh et al. (2004), the rate constant and $t_{dec1/2}$ were estimated.

Residue levels of *p,p′*-DDT have decreased from 4700 to 2700 ng g^{-1} lipid wt. over a period of 10 years with $t_{dec1/2}$ of around 3 years. On the other hand, *p,p′*-DDE decreased rather slowly with a $t_{dec1/2}$ of 6 years. This result is somewhat in agreement with those in Sweden showing half-life of 4 and 6 years for *p,p′*-DDT and *p,p′*-DDE, respectively (Noren & Meironyte, 2000). The slightly shorter half-life observed in Vietnam could be due to the tropical climate that exist in Vietnam which might have facilitated the volatilization of *p,p′*-DDT in the environment leading to its faster decrease in food chains (and thus in humans). Assuming that the decrease in the trend of DDTs remain more or less constant, we can estimate the DDTs levels may reach approximately 700 ng g^{-1} lipid wt. in the year 2011 (Fig. 11.12). However, lower residue levels in future can be expected if the use of DDTs is completely phased out now. The decreasing trend of PCBs was lower compared to those of DDTs (11–18 years for some major congeners such as CB-138, -153, and -180). This result is somewhat in agreement with those reported in Sweden showing the half-life for some PCB congeners varying from 11 to 17 years (Noren & Meironyte, 2000).

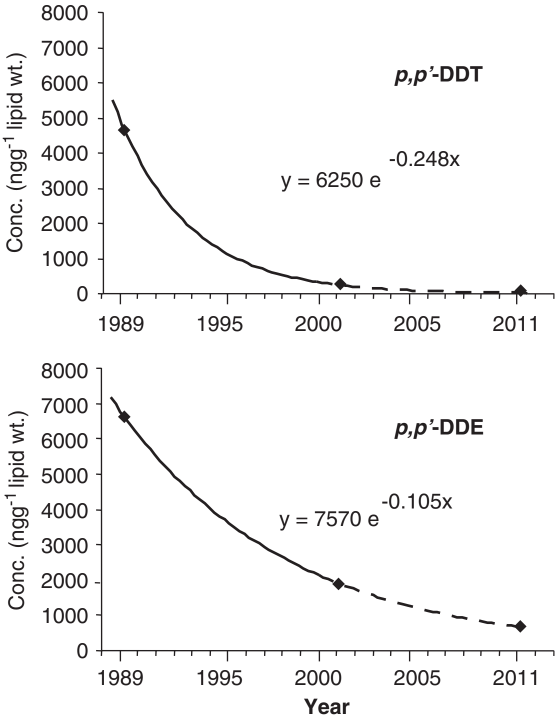

Figure 11.12. Estimation of time-trend curve of *p,p′*-DDT and *p,p′*-DDE residues in human breast milk in Vietnam.

11.7. Environmental and human health implications

Widespread contamination by OC insecticides, particularly DDTs in different environmental samples of Vietnam has been apparent as indicated in our survey in early 1990s. In a survey of estuarine sediments collected from various locations from the northern to southern part of the country, higher concentrations of DDTs were observed (Iwata et al., 1994). The Environment Canada has recently updated the sediment quality guidelines for protection of the aquatic life. The Interim Fresh water Sediment Quality Guidelines (ISQG) and the Probable Effect Levels (PEL) for *p,p′*-DDE are 1.42 and 6.75 ng g^{-1} dry wt., respectively, while these values for *p,p′*-DDT are 1.19 and 4.77 ng g^{-1} dry wt. (Canadian Council of the Ministers of the Environment, 2002). Among the 18 locations examined throughout Vietnam during the survey in early 1990s (Iwata et al., 1994), about half of the sediment samples contained *p,p′*-DDE and *p,p′*-DDT greater than the ISQG values. Some samples collected from the municipal sewage canals contained elevated levels of DDTs, far exceeding the PEL. PCB concentrations in Vietnamese sediments in these locations were also beyond the PEL level for PCBs. Likewise, residue concentrations of DDTs in many soil samples collected from some locations from north, middle, and south Vietnam (Thao et al., 1993) approached or exceeded the guideline level of 700 ng g^{-1} dry wt. proposed by Environment Canada and the level of 1000 ng g^{-1} dry wt. recommended by Japanese Government. Taking into account all these facts, it is important to note that the magnitude of contamination by DDTs in Vietnam is of concern and warrant further studies.

As for PCDD/Fs, the formation of these contaminants in open dumping sites in Asian developing countries raised a considerable human health concern for not only communities living near the dumping sites, but also for people who live far away because PCDD/Fs may undergo atmospheric transport and deposit in distant areas. For risk assessment of soils contaminated by dioxins and related compounds, The Agency for Toxic Substances and Disease Registry (ATSDR) proposed guidelines recommending that areas having soil concentrations within the range from 50 to 1000 pg TEQ g^{-1} should be evaluated for bioavailability, ingestion rates, community concerns, etc., and soils with the concentrations over 1000 pg TEQs g^{-1} should be considered for stronger actions like health studies, exposure investigations, etc. (ATSDR, 1997). Japanese Government recently issued new standards for dioxins in soil, establishing 1000 pg TEQ g^{-1} as the maximum acceptable level and those within 250–1000 pg TEQ g^{-1} be kept under surveillance. Many soil samples in dumping sites contained TEQ concentrations exceeding 250 pg g^{-1} TEQs (Fig. 11.13, Minh et al., 2003), suggesting the necessity of continuous monitoring. Particularly, some soils from dumping sites in Cambodia and Hanoi, Vietnam contained TEQ concentrations beyond the level of 1000 pg g^{-1}, suggesting their potential for causing adverse health risk for humans and wildlife.

In the perspective of human health implications, surveys conducted in early 1990s on OCs in foodstuffs provided useful information regarding the dietary intake of these compounds by Vietnamese population (Kanan et al., 1992). Interestingly, the estimated average daily intakes based on the exposure through foodstuff to PCBs in Vietnam were higher than India, Thailand and comparable to those reported for developed nations like USA and Germany. Particularly, average daily intake of DDTs by Vietnamese was estimated to be 19 μg person^{-1} day^{-1}; and this value was the highest as compared to the countries in the region and in developed nations (Kanan et al., 1992). Although the data used for estimation have been reported a decade before, this fact clearly suggests elevated exposure to DDTs and PCBs by Vietnamese population during the past 10 years.

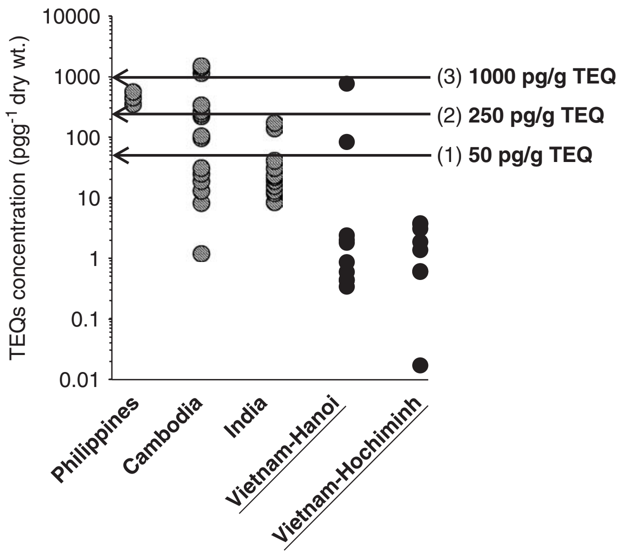

Figure 11.13. Concentrations of PCDD/Fs in soils from dumping sites in Asian developing countries in comparison with various environmental guideline values.

Surveys in the framework of recent Asia-Pacific Mussel Watch Program indicated that dietary intake of DDTs and PCBs from fish in Vietnam were higher than those in Cambodia and Thailand, but still lower than those in industrialized nations such as Australia, Japan, and Hong Kong (Monirith et al., 2000). On the basis of the recent data of average seafood consumption reported by Food and Agriculture Organization of the United Nations, the average daily intake of PCBs and DDTs from seafood for different countries in Asia-Pacific region were estimated (Monirith et al., 2003) (Table 11.5). Interestingly, results again showed that intakes of DDTs by Vietnamese population were apparently higher than those reported in other countries examined.

In addition to the elevated exposure of DDT via seafood to Vietnamese general population, certain cohorts living near the municipal dumping sites may be at a higher risk by toxic substances: dioxins and dibenzofurans. A methodical approach has been developed to evaluate the risk of exposure to PCDD/Fs via soil ingestion and dermal absorption (Minh et al., 2003). Human exposure to PCDD/Fs in soil is considered to be different for children and adults due to the differences in the ingestion rate as well as body weight of children and adult. Intakes of dioxins were estimated to be the highest in people of Philippines, followed by Cambodia, India, Hanoi (North Vietnam), and Hochiminh City (South Vietnam). Intakes of

Table 11.5. Estimated daily intakes of persistent organochlorines via mussels by different populations in Asia-Pacific region

Country	Survey year	Seafood consumption[a] (g person^{-1} day^{-1})	Intake of PCBs[b] (ng person^{-1} day^{-1})	Intake of DDTs (ng person^{-1} day^{-1})	Intake of HCHs (ng person^{-1} day^{-1})
Cambodia	1998	20	15	6.6	<0.2
China	1999–2001	71	180	17000	57
Hong Kong	1998–1999	69	260	8300	14
India	1998	13	49	55	26
Indonesia	1998	52	68	52	2.1
Japan	1994	196	5900	690	63
South Korea	1998	114	420	400	30
Malaysia	1998	156	160	220	<1.6
Philippines	1998	77	440	31	2.3
Russia	1999	54	3400	650	54
Vietnam	1997	47	66	1900	2.8

[a]Seafood consumption data were cited from FAO Food Balance Sheets, FAO Statistics Division, FAO 2006.
[b]Intakes were estimated on the basis of residue concentrations in mussels (Asia-Pacific Mussel Watch Program) reported by Monirith et al. (2003).

PCDD/Fs by the people living near dumping sites in Vietnam were ~2200-fold greater than those for the people in control sites, and thus emphasizing the greater health risk, threatening those people. In addition, it is important to note that the estimated intakes of dioxins via soil ingestion and dermal exposure for children were higher than those for adults, suggesting greater risk of dioxin exposure for children in dumping sites (Minh et al., 2003). Further investigations should be focused on children and infants as they are the most susceptible group and have higher exposure levels to dioxins. The breast-fed children intakes of PCDD/Fs estimated on the basis of residues in breast milk of women living in open dumping sites in Asian countries were given in Fig. 11.14. The intake estimated for Vietnamese were comparable to those in Cambodia but lower than in the Philippines and India. In addition, it is important to note that intakes estimated for children living near the hot spot of dioxin contamination due to Agent Orange in southern Vietnam were still very high even after the Agent spraying ended almost three decades (Fig. 11.14, Dwernychuk et al., 2002). Thus, Vietnam could serve as suitable location for future research on possible toxic effects of dioxins on wildlife and humans due to the unique situation where both current and historical dioxin contamination exists.

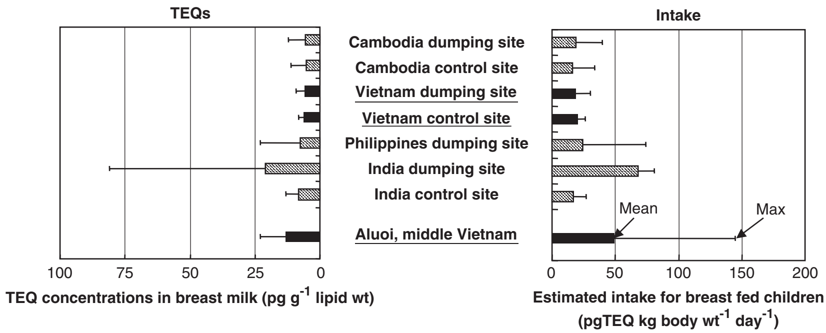

Figure 11.14. TEQs concentrations and estimated intakes of PCDD/Fs for breast-fed children from open dumping sites and control sites in Asian countries and Aluoi Valley, a former Agent Orange spraying during Vietnam War.

11.8. Conclusions and recommendations for future research

Multimedia monitoring studies conducted during the last decade on POPs in Asia-Pacific region including Vietnam indicated that contamination by OC insecticides, particularly DDTs, has been apparent. As a consequence, high degree of exposure of general populations to DDTs via foodstuff, particularly fish and other seafood has been of concern over the last several years. In addition, a certain group of people living near the dumping sites of municipal wastes are exposed to elevated concentrations of PCDD/Fs and other toxic chemicals in dumping sites, and may be at higher risk. It is important to note that despite the decrease in global contamination by POPs in the future, developing countries in Asia-Pacific region may continue to be a potential source for certain contaminants such as DDTs and PCDD/Fs. Systematic temporal trend studies are therefore needed for developing countries. Possible toxic effects on human health and wildlife should be investigated. Capacity building on advanced technologies and providing laboratory facilities to developing countries through international cooperative research programs is indispensable.

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