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Chapter 7

Persistent Organic Pollutants in Hong Kong

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Abstract

The Stockholm Convention on Persistent Organic Pollutants commits the international community to protecting human health and the environment from harmful effects of persistent organic pollutants (POPs) and aims to end global use and release of 12 most toxic POPs. A POPs inventory in Hong Kong has been compiled for the period 2000–2004 for assessing POPs' potential impacts on the local environment and human health. None of the nine POPs pesticides (i.e., aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, HCB, mirex and toxaphene) are now registered for use in Hong Kong. The inventory indicates that only a small quantity of PCBs in PCB-containing equipment was in local use/stockpile in 2004. The estimated total annual release of dioxins/furans to the environment in 2003 was 20.3 g TEQ which on a "per capita" basis, was the 2nd lowest in air emission among 26 countries/regions in Asia, Europe, North America and Australia compared. The level of POPs contamination in the local environment was generally comparable to the range reported in most other urban locations worldwide. The estimated total exposure of Hong Kong residents to dioxins/furans in 2003 via the dietary and inhalation routes was 0.93 pg TEQ kg^{-1} bw d^{-1}, falling at the lower end of the range of tolerable daily intake (1–4 pg TEQ kg^{-1} bw d^{-1}) set by the WHO (1998). Overall, the current level of POPs contamination was found to pose no unacceptable risk of potential toxicological concern to the local environment or human health.

7.1. Introduction

Persistent organic pollutants (POPs) are organochlorine compounds widely used as pesticides and/or industrial chemicals. These chemicals share four common properties: highly toxic, persistent, capable of long-range transport and bio-accumulation in the fatty tissues of living

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organisms. Their "grasshopper" movement within environmental compartments and global circulation often result in serious threat to the people and the wildlife near and distant from their origin of production. To respond to the increasing global concern about POPs' potentially harmful effects and to better safeguard public health and the environment, the international community has stepped up its efforts to control, ban or restrict the trade, manufacture, use or release of some of the most toxic POPs worldwide by adopting the Stockholm Convention on Persistent Organic Pollutants which entered into force on May 17, 2004. As at January 15, 2006, 117 countries have become Parties to the Convention (http://www.pops.int).

The Stockholm Convention is a global treaty committing the international community to protecting human health and the environment from the potentially harmful effects of POPs (UNEP Chemicals, 2005). The United Nations Environment Programme (UNEP) has identified 12 most toxic POPs (the "Dirty Dozen") for control under the Convention, including 10 intentionally produced POPs pesticides/industrial chemicals (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene (HCB), mirex, toxaphene and polychlorinated biphenyls (PCBs)) and two unintentionally produced POPs by-products (polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs)). In implementing the Convention, Parties to the Convention will take measures to restrict the trade, production and use of the intentional POPs and to reduce and, where possible, to ultimately eliminate the production and release of the unintentional POPs by-products.

The Stockholm Convention became effective to the People's Republic of China (PRC), including the Hong Kong Special Administrative Region (HKSAR), on November 11, 2004. Under the Convention, the PRC will submit a National Implementation Plan (NIP), which includes the Hong Kong Special Administrative Region Implementation Plan (HKSARIP), to the Conference of the Parties of the Stockholm Convention within two years of ratification of the Convention. In preparing the HKSARIP, the Environmental Protection Department (EPD) of the HKSAR Government conducted a thorough review of the current POPs situation and compiled a comprehensive POPs inventory on the 12 most toxic POPs regulated by the Stockholm Convention in Hong Kong. The inventory provided a scientific basis for assessing the environmental and human health impacts of POPs and supported the policy-makers' development of an effective POPs management and implementation strategy for the HKSAR. This chapter presents the POPs inventory in Hong Kong for the period 2000–2004 and the findings of a science-based assessment of their potential impacts on the local environment and human health.

7.2. The HKSAR basic profile

The HKSAR is a sub-tropical city situated in the Pearl River Delta (PRD) at the south-eastern tip of Mainland China. It has a total area of 1104 km^2, comprising Hong Kong Island, the Kowloon Peninsula, the New Territories and 262 outlying islands (Fig. 7.1).

Hong Kong has one of the finest deep-water ports in the world and is a well-established international financial, trading and business centre. It is widely recognized as the world's freest economy (Heritage Foundation's 2005 Index of Economic Freedom) and one of the most competitive economies in the world (International Institute for Management Development's World Competitiveness Yearbook 2005). Over the past few decades, there has been a structural transformation of the Hong Kong economy from manufacturing to service orientation. The local industrial activities have shrunk to a substantial extent in both variety and size as manufacturing enterprises have progressively relocated their production lines to the Mainland. On the other hand, trading and logistics, finance and banking, tourism and a wide range of business services are steadily gaining importance.

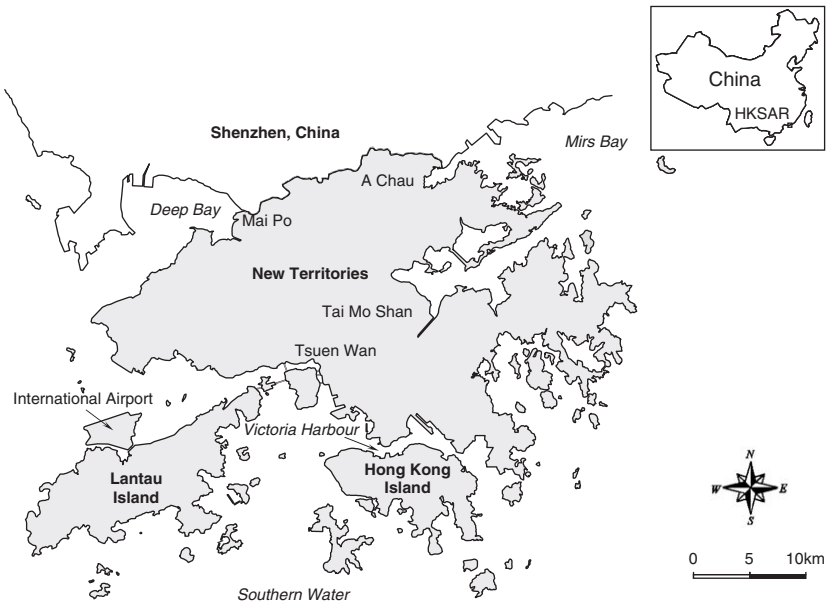

Figure 7.1. Map of the Hong Kong Special Administrative Region (HKSAR), China.

With a population of 6.9 million, Hong Kong is one of the world's most densely populated cities (6380 persons per km^2 according to data of the Census and Statistics Department, the HKSAR Government) (CSD, 2004). Over the years, Hong Kong has developed an efficient wholesale and retail network to cater for the growing consumption needs of a more affluent population. The dense population coupled with a high level of dynamic economic activities has exerted intense pressure on Hong Kong's environment. This is further compounded by the effects of immense economic growth in the PRD, one of the fastest developing regions in the world. Since the 1980s, the HKSAR Government has been implementing various plans and programmes to meet the local environmental challenges. Pollution by toxic substances including POPs is a relatively new area of focus in Hong Kong, but has received increased attention in recent years. Programmes for monitoring air and water toxic pollutants have been established to assess background pollution and to better safeguard the environment and human health (EPD 2004a, 2005a).

7.3. Source inventories of POPs

The source inventories of POPs in Hong Kong were developed in accordance with relevant UNEP guidance documents (UNEP Chemicals, 2003a,b) and compiled based on existing information gathered from all available sources to represent the broadest possible sweep of relevant local data. The main sources of information included annual government reports of routine monitoring and inspection programmes, relevant reports of ad hoc and case studies, and government-funded consultancy studies. The manufacture, use and stockpile inventory of pesticides was reported for a five-year period (2000–2004) for which data were available. The dioxin/furan emission inventory was compiled for the year 2003, the most recent year of complete data entries.

Data screening and quality assurance checking were conducted at initial information retrieval and all data entries cross-checked during subsequent data compilation. Production/activity levels were verified against different information sources including annual records, self-monitoring reports and ad hoc study reports. There was inadequate documentation of local industrial/commercial/urban activities and/or limited analytical data on the level of POPs contamination in some classes of emission sources. These were identified as inventory data gaps for follow-up actions.

7.3.1. Trade, production and use of intentional POPs

7.3.1.1. Pesticides

In Hong Kong, the nine intentional POPs pesticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, HCB, mirex and toxaphene) targeted for global elimination or restricted production and use were not registered, or their registration status had been cancelled for many years due to toxicological or environmental concern.

Aldrin	Chlordane	DDT	Dieldrin	Endrin	Heptachlor	HCB	Mirex	Toxaphene
1988[a]	1991[a]	1988[a]	1988[a]	NR	NR	NR	1997[a]	1984[a]

Note: NR = Not registered.
[a]The year in which all use and trade activity were prohibited unless under a pesticide permit granted in exceptional circumstances.

Table 7.1 presents the local source characterization and quantification of the nine intentional POPs pesticides. There was neither import, export, manufacture nor use and no stockpiling of any of these pesticides in Hong Kong for the past five years (2000–2004). Transhipment of DDT was reported in 2000–2003 but not in 2004, while transhipment of mirex was recorded in 2004 only.

7.3.1.2. Polychlorinated biphenyls

Stockpiles of PCBs contained in PCB-products manufactured from past industrial activities exist. Results of periodic PCB-equipment surveys conducted by EPD in 1994/1995, 2001/2002 and 2004 are presented in Table 7.2. There has been no PCB-containing transformer stockpile in Hong Kong since 2001/2002 and the number of PCB-capacitor units dropped significantly from 830 in 1994/1995 to 303 in 2001/2002. In 2004, the number of PCB-capacitor units further dropped to 191. Most of these capacitor units were small. Of the 191 capacitor units, only 85 were still in use and 106 were stockpiles being stored in the workplace to be disposed of anytime. The total quantity of PCBs in use/stockpile was estimated to be 422 kg. Phased out PCB-containing equipment is classified as a chemical waste in Hong Kong, the disposal of which is governed by the Waste Disposal Ordinance. Small PCB-containing equipment and PCB-fluid removed from large PCB-containing equipment are incinerated at the Chemical Waste Treatment Centre (CWTC). The PCB-contaminated

Table 7.1. Source characterization and quantification of POP-pesticides in Hong Kong in 2000–2004

Chemical	Import (t a^{-1})	Export (t a^{-1})	Manufacture (t a^{-1})	Use (t a^{-1})	Stockpile (kg)	Transhipment (kg)				
					2000–2004	2000	2001	2002	2003	2004
Aldrin	0	0	0	0	0	0	0	0	0	
Chlordane	0	0	0	0	0	0	0	0	0	
DDT	0	0	0	0	0	112,600	274,228	153,118	123,440	0
Dieldrin	0	0	0	0	0	0	0	0	0	
Endrin	0	0	0	0	0	0	0	0	0	
Heptachlor	0	0	0	0	0	0	0	0	0	
Hexachlorobenzene	0	0	0	0	0	0	0	0	0	
Mirex	0	0	0	0	0	0	0	0	0	125
Toxaphene	0	0	0	0	0	0	0	0	0	

Table 7.2. Domestic use of PCBs and PCB waste disposal in Hong Kong for the period 1994–2004

PCB-containing equipment	1994/1995	2001/2002	2004
High voltage transformer (no. of units)	13	0	0
Power plants/power stations			
Railway/mass transit railway			
High voltage capacitor (no. of units)	830	303	191
Factories/old buildings			
High voltage capacitor in use (no. of units)			85
Industries			27
Dockyard			48
Hospital			3
Estate management			7
High voltage capacitor stockpile (no. of units)			106
Total PCB in use/stockpile (kg)			422*
PCB-waste disposal		1994–2001 (kg)	2002–2004 (kg)
PCB-fluid waste disposed of at CWTC		25,305	2
PCB-containing solid waste disposed of at CWTC		16,379	3210
PCB-contaminated solid waste disposed of at landfills		48,225	0

*The PCB content of individual capacitor unit was calculated based on its unit volume, assuming a capacitor of size (60 cm × 30 cm × 15 cm) would contain 1.4 kg of 100% PCB fluid.

solid waste is disposed of at landfills. The total quantities of PCB-waste disposed of during 1994–2001 and 2002–2004 are shown in Table 7.2.

It was noted that PCBs might also be present in minute quantities in some consumer products such as small old electrical appliances/parts, electronics, impact papers, adhesives, sealants, plastic materials and paints. The 2003 Hong Kong Census and Statistic figures showed local trading activities of these consumer products. However, in the absence of information on the product content of PCBs, no estimate of total PCBs in semi-closed and open application could be made. The relative contribution from this category to total PCB use was likely to be insignificant.

7.3.2. Release of unintentional POPs as by-products

7.3.2.1. Development of the dioxin/furan release inventory

PCDDs and PCDFs are unintentional by-products of industrial and combustion processes. The 2003 dioxin/furan release inventory in Hong Kong

was generated based on the "UNEP Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases" (UNEP Chemicals, 2003b). The known potential local sources of environmental releases of dioxins/furans were divided into nine major emission categories, each containing a number of subcategories and classes of similar processes. For each identified process with a known local activity, the estimated average annual release of dioxins/furans to individual vector (air, water, land, products and residues) was calculated using the following basic equation:

$$\text{Annual emission or release} = \text{emission factor} \times \text{production or activity rate}$$

If locally measured emission data were available for a process, a local emission factor (EF) specific to Hong Kong was derived to provide a more accurate estimate of its local annual release. For all other processes, the generic EFs published in the Toolkit (UNEP Chemicals, 2003b) were adopted. It was noted that where available, local EFs were generally lower than the corresponding UNEP default values for the same processes.

7.3.2.2. The 2003 dioxin/furan release inventory in Hong Kong

A summary of the 2003 local dioxin/furan emission profile is presented in Table 7.3. The annual release of dioxins/furans to the environment via all vectors was estimated to be 20.3 g TEQ. Figure 7.2a shows the relative contribution of different emission categories. The top three contributing categories were "Ferrous and Non-Ferrous Metal Production" (39.3%), "Disposal/Landfill" (28.7%) and "Power Generation and Heating/Cooking" (25.9%). Together, they represented 93.9% of the total annual dioxin/furan emission in 2003. A "zero" emission value was assigned to Category 7 "Production of Chemicals, Consumer Goods" due to a general lack of local data on the contamination level of dioxins/furans in consumer goods.

On a vector basis (Fig. 7.2b), the major route of release was "residues", responsible for 82.4% of the total, followed by "air" (12.9%) and "water" (4.2%). The "land" and "products" together contributed to only 0.5% of the total annual release. It was observed that for the "land" and "products" vectors, a "blank" release value was assigned to many classes of potential emission sources due to a general lack of data on EFs.

The 2003 annual dioxin/furan release to the atmosphere was 2.61 g TEQ. The relative contribution of different source categories to total air emission is shown in Fig. 7.2c. The top four contributing classes of local emission sources were: (a) "coal fired power boilers plants" (45.3%); (b) "crematoria" (13.4%); (c) "aluminium production (secondary)" (10.3%) and (d) "accidental fires—houses, factories and vehicles" (9.6%). These

Table 7.3. The 2003 inventory of annual dioxin/furan (PCDD/F) emissions in Hong Kong—a breakdown on subcatergories and individual classes of activity

Cat.	Source categories	Production (t a^{-1})	Potential release route (μg TEQ t^{-1})					Annual release (g TEQ a^{-1})†					All routes† (g TEQ a^{-1})
			Air	Water	Land	Products	Residues	Air	Water	Land	Products	Residues	
1.	**Waste incineration**							**0.008**	**0.000**	**0.000**	**0.000**	**0.057**	**0.065**
	Hazardous waste incineration	10,507	*0.3*				*2.27* (BA)	0.003				0.024	0.027
	Medical/hospital waste incineration	36	*125*				*920* (FA)	0.005				0.034	0.038
2.	**Ferrous and non-ferrous metal production**							**0.272**	**0.000**	**0.000**	**0.000**	**7.700**	**7.972**
	Iron/steel foundries and brass/bronze production	15,570	*0.13*					0.002					0.002
	Aluminum production (secondary)	77,000	3.5				100	0.270				7.700	7.970
3.	**Power generation and heating/cooking**							**1.549**	**0.000**	**0.000**	**0.000**	**3.692**	**5.242**
	Fossil fuel power plants	320,424						1.214				3.692	4.907
	Coal fires power boilers plants	263,737	*4.48*				14	1.182				3.692	
	Heavy fuel fired power boilers	1,851	2.5					0.005					
	Light fuel oil/natural gas fired power boilers	54,836	0.5					0.027					
	Landfill and biogas combustion							0.037					0.037
	Biogas-fired boilers, motors/turbines and flaring	4,627	8					0.037					
	Domestic heating—fossil fuels	57,029						0.298					0.298
	Coal fired stoves	242	70				5 μg TEQ kg^{-1} ash	0.017				ND	
	Oil fired stoves	23,053	10					0.231					
	Natural gas fired stoves	33,734	1.5					0.051					
4.	**Production of Mineral Products**							**0.009**	**0.000**	**0.000**	**0.000**	0.074	0.082
	Asphalt mixing	1,230,000	0.007				0.06	0.009				0.074	0.082
5.	**Transport***							**0.117***	**0.000**	**0.000**	**0.000**	**0.000**	**0.117***
	4-Stroke engines	355,992						0.002					0.002

Table 7.3. (*Continued*)

Cat.	Source categories	Production (t a^{-1})	Potential release route (μg TEQ t^{-1})					Annual release (g TEQ a^{-1})†					All routes† (g TEQ a^{-1})
			Air	Water	Land	Products	Residues	Air	Water	Land	Products	Residues	
	Unleaded fuel without catalyst	18,682	0.1					0.002					
	Unleaded fuel with catalyst	337,310	0.00										
	2-Stroke engines	143						0.0004					0.0004
	Unleaded fuel without catalyst	143	2.5					0.0004					
	Diesel engines	1,144,969	0.1					0.114					0.114
	Heavy oil fired engines (all types)*	3,021,753	4					12.087*					12.087*
6.	**Uncontrolled combustion processes**							**0.312**	**0.000**	**0.048**	**0.000**	**0.213**	**0.573**
	Fires/burnings—biomass	12,076						0.060		0.048			0.109
	Forest fires	6,038	5		4			0.030		0.024			
	Grassland and moor fires	6,038	5		4			0.030		0.024			
	Fires, waste burning, landfill fires, industrial fires, accidental fires	1,020						0.251				0.213	0.464
	Accidental fires in houses, factories	510	400				400	0.204				0.204	
	Accidental fires in vehicles (per vehicle)	485	94				18	0.046				0.009	
	Open burning of wood (construction/demolition)	25	60				10	0.002				0.000	
7.	**Production of chemicals, consumer goods**							**0.000**	**0.000**	**0.000**	**ND**	**0.000**	**0.000**
	Textile plants	ND									ND		
	Leather plants	ND									ND		
8.	**Miscellaneous**							**0.347**	**0.000**	**0.000**	**0.000**	**0.065**	**0.412**
	Crematoria[a]	30,161						0.347				0.065	0.412
	No control plants[a]	4,182	*52.47*					0.219					
	Medium control plants[a]	16,127	*7.89*				2.5	0.127				0.040	
	Optimal control plants[a]	9,852	*0.01*				2.5	0.000				0.025	
	Dry cleaning residues	17					50					0.0009	
	Tobacco smoking[b]	4,216,948,889						0.0004					0.0004
	Cigar[b]	11,820,820	0.3					0.000					
	Cigarette[b]	4,205,128,070	0.1					0.000					

9.	**Disposal/landfill**					**0.000**	**0.855**	**0.000**	**0.062**	**4.895**	**5.812**
	Landfill leachate	1,469,174					0.005				0.005
	Non-hazardous waste[c]	1,469,174	*3.62*				0.005				
	Sewage/sewage treatment						0.850			4.895	5.745
	Sewage-Mixed industrial, commercial, and domestic	944,984,329					0.850				
	-No sludge removal[c]	276,198,167	*2.86*				0.790				
	-With sludge removal[c,d]	668,786,162	*0.09*				0.060				
	Sludge-Mixed industrial, commercial, and domestic	97,890								4.895	
	-CEPT[c]	72,067			50					3.603	
	-Secondary treatment[c]	25,823			50					1.291	
	Open water dumping	ND					ND				
	Composting	4,112							0.062		0.062
	Livestock wastes	4,112		15					0.062		
1–9.	**Total (g TEQ a^{-1}) (excluding Cat. 5d—bunker fuel consumption)**					**2.613**	**0.855**	**0.048**	**0.062**	**16.696**	**20.274**

Note: BA = bottom ash; FA = fly ash.
ND = no data; figures in Italic represent HK data.
[†]Values may not add up to "total" due to rounding.
[*]Not included in the annual dioxin emission estimate 2003; the sale of bunker fuel to international ocean-going vessels is not considered representative of local fuel consumption.
[a]Production = annual no. of cremations; unit of EF = μg TEQ/cremation.
[b]Production = annual consumption of tobacco items; unit of EF = pg TEQ/item.
[c]Unit of EF = ng TEQ t^{-1}.
[d]Local EF for chemically enhanced primary treatment (CEPT) used for all sewage with sludge removal (CEPT + secondary) in the absence of reliable dataset on secondary treated sewage, assuming that sewage quality after secondary treatment would be equal/better than that of primary treatment.
[e]Unit of sludge production = t dw a^{-1}; unit of residue EF = μg TEQ t^{-1} dw.

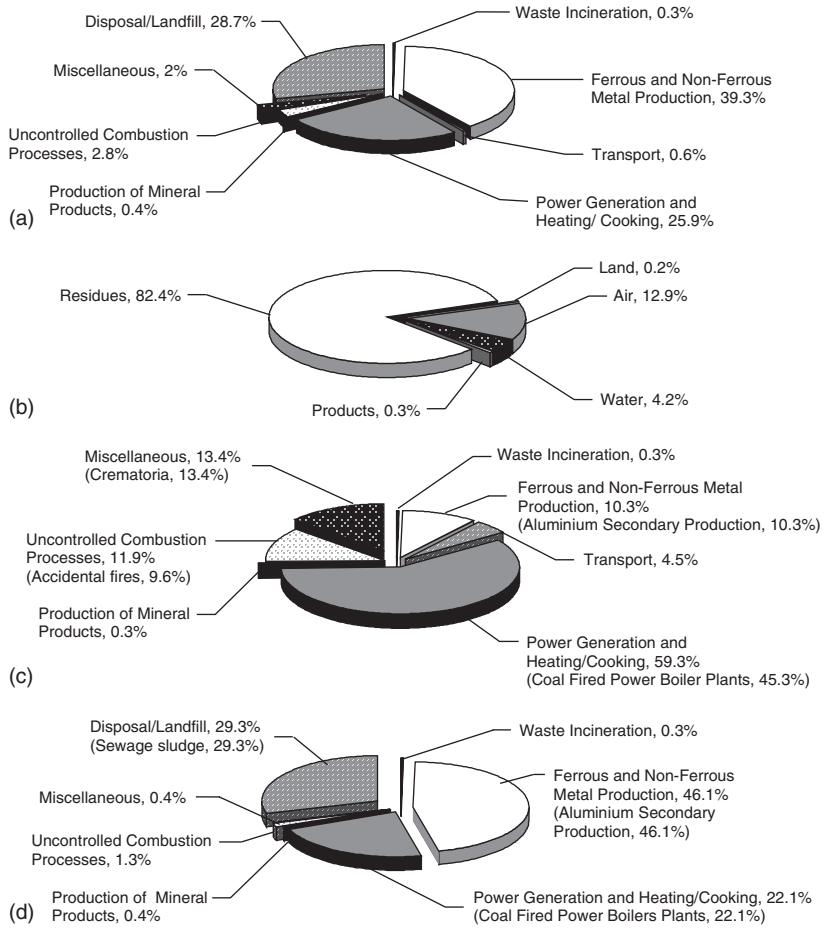

Figure 7.2. Percentage contribution of individual source categories to annual dioxin/furan emission in 2003 (a) total emission; (b) on a vector basis; (c) emission to air and (d) emission to residues.

four classes of activities together accounted for 78.6% of the total annual air emission while the other 18 classes were responsible for the remaining 21.4%. Contributions from the ''coal fired power boilers plants'' and ''crematoria'' were well characterized and the emissions were calculated based on locally developed EFs. Estimation of local dioxin/furan emission from the ''aluminium production (secondary)'' and ''accidental fires'' activities was made by adopting the more conservative, generic EFs published in the UNEP Standardized Toolkit (2003). Considering that the reported local annual aluminium production (secondary) activity also

appeared unusually high compared with the values reported in other Asian and European regions, the annual dioxin/furan emission from this class of industrial activity would be likely to be over-estimated. While the contribution from "accidental fires" could hardly be controlled, efforts to establish a more representative local annual activity and emission level from the "aluminium production (secondary)" process would be necessary to better understand and assess the performance of the industry and its contribution to local air dioxin/furan release.

The 2003 annual dioxin/furan release to the local marine environment was 0.86 g TEQ, contributed solely by the "Disposal/Landfill" category. Within this category, the two major contributing classes of emission sources were "sewage with no sludge removal" (92.4%) and "sewage with sludge removal" (7.0%), while the landfill leachate contributed to only a minor 0.6%. Given the limited local data available and considering the large quantity of annual sewage production in Hong Kong, further analysis of sewage discharge at source would be warranted for a better estimate of its contribution to the local annual dioxin/furan release.

For release "to land", the only category with an EF available was "Uncontrolled Combustion Processes". Burning of biomass in forest/grassland fires contributed to the total annual land dioxin/furan release of 0.05 g TEQ. There was a general lack of information on other potential local land sources of dioxin/furan release.

The 2003 annual dioxin/furan release "in products" was 0.06 g TEQ, contributed solely by the composting of livestock wastes process within the "Disposal/Landfill" category. Release from composting of livestock wastes was estimated using a UNEP generic EF for composting of garden and kitchen wastes as surrogate. A local EF specific to livestock waste would need to be determined for a better estimate of contribution from this class of emission source. The compost was used as product for landscaping and horticulture work. There was a general lack of information on other potential local sources of dioxin/furan release in products.

The 2003 annual dioxin/furan release "in residues" was 16.7 g TEQ. The relative contribution of different source categories to emission in residues is presented in Fig. 7.2d. The top three contributing classes were: (a) "aluminium production (secondary)" (46.1%); (b) "disposal of sludge from sewage treatment works" (29.3%) and (c) "coal fired power boilers plants" (22.1%). These three classes of activities together accounted for 97.5% of the total local annual dioxin/furan release in residues. Estimates of annual dioxin/furan release from the "aluminium production (secondary)", "sludge disposal" and "coal fired power boiler plants" activities were made by adopting the conservative, generic EFs published in the UNEP Standardized Toolkit (2003). Hong Kong specific, local EFs

should be generated to better estimate their relative contribution to the annual dioxin/furan release profile in residues.

7.3.2.3. Annual release of dioxins/furans per capita

In 2003, the calculated annual release of dioxins/furans in Hong Kong per capita was 2.96×10^{-6}. A comparison with the five Asian countries that participated in the 2003 Asian UNEP Toolkit Project (UNEP Chemicals, 2003c) indicated that the total annual dioxin/furan release per capita in Hong Kong was similar to that of Jordon, Lebanon, the Philippines or Vietnam, but significantly lower than that reported in Brunei (Fig. 7.3). On a vector basis, Hong Kong's annual air dioxin/furan emission per capita was ranked the 2nd lowest among 26 countries/regions in Asia (UNEP Chemicals, 2003c; Government of Japan, 2004), North America (Environment Canada, 2005; USEPA, 2005), Europe (European Commission, 2000) and Australia (Australian Government, 2004a). The local annual water or residue dioxin/furan releases per capita was generally comparable to the range reported in most countries/regions under comparison.

7.3.2.4. Release of polychlorinated biphenyls as by-products

There was comparatively little information on the release of PCBs as unintentionally produced POPs. PCBs are known to be produced as unintentional combustion by-products of incineration and combustion processes. The current UNEP Toolkit (2003) does not give EFs for PCBs. There was little information on the release of PCBs from known local emission sources. A few measured emission data were available from a number of incinerators, crematoria and power plants to permit local EFs to be derived and the annual release of dioxin-like PCBs to be estimated for these processes. Results indicated that the measured total annual air emission of dioxin-like PCBs was very low (less than 0.1 g TEQ). Compilation of the local dioxin-like PCB emission profile would await further emission data from other potential sources.

7.4. Environmental levels of POPs

"POPs in the environment" has been an area of increasing global concern in recent years and has received close attention in Hong Kong. The environmental POPs inventory (2000–2004) was compiled to give an overview of the existing status of POPs contamination in the environment of Hong Kong and to provide the basis for assessing their environmental and human health impacts (EPD, 2005b). The major sources of

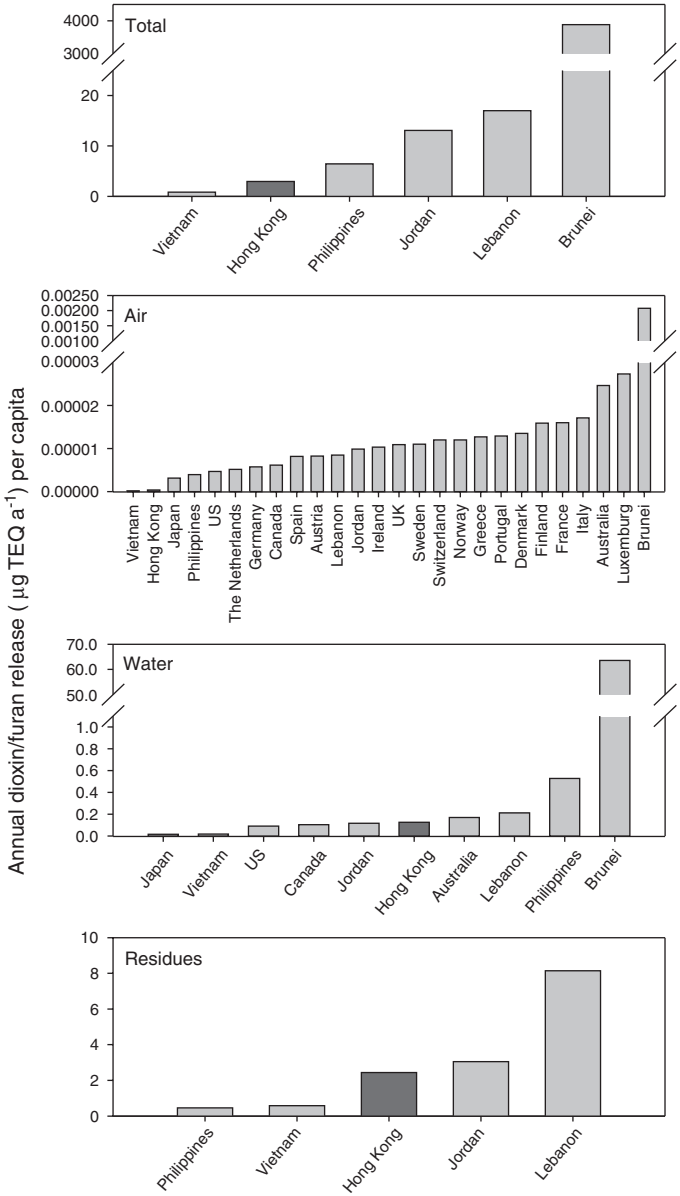

Figure 7.3. Comparison of annual dioxin/furan release on a "per capita" basis in Hong Kong and other countries.

information that contributed to the inventory were reports of the EPD routine monitoring programmes and government-funded consultancy studies. Study reports generated by local academia and relevant publications in the open literature were also critically reviewed for their suitability to be included in the inventory.

7.4.1. Contamination levels of POPs in environmental media

A summary of the levels of POPs contamination reported in the environmental media (ambient air, surface water, sediment and soil, and vegetation) of Hong Kong in 2000–2004 is presented in Table 7.4. The mean environmental levels of POPs were weighted arithmetic sample means calculated based on samples analyzed and reported in individual studies. If the level of a POP chemical was found to be below the analytical method detection limit (DL) in all samples analyzed in a particular medium, the mean value was reported as "0". If a measurable level (i.e., $>$DL) of a POP chemical was reported in some or all samples analyzed in a particular medium, the mean value was calculated by assuming a value of 0.5DL for sample levels of $<$DL, unless stated otherwise.

7.4.1.1. Ambient air

Ambient levels of total PCBs and dioxins/furans had been routinely monitored at two general urban locations (Tsuen Wan and Central & Western) in Hong Kong since mid-1997 (EPD, 2004a). The 24-hour ambient air samples were collected monthly and analyzed for PCBs and dioxins/furans to provide the annual and seasonal trends of their presence in the atmosphere. In addition, dioxin data collected from a year-round dioxin-monitoring project that targeted suspected local emission sources at Tsing Yi (where the CWTC is located) (2000–2004) and from an ad hoc study conducted at Tai Mo Shan (a rural site at the highest point in Hong Kong) (2000–2001) were included in the calculation of the mean local ambient air dioxin/furan concentration (Sin et al., 2002; Louie and Sin, 2003). The average ambient air concentration of PCBs and dioxins/furans measured for the period 2000–2004 was 0.48 ng m^{-3} and 0.06 pg I-TEQ m^{-3}, respectively. Data on the level of local ambient air POPs pesticides were very limited. The few data on ambient air POPs pesticides concentrations reported in the inventory were from ad hoc measurements taken in a single sampling event at the Tai Mo Shan Station. Relatively low concentrations of DDT (0.05 ng m^{-3}), heptachlor (0.03 ng m^{-3}) and HCB (0.16 ng m^{-3}) were found.

Table 7.5 compares the reported ambient air concentrations of dioxins/furans in Hong Kong and other urban locations worldwide. Overall, the mean local ambient air dioxin concentration of 0.06 pg I-TEQ m^{-3} measured in 2000–2004 was highly comparable to the range reported in most other urban locations in Asia (Government of Japan, 2005), Europe (Buckland et al., 1999; Gras and Müller, 2004), Australia (Taucher et al., 1992), New Zealand (Buckland et al., 1999) and the US (Riggs et al., 1996), and was lower than that reported in Korea (Park and Kim, 2002) or Spain (Gras and Müller, 2004).

7.4.1.2. Surface water

Data on marine water POPs were mainly generated from two consultancy studies on toxic substances pollution in Hong Kong commissioned by the EPD (EPD, 2003a,b). The 2004 EPD in-house toxic substance monitoring programme (EPD, 2005a) also contributed to the inventory, especially on the marine water levels of DDT, PCBs and dioxins/furans. None of the nine POPs pesticides was detected at any of the sampling sites. PCBs was found to be below DL in all 180 water samples analyzed from 38 sites located throughout Hong Kong. The 2,3,7,8-TCDD was not detected in any of the 104 local marine water samples analyzed in 2000–2004. The calculated mean concentration of dioxins/furans was 0.55 (lower bound, assuming zero for individual congener level $<$DL) and 5.21 (upper bound, assuming 1/2DL for individual congener level $<$DL) pg I-TEQ L^{-1}, respectively. There were no data available on the level of POPs in inland waters of Hong Kong.

The calculated mean (lower bound) dioxin/furan concentration of 0.55 pg TEQ L^{-1} fell at the high end of the range (0.24–0.40 pg TEQ L^{-1}) reported in public waters of Japan in 1998–2000 (Government of Japan, 2002). Little other marine water dioxin/furan data from elsewhere were available for comparison.

7.4.1.3. Surface sediment

Contamination of local marine sediment by toxic chemical pollutants has been relatively well documented. The marine sediment POPs inventory was compiled based primarily on data generated from a major consultancy study on local toxic substances pollution (EPD, 2003a), EPD routine and ad hoc marine monitoring programmes of 2003/2004 and study reports published by local academia (Zheng et al., 2000; Müller et al., 2002; Tam and Yao, 2002; Wong et al., 2001, 2005). With the exception of mirex and toxaphene, all other POPs pesticides were detected in the

Table 7.4. Mean levels of POPs contamination in the environment of Hong Kong in 2000–2004

Chemical	Ambient air (ng m^{-3})			Surface water (ng L^{-1})			Surface sediment (μg kg^{-1} dw)			
				Marine water			Marine sediment			River Sediment
	No. of sites	No. of samples	Mean[b] (min–max)	No. of sites	No. of samples	Mean[c] (min–max)	No. of sites	No. of samples	Mean[c] (min–max)	No. of sites
Aldrin	1	4	0	22	84	0	28	54	4.7 (1.30–9.2)	
Chlordane				22	84	0	28	54	4.2 (<0.01–<10.0)	
DDT	1	4	0.05 (0–0.10)	32	104	0	46	168	6.81 (0.30–33.1)	5
Dieldrin	1	4	0	22	84	0	28	54	5.19 (2.40–11.0)	
Endrin	1	4	0	22	84	0	28	54	3.86 (<0.01–<10.0)	
Heptachlor	1	4	0.03 (0–0.09)	22	84	0	28	54	4.48 (<0.01–<100)	
HCB	1	4	0.16 (0.05–0.23)	22	84	0	22	54	5.98 (0.05–23.8)	
Mirex				20	80	0	20	40	0	
Toxaphene				22	84	0	20	40	0	
PCBs	2	209	0.48 (0.01–1.81)	38	180	0	118	381	24.1 (0.63–330)	5
Dioxins/furans[a]	4	271	0.06 (0.04–0.35)	32	104	0.55[d], 5.21[e] (0.0005–24.4)	52	89	9.1 (2.28–38.7)	

[a]Unit of dioxins/furans in ambient air = pg I-TEQ m^{-3}; in surface water = pg I-TEQ L^{-1}; in surface sediment/surface soil/vegetation = ng I-TEQ kg^{-1} dw.

[b]"0" indicates values were <DL; DL of pesticides in ambient air = 0.02 ng m^{-3}; if mixed values of >DL and <DL were recorded in a sample pool, mean value was calculated by assuming "0" for samples <DL calculated by assuming "0.5DL" for samples <DL.

[c]"0" indicates values were <DL; DL DDT, all other pesticides and PCB in marine water = 15, 10 and 100 ng L^{-1}, respectively; DL of mirex and toxaphene in marine sediment = 10 μg kg^{-1} dw; if mixed values of >DL and <DL were recorded in a sample pool, mean values was calculated by assuming "0.5DL" for samples <DL.

[d]The value was calculated assuming zero for individual congener level <DL. 2,3,7,8-TCDD<DL in all 104 samples.

[e]The value was calculated assuming 0.5DL for individual congener level <DL.

Surface sediment (μg kg^{-1} dw)		Surface soil (μg kg^{-1} dw)			Vegetation (μg kg^{-1} dw)					
River Sediment					Ground vegetation			Tree bark		
No. of samples	Mean (min–max)	No. of sites	No. of samples	Mean[c] (min–max)	No. of sites	No. of samples	Mean (min–max)	No. of sites	No. of samples	Mean (min–max)
15	4.96 (2.82–8.63)	46	46	0.52 (<0.004–6.00)						
		46	46	0.01 (<0.004–0.10)						
		46	46	0.01 (<0.001–0.30)						
15	193 (43.0–461)	46	46	0.1 (<0.004–0.16)						
		5	40	5.33 (0.35–32.8)	5	40	2.13 (0.29–14.1)	5	10	1.47 (0.49–3.57)

Table 7.5. Comparison of ambient air concentrations of dioxins/furans (PCDD/Fs) in Hong Kong and other urban locations

Location	Period	Concentrations of PCDD/Fs (pg I-TEQ m^{-3}) mean (min–max)	Reference
Hong Kong, China	2000–2004	0.06 (0.04–0.35)	EPD, 2005b
Australia	1992	0.02–0.06	Taucher et al., 1992
Belgium	1993	0.02–0.59	Wevers et al., 1993
Germany	1993–1997	0.071 (0.009–0.231)	Buckley-Golder, 1999
Japan	2003	0.068 (0.0066–0.72)	Government of Japan, 2005
Korea	2000–2001	0.282 (0.017–0.803)	Park and Kim, 2002
New Zealand	1996–1997	0.0536 (0.00699–0.234)	Buckland et al., 1999
Portugal	1998	0.036–0.49	Gras and Müller, 2004
Spain	1994–2000	0.158–0.264	Gras and Müller, 2004
UK	1998	0.02–0.51	Gras and Müller, 2004
USA	1996	0.09–0.45	Riggs et al., 1996

marine sediment sampled at over 20 locations throughout Hong Kong. The mean sediment pesticide concentrations ranged $<$DL–6.81 μg kg^{-1} dw. DDT (6.81 μg kg^{-1} g dw), HCB (5.98 μg kg^{-1} dw) and dieldrin (5.19 μg kg^{-1} dw) were found to be the major POPs pesticide contaminants. PCBs and dioxins/furans were widely distributed, with sediment levels ranging 0.63–330 μg kg^{-1} dw and 2.28–38.7 ng I-TEQ kg^{-1} dw for PCBs and dioxins/furans, respectively.

Information on POPs in local river sediments was sketchy. One ad hoc study of the inland water systems in Hong Kong was available and the study data were reported in this inventory (Zhou et al., 1999). River sediment samples were taken at 15 sites along the 3 main local rivers (Shing Mun River, Tai Po River and Lam Tsuen River in the New Territories) and analyzed for DDT and PCBs. The mean level of DDT contamination was 4.96 μg kg^{-1} dw, while that of PCB contamination was 193 μg kg^{-1} dw.

Comparison of the level of POPs contamination in marine sediment of Hong Kong and other countries/regions was made based on best available data and the results are summarized in Table 7.6. Overall, the level of POPs measured in local marine surface sediment was comparable to those reported in most other locations around the world. For DDT, a POPs pesticides of regional interest, the level of mean local sediment contamination was found to be well within the range reported in the Pearl River Estuary (Li et al., 2001), the east coast estuaries of China (Yuan et al., 2001), the coast of Argentina (Menone et al., 2001), the Netherlands (Stronkhorst and Hattum, 2003) and Pakistan (Sanpera et al., 2003), and

Table 7.6. Comparison of the level of POPs contamination in marine sediment of Hong Kong and other urban locations

Location	Period	DDT[b]	Dieldrin[b]	Endrin[b]	Heptachlor[b]	HCB[b]	PCBs[b]	PCDD/Fs[c]	Reference
Hong Kong, China	2000–2004	6.81 (0.30–33.1)	5.19 (2.40–11.0)	3.86 (<0.01–<10.0)	4.48 (<0.01–<10.0)	5.98 (0.05–23.8)	24.1 (0.63–330)	9.10 (2.28–38.7)	EPD, 2005b
Argentina	1996	0.77–3.14	0.10–0.24	0.05–0.26	10.7–12.3	<0.0013–0.053	0.31–1.61		Menone et al., 2001
Australia	2001–2002							0.67 (0.000002–3.9)	Australian Government, 2004b
Baltic Sea	1993							26–71	Koistinen et al., 1997
China									
East Coast Estuaries	1996, 1999	6.17–73.7					1.69–14.3		Yuan et al., 2001
Pearl River Delta	1997						26.7–32.0		Mai et al., 2005
Pearl River Estuary	1997	1.56–26.5	ND–0.19	ND–0.61	0.47–1.62				Li et al., 2001
Dutch	1999–2000	<1–40				<1–67			Stronkhorst and Hattum, 2003
Finland	1999							0.70–100	Fiedler et al., 1999
Japan, Tokyo Bay	2003[a]							3.30–52.0	Hosomi et al., 2003
Korea	2000							0.01–5.50	Moon et al., 2001
New Zealand	1999[a]							0.53 (0.081–2.71)	Scobie et al., 1999
North Sea	1994[a]							0.60–2.80	Tyler et al., 1994
Pakistan	1999–2000	7.80					2.20		Sanpera et al., 2003
South Africa	2003[a]							0.20–22.0	Vosloo and Bouwman, 2003
Sweden	1999							0.80–207	Fiedler et al., 1999
USA									
Florida Bay	2003[a]							0.50–77.8	Hemming et al., 2003
Santa Monica Bay	1997	31.0–290					2.50–924		Bay et al., 2003
Tampa Bay	1995–1999		0.33	0.18	0.78				Grabe and Barran, 2004
New York Harbour	1994–1996						80–1410		Huan et al., 1998
	2003[a]							23–880	Litten et al., 2003

Note: ND = not detected.
[a]Year of data reporting.
[b]Expressed as mean (min–max); unit = μg kg^{-1} dw.
[c]Expressed as mean (min–max); unit = ng I-TEQ kg^{-1} dw.

much lower than that in the California coast (Bay et al., 2003). For PCBs, the mean local sediment contamination level fell at the lower end of the range reported in New York Harbour (Huan et al., 1998) and the Californian coast (Bay et al., 2003), was comparable to that found in the PRD (Mai et al., 2005) and higher than that reported in the coast of Argentina (Menone et al., 2001) and Pakistan (Sanpera et al., 2003). For dioxins/furans, the measured local sediment contamination level was comparable to that found in Tokyo Bay (Hosomi et al., 2003) or the coast of South Africa (Vosloo and Bouwman, 2003), at the higher end of the range reported in Australia (Australian Government, 2004b), Korea (Moon et al., 2001), New Zealand (Scobie et al., 1999) and the North Sea (Tyler et al., 1994), but much lower than that reported in New York Harbour (Litten et al., 2003), the coast of Sweden and Finland (Fiedler et al., 1999) and the Baltic Sea (Koistinen et al., 1997).

7.4.1.4. Surface soil

The soil POPs pesticide inventory was compiled based on one ad hoc territory-wide background monitoring of surface soil in Hong Kong (NISS/CAS and HKBU, 2004). Rural surface soil samples were collected from 46 locations across the region, mostly woodland and grassland and analyzed for DDT, endrin, HCB and PCBs. The level of POPs pesticides contamination in the soil was generally very low, with mean values ranging from 0.01 (endrin and HCB) to 0.52 $\mu g\ kg^{-1}$ dw (DDT). The mean soil PCBs concentration (0.1 $\mu g\ kg^{-1}$ dw) was found to be 241 times and 1930 times lower than that found in the local marine and river sediments, respectively. Dioxins/furans were measured in an EPD-commissioned monitoring consultancy study in 2001/2002 that targeted potential local dioxin emission sources (EPD, 2004b). Forty soil samples were taken from five locations near landfill sites, the CWTC and livestock waste composting sites. Low soil dioxin/furan concentrations ranging 0.35–32.8 ng I-TEQ kg^{-1} dw were recorded.

The level of DDT contamination of surface soil in Hong Kong recorded in 2000–2004 was found to be the lowest among those reported in most other urban locations of Mainland China (Chau, 2005; Nakata et al., 2005), in Cuba (UNEP Chemicals, 2003d), India (UNEP Chemicals, 2003d), the subtropical Atlantic (Ribes and Grimalt, 2002) and the US (Aigner et al., 1998) (Table 7.7). While the mean local soil PCBs concentration was generally comparable to that found in most other urban locations of China (Nakata et al., 2005), it was at the lower end of the range reported in the subtropical Atlantic (Ribes and Grimalt, 2002), Amazon (Buckland et al., 1998a) and Panama regions (Meijer et al., 2003).

Table 7.7. Comparison of the level of POPs contamination in surface soil of Hong Kong and other urban locations

Location	Period	DDTs[b]	PCBs[b]	PCDD/Fs[c]	Reference
Hong Kong, China	2000–2004	0.52 (<0.004–6.00)	0.10 (<0.004–0.16)	5.33 (0.35–32.8)	EPD, 2005b
Amazon	1998[a]		0.1–7.7		Buckland et al., 1998a
	1998[a]			0.02–0.4	Buckland et al., 1998a
China					
Haining	2001	83±83			Nakata et al., 2005
	2001		0.05±0.01		Nakata et al., 2005
Pearl River Delta	2005[a]	15–125			Chau, 2005
Shanghai	2001	34±23			Nakata et al., 2005
	2001		0.41±0.20		Nakata et al., 2005
Shaoxing	2001	0.70±0.39			Nakata et al., 2005
	2001		<0.01		Nakata et al., 2005
Cuba	1983	60–350			UNEP Chemicals, 2003d
France	1998			0.2–17	UNEP Chemicals, 2002
India	2003[a]	5–49			UNEP Chemicals, 2003d
Italy	2002[a]			1.0–6.2	UNEP Chemicals, 2002
New Zealand	1998[a]			0.26–6.67	Buckland et al., 1998a
Panama	2003[a]		0.026–97		Meijer et al., 2003
Portugal	2002[a]			2.04–16.4	Coutinho et al., 2002
Spain	2001[a]			0.15–24.2	Eljarrat et al., 2001
Subtropical Atlantic	2002[a]	5.4 (0.01–40)			Ribes and Grimalt, 2002
	2002[a]		1.2 (0.04–9.2)		Ribes and Grimalt, 2002
USA, Corn Belt	1995–1996	9.63			Aigner et al., 1998

[a]Year of data reporting.
[b]Expressed as mean (min–max); unit = μg kg^{-1} dw.
[c]Expressed as mean (min–max); unit = ng I-TEQ kg^{-1} dw.

For dioxins/furans, the mean level of contamination of local soil was comparable to that reported in most European countries (Eljarrat et al., 2001; Coutinho et al., 2002; UNEP Chemicals, 2002) and higher than that found in the Amazon region (Buckland et al., 1998a).

7.4.1.5. Vegetation

The level of dioxin/furan contamination of ground vegetation and tree barks was measured in an EPD-commissioned monitoring consultancy study in 2001/2002 that targeted suspected local dioxin emission sources (EPD, 2004b). Forty samples of ground vegetation and 10 tree bark samples were taken from 5 locations near landfills, the CWTC and livestock waste composting sites. The mean level of dioxin/furan contamination of ground vegetation and tree barks in the vicinity of potential local sources of dioxin emission was 2.13 and 1.47 ng I-TEQ kg^{-1} dw,

respectively. No data on POPs pesticides contamination of local vegetation were available.

7.4.2. Contamination levels of POPs in aquatic biota

Table 7.8 summarizes the level of POPs contamination reported in representative freshwater and marine biota (fish, shellfish, water bird eggs and marine mammals) of Hong Kong in 2000–2004. The mean tissue levels of POPs were weighted arithmetic means calculated based on tissue samples analyzed and reported in individual studies.

7.4.2.1. Freshwater fish

There was a general paucity of information on POPs in local freshwater biota. Ad hoc studies reported by local academia contributed to all the data compiled in this section of the inventory (Zhou et al., 1999; Kong, 2004). Four freshwater fishes from a few (1–3) sampling sites were analyzed. DDT was the only POPs pesticide detected, with a mean tissue concentration of 6.78 μg kg^{-1} ww. PCBs was measured in only one fish species from two locations and a mean tissue level of 57.8 μg kg^{-1} ww was reported.

7.4.2.2. Marine fish and shellfish

Unlike the freshwater biota, POPs in local marine fish and shellfish were relatively well studied. Data were retrieved primarily from two toxic substances consultancy studies (EPD, 2003a,b), the EPD ad hoc baseline survey (EPD, 2003c), and the 2004 CEDD Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau (CEDD, 2005). Ad hoc studies by local academia also contributed significantly to the data pool (Lam and Lam, 2004; So et al., 2005; Wong et al., 2005).

Common local marine fish investigated included the pony fish (*Leiognathus brevirostris*), burrowing goby (*Trypauchen vagina*), ovate sole (*Solea ovata*), gizzard shad (*Clupanodon punctatus*), flathead mullet (*Mugil cephalus*), Indian mackerel (*Rastrelliger kanagurta*), rabbit fish (*Siganus oramin*) and tilapia (*Tilapia spp.*). Common local marine shellfish investigated included shrimps (*Palaeomonetes spp.*, *Metapenaeus spp.*, *Oratosquilla spp.*), crabs (*Varuna litterata*), bivalves (*Perna viridis*) and molluscs (*Bucardium fimbriatum*, *Anadara ferruginea*). Most POPs pesticides were detected in a variety of marine fish and shellfish sampled at multiple sites throughout Hong Kong. DDT, endrin and heptachlor were found to be the major POPs pesticide contaminants of both marine fish

Table 7.8. Mean levels of POPs contamination in aquatic biota of Hong Kong in 2000–2004

Chemical	Freshwater fish (μg kg^{-1} ww)			Marine fish (μg kg^{-1} ww)			Marine shellfish (μg kg^{-1} ww)			Water bird eggs (μg kg^{-1} ww)			Marine cetaceans (μg kg^{-1} ww)		
	No. of sites	No. of genus	Mean[b] (min–max)	No. of sites	No. of genus	Mean[b] (min–max)	No. of sites	No. of genus	Mean[b] (min–max)	No. of sites	No. of genus	Mean (min–max)	No. of sites	No. of genus	Mean (min–max)
Aldrin	1	4	0	3	7	28.9 (0.08–<100)	11	7	0						
Chlordane				3	7	3.8 (0.39–16.4)	10	6	1.12 (0.11–5.02)	2	2	156 (31.0–280)			
DDT	3	4	6.78 (3.32–10.9)	13	14	27.6 (0.83–99.0)	21	14	7.73 (0.16–28.6)	2	2	900 (600–1200)	NR	1	32,763
Dieldrin	1	4	0	9	8	2.18 (<0.08–15.8)	17	9	0.21 (<0.01–0.40)						
Endrin	1	4	0	9	8	28.1 (0.14–<100)	17	9	5.86 (<0.01–25.2)						
Heptachlor	1	4	0	9	8	25.3 (0.18–<100)	17	9	5.99 (<0.01–25.1)						
HCB				11	8	5.8 (<0.20–18.1)	18	7	0.8 (0.13–3.43)						
Mirex				2	4	0	2	2	0				NR	2	178 (70.5–286)
Toxaphene				2	4	1.33 (0.25–2.36)	2	2	0				NR	2	32 (19.7–44.2)
PCBs	2	1	57.8	16	13	22.6 (<2.00–153)	23	11	13.8 (<1.00–55.0)	2	2	595 (230–960)	NR	1	8190
Dioxins/furans[a]				2	4	0.33 (0.09–0.57)	2	2	0.53 (0.21–0.85)						

Note: NR = multiple sites, exact number not recorded.

[a]Unit of dioxins/furans = ng I-TEQ kg^{-1} ww.

[b]"0" indicates values were <DL; DL of pesticides in freshwater fish = 0.01 μg kg^{-1} ww; DL of aldrin/mirex and toxaphene in marine fish/shellfish = 100 and 0.2 μg kg^{-1} ww, respectively; if mixed values of >DL and <DL were recorded in a sample pool, mean value was calculated by assuming "0.5DL" for samples <DL.

and shellfish, while aldrin was prominent only in the marine fish. The mean concentration of PCBs in local marine fish and shellfish was 22.6 and 13.8 μg kg^{-1} ww, respectively. Dioxins/furans were detected in all fish and shellfish genera examined. The mean level of dioxin/furan contamination of marine fish was 0.33 ng I-TEQ kg^{-1} ww and that of marine shellfish was 0.53 ng I-TEQ kg^{-1} ww. With the exception of dioxins/furans, the level of POPs contamination was found to be generally higher in marine fish than shellfish.

Table 7.9 compares the level of POPs contamination of marine fish in Hong Kong and other countries/regions. On the whole, the level of POPs contamination of local fish was comparable to that found in fish of most other coastal locations around the world. The concentration of HCB in local marine fish appeared high compared to the extremely low range reported in many Asian countries (Monirith et al., 1999; Ueno et al., 2003), Brazil, the Mediterranean (Stefanelli et al., 2002) and North Pacific regions (Ueno et al., 2003). The mean concentration of DDT in marine fish of Hong Kong was similar to that of the Mainland coast, the Japanese Sea (Ueno et al., 2003) and the Mediterranean coast (Stefanelli et al., 2002), but slightly higher than the range reported in most South East Asia locations (Monirith et al., 1999; Ueno et al., 2003). The mean concentration of PCBs in local marine fish was generally comparable to that reported in the Mainland coast, the Brazilian coast and the North Pacific (Ueno et al., 2003), and fell at the lower end of the range recorded in the Mediterranean coast (Stefanelli et al., 2002) and the Japanese Sea (Ueno et al., 2003). The dioxin/furan concentration in marine fish of Hong Kong was in the same range as that of the Adriatic Sea (Bayarri et al., 2001) and the San Francisco Bay (Fairey et al., 1997), above that found in Australia (Australian Government, 2004b) and the Finnish coast (UNEP Chemicals, 2002), but below the range reported in the Baltic Sea (Kiviranta et al., 2003), Tokyo Bay (Tsutsumi et al., 2003), New York Harbour (Litten et al., 2003) and Southern Norway (Knutzen et al., 2003).

Similarly, a comparison was made on the level of POPs contamination of marine shellfish in Hong Kong and other countries/regions and the results are presented in Table 7.10. The concentration of POPs pesticides and PCBs in local marine shellfish was found to be generally comparable to that reported in most Asian countries (Tanabe et al., 2000; Monirith et al., 2000, 2003; Bayen et al., 2004) and Australia (Australian Government, 2004b). Exceptions were the level of DDT contamination which was significantly lower than that in the Mainland coast (Monirith et al., 2003) and the concentration of PCBs which fell at the very low end of the range reported in the Mediterranean coast of Egypt (El Nemr et al., 2003). The mean dioxin/furan concentration in local marine shellfish was similar

Table 7.9. Comparison of the level of POPs contamination in marine fish of Hong Kong and other coastal locations

Location	Period	Chlordane[b]	DDT[b]	HCB[b]	PCBs[b]	PCDD/Fs[c]	Reference
Hong Kong, China	2000–2004	3.80 (0.39–16.4)	27.6 (0.83–99.0)	5.80 (<0.20–18.1)	22.6 (<2.00–153)	0.33 (0.09–0.57)	EPD, 2005b
Australia	2004[a]					0.0054–0.095	Australian Government, 2004b
Baltic Sea	2003[a]					15.0 (1.77–74.0)	Kiviranta et al., 2003
Brazil	1997–2001	3.40 (1.73–4.75)	4.97 (2.43–8.10)	0.13 (0.097–0.162)	24.8 (18.4–31.9)		Ueno et al., 2003
Cambodia	1997	<0.01–0.23	0.30–4.00	<0.01–0.18	0.07–1.20		Monirith et al., 1999
China							
East China Sea	1997–2001	3.65–4.76	18.6–35.3	0.078–0.173	34.7–37.1		Ueno et al., 2003
South China Sea	1997–2001	3.08	54.3	0.178	11.3		Ueno et al., 2003
Finnish Coast	2002[a]					0.0029–0.024	UNEP Chemicals, 2002
Germany, Baltic Sea	2002[a]					1.90	Karl et al., 2002
Indonesia	1997–2001	0.53 (0.51–0.56)	2.11 (1.77–2.38)	0.09 (0.09–0.09)	3.40 (2.86–3.94)		Ueno et al., 2003
Italy, Adriatic Sea	2001[a]					0.23–1.07	Bayarri et al., 2001
Japan	1997–2001	10.5 (6.08–13.3)	48.5 (41.8–54.2)	0.49 (0.40–0.60)	85.5 (77.9–114)		Ueno et al., 2003
Tokyo Bay	2003[a]					0.05–23.1	Tsutsumi et al., 2003
Mediterranean, Sicilian coast	1999	1.37 (0.30–4.70)	52.0 (0.95–300)	0.22 (<0.01–0.92)	74.9 (21.4–325)		Stefanelli et al., 2002
North Pacific	1997–2001	0.90–3.05	2.13–4.13	0.14–0.67	7.81–19.1		Ueno et al., 2003
Norway	2003[a]					1.90–26.2	Knutzen et al., 2003
Pakistan	1999 -2000		6.97		1.26		Sanpera et al., 2003
Philippines	1997–2001	0.49 (0.41–0.70)	2.84 (1.62–3.77)	0.049 (<0.04–0.09)	5.51 (4.06–7.54)		Ueno et al., 2003
USA							
New York Harbour	2003[a]					1.90–29.0	Litten et al., 2003
San Francisco Bay	1997[a]					0.12–1.75	Fairey et al., 1997

Note: ND = not detected.
[a]Year of data reporting.
[b]Expressed as mean (min–max); unit = μg kg^{-1} ww.
[c]Expressed as mean (min–max); unit = ng I-TEQ kg^{-1} ww.

Table 7.10. Comparison of the level of POPs contamination in marine shellfish of Hong Kong and other coastal locations

Location	Period	Chlordane[b]	DDT[b]	HCB[b]	PCBs[b]	PCDD/Fs[c]	Reference
Hong Kong, China	2000–2004	1.12 (0.11–5.02)	7.73 (0.16–28.6)	0.80 (0.13–3.43)	13.8 (<1.00–55.0)	0.53 (0.21–0.85)	EPD, 2005b
Australia	2004[a]					0.012–0.9	Australian Government, 2004b
Corio Bay, Victoria	1992	0.038–0.18		0.005–0.012	0.65–4.55		Prest et al., 1995
Cambodia	2000[a]	0.12±0.03	0.50±0.50	0.02±0.01			Tanabe et al., 2000
China (Mainland)	1999, 2001	3.0 (0.20–10.0)	240 (15.0–640)	1.30 (<0.01–13.0)	2.50 (0.30–13.0)		Monirith et al., 2003
Egypt, Mediterranean Coast	2000				7.70–436		El Nemr et al., 2003
India	2000[a]	0.50±0.50	11.0±10.0	0.06±0.11			Tanabe et al., 2000
Indonesia	2000[a]	0.30±0.10	1.10±0.90	0.01±0.01			Monirith et al., 2000
Italy, Adriatic Sea	2001[a]					0.07–0.24	Bayarri et al., 2001
Japan	1994	6.0 (1.70–17.0)	3.50 (0.80–12.0)	0.08 (<0.01–0.30)	30.0 (7.40–84.0)		Monirith et al., 2003
	2003[a]					0.07–1.10	Tsutsumi et al., 2003
Korea	2001[a]					0.001–1.20	Choi et al., 2001
Malaysia	2000[a]	2.20±3.20	1.40±1.50	0.01±0.01			Monirith et al., 2000
Mediterranean, Baltic Sea	2001[a]	0.06–0.09					Falandysz et al., 2001
New Zealand	1999[a]					0.015–0.26	Scobie et al., 1999
Norway	2002[a]					1.60–3.0	Karl et al., 2002
Philippines	2000[a]	3.70±3.70	1.70±1.20	0.01±0.01			Tanabe et al., 2000
Singapore	2002	1.40 (0.43–3.30)	3.40 (0.51–12.0)	<0.01			Bayen et al., 2004
South Korea	1998	0.55 (0.20–1.20)	3.50 (0.70–7.50)	0.05 (<0.01–0.20)	3.70 (0.80–7.20)		Monirith et al., 2003
Thailand	1997[a]	1.20±1.40	5.60±8.10	0.05±0.04			Kan-atireklan et al., 1997
USA							
Acata Bay	2003[a]					0.22(0.16–0.25)	Wenning et al., 2003
New York Harbour	2003[a]					1.50–38.0	Litten et al., 2003
Vietnam	2000[a]	0.30±0.40	44.0±111	0.01±0.02			Tanabe et al., 2000

Note: ND = not detected.
[a]Year of data reporting.
[b]Expressed as mean (min–max), min–max or mean±SD; unit = μg kg^{-1} ww.
[c]Expressed as mean (min–max) or min–max; unit = ng I-TEQ kg^{-1} ww.

to the low range reported in Japan (Tsutsumi et al., 2003), Korea (Choi et al., 2001), Australia (Australian Government, 2004b), New Zealand (Scobie et al., 1999) and a number of European countries (Bayarri et al., 2001; Karl et al., 2002), and well below that of New York Harbour (Litten et al., 2003).

7.4.2.3. Water bird eggs

Data on POPs contamination in local water birds were limited. Results of one ad hoc study conducted by the local academia on persistent organic contaminants in Ardeids contributed to the inventory on POPs in local water birds, using the bird egg as a body burden indicator. The eggs of two Ardeid species, the Little Egret (*Egretta garzetta*) and the Black-crown Night Heron (*Nycticorax nycticorax*), were collected from two egretries located in the woodlands of the New Territories (Mai Po Marshes in the west and A Chau in the east) and analyzed for chlordane, DDT and PCBs (Connell et al., 2003; Lam and Lam, 2004). A relatively high level of all three POPs was detected in the Ardeid eggs, with average concentration of 156, 900 and 595 $\mu g\ kg^{-1}$ ww for chlordane, DDT and PCBs, respectively.

7.4.2.4. Marine mammals

Levels of POPs in two local marine mammals, the Indo-Pacific humpback dolphin (*Sousa chinensis*) and finless porpoise (*Neophocaena phocaenoides*), were measured in two ad hoc studies of stranded cetaceans in 1995–2000 and 2000–2001, respectively (Jefferson et al., 2002; Imanishi et al., 2004). Cetacean tissue samples were collected from stranded animals found in Hong Kong and analyzed for DDT, mirex, toxaphene and PCBs. High mean blubber concentrations of DDT (32.8 $mg\ kg^{-1}$ ww) and PCBs (8.19 $mg\ kg^{-1}$ ww) were reported.

Table 7.11 summarizes the level of POPs contamination in cetaceans of Hong Kong and other countries/regions. The mean DDT concentration in local cetaceans was similar to the range reported in the South China Sea (Parsons et al., 1999) and the California coast (Kajiwara et al., 2001), and was among the highest found in marine habitats around the world. The mean PCBs concentration fell in the general range reported in the South China Sea (Parsons et al., 1999), the Philippines, India (Minh et al., 2000), Australia, Costa Rica, Caribbean Sea and the Arctic (UNEP Chemicals, 2003d); higher than that found in the Alboran Sea (Borrell and Aguilar, 2005) and Bering Sea (Deagars and Garlich-Miller, 2001), and substantially lower than the range recorded in Japan (Minh et al., 2000), the California coast (Kajiwara et al., 2001), the coast of

Table 7.11. Comparison of the level of POPs contamination in cetaceans of Hong Kong and other marine habitats

Location	Period	DDT[a]	Mirex[a]	Toxaphene[a]	PCBs[a]	Reference
Hong Kong, China	2000–2004	0.03	0.18 (0.07–0.29)	0.03 (0.02–0.04)	8.19	EPD, 2005b
Arctic	2003	0.23–3.60			0.24–2.87	UNEP Chemicals, 2003d
Australia	2003	0.98–3.34			1.20–3.30	UNEP Chemicals, 2003d
Brazil	1998–1999		0.05–0.20	0.02–0.12		Imanishi et al., 2004
Costa Rica	2003	2.70–6.50			1.50–6.40	UNEP Chemicals, 2003d
India	1990–1992		0.010	0.86		Imanishi et al., 2004
Bay of Bengal	1990				1.60–3.0	Minh et al., 2000
Japan	1998–2001		0.005–0.06	0.17–2.67		Imanishi et al., 2004
	1989–1993				4.10–57.0	Minh et al., 2000
Mediterranean						
Alboran Sea	1992–1994	1.71–115			2.85–83.5	Borrell and Aguilar, 2005
Black Sea	1993		0.009	1.50		Imanishi et al., 2004
Caribbean Sea	2003	1.40–7.40			2.0–5.0	UNEP Chemicals, 2003d
The Irish & the Aegean Sea	1987–1991				1.39–25.8	Troisi et al., 1998
Philippines	1996		0.02	0.66		Imanishi et al., 2004
	1996				2.40–8.60	Minh et al., 2000
Russia, Pacific Coast	2003			0.93–1.30		UNEP Chemicals, 2003d
South China Sea	1994	33.0	0.01		1.79	Parsons et al., 1999
USA						
Bering Sea, Alaska	1991				0.09–0.45	Deagars and Garlich-Miller, 2001
California Coast	1991–1997	7.55–104			4.55–247	Kajiwara et al., 2001
Coast of Massachusetts	1986, 1990	7.0 ± 0.93			15.0 ± 2.2	Tilbury et al., 1999

[a]Expressed as mean, min–max, mean (min–max) or mean $\pm$ SD; unit = $mg\,kg^{-1}$ ww.

Massachusetts (Tilbury et al., 1999), the Irish Sea and the Aegean Sea (Troisi et al., 1998).

7.5. Dietary exposure to POPs

7.5.1. Contamination levels of POPs in locally consumed foods

The level of contamination of POPs in locally consumed foods is monitored year-round by the Food and Environmental Hygiene Department (FEHD) of the HKSAR Government under a routine food surveillance programme (FEHD, 2003). Food items (mainly imports from the Mainland and other countries) are sampled on a regular basis from local market stalls, supermarkets, fresh provision shops, food wholesalers and at the points of entry into Hong Kong (e.g., border checkpoint at Man Kam To and the International Airport). Analysis of toxic chemical contamination is carried out by the Government Laboratory (GL) of the HKSAR Government.

Table 7.12 summarizes the level of POPs contamination in eight main locally consumed food groups in 2003. With the exception of DDT and HCB, POPs pesticides were not detected in most food groups. DDT was found in cereals, fruits, dairy products and seafoods, while HCB was detected in cereals only. PCBs was not detected in fruits, dairy products, meats or poultry, but found in seafood items at a mean concentration of 4.07 μg g^{-1} food. Measurable levels of dioxins/furans were found in cereals, dairy products, eggs, seafoods, meats and poultry, with mean dioxin/furan levels ranging from 0.001 (meats) to 0.285 (seafoods) pg TEQ g^{-1} food. Dioxins/furans were not analyzed in vegetable and fruit items sampled in 2003.

7.5.2. Estimate of daily dietary exposure to POPs

Human exposure to POPs through dietary intake was estimated based on measurement of the level of POPs contamination in various foods and information on daily food consumption pattern of the local population. Since comprehensive local food consumption data at the population level was not available, the food consumption patterns of Far East countries (including China) published by WHO in 2003 (GEMS/Food Regional Diets 2003) were adopted for estimation of human exposure to POPs through the dietary intake pathway. Dietary exposure of Hong Kong residents to DDT, HCB, PCBs and dioxins/furans was estimated to be 29.3 ng, 1.11 ng, 8.31 ng and 0.91 pg-TEQ kg^{-1} bw d^{-1}, respectively

(Table 7.12). The major food groups contributing to POPs exposure were cereals, seafoods and dairy products.

The dietary exposure of the local population to DDT was comparable to the range reported in many European countries and the US (Herrera et al., 1996); higher than that in Australia (Kannan et al., 1994; Miller et al., 2002) and New Zealand (Pesticide Action Network UK, 1998), but substantially lower (by 1–3 orders of magnitude) than that in Mainland China (Chen and Gao, 1993), Vietnam, India (Kannan et al., 1992) and Egypt (Pesticide Action Network UK, 1998) (Table 7.13). The estimated dietary intake of HCB was found to be generally similar among residents of Hong Kong, other Asian countries/regions (Kannan et al., 1992), Australia (Kannan et al., 1994; Miller et al., 2002), the US (Herrera et al., 1996), the Netherlands (Brussard et al., 1996) and Slovakia (Prachar et al., 1996), but lower than the value reported in Spain or Switzerland (Herrera et al., 1996). Based on the few published data available for comparison, the level of local dietary PCBs exposure was found to be much lower than in other Asian countries (Kannan et al., 1992). The estimated dietary exposure of Hong Kong residents to dioxins/furans was generally comparable to the level reported in most European countries (Malisch, 1998), Canada (Codex Alimentarius Commission, 2003) and the US (USEPA, 2001); slightly higher than the values recorded in Australia (Australian Government, 2004c), New Zealand (Buckland et al., 1998b) or the UK (Food Standards Agency, 2003), but appreciably lower than that found in Norway and Spain (Jimenez et al., 1996).

7.6. Human body burden of POPs

POPs in the environment can enter the food chain, bio-accumulate and bio-magnify as they move up the trophic levels and ultimately end up in the human body. It is expected that POPs will continue to accumulate in the body fat and their average concentrations will increase with age. The level of POPs contamination in human blood/serum and breast milk can serve as a good indicator of their body burden.

Local data on the level of POPs in breast milk of lactating mothers were reported in two ad hoc studies of Hong Kong residents, including a study conducted by local academia as part of the 3rd Round WHO/EURO Exposure Study 2002–2003 (Wong et al., 2002; Hedley et al., 2004). Table 7.14 presents the level of POPs contamination in breast milk of lactating mothers in Hong Kong in 2000–2003. In total, 115 local lactating mothers (aged 22–46, during their weeks 3–5 postpartum) participated in the milk sampling for analysis of DDT and PCBs and 316

Table 7.12. Estimates of dietary exposure to POPs contamination in foods of Hong Kong in 2003

	Cereals	Vegetables	Fruits	Dairy products	Eggs	Seafoods	Meats	Poultry	Daily consumption/exposure
Food consumption (g per capita d^{-1})[b]	445.7	340.3	186.3	66.3	22.2	122.5	33.3	26.3	1242.9
Contamination level (μg kg^{-1} food)									
Aldrin	0[a]	0	0	0	–		0	–	
Chlordane	0	0	0	0	–	0	0	0	
DDT	0.85	0	0.14	1.00	–	10.5	0	0	
Dieldrin	0	0	0	0	–	–	0	–	
Endrin	–	0	0	–	–	–	–	–	
Heptachlor	0	0	0	0	–	0	0	0	
HCB	0.15	0	0	0	–	0	0	0	
Mirex	–	0	0	–	–	–	–		
PCBs	–	–	0	0	–	4.07	0	0	
Dioxins/furans (pg TEQ g^{-1} food)	0.015	–	–	0.100	0.137	0.285	0.001	0.131	
Estimated daily exposure (ng kg^{-1} bw d^{-1})[c]									
Aldrin	0	0	0	0	–	–	0	–	0
Chlordane	0	0	0	0	–	0	0	0	0
DDT	6.31	0	0.43	1.11	–	21.4	0	0	29.3
Dieldrin	0	0	0	0	–	–	0	–	0
Endrin	–	0	0	–	–	–	–	–	0
Heptachlor	0	0	0	0	–	0	0	0	0
HCB	1.11	0	0	0	–	0	0	0	1.11
Mirex	–	0	0	–	–	–	–	–	0
PCBs	–	–	0	0	–	8.31	0	0	8.31
Dioxins/furans (pg TEQ kg^{-1} bw d^{-1})	0.110	–	–	0.111	0.051	0.582	0.001	0.057	0.91

[a]"0" indicates values were $<$DL; DL of pesticides and PCB $= 0.005$ mg kg^{-1}; DL of dioxins/furans $= 0.02/0.05/0.10$ ng kg^{-1} for individual congeners.

[b]Due to the lack of local data, food consumption patterns of Far East Countries (including China) published by WHO (2003) in "GEMS/Food Regional Diets" were adopted for estimation of daily dietary exposure, except in the case of the Seafoods Group where local Hong Kong data were available.

[c]Estimate was based on an average adult body weight of 60 kg.

Table 7.13. Comparison of dietary intake of POPs by the residents of Hong Kong and other urban locations

Location	Dietary intake (ng kg^{-1} bw d^{-1})				Reference
	DDT	HCB	PCBs	PCDD/Fs[a]	
Hong Kong, China	29.3	1.1	8.3	0.91	EPD, 2005b
Australia	7	4.67		0.03–0.34	Kannan et al., 1994; Miller et al., 2002; Australian Government, 2004b
Canada				0.8	Codex Alimentarius Commission, 2003
China, Mainland	341				Chen and Gao, 1993
Egypt	13,700				Pesticide Action Network UK, 1998
Finland	26				Pesticide Action Network UK, 1998
France				1.45	Miller et al., 2002
Germany				0.88	Malisch, 1998
India	800	2.17			Kannan et al., 1992
Italy				0.25–2.13	Zanotto et al., 1999
New Zealand	3			0.22	Pesticide Action Network UK, 1998; Buckland et al., 1998b
Norway				2.28–3.16	Becher et al., 1998
Slovakia	95.8	3.75			Prachar et al., 1996
Spain	20.3	17.2		2.4	Herrera et al., 1996; Jimenez et al., 1996
Switzerland	28.3	18.3			Herrera et al., 1996
Sweden				1.06	Miller et al., 2002
Thailand	70	1.3	25		Kannan et al., 1992
The Netherlands	16.7	3.33		0.67	Brussard et al., 1996; Freijer et al., 2001
UK	50			0.3	Pesticide Action Network UK, 1998; Food Standards Agency, 2003
USA	26	0.5		0.56	Herrera et al., 1996; USEPA, 2001
Vietnam	320	1.7	62		Kannan et al., 1992

[a]Unit = pg TEQ kg^{-1} bw d^{-1}.

Table 7.14. The level of POPs contamination in breast milk of lactating mothers in Hong Kong in 2000–2002

Chemical	Human breast milk concentration			
	No. of participants	Mean	Min	Max
DDT (μg g^{-1} lipid wt)	115	2.68	0.66	5.61
PCBs (μg g^{-1} lipid wt)	115	0.04	0.01	0.07
Dioxin-like PCBs (pg TEQ g^{-1} lipid wt)	316	4.67	2.80	6.58
Dioxins/furans (pg TEQ g^{-1} lipid wt)	316	8.25	5.80	10.1

local lactating mothers (aged 18–42, during their weeks 2–6 postpartum) contributed milk samples for analysis of dioxin-like PCBs and dioxins/furans. The mean breast milk concentration of DDT and indicator PCBs in Hong Kong mothers was 2.68 and 0.04 μg g^{-1} lipid wt, respectively, and that of dioxin-like PCBs and dioxins/furans was 4.67 and 8.25 pg TEQ g^{-1} lipid wt, respectively. No information on the level of POPs contamination in the blood/serum of local residents was available.

A WHO study was conducted to compare the level of POPs contamination in breast milk of lactating mothers from different countries/regions worldwide (Malisch and van Leeuwen, 2002, 2004). Figure 7.4 summarizes the study results. The level of DDT contamination in breast milk of Hong Kong mothers ranked the highest among 16 countries/regions which participated in the study. In contrast, the contamination level of indicator PCBs, dioxin-like PCBs and dioxins/furans in breast milk of Hong Kong mothers was the 8th, 10th and 13th lowest, respectively, among the 26 participating countries/regions.

7.7. Ecological risk assessment

7.7.1. Approach and methodology

The ecological risk assessment was conducted in accordance with the USEPA guidance document "*Guidelines for Ecological Risk Assessment* (USEPA, 1998)". A four-step assessment process was adopted: problem formulation, exposure characterization, characterization of ecological effects and risk evaluation.

The receptors of interest included pelagic organisms, benthic organisms and marine mammals (dolphins/porpoises). For the pelagic and benthic organisms, ecological risk assessment was conducted at the population level. For the dolphins and porpoises, risk assessment was conducted at the organism level.

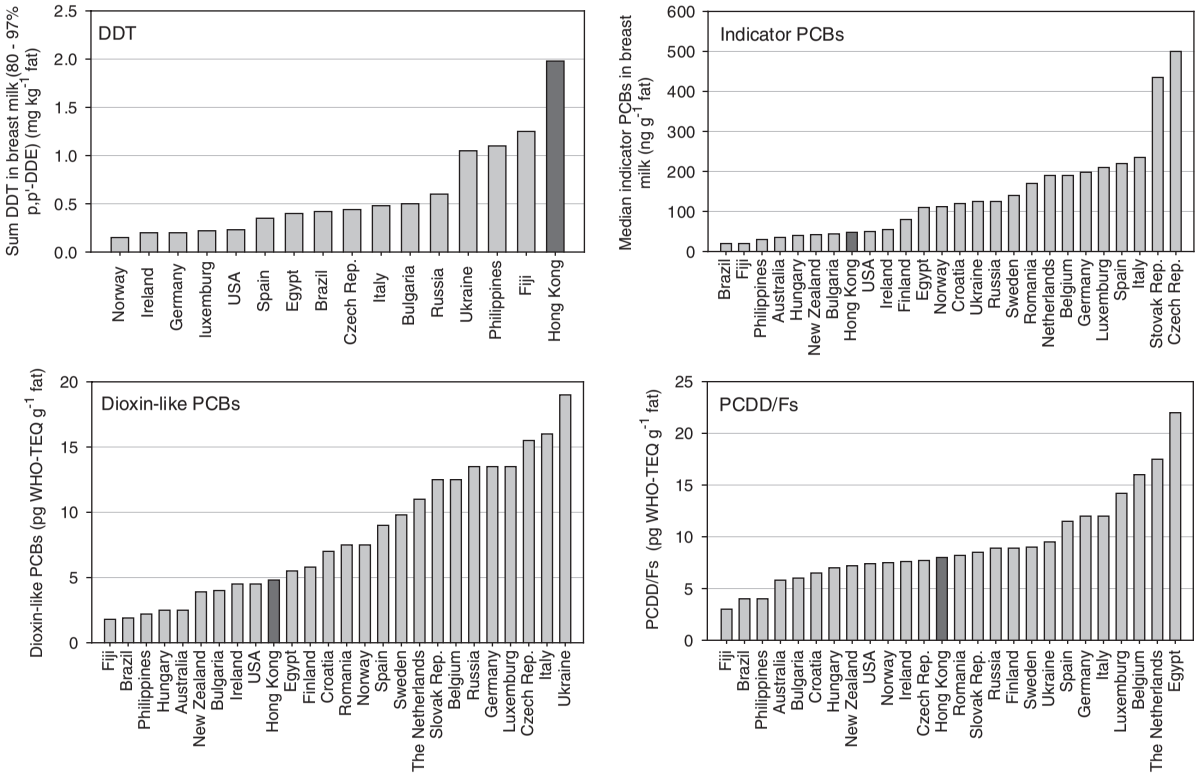

Figure 7.4. Comparison of the level of POPs contamination in breast milk of lactating mothers in Hong Kong and other countries (from Malisch and van Leeuwen, 2004).

7.7.1.1. Pelagic organisms risk assessment

A two-tiered approach was adopted for the population level ecological risk assessment for pelagic organisms. The Tier 1 assessment process involved calculation of a simple deterministic Hazard quotient (HQ) of individual POPs. The HQ was defined as the ratio of mean POPs concentration in the local marine water to its chronic toxicity value. Relevant existing water quality guidelines/criteria established by regulatory authorities, including the United States Environmental Protection Agency (USEPA) (USEPA, 2002), the Australian and New Zealand Environmental and Conservation Council (ANZECC) (ANZECC, 2000) and the Canadian Council of Ministers of the Environment (CCME) (CCME, 1999), were used as chronic toxicity values. For the POPs that did not have appropriate existing guideline/criteria values available, conservative chronic toxicity values were estimated by using an ''acute-to-chronic'' ratio of 50.

POPs with a calculated HQ less than unity were judged to be unlikely to pose ecological risk of toxicological concern to the local pelagic organisms and therefore were not considered further in the Tier 2 risk assessment. POPs with a HQ greater than unity were identified as chemicals of potential toxicological concern and were subject to further, in-depth Tier 2 Probabilistic Risk Assessment (PRA) using the procedures described by Solomon and Takacs (2002).

Tier 2 PRA process involved developing environmental exposure data and chronic toxicity data distributions for individual POPs. The mean concentrations of POPs in local marine water measured at various locations were used as exposure data in the construction of the exposure distribution. The chronic toxicity data distribution was established based on published international acute toxicity data (LC_{50}, EC_{50}) on a variety of aquatic organisms tested in many jurisdictions, drawn primarily from the USEPA ECOTOX database (2002) (available at http://www.epa.gov/ecotox). If the upper 5th centile of the measured chemical exposure data distribution did not exceed the lower 5th centile of its estimated chronic toxicity distribution, the potential ecological risk posed by the chemical was judged to be tolerable (Hall and Giddings, 2000).

7.7.1.2. Benthic organisms risk assessment

The ecological risk to local benthic organisms from potential exposure to POPs through direct contact with marine sediment was also assessed. Direct contact with the contaminated sediment was the most significant pathway of exposure for benthic organisms. The use of chemical specific

toxicity data on aquatic organisms as surrogate was in accordance with the Fugacity theory (Mackay, 1991) which predicts that benthic organisms would accumulate organic chemicals proportionally to the concentration of these chemicals in the sediment pore water.

A two-tiered approach similar to that for pelagic organisms was adopted for the population level ecological risk assessment for benthic organisms. In the Tier 1 assessment process, simple deterministic HQ of individual POPs were calculated by comparing mean concentrations of POPs in the local marine sediment to the range of published Screening Sediment Quality Criteria (SQC)/Guidelines by other regulatory authorities including the US National Oceanic and Atmospheric Administration (NOAA), Environment Canada, Ontario Ministry of Environment, Canada and ANZECC.

POPs with a calculated HQ less than unity were judged to be unlikely to pose ecological risk of toxicological concern to the local benthic organisms and therefore were not considered further in the Tier 2 risk assessment. POPs with a HQ greater than unity were identified as chemicals of potential toxicological concern and were subject to further, in-depth Tier 2 PRA using site-specific SQC, taking into account the local sediment properties (i.e., organic carbon content, partitioning coefficient for sediment organic carbon, etc.) (Long et al., 1995).

7.7.1.3. Marine mammals risk assessment

Contrary to that for the pelagic and benthic organisms, ecological risk assessment for the marine mammal (dolphins and porpoises) evaluated the potential adverse health effects of exposure to POPs in the marine environment at the organism level. Two species of local cetaceans, the Indo-Pacific hump-backed dolphins (*S. chinensis*) and the finless porpoises (*N. phocaenoides*), had been studied (Jefferson et al., 2002; Imanishi et al., 2004). Ecological risk assessment of POPs was conducted following an individual-based methodology analogous to the human health risk assessment process and using chronic toxicity values derived from terrestrial mammalian studies as surrogates.

Consumption of fish and shellfish was identified as the significant pathway for potential exposure of dolphins/porpoises to the POPs. Little information existed on the feeding habits of local dolphins/porpoises in Hong Kong waters. Based on the limited data available (Parsons, 1997; Jefferson, 2001), it was assumed that the dolphin diet consisted of 90% fish and 10% shellfish (mainly crustaceans and cephalopods), while the ratio of fish and shellfish in the porpoises diet was 50:50. Dietary exposure to individual POPs was calculated based on the concentration of POPs

measured in local marine biota (i.e., the local marine fish and shellfish data), assuming a typical dolphin weight of 225 kg and porpoise weight of 55 kg, and adopting a conservatively estimated consumption rate of 0.065 and 0.075 kg food kg^{-1} bw d^{-1} for the dolphins and porpoises, respectively (Montgomery Watson, 1998; Parsons, 1998). Exposure to POPs from water ingestion was not accounted for in the absence of corresponding water sampling data, but contribution from this exposure pathway was expected to be relatively insignificant.

The simple deterministic HQ of individual POPs were calculated by comparing the estimated dietary exposure to the adopted surrogate chronic toxicity values published by other national authorities and international organizations (USDoE, 1996; USEPA Integrated Risk Information System (IRIS) database (available at http://www.epa.gov/iris); US Agency for Toxic Substances and Disease Registry (ATSDR) database ToxFAQs™ (available at http://www.atsdr.cdc.gov/toxfaq.html); WHO, 1998). POPs with a calculated HQ less than unity were judged to be unlikely to pose ecological risk of toxicological concern to the local dolphins/porpoises residing in the Hong Kong waters. POPs with a calculated HQ greater than unity would suggest that the current exposure level of local cetaceans to the POPs concerned might be of toxicological relevance and warranted further, in-depth investigation.

7.7.2. Assessment results

7.7.2.1. Pelagic organisms risk assessment

The calculated HQs for POPs, except DDT, were all below unity, indicating that there was no unacceptable risk of toxicological significance associated with exposure of local pelagic organisms to these POPs (Table 7.15). DDT was subject to further evaluation by the in-depth Tier 2 PRA. The results of the PRA, as illustrated by Fig. 7.5, indicated that the lower 5th centile of the estimated chronic DDT toxicity distribution was not exceeded by the upper 5th centile of aquatic DDT exposure distribution, suggesting the potential ecological risk posed by exposure of local pelagic organisms to DDT was within a tolerable range.

7.7.2.2. Benthic organisms risk assessment

The calculated HQs for all POPs in the marine sediment, against the range of published SQC/Guidelines, were <1 (Table 7.16). The mean contamination level of POPs in the marine sediment of Hong Kong generally fell at the lower end of the range of screening concentrations

Table 7.15. Tier 1 ecological risk assessment of POPs to pelagic organisms in Hong Kong in 2000–2004

Chemical	Mean concentration in Hong Kong's marine water (ng L^{-1})	Conservative screening chronic toxicity value	Hazard quotient[g]
Aldrin	<10	21.3[d]	<1
Chlordane	<10	88.0[d]	<1
DDT	<15	1.4[d]	>1
Dieldrin	<10	22.0[d]	<1
Endrin	<10	44.0[d]	<1
Heptachlor	<10	68.0[d]	<1
HCB	<10	600[d]	<1
Mirex	<10	400[e]	<1
Toxaphene	<10	43.2[d]	<1
PCBs	<100	7800[d]	<1
Dioxins/furans[a]	0.55[b], 5.21[c]	10[f]	<1

[a]Unit of dioxins/furans = pg I-TEQ L^{-1}; 2,3,7,8-TCDD <DL in all 104 samples.
[b]The value was calculated assuming zero for individual congener level <DL.
[c]The value was calculated assuming 0.5 DL for individual congener level <DL.
[d]The value represents LC_{50} divided by 50; LC_{50} = lethal concentration that kills 50% of the organisms under a specified time duration.
[e]Value from ANZECC—Australian and New Zealand Guidelines for Marine Water Quality 2000.
[f]Value from Human Health and Ecological Risk Assessment Work Plan (USEPA, 2004) and from Development of Aquatic Quality Standards for Dioxins (Final Report to the Department for Environment, Food and Rural Affairs, UK, 2003).
[g]Hazard quotient = ratio of mean concentration in marine water to screening chronic toxicity value.

published in the SQC/Guidelines of the US, Canada and Australia/New Zealand. The results indicated that there would be unlikely to be any risk of toxicological significance associated with exposure of local benthic organisms to the current level of POPs in the marine sediment.

7.7.2.3. Marine mammals risk assessment

Results of the ecological risk assessment of POPs in the marine environment to local cetaceans (the hump-backed dolphins and the finless porpoises) showed the HQs for eight POPs studied (chlordane, DDT, dieldrin, heptachlor, HCB, toxaphene, PCBs and dioxins/furans) were all less than unity, suggesting that there was no unacceptable risk of toxicological significance associated with exposure of local cetaceans to the current contamination level of these POPs in the marine environment (Table 7.17).

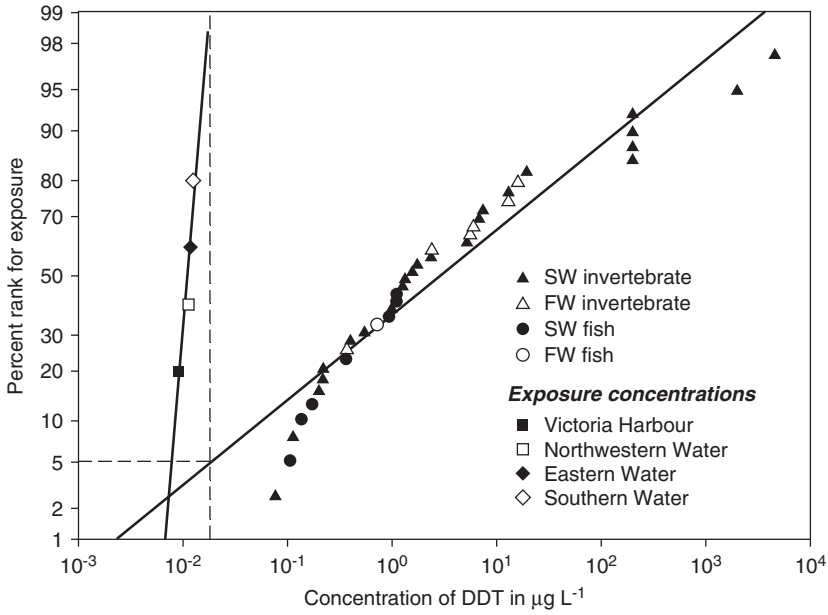

Figure 7.5. Tier 2 probabilistic risk assessment on pelagic organisms exposed to DDT.

7.8. Human health risk assessment

7.8.1. Approach and methodology

The human health risk assessment was conducted based on exposure estimates from two most relevant exposure pathways, namely dietary intake of POPs from food consumption and inhalation intake of airborne POPs contaminants. The potential intake of POPs from drinking water (considered to be a relatively minor exposure pathway) was not taken into account due to lack of relevant local data necessary for their estimation.

7.8.1.1. Human non-carcinogenic risk assessment

The potential for non-carcinogenic health effects associated with exposure of local residents to POPs in locally consumed food items and the ambient air was evaluated by calculating the relevant HQ for individual POPs. The HQ was defined as the ratio of the estimated lifetime average daily dose (LADD) of POPs from dietary (Table 7.6) and inhalation

Table 7.16. Tire 1 ecological risk assessment of POPs to benthic organisms in Hong Kong in 2000–2004

Chemical	Mean concentration in Hong Kong's marine sediment (μg kg^{-1} dw)[b]	Screening sediment quality criteria	Reference
Aldrin	4.70	9.5	NOAA, SQuiRTs^{TM}, AET[c]
		2–80	Ontario Guideline, Low to severe[d]
Chlordane	4.20	4.50–8.87	Canadian Sediment Quality Guideline, ISQG to PEL[e]
		0.5–6	NOAA, SQuiRTs^{TM}, ERL to ERM[c]
		0.5–6	ANZECC ISQG, Low to high[f]
		7–60	Ontario Guideline, Low to severe[d]
DDT	6.81	1.58–46.1	NOAA, SQuiRTs^{TM}, ERL to ERM[c]
		1.58–46.1	ANZECC ISQG, Low to high[f]
		7–120	Ontario Guideline, Low to severe[d]
		6.15–20.03	Canadian Sediment Quality Guideline, ISQG to PEL[e]
		20.4	Sediment Quality Criteria[g]
Dieldrin	5.19	0.02–8	NOAA, SQuiRTs^{TM}, ERL to ERM[c]
		0.02–8	ANZECC ISQG, Low to high[f]
		2.85–6.67	Canadian Sediment Quality Guideline, ISQG to PEL[e]
		2–910	Ontario Guideline, Low to severe[d]
		76.6	Sediment Quality Criteria[g]
Endrin	3.86	2.67–62.4	Canadian Sediment Quality Guideline, ISQG to PEL[e]
		0.02–8	ANZECC ISQG, Low to high[f]
		3–1300	Ontario Guideline, Low to severe[d]
Heptachlor	4.48	298	Sediment Quality Criteria[g]
HCB	5.98	6	NOAA, SQuiRTs^{TM}, AET[c]
		380	Washington State Sediment Criteria[h]
Mirex	<10.0	7–1300	Ontario Guideline, Low to severe[d]
		96.0	Sediment Quality Criteria[g]
Toxaphene	<10.0	0.1	Canadian Sediment Quality Guideline, ISQG[e]
		43.2	Sediment Quality Criteria[g]
PCBs	24.1	22.7–180	NOAA, SQuiRTs^{TM}, ERL to ERM[c]
		21.5–189	Canadian Sediment Quality Guideline, ISQG to PEL[e]
		70–5300	Ontario Guideline, Low to severe[d]
		237	Sediment Quality Criteria[g]

Table 7.16. (*Continued*)

Chemical	Mean concentration in Hong Kong's marine sediment ($\mu g\ kg^{-1}$ dw)[b]	Screening sediment quality criteria	Reference
Dioxins/ furans[a]	9.10	0.85–21.5	Canadian Sediment Quality Guideline, ISQG to PEL[e]
		16.6	Sediment Quality Criteria[g]

[a]Unit for dioxins/furans = ng I-TEQ kg^{-1} dw.
[b]The average organic carbon content in Hong Kong marine sediments is approximately 0.8% (2004 data); 1% is assumed for ease of calculation and comparison in this table.
[c]US National Oceanic and Atmospheric Administration (NOAA) Sediment Guidelines, Screening Quick Reference Table for Organics (SQuiRT^{TM}), 1999; AET = Apparent Effects Threshold; ERL = Effect Range Low; ERM = Effect Range Medium.
[d]Ontario Ministry of Environment Screening Level Guideline (normalized to 1% organic carbon), 1993; a low level is the lowest concentration that toxic effects become apparent; a severe level represents concentrations that could effectively eliminate most of the benthic organisms.
[e]Canadian Sediment Quality Guideline for Protection of Aquatic Life, 2002; ISQG = Interim Sediment Quality Guideline; PEL = Probable Effect Level.
[f]ANZECC recommended interim sediment quality guideline (ISQG) (normalized to 1% organic carbon), 2000; the ISQG low and high values correspond to the ERL and ERM used in the NOAA listing.
[g]Sediment quality criteria adopted in EPD's consultancy study "A Study of Toxic Substances Pollution in Hong Kong, Agreement No. CE 22/99 (Environmental)"; unit for dioxins/furans = ng I-TEQ kg^{-1}.
[h]Washington State Sediment Quality Chemical Criteria, WAC 173-204-320 (a).

Table 7.17. Ecological risk assessment of POPs to cetaceans in Hong Kong in 2001–2002

Chemical	Overall exposure dose[a] ($\mu g\ kg^{-1}$ bw d^{-1})		Adopted toxicity value ($\mu g\ kg^{-1}$ bw d^{-1})	Hazard quotient (exposure dose/ toxicity value)	
	Dolphin	Porpoise		Dolphin	Porpoise
Chlordane	1.21×10^{-1}	8.55×10^{-2}	1.88×10^{1}	<1	<1
DDT	6.68×10^{-1}	4.71×10^{-1}	1.00×10^{2}	<1	<1
Dieldrin	1.26×10^{-2}	1.06×10^{-2}	6.25×10^{-1}	<1	<1
Heptachlor	1.60×10^{-2}	1.14×10^{-2}	1.25×10^{0}	<1	<1
HCB	3.07×10^{-2}	2.30×10^{-2}	1.00×10^{1}	<1	<1
Toxaphene	7.56×10^{-2}	5.51×10^{-2}	4.38×10^{1}	<1	<1
PCBs	7.12×10^{-1}	5.88×10^{-1}	6.25×10^{0}	<1	<1
Dioxins/furans	2.28×10^{-5}	2.66×10^{-5}	1.25×10^{-4}	<1	<1

[a]Exposure dose = estimated chemical intake from local marine fish and shellfish consumption; data extracted from EPD's consultancy study "A Study of Toxic Substances Pollution in Hong Kong, Agreement No. CE 22/99".

(Table 7.4) pathways to the reference dose (RfD) (USEPA) or tolerable daily intake (TDI) (WHO). Exposure levels below the RfD or TDI (i.e., HQs < 1) would be considered unlikely to elicit adverse health effects.

7.8.1.2. Human carcinogenic risk assessment

The potential for carcinogenic health effects associated with exposure of local residents to POPs, being known/probable/possible human carcinogens, was evaluated by the total excess lifetime cancer risk of exposure to individual POPs in the ambient air (inhalation cancer risk) and in locally consumed food items (dietary cancer risk). The excess lifetime inhalation cancer risk of POPs was estimated based on the measured concentration of POPs in the ambient air (for 2000–2004) and using unit risk factors published by USEPA (USEPA IRIS database). The excess lifetime dietary cancer risk of POPs was calculated by multiplying the LADD of chemical exposure from consumption of local food items by its carcinogenic slope factor (USEPA IRIS database). Since the carcinogenic slope factor often represented an upper 95th centile confidence limit of the probability of response based on experimental animal data in a multistage model, the calculated excess lifetime cancer risk would generally be an upper-bound estimate, i.e., the actual excess risk was likely be lowered. Excess lifetime cancer risk of a POPs chemical in the range of 1×10^{-4}–1×10^{-6}, commonly considered acceptable for regulatory purposes in protecting human health in various USEPA programmes, was adopted as the limit of acceptable carcinogenic risk of toxicological concern associated with a lifetime exposure to the chemical.

7.8.1.3. Health risk assessment of POPs in the local marine environment

The health risk to local residents associated specifically with exposure to POPs contamination in the local marine environment was assessed by (a) comparing the levels of POPs contamination in marine fish and shellfish sampled in the local waters with relevant Food Safety Standards/Action Levels; and (b) evaluating the non-carcinogenic and carcinogenic risks of individual POPs intake via consumption of locally caught seafood and incidental ingestion of seawater during recreational activities.

The potential for non-carcinogenic risk associated specifically with exposure to POPs contamination in the local marine environment was evaluated by calculating the HQ which was defined as the ratio of the LADD from consumption of locally-caught seafood (marine fish and shellfish) and incidental ingestion of marine water (during recreational activities) to the RfD (USEPA) or TDI (WHO) appropriately

apportioned for exposure attributed to locally caught seafood only (taking into full account background exposure due to local consumption of all other non-seafood food items). Exposure levels below the apportioned RfD or TDI (i.e., HQ < 1) would be considered unlikely to elicit any adverse systemic health effects.

The potential for carcinogenic risk associated specifically with exposure to POPs contamination in the local marine environment was evaluated by the excess lifetime cancer risk calculated by multiplying the LADD of individual POPs exposure from consumption of locally caught seafood (marine fish and shellfish) and incidental ingestion of marine water (during recreational activities) by its carcinogenic slope factor (USEPA IRIS database). Excess lifetime cancer risk of a POPs chemical in the range of 1×10^{-4}–1×10^{-6} was adopted as the limit of acceptable carcinogenic risk of toxicological concern.

7.8.2. Assessment results

7.8.2.1. Human non-carcinogenic risk assessment

Results of assessment of non-carcinogenic risk associated with exposure of local residents to POPs in the locally consumed food items and the ambient air are presented in Table 7.18. The calculated HQs of all 12 POPs under the Stockholm Convention were well below unity, indicating that there was no unacceptable non-carcinogenic risk of toxicological significance associated with a lifetime exposure of local residents to the current levels of POPs contamination in locally consumed food items and the ambient air. The estimated level of exposure of local residents to dioxins/furans (0.93 pg TEQ kg^{-1} bw d^{-1}, assuming negligible intake via the drinking water route) fell at the lower end of the range (1–4 pg TEQ kg^{-1} bw d^{-1}) of TDI of dioxins/furans set by WHO (1998). Dietary exposure was the major route, accounting for 98.2% of total exposure to dioxins/furans, while inhalation exposure accounted for only 1.8%. The finding was in good agreement with internationally reported data.

7.8.2.2. Human carcinogenic risk assessment

Results of assessment of dietary and inhalation carcinogenic risks associated with exposure of local residents to POPs in the locally consumed food items and the ambient air are presented in Table 7.19. The calculated dietary or inhalation or total excess lifetime cancer risks of POPs all fell at the lower end of the 1×10^{-4}–1×10^{-6} range, indicating there was no unacceptable dietary or inhalation or total cancer risk of toxicological

Table 7.18. Non-carcinogenic risk assessment of POPs to the residents of Hong Kong in 2003

Chemical	Daily intake (mg kg^{-1} bw d^{-1})			Reference dose (RfD)/ tolerable daily intake (TDI) (mg kg^{-1} bw d^{-1})[d]	Hazard quotient (total daily intake/RfD or TDI)
	Dietary[b]	Inhalation[c]	Total		
Aldrin	0	0	0	3.00×10^{-5}	<1
Chlordane	0	–	0	5.00×10^{-4}	<1
DDT	2.93×10^{-5}	1.44×10^{-8}	2.93×10^{-5}	5.00×10^{-4}	<1
Dieldrin	0	0	0	5.00×10^{-5}	<1
Endrin	0	0	0	3.00×10^{-4}	<1
Heptachlor	0	8.64×10^{-9}	8.64×10^{-9}	5.00×10^{-4}	<1
HCB	1.10×10^{-6}	4.61×10^{-8}	1.15×10^{-6}	8.00×10^{-4}	<1
Mirex	0	–	0	2.00×10^{-4}	<1
Toxaphene	–	–	–	–	–
PCBs	8.31×10^{-6}	1.38×10^{-7}	8.45×10^{-6}	2.00×10^{-5}	<1
Dioxins/furans[a]	0.91	0.02	0.93	1–4	<1

[a]Unit for daily intake of dioxins/furans = pg TEQ kg^{-1} bw d^{-1}.
[b]Dietary intake estimated by adopting the oriental food consumption pattern published in WHO GEMS 2003.
[c]Assuming a respiratory rate of 20 min^{-1} and a tidal volume of 600 ml, for an average adult of 60 kg bw.
[d]Data from USEPA Integrated Risk Information System (IRIS) database, except for dioxins/furans (TDI from WHO 1998).

concern associated with a lifetime exposure of local residents to the current levels of POPs contamination in the locally consumed foods and the ambient air.

7.8.2.3. Health risk assessment of POPs in the local marine environment

In the absence of Food Safety Standards on POPs specific to Hong Kong, the level of POPs contamination in marine fish and shellfish sampled in the local waters was examined against Food Safety Standards/Action Levels published by other regulatory authorities (Table 7.20). The level of POPs contamination in marine fish and shellfish from Hong Kong waters was well below (by 1–2 orders of magnitude) the Food Safety Standards/ Action Levels set by the US, Mainland China and/or the European Community.

Furthermore, the estimated level of exposure of local residents to all 12 POPs under the Stockholm Convention was found to be well below

Table 7.19. Carcinogenic risk assessment of POPs to the residents of Hong Kong in 2003

Chemical	USEPA Cancer Classification[a]	Dietary			Inhalation			Total Excess Lifetime Cancer Risk	Acceptable Range of Excess Lifetime Cancer Risk (USEPA)
		Daily Intake[†] (mg kg^{-1} bw d^{-1})	Slope Factor[c]	Excess Lifetime Cancer Risk	Daily Intake[‡] (mg kg^{-1} bw d^{-1})	Unit risk[c]	Excess Lifetime Cancer Risk		
Aldrin	B2	0	1.70×10^{1}	0	0	4.90×10^{-3}	0	0	1×10^{-4}–1×10^{-6}
Chlordane	B2	0	3.50×10^{-1}	0	–	3.70×10^{-4}	–	0	1×10^{-4}–1×10^{-6}
DDT	B2	2.93×10^{-5}	3.40×10^{-1}	9.96×10^{-6}	1.44×10^{-8}	9.70×10^{-5}	4.9×10^{-9}	9.97×10^{-6}	1×10^{-4}–1×10^{-6}
Dieldrin	B2	0	1.60×10^{1}	0	0	4.60×10^{-3}	0	0	1×10^{-4}–1×10^{-6}
Endrin	D	0	–	–	0	–	–	–	–
Heptachlor	B2	0	4.50×10^{0}	0	8.64×10^{-9}	1.30×10^{-3}	3.90×10^{-8}	3.90×10^{-8}	1×10^{-4}–1×10^{-6}
Hexachlorobenzene	B2	1.10×10^{-6}	1.60×10^{0}	1.76×10^{-8}	4.61×10^{-8}	4.60×10^{-4}	7.40×10^{-8}	9.16×10^{-8}	1×10^{-4}–1×10^{-6}
Mirex	2B[b]	0	–	–	–	–	–	–	–
Toxaphene	B2	–	1.10×10^{0}	–	–	3.20×10^{-4}	–	–	–
PCBs	B2	8.31×10^{-6}	4.00×10^{-1}	3.32×10^{-9}	1.38×10^{-7}	9.30×10^{-5}	4.50×10^{-8}	4.83×10^{-8}	1×10^{-4}–1×10^{-6}
Dioxins/furans*	B2	9.11×10^{-10}	1.00×10^{5}	9.11×10^{-5}	1.73×10^{-11}	3.30×10^{1}	2.00×10^{-6}	9.33×10^{-5}	1×10^{-4}–1×10^{-6}

*Unit for daily intake of dioxins/furans = mg TEQ kg^{-1} bw d^{-1}.

[†]Dietary intake estimated by adopting the oriental food consumption pattern published in WHO GEMS 2003.

[‡]Assuming a respiratory rate of 20 min^{-1} and a tidal volume of 600 ml, for an average adult of 60 kg bw.

[a]USEPA Weight-of-Evidence Cancer Classification System (B2 = probable human carcinogen; D = not classifiable).

[b]International Agency for Research on Cancer (IARC) Cancer Classification (2B = possible human carcinogen).

[c]USEPA Integrated Risk Information System (IRIS) database.

Table 7.20. Comparison of the level of POPs contamination in marine fish and shellfish sampled in Hong Kong waters (2000–2004)

Chemical	Mean concentration (μg kg^{-1} ww)		Food safety standards/action levels
	Marine fish	Marine shellfish	
Aldrin	28.9	10.9	300 (USFDA[b])
Chlordane	3.8	1.12	300 (USFDA[b])
DDT	27.6	7.73	5000 (USFDA[b]) 1000 (PRC[c])
Dieldrin	2.18	0.21	300 (USFDA[b])
Endrin	28.1	5.86	
Heptachlor	25.3	5.99	300 (USFDA[b])
HCB	5.80	0.80	
Mirex	0	0	100 (USFDA[b])
Toxaphene	1.33	0	
PCBs	22.6	13.8	2000 (USFDA[b])
		0	200 (PRC[c])
Dioxins/furans[a]	0.33	0.53	4 (EC[d])

[a]Unit for dioxins/furans = pg I-TEQ g^{-1} ww.
[b]USFDA Chemical Contaminant and Pesticide Action Levels, and Guidance Levels; unit = μg kg^{-1} ww.
[c]PRC Seafood Standard; unit = μg kg^{-1} ww.
[d]European Community Seafood Standard for fish and fish products; unit = pg WHO-TEQ g^{-1} ww.

the apportioned RfD or TDI and all calculated HQs were below unity (Table 7.21). The results indicated that there was no unacceptable non-carcinogenic risk of toxicological concern associated specifically with a lifetime exposure of local residents to the current level of POPs contamination in the local marine environment via dietary intake of locally caught seafood (marine fish and shellfish) and incidental ingestion of seawater during recreational activities, taking into full account background dietary exposure to POPs from consumption of all other local, non-seafood food items.

Results of assessment of carcinogenic risks associated with exposure of local residents to POPs contamination in the local marine environment are presented in Table 7.22. The calculated cancer risks of POPs all fell well within the 1×10^{-4}–1×10^{-6} range, indicating there was no unacceptable cancer risk of toxicological concern associated specifically with a lifetime exposure of local residents to the current level of POPs contamination in the local marine environment via dietary intake of locally caught seafood (marine fish and shellfish) and incidental ingestion of seawater during recreational activities.

Table 7.21. Human non-carcinogenic risk assessment of POPs pollution in the marine environment of Hong Kong in 2000–2004

Chemical	Background exposure[a] (mg kg^{-1} bw day^{-1})	Lifetime average daily exposure[b] (mg kg^{-1} bw day^{-1})	RfD[c] or TDI[c] (mg kg^{-1} bw day^{-1})	Hazard quotient (LADD/RfD[c] or TDI[c])
Aldrin	0	5.78×10^{-6}	3.00×10^{-5}	<1
Chlordane	0	8.01×10^{-7}	5.00×10^{-4}	<1
DDT	7.85×10^{-6}	5.80×10^{-6}	2.12×10^{-4}	<1
Dieldrin	0	4.44×10^{-7}	5.00×10^{-5}	<1
Endrin	0	5.83×10^{-6}	3.00×10^{-4}	<1
Heptachlor	0	5.28×10^{-6}	5.00×10^{-4}	<1
HCB	1.11×10^{-6}	1.19×10^{-6}	4.14×10^{-4}	<1
Mirex	0	0.00×10^{0}	2.00×10^{-4}	<1
Toxaphene	–	2.66×10^{-7}	–	–
PCBs	0	5.03×10^{-6}	2.00×10^{-5}	<1
Dioxins/furans (mg TEQ kg^{-1} w day^{-1})	3.3×10^{-10}	8.92×10^{-11}	$(2.13–8.51) \times 10^{-10}$	<1

[a]Background exposure = exposure attributed to consumption of all non-seafood food items calculated based on estimates of daily dietary exposure (Table 7.12).
[b]Lifetime average daily exposure = exposure attributed to consumption of locally caught fish and shellfish (Table 7.8) and incidental ingestion of seawater during recreational activities (Table 7.4).
[c]RfD or TDI apportioned for seafood only, taking into account background contribution from all non-seafood food items.

7.9. Assessment of current POPs situation in Hong Kong

Overall, the current level of POPs contamination was found to pose no unacceptable risk of potential toxicological concern to the local environment or human health. Key assessment findings are summarized below:

1. None of the nine intentional POPs pesticides (i.e., aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, HCB, mirex and toxaphene) were registered pesticides for use in Hong Kong. The 2004 data in the inventory indicated that there was only a very small quantity of PCBs in PCB-containing equipment in local use/stockpile compared with those reported for other industrialized areas around the world. Indeed, results of an initial questionnaire survey conducted by the EPD in early 2005 suggested that there was little current trading, domestic production and/or use of any of these Convention POPs chemicals in Hong Kong.

Table 7.22. Human carcinogenic risk assessment of POPs pollution in the marine environment of Hong Kong in 2000–2004

Chemical	USEPA Cancer Classification[b]	LADD (total, mg kg^{-1} bw d^{-1})[d]	Slope factor[e]	Excess lifetime cancer risk	Acceptable range of excess lifetime cancer risk (USEPA)
Aldrin	B2	5.78×10^{-6}	1.70×10^{1}	9.83×10^{-5}	1×10^{-4}–1×10^{-6}
Chlordane	B2	8.01×10^{-7}	3.50×10^{-1}	2.80×10^{-7}	1×10^{-4}–1×10^{-6}
DDT	B2	5.80×10^{-6}	3.40×10^{-1}	1.97×10^{-6}	1×10^{-4}–1×10^{-6}
Dieldrin	B2	4.44×10^{-7}	1.60×10^{1}	7.10×10^{-6}	1×10^{-4}–1×10^{-6}
Endrin	D	5.83×10^{-6}	–	–	
Heptachlor	B2	5.28×10^{-6}	4.50×10^{0}	2.38×10^{-5}	1×10^{-4}–1×10^{-6}
Hexachlorobenzene	B2	1.19×10^{-6}	1.60×10^{0}	1.90×10^{-6}	1×10^{-4}–1×10^{-6}
Mirex	2B[c]	0.00×10^{-0}	–	–	
Toxaphene	B2	2.66×10^{-7}	1.10×10^{0}	2.93×10^{-7}	1×10^{-4}–1×10^{-6}
PCBs	B2	5.03×10^{-6}	4.00×10^{-1}	2.01×10^{-6}	1×10^{-4}–1×10^{-6}
Dioxins/furans[a]	B2	8.92×10^{-11}	1.00×10^{5}	8.92×10^{-6}	1×10^{-4}–1×10^{-6}

[a]Unit for dioxins/furans = mg TEQ kg^{-1} bw d^{-1}.
[b]USEPA Weight-of-Evidence Cancer Classification System (B2 = probable human carcinogen; D = not classifiable).
[c]International Agency for Research on Cancer (IARC) Cancer Classification (2B- possible human carcinogen).
[d]Lifetime average daily exposure = exposure attributed to consumption of locally caught fish and shellfish (Table 7.8) and incidental ingestion of seawater during recreational activities (Table 7.4).
[e]USEPA Integrated Risk Information System (IRIS) database.

2. On a "per capita" basis, the current (2003) annual dioxin/furan release in Hong Kong was generally similar to those in Asian regions, Canada, the US and Australia, and was the 2nd lowest in air emission.
3. The level of POPs contamination in the local environment (ambient air, marine water, marine sediment, marine fish and shellfish) was generally comparable to the range reported in most urban locations in Asia Pacific, Europe, the US and Australia.
4. Assessment based on best available data indicated that overall, there was unlikely to be any unacceptable ecological risk of toxicological significance associated with exposure of local marine life to the current level of POPs contamination in the marine environment of Hong Kong.
5. The daily exposure of local residents to DDT, heptachlor, HCB and PCBs was well below (by 1–5 orders of magnitude) the RfD set by USEPA. The estimated total exposure (inhalation and dietary) to dioxins/furans was 0.93 pg TEQ kg^{-1} bw d^{-1}, falling at the lower end of the TDI of 1–4 pg TEQ kg^{-1} bw d^{-1} set by the WHO (1998). Dietary intake was the major route, accounting for 98.2% of total exposure to dioxins/furans.
6. Results of human health risk assessment indicated that there was no unacceptable inhalation nor dietary chronic/carcinogenic risk of toxicological concern associated with a lifetime exposure of Hong Kong residents to the current level of POPs contamination in the local environment and locally consumed foods.
7. The level of POPs contamination in the marine fish and shellfish from Hong Kong waters was found to be well below (by 1–2 orders of magnitude) the Food Safety Standards/Action Levels set by Mainland China, the US and/or the European Community.

7.10. POPs management and implementation strategy in Hong Kong under the Stockholm Convention

The HKSARIP for the Stockholm Convention has identified legislative and inventory data gaps, as well as action items in order for the HKSAR to fully comply with the Convention. On strengthening the institutional and regulatory systems, we need to develop an integrated and transparent legislative framework to effectively control, minimize and prevent the potentially harmful impact of POPs on human health and the environment. On the data gaps identified in the local emission sources, environmental levels, dietary exposure and human body burden of POPs, we need to put in place structured and comprehensive monitoring and auditing to validate and refine the POPs inventory. On measures to

reduce production and release of unintentional POPs, i.e., dioxins/furans, we have been and shall continue pursuing the various reduction measures as part of the HKSAR Government's environmental portfolio in accordance with the established timetable. These measures address emission of dioxins/furans to air and to the aquatic environment as well as integrated environmental waste management. We should uphold the principle of environmental sustainability in pursuing community development and endeavour to apply Best Available Techniques (BAT) and Best Environmental Practices (BEP) to achieve the goal of further reducing and, where feasible, ultimately eliminating POPs from our environment.

Raising public awareness of the POPs-related issues and encouraging public participation are also important elements of the Stockholm Convention. On the public awareness campaign, the HKSAR Government has launched, as a priority action item of the HKSARIP, a dedicated EPD thematic website on POPs (available at http://www.epd.gov.hk/epd/english/international_conventions/pops/pops_main.html) and integrated the topic into the overall environmental protection education programme.

Hong Kong is geographically located at the Pearl River Estuary. Sound and effective environmental management of POPs has a regional dimension to encompass the PRD Region as a whole. On capacity building and strengthening regional collaboration with the PRD, we need to enhance technical information exchange and data sharing, involving not only the state and regional authorities, but also the academia at large. Harmonization of monitoring protocol and risk assessment methodology underpins the successful planning of future joint regional POPs monitoring and inventory development.

7.11. Conclusions

This chapter focuses on the 12 most toxic POPs subject to control of the Stockholm Convention. It is recognized that there are other POPs which have been demonstrated to elicit adverse effects of toxicological significance on human health and the environment, for which international agreement has yet to be reached on their inclusion in the Convention list. Indeed, five new POPs candidates (hexabromobiphenyl (6-PBB), pentabromodiphenyl ether (PBDE), perfluorooctane sulfonate (PFOS), chlordecone and lindane) were proposed and considered at the First Meeting of the POPs Review Committee of the Stockholm Convention in November 2005 (UNEP, 2005). The challenge is for the local scientific

community and regulatory authorities to keep abreast of development in the international POPs arena and join force on the local/regional/global fronts in combating the POPs problem and working towards a POPs free environment for our future generations.

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