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Chapter 10

Persistent Toxic Substances in Thailand

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Abstract

Thailand was one of the Asian countries that are very conservative with regard to the import, introduction and usage of any toxic chemical. The first ever known usage of such a chemical in Thailand was the application of DDT in the early 1950s followed by the chemicals like dieldrin, aldrin, endrin, toxaphene and BHC. The first official report on the import statistics of these chemicals was made only in 1971, even though the country has been busy tackling the occupational health and environmental problems systematically and at national level, even from the early 1960s. There were increases and decreases year by year from the 1950s until various chemicals were banned in different years starting from the ban of DDTs for agricultural use in the year 1983. Studies initiated by Thailand's National Environment Board found organochlorine and organotin compounds as the most common pollutants in the major rivers of Thailand followed by their detection in almost all the environmental and biotic media. In order to control the utilization of toxic substances for various purposes the "Toxic Substance Act of 1967" was first promulgated in Thailand in 1967 and the import, export, manufacture and possession of hazardous substances have been controlled under the Hazardous Substances Act 1992. Even beyond these Acts and several other control measures initiated by the Government of Thailand, the demand for agricultural productivity and the expansion of industry is now causing a rapid increase in the use of many chemicals in Thailand. As a result, wide spread contamination of several persistent chemicals were noticed in almost all the environmental and biotic matrices. Most recently, improved government policy has resulted in better control of chemical management. Even then, the present status of chemicals pollution in Thailand indicates that it may take several more years to reduce the levels of these chemicals considerably from the Thailand environment. Until then, a continuous

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survey for monitoring the present persistent organic pollutnats and several new chemicals that may come in to use in future is an absolute necessity.

10.1. Introduction

Thailand is located in the center of the Southeast Asian region and share borders with four neighboring countries, namely Myanmar in the north and west, Laos in the northeast, Cambodia in the east, and Malaysia in the south. Thailand is the third largest country in Southeast Asia, with a total land area of 513,115 km^2, next only to Indonesia and Myanmar. The borders around Thailand are totally ~8031 km long, of which 5326 km are inland and the other 2705 km are coastlines, including 1840 km of coastlines of the Gulf of Thailand and 865 km along Andaman seaside. Thailand is blessed with four geological features. In the North, high mountains give rise to several rivers and streams. In the northeast is a high plateau while an enormous plain covers the central region. The south is bordered on both sides by seas, namely the Andaman Sea and the Gulf of Thailand, which is part of the Malay Peninsula. Thailand is situated in the tropical zone; the temperature is rather high throughout the year. The climate is monsoonal in character with dry season during October–April and wet season during May–September. However, occasionally the weather turns unusually cold under the influence of a cold mass of air from China and Mongolia during December–February.

The population of Thailand is ~62.42 million in 2005 (Bureau of Registration Administration, 2006), which is currently increasing at an annual rate of ~2% (www.chem.unep.ch/pops). Thailand's economy has been dominated by agriculture during the period from the 1950s to the early 1970s; ~70% of the population was engaged in agriculture sector that provided most of the country's export earning. At present, roughly 47% of Thailand's population is employed in agriculture sector with rice as the country's most important crop. Other agricultural commodities produced in significant amounts include tapioca, rubber, corn, coconuts, and soybean. Thailand has used organochlorine compounds as pesticides to control pests in agriculture and malaria vector control for several decades. However, the demand for organochlorine pesticides is declining sharply and replaced gradually by other chemicals of less persistence.

During the last three decades, Thailand was one of the rapidly developing nations in Southeast Asia. Increasingly diversified industrial sector contributed to the growth of Thailand's economy with a growing number of industrial plants using hazardous chemicals. Between 1970 and

1985, the number of industries registered as using hazardous chemicals increased from ~19,700 to 51,500 (Ross, 1995). Recently, the number has increased to 122,300 in 2005 (Department of Industrial Works, 2006). Such an increase in Thailand's industrial sector is suggestive of greater production and usage of toxic chemicals and exposure of humans and wildlife leading to environmental problems and toxic implications on wildlife. Thus the demand for both agricultural productivity and industrial expansion caused a rapid increase in the usage of chemicals. Thailand's import of chemicals increased from 600,000 MT in 1978 to 13,124,438 MT in 1988 and to 60,395,565 MT in 2003 (National Research Center for Environmental and Hazardous Waste Management, 2004). A rapid increase of urbanization and use of chemicals in industrial and agricultural activities impose potential risk for considerable contamination by chemical substances in the environment (Hungspreugs et al., 1989).

Increase in Thailand's chemical trade is suggestive of greater production and usage of toxic chemicals and exposure of humans and wildlife to those chemicals. Therefore, corresponding environmental problems caused by hazardous chemicals are of great concern in Thailand. This chapter will give information on the sources, transport, persistence in the environment, and biota, import, usage, and control and management of some persistent chemicals in Thailand.

10.2. Sources of persistent toxic substances

Due to the extensive agriculture activities, manufacture and use of pesticides increased dramatically in Thailand. Figure 10.1 shows pesticides from one of the toxic groups of chemicals imported increasingly, from 19,456 MT in 1978 to 29,696 MT in 1993 (Department of Agriculture, 1993). Organochlorine pesticides have been widely used in Thailand for pest control in agriculture as well as for public health purposes (Siriwong et al., 1991). During the last three decades, most of the developed nations have banned or restricted the use of such persistent toxic chemicals, because their extensive usage has resulted in severe environmental problems and human health hazards (Tayaputh, 1996). During the period from 1950 to 1970, most of the imported pesticides were organochlorines including those specified POPs chemicals such as DDT, toxaphene, drins, heptachlor, and others. The trends of organochlorine residues seen in various environmental media showed an increasing trend even after the ban on their use. Under strict enforcement of the ban, the demand for organochlorine pesticides is declining sharply, being replaced gradually by organophosphorus pesticides that are degradable in the

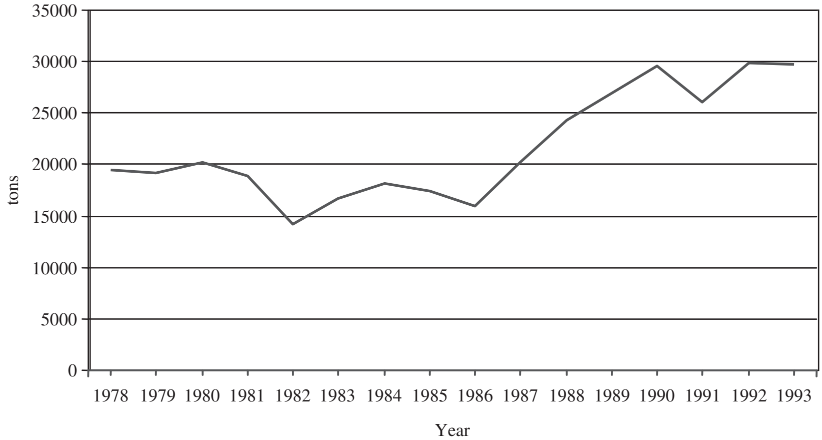

Figure 10.1. Pesticide imports of Thailand between 1978 and 1993. (*Source*: Raw data obtained from Department of Agriculture, 1993. Also see Kan-atireklap et al., 2002)

environment and less accumulative in food chain (Hungspreugs et al., 1989; Tayaputh, 1996).

After the Second World War, DDT (1,1,1-trichloro-2,2-*bis* (*p*-chlorophenyl) ethane) was first introduced for malaria control in a northern province in 1949 by the Ministry of Public Health of Thailand. During those days, malaria epidemic was very serious and caused over 38,000 deaths at the rate of 201.5 persons per 100,000 population. After the initial use of DDT, it was gradually expanded to cover all malaria transmission areas. During the 1970s to the 1980s, DDT has been widely applied with a dosage of $2\,g\,m^{-2}$ and two cycles per year in mountainous and high malarial areas. However, DDT has not only been used for malaria control but also in agriculture for pest control. Although DDT has been banned for agriculture purpose in 1983 and for vector control since 1995 by the Ministry of Public Health, the left over stocks are still being used in remote mountainous areas. However, it was also reported that the Ministry of Public Health used the leftover stockpile until 1999. Since 1995, DDT has been replaced by deltamethrin for vector control and DDT was phased out from 1996 in Thailand (Ministry of Public Health of Thailand, 2003). DDT was used mainly for malaria vector control till 1998 in national boundary areas, such as Cambodia in the east, Myanmar in the west, and Malaysia in the south (Boonyatumanond et al., 2002).

Under the Stockholm Convention, 12 organochlorine compounds were designated as persistent organic pollutants (POPs) and called for their immediate control because they were the most dangerous among all the persistent pollutants released into the environment by human activities. POPs were grouped into three categories, namely pesticides: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, and toxaphene; industrial chemicals: hexachlorobenzene and polychlorinated biphenyls (PCB); and generated unintentionally as by-products of various industrial processes: dioxins and furans. In fact, only seven specified POPs pesticides were imported in Thailand, namely aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, and toxaphene, whereas hexachlorobenzene and mirex have never been imported (Wong-ek, 2000).

Information on the import of the 12 specified POPs chemicals has not really been collected from the very beginning of its usage in the country. Until the mid-20th century, Thailand was very conservative with regard to the import, introduction, and usage of any toxic chemical. The first ever known usage of such a chemical was the application of DDT in Chiangmai Province for control of malaria and later used very widely from the year 1951 for disease control. In the year 1953, DDT was first applied to control the epidemic of grasshopper and then on cotton bole worm from the year 1955. Following DDT, the chemicals like dieldrin, aldrin, endrin, toxaphene, and BHC were first imported in the year 1955.

PCBs were first used in small quantities in industrial fluids for hydraulic systems and gas turbines, and as plasticizers. The other main purpose for which they were used in a relatively large quantity was as dielectric fluid for electric capacitors. PCB was totally banned in the year 1975. But, reports by the Electricity Generating Authority of Thailand (EGAT), Metropolitan Electricity Authority (MEA), and Provincial Electricity Authority (PEA) indicate possession of PCBs containing transformers and capacitors.

The first official report on the import statistics of these chemicals was made in 1971. After this, the import of POPs chemicals increased year by year. There were increases and decreases year by year until various chemicals were banned in different years. For example DDT was banned for agricultural use in the year 1983 and totally in the year 1994; aldrin in the year 1988; dieldrin in 1986; endrin in 1981; heptachlor in 1988; toxaphene in 1982; HCB in 1980; and PCBs in the year 1975. Only chlordane remained in use until 1996 (www.chem.unep.ch/pops-Inc/).

At present, Thai government initiated systems for monitoring import of hazardous materials which is now successfully implementing and able to give fairly accurate import statistics of hazardous materials. For example, although dieldrin was banned since 1988, this monitoring system showed that dieldrin is being imported until recently (Danutra and Ratanasatian, 2002). They have also shown that, even after all of the specified POPs pesticides were banned in Thailand before the year 2000, small amounts of some organochlorine pesticides, namely DDT, aldrin, dieldrin, and endrin, were imported during the period 2001–2005.

Organotin compound is one of the organometalic chemicals, which are widely used for industrial and agriculture purposes. The first application was as a mothproofing agent in 1925 and for stabilizing chlorinated benzenes and diphenyls used in transformers and capacitors in 1932. Since the biocidial properties of trialkylated organotins were recognized in the 1950s, an increasing number of organotin compounds were developed and used as important industrial and agricultural commodities (Champ and Pugh, 1987). At present there are three major areas of utilization of organotin compounds, namely heat stabilizers for polyvinyl chloride polymers, industrial and agricultural biocides, and industrial catalysts (Fent, 1996).

Application and usage statistics of organotin compounds was first compiled by the International Tin Research Institute (ITRI), which was initially financed by five of the major tin producing countries of the world, viz. Indonesia, Malaysia, Nigeria, Thailand, and Zaire. Although Thailand is one of the major tin producing countries, use of organotin compounds in Thailand is limited mainly because the chemicals must be imported from abroad, making them more expensive and not competitive with other compounds having similar application values (Visoottiviseth, 2001). The biocidial use of organotin compounds were estimated to account for ~30% of total present use.

Among the organotin compounds, the trialkyltins are mainly used as biocides. Tributyltin (TBT) is used as an antifouling agent in paints applied on boats and fishnets, lumber preservatives, and as slimicides in cooling systems. Dibutyltin (DBT) is used as a polyvinyl chloride stabilizer and as a catalyst in some industrial processes (Maguire, 1987). The biocidial use as antifouling agent in paints applied on boats give rise to the largest proportion of free butyltin in the aquatic environments. The aquatic pollution by butyltin compounds arising from antifouling paints has been of great concern in many countries due to their effect on non-target marine organisms, which occur even at few nanograms per liter of aqueous TBT concentrations (Alzieu and Heral, 1984; Alzieu and Portmann, 1984; Beaumont and Budd, 1984; Bryan and Gibbs, 1991). These adverse effects prompted the restriction of TBT usage in many countries like USA, France, UK, Switzerland, New Zealand, and Japan (Alzieu, 1991; Waite et al., 1991; Dowson et al., 1993; Horigushi et al., 1994; Smith, 1996; Tóth et al., 1996). Although TBT use on small vessels of length less than 25 m was banned in many countries, TBT-based antifouling paints are still being used on larger or far sea vessels, particularly on commercial ships, which utilize ~75% of the total TBT used as antifouling paints. The number of commercial vessels loading and unloading in Thai coastal waters increased from 73,292 in 1998 to 103,482 in 2004 (Marine Department, 2006) and still increasing. In addition, an increasing demand for antifouling paints is predicted in the Asia-Pacific region including Thailand (Layman, 1995; Reisch, 1996), and hence the aquatic environment in this region may face serious organotin pollution in future.

On the other hand, triphenyltin acetate and triphenyltin hydroxide were the first commercial products introduced during the early 1960s followed by triphenyltin chloride, tricyclohexyltin hydroxide, bis(trineophenyltin) oxide, and tricyclohexatin-1,2,4-triazole, respectively. Triphenyltin hydroxide was one of the recommended pesticides for rice and necessary for countries like Thailand where rice is a major component of both domestic and export markets (Visoottiviseth, 2001).

At present, the usage of organotin compounds in Thailand is still unclear. Before 1998, the import data of organotin compounds was lacking. Recent data show that tributyltin fluoride as one of butyltin compounds was used as a biocidial agent in Thailand and imported increasingly from 1.4 MT in 1998 to 6.3 MT in 2001 as shown in (Kan-atireklap et al., 2004). The purpose and usage statistics of this compound in Thailand is not known. To our knowledge, the usage of organotin compounds in Thailand is not yet controlled and the possible usage of butyltin compounds as antifouling agents in paints in the country is also not clear. Further, data on the occurrence of butyltin compounds in environment of Thailand is very much lacking.

10.3. Status of contamination

10.3.1. Abiotic environment

Very limited information is available, either in the scientific literature or in popular literature available through Internet. Thapinta and Hudak (2000) in their report on the pesticide use and residual occurrence in Thailand reviewed the import and usage statistics of different pesticides and also their residual levels in different environmental samples. Thailand is a country where the climatic conditions make it suitable for cultivating a wide range of tropical and semi-tropical crops. Recently, Thailand is improving fast in the industrial sector, all these activities leading to the import of many chemicals from several nations. Chemicals import, especially those of pesticides to Thailand have increased rapidly over the past decade—more than double between 1987 and 1996, that is from 20,357 MT in 1987 to 45,071 MT in 1996 (DOA, 1996).

Table 10.1. Pesticide residue levels in water samples from main rivers in Thailand, 1985–1988 (*Source*: Thapinta and Hudak, 2000)

Chemical	Type	Concentration (μg L^{-1})				Standard (μg L^{-1})
		1985	1986	1987	1988	
Aldrin	OC	NA	NA	0.01–0.44	0.01–0.02	0.1
Alpha-BHC	OC	0.01	NA	NA	<0.01	0.02
Beta-BHC	OC	0.04	NA	NA	NA	0.2
Gamma-BHC	OC	0.01–0.02	NA	NA	NA	–
DDT	OC	0.01–0.02	NA	0.02–0.55	0.10–0.35	1.0
Dieldrin	OC	0.01–0.13	NA	0.003–0.10	0.01–0.13	0.1
Heptachlor	OC	NA	NA	0.01–0.14	0.01–0.3	0.2
Heptachlor epoxide	OC	0.01–0.07	NA	NA	NA	0.2
Lindane	OC	NA	NA	0.04	0.04	–
Methyl parathion	OP	0.01–0.20	NA	0.09–0.68	0.01–0.68	–
Dimethoate	OP	0.03–0.24	NA	0.06	0.06	–
Diazinon	OP	0.19	NA	0.07–0.28	0.01–0.28	–
Carbofuran	C	0.01–1.37	NA	0.01–1.37	NA	–

Source: Office of the National Environment Board (1991).
Note: NA (data not available); OC (organochlorine insecticide); OP (organophosphate insecticide); C (carbamate insecticide).

Studies initiated by Thailand's National Environment Board (ONEB, 1991) found that various organochlorine pesticides occurred frequently in water samples of the main rivers of Thailand (Table 10.1). Further, a study by Thailand's Pollution Control Department (PCD, 1977a, b) showed that organochlorine insecticides are the most common pollutants in the ground water samples from agricultural areas in Thailand (Table 10.2). At the same time, organophosphate concentrations were found to be higher than organochlorine levels, because of their wide use in the country. However, some organochlorine insecticides were banned a decade before the sampling for this study. Recently, a monitoring study conducted by a group of scientists from the Environmental Research and Training Center of the Department of Environment Quality Control of the Ministry of Natural Resource and Environment during 2002–2003 on a batch of 48 water samples collected from four main rivers namely The Chao Pharya River, The Mae-Klong River, The Bang-Pakong River, and The Tha-Chin River has reported very low concentrations of OCs like DDTs, CHLs, endrin, dieldrin, aldrin, etc. (http://landbase.hq.unu.edu/Country reports/2000/Thailand2002.htm). It was also suggested in that study that the tropical climatic conditions facilitated the loss of residues from the soil and heavy

Table 10.2. Pesticide residues in water samples from agricultural areas of Thailand 1996–1997 (*Source*: Thapinta and Hudak, 2000)

Chemical	No. of samples	Type	Concentration ($\mu g\,L^{-1}$)		Standard ($\mu g\,L^{-1}$)
			1996[a]	1997[b]	
Alpha-BHC	47	OC	NA	0.002–0.005	0.02
Beta-BHC	78	OC	NA	0.001–0.024	0.2
Gamma-BHC	61	OC	NA	0.001–0.032	–
Aldrin	38	OC	NA	0.001–0.006	0.1
DDT	56	OC	0.007	0.001–0.089	1.0
Dieldrin	33	OC	0.003–0.576	0.006–0.017	0.1
Endrin	21	OC	NA	0.003–0.011	0.0
Endosulfan	79	OC	0.003–1.350	0.001–0.460	–
Heptachlor	57	OC	NA	0.001–0.006	0.2
Heptachlor epoxide	79	OC	NA	0.001–0.300	0.2
Methyl parathion	21	OP	0.007–8.720	NA	–
Methamidophos	11	OP	0.002–0.011	NA	–
Mevinphos	21	OP	0.014–47.500	NA	–
Permethrin	10	PY	2.81	NA	–
Dicofol	21	A	0.007–10.510	NA	–

Source: Pollution Control Department (1997a).
Note: NA (data not available); OC (organochlorine insecticide); OP (organophosphate insecticide); PY (pyrethroid insecticide); A (acaricide).
[a]Data collected from northern part of Thailand.
[b]Data collected from eastern part of Thailand.

rainfall carried away the chemicals to the coastal regions of the Andaman Sea. A study conducted by the Department of Agriculture in five main rivers of Thailand showed detection of organochlorines in 40.6% among the 805 water samples (range $<$0.02–1.21 mg l^{-1}) and in 46.6% of 693 sediment samples (range $<$0.01–7.43 mg kg^{-1}).

With regard to sediments, in an earlier study Menasveta and Cheevaparanapiwat (1981) detected organochlorines, especially DDT and its metabolites but no PCBs in the sediments of the mouths of rivers Mae Klong, Tha Chin, Chao Pharya, and Bang-Pakong. Most recently, Boonyatumanond et al. (2007), in their work on four sediment cores collected from an offshore transect in the upper Gulf of Thailand found a subsurface maximum ($\sim$2000 pgg^{-1}) of PCBs in layers corresponding to the 1970s, indicating the effectiveness of regulation of PCBs in Thailand, which was enforced in the year 1975. The authors have also suggested possible leakage of PCBs from the transformers and capacitors in use and in storage at present in the country contributing to ambient soils and sediments. Apart from POPs, Kan-atireklap et al. (1997a) found that the coastal sediments of Thailand are contaminated by butyltin compounds, the levels being consistently related to various activities like commercial vessel transport, coastal mariculture, etc. (Table 10.3).

Vulnerability studies of agricultural soils and 90 wells at three different provinces of Thailand conducted by Thapinta and Hudak (2003) for several pesticides using Geographical Information Systems showed that the depth of the wells was the most significant vulnerability factor followed by soil texture, percent slope, and average monthly rainfall. As a result, they found that the agricultural areas in Central Thailand characterized by fine-textured soils and unconsolidated aquifers reduce the threat of pesticide contamination in the region. While the data on the actual levels of different persistent chemicals are limited in the soils and sediments of Thailand, various studies were conducted on the effects of different soil types (Parkpian et al., 1998) and water flow and percolation patterns (Ciglasch et al., 2005; Chatupote and Panapitukku, 2005) on the distribution of pesticides in the country.

10.3.2. Wildlife

Since 1979, several studies have detected the presence of organochlorine pesticides in various environmental compartments such as agricultural commodities, soil, fresh and marine waters, and marine organisms in Thailand (Menasveta & Cheevaparanapiwat, 1981; Thoophom et al., 1984; Siriwong et al., 1991; Ruangwises et al., 1994; Kanatharana et al., 1994; Impithuksa et al., 1995; Kan-atireklap et al., 1997b; Chamrasakul et al., 1999). During the last three decades, improved governmental policy through legislation and monitoring has resulted in better control of pesticides. Since 1979, numerous samples from different sources were collected and analyzed each year. Relatively small amounts of organochlorine pesticides were found in different percentages of samples collected. During 1987–1994, organochlorine pesticide residues were detected in relatively lower levels and percentages of samples (Wong-ek, 2000). Most samples were reported to contain a very few parts per billion or even at non-detectable level of several compounds.

Tanabe et al. (2000) by their analyses of the organochlorines PCBs, DDTs, CHLs, HCHs, and HCB by collecting the green mussels (*Perna viridis*) from 21 locations in Thailand, 13 locations in the Philippines, and 19 locations in India during the years 1994–1997 found widespread contamination of all the compounds in all the three countries. There were subtle differences in the mean values which were not statistically significant (Fig. 10.2). In this study, concentrations of PCBs in green mussels from coastal waters of Thailand exhibited a smaller variation among locations. Relatively high levels of PCBs were detected at some locations around

Table 10.3. Concentrations (ng g^{-1} dry wt.) of butyltin compounds in sediments from various areas in the world (*Source*: Kan-atireklap et al., 1997a)

Location	Year	MBT	DBT	TBT	References
Vancouver Harbour, Canada	1982–1985	nd–3400	nd–8500	nd–11,000	Maguire et al. (1986)
Poole Harbour, UK	1985–1987	NA	10–570	20–520	Langston et al. (1987)
Boston Harbor, USA	1988	nd–130	nd–316	nd–518	Makkar et al. (1989)
East, Gulf, and Pacific coasts of USA	1986–1991	NA	NA	< 10–770	Krone et al. (1996)[a]
Mediterranean Sea (French, Italy, Turkey, and Egypt coasts)	1988	nd–670	nd–830	70–3400	Gabrielides et al. (1990)
Marina area, Hong Kong	1988–1989	NA	NA	60–1160	Lau (1991)
	1994	NA	NA	nd–130,000	Ko et al. (1995)
Auckland, New Zealand	1990	NA	NA	< 2–1360	de Mora et al. (1995)
Bohemia River, Chesapeake Bay, USA	1991	0–13	4–110	15–590	McGee et al. (1995)
Portland and Boothbay Harbor, Maine, USA	1990–1992	NA	15–2240	24–12,400	Page et al. (1996)
Coasts, Thailand	1995	7–410	2–1900	4–4500	This study

Note: All concentrations expressed as tin (Sn) we converted to MBT, DBT, and TBT cation by a factor of 1.48, 1.96, and 2.44, respectively; nd (not detected); NA (no data available).

[a] ng g^{-1} wet wt.

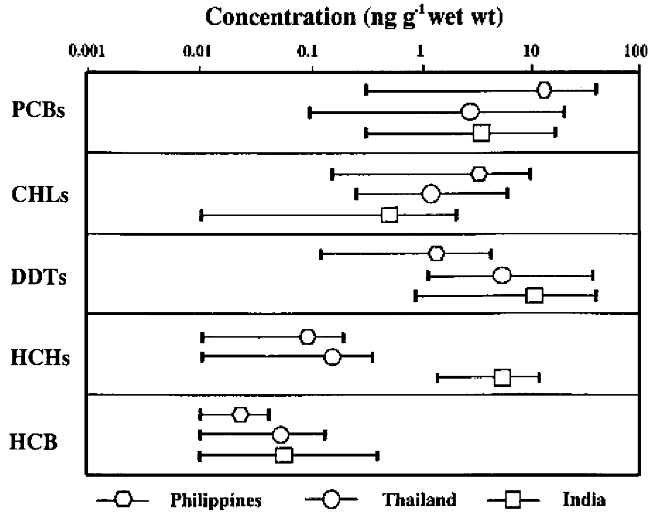

Figure 10.2. Comparison of organochlorine residue levels in green mussel (*Perna viridis*) from India, the Philippines, and Thailand. (*Source*: Tanabe et al., 2000.)

populated and industrialized cities like Samut Prakan and Chonburi. Transformers and capacitors imported by Electric Authority of Thailand were considered as major PCB pollution source in Thailand. Watanabe et al. (1996) also found in an earlier work that the dumped electrical appliances were also a prime source of PCB pollution proximal to the estuary of Chao Pharya River at the suburbs of Bangkok.

DDT and its metabolites (DDTs) have been reported to be present in green mussels along the coastal waters of Thailand, ranging from 32 to 42 ng g^{-1} in 1979 (Menasveta and Cheevaparanapiwat, 1981), 0.39–7.41 ng g^{-1} in 1989 (Siriwong et al., 1991), 0.74–5.38 ng g^{-1} in 1991 (Ruangwises et al., 1994), 1.3–38 ng g^{-1} in 1994 and 1.2–15 ng g^{-1} in 1995 (Kan-atireklap et al., 1997b), 0.05–5.7 ng g^{-1} during 1997–1999 (Boonyatumanond et al., 2002), and 0.86–2.11 ng g^{-1} in 1998 (Noicharoen, 2000).

DDTs were also detected in marine fish collected from market in Bangkok during 1989–1993, ranging from 0.48 to 19 ng g^{-1} (Kannan et al., 1995b) and from coastal water areas along the east coast of the Gulf of Thailand during 1999–2000, ranging from <0.01–17.48 ng g^{-1} (Kan-atireklap et al., 2002). In general, *p,p′*-DDE the metabolite of *p,p′*-DDT under aerobic condition was predominant, showing a possible decrease in the usage of DDT. Even though the usage of DDT for agriculture purposes has been banned since 1983 and for vector control purposes since 1995, DDT was used mainly for malaria vector control till 1998 in the boundary areas between Myanmar, Cambodia, and Malaysia (Boonyatumanond et al., 2002).

Considerable proportion of *p,p′*-DDT in DDTs was found in green mussel, oyster, and marine fish from several locations during the period of 1998–2000 (Noicharoen, 2000; Saisith, 2002; Boonyatumanond et al., 2002; Kan-atireklap et al., 2002). This may indicate the presence of significant current sources of DDT in Thailand related to public health issues.

In the fresh water environment, Kumblad et al. (2001) found DDT and its metabolites in four species of fish (Sactophagus argus, Protosus canius, Channa striata, and Zonichthys nigrofasciata) from Songkhla Lake. The mean $\sum$DDT concentrations in fish from different locations of the lake ranged from 33 to 170 ng g^{-1} lipid wt. (0.086–7.7 ng g^{-1} fresh wt.), which is well below the recommended maximum residue levels for aquatic animals (5000 ng g^{-1} fresh wt.) in Thailand. The authors have attributed such low concentrations in fresh water fish, in spite of wide use, may be due to the high volatilization and degradation of DDT in the tropical condition in Thailand and/or due to the high biological productivity in the lake leading to dilution and degradation of the pollutants.

Chlordane compounds (CHLs) were detected in green mussel, ranging from 0.3 to 5.9 ng g^{-1} in 1994 and 0.25–3.5 ng g^{-1} in 1995 (Kan-atireklap et al., 1997b) and 0.22–12.0 ng g^{-1} during 1997–1999 (Boonyatumanond et al., 2002). However, the CHLs were detected in marine fish which showed a similar range of concentration from 0.1 to 15 ng g^{-1} during 1989–1993 (Kannan et al., 1995b) and from <0.01 to 4.7 ng g^{-1} during 1999–2000 (Kan-atireklap et al., 2002).

Hexachlorocyclohexanes (HCHs) were found in fish from Bangkok, ranging from 0.22 to 1.8 ng g^{-1} during 1989–1993 (Kannan et al., 1995b), whereas the range of concentrations was from <0.01 to 1.15 ng g^{-1} during 1999–2000. These may be because the usage of HCHs in Thailand has been banned since 1980. Lower residence time of HCHs in the aquatic environment of this tropical country might be because of the prevailing high temperature leading to easy volatilization and transport from the point source as observed by Takeoka et al. (1991) in India.

Hexachlorobenzene (HCB) contamination seems to have originated from the usage of fungicides or as an impurity in pesticide formations, a by-product of various chlorination processes and the combustion of industrial and municipal wastes (Kannan et al., 1995b). The earlier studies showed low concentrations of HCB in green mussels, ranging from <0.02 to 0.31 ng g^{-1} in 1989 (Siriwong et al., 1991), <0.02–0.21 ng g^{-1} in 1991 (Ruangwises et al., 1994), <0.01–0.09 ng g^{-1} in 1994, and <0.01–0.12 ng g^{-1} in 1995 (Kan-atireklap et al., 1997b), whereas in the fish collected during 1999–2000 HCB was not detected (Kan-atireklap et al., 2002).

However, in recent studies on marine organisms collected from east coast of the Gulf of Thailand during 1999–2000, several organochlorine pesticides were detected in some marine fish, namely monocle bream (*Scolopsis* spp.), threadfin bream (*Nemipterus* spp.), lizardfish (*Saurida* spp.), goatfish (*Parupeneus* spp.), and common squid (*Loligo* spp.) with ranges of <0.01–$17.48\,\mathrm{ng\,g^{-1}}$ for DDTs, <0.01–$1.15\,\mathrm{ng\,g^{-1}}$ for HCHs, and <0.01–$4.74\,\mathrm{ng\,g^{-1}}$ for CHLs, whereas HCB was not detected. Among the organochlorine pesticides examined, DDTs were found to be the highest, followed by CHLs and HCHs, respectively (Kan-atireklap et al., 2002).

In general, earlier results showed that DDT residues were the highest among various pesticides analyzed, followed by CHLs, HCHs, and HCB, in that order. On the other hand, higher levels of CHLs than DDTs were detected in mussels during 1997–1999 (Boonyatumanond et al., 2002). These results may indicate that the usage of DDT in several locations in Thailand decreased after the ban, whereas CHLs were being widely used until its ban in the year 2000.

From the public health point of view, high DDT levels in fish and squid collected during 1999–2000 did not exceed the Extraneous Residues Limit (ERL) of $1000\,\mathrm{\mu g\,kg^{-1}}$ (wet weight basis) for meat and entrails of aquatic animals, issued by the Ministry of Public Health of Thailand as shown in Fig. 10.3 (Kan-atireklap et al., 2002), and $300\,\mathrm{\mu g\,kg^{-1}}$ for poultry meat, as recommended by FAO/WHO (FAO/WHO, 2000). Based on the average daily consumption (57 g/day/person) of fish by Thai (FAO, 1991 cited by Kannan et al., 1995a) of 60 kg body weight and using the values on the levels of DDTs in marine fish and squid collected during 1999–2000, the daily intake of DDTs by Thai were estimated. The average dietary intake value of Thai was found to be 0.062 μg/person/day with the highest value of 0.996 μg/person/day. The dietary exposure to DDTs from marine fish and squid by Thai was lower than that of the Provisional Tolerable Daily Intake (PTDI) of 600 μg/person/day recommended by FAO/WHO (FAO/WHO, 2000). However, the dietary intake of DDTs was likely to be an underestimation of the actual consumption because the values were obtained from fish only.

Up to now, some studies have reported the contamination by organotin compounds in Thailand. Tributyltin contaminations in sea water, fish, bivalves, and sediments collected from Thailand have been reported (Kannan et al., 1995a; Kan-atireklap et al., 1997a, b; Tiensing, 1997; Lommettra, 2001; Kan-atireklap et al., 2004) and imposex widely reported as being caused by tributyltin was also recorded in gastropods in the coastal areas of the Gulf of Thailand and Andaman Sea (Swennen et al.,

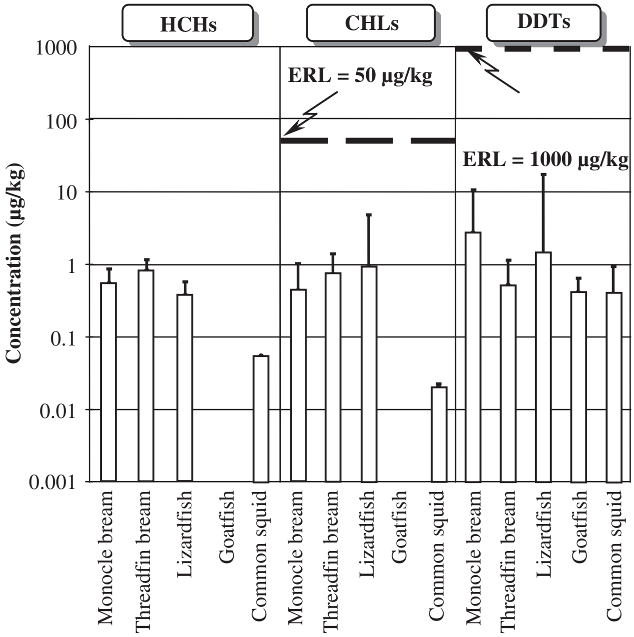

Figure 10.3. Average (white bar) concentration levels of organochlorine pesticides contaminated in marine organisms from Eastern coast of the gulf of Thailand comparing to Extraneous residue Limit (ERL). (*Source*: Kan-atireklap et al., 2002.)

1997; Bech, 1999). These observations indicate that butyltin compounds are widespread in Thai waters.

The occurrence of organotin compounds in Thailand was first reported in fish, namely Silver pomfret, Indian mackerel, and Giant seaperch collected from Bangkok in 1994 (Kannan et al., 1995a). Concentrations of total butyltin compounds in fish muscles ranged from 2.9 to 16 $ng\,g^{-1}$ on wet wt. Among various butyltin derivatives, tributyltin was a predominant compound found in muscle of fish with the range of 1.3–13 $ng\,g^{-1}$ on wet wt. Similarly, tributyltin was also detected in muscles of demersal fish collected from offshore of east coast of the Gulf of Thailand in 2000, ranging from 0.2 to 10.1 $ng\,g^{-1}$ wet wt., whereas the concentration range of total butyltin compounds was from 0.2 to 11.5 $ng\,g^{-1}$ wet wt. (Kan-atireklap et al., 2004).

During 1994–1995, butyltin compounds in green mussels (*P. viridis*) collected along the coastal areas of Thailand, both in the Gulf of Thailand and Andaman Sea were widely detected in a range of 4–800 $ng\,g^{-1}$ wet wt., suggesting a widespread contamination along the coastal waters of Thailand. Relatively high concentrations of butyltin compounds in green mussel were found in high boating activity and coastal aquaculture areas, implying the usage of tributyltin as a biocide in antifouling paints used on boat hulls and marine aquaculture facilities (Kan-atireklap et al., 1997b). Concentration ranges were from <3 to 45 ng g^{-1} wet wt. for monobutyltin, 1–80 ng g^{-1} wet wt. for dibutyltin, and 3–680 ng g^{-1} wet wt. for tributyltin. The composition of butyltin derivatives in mussel was in the order of tributyltin > dibutyltin > monobutyltin, suggesting also the presence of significant and recent butyltin source in coastal Thailand. Butyltin residual pattern in green mussels revealed higher levels in aquaculture than in boating activity sites. Butyltin compounds in marine fish (Kan-atireklap et al., 2004) was lower than sediments (Kan-atireklap et al., 1997a) and mussel (Kan-atireklap et al., 1997b) (Fig. 10.4). Further, a study on the distribution of BTs in green mussels (*P. viridis*) by Kan-atireklap et al. (1997b) showed a widespread contamination all along the coastal areas of Thailand (Fig. 10.5). Recently, 10 ng l^{-1} has been designated as the safe level for all coastal areas in Thailand (PCD, 2006).

In addition, Tiensing (1997) determined tributyltin residues in sea water and oyster (*Saccostrea cucullata*) samples collected from the high boating activity along the east coast of the Gulf of Thailand and detected these compounds in ranges of 62.2–93.9 ng l^{-1} for sea water and 19.7–237 ng g^{-1} wet wt. for oyster. In 2000, butyltin compounds in the eastern coast of the Gulf of Thailand were detected in the ranges of 43.1–277.1 ng l^{-1} in sea water, 2.3–73.4 ng g^{-1} wet wt. in bivalves, and 8.7–63.9 ng g^{-1} wet wt. in marine fish (Lommettra, 2001). On the other hand, a recent investigation

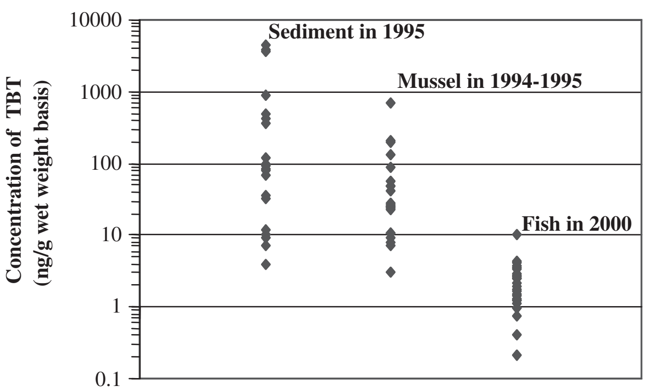

Figure 10.4. Comparison of TBT in environmental samples from Thailand. (*Source*: Kan-atireklap et al., 1997a,b; Kan-atireklap et al., 2004.)

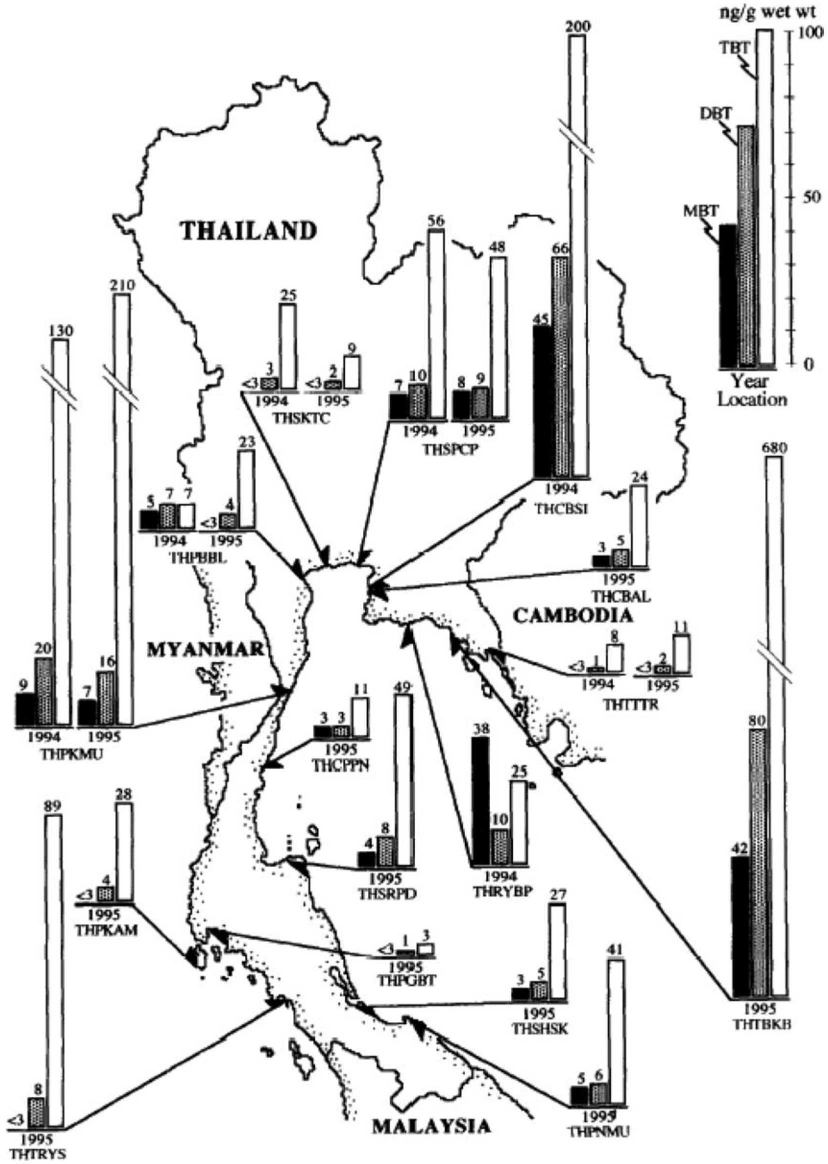

Figure 10.5. Distribution of butyltin compounds in green mussel (*Perna viridis*) from Thailand coastal waters. (*Source*: Kan-atireklap et al., 1997b.)

has shown the presence of lower concentrations of tributyltin in coastal fish than those from offshore areas far from tributyltin sources (Kan-atireklap et al., 2004). According to a monitoring survey of Pollution Control Department of Thailand, tributyltin concentrations in sea water collected from coastal areas of Thailand in 2003 ranged from 2 to $52\,ng\,l^{-1}$ (Pollution Control Department, 2004). The high TBT concentration levels were found in high shipping areas.

Numerous investigations have shown that there is a significant correlation between incidence of imposex and the concentration of tributyltin in the tissue of gastropods (Gibbs et al., 1990). Recent studies showed widespread occurrence of imposex in coastal waters of Thailand (Swennen et al., 1997; Bech, 1999). Swennen et al. (1997) reported the percentage of occurrence of imposex in gastropods from high shipping areas was 100% in some locations along the east coast of the Gulf of Thailand and 86% in southern part of Thailand. Nearly 100% of *Thais bitubercularis* female had imposex in the harbor area and up to 1 km from any known source of tributyltin (Bech, 1999).

Recently, imposex in *Thais distinguenda* increased significantly from 1996 to 2000 at Phanga Bay along the east coast of Phuket Island, Thailand. The area of occurrence of females with imposex increased, extending from 3.5 km in 1996 to 10 km from the harbor areas in 1999 and 2000 (Bech, 2002). Even the less sensitive species of gastropods *Morula musiva, M. granulata, M. margariticola*, and *Thais rufotincta* also developed imposex at three main areas of intense shipping and tourism activities in the region. The author has also mentioned that his results suggest that TBT contamination is worsening, against global trends, because regulations prohibiting the use of TBT-paints do not exist in Thailand.

According to some earlier studies, detection of butyltin compounds in sediments (Kan-atireklap et al., 1997a) and mussels (Kan-atireklap et al., 1997b) of Gulf of Thailand suggest the source of tributyltin is the usage of antifouling paints in coastal aquaculture and in far sea vessels or boating activities. High concentrations of butyltin compounds were found in mussels from coastal aquaculture areas and high fishing boat activities, whereas far sea vessel areas were lower. On the other hand, high butyltin levels were detected in sediments from commercial or far sea vessel areas, whereas the levels in high fishing boat and coastal aquaculture areas were lower. Despite early restriction on the use of tin-containing boat paints, a considerable amount of butyltin compounds is still stored in polluted sediments with a half-life of several years (Sarradin et al., 1994, 1995; de Mora et al., 1995). Therefore, butyltins in sediment might exhibit earlier contamination, whereas mussels may reveal a present contamination of butyltin compounds in respective aquatic environment. This pattern implies that butyltin usage in coastal aquaculture in Thailand might have increased from the past to present, while usage in far sea vessels or boating activities were in a steady state or could have slightly increased.

Additionally, continuous input of tributyltin into the coastal waters of the Gulf of Thailand may also provide a plausible explanation for the higher ratio of tributyltin found in fish samples (Kan-atireklap et al., 2004). The usage of organotin compounds in antifouling paints and other purposes was not controlled in Thailand yet. Fent (1996) suggested butyltin contaminations must be regarded as a global problem, particularly where no regulation has been implemented, such as in countries in Asia, Africa, and South America. In addition, an increasing demand for antifouling paints is predicted in the Asia-Pacific region (Layman, 1995). Considering the unregulated usage and the increasing demand of butyltin compounds in Thailand, organotin contamination in aquatic environment may increase in the future.

10.3.3. Human

Since the 1960s, monitoring programs of persistent compounds in human tissues have been implemented in many industrialized and some developing countries (Tanabe and Subramanian, 2006) for assessing environmental pollution and to estimate the body burden as well as their toxic risks. Thailand has been using organohalogen compounds from the middle of 20th century, but over the past 20 years many of these compounds, especially the organochlorines were banned by Thai government. In spite of such widespread use and ban based on various estimates of the levels of pollutants in the environment and wildlife, information on the human levels of PTS in Thailand is very much scanty.

In earlier attempts Schecter et al. (1989a) found that the human milk samples of Thailand contained higher levels of DDT and its metabolite DDE than in USA and Germany. They have also reported detection of PCDD/DF in the human milk from Thailand. It was also reported by Schecter et al. (1991) that the human blood samples from Thailand contained measurable levels of PCCDD/DF and also PCBs. Further, the same group of authors (Schecter et al., 1989b) reported that the soy milk preparations and cow milk from Thailand, to which the newborn infant changes after weaning, contained quite low levels of dioxins and dibenzofurans as compared to human milk, pointing out to a matter of severe concern in Thailand.

A survey on the levels of organochlorine pesticides in human milk from Hmong hill tribes in northern Thailand (Stuetz et al., 2001) reported considerable levels of heptachlor ($125\,ng\,g^{-1}$ lipid), heptachlor epoxide

(177 ng g^{-1} lipid), DDE (8210 ng g^{-1} lipid), and DDT (2600 ng g^{-1} lipid). Further, the estimated daily intakes of DDT, heptachlor, and heptachlor epoxide by the infants exceeded up to 20 times the acceptable daily intakes recommended by the FAO and WHO. The authors found that HCB values in many of their samples also exceeded the tolerable daily intake guidance values recommended by WHO. Even though the use of many of the organochlorines are banned in Thailand, it may take 10–20 years before low levels of OCP residues, such as those in developed countries at the end of the 1990s, can be reached.

10.3.4. Food items

As early as in 1991, Tanabe et al. analyzed the raw food items like fish meal, meat, farm products, etc. from Bangkok, Thailand, for their organochlorine pesticide levels and found that PCBS, DDTs, HCHs, HCB, aldrin, dieldrin, and heptachlor epoxide were found at least in trace amounts in all the samples analyzed (Tanabe et al., 1991). They found higher HCH levels in the farm products whereas DDTs were higher in fishes including fish flakes and fish meal. Meat samples contained higher DDTs and dieldrin. PCBs were also found in low levels. However the levels were lower than the food safety levels set forth by FAO/WHO/FDA. Food contamination in Bangkok by HCB, heptachlor, and heptachlor epoxide was comparatively lower. Earlier to this report, Schecter et al. (1989b) found measurable levels of PCDDs/DFs in soy preparations and in cow's milk of Thailand indicating a severe concern on infant health. In their attempt in reviewing the organotin levels in seafood of several countries, Belfroid et al. (2000) have stated that the literature data on TBT show that the Tolerable Average Residue Level (TARL) is exceeded in one or more samples in developed nations such as Canada, France, Italy, Japan, and USA and in some developing countries such as Taiwan, Korea, and also Thailand. Other than these, not much information is available on the levels of persistent toxic chemicals as has been available from developed and some other developing nations.

10.4. Management of hazardous substances

10.4.1. Laws, regulations, and implementation

Ever since the early 1960s, Thailand has been busy tackling the occupational health and environmental problems systematically and at national level. At present, there are many government agencies responsible in the field of chemical control and management. Before 1967, production, import, export, sale, or handling of toxic substances in Thailand was not controlled. In order to control the utilization of toxic substances for various purposes, the "Toxic Substance Act of 1967" was promulgated in Thailand in 1967. In 1973, some more measures on registration of manufacturers of toxic substances were added to the amendment of the Act, which was promulgated as the "Toxic Substance Act, 2nd Amendment of 1973."

Later, a large number of hazardous substances, other than those specified in the above Acts, were used in various industries and agriculture in Thailand. Several Ministries, bureaus, and departments administered the then existing laws. As a consequence, different proclamations were made during different periods of time, resulting in discrepancies and incomprehensiveness of the provisions of the existing Acts. So, concerned agencies collaborated in the revisions and integration of the then existing laws into one law known as Hazardous Substance Act of 1992. By definition, the "Hazardous Substance" means any of the following substances: explosives, flammable, oxidizing agents and peroxides, toxic, infectious, radioactive, mutant causing (mutagens), corrosive, irritating, and other substances either chemicals or otherwise which may cause injury to humans, animals, plants, properties, or the environment. Three ministries, namely the Ministry of Industry, the Ministry of Agriculture and Cooperatives, and the Ministry of Public Health are directly involved in the control of hazardous substances.

The Ministry of Industry has established quality standards and control of industries and factories involved with chemicals, particularly those generating hazardous or toxic chemicals under the provision of the Factory Act of 1969 (amended in 1972, 1975, 1979, and 1992). The Ministry of Agriculture and Cooperatives has the authority to control toxic substances in agriculture, particularly pesticides. Under the same Act, the Ministry of Public Health also controls the toxic substances used as consumer products and for some purposes of human health. After 1992, those ministries included a lot of hazardous substances in the Ministerial Notification by periodically following the evaluation of such substances, either old or newly introduced.

The Ministry of Natural Resources and Environment is responsible for developing policies, strategies, and action plans to achieve environmental quality standards and pollution control. This ministry is composed of various departments, such as Department of Environmental Quality Promotion, Pollution Control Department, and Office of Natural Resources and Environmental Policy and Planning. Recommendations have been made with regard to the maintenance of environmental quality standards and control of pollution by toxic chemicals as protective measures under the Enhancement and Conservation of National Environmental Quality Act of 1975, 1978, 1979, and amended in 1992. In addition, Ministry of Natural Resources and Environment, Ministry of Agriculture and Cooperatives, and Ministry of Public Health have done a great deal of monitoring and analysis of residues of hazardous substances including those of POPs chemicals.

The Customs Department under the Ministry of Finance is responsible for prevention and control of smuggling of all goods and other illegal products including import, export, and re-export of hazardous substances, chemical products, and hazardous wastes. This agency is not directly responsible for control of pollution but works in collaboration with other agencies in order to play a role in controlling substances or chemicals that are imported for use as a raw material or catalyst in some industrial processes.

10.4.2. Bans and restrictions

Import, export, manufacture, and possession of hazardous substances have been controlled under the Hazardous Substances Act, 1992. However, banning of the import or severely restricted uses of chemicals had been notified in the Ministerial Notifications since 1977. Two insecticides, namely chlordimeform and leptophos were the first two of the banned chemicals in 1977. According to the Act, Ministerial Notifications of the Ministry of Industry were issued to banning of nine specified POPs pesticides usage since 1980 (Table 10.4). Only seven specified POPs pesticides were imported and widely used in Thailand, namely aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, and toxaphene, whereas hexachlorobenzene and mirex have never been imported. Although

Table 10.4. List of banned specified persistent organic pollutants (POPs) pesticide in Thailand (*Source*: Wong-ek, 2000)

POPs pesticides	Date of banned
Aldrin	September 1988
Chlordane	May 2000
DDT	March 1983, 1995
Dieldrin	May 1988
Endrin	July 1981
Heptachlor	September 1988
Hexachlorobenzene	March 1980 and never been imported
Mirex	Never been imported
Toxaphene	March 1983

hexachlorobenzene was never been imported, it was the first one to be banned in 1980, followed by endrin in 1981 and toxaphene in 1983. DDT has been used both in agriculture and for malaria control but it was banned for agricultural uses from 1983 and for malaria control in 1995 pending availablity of other alternatives. Dieldrin, aldrin, and heptachlor were banned in 1988. Chlordane was the last one to be banned in 2000. On the other hand, the regulation prohibiting the usage of other organohalogen chemicals and organotin compounds in industrial and agriculture sections do not exist now in Thailand.

10.5. Conclusion

The demand for agricultural productivity and the expansion of industry is now causing a rapid increase in the use of many chemicals in Thailand. Most chemicals, organic and inorganic were imported from ~40 countries including developing and developed countries and were widely used in almost all over the country. As a result, widespread contamination of several persistent chemicals were noticed in almost all the environmental and biotic matrices. In the past 20 years, improved government policy has resulted in better control of chemical management including legislation and management. Import of many chemicals, including those of specified POPs chemicals have now been prohibited for all uses. In spite of these control measures the levels of some of the banned chemicals still appear in the environment as well as biota, some times even above the safety levels specified by international agencies. It may take few more years to few decades for those chemicals to disappear from Thai environment and biota, depending on the persistence and bioavailability of the chemical. Apart from these, several new chemicals, whose existence in the environment and biota are not yet known, may be detected. Continuing a clear vision on environmental issues and monitoring the chemical(s) under concern are the need of the hour in Thailand.

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