

Chapter 3

Organochlorine Pesticides in China

Jianxin Hu, Tong Zhu and Quanlin Li*

Abstract

DDT, HCH, toxaphene, HCB, chlordane, heptachlor, and mirex were produced in China. Historically, there were about 60 POP pesticide-producing enterprises located in 18 provinces in China. The accumulated output of DDT, toxaphene, and HCB were 459,000, 20,660, and 79,278 MT, respectively, while the accumulated output of HCH was 141,366 MT during 1990-2003. In the 1980s, China set up the legal framework for controlling organochlorine pesticides, and the production and use of organochlorine pesticides for agriculture were banned. Presently, DDT and HCH can still be detected in air, water, sediment, field soil, grains, vegetables, fruits, meat, animals and human tissue in many areas, although their concentrations are lower than the relevant standards.

3.1. Institutional, policy, and legal framework for organic pesticides in China

3.1.1. *Environmental policy, sustainable development policy, and general legislative framework*

Environmental protection is one of the basic national strategies of China, as well as one of the basic functions of government at various levels. Since 1980, China has successively established agencies for environmental protection at central, provincial, municipal, and county levels. The environmental protection, supervision, and management system has gradually improved. According to environmental protection and other relevant laws and regulations, the environmental protection bureaus at various administrative levels shall be responsible for the overall supervision and management of the environmental protection within their jurisdiction, and other relevant agencies shall exercise supervision and management over pollution prevention within the scope of their responsibility. The local governments shall be responsible for the environmental

*Corresponding author: E-mail: tzhu@pku.edu.cn

quality within their jurisdictions. Chinese environmental policies mainly include:

- (a) Prevention first and combining prevention with control. Environmental impact assessment and a “3-simultaneous” system should be carried out for new or expanded projects or regional development projects to reduce generation and discharge of pollutants. The existing polluters are required to declare, register, and apply for permits for pollution discharge and to pay pollution discharge fees. The government at the county level or above should take legal measures to make serious polluting enterprises treat pollution within a definite time limit.
- (b) The principle of “polluters treat pollution”. Chinese laws state that polluters shall bear the responsibilities of pollution treatment and ecological restoration. According to the Law on Prevention of Environmental Pollution Caused by Solid Waste, if the accountable units or individuals do not properly dispose of hazardous wastes, the department of environmental protection at the county level or above can designate other competent entities to make proper disposal, and the accountable units or individuals shall pay all associated costs.
- (c) Strengthen environmental monitoring and management. Rules for environmental supervision and management should be established and improved. The public participation in environmental supervision and management should be encouraged and supported. Posters and information on national and local environmental status should be published periodically. Air quality and water quality in key basins should be published. Environmental hotlines and a system for complaint letters and visits should be established. According to Interim Measures for Public Participation in Environmental Impact Assessment, the environmental impact assessments of special programs involving public interests and construction projects having potentially significant environmental impacts should include hearings and other forms of communication to collect the views of stakeholders.

After the 1992 United Nations Conference on Environment and Development, the Chinese government developed its own strategy for sustainable development called China’s Agenda 21. The strategy advocates sustainable development by industrial policies, including:

- (a) Adjust the industrial structure by limiting or forbidding the production and use of equipment and industrial processes that are characterized by high consumption and pollution and are inconsistent with the industrial policies. The State Council Decision on Several

Environmental Protection Issues of 1996 required closure of 15 types of small-scale enterprises. The 2005 Guiding Catalog of Industrial Structure Adjustment issued by the State Development and Reform Commission classified more than 1,000 specific industries into categories of support, limitation, and phaseout. Persistent organic pollutants (POPs) were classified into the limitation or phase-out categories.

- (b) Establish and implement policies for saving resources and improving the efficiency of resource and energy use. Related laws and regulations were enacted to require comprehensive use of resources and reduction of resource waste in the aspects of water, electricity, coal, minerals, land, forest, grassland, ocean, and climate and to support the enterprises and the society to recover and reuse waste resources. Related departments are drafting some special regulations such as Regulations on Comprehensive Use of Resources, Regulations on Recovery and Treatment of Waste Electric Appliances and Electronic Products, Regulations on Recovery and Reuse of Waste Tires, and Management Methods for Recovery and Reuse of Packaging Materials. In addition, some technical standards and codes for energy efficiency of energy-consuming equipment, a water drawing quota of water-consuming sectors, energy-saving design of energy-consuming sectors, and labeling of reusable products are being developed.
- (c) Promote cleaner production and a recycling economy and accelerate the change of the economic growth manner. The Cleaner Production Promotion Law was enacted and came into effect in July 2003. The State Council issued Guidance on Acceleration of Development of Recycling Economy in July 2005. The State Development and Reform Commission, together with the State Environment Protection Administration, supervises, guides, and inspects the national implementation of the recycling economy. Metallurgy, nonferrous metal, electricity, coal, petrochemistry, chemical industry, building material, light industry, textile, and agriculture are determined as key sectors for development of the recycling economy, and specific targets have been established. The program for development of the recycling economy is under expedited preparation, and the recycling economy legislation has been initiated.

The Guideline of the 11th National Five-Year Program and the State Council Decision on Intensification of Environmental Protection emphasized socio-economic policies closely related to environmental protection, including boosting the optimization and upgrading of industrial structure, promoting regional harmonious development, and building a

resource-economy and environment-friendly society. Optimized development should be conducted in regions that have limited environmental capacity and natural resources but a better-off economy. Environmental concerns should be treated as a priority. Technologies should be supported that optimize the industrial structure and accelerate the upgrading of the industries and products, as well as take the lead in reducing the total discharge of pollution and attaining growth with less pollution. Control of POPs, particularly the control of dioxin pollution, is consistent with the goals of these strategies and policies.

The Guideline of the 11th National Five-Year Program also put forward the strategic objective to build a new socialist countryside. It supports the development of modern agriculture and the application of advanced agricultural technologies, including scientific and proper application of chemical fertilizers and pesticides and extensive adoption of biological control of plant diseases and pests. These techniques are conducive to reducing, eliminating, and preventing pollution that results from intentional production and use of POPs.

China has established a policy and legal framework for environmental protection, which includes these levels: (1) the provisions related to environmental protection and resources in the Constitution; (2) the comprehensive law on environmental protection, viz. Law on Environmental Protection; (3) the thematic laws on environmental protection and pollution control (Table 3.1); (4) the administrative regulations on

Table 3.1. Existing laws on environmental pollution control and protection in China

Prevent and control environmental pollution	Protect the ecology	Protect natural resources
Law on air pollution prevention and control	Law on wild animal protection	Law on land management
Law on water pollution prevention and control	Law on water and soil conservation	Law on mineral resource
Law on the prevention and control of pollution from solid wastes	Law on prevention and control of desertification	Coal law
Law on noise pollution prevention and control		Water law
Law on the protection of the marine environment		Forest law
Law on environmental impact assessment		Prairie law
Law on the promotion of cleaner production		Fishery law
		Law on energy saving

environmental and resources protection; (5) the departmental regulations on environmental and resources protection; (6) the local regulations on environmental and resources protection; and (7) international treaties of resources and environmental protection China has approved of or acceded to. In addition, China has also set up comprehensive standards for resources and environmental protection.

3.1.2. Existing laws and regulations on pesticidal POPs

The Environmental Protection Law is a comprehensive law on environmental protection. Article 33, which is directly related to management of POPs, states, “The production, storage, transportation, sale and use of toxic chemicals and materials containing radioactive substances must comply with the relevant state provisions so as to prevent environmental pollution.” In addition, the Law on the Prevention and Control of Water Pollution, the Law on the Prevention and Control of Air Pollution, the Marine Environment Protection Law, the Law on Environmental Impact Assessment, and the Law on the Prevention and Control of Environmental Pollution by Solid Wastes have all put forward pollution prevention requirements. Previous experience can also be used in the management of POP-like materials. Presently, China has no laws that specifically address management of POPs.

Currently, the Regulation on the Safety Management of Hazardous Chemicals issued in 2002 is closely related to POP management. It provides detailed regulations on the production, operation, use, import and export, and key hazardous source monitoring and management of hazardous chemicals. POP production falls under the management scope of these regulations:

Production of POPs: In accordance with the provisions of the Regulation on the Safety Management of Hazardous Chemicals, a permit system is applied to the manufacturing and operation of POPs. In order to implement this management system, relevant government organizations issued the Measures for Permit Administration of Hazardous Chemicals in 2002, the Measures for Implementation of Work Safety Licenses of Hazardous Chemical Production Enterprises in 2004, and Measures on Safety Inspections of Construction Projects of Hazardous Chemicals in 2005.

Use of POPs (production sites): The management on the use (production sites) of hazardous chemicals shall observe the Regulations on Labor Protection in Workplaces Where Toxic Substances Are Used promulgated in 2002, the Provisions on the Safe Use of Chemicals in Workplaces

promulgated in 1996, and the Occupational Exposure Limit for Hazardous Agents in the Workplace (GBZ2-2002).

Import and export of POPs: China follows the London Guidelines for the Exchange of Information on Chemicals in International Trade, the Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, and other international conventions and trade regulations. The country has also implemented an import and export registration system. It mainly observes Environmental Management on the First Import of Chemicals and the Import and Export of Toxic Chemicals promulgated in 1994 and Detailed Rules on Implementing the Registration of the Environmental Management on the First Import of Chemicals and the Import and Export of Toxic Chemicals promulgated in 1995. In 2005, the State Environmental Protection Administration of China (SEPA) enacted Notice No. 65, the List of Toxic Chemicals Banned in Export and Import. Such substances include DDT, HCB, chlordane, and mirex. In December 2005, the Ministry of Commerce, General Administration of Customs, and SEPA jointly promulgated Notice No. 116, List of Goods Prohibited from Import (Sixth Group) and List of Goods Prohibited from Export (Third Group). Dieldrin and endrin were added on the List of Substances Prohibited from Import, and aldrin, dieldrin, endrin, heptachlor, and chlorinated camphene are on the List of Substances Prohibited from Export.

Packaging of POPs: China has adopted a designated manufacturer management system for POPs. It promulgated Hazardous Chemical Packing Material and Container's Labeling Manufacturing Management Means in 2002. Relevant standards include General Rules for Precautionary Labeling for Industrial Chemicals (GB6944-2005) and Labels for Packages of Hazardous Goods (GB190-1990).

Storage of POPs: Related enterprises shall establish storage facilities meeting relevant conditions and also that meet the requirements of Rule for Storage of Hazardous Chemicals (GB15603-1995). For new construction, renovation, or expansion projects of such facilities, the Chinese government shall impose a strict approval system. To this end, Measures on Safety Inspection of Construction Projects for Production and Storage of Hazardous Chemicals were issued in 2005.

Transportation of POPs: Relevant departments have formulated related provisions for railway, waterway, and highway transportation of POPs. These provisions include Rules Concerning the Railway Transport of Hazardous Goods, Rules Concerning the Waterway Transport of Hazardous Goods, and Provisions on the Administration of the Road

Transport of Hazardous Goods, as well as General Specifications For Transport Packages of Hazardous Goods (GB12463-1990).

Wastes containing POPs: China has listed wastes containing POPs in the Catalogue of Hypertoxic Chemicals as hazardous wastes, under the management of the Prevention and Control of Pollution of the Environment by Solid Wastes, the Measures on Prevention of Environmental Pollution Caused by Hazardous Waste, and the Technical Specifications for the Prevention and Control of Pollution Caused by Hazardous Waste. China implemented related provisions in the Measures for the Administration of Permits for Operation of Hazardous Wastes for business activities related to wastes containing POPs. Such provisions are in the List of Goods Prohibited from Import, Provisional Regulations on Environmental Protection. In cases of waste importation, Measures on the Management of Duplicated Forms for Transfer of Hazardous Wastes and the Basel Convention shall be observed for the import and export of wastes containing POPs. To prevent environmental pollution caused by wastes containing POPs, the Chinese government has formulated and implemented a series of standards, including Identification Standards for Hazardous Wastes, Standard for Pollution Control on Hazardous Waste Storage, Standard for Pollution Control on the Security Landfill Site for Hazardous Wastes, and Standard for Pollution Control on Hazardous Waste Incineration.

Sites contaminated by POPs: The Methods for the Prevention and Control of Environmental Pollution Caused by Abandoned Hazardous Chemicals promulgated and implemented in 2005 states that if hazardous chemical production, stockpiling, and consuming units want to change the line of production, stop production, close off, or dissolve, they should report the environmental restoration program to the environmental protection department above the county level. Upon obtaining the approval of the department, the contaminated sites shall be restored within a stipulated time period.

The Administrative Regulations of the People's Republic of China on Pesticides made specific regulations on pesticide production, import and export, operation and use, and established a corresponding management system, including a pesticide registration system and pesticide production permitting system. The regulations are also applicable to pesticide-related POPs management. As a responsible country, China has been very supportive of international environmental conventions. Since the 1980s, the Chinese government has joined more than 30 international treaties on environmental and resources protection, including the Stockholm

Convention on Persistent Organic Pollutants, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, and the Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.

On May 23, 2001, the Chinese government signed the Stockholm Convention on Persistent Organic Pollutants. The 10th Standing Committee of the National People's Congress approved the decision to accede to this convention on June 25, 2004, and the convention came into effect in China on November 11, 2004.

The Chinese government signed the Basel Convention on March 22, 1990, which came into force in 1992. The Law on Prevention of Environmental Pollution Caused by Solid Waste, promulgated in 1995 and revised in 2004, prohibits other countries from dumping, stockpiling, or disposing of solid wastes in China's territory, and implements administrative and criminal punishment over illegal solid waste import. Industry and local government will also construct facilities for disposal of hazardous waste in line with the Basel Convention.

The Rotterdam Convention, which was signed by the Chinese government on August 24, 1999 came into effect in China on June 20, 2005. For implementation of the Rotterdam Convention, the Chinese government has taken a number of effective measures and actions, including accomplishing specific tasks of convention implementation, actively participating in international activities and work related with the convention, substituting severely hazardous pesticides, and strengthening capacity building in risk assessment of pesticides.

3.2. History of manufacturing, industrial applications, and emission sources

Organochlorine pesticides were predominantly used during the 1950s–1970s in China. DDT, HCH, toxaphene, HCB, chlordane, heptachlor, and mirex used to be produced in China. Historically, there have been ~60 POP pesticide-producing enterprises, which were located in 18 provinces in China.

The production and use of most POP pesticides have been prohibited in China, but DDT, HCB, chlordane, and mirex were still in production and use in 2003. DDT is used as an intermediate for producing Dicofol, anti-fouling paint, as an ingredient in some mosquito-repellent incense, and for malaria prevention (including export). HCB is never used as a pesticide in China, but it is used as an intermediate to produce sodium pentachlorophenol (Na-PCP), which is used extensively to kill snails in those places where schistosomiasis prevails. Owing to their specific

characteristics, chlordane and mirex are still used to prevent and kill termites, and small amounts are used in agriculture, sericulture, and to kill cockroaches. Tables 3.2 and 3.3 summarize the basic status of POP pesticides in China.

3.2.1. DDT

In China, the production of DDT started in the 1950s and there are 11 DDT producers in China. Until now the accumulated output of DDT

Table 3.2. Production and consumption of POP pesticides in 2003

Category	Output (MT yr ⁻¹)	Number of producers as of 2003	Total output (MT)	Consumption purpose
DDT	3236	2	459,000	Raw material for Dicofol, additives for paints and mosquito-repellent incense, and malaria prevention
HCB	3522	1	> 79,278 ^b	Raw material for Na-PCP
HCH	1406	2	141,366 ^c	Raw material for HCB, lindane for locust and wheat midge control
Chlordane	450	9	8673	Termite prevention
Mirex	9	5 ^a	151	Termite and cockroach control

^aAll the enterprises that produce Mirex also produce chlordane.

^bTotal output during 1988–2003.

^cTotal output during 1993–2003.

Table 3.3. The basic status of other never-produced or already prohibited POP pesticides

Category	Status	The largest annual output (MT yr ⁻¹ , year)	Total output (MT)	Different consumption purposes
Toxaphene	Was produced, but production ceased in 1980s	3740 (1973)	20,660	Agriculture (foodstuff and cotton protection)
Heptachlor	Was produced, but production ceased in 1980s	11 (1968)	< 100	Crosstie (railway protection)
Aldrin		Researched but never produced		
Dieldrin		Researched but never produced		
Endrin		Never researched, never produced		

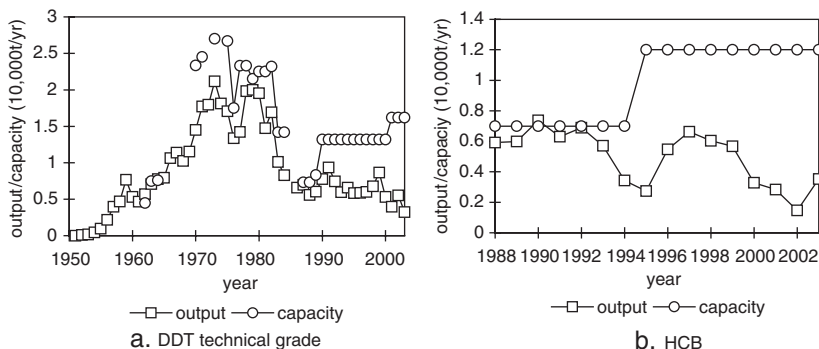


Figure 3.1. The output/capacity of technical grade DDT and HCB in China.

was $\sim 459,000$ MT (including 60,000 MT as raw material to produce Dicofol); the output of DDT in 2003 was 3236 MT. Figure 3.1 shows the annual output of DDT (Office for Stockholm Convention Implementation in China, 2004). The highest output of technical-grade DDT was $21,164 \text{ MT yr}^{-1}$ in 1973. In March 1983, the State Council began to restrict the consumption of DDT in agriculture areas, and most plants subsequently stopped producing DDT. Since 1984, the annual output of DDT has never exceeded 10,000 MT. With the exception of an annual output of 8679 MT in 1999, the output of technical-grade DDT has been 5000–6000 MT since 1995, most of which is used to produce Dicofol. At present, only two plants are authorized to produce DDT: one is in Tianjin while the other is in Jiangsue Province where DDT is produced only as an intermediate for Dicofol production.

Before 1983, the Chinese government, under the planning economy policy, centrally controlled the production and marketing of pesticides. Individual plants had no right to sell or make other transactions regarding pesticides. After 1983, the Tianjin plant continued to produce DDT according to the quantity assigned by the former Ministry of Chemical Industry and sold DDT to appointed factories as a raw material to produce Dicofol, antifouling paint for ships, for mosquito-repellent incense, and for export. It is the only company that exports DDT. After the former ministry of Chemical Industry was repealed in 1998, the plant according to the relevant regulation issued by the State and the market demand determined the production and sale of DDT.

Before 1983, DDT was used as a pesticide in agriculture, forestry, and sanitation areas, part of which was used to produce Dicofol, and a small proportion of which was used to control termites. In agricultural areas,

DDT was used to prevent migratory locusts, armyworms, acarids, aphids, phralidid caterpillars, and soil insects in orchards, paddy fields, and vegetable fields. For sanitation and epidemic prevention, DDT was used to kill mosquitoes, flies, cooties, fleas, bedbugs, cockroaches, etc.

After 1983, the Standing Committee of State Council decided to stop the application of DDT in agriculture. Thereafter, DDT was mainly used as a raw material to produce Dicofol, with a small portion consumed as raw material to produce paints, as additives to produce mosquito-repellent incense, and to prevent malaria. The Chinese Center for Disease Control and Prevention (CDC) has decided that DDT can be used in closed systems and indoor sites in small amounts to control disease vectors, but its outdoor use is forbidden to prevent pollution. Malaria control in China has been effective, and DDT has not been used by local CDCs since 2001. The sale and consumption of DDT in 2001 and 2002 are shown in Table 3.4. It is seen that 83.9% of DDT produced was used to produce Dicofol; 8.5% of that was exported for malaria prevention, 2.5% was used to produce mosquito-repellent incense, and 3.9% was used to produce paints. The investigation of consumption in 10 provinces and cities of China indicates that DDT is no longer used for agriculture or termite control, and a small portion of DDT is still used to prevent malaria. For example, 380 MT of DDT was used to control malaria between 1997 and 2000 in Yunnan province.

After 1983, most DDT produced was used to produce Dicofol. There were six Dicofol producers in China in 2003. The highest annual domestic output of Dicofol was 5613 MT in 1999, resulting in peak DDT consumption. The accumulative output of Dicofol was ~40,356 MT from 1988 to 2002, and the corresponding consumption of DDT was estimated as ~60,000 MT. The total output of Dicofol was 3345 MT in 2002.

Table 3.4. Domestic gross sales of DDT in 2001 and 2002 in China (MT yr⁻¹)^a

Market	Purposes	2001		2002	
		Sales	Proportion (%)	Sales	Proportion (%)
Domestic	Dicofol	3341	78.5	3867	83.9
	Mosquito-repellent and others	208	4.9	113	2.5
	Anti-fouling paint for ships	152	3.6	180	3.9
Export	Malaria prevention	466	11.0	390	8.5
	Total	4254		4607	

^aThe data were provided by the producers. The final purpose has not been verified.

Table 3.5. Export volume of DDT from 1998 to 2003 (MT)

Content	Year					
	1998	1999	2000	2001	2002	2003
DDT	255.8	328.5	82.8	401.3	318.1	448.3

A certain amount of DDT is exported from China. In total, 1834.8 MT of DDT was exported during 1998–2002, as shown in Table 3.5. There is no DDT imported to China. DDT was mainly exported to Africa and Southeast Asia. The exported DDT was mainly used for malaria control, and a small portion was used to antisepticize woods.

There is a large volume of stockpiled or waste DDT in some DDT-producing sites, including those where DDT production has ceased for many years. Seven DDT producers have never cleaned their operating sites where DDT wastes still remain. These have become potential polluting sources.

3.2.2. HCB

China began to produce HCB in 1951, and there have been six HCB producers with a total output of 79,278 MT since 1988 (of which 78,323 MT was used to produce Na-PCP and PCP, accounting for 98.8% of the total output). The largest output volume of HCB of 7365 MT occurred in 1990. The HCB output was 3522 MT in 2003. Figure 3.1 illustrates the output of HCB from 1988 to 2002. After 1983, because the production of HCH was restricted, there remained only one HCB producer, which is located in Tianjin.

HCB is not used and has never been registered as a pesticide in China. As discussed above, it is used principally as an intermediate to produce pentachlorophenol (PCP) and Na-PCP in closed systems. After 1995, HCB was mainly used as an intermediate to produce Na-PCP. From 1988 to 2003, there was a cumulative output of 4840 MT of PCP (accounting for 5% of total output) and 104,323 MT of Na-PCP (accounting for 95% of total output) from the Tianjin plant. During this period, 793 MT of HCB (accounting for 1.2% of total output) was sold as raw material to produce fireworks and as reagents.

Na-PCP is highly effective in killing snails and is used extensively to kill them in places where schistosomiasis prevails. Na-PCP can kill mature snails, larva, eggs, the larva of a tapeworm, and the cercaria for disease vector control. Na-PCP is also registered as an herbicide and a timber preservative by some enterprises, and it is consumed for these purposes in

some regions. Investigation shows that, after the largest output volume of 9049 MT in 1992, the output of Na-PCP decreased. The Na-PCP output was 3,010 MT in 2003.

Without importing HCB, from 1998 to 2000, China exported 134.5, 112, and 9 MT of HCB, respectively, totaling 255.5 MT over these 3 years. However, HCB has not been exported since 2001.

3.2.3. HCHs

China began producing HCHs in 1951 in Shanghai. In 1983, HCHs were banned as pesticides for normal agricultural use, and only one producer in Tianjin continued producing HCHs as an intermediate of HCB. The production of lindane with a purity requirement of 99.5% began in 1982 in China. From 1986 until 1995, the former Ministry of Chemical Industry sanctioned another HCH plant in Shengyang to continue producing HCH only as the intermediate of trichlorobenzene; thereafter, the plant obtained permission to produce lindane for export. There were two plants producing HCH and lindane after 1986. The output of HCH and lindane decreased year after year, from 24,617 and 2260 MT, respectively, in 1996 to 1402 and 132 MT, respectively, in 2003.

In addition to the two lindane producers, there have been five plants that process lindane formulation in China. These plants were located in Henan Yuanyang, Anhui Woyang, Shenyang, Heilongjiang Pingshan, and Henan Anyang, but only one plant produces lindane products in 2003.

After the 1980s, γ -HCH was used to produce lindane; and other HCHs were mainly used as intermediates of HCB. There was no direct use of α - and β -HCH after the 1980s. Lindane was used for locust and wheat midge control. Three kinds of lindane formulation were registered in the pesticide registration information system of the Chinese Ministry of Agriculture for wheat midge and locust control: 1.5% powder, 6% powder, and 6% wettability powder.

Since 2000, sale of 1.5% lindane powder is approximately 700–800 MT yr⁻¹, whereas sale of 6% lindane powder is approximately 100–200 MT, much less than 1.5% lindane powder due to its higher price. The domestic use of raw lindane is estimated at approximately 16–24 MT in recent years. The main purchasers of lindane formulation from dealers in Shandong, Hebei, and Hennan province (the major areas that suffered wheat midge damage in China) and the end users are local farmers. The lindane is used for preventing wheat midge. China has exported lindane since the 1990s. The accumulated export amount is 1,861 MT ([China Chemical Industry Yearbook](#)).

3.2.4. Chlordane

Since the 1950s, China began to develop techniques to produce chlordane, and the production capacity and output steadily increased into the 1970s. The annual output of chlordane reached 465 MT in 1974, but chlordane production gradually stopped after 1975 due to faulty techniques and severe occupational harm to workers. However, the productive capacity of chlordane was rebuilt after 1988 because of a serious termite disaster in the south of China and the lack of effective and inexpensive termiticides. There have been approximately 20 chlordane producers in China, but all of them were on pilot scale. In 2003, there were nine plants producing chlordane crude oil and emulsifiable solution in China, and six of them reported an output of 450 MT in total. Figure 3.2 shows the annual output of chlordane crude oil in China. It was shown that the output of chlordane was up to 834 MT in 1998, with a capacity of 1480 MT per year.

Before 1980, all the chlordane-producing enterprises were state-owned, and the central government managed sales. After 1988, most chlordane producers became privately owned, and their outputs were usually controlled by market demand. A statistical survey shows that usually 95% of Chlordane is used in houses and buildings to protect them from termite damage, 4% is used in clay embankment protection, and the rest (1%) is used to protect electric cables. Furthermore, there has also been a small amount of chlordane usage in sugarcane growing and sericulture operations.

The survey on the consumption of chlordane shows that there were differences in chlordane usage among different termite-affected provinces

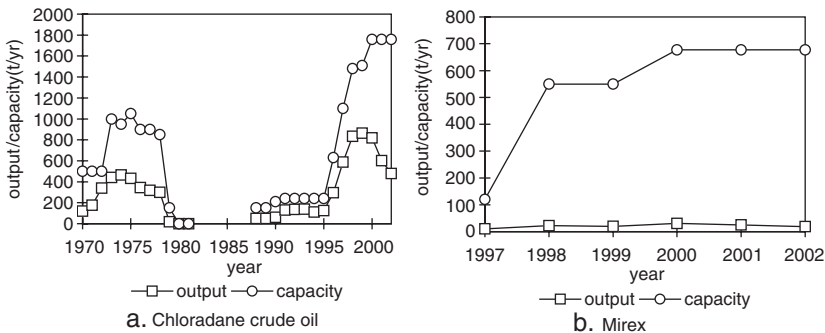


Figure 3.2. The output/capacity of crude oil chlordane and mirex in China.

from 1997 to 2001. Almost all of the 19 termite-affected provinces have used chlordane in termite control, except the City of Tianjin. Zhejiang province used the largest amount of chlordane, while Jiangsu, Guangdong, Sichuan, Jiangxi, Hunan, Guangxi, Anhui, Hubei, Fujian, Chongqing, Shanxi, Shanghai, and Shandong used moderate amounts. Hainan, Yunnan, and Liaoning used small amounts, and Beijing used the least amount. The amount of chlordane used peaked in 1999; thereafter, its consumption gradually declined due to the impact of the Stockholm Convention.

There has been no import or export of chlordane in China.

3.2.5. Mirex

Since the 1960s, China began to develop the techniques to produce mirex, but the output was kept at a low level for a long time. After 1975, due to faulty techniques and severe harm to artisans, mirex production gradually stopped. However, as was the case with chlordane, the production of mirex resumed after 1997 because of a serious termite disaster in the south of China. There had been seven mirex producers in China, five remained until 2003, and three of them reported a total output of 9 MT. Figure 3.2 shows the annual output and productive capacity of mirex by year. It can be seen that the productive capacity of mirex was much larger than the output. The output of technical-grade mirex reached its peak value of 31 MT in 2000, and the accumulative output of technical-grade mirex is 151 MT.

The existing mirex-producing enterprises are privately owned, and outputs are controlled by market demand. Most mirex is used to control and kill termites, ants, and cockroaches. It is estimated that ~20–30% of the total annual consumption of mirex is used for termite control, 10–20% for ant control, and the rest is used for control of other pests. In China, mirex is not used as a pesticide for agriculture, and the Chinese Ministry of Agriculture has never registered it. Mirex is the major termiticide in termite control, and there is no viable alternative product yet. Fifteen termite-affected provinces have used mirex. Mirex was used mostly in Jiangxi, Guangxi, Fujian, Guangdong, Zhejiang and Jiangsu—all located in Southeast China, where termite damage is severe.

In addition, in the sanitation field, Shanghai, Jiangsu, Yunnan, Shanxi, and Guangxi once used mirex to kill domestic ants. There are no records of import and export of mirex after 1998.

3.2.6. Other POP pesticides

3.2.6.1. Toxaphene

In the early 1970s, toxaphene-producing facilities with a capacity of 1200 MT per year were built in China. This capacity reached 5930 MT per year in 1973, with 16 toxaphene producers and a maximal output up to 3740 MT. By 1985, the accumulative output of toxaphene was 20,660 MT.

Toxaphene was used to protect cotton and foodstuffs from damage by bollworms, red spiders, and aphids. Before 1980, toxaphene was uniformly purchased and sold by the government.

Since 1979, the output of toxaphene constantly reduced. In 1985, toxaphene production ceased due to its low efficiency in pest control, high toxicity to fish, and inconsistent quality.

According to the Memorandum of Registration of Pesticides, during the period from May 1990 to May 1995, toxaphene was approved by the Ministry of Agriculture to be registered as an agricultural pesticide. It was regulated to protect cotton, forests, and maize from pests and soil insect damage by spraying and soaking of seeds. In 1996, the ministry repealed the registration of toxaphene as an agricultural pesticide and stopped its production and use.

3.2.6.2. Heptachlor, aldrin, and dieldrin

In China, heptachlor was produced mainly between 1967 and 1969. The accumulative output was 17 MT. Thereafter, small-scale heptachlor production continued until 1978, when it was stopped due to high toxicity and poor environmental condition at the production sites. In 1978, the heptachlor-producing equipment was disassembled, and the sites were cleaned up. Currently, heptachlor is generated as a by-product of chlordane production.

Historically, heptachlor was mainly used to prevent termite damage to railroad crossties. However, it has never been registered or used as a pesticide in agriculture in China.

Aldrin and dieldrin have never been produced industrially in China but were produced on a pilot scale for termite control. Endrin has never been produced in China. Both aldrin and dieldrin are agricultural pesticides, which can prevent the damage caused by soil insects, such as termites, locusts, moths in wood, etc. However, the Ministry of Agriculture has never approved the registration and use of aldrin and dieldrin as agricultural pesticides. The application of dieldrin was concentrated in

Zhejiang, Shanghai, and Guangdong, and the use of aldrin was concentrated in Shanghai, Guangdong, Chongqing, and Shanxi.

According to data from the Customs General Administration, China did not import and export any toxaphene, heptachlor, aldrin, or dieldrin.

3.2.7. Summary

- (1) China had produced many kinds of POP pesticides, i.e., DDT, HCB, HCH, chlordane, mirex, toxaphene, heptachlor, aldrin, and dieldrin, although some were produced only tentatively and on a very small pilot scale. While endrin has never been produced in China, DDT, HCH, HCB, toxaphene, and chlordane have been produced in relatively large amounts.
- (2) There were ~60 enterprises, which have produced POP pesticides in the past. There are still two enterprises producing technical-grade DDT, and a few are producing chlordane and/or mirex.
- (3) The pollution in pesticide production is serious due to faulty technology and a lack of pollution prevention technology. These problems include: DDT powder dust pollution from the production of soluble DDT powder; polluted mud in sink pools and other dangerous wastes containing obsolete acids and wastewater generated during DDT production; leakage of DDT during the production of Dicofol when the sacks containing DDT are torn open and fed into equipment; and remnants of DDT in Dicofol. It is necessary to improve the environmental regulations and standards and to adopt clean production and technology for preventing pollution.
- (4) Most former manufacturers in China have dismantled their equipment and roughly cleaned the stockpiles and wastes of POP pesticides. However, there was no regulation on clean-up and remediation of the former operating fields during that time.
- (5) Before the 1980s in China, DDT and toxaphene were extensively used as agricultural pesticides. After 1983, DDT was banned as an agricultural pesticide, but it is still allowed for disease vector control. The production and use of toxaphene stopped in 1985. Chlordane was registered as an agricultural pesticide prior to 1992. Chlordane is still used in termite control, and a small fraction is consumed for seed soaking and sericulture. Mirex is widely used to control termites and cockroaches. China has never used or has stopped using toxaphene, heptachlor, aldrin, dieldrin, and endrin.

3.3. Research on POP pesticides

3.3.1. Atmosphere

3.3.1.1. General description

Besides the spray drift during the application of pesticides, the organochlorine pesticides in air could also come from the exchange between air and polluted water or soil. Due to their persistence and semi-volatility, organochlorine pesticides could be transported over long distances after entering the atmosphere and thus contribute to the organochlorine pesticide pollution in areas far from the emission sites, such as in the Arctic and the Mt. Everest (Li et al., 2006). The long-distance transport of POPs plays an important role in their global distribution. However, studies on airborne POP pesticides in China are very limited. As a result, available data are scarce. Due to the diffusivity of air, spatial differences in the air concentration of POP pesticides are very small compared to other media.

3.3.1.2. Atmospheric pollution of POP pesticides in China

The POP pesticides in the atmosphere can exist in gaseous or particulate phases. In China, studies on persistent pesticides in the atmosphere mainly focus on particles. For example, from 1994 to 1995, Cheng et al. (2000) analyzed the compositions and concentrations of organochlorine pesticides from aerosol samples collected in industrial, chemical industrial, commercial, traffic, and “clean” (i.e., considered non-polluted) districts in Guangdong, Shenzhen, Zhuhai, and Hong Kong, as well as smoke samples from a restaurant in Guangzhou. Twelve organochlorine pesticides, including six DDTs and metabolites, three HCHs, dieldrin, and heptachlor were detected in the aerosol and smoke samples from the study areas. The concentration of DDT and its metabolites in aerosols collected in Hong Kong and Shenzhen was relatively low ($3.97\text{--}7.01\text{ pg m}^{-3}$), compared to $65.07\text{--}112.70\text{ pg m}^{-3}$ in aerosol samples collected in Zhuhai and Guangzhou and smoke samples from a Guangzhou restaurant (Cheng et al., 2000).

Tong et al. (2000) used a five-stage sampler and collected and measured organochlorine pesticides in airborne particles with different sizes ($>7.0\text{ }\mu\text{m}$ – $7.0\text{--}3.3\text{ }\mu\text{m}$, $3.3\text{--}2.0\text{ }\mu\text{m}$ – $2.0\text{--}1.1\text{ }\mu\text{m}$, and $<1.1\text{ }\mu\text{m}$). Samples collected in residential and traffic areas in Huhehaote during the winter and summer of 1996 were compared. The results showed that organochlorine pesticides (HCH and *p,p'*-DDE) were found on airborne particles of all sizes. The mean concentration of HCH was 0.502 ng m^{-3} in

winter and 1.070 ng m^{-3} in summer, and the *p,p'*-DDE concentration was 0.085 ng m^{-3} in winter and 0.108 ng m^{-3} in summer. The air concentrations of organochlorine pesticides in Huhehaote were higher in summer than in winter. Distribution of organochlorine pesticides on particles of different diameters showed that $\sim 30.6\text{--}70.5\%$ of the organochlorine pesticides were associated with fine particles ($< 1.1 \mu\text{m}$) in winter, while in summer the organochlorine pesticides were distributed on five sizes of particles. The total HCH concentrations were close to that found in samples collected in Stockholm of Sweden in 1986 (Bidleman et al., 1987) but lower than those measured in Paris in 1992–1993 (Cheveruil et al., 1996). The *p,p'*-DDE concentrations were also close to those measured in Mexico Bay in 1977 (Glam et al., 1980) and were higher than those measured more recently in Stockholm and Paris (Tong et al., 2000).

In China, measurements of gas-phase POP pesticides are very limited. Qiu et al. (2004) analyzed organochlorine pesticides in air samples collected in the Taihu Lake region in July–August 2002. α -HCH, β -HCH, γ -HCH, HCB, Heptachlor, α -endosulfan, *p,p'*-DDT, *p,p'*-DDE, *p,p'*-DDD, and *o,p'*-DDT were detected in the samples, with average concentrations of 74, 47, 46, 47, 53, 307, 124, 212, 36, and 767 pg m^{-3} , respectively. While the concentrations of HCH and HCB in the Taihu Lake region were lower than those measured in the Great Lakes (McConnell et al., 1993, 1998) and Lake Baikal (McConnell et al., 1996), concentrations of DDTs were much higher. It is worth mentioning that not only were DDT concentrations high in the Taihu Lake region, but also the average ratio of *o,p'*-DDT/*p,p'*-DDT was as high as 6.3, and the average ratio of *p,p'*-DDE/*p,p'*-DDT was as high as 1.8. This indicates that there could be new sources for *o,p'*-DDT and *p,p'*-DDE. Dicofol has been proposed as a new source of DDTs and its contribution to current DDT pollution in China has been estimated. (Qiu et al., 2005).

While studying the global fate and transport of POPs, Iwata et al. (1993) measured POPs in the atmosphere over the South China Sea and the East Sea and detected HCH, chlordane, DDTs, and PCBs. The concentrations of Σ DDTs in the East and South China Sea were 2.9–43 and 7.8–140 pg m^{-3} , higher than the concentrations measured in the Bering Strait, North Atlantic, and the East Indian Ocean, while close to those measured in the Mediterranean Sea, Red Sea, and Mexico Bay and lower than those measured in the Strait of Malacca and Bengal Bay (Iwata et al., 1993).

Besides gas and particulate phases, samples of precipitation collected in the 1980s in a number of cities in China were analyzed for organochlorine pesticides. For example, Zhao et al (1985) and Yang and Zhang (1987) detected HCH and DDT in rain samples collected in Shijiazhuang and

Wuhan. The concentrations of Σ DDT were in the range of ND-30 ng l⁻¹ (Zhao et al., 1985; Yang and Zhang, 1987).

In addition to direct measurement of POPs in air, particles, and rain-water, there is an indirect measurement method using concentrations of POPs in pine needles to describe the POP pollution in the air. Recently, pine needles have been used as a bio-indicator in air pollution research. Xu and Zhong (2002) measured concentrations of HCH and DDT in pine needles from the north, east, south, and southwest of China. The results showed that the concentrations of HCH in pine needles ranged from 24.7 to 35.5 ng g⁻¹ dry weight, 14 and 10 times higher than those measured in Sweden and France. Among the four HCH isomers, β -HCH had the highest concentrations and accounted for 38–46% of total HCH. The concentrations of Σ DDT in pine needles were in the range of 6.0–12.6 ng g⁻¹ dry weight, 34 and 8 times higher than those reported in Sweden and France. The ratio of DDE/DDT was 1.1 in North China, but was <1 in South and Southwest China, which indicated new inputs of DDT to the air in these regions. However, compared to concentrations of organochlorine pesticides in pine needles in the north of China in the 1980s, concentrations of HCHs and DDTs decreased to 99% and 90%, respectively, which could reflect the effectiveness of the 1980s ban on agricultural use of organochlorine pesticides (Xu and Zhong, 2002).

Currently, there are no air quality standards for pesticide POPs in China. Measurement results can only be evaluated by comparing them with results from other countries and regions. Using DDT as an example, Table 3.6 summarizes measurement results of air concentrations of pesticide POPs in recent years in China.

3.3.1.3. Summary

The research on persistent pesticides in the atmosphere has focused on the gas phase, particulate phase, rainfall, and pine needles. In China, there are only a limited number of studies on POP pesticides in the atmosphere, and these focus mainly on airborne particles. The spatial difference in concentration of persistent pesticides in air is small due to diffusion and transport. Since the agricultural ban on use in 1983, the concentration of POP pesticides in the atmosphere has decreased dramatically in China. In some regions, however, the concentrations of pesticide POPs in the atmosphere are unusually high, particularly for DDTs, which indicates that there might be new sources of POPs in these regions, such as Dicofol. In China, no environmental quality standards about pesticide POPs in the atmosphere have been established.

Table 3.6. Pesticide POPs concentrations in the atmosphere of China (exemplified by DDTs)

Regions	Type	Monitoring time	POPs measured	Σ DDTs (pg m ⁻³)	References
Guangzhou plant	Aerosol	1994–1995	α,β,γ -HCH, <i>o,p'</i> -DDT/DDD/DDE, <i>p,p'</i> -	109.38	Cheng et al. (2000)
Shenzhen plant	Aerosol	1994–1995	DDT/DDD/DDE, heptachlor, dieldrin	7.01	Cheng et al. (2000)
Shenzhen downtown	Aerosol	1994–1995		3.97	Cheng et al. (2000)
Zhuhai school	Aerosol	1994–1995		65.07	Cheng et al. (2000)
Hong Kong shore	Aerosol	1994–1995		6.56	Cheng et al. (2000)
Guangzhou restaurant	Cooking smoke	1996		122.07	Cheng et al. (2000)
Huhehaote winter	Particle	1996	α,β,γ -HCH, <i>p,p'</i> -DDE	85 (41–134)	Tong et al. (2000)
Huhehaote summer	Particle	1996		108 (72–138)	
Tianjin downtown	Particle	2002	$\alpha,\beta,\gamma,\delta$ -HCH, <i>p,p'</i> -DDT/DDD/DDE	1874	Wu et al. (2003)
Taihu region	Air	2002	α,β,γ -HCH, <i>o,p'</i> -DDT, <i>p,p'</i> -DDT/DDD/DDEHCB, heptachlor, α -endosulfan	1139	Qiu et al. (2004)
East China Sea	Air	1989–1990	α,γ -HCH, <i>o,p'</i> -DDT, <i>p,p'</i> -DDT/DDE,	19 (2.9–43)	Iwata et al. (1993)
South China Sea	Air	1989–1990	chlordan, PCBs	54 (7.8–140)	
North China, South China, Southwest China	Pine needle	2001	$\alpha,\beta,\gamma,\delta$ -HCH, <i>p,p'</i> -DDT/DDD/DDE, chlordan, heptachlor, aldrin	1.5–12.1 ng g ⁻¹ DW	Xu and Zhong (2002)
Beidaihe		1982	HCH		Mo et al. (1984)
Shijiazhuang	Rainfall	1981–1983	$\alpha,\beta,\gamma,\delta$ -HCH		Zhao et al. (1985)
Wuhan	Rainfall	1984	$\alpha,\beta,\gamma,\delta$ -HCH, <i>o,p'</i> -DDT	ND–30 ng l ⁻¹	Yang and Zhang (1987)

3.3.2. Water

3.3.2.1. General description

The POP pesticides are hydrophobic compounds with low water solubility. However, natural waters play an important role in the transport and transformation of POPs, because similar to air, water is capable of transporting POPs through convection to areas far from application sites, such as β -HCH found in the Arctic. More importantly, water is essential for humans and all living species and is closely related to their activities. Aquatic mammals are the species most seriously endangered by POP pollution of natural waters. Fish and shellfish are important pathways for POPs to enter the human body through diet. Aquatic ecosystems are very influential on human beings. Therefore, water pollution by pesticides has generated wide concern.

The main pathways of the POP pesticides that enter water include drift during field application, air-water diffusion, dry and wet deposition from the atmosphere, discharges of polluted wastewater, and exchange between groundwater and sediments. Water, suspended particles, living species, and sediments are often monitored separately. In this section, pollutants in the water phase and pore water are summarized. Suspended particles and sediments will be described in Section 3.3.4.

3.3.2.2. Water pollution by POP pesticides in China

Studies on water pollution by POPs can be categorized according to the water bodies studied, such as rivers, seas, and oceans; harbors, lakes, and reservoirs; and groundwater. They can also be categorized according to sample types, e.g., surface water, deepwater, surface micro-layer, and pore water in sediments. In China, extensive monitoring of pesticide POPs has been carried out in rivers, bays and harbors, and lakes. The results show that the spatial differences of pesticide concentrations in water are larger than that in air, but smaller than that in soil.

Rivers: Monitoring of organochlorine pesticides in rivers of China began relatively early. In 1976, Li (1985) measured concentrations of HCH and DDT in the water of the Hangu section of the Ji Canal. The discharge of wastewater from the Tianjin Chemicals Factory was responsible for Σ DDT concentrations in the upstream water of the canal that were as high as 21,900 ng l⁻¹. In 1977, the wastewater flow was diverted from the unpolluted stream. Consequently, the HCH and DDT concentrations in the river decreased significantly. In 1980, the Σ DDT concentration was as low as 69 ng l⁻¹ (Li, 1985). Li et al. (1989) studied

the Second Songhaujiang River in 1982, and Lang et al. (1993) studied the mid-section of the Songhuajiang River in 1984. The Σ DDT concentrations were typically ~ 10 – 100 ng l^{-1} (Li et al., 1989). In recent years, with the development of more sensitive monitoring techniques, other persistent pesticides, such as heptachlor and endrin, have also been detected. Information about isomers and metabolites of HCH and DDTs has been obtained from detailed analyses. In May and December of 1998, Zhang et al. (2000a) detected eight pesticides, including DDTs, HCHs, dieldrin, endrin, and heptachlor in the downstream water of the Liao River. The Σ DDT concentrations were in the range of nd– 4.16 ng l^{-1} (December) and 17.5 – 63.2 ng l^{-1} (May), which were much lower than the concentrations measured in the Ji Canal and the Songhuajiang River during the 1970s and 1980s. However, these levels were much higher than those measured in the St. Lawrence River of Canada in 1993, the Guadalquivir River in Spain in 1992, and the Swiss Ebro River in 1999 (Zhang et al., 2000a; Zhang and Dong, 2002).

From 1999 to 2001, with the support of the European Union, the Nanjing University and the Dalian Technology University collaborated with German and Australian institutions to carry out systematic monitoring of organochlorine pesticides in the Liao and Yangtze rivers. Various methods were used simultaneously to monitor DDTs, HCHs, dieldrin, aldrin, endrin, and heptachlor in the river water. The Σ DDT concentrations in the Liao and Yangtze rivers were 7.04 and 1.68 ng l^{-1} , respectively, with low spatial differences (China-EU Project Report, 2002). Studies on other rivers include Zhang et al. (1998) on the Hai River and the New Port River, Zhang et al. (1982) on the Xiangjiang River, Wang et al. (1986) on waste emissions in rivers in Beijing, and Zhang et al. (1982) and Wen (1990) on the Huaihe River.

Bays and Harbors: Due to close ties with human activities, the pollution by POP pesticides in bays and harbors is of great concern. In November 1994, Cai et al. (1997) studied concentrations and distributions of HCH and DDT during the dry season in the seawater of the Pearl River estuarine. The results showed the Σ DDT concentrations in surface and deep-sea water were 80 and 506 ng l^{-1} , respectively, slightly lower than that reported by Liao in 1983 (Cai et al., 1997). In 1999, Zhang et al. (2002) measured 18 organochlorine pesticides in surface waters at 15 stations and in pore water at 13 stations of the Jiulongjiang River estuarine. The results showed that the total concentrations of organochlorine pesticides in the surface water were in the range of 51.3 – 2479 ng l^{-1} and Σ DDT concentrations were in the range of 0.16 – 63.2 ng l^{-1} . Σ DDT concentrations in the pore water were in the range of 1.00 – 193 ng l^{-1} .

DDE was the main DDT, and its concentration accounted for more than 50% of the total DDTs. This indicates that DDT in the environment has mainly degraded to DDE. Besides DDT and HCH, methoxychlor/endosulfan sulfate, endrin, endosulfan, and dieldrin were found in relatively high concentrations. The pollution level was comparable with other harbors in China, while at a number of stations the water quality exceeded the first level of the National Water Quality Standard for organochlorine pesticides (HCHs and DDTs) (Zhang et al., 2001c). In July 1998, Zhang et al. (2000b) analyzed 18 organochlorine pesticides in surface water from nine stations of the West Harbor of Xiamen. The concentrations of organochlorine pesticides were in the range of 60–32.6 ng l⁻¹. The DDT concentrations were in the range of 0.95–2.25 ng l⁻¹, with a mean of 1.45 ng l⁻¹. Aldrin, dieldrin, and heptachlor epoxide were also found in small amounts. The pollution level was relatively low compared to other harbors. The DDTs were ranked as DDT > DDE > DDD by decreasing concentration, indicating new emission of DDT in recent years (Zhang et al., 2000b, 2001c). In August 1999, Qiu et al. (2002) collected subsurface water in the Daya Bay and analyzed 18 organochlorine pesticides. The concentrations of total organochlorine pesticides were in the range of 143–5105 ng l⁻¹, with a mean value of 927 ng l⁻¹. The ΣDDT concentrations were in the range of 26.8–976 ng l⁻¹, with a mean value of 188 ng l⁻¹. The DDT/DDE+DDD ratio was relatively high, indicating that there were still emissions of DDT into the Daya Bay. Aldrin, dieldrin, endrin, endosulfan, heptachlor epoxide, and methoxychlor were also detected (Qiu et al., 2002). In July 1999, Lv et al. (2002) measured concentrations of 16 organochlorine pesticides in surface and micro-surface water of the Dalian Bay and the Liaodong Bay. The results showed that the average concentration of organochlorine pesticides in the surface water of the Liaodong Bay was 41.9 ng l⁻¹, much higher than that of the Dalian Bay (4.52 ng l⁻¹). However, the organochlorine pesticide concentrations of the two bays did not exceed the National Sea Water Quality Standard (GB3097-1997, State Ocean Administration, P. R. China). The organochlorine pesticide concentrations in micro-surface water of the stations in the Dalian Bay were significantly higher than those of the surface water, indicating micro-surface water could strongly concentrate organochlorine pesticides, with average concentration factors of 5.1–15.4 (Lv et al., 2002). Other estuarine studies include those on isomers of HCH and α-HCH enantiomer in the New Harbor (Zhang et al., 1998); HCH, DDT, and PCBs in the Yangtze River estuarine (Ye et al., 1991); some pesticides in the Minjiang River estuarine (Zhang et al., 1999); and others (Zhang, 1998; Ye et al., 1991; Zhang, et al., 2001c).

Other water bodies: During 1994–1995, Dou and Zhao (1996) measured HCH and DDT in the Beiyangdian Lake. The results showed that the concentrations of DDT and its degradation products were in the range of 0–900 ng l⁻¹, with a mean value of 250 ng l⁻¹, which are lower than the Chinese National Fishery Water Quality Standard. Compared to the measurement results of 1975–1977, the concentrations of organochlorine pesticides in water increased slightly, possibly due to the emission of wastewater from pulp and dye industry, as well as irrigation using wastewater (Dou and Zhao, 1998). Other water bodies investigated for organochlorine pesticides include the Guanting Reservoir-Yongding River in Beijing in 2000 (Kang et al., 2003), Taihu Lake in 1999 (Feng et al., 2003), Jingtang Reservoir in Liaoning province in 1997 (Yu et al., 2001), Fuxian Lake in Yunnan province in 1998 (Lin and Duan, 1999), and the Jiulongjiang River in Fujian province in 1989 (Lin and Huang, 1994). Table 3.7 summarizes monitoring results of pesticide POPs in water bodies in China (DDT concentrations are used as the example).

3.3.2.3. Summary

The number of studies on pesticide POPs in China is relatively large, and the studies covered different regions and water bodies. Since the ban on agricultural use in 1983, the concentrations of persistent pesticides in water gradually decreased. However, in some regions, the concentrations of POP pesticides in water still exceed the national water quality standards. Similar to the air, high concentrations of pesticide POPs were observed in some waters, such as Baiyangdian, Xiamen Harbor, and Daya Bay, indicating recent emission of pesticide POPs. Some POP pesticides such as DDT are included in the Chinese National Water Quality Standards for seawater, groundwater, fishery water, and drinking water, which could be used as the criteria when assessing the pollution level of POP pesticides in water.

3.3.3. Soil

3.3.3.1. General description

Soil is the main media for POP pesticide residues in the environment. Approximately 40–50% of pesticides deposited on soil during application, and 10–20% of the pesticides on the surface of plants will enter air and soil through volatilization and rainfall, respectively. Most of the

Table 3.7. Pesticide POP concentrations in water bodies of China (exemplified by DDTs)

Water area	Monitoring time	Depth	POPs	DDTs (ng l ⁻¹)	References
Ji Canal (Hangu segment)	1976		DDTs, HCHs	21,900	Li (1985)
2nd Songhua River	1982		DDTs, HCHs, PCBs	71	Li et al. (1989)
Huai River	1986		DDTs, HCHs	ND	Wen (1990)
Hai River	1997	3 m	DDTs, HCHs, α -HCH enantiomer		Zhang et al. (1998)
Liao River	1998		DDTs, HCHs	ND–4.16	Zhang and Dong (2002)
Liao River	1998		DDTs, HCHs, dieldrin, aldrin, endrin, heptachlor	17.5–63.2	Zhang and Dong (2002)
Yangtse River (Nanjing segment)	1998		HCB, DDTs, HCHs, PCB	67 (1.57–1.79)	Jiang et al. (2000)
Liao River	1998–2000		DDTs, HCHs, dieldrin, endrin, heptachlor	7.04	China-EU Project report (2002)
Yangtse River	1998–2000		DDTs, HCHs, HCB, endosulfan, methoxychlor	1.68	China-EU Project report (2002)
Xiangjiang			HCHs		Zhang et al. (1982)
Pearl River Estuary	1994	Deep surface	$\alpha, \beta, \gamma, \delta$ -HCH, <i>o,p'</i> -DDT, <i>p,p'</i> -DDT/DDD/DDE	87 (ND–236)	Cai et al. (1997)
Minjiang Estuary	1999		DDTs, HCHs, heptachlor, endosulfan	506 (ND–1220)	
Xiamen harbor	1998	Surface	$\alpha, \beta, \gamma, \delta$ -HCH, <i>o,p'</i> -DDT, <i>p,p'</i> -DDT/DDD/DDE, heptachlor, aldrin, dieldrin, endrin, endosulfan	159 (89.1–234)	Zhang et al. (2003)
Jiulongjiang Estuary	1999	Surface	DDTs, HCHs, methoxychlor, endosulfan, dieldrin.	1.45 (0.95–2.2)	Zhang et al. (2000)
Jiulongjiang Estuary	2000	Pore water	18 OCPs	12.8 (0.2–63)	Zhang et al. (2001c)
Daya Bay	1999	Surface	DDTs, HCHs endosulfan, heptachlor, aldrin, dieldrin, endrin	31.1 (1.00–193)	Zhang et al. (2002)
		0.5 m		19.24–96.64	Qiu et al. (2002)
				188.4 (26.8–975.9)	

Dalian Bay	1999	Surface	16 OCPs DDTs, HCHs, HCB, heptachlor, aldrin	1.01 (0.53–2.02)	Lv et al. (2002)
Dalian Bay		Micro-surface		3.16 (0.80–7.77)	Lv et al. (2002)
Liaodong Bay		Surface		8.19 (ND–36.16)	Lv et al. (2002)
Changjiang Estuary	1986		DDT, HCH, PCBs	0.18–1.58	Ye et al. (1991)
	1986			0.11–6.80	Ye et al. (1991)
Baiyangdian	1995		$\alpha,\beta,\gamma,\delta$ -HCH, <i>o,p'</i> -DDD, <i>p,p'</i> -DDT/DDD/DDE	100	Dou et al. (1997)
Baiyangdian	1994–1995		$\alpha,\beta,\gamma,\delta$ -HCH, <i>o,p'</i> -DDD, <i>p,p'</i> -DDT/DDD/DDE	250 (0–900)	Dou and Zhao (1998)
Taihu Lake	1999–2000		HCH, DDT	0.2–9.3	Feng et al. (2003)
Guanting reservoir–Yongding River	2000		DDTs, heptachlor, aldrin, dieldrin, endrin, etc.	ND–46.8	Kang et al. (2003)
Fuxian Lake	1998	Deep surface	DDTs, γ -666, etc.	ND	Lin and Duan (1999)
Jiulongjiang tidewater	1989	Tidewater	DDTs, HCHs	210–670	Lin and Huang (1994)
Beijing drainage river	1984		DDT, HCH	ND	Wang et al. (1986)
East China Sea	1989–1990	Surface	α,γ -HCH, <i>o,p'</i> -DDT, <i>p,p'</i> -DDT/DDE, chlordane, PCBs	16 (1.5–41)	Iwata et al. (1993)
South China Sea	1989–1990	Surface		6.9 (3.5–12)	Iwata et al. (1993)
Sea water quality standard	1997			DDTs < 50, HCHs < 1000	GB3097-1997
Drinking water quality standard	1985			DDTs < 1000, HCHs < 5000	GB5749-1985
Fishery water quality standard	1989			DDTs < 1000, γ -HCH < 2000	GB11607-1989
Groundwater quality standard	2002			DDT \leq 1000	GB3838-2002

Notes: Sea water quality standard (GB3097-1997), 1997, State Oceanic Administration, P. R. China. Drinking water quality standard (GB5749-85), 1985, Ministry of Health, P. R. China; fishery water quality standard (GB11607-89), 1989, State Environmental Protection Administration, P. R. China; surface water quality standard (GB3838-2002), 2002, State Environmental Protection Administration, P. R. China.

pesticides will enter soil when they are applied directly into the soil or in the form of soaked seeds. Combined with the fact of slow pesticide degradation in soil, soil becomes the most important reservoir for pesticide POPs and impacts on humans through agricultural crops.

Besides drift of pesticides during application, air-surface exchange, dry and wet deposition from the atmosphere, and groundwater are all pathways for POPs to enter soil. The sinks of pesticide POPs in soil include biochemical degradation, evaporation, and erosion. Because soil is a nonfluid media, the spatial distribution of pesticide POPs has large differences and is closely related to the application of pesticides, irrigation, and plant coverage.

3.3.3.2. Soil pollution of POP pesticides in China

Based on literature reports, in 1985, the average concentration of DDT in soil in China was at the level of 0.2–0.3 mg kg⁻¹. Since the 1983 ban on agriculture use of HCH and DDT, the concentration of DDT in soil has gradually decreased.

From 1999 to 2000, [Feng et al. \(2003\)](#) studied POP pesticides in soil at different depths in the Taihu Lake region. The DDT concentrations were in the range of 0.3–5.3 µg kg⁻¹ in the upper layer of soil (0–15 cm), 0.5–4.0 µg kg⁻¹ in the middle layer (16–30 cm), and 0–2.7 µg kg⁻¹ in the deep layer (31–50 cm). HCH had a similar vertical distribution pattern. The soil concentrations of POP pesticides were significantly less than the concentrations measured by [Lin et al \(2000\)](#) in the Yangtze River Delta ([Feng et al., 2003](#)). From 1993 to 1999, [Zhao and Ma \(2001a\)](#) measured DDT and HCH in soil from seven counties of the Ninbo district, the agricultural production base of Zhejiang province. The results showed that due to the wide application of DDT during a 5-year period in the 1980s, (600 tons of DDT were used from 1980 to 1984), DDT was detected in all types of soil for different crops in the Ninbo district. The average concentrations of DDT in different areas ranged from 0.002 to 0.764 mg kg⁻¹, and the average concentrations of HCH ranged from 0.0003 to 0.0152 mg kg⁻¹. The pollution level in some areas still exceeded the second level of the Chinese National Soil Environmental Quality Standards (GB15618-95) ([Table 3.8](#)). The study also indicated differences in POP pesticide concentrations exist for different types of soil and different types of cultivation ([Zhao and Ma, 2001a](#)). In 1989–1999, [Zhang et al. \(2001a\)](#) collected 186 soil samples from the green food production base in the Liaolin provinces of Shenyang, Yingkou, Dalian, Panjing, and Benxi and analyzed HCH and DDT. The results showed that the

Table 3.8. Pesticide POP concentrations in soil of China (exemplified by DDTs)

Regions	Monitoring time	Soil type	POPs	DDTs (mg kg ⁻¹)	References
Ningbo	1993–1999	Vegetable, tea garden, dry and paddy fields	DDT, HCH	0.002–0.7644	Zhao and Ma (2001a)
Liaoming	1998–1999	Meadow soil, paddy soil	$\alpha,\beta,\gamma,\delta$ -HCH, <i>o,p'</i> -DDT, <i>p,p'</i> -DDT/DDE/DDD	0.022–0.030	Zhang et al. (2001a, b, c)
Cixi	2001	Vegetable land	DDTs, HCHs	0.032	Wang et al. (2003)
Tianjin	2001	Wastewater irrigated area	$\alpha,\beta,\gamma,\delta$ -HCH, <i>o,p'</i> -DDT, <i>p,p'</i> -DDT/DDE/DDD	0.628–2.840	Gong et al. (2002a)
Jiashan, Zhejiang	2001	Paddy soil	HCHs, DDTs, PCP-Na	0.049–0.1905	Zhao et al. (2002b)
Anhui	1988	Cropland	$\alpha,\beta,\gamma,\delta$ -HCH, <i>o,p'</i> -DDT, <i>p,p'</i> -DDT/DDE/DDD	0.361 (0.018–4.43)	Yue and Hua (1990)
Inner Mongolia Grassland	1985	Grassland	DDT, HCH	ND	Wu et al. (1995)
Huhehaote	1986–1988	Garden	DDT, HCH	0.0046–0.852	Liu et al. (1991)
Shenyang	1987	Garden	DDTs, HCHs	0.53 (ND-2.92)	Niu et al. (1991)
Wu county Jiangsu	1982–1983	Cropland, woodland, grassland	DDTs, HCHs	0.147 (0.013–5.747)	Ma et al. (1986)
Suzhou	1980–1981	Paddy soil	HCHs		Liu and Ji (1983)
Heilongjiang	1978	Cropland	DDTs, HCHs	0.014–0.09	Dou et al. (1982)
Tianjin	1976	Cropland	DDTs, HCHs	0.037	Li (1985)
Shenyang	1979–1980	Garden, dry and paddy field	DDTs, HCHs	0.02–0.06	
South China	1980	Tea garden	DDTs, HCHs	0.05–0.361	Chen et al. (1986)
Soil quality standard	1995			Level 1: ≤ 0.05 ; Level 2: ≤ 0.5 ; Level 3: ≤ 1.0	GB15618-95

Note: Soil environment quality standard (GB15618-95), 1995, State Environmental Protection Administration, P. R. China.

concentrations of DDT and HCH were quite low, with DDT concentrations in the range of 0.022–0.030 mg kg⁻¹, while HCH concentrations ranged from 0.007 to 0.025 mg kg⁻¹. In addition, the pollution index was smaller than 1, indicating the soil was relatively unpolluted and met the national standard (Zhang et al., 2001a).

In 1985, Wu et al. (1995) collected soil samples in 15 villages in the Hulunbeier grassland of Inner Mongolia, and analyzed DDT and HCH. The results showed that the pollution level of pesticides in the Hulunbeier Grassland was low. HCH concentrations ranged from 0.0140 to 0.0574 mg kg⁻¹, and those of DDT were close to the detection limit (Wu et al., 1995). In contrast, in 2001 Gong et al. (2002a) studied soil from three agricultural fields in a wastewater irrigation area in Tianjin. DDT and HCH were detected, with average concentrations in the range of 0.628–2.84 mg kg⁻¹ for DDT and 0.386–4.69 mg kg⁻¹ for HCH. β -HCH and *p,p'*-DDE had concentrations of 4.67 and 1.42 mg kg⁻¹, respectively, which are the highest among the HCHs and DDTs. By comparison, the concentration of *p,p'*-DDE in an agricultural field in Alabama (U.S.) was only 0.052 mg kg⁻¹, and the average concentrations of β -HCH and *p,p'*-DDE in a paddy field in Korea were only 0.0008 and 0.00034 mg kg⁻¹. This indicated that in Tianjin the soil in the wastewater irrigation area, especially the soil on which vegetables were grown, was seriously polluted by organochlorine pesticides.

In 1988, Qiu et al. (2002) conducted research on DDT and HCH in agricultural soil of 16 counties in Anhui province. The average concentration of HCH in soil was 0.150 mg kg⁻¹, and the main compounds were α - and γ -HCH. At the provincial level, the average concentration of DDT in agricultural soil was 0.36 mg kg⁻¹, and the main compounds were *p,p'*-DDT and *p,p'*-DDD. The high concentrations of HCH and DDT in some areas indicated new pollution sources.

Other studies on pesticide POPs in soils include Wang et al. (2003) on soil used for vegetable production in Chixi; the Nankai University (1976) on soil used for grain production in the Han-Gu district in Tianjin; Zhao and Ma (2001) on paddy soil in the Jiashan County of Zhejiang province; Liu et al. (1991) on soil for vegetable production in rural areas of Huhehaote; Niu et al. (1991) on soil for vegetable production in Shenyang; Ma et al. (1986) on soil from Wuxian County of Jiangsu province; Liu et al. (1983) on paddy soil in Suzhou; and Dou et al. (1982) on soil of Heilongjiang Province. Table 3.8 summarizes recent monitoring results on pesticide POPs in soil in China (concentrations of DDT were used as the example).

3.3.3.3. *Summary*

There is a relatively small number of studies on persistent pesticides pollution in soil in China. The reported studies only cover a few regions and most of them were conducted 10–20 years ago. Since the 1983 ban on agricultural use, recent reported studies are even less and the concentrations of pesticide POPs in soil gradually decreased. However, in some areas, such as wastewater irrigated fields and vegetable fields, the soil pollution caused by pesticide POPs was serious. This indicates the large spatial differences in concentration of pesticide POPs in soil. Until now, the reported studies are about agricultural fields, and no studies on pesticide POPs pollution of production and storage sites are reported. More attention should be paid to POP pesticides at polluted sites at local level. In addition, monitoring activities need to be strengthened in future implementation of the Stockholm Convention in China, to reduce risk to humans and the environment from pesticide POPs and for soil remediation.

3.3.4. *Sediment*

3.3.4.1. *General description*

Sediment is an important media for the transformation of POPs in the environment. Many years after production has ceased and the ban on the use of POP pesticides globally, research in other countries indicates that sediment has the highest concentrations of POP pesticides, as compared to soil, water, and air. Without emission sources of POP pesticides on land, sediment in some water bodies, especially inland lakes, became the source of POP pesticides in air and water. The recent research in China on sediments of inland lakes and costal areas has corroborated this finding.

Sediment can be divided into solid and liquid phases. The liquid phase is the pore water, which is discussed above in Section 3.3.2. In the following section, suspended particles and the solid phase of sediment will be described. Usually, studies on sediments and water bodies were carried out at the same time.

3.3.4.2. *Studies on sediment pollution of POP pesticides in China*

There are many studies on monitoring POP pesticides in sediments in China. In 1976, Li (1985) measured DDT and HCH in the sediment of the Han-Gu section of the Jiyun Canal. Because of the emission of

wastewater from the Tianjin Chemicals Factory, the Σ DDT concentrations in the sediment of the Jiyun Canal were as high as 14,720 (150–179,000) ng g^{-1} (Li, 1985). Studies in the early 1980s on the mid-section of the Songhuajiang River and the Second Songhuajiang River found that the Σ DDT concentrations in sediment were in the range of 0.5–1 and 7.5–56.1 ng g^{-1} (Lang et al., 1993; Li et al., 1989). In recent years, with the further development of monitoring techniques, other pesticide POPs, such as heptachlor and eldrin, have also been detected. Information about isomers and metabolites of HCH and DDTs has also been obtained from detailed analyses. From 1999 to 2001, with the support of the European Union, the Nanjing University and the Dalian Technology University collaborated with German and Australian institutes to carry out systematic monitoring of organochlorine pesticides in the Liao and Yangtze rivers. Various methods were simultaneously used to monitor DDTs, HCHs, dieldrin, aldrin, endrin, and heptachlor in river sediment. The results showed that the main pollutants in the upper layer of the sediment were HCB and its metabolites, pentachlor, and metabolites of DDT. The concentrations of other persistent pesticides were low. The Σ DDT concentrations in sediment of the Liao and the Yangtze rivers were 0.84–6.93 and 3.24 ng g^{-1} , respectively, much lower than those of the Jiyun Canal and the Second Songhuajiang River, and comparable to those of Simbrizzi Lake in Italy (1998) and the Ebro River in Switzerland (1999). Compared to the relatively homogeneous distribution in water, the organochlorine pesticide pollution in sediment is quite different for different water bodies, indicating differences in deposition of suspended particles (China-EU Project Report, 2002). Organochlorine pesticides in river sediments were also investigated for the Pearl River (Mai et al., 2001), the Guanting Reservoir, the Yongding River (Ma and Wang, 2001), and the Yellow River (Zhang et al., 2001b).

Because of close ties with human activities, the POP pesticide pollution in estuaries, harbors, and bays has generated wide concern, and many studies on pesticide POPs in sediments of these waters have been carried out. Usually, concentrations of pesticide POPs in the sediment of estuaries and bays are generally higher than that in rivers, but lower than that in oceans and straits. From 1981 to 1993, Wu et al. (1999) studied DDT, HCH, and PCBs in estuarine sediments from the Daliaohe, Lun, Hai, Yellow, Yangtze, Huangpu, Qiantang, Min, Jiulong, and Pearl rivers. Except for the Pearl River, the HCH concentrations in sediments were low. The DDT concentrations have followed the trend of being lower in the north of China and higher in the south, and the sediments of the Pearl River, Min River, and Haihe River have relative high sediment concentrations of DDT. Based on the DDE/DDT ratio, it was suggested that a

new emission source could exist in the estuaries of the Jiulongjiang and the Pearl rivers (Wu et al., 1999).

Organochlorines in the sediment of the estuarine beach of the Yangtze River were measured in 2001 (Yang et al., 2002), and the results showed that the total concentration of organochlorine pesticides ranged from 1.25 to 36.0 ng g⁻¹. Aldrin, dieldrin, and endosulfan were also detected. The closer to the emission sources of wastewater, the higher the concentrations, and the concentrations in the estuarine areas were much higher than those in coastal areas. In the estuarine beach of the Yangtze River, the co-relations between the organochlorines, total organic carbon, and particle size of the sediment were low, which indicated the unique and complicated characteristics of the research area (Yang et al., 2002).

In 1989, Liu et al. (2001) measured OCPs in the surface sediment of the Dalian Bay, and detected 10 organochlorine pesticides, including DDT, HCH, aldrin, dieldrin, and endrin. Concentrations of HCHs and DDTs accounted for 54.5 and 38.1% of the total organochlorine pesticides, respectively, and β -HCH was the most abundant of the HCHs. Compared to 1996 data, concentrations of organochlorine pesticides in the sediment decreased significantly (Liu et al., 2001). In 1992, the surface sediment of the Victoria Bay in Hong Kong was found to contain DDTs in the same concentration range as the sediment in coastal areas (Zhang et al., 1994). In 1997, Mai et al. (2001) studied organochlorine pesticide pollution in the sediment of the Guangzhou, Xijiang, and Lingdingyang estuaries of the Pearl River. DDT concentrations were between 10 and 100 ng g⁻¹ and significantly higher than the range of surface sediment in global coastal areas reported by Fowler (<0.1–44 ng g⁻¹) and also higher than the DDT concentrations in river sediment reported in other agricultural areas in the world (e.g., San Joaquin California, U.S.) (Mai et al., 2001). DDT and HCH in the sediment of the Yangtze estuarine area and the Hangzhou Bay were measured using laminated sediment cores to reflect the pollution history of the area (Chen et al., 1999). Other studies on the sediment of estuarine areas include Kang et al. (2001) on the Macao estuarine of the Pearl River; Doong and Liao (2001) on the Wushi River in Taiwan; Chen et al. (1996) on Xiamen Island and Minjiang Bay; Lv et al. (2002) on the Dalian Bay and the Liaodong Bay; Zhao et al. (2002a) on areas of fishery cultivation in Dalian; Qiu et al. (2002) on the Daya Bay; Ma and Wang (2001) on the Guanting Reservoir and the Yongding River; and Zhang and Chen (1996a) on the West Harbor of Xiamen.

Sediments in other water bodies, such as inland lakes, have also been studied. From 1994 to 1995, Dou and Zhao (1998) measured HCH and DDT in surface sediment of the Baiyangdian Lake of the Hebei Province.

The results showed concentrations of DDT and its degradation products that were in the range of 0.56–2.61 ng g⁻¹, which is lower than that of the Lagoon River and the Jamuna River of India, the Ovens Lake of Australia, and the Vojvodina Lake of Yugoslavia. The main degradation product of DDT was *p,p'*-DDE. In some areas, *o,p'*-DDT and *p,p'*-DDT were also found, which indicated recent pollution by DDT (Dou and Zhao, 1998). In 2000, Yuan et al. (2003) analyzed organochlorine pesticides in the sediment of the Taihu Lake and found DDT and its metabolites, isomers of HCH, aldrin, dieldrin, HCB, and heptachlor. β -HCH, *p,p'*-DDT, and HCB were found in the highest concentrations. The average concentrations were as high as 6.57, 1.43, and 2.16 ng g⁻¹ (dry weight), respectively. The HCH concentrations were significantly higher than DDT concentrations. The results showed that concentrations of HCHs and DDT in the sediment of the Taihu Lake were higher than those measured in rivers but lower than that of bays in Xiamen, Hong Kong, and Macao. Compared to lake sediment of remote areas of Canada and the Arctic, the DDT concentrations in the sediment of the Taihu Lake were slightly higher, and the HCH concentrations were a magnitude higher, indicating relatively high usage and emissions of organochlorine pesticides in the Taihu Lake catchments (Yuan et al., 2003). Table 3.9 summarizes recent results of the measurement of pesticide POPs in sediment in China (concentrations of DDT were used as an example).

3.3.4.3. Summary

Since the 1983 ban of the agriculture use of POP pesticides in China, the concentrations of the POP pesticides have gradually decreased. However, the POP pesticides tended to concentrate in sediment, and resulted in relatively high concentrations of POP pesticides in this environmental media. Many measurements of POP pesticides in sediment have been conducted in China, covering different regions and different types of water bodies. Sediments of harbors and estuaries have the highest concentration of POP pesticides, compared to concentrations measured in other water bodies. The concentration of POP pesticides was highest in the sediments of estuaries of the Pearl River, Minjiang River, Jilongjiang River, and the Macao Harbor. Although the concentration of POP pesticides in sediments has fallen dramatically since the 1980s, in some regions the ecological risk standards for oceans and estuaries established by other countries are still exceeded. Serious ecological impact might have been caused by the high concentrations of POP pesticides in sediment, and these regions should be classified as high environmental risk areas.

Table 3.9. Pesticide POPs concentrations in sediment of China (DDTs as example)

Regions	Monitoring time	Types	POPs	DDTs (ng g ⁻¹)	References
Yangtze River (Nanjing segment)	1998	Suspended particles	DDT, HCH, aldrin, dieldrin, heptachlor	14.63–20.72	Jiang et al. (2000)
Yangtze River (Nanjing segment)	1998			0.21–4.50	Xu et al. (2000)
Liao River	1998		HCH, DDT, endrin, HCB, aldrin, heptachlor, etc.	1.0–2.7	Zhang et al. (2002)
Jiyun River (Hangu)	1976			356	Li (1985)
Second Songhua River	1997		DDT, HCH, PCBs, aldrin, heptachlor	2.0–56.1	Liu et al. (1998)
Guanting Reservoir–Yongding River	1999		HCH, DDT	2.5–26.7	Mai et al. (2001)
Several estuaries, China					
LiaoHe	1989		HCH, DDT, PCBs	0.2	Wu et al. (1999)
LianHe	1991	Downriver country		ND	
Hai	1984–1985			9.5–11.5	
HuangHe	1984–1986	City in estuary		ND	
Yangtse	1986–1988			0.1–0.2	
Huangpu	1988	City downriver		1.3	
Qiantang	1984			0.1	
Minjiang	1986	City in estuary		6.9–13.1	
Jiuling	1993			4.1–6.1	
Zhujiang	1984			6.5–14.5	
Dalian Bay	1996		HCH, DDT, aldrin, dieldrin, endrin, HCB, heptachlor, endosulfan, etc.	21.746 (2.118–72.299)	Liu et al. (2001)
Dalian Bay	1999			2.208 (0.727–5.723)	
Liaodong Bay	1999			2.95 (0.98–7.51) specific site 155	Lv et al. (2002)
Daya Bay	1999			0.14–20.27	Qiu et al. (2002)
Minjiang Estuary	1996	Offshore launch	DDT	6.17–63.88	Yuan et al. (2001)

Table 3.9. (Continued)

Regions	Monitoring time	Types	POPs	DDTs (ng g ⁻¹)	References
Zhujiang Estuary	1996		DDT	28.57	
Jiulongjiang Estuary	1999		DDT	8.61–73.70	
Minjiang River	1999		DDT, HCH, heptachlor, endosulfan	1.57–13.6	Zhang et al. (2003)
Xiamen Harbor	1993		HCH, DDT, PCB, endrin, aldrin, heptachlor	9.27 (4.45–17.4) specific site 311	Zhang et al. (1996)
Xiamen Harbor	1998			0.025 (0.01–0.06)	Hong et al. (1999)
Xiamen-inmen Sea Area	1995		DDT, HCH	4.71 (2.97–9.16)	Chen et al. (1996)
Victoria Harbor	1992		HCH, DDT, PCBs	10.2 (1.38–25.4) specific site 69	Zhang et al. (1994)
Pearl River Delta	1997	Guangzhou	HCH, DDT, PCBs, PAHs	35.1–90.9	Mai et al. (2001)
		Shiziyang		22.9–40.4	
		Xijiang		4.94–16.6	
		Lingdingyang		2.6–115.6	
		Macao Harbor		1628.8	
Zhujiang Estuary	1994		HCH, DDT	33.46 (17.79–51.71)	Cai et al. (1997)
Yangtse Estuary	1981	Sediment core	DDT, HCH	6.93–12.6	Chen et al. (1999)
Hangzhou Bay	1988			1.04–3.46	
	1992			0.56–1.85	
	1997			0.05–0.31	
Yangtse Estuary	1981		HCH, DDT	10.9 (6.9–16.0)	
Macao Estuary	1999	Sediment core	DDT, HCH, aldrin, endrin	1.92–39.13	Kang et al. (2001)
				10.53	
Baiyangdian	1994		DDT, HCH	0.56–2.61	Dou and Zhao (1998)
	1995				
Taihu Lake	1999–2000		DDT, HCH	0.1–8.8	Feng et al. (2003)
Taihu Lake	2000		DDT, HCH	3.27	Yuan et al. (2003)
Boyang Lake	1983		DDT, HCH	ND	Qian et al. (1986)
Yangtse Beach	2001	Sediment	HCH, DDT, PCB, dieldrin, aldrin, heptachlor, endosulfan	ND–0.565	Yang et al. (2002)

Monitoring and remediation of polluted sediment should be an important task in the implementation of the Stockholm Convention in China.

3.3.5. Food

3.3.5.1. General description

The POP pesticides have three pathways to enter the human body: inhalation, ingestion (food intake), and dermal contact. The intake of food through the digestive system accounts for 90% of the pesticide POPs that enter the human body (Campoy et al., 2001). HCH and DDT can enter plants through soil and water, and enter animal bodies through water and food. These compounds remain in fat tissues for a long time. Although most of the recent monitoring reports indicate that the pollution level of pesticide POPs such as DDT in food have been reduced to low levels, it should not be ignored because it is closely related to adverse health effects in humans and animals.

3.3.5.2. The pollution level of POP pesticides in foodstuff in China

Two investigations of organochlorine pesticides in food were carried out in China, one in 1992 and one in 2000. The investigation in 1992 was to implement the Global Food Pollutants Monitoring Program constituted in 1976 by the UNEP, FAO and WHO. China joined the program in 1981. During the 1992 investigation, organochlorine pesticides and heavy metals in food were measured. Helongjiang Province, Beijing, Sichuan Province, Zhejiang Province, and Guangdong Province were selected as monitoring sites to represent the northeast, north, southwest, and south of China (Zhang et al., 1996b).

The investigation in 2000 was carried out by the food pollution monitoring network of the Ministry of Health of China in Beijing, Chongqing and provinces of Jilin, Henan, Shanxi, Zhejiang, Fujian, Guangdong, Hubei, and Shandong. Compounds monitored included organochlorine pesticides and other pollutants. The results indicated that after nearly a 20-year ban on agricultural use, the pollution level of organochlorine pesticides in the environment was significantly reduced through degradation. Currently, concentrations of HCHs and DDTs in food are below the national standards. Table 3.10 shows the concentrations of HCH and DDT in several foods in China in 2000 (Wang et al., 2002).

Among various foods, grains, vegetables, fruits, meat, fish, eggs, milk, vegetable oil, and tea are often monitored for pesticide POPs. Currently, only HCH (including α -HCH, β -HCH, and γ -HCH) and DDT (including

Table 3.10. Residue of DDT and HCH in several types of food in China, 2000

Types	Number of samples	Average concentration (ng g ⁻¹)			National standard
		<i>p,p'</i> -DDE	<i>o,p'</i> -DDT	<i>p,p'</i> -DDT	
Grain	80	4.1	7	14.1	200
Vegetables	88	0.8	1.3	0.8	100
Fruits	40	0.8	2.3	2.7	100
Meat	41	5.6	1.3	1.8	200
Fish	30	3.6	0.9	2.5	500
Eggs	51	2.5	0.5	1.5	1000
Milk powder	15	0.6	0.6	2.0	Convert to milk
Milk	5	5.7	25.5	1.3	100
Vegetable oil	10	0.2	0.5	1.0	500
Tea	44	10.8	13.8	31.1	200
		α -HCH	β -HCH	γ -HCH	
Grain	80	1.0	3.8	0.5	300
Vegetables	88	0.9	0.8	3.1	200
Fruits	40	0.4	1.1	0.2	200
Meat	41	5.3	7.1	7.0	400
Fish	30	1.8	1.4	1.8	500
Eggs	51	0.6	13.3	0.4	1000
Milk powder	15	2.1	10.2	1.1	Convert to milk
Milk	5	0.4	0.2	0.1	100
Vegetable oil	10	2.6	20.2	5.1	500

p,p'-DDT, *p,p'*-DDE, and *o,p'*-DDT) are measured. Besides the investigations of foods in 1992 and 2000 at the national scale, for public health purposes comprehensive investigations in Zhejiang and Sichuan Provinces and a large number of local investigations on certain foods have been conducted.

Grain: Compared to the early 1980s, during the 1990s the concentrations of organochlorine pesticides in food in China have significantly decreased and many meet the national standards. Among the DDTs, *p,p'*-DDT has the highest concentration in grain. For example, concentrations of DDT in commercial grains from the north and southwest of China significantly exceed the national average value. Because more HCHs are used than DDT during grain production in China, the concentrations of HCH in grain in China are relatively high among the organochlorine pesticides. Table 3.11 lists concentrations of organochlorine pesticides in grain in China.

Fruits and vegetables: Table 3.12 shows that the concentrations of organochlorine pesticides in fruits and vegetables in China decreased year after year. The concentration values obtained in 2000 are significantly

Table 3.11. Residues of organochlorine pesticides in grain in China

Regions	Types	Monitoring time	Number of samples	DDT (ng g ⁻¹)	HCH (ng g ⁻¹)	References
Yixing	Rice	2000	1	<0.04	0.05	Nakata et al. (2002)
Yixing	Wheat	2000	1	0.46	0.10	Nakata et al. (2002)
Weihai	Wheat	1998	30	6.4–17.9	<5.0–50.7	Su et al. (2001)
	Maize		30	<5.0–7.2		
	Earthpea		30	5.8–41.7		
Xinjiang	Wheat	1989	200	7.4 (6–14)	13 (5.5–221)	Ma et al. (1996)
	Maize		90		6.2 (3.6–98.4)	Ma et al. (1996)
	Rice		14		5.1	Ma et al. (1996)
Hangzhou	Rice	1992–1999	16	7.4 (6–14)	4.2 (3–7.3)	Lu et al. (2000)
Hangzhou	Flour	1992–1999	14	6.3	4.3	Lu et al. (2000)
Gansu	Wheat	1991	127	2.2	46.2	Zhou et al. (1995)
	Maize		86	1.7	44.6	
	Rice		5	3.1	6.7	
	Millet		2	1.6	12.6	
Jiashan, ZJ	Rice	1996	143	0–137	0–220	Zhao et al. (2002b)
Chengdu	Corn		4.6	309		
Heilongjiang	Food grain	1992	16	6.5	5.3	Xiao et al. (1999)
China (average)	Food grain	1992	65	27	13	Xiao et al. (1999)
China (average)	Food grain	2000	80	25.2	5.3	Wang et al. (2002)
National standard	Level 1	1981		<20	<10	GB2763-81
	Level 2			20–200	10–300	
	Level 3			200	300	

Note: Residual standard of HCH and DDT in grain, vegetables, and other food (GB2763-81), Ministry of Health, P. R. China, 1981

Table 3.12. Residue of DDT pesticides in fruits and vegetables in China

Regions	Types	Time	Number of samples	DDT (ng g ⁻¹)	References
Shanghai fruits	Apple	2000	1	0.40	Nakata et al. (2002)
	Grape	2000	1	0.83	
Shanghai vegetables	Celery	2000	1	2.49	Lin et al. (1995)
	Soybean	2000	1	3.9	
	Cucumber	2000	1	0.09	
	Taro	2000	1	0.07	
	Pea	2001	1	0.33	
	Mushroom	2001	1	ND	
	Asparagus	2001	1	ND	
	Eggplant	2001	1	0.09	
	Spinach	2001	1	0.12	
	Onion	2001	1	0.15	
	Green pepper	2001	1	ND	
	Sichuan	Vegetable	1992	11	
Zhejiang	Vegetable	1975–1979		70	Zhao and Ma (2001a,b)
Zhejiang	Vegetable	1994–1996	76	3.2 (0–24.7)	Zhao and Ma (2001a,b)
Zhejiang	Fruit	1975–1979		30–210	Zhao and Ma (2001a,b)
Zhejiang	Fruit	1994–1996	31	0.5 (0–1.4)	Zhao and Ma (2001b)
Hangzhou	Vegetable, fruit	1992–1999	40	4.5	Lu et al. (2000)
Hainan	Vegetable			ND–48	Zhuo et al. (1998)
Huhehaote	Potato	1986–1988	51	7.5	Liu et al. (1991)
	Cabbage		39	6.6	
	Carrot		31	8.2	
	Beans		21	11.9	
	Pepper		46	11.9	
	Tomato		34	10	
Gansu	Vegetable	1991	182	1–27.5	Zhou et al. (1995)
Gansu	Fruit	1991	77	0.8–14.5	Zhou et al. (1995)
Chengdu	Vegetable	1996		13.7	Hou et al. (1999)
Chengdu	Fruit	1996		13.3	Hou et al. (1999)
Heilongjiang	Vegetable	1992	11	6.1	Xiao et al. (1999)
Heilongjiang	Fruit	1992	9	12	Xiao et al. (1999)

Table 3.12. (Continued)

Regions	Types	Time	Number of samples	DDT (ng g ⁻¹)	References
China (average)	Vegetable	1992	68	24	Xiao et al. (1999)
China (average)	Vegetable	2000	88	2.9	Wang et al. (2002)
China (average)	Fruit	1992	33	35	Xiao et al. (1999)
China (average)	Fruit	2000	40	5.8	Wang et al. (2002)
National standard	Vegetable			100	GB2763-81
National standard	Fruit			100	GB2763-81

Note: Residual standard of HCH and DDT in grain, vegetable and other food (GB2763-81), 1981 Ministry of Health, P. R. China.

lower than those measured in 1992. During the national-scale investigation in 2000, the major DDT compounds in fruits and vegetables were *p,p'*-DDT and *o,p'*-DDT, respectively.

Fish and mussels: Organochlorine pesticides have serious impacts on aquatic species. Because of bioaccumulation effects, concentrations of POPs in fish are a few orders higher than those in water. Fish and mussels are important sources of human exposure to POPs due to consumption (i.e., ingestion route). From 1994 to 2001, Monirith et al. (2003) investigated DDTs, HCHs, HCB, and PCBs in sea waters of a number of Asian-Pacific countries and found concentrations of DDTs in fishes and mussels of certain sea waters close to Xiamen, Shenzhen, Shanghai, Zhejiang, and Fujian (1999–2001) were much higher than those in India (1998), Indonesia (1998), Korea (1998), and Japan (1994). Table 3.13 summarized the concentrations of DDTs in fish and mussels during investigations in China in recent years.

Meat, eggs, and milk: The POPs are hydrophobic and lipophilic substances, and can easily transfer into materials with high organic contents, leading to bioaccumulation. Due to the high fat content of meat, eggs, and milk, these foods are important potential sources of human exposure to pesticide POPs. Table 3.14 shows the residue of pesticide DDT in meat, eggs, and milk in China.

Others: Investigations on POP residues in edible materials, such as tea, breast milk, and herbs, have also been carried out in China. Tables 3.15

Table 3.13. Residue of DDT pesticides in fish and mussels in China

Regions	Types	Monitoring time	Number of samples	DDTs (ng g ⁻¹)	Remark (Lipid %)	References
Xiamen	Green mussel	1999	24	23,000	0.56	Monirith et al. (2003)
Shenzhen	Green mussel	1999	18	30,000	1.1	
Fuzhou	Green mussel	1999	20	2400	2.4	
Liaoning	Blue mussel	2001	34	830	1.7	
Jiaozhouwan	Blue mussel	2001	17	6200	2.4	
Chongmingdao	Blue mussel	2001	33	29,000	2.2	
Zhejiang	Blue mussel	2001	12	8600	2.9	
Zhejiang	Blue mussel	2001	8	2200	3.5	Monirith et al. (2003)
Fujian	Green mussel	2001	20	7800	1.9	
Fujian	Green mussel	2001	9	54,000	1.2	
Shanghai	Mussel	2000	10	34,000	1.3	Nakata et al. (2002)
	Shrimp		37	200	1.2	
	Crab		4	830	1.1	
	Squid		12	220	1.2	
	Fish		1	1000	0.91	
	Horse-mackerel		4	710	5.9	
	Tongue sole		6	560	2.3	
Hong Kong	15 fishes	1997		3.3–76	WW	Chan et al. (1999)
Hong Kong	Fish liver	1997	2	27 ± 11 71 ± 34	WW	Chan et al. (1999)
Xiamen Island	Shellfish	1995–1996	12	75.2–2143	DW	Chen et al. (2002)
Minjiang Bay	Shellfish	1995–1996	9	21.5–2396	DW	Chen et al. (2002)
Xiamen	Fish liver	1998–1999		150–2200	WW	Klumpp et al. (2002)
	Fish meat			<0.5–220	WW	Klumpp et al. (2002)
	Mussel			50–200	WW	Klumpp et al. (2002)

Coastal area in North China							
Yalujiang	Many kinds of mussels	1990	5	1.9	WW	Liu et al. (1996)	
Dalian Bay			5	4.5	WW		
Jinzhou Bay			5	3.1	WW		
Bohai Bay			4	1.03	WW		
Jiaozhou Bay			4	11.9	WW		
Liaohe			2	0.5	WW		
Lvsi			4	3.9	WW		
Yangtse			2	13.5	WW		
Sichuan	Fish	1992–1999	10	12.5	WW	Lu et al. (2000)	
Hangzhou	Marine product	1992–1999	8	11.5	WW	Lu et al. (2000)	
Pearl River Estuary	Jade mussel	1996	13	9.5–191	WW	Fang et al. (2001)	
Pearl River Estuary	19 Animals	1985–1993		1–133	WW	Luo et al. (2001)	
Yangtse Estuary	Fish	< 1991		410	WW	Luo et al. (2001)	
Hangzhou Bay	Fish	< 1991		270	WW		
Baiyangdian fish	Herbivorous	1995		29.6	WW	Dou and Zhao (1998)	
	Polyphagia			108.5			
	Carnivorous			124.4			
Baiyangdian	Crucian	1994–1995		14.1	WW	Dou and Zhao (1996)	
Coastal area in Guangdong	Oyster	1989	10	8.3	WW	Jia et al. (1996)	
		1991	10	3.1			
		1992	10	1.5			
		1993	10	0.6			
Heilongjiang	Aquatic product	1992	6	33		Xiao et al. (1999)	
Chengdu	Aquatic product	1996		81.2		Hou et al. (1999)	
China (average)	Aquatic product	1992	35	46		Xiao et al. (1999)	
China (average)	Fish	2000		7		Wang et al. (2002)	
National standard	Fish			500		GB2763-81	

Note: Residual standard of HCH and DDT in grain, vegetable, and other food (GB2763-81), 1981, Ministry of Health, P. R. China.

Table 3.14. The residue of DDT pesticides in meat, eggs, and milk in China

Regions	Types	Monitoring time	Sample number	DDT (ng g ⁻¹)	References
Shanghai	Pork fat	2000	1	3.32	Nakata (2002)
Shanghai	Pork muscle	2000	1	0.15	Nakata et al. (2002)
Shanghai	Ham	2000	1	0.55	Nakata et al. (2002)
Shanghai	Sausage (pork)	2000	1	6.67	Nakata et al. (2002)
Yixing	Chicken	2000	1	0.64	Nakata et al. (2002)
Yixing	Chicken (liver)	2000	1	3.92	Nakata et al. (2002)
Shanghai	Eggs	2000	1	1	Nakata et al. (2002)
Yixing	Milk	2000	1	1.91	Nakata et al. (2002)
Sichuan	Milk	1992	10	0.9–2.8	Lin et al. (1995)
Sichuan	Meat	1992	10	4.4–113.6	Lin et al. (1995)
Sichuan	Eggs	1992	10	2.1–48.9	Lin et al. (1995)
Hangzhou	Vegetable oil	1992–1999	12	21.2	Lu et al. (2000)
	Eggs		12	10	
	Pork		10	10.6	
Hangzhou	Duck	1992–1999	10	6	Lu et al. (2000)
	Beef		11	6	
	Chicken		12	4	
	Milk		12	10	
Chengdu	Meat	1996		5.9	Hou et al. (1999)
	Eggs	1996		40.4	Hou et al. (1999)
Heilongjiang	Vegetable oil	1992	6	65	Xiao et al. (1999)
	Fowl		10	13	
	Eggs		6	32	
	Milk		16	50	
China (average)	Vegetable oil	1992	34	35	Xiao et al. (1999)
	Fowl		58	32	
	Eggs		28	30	
China (average)	Vegetable oil	2000	10	1.7	Wang et al. (2002)
	Meat		41	8.7	
	Eggs		51	4.5	
	Milk		5	32.5	
National standard	Vegetable oil			500	GB2763-81
	Meat			500	
	Eggs			1000	
	Milk			100	

Note: Residual standard of HCH and DDT in grain, vegetable and other food (GB2763-81), 1981, Ministry of Health, P. R. China.

Table 3.15. Residues of organochlorine pesticides in tea in China

Regions	Monitoring time	Sample number	DDT (ng g ⁻¹)	HCHs (ng g ⁻¹)	References
Shanghai	2000	1	4.58	0.53	Nakata et al. (2002)
	2000	1	0.50	0.34	
	2000	1	1.98	0.57	
Weihai	2000	40	5–3630	5–80	Cong et al. (2001)
Zhejiang	1975–1979		6–750	30–1300	Zhao and Ma (2001b)
Zhejiang	1994–1996	22	1.8 (0–5.6)	3.5 (0.2–22.9)	Zhao and Ma (2001b)
China (average)	2000	44	55.7		Wang et al. (2002)
National standard			200		GB2763-81

Table 3.16. Residue of DDT pesticide in breast milk in China

Regions	Time	Number of samples	<i>p,p'</i> -DDT (µg g ⁻¹ fat)	<i>p,p'</i> -DDE (µg g ⁻¹ fat)	References
Beijing	1983		1.6	5.9	Yu et al. (2001)
Beijing	1998	15	0.24	1.72	Yu et al. (2001)
Changchun	1987		0.260	7.91	Li et al. (2000)
Changchun	1998	52	0.230	0.488	Li et al. (2000)
Nanchang	1988	60	4.23	10.4	He et al. (2001)
Nanchang	1998	60	0.21	1.46	He et al. (2001)
Weihai	1985	50	3.78	7.00	Cong et al. (2001)
Weihai	1998	89	0.005	2.03	Cong et al. (2001)
Guangzhou	2000	54	0.70	2.85	Wong et al. (2002)
Hong Kong	1985	25	2.17	11.67	Wong et al. (2002)
Hong Kong	1999	132	0.39	2.48	Wong et al. (2002)
Hangzhou	1983	80	4.96	20.40	Lu et al. (2000)
	1985	59	2.82	13.95	Lu et al. (2000)
	1987	60	1.59	12.20	Lu et al. (2000)
Nanjing	1985	60	3.4	12.0	Jiang (1989)
Nanjing	1987	60	1.5	10.5	Jiang (1989)
China (average)	1984	861	2.64	8.08	Cong et al. (2001)

and 3.16 summarize concentrations of organochlorine pesticides in tea and breast milk in China. The DDT concentrations in breast milk directly reflect the impact of DDT on the Chinese population. Large amount of HCHs and DDT have been used in China as pesticides; therefore, the concentrations of HCHs and DDT in breast milk in China are apparently

higher than those in some other countries. Compared to the early 1980s, the concentrations of DDT and DDE in breast milk in major cities in China have decreased significantly but are still higher than those measured in Sweden and Canada. Cities with relatively high DDT concentrations in breast milk include Hangzhou and Hong Kong.

3.3.5.3. *Summary*

The large amount of application of DDT and HCH in 1950–1970 in China has caused serious and large-scale food contamination. However, with the ban on agricultural use and the degradation in environment, the concentrations of DDT and HCH in food have significantly decreased. According to the follow-up investigation and monitoring in Zhejiang Province from 1972 to 1999, using the 1985 concentrations for comparison, the concentrations of HCH in rice, vegetables, pork, freshwater fish, and eggs measured in the 1990s decreased by almost 100%, and concentrations of DDT decreased by 20–90%. Recent monitoring of drinking water, tea, and breast milk indicates a large reduction in the DDT pollution level since the 1980s, and the DDT concentrations now meet the national standards.

However, the pollution of pesticide POPs in food or the food web in China is still a serious concern. The concentrations of DDT in breast milk in China are still higher than those often observed in developed countries and also higher than levels specified in the guidelines of international organizations. Emission sources of pesticide POPs still exist in some areas in China, and the concentrations of DDT in tea, fish, and mussels are still high in some regions. Even after a 20-year ban on the use of organochlorine pesticides in China, monitoring in the Taihu Lake, an inland lake located in the economically developed part of China, has found isomers of HCHs, DDT and its metabolites, endrin, and heptachlor epoxide in bird eggs. The concentrations and detection rate of HCH and DDT are very high. Therefore, the potentially high impact of pesticide POPs on human health still exists.

3.3.6. *Others*

Above, the pollution situation associated with persistent pesticides in China has been summarized for environmental media including air, water, soil, and sediment. The residues of pesticide POPs in food have also been summarized. Other studies on POP residues, such as residues

measured in Hubei, in snails in Yixin, and in fat tissues of whales in the South China Sea are not summarized here (Lu et al., 2000).

While the residues in the environment could reflect the current pollution level of pesticide POPs in China, the residues in fat, blood, and tissues of the human body reflect the impact of pesticide POPs on humans. Currently, the research on residues of pesticide POPs in the human body is being done mainly for medical purposes. Although a detailed description is outside the scope of this paper, a brief description is provided below.

An investigation in the 1970s and 1980s showed that the residues of DDT in the body fat of residents in a number of cities in China were in the range of 2.59–23.6 $\mu\text{g g}^{-1}$. The concentrations were higher in Zhejiang and Shanghai, at levels close to 20 $\mu\text{g g}^{-1}$. These values are comparable to the levels measured in the 1960s and 1970s in the U.S. Canada, and Japan (Wang et al., 1981). However, a study in 2001 in Shanghai showed DDT concentrations in women's breast milk were still as high as 7.6 $\mu\text{g g}^{-1}$, while the figures for the U.S. (1998) and Japan (1997) were 0.072 and 0.78 $\mu\text{g g}^{-1}$ respectively. The concentrations of HCHs in breast milk in China were also much higher than those measured in many other countries (Nakata et al., 2002). This can be explained by the relatively high concentrations of POPs in food and subsequently high human exposure to pesticides in China.

REFERENCES

- Bidleman, T.F., et al., 1987. Organochlorine pesticides and polychlorinated biphenyls in the atmosphere of southern Sweden. *Atmos. Environ.* 21, 641–654.
- Cai, F.L., Lin, Z.F., et al., 1997. The study on the behaviour characteristics of BHC and DDT in the tropical marine environment I: The content and distribution of BHC and DDT in the dry season in the Zhujiang Estuary. *Marine Environ. Sci. (Chinese)* 16, 9–14.
- Campoy, M., et al., 2001. Analysis of organochlorine pesticides in human milk: Preliminary results. *Early Human Dev.* 65(Supplement), S183–S190.
- Chan, H.M., Chan, K.M., Dickman, M., 1999. Organochlorines in Hong Kong Fish. *Marine Pollut. Bull.* 39, 346–351.
- Chen, J.F., Ye, X.R., et al., 1999. Preliminary study on the marine organic pollution history in Changjiang Estuary-Hangzhou Bay-BHC and DDT stratigraphical records. *China Environ. Sci. (Chinese)* 19, 206–210.
- Chen, W.Q., Zhang, L.P., et al., 1996. Concentrations and distributions of HCHs, DDTs, and PCBs in surface sediments of the sea area between Xiamen and Jinmen. *J. Xiamen Univ. (Nat. Sci.) (Chinese)* 35, 936–940.
- Chen, W.Q., Zhang, L.P., et al., 2002. Residue levels of HCHs, DDTs and PCBs in shellfish from coastal areas of east Xiamen Island and Minjiang estuary. *China Marine Pollut. Bull.* 45, 385–390.

- Chen, Z.M., Han, H.Q., et al., 1986. Source analysis of HCH and DDT in tea leaves. *Acta Sci. Circumstan.* (Chinese) 6, 278–285.
- Cheng, Y., Sheng, G.Y., et al., 2000. Characteristics and sources of organochlorine pesticides from cooking smoke and aerosols. *China Environ. Sci.* (Chinese) 20, 18–22. China-EU Project Report, 2002.
- China National chemical Information Center, China Chemical Industry Yearbook, 2003–2004 (20), ISSN: 1005–3336.
- Cheveruil, M., et al., 1996. Occurrence of organochlorines (PCBs, pesticides) in the atmosphere and in the fallout from urban and rural stations of the Paris area. *Sci. Total Environ.* 18, 25–37.
- Doong, R.A., Liao, P.L., 2001. Determination of organochlorine pesticides and their metabolites in soil samples using headspace solid-phase microextraction. *J. Chromatogr. A* 918, 177–188.
- Dou, C.J., Wu, J.X., et al., 1982. Pollution and prevention of organochlorine pesticides in Heilongjiang Province. *Tech. Equip. Environ. Pollut. Control* (Chinese) 3, 57–60.
- Dou, W., Zhao, Z.X., 1996. A study on bioaccumulation of BHC and DDT in fish muscles of different food structures from Baiyangdian Lake. *Adv. Environ. Sci.* (Chinese) 4(6), 51–56.
- Dou, W., Zhao, Z.X., 1998. Contamination of DDT and BHC in water, sediments and fish muscle from Baiyangdian Lake (in Chinese). *Acta Sci. Circumstan.* (Chinese) 18, 308–312.
- Fang, Z.Q., Cheung, R.Y.H., et al., 2001. Concentrations and distribution of organochlorine pesticides and PCBs in green lipped mussels, *Perna viridis* collected from the Pearl River estuarine zone. *Acta Sci. Circumstan.* (Chinese) 21, 113–116.
- Feng, K., Yu, B.Y., et al., 2003. Organochlorine pesticide (DDT and HCH) residues in the Taiu Lake region and its movement in soil-water systems I. Field survey of DDT and HCH residues in ecosystems of the region. *Chemosphere* 50, 683–687.
- Glam, C.S., Atlas, E.L., et al., 1980. Phthalate esters, PCB and DDT residues in the Gulf of Mexico atmosphere. *Atmos. Environ.* 5, 65–69.
- Gong, Z.M., Cao, J., et al., 2002a. Organochlorine pesticide residues in agricultural soil from Tianjin. *Agro-environ. Protect.* (Chinese) 21, 459–461.
- Gong, Z.M., Zhu, X.M., et al., 2002b. Local spatial variation of organochlorine pesticides in agricultural soil from Tianjin. *Urban Environ. Urban Ecol.* (Chinese) 15, 4–6.
- He, J.F., Wan, Y., et al., 2001. Survey on pollution levels of organochlorine pesticides in human milk of Nanchang City. *Hubei Prev. Med.* (Chinese) 12, 22.
- Hong, H.S., Chen, W.Q., et al., 1999. Distribution and fate of organochlorine pollutants in the Pearl River estuary. *Marine Pollut. Bull.* 39, 376–382.
- Hou, W.D., Chen, C., et al., 1999. Study on pesticide residues and safety evaluation for the urban and rural residents diet in Chengdu. *Prev. Med. Inform.* (Chinese) 5, 77–79.
- Iwata, H., Tanabe, S., et al., 1993. Distribution of persistent organochlorines in the oceanic air and surface seawater and the role of the oceans on their global transport and fate. *Environ. Sci. Tech.* 27, 1080–1098.
- Jia, X.P., Lin, Q., et al., 1996. Variation tendency of BHC and DDT concentrations in oysters from the coast of Guangdong Province. *J. Fish. Sci. China* (Chinese) 3, 75–83.
- Jiang, X.F., 1989. Survey and monitoring of HCH and DDT residues in human milk in Nanjing City. *Environ. Monit. Manage. Technol.* (Chinese) 1, 25–27.
- Jiang, X., Xu, S.F., et al., 2000. Polychlorinated organic contaminants in waters, suspended solids and sediments of the Nanjing section, Yangtze River. *China Environ. Sci.* (Chinese) 20, 193–197.

- Kang, Y.H., Liu, P.B., et al., 2003. Persistent organochlorinated pesticides in water from Guanting reservoir and Yongdinghe River, Beijing. *J. Lake Sci. (Chinese)* 15, 125–132.
- Kang, Y.H., Sheng, G.Y., et al., 2001. Vertical distribution characteristics of organochlorinated pesticides in sediment core from Macao estuary, Pearl River delta. *Environ. Sci. (Chinese)* 22, 81–85.
- Klumpp, D.W., Hong, H.S., et al., 2002. Toxic contaminants and their biological effects in coastal waters of Xiamen, China. I. Organic pollutants in mussels and fish tissues. *Marine Pollut. Bull.* 44, 752–760.
- Lang, P.Z., Ding, Y., et al., 1993. A study of the pollution by toxic organics in the Songhua river between middle reaches of Shaokou and Songhua river village. *Tech. Equip. Environ. Pollut. Control (Chinese)* 06.
- Li, J., Zhu, T., et al., 2006. Observation of organochlorine pesticides in the air in Mt. Everest region. *Ecotoxicol. Environ. Safety* 63, 33–41.
- Li, M.X., Yue, G.C., et al., 1989. Transport and distribution of PCBs and organochlorine pesticides in the Second Songhua River. *Environ. Chem. (Chinese)* 8, 49–54.
- Li, Q.S., 1985. Integrative analysis on the pollution level of organochlorine pesticides in the Hangu area, Tianjin. *Environ. Sci. Ser. (Chinese)* 6, 5–14.
- Li, Y.H., Wang, A., et al., 2000. Accumulative levels of organochlorine pesticides among women during their lactation period in Changchun. *J. Environ. Health (Chinese)* 17, 19–20.
- Lin, L., Fu, S., et al., 1995. The residuals of organic chloride pesticides in foods in Sichuang. *Chinese Journal of Food Hygiene* 7(4), 20–22.
- Lin, M.Q., Duan, Y.H., 1999. The study on the residual levels of aromatic hydrocarbon, halohydrocarbon and organochlorine pesticides in the water of Fuxian Lake. *J. Environ. Health (Chinese)* 16, 151–153.
- Lin, P., Huang, J.B., 1994. The distribution and dynamics of organochlorine pesticides in the mangrove area of Jiulongjiang estuary, Fujian. *J. Xiamen Univ. (Nat. Sci.) (Chinese)* 33(Suppl.), 43–49.
- Lin, Y., Gong, R., et al., 2002. *Pesticide and Eco-environmental Protection*, Chemical & Technologies Publish House, Beijing, pp. 14–15.
- Liu, J.A., Wang, W.H., et al., 1998. Contents of persistent pollutants in the sediment samples of the Second Songhua River. *China Environ. Sci. (Chinese)* 18, 518–520.
- Liu, R.Y., Wu, S.P., et al., 1996. Distribution and evaluation of the organic chlorine pesticide and PCB in shellfish from north of the Changjiang Mouth. *Marine Environ. Sci. (Chinese)* 15, 29–35.
- Liu, S.B., Huang, Y.Q., et al., 1991. Investigation and research on the organochlorine insecticide pollution state in vegetables and soil near Huhhat. *Rural Ecol. Environ. (Chinese)*(4), 63–65.
- Liu, X.M., Xu, X.R., et al., 2001. Organochlorine pesticides and PCBs in Dalian Bay. *Marine Environ. Sci. (Chinese)* 20, 40–44.
- Liu, Z.H., Ji, Y.L., 1983. Dynamic analysis on HCHs residues in the Suzhou area. *Environ. Sci. Ser. (Chinese)* 4, 37–43.
- Lu, D.S., Yu, C., et al., 2000. Analysis on dynamic trends of organochlorine pesticide residues in foodstuff of Zhejiang province. *China Public Health (Chinese)* 16, 1027–1029.
- Luo, S.C., Yu, H.S., et al., 2001. Studies on the contents of BHC and DDT in the organisms in the Pearl River estuary and adjacent sea area. *Marine Sci. Bull. (Chinese)* 20, 44–50.
- Lv, J.C., Zhao, Y.F., et al., 2002. Contamination by organochlorine pesticides in aquaculture water in Dalian Bay and Liaodong Bay, North China Sea. *J. Fish. Sci. China (Chinese)* 9, 73–77.

- Ma, J.X., Ma, H., et al., 1996. General survey and analysis of residues of organochlorine pesticides in grain in the Xinjiang autonomous region of China. *Grain Storage (Chinese)* 25, 31–34.
- Ma, M., Wang, Z.J., 2001. Contamination by PCBs and organochlorinated pesticides in the sediment samples of Guanting Reservoir and Yongding River. *Environ. Chem. (Chinese)* 20, 238–243.
- Ma, X.F., Zhang, Y.M., et al., 1986. Study on organochlorine pesticide pollution in soil, crops and water of Wu County. 7, 7–13.
- Mai, B.X., Lin, Z., et al., 2001. The pollution situation and risk assessment of toxic organic compounds in sediments from Pearl River Delta. *Res. Environ. Sci. (Chinese)* 14, 19–23.
- McConnell, L.L., Bidleman, T.F., Cotham, W.E., Walla, M.D., 1998. Air concentrations of organochlorine insecticides and polychlorinated biphenyls over Green Bay, WI, and the four lower Great Lakes. *Environ. Pollut.* 101, 391–399.
- McConnell, L.L., Cotham, W.E., Bidleman, T.F., 1993. Gas exchange of hexachlorocyclohexane in the Great Lakes. *Environ. Sci. Technol.* 27, 1304–1311.
- McConnell, L.L., Kucklick, J.R., Bidleman, T.F., Ivanov, G.P., Chernyak, S.M., 1996. Air-water gas exchange of organochlorine compounds in Lake Baikal, Russia. *Environ. Sci. Technol.* 30, 2975–2983.
- Mo, H.H., Yun, Z.Q., et al., 1984. Distribution, transfer and transport of HCHs and DDTs in sediment of Jiyun River. *Environ. Chem. (Chinese)* 3, 50–57.
- Monirith, I., Ueno, D., et al., 2003. Asia-Pacific mussel watch: Monitoring contamination by persistent organochlorine compounds in coastal waters of Asian countries. *Marine Pollut. Bull.* 46, 281–300.
- Nakata, H., Kawazoe, M., et al., 2002. Organochlorine pesticides and polychlorinated biphenyl residues in foodstuffs and human tissues from China: Status of contamination, historical trend and human dietary exposure. *Arch. Environ. Contam. Toxicol.* 43, 473–480.
- Niu, S., Zhou, Y.M., et al., 1991. Report on determining residues of organochlorine pesticides in vegetables and soils in Shengyang City. *J. Shengyang Agricultural Univ. (Chinese)* 22, 140–144.
- Office for Stockholm Convention Implementation in China, 2004. College of Environmental Science, Peking University. Strategy for phase out of POP pesticides in China.
- Qian, W.C., Gan, W.M., et al. 1986. Residue and distribution of HCH, DDT, and PCP in sediment of Boyang Lake. 7, 41–45.
- Qiu, X.H., Zhu, T., et al., 2004. Organochlorine pesticides in the air around the Taihu Lake, China. *Environ. Sci. Technol.* 138, 1368–1374.
- Qiu, X.H., Zhu, T., et al., 2005. Contribution of Dicofol to the current DDT pollution in China. *Environ. Sci. Technol.* 39, 4385–4390.
- Qiu, Y.W., Zhou, J.L., et al., 2002. Study on polychlorinated biphenyl congeners and organochlorine insecticides in Daya Bay. *Marine Environ. Sci. (Chinese)* 21, 46–51.
- Su, J.W., Cong, Q.M., et al., 2001. Investigation on residue levels of organochlorine pesticides in agricultural products and breast milk in Weihai. *J. Environ. Health (Chinese)* 18, 29–31.
- Tong, Q., Feng, S.Y., et al., 2000. Distribution of organochlorine pesticides on different diametral atmospheric particulate. *Environ. Chem. (Chinese)* 19, 306–312.
- Wang, J.B., Hu, Z.F., et al., 1981. Survey on residues of HCH and DDT in 239 human fat of residents of Tangshan city. *Environ. Sci. (Chinese)* 2, 44–46.

- Wang, J.W., Lu, H., et al., 2003. Investigation on residues of organochlorine pesticides in vegetable gardens in Cixi City, Zhejiang. *Environ. Sci. (Chinese)*(1), 40–41.
- Wang, K.O., Bao, Z.C., et al., 1986. Investigation on the main organic pollutants in a Beijing sewerage river. 5, 43–48.
- Wang, M.Q., Wang, Z.T., et al., 2002. Food contamination monitoring and analysis in 2000 in China. *Chinese J. Food Hyg. (Chinese)* 14, 3–8.
- Wen, X.D. (1990). Wen Xiaodan, First exploration of the relationship between the organic chloride pesticides content and the discharge in the HuaiHe River, *ChongQing Env. Sci. (in Chinese)*, 1990, 12 (5) 24–27.
- Wong, C.K.C., Leung, K.M., et al., 2002. Organochlorine hydrocarbons in human breast milk collected in Hong Kong and Guangzhou. *Arch. Environ. Contam. Toxicol.* 43, 364–372.
- Wu, L.J., Fu, Y.S., et al., 1995. The determined and studied organochlorine pesticides residues in the fine herbage and soil of Hulunbuie grassland. *Environ. Eng. (Chinese)* 13, 53–55.
- Wu, S.P., Cao, J., et al., 2003. Residues and distribution of organochlorine pesticides in airborne particles of different sizes from urban areas. *Res. Environ. Sci. (Chinese)* 16, 36–39.
- Wu, Y., Zhang, J., et al., 1999. Persistent organochlorine residues in sediments from Chinese river/estuary systems. *Environ. Pollut.* 105, 143–150.
- Xiao, B.M., Lin, X.L., et al., 1999. Analysis on residues of organochlorine pesticides from foodstuff in the Northeast China area. *Chinese Primary Health Care (Chinese)* 13, 35–36.
- Xu, D.D., Zhong, W.K., 2002. Studies on the organic chlorine pesticides HCH and DDT in pine needles. *China Environ. Sci. (Chinese)* 22, 481–484.
- Xu, S.F., Jiang, X., et al., 2000. Gas chromatographic method for the determination of organochlorine pesticides in suspended solids and sediments of the Yangtze River. *Acta Sci. Circumstan. (Chinese)* 20, 494–498.
- Yang, J.W., Zhang, N.D., 1987. Primary investigation on concentration of organochlorine pesticides in rainfall. *Environ. Sci. (Chinese)* 8, 64–67.
- Yang, Y., Liu, M., et al., 2002. Distribution of polychlorinated organic compounds in Yangtze estuary and its correlation with TOC and particle size. *Shanghai Environ. Sci. (Chinese)* 21, 530–533.
- Ye, X.R., Yang, H.F., et al., 1991. Study on PCBs, BHC and DDT in waters of Yangtze River and nearby coastal area. *Marine Environ. Sci. (Chinese)* 10, 52–56.
- Yu, H.F., Zhu, Z.Q., et al., 2001. Pollution level of organochlorine pesticides (DDT, HCHs) in human milk of Beijing City, 1998. *China Public Health (Chinese)* 17, 735.
- Yuan, D.X., Yang, D.N., et al., 2001. Status of persistent organic pollutants in the sediments from several estuaries in China. *Environ. Pollut.* 114, 101–111.
- Yuan, X.Y., Wang, Y., et al., 2003. Organochlorine residues of sediments in Taihu Lake and its risk evaluation. *Environ. Sci. (Chinese)* 24, 121–125.
- Yue, Y.D., Hua, R.M., 1990. Residual form and level of BHC and DDT in the agroenvironment of Anhui. *J. Anhui Agricultural Univ. (Chinese)* 17, 194–197.
- Zhang, H.L., Che, H.Y., et al., 2001a. Analysis on residue of organochlorine pesticides in the product base of green food. *Liaoning Prov. Rain Fed Crops (Chinese)* 21, 44–45.
- Zhang, J.Z., Wang, X.F., et al., 2001b. Determination of PCBs and organochlorine pesticides in river Huanghe sediment by gas chromatography. *Shanghai Environ. Sci. (Chinese)* 20, 299–301.
- Zhang, L.C., Dong, W.J., et al., 1982. Chemical and geographic characteristics of HCH in water of Xiangjiang River. 4(5), 8–13.

- Zhang, L.P., Chen, W.Q., et al., 1996a. Concentrations and distribution of HCHs, DDTs, and PCBs in surface sediments of Xiamen Western Bay. *Tropic Oceanol.* (Chinese) 15, 91–95.
- Zhang, P., Hong, H.S., et al., 1994. Concentrations and distribution of organochlorine pesticides and PCBs in sediments of Victoria Harbor, Hong Kong. *J. Xiamen Univ. (Nat. Sci.)* (Chinese) 33, 731–733.
- Zhang, W.L., Zhang, G., et al., 2003. A preliminary study of organochlorine pesticides in water and sediments from two Tibetan lakes. *Geochem.* (Chinese) 32, 363–367.
- Zhang, X.F., Dong, X.L., 2002. Organic chlorinated pesticides in middle and lower reaches of Liaohe. *J. Dalian Inst. Light Ind.* (Chinese) 21, 24–26.
- Zhang, X.F., Quan, X., et al., 2000a. Investigation of polychlorinated organic compounds (PCOCs) in middle and lower reaches of Liaohe River. *China Environ. Sci.* (Chinese) 20, 31–35.
- Zhang, Y., Yang, D.J., et al., 1996b. Analysis on the organochlorine residues level in food in China. *Pesticide Sci. Admin.* (Chinese) 17, 20–23.
- Zhang, Z.C., Dai, S.G., et al., 1998. Enantioselective breakdown of α -HCH and concentrations of α , β , γ , δ -HCH isomers in Xingang Harbour marine water and Haihe River estuary water of Tianjin. *China Environ. Sci.* (Chinese) 18, 197–201.
- Zhang, Z.L., Chen, W.Q., et al., 2001c. Evaluation and fate of the organic chlorine pesticides of the waters in Jiulong River estuary. *Environ. Sci.* (Chinese) 22, 88–92.
- Zhang, Z.L., Hong, H.S., et al., 2000b. The trends and characteristics of organochlorines pollution in surface sediments of Xiamen Western Bay. *Acta Sci. Circumstan.* (Chinese) 20, 731–735.
- Zhang, Z.L., Hong, H.S., et al., 2002. Determination and load of organophosphorus and organochlorine pesticides at water from Jiulong River estuary, China. *Marine Pollut. Bull.* 45, 397–402.
- Zhao, L., Ma, Y.J., 2001a. The effect of organochlorine pesticides on the soil environment. *Soil* (Chinese)(6), 281–283.
- Zhao, L., Ma, Y.J., 2001b. The residue status of organochlorine pesticides in the agricultural environment. *Agricultural Environ. Dev.* (Chinese)(1), 37–39.
- Zhao, Y.F., Lv, J.C., et al., 2002a. Contamination of organochlorine pesticides of the aquaculture sea area in Dalian Bay. *Trans. CSAE* (Chinese) 18, 108–112.
- Zhao, Y.H., Wang, Y.W., et al. 1985. Residue and spatio-temporal variation of HCH in atmospheric rainfall of Shijianzhuang. 6, 33–36.
- Zhao, Y.W., Chen, K., Ma, X.Y., et al., 2002b. A study on the residue of the organochloride pesticide in soil and rice. *Zhejiang J. Prev. Med.* (Chinese) 14, 1–3.
- Zhou, Y.K., Lei, Y.Q., et al., 1995. Monitoring report on residues of HCH and DDT in farm products of Gansu province. *Gansu Agricultural Tech.* (Chinese)(6), 34–35.
- Zhuo, H., Liu, X., et al., 1998. Analysis on BHC and DDT residue in Part of Hainan Export Foods. *Nature Science Journal of Hainan University* 16(2), 128–132.

CITED GOVERNMENT DOCUMENTS

- Drinking water quality standard (GB5749-85), 1985, Ministry of Health, P. R. China.
- Fishing water quality standard (GB11607-89), 1989, State Environmental Protection Administration, P. R. China.

Surface water quality standard (GB3838-2002), 2002, State Environmental Protection Administration, P. R. China.

Soil environment quality standard (GB15618-95), 1995, State Environmental Protection Administration, P. R. China.

Residual standard of HCH and DDT in grain, vegetable and other food (GB2763-81), 1981, Ministry of Health, P. R. China.