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UNSEEN POISONS IN ASIA

A review of persistent organic pollutant levels in South and Southeast Asia and Oceania

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SUMMARY
Persistent organic pollutants (POPs) are a group of chemicals which are very resistant to natural breakdown processes and are therefore extremely stable and long-lived. POPs are not only persistent in the environment but many are also highly toxic and build up (bioaccumulate) in the tissues of animals and humans. Most do not occur in nature but are synthetic chemicals released as a result of anthropogenic activities. Vast amounts of POPs have been released into the environment and due to long-distance transport on air currents, POPs have become widespread pollutants and now represent a global contamination problem. Certain POPs have been responsible for some catastrophic effects in wildlife, ranging from interference with sexual characteristics to dramatic population losses. POPs are suspected of causing a broad range of adverse health impacts in humans and there is evidence that current levels of POPs in women in the general population of some countries is sufficient to cause subtle undesirable effects in their babies due to transfer of these contaminants across the placenta and via breast milk.

In recent decades, numerous POPs have been produced in large quantities worldwide and many are still in production and use. Some POPs, such as dioxins and furans, are not produced intentionally but are generated as by-products of many industrial processes including incineration. A few POPs, notably organochlorine pesticides, have been banned in industrialised countries but due to their persistence, high levels are still found in such countries including parts of Southeast Asia and Oceania. In addition, some of these organochlorines are still being used both legally and illegally in tropical regions of Southeast Asia for agriculture and public health programs to control pests and vector borne diseases. Indeed it was predicted over 20 years ago that there would be a southward shift of DDT use from industrialised countries of the Northern Hemisphere to tropical countries. Studies on levels of DDT in the global environment show that high levels of DDT are now found in terrestrial and marine environments of tropical Southeast Asia. Research on levels of organochlorines in the environment indicates that a southward expansion in the use of chlordane and PCBs into this region has also occurred in recent years. Furthermore, it is predicted that PCB pollution will increase in the tropics as a consequence of inadequate disposal of electrical equipment.

This report draws together published scientific literature on levels of POPs in the environment and in animals and humans of Southeast Asia and Oceania. The data reveals the state of contamination for this region of the globe and gives insight into the fate of POPs in tropical regions. Studies demonstrate that the current release of POPs in tropical Southeast Southeast Asia is not simply a localised problem. High temperatures and heavy rainfall in this region appears to lead to rapid dissipation of POPs to the atmosphere such that POPs released in tropical Southeast Asia add to the global problem of POPs contamination.

WHAT ARE POPs?

POPs encompass many different and varied groups of man-made chemicals. Some POPs have been highlighted by national and international organisations as being chemicals of concern. For instance, the United Nations Environment Program (UNEP) has listed certain POPs, which are organochlorines, as being chemicals of clear concern. Organochlorines are substances containing chemically combined chlorine and carbon. They are a huge group of chemicals that include many POPs. The UNEP list notes 12 organochlorines – known as the dirty dozen. They are the dioxins and furans, (produced as unintentional by-products of combustion and processes involving the manufacture, use and disposal of organochlorines. For instance, they are produced as by products of municipal and medical waste incinerators, open burning, landfill fires and during the production of PVC); PCBs, (industrial chemicals that have been banned but are still released to the environment in significant amounts from old sources and as unintentional by products of combustion and processes involving the manufacture, use and disposal of organochlorines.); HCB (used as a pesticide and in the manufacture of pesticides and produced as an unwanted by-product of various industrial processes involving organochlorines); several organochlorines used as pesticides, - DDT, chlordane, toxaphene, dieldrin, aldrin, endrin, heptachlor and mirex. Use of these organochlorine pesticides is banned or is severely restricted in most countries, but not in all.

POPs included in the above list are of immense concern given that they contaminate the environment and are toxic. Most research on POPs is limited to a few of these chemicals only. There are however numerous other POPs which are also environmental contaminants and are of great concern. These include pentachlorophenol, brominated flame retardants, HCH isomers - such as the organochlorine pesticide lindane, organotin compounds (for example, used as anti-fouling agents for ships), short chained chlorinated paraffins (for example, used in cutting oils and lubricants) and certain phthalates – DBP and DEHP, which are not particularly persistent but are non the less hazardous (main uses as plastic softeners, especially in PVC).

WHERE ARE THEY FOUND?

All environmental media can become contaminated by POPs once they are released into the environment. For instance, spraying pesticides that are POPs on crops can contaminate vegetation and soils, direct discharges from POPs manufacturing facilities may contaminate rivers and releases of POPs from the stacks of incinerators and industrial facilities contaminate air. POPs can therefore contaminate local areas close to where they are released. However, some POPs are volatile/semivolatile and may evaporate from soil or water to air. Subsequently they may be transported for thousands of kilometers on air currents and contaminate regions remote from their source. These POPs migrate on air currents from warmer regions of the globe towards colder polar regions. Once they reach colder temperatures they condense and are deposited again on the Earth’s surface. POPs may also be transported for long distances by rivers, ocean currents and as contaminants in wildlife. Due to the extensive releases of POPs and long distance transport they have become global contaminants.

POPs IN FOOD WEBS

Many POPs which pollute the environment become incorporated into food webs. They accumulate and persist in the fatty tissues of animals and humans because they are soluble in fats and are not easily broken down in the body. Even low environmental levels of POPs can lead to high levels in the body tissues of animals and humans. For many POPs, the levels in fat increase as one animal eats another, so that the highest levels are found in predator animals at the top of food webs, such as polar bears, seals, toothed whales, birds of prey and humans. Marine mammals accumulate particularly high levels of POPs because of their large quantities of fatty blubber and a reduced capacity to break down some POPs compared to other species.

POPs IN SOUTHEAST ASIA AND OCEANIA

THE MARINE ENVIRONMENT

Air and Seawater

Studies were located on levels of certain organochlorines and organotins in air and seawater of Southeast Asia and Oceania. Levels of DDT were found to be higher in tropical Southeast Asia than from seas around Australia and the mid-latitudes of the Northern Hemisphere. This was suggestive of the continued use of DDT in the tropics compared to other regions. Levels of chlordane implicated countries in the Northern Hemisphere as emission sources of this pesticide although results also suggested current sources around tropical

Southeast Asia. PCBs have previously been associated with industrialised countries but the distribution of PCBs in seawater was uniform for the Northern and Southern Hemisphere. This was suggestive of the expansion of PCB usage to the tropics during the 1980s.

Seawater samples taken from around New Zealand, Japan, India, Thailand and Malaya were found to have levels of organotins that were reached levels or were greater than levels which are known to cause deleterious effects in shellfish. Indeed, research shows that adverse effects in shellfish have been reported in countries of Southeast Asia and Oceania.

Fish and Shellfish

DDT was found to be the predominant organochlorine compound in fish from tropical Southeast Asia and levels suggested current inputs of DDT in this region. Other organochlorine compounds were lower in fish from tropical Southeast Asia than more temperate regions. For instance, levels of PCBs in fish were higher for the industrialised countries of Australia and Japan and levels of chlordane and HCB were higher around Australia than other Southeast Asian countries. An exception is for HCH compounds that were highest in fish from around India, indicating the extensive use of HCH in this country.

For organotins, the highest levels in fish were located in Japan where threats to aquatic life from these chemicals is of great concern. Elevated levels were also found for Bangladesh, India and Australia. The main sources of organotins in Southeast Asia and Oceania are likely to be anti-fouling paints on ships, ship-scrapping activities and sewage disposal. Given the toxic effects of organotins on aquatic organisms, it is most worrying that levels of organotins are expected to rise in Southeast Asia in the future.

Marine Mammals

A similar distribution pattern of POPs from tropical Southeast Asia was found in marine mammals as in fish, in that levels of organochlorines were lower in animals from tropical waters than in those from temperate waters. Again, the exception was for DDT which was elevated in tropical marine mammals of Southeast Asia at levels similar to those temperate waters. Even though levels of some organochlorines were somewhat lower in tropical species, the concentrations were considered to be high and of concern with regard to potential toxicity. Marine mammals assessed from seas around Japan, Hong Kong, India and the Philippines fitted into this category. In Australia, lower levels of organochlorines were found in marine mammals than species from Southeast Asia.

As in other aquatic organisms, the highest levels of organotins were evident in marine mammals from coastal waters of Japan. Of other countries in Southeast Asia, the highest levels were found in marine mammals from waters surrounding more industrialised countries.

TERRESTRIAL ENVIRONMENT

Soil

Levels of DDT were particularly high in India and some areas of Vietnam suggesting the continued use of this compound in these countries. By comparison, levels of DDT in Thailand, Indonesia, Malaysia and Taiwan were low. In New Zealand and Australia residues were relatively high which was indicative of the past agricultural use of DDT in Oceania and the persistent nature of DDT in soils. Levels of HCH were found to be very high in India and by comparison levels were lower in Taiwan, Vietnam and Thailand. Little information was available on HCH in Oceania but HCH was reported to be detectable in soils from Australia. Other organochlorine pesticides were also detectable in soils of Southeast Asia and Oceania despite bans on their use. The organochlorine pesticide endosulfan is still being widely used in Southeast Asia. It has been noted that governments of Korea, Thailand and Philippines are encouraging Integrated Pesticide Management Schemes to lessen dependence on pesticides, since studies show their use is often unnecessary.

Levels of PCBs and dioxins and furans were found to be highest in industrialised countries of Southeast Asia including Japan and Taiwan, most likely due to incineration and past pesticide uses. Sporadic high levels of PCBs in Vietnam were found possibly as a result of contamination from old warfare equipment/weapons.

Air and Surface Water
In air and surface waters, levels of DDT and HCH were generally higher in tropical Southeast Asia compared to other regions of Southeast Asia and Oceania. For air, the highest levels of HCH were found in India and Vietnam probably due to use for vector control. Similarly, DDT was elevated in cities in India, Thailand, Vietnam and the Solomon Islands most likely due to its use for vector control. Research suggested the significant use of chlordane in tropical Southeast Asia, particularly in cities in India and Thailand.

Studies of organochlorine compounds in river water revealed the highest levels of DDT were evident in India and Malaysia. Other areas had significantly lower levels although the use of DDT was suggested by findings on DDT levels in Vietnam and the Solomon Islands. Significant levels of HCH were detected in rivers from tropical Southeast Asian countries with notably high levels for India. In Australia, Solomon Islands and Malaysia, results suggested the use of lindane. High residues of chlordane were apparent in rivers of Southeast Asia and Oceania. Similarly, PCBs were found to be uniformly distributed in rivers across Southeast Asia and Oceania which reflects the southward migration of the use of these compounds to less industrialised countries of tropical Southeast Asia.

Sediments
Organochlorines, including DDT and HCH, in sediments of rivers and estuaries were more uniformly distributed across Southeast Asia and Oceania than levels in air and surface waters. This difference has been attributed to the rapid evaporation of organochlorines from water bodies in tropical areas which has the effect of protecting sediments.

Studies on dioxins and furans in river and lakes of Japan, China and Korea reported that the sources of these chemicals appeared to be in part due to past uses of the pentachlorophenol (PCP) in agriculture and the use of PCP for control of schistomiasis in China.

Human Tissues
Levels of DDT in human tissue was highest in Cambodia, India, Thailand and Vietnam reflecting the use of DDT in tropical Southeast Asia. Comparatively low levels were found in Australia and Japan where DDT has been banned for some years. Extremely high levels of HCH were evident in India and China reflecting its widespread use in these countries. Little data was available on other organochlorine pesticides in human tissues. HCB, chlordane and dieldrin were significantly higher in Australia than Thailand and Vietnam. High levels of dieldrin, oxychlordane and heptachlor epoxide in human milk from Australia were associated with its use in homes as a termiticide.

Levels of dioxins and furans in human tissues were higher in more industrialised countries including Japan and New Zealand than tropical Southeast Asian countries. An exception is the south of Vietnam where high levels still persist in human tissues as a consequence of the spraying of Agent Orange, a herbicide contaminated with dioxins and furans, during the war.

CONCLUSIONS

There are large gaps in the scientific data on levels of POPs in the environment of Southeast Asia and Oceania and of the available data, most is restricted to investigating levels of a few organochlorines with little or no data on other POPs such as the brominated flame retardants. Research on levels of dioxins and furans in the marine environment is extremely sparse and data on dioxins and furans in the terrestrial environment are also very limited. This crucial gap in the data needs to be fully characterised and remedied.

Published studies clearly show that POPs contaminate all environmental media of Southeast Asia and Oceania. Notably high levels of organochlorines are evident in some countries of tropical Southeast Asia where some of the compounds are still used. In addition, high levels of organochlorines also persist in the environment of Southeast Asia and Oceania as a result of past uses of these compounds. Marine pollution by organotins was high across the region but exceptionally high around Japan.

POPs which are released in tropical Southeast Asia not only cause local contamination problems but may also contribute to pollution in areas of the world far away from their source. Studies on rivers and sediments indicate that because of high temperatures in the tropics, the residence time of POPs is shorter in water bodies and transfer to the atmosphere is greater. Shorter residence times in tropical waters may be favorable for this aquatic environment but transfer to air has wider implications for the global environment. Semivolatile and persistent POPs such as HCB and HCH appear to be gradually redistributed from tropical point sources to colder regions on a global scale. In the marine environment, it has been suggested that chlordanes and PCBs are likely to disperse to remote oceans through the ocean atmosphere whereas HCHs and DDTs are less transportable through the ocean atmosphere and are rapidly absorbed in the water bodies close to the emission source.

POPs – A Global Problem

The problem of global POPs contamination is set to continue because the majority of POPs from anthropogenic activities are still being released into the environment. Decreases in the levels of POPs which are banned in some countries gives no room for optimism or complacency. Levels of POPs are still high enough to be of concern, and moreover, levels of other POPs which are still widely produced, such as the brominated flame retardants and organotins, add to the already heavy burden of POPs. Because the release of POPs into the environment is continuing, there is a potential for further severe impacts on the health of wildlife and humans. Given the persistent nature of POPs there is only one way forward to safeguard the environment and future generations. This is to phase out the production and use of all POPs, and the processes that lead to the generation of unintentional POPs as by-products internationally and implement clean production technologies. Action must be taken now to address the existing POPs problems, prevent new problems and start on the road to a Toxics Free Future.

GREENPEACE DEMANDS…

- The production and use of all POPs, and human activities that lead to the generation of POPs, must be phased out at an international and, ultimately, at a global level.
- This must be achieved through the substitution of POPs (or the processes and materials which generate them) with non-hazardous alternatives.
- Industry and agriculture must pursue clean production technologies and manufacture clean products, recognising that the only way to prevent releases of POPs into the environment is to avoid their production and use.
- As a matter of urgency, action must be taken to stop production, and eliminate all discharges, emissions and losses of those chemicals prioritised for action by UNEP.
- Presume that all chemicals are hazardous until demonstrated otherwise, i.e. until hazard identification is completed, or in those instances where hazard identification is limited by lack of information, chemicals must be assumed to present hazards of unknown proportions.
- Ultimately, measures to eliminate releases of POPs and other hazardous substances to the environment will need to be taken both at a regional basis and on a global basis, because chemical contamination of the environment is a global problem and chemicals do not respect national boundaries.

1. INTRODUCTION

The building blocks of living organisms are organic compounds – that is chemical compounds that contain carbon and hydrogen (and in some cases other elements as well). These compounds are never indestructible and many break down relatively easily. On the other hand, man has learnt to manufacture organic compounds which are extremely difficult to break down. These chemicals are termed persistent organic pollutants (POPs).

A large number of hazardous chemicals have been, and continue to be, manufactured by the chemical industry both intentionally, as products, and unintentionally, as by-products and wastes. These hazardous substances include numerous POPs. Some of these POPs, notably the dioxins and furans, are also generated unintentionally as by-products of combustion processes.

The production and use of POPs, and the generation of POPs as unintentional by-products has led inevitably to the pollution of the environment with these substances. Because they are not easily degraded by natural processes, many persist in the environment for years. Therefore, even if production and releases of all POPs ceased today, they would continue to pollute the environment for many years to come. Numerous POPs have become very widespread contaminants in the environment because they can be transported for thousands of kilometers on air currents, and in rivers and oceans. As a result of this long-distance transport, some POPs even contaminate remote regions such as the deep oceans, high mountain areas and even the Arctic. Indeed, they may be considered as global pollutants.

In addition to being persistent, many POPs are, by their chemical nature, highly soluble in fats (lipophilic). Consequently they have a tendency to concentrate in the fatty body tissues of living organisms and, over time, can build up (bioaccumulate) to high levels in such tissues. In some cases the levels increase (biomagnify) as one animal consumes another in the food chain so that the highest levels are present in top predator species. Some POPs, such as organotin compounds, accumulate to particularly high levels in the liver and other tissues.

Many POPs are toxic and their long-lives in living tissues may lead to adverse effects on health. Although over time POPs may be metabolized (transformed or broken down) in the body to other compounds (metabolites), some of the metabolites produced are more toxic and persistent than the original chemical. For example, the pesticides heptachlor and chlordane are respectively broken down to heptachlor epoxide and oxychlordane which are more toxic than the original chemicals.

Man-made chemicals occur in the environment and in our bodies not as single entities but as complex mixtures. We are exposed, therefore, not to individual hazardous chemicals, but to many; not to individual POPs, but to diverse mixtures. The significance of such multiple exposure remains poorly understood. Moreover, a substantial proportion of the

chemicals which occur in the environment and to which we may be exposed simply cannot be identified. This further complicates the problem.

1.1 The Chemicals of Concern

POPs may be defined in general terms as persistent organic chemicals, including synthetic substances from a range of chemical groups. A prominent and diverse group of POPs are the organohalogens, i.e. organic compounds of fluorine, chlorine, bromine and iodine. Of the halogens, chlorine has been particularly widely used by the chemical industry, in order to manufacture organochlorine chemicals for use as pesticides, industrial chemicals, solvents, cleaning agents and plastics, particularly PVC. Indeed, PVC is the largest single use of chlorine.

Indeed, all of the 12 POPs so far prioritised for action to reduce or prevent emissions under the United Nations Environment Programme (UNEP) Draft POPs Convention (see Chapter 7) are organochlorine chemicals (UNEP 1995). These chemicals are described in Box 1.1

Environmental and health problems caused by POPs included on the UNEP list have been recognised for some years and, as a consequence, the PCBs and many of the pesticides have been banned or have restricted use in most countries. However, POPs do not respect national boundaries, such that their continued production and use and generation as unintentional by-products in some countries adds to the global burden of these chemicals. In the case of dioxins, still produced unintentionally by many industrial and waste combustion processes as well as open burning, landfill fires and accidental fires in buildings, vehicles and warehouses throughout the globe. In some countries steps have been taken to reduce air emissions of dioxins from point sources, such as incinerators, but releases to air and soil from such facilities continue with little of no abatement. Moreover, few countries have established the material policies needed to address the chlorine-containing materials (e.g. PVC) that are, in effect, the dioxin sources during incineration as well as for diffuse sources, such as open burning and landfill fires.

The 12 UNEP POPs are only part of the problem we face. Many more persistent organic chemicals are still in widespread production and use, in both industrialised and less industrialised countries. A few of these are shown in box 1.2 While the chemical industry continues to manufacture such chemicals to solve day-to-day problems, they may be creating other, long-term or even irreversible problems and compromising the ability of future generations to meet their own needs. They may also be threatening the fundamental processes which support the diversity of life itself.

Box 1.1 POPs listed by UNEP

- Dioxins and furans: Polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are commonly referred to dioxins and furans or collectively as "dioxins." There are 210 individual congeners (chemicals) in the group, although some are more toxic, and some more abundant, than others. 2,3,7,8 - tetrachlorodibenzo-p-dioxin (2,3,7,8 -TCDD) is the most toxic congener, or chemical form, and is now recognised as a human carcinogen. Dioxins are produced as unintentional by-products of many manufacturing and combustion processes that use, produce or dispose of chlorine or chlorine derived chemicals. Important sources of dioxins to the environment include waste incineration, combustion of PVC in landfill fires and open burning, and many organochlorine production processes, including PVC production.

- Polychlorinated Biphenyls (PCBs): PCBs comprise of a group of 209 different congeners. Around half this number have been identified in the environment. The more highly chlorinated PCB congeners are the most persistent and account for the majority of those polluting the environment. PCBs were produced as industrial chemicals that were mainly used for insulation in electrical equipment. Production of PCBs has almost totally ceased worldwide, although there are reports of it continuing in Russia. At least one third of PCBs that have been produced are estimated to have entered the environment (Swedish EPA 1999). The other two thirds remain in old electrical equipment and in waste dumps from where they continue to leach into the environment. Although this is the major source of PCB pollution in the environment today, some PCBs are also produced as by-products of incineration and certain chemical processes involving chlorine such as PVC production.

- Hexachlorobenzene (HCB): This chemical was previously used as a fungicide for seed grain. It is also produced unintentionally as a by-product during the manufacture of chlorinated solvents, other chlorinated compounds, such as vinyl chloride, the building block of PVC, and several pesticides. It is a by-product in waste streams of chlor-alkali plants and wood preserving plants, and in fly ash and flue gas effluents from municipal waste incineration. Its major source today remains the manufacture of pesticides (Foster 1995, ATSDR 1997).

- Organochlorine Pesticides: There are eight pesticides in this category listed by UNEP. These are aldrin, dieldrin, endrin, DDT, chlordane, mirex, toxaphene and heptachlor. The majority of these are banned or restricted in many countries, although not all. For example, DDT is still widely used in developing countries particularly for mosquito control (e.g. Lopez-Carrillo et al. 1996).

Although the greatest attention to date has focused, understandably, on persistent organochlorine chemicals, the general problem of the widespread contamination of the environment with persistent chemicals extends across other chemical groups. In order to ensure protection of the environment, action must be taken to reduce and ultimately prevent emissions of all hazardous substances, particularly those which are persistent and bioaccumulative.

Box 1.2 Other POPs

- Hexachlorocyclohexane isomers (HCH). γ-HCH, or lindane, is an organochlorine pesticide and a component of some shampoos for treatment of headlice. Its use as a pesticide in agriculture has declined in recent years, but it nevertheless continues to be used for this purpose in some countries of Europe (Swedish EPA 1999). Use of technical HCH, a mixture of HCH isomers including alpha-HCH, is yet more restricted. Nevertheless, as a result of some continued releases and its persistence in the environment, alpha-HCH remains widespread in the environment, including the Arctic.

- Brominated flame retardants. These chemicals are widely used as fire retardants in electronic equipment e.g. electronic boards in computers, radios and television sets, in plastics, textiles, building materials, carpets and in vehicles and aircraft. The production and use of some these chemicals is increasing. Brominated flame retardants include polybrominated diphenyl ethers (PBDEs), and polybrominated biphenyls (PBBs), as well as the more recently developed tetrabromobisphenol-A. It is becoming increasingly clear that PBDEs are widely distributed in the global environment and can accumulate in the tissues of humans and wildlife; similar evidence is growing for other brominated flame retardants

- Organotin Compounds: Organotin compounds are used as active ingredients in anti-fouling agents, fungicides, insecticides and bactericides. One of the chemicals in this group, tributyltin (TBT), has been used as an anti-fouling agent in paints for boats and aquaculture nets since the 1960s, although its use is now restricted to large vessels and a global ban is under discussion. TBT is perhaps best know for its hormone disrupting effects in marine invertebrates, although it is also highly toxic to other organisms. It has been described as perhaps the most toxic chemical ever deliberately introduced into natural waters and has become widespread in the marine environment.

- Short Chain Chlorinated Paraffins: These chemicals have for many years been used to produce a range of products, including use as fire retardants and plasticisers in PVC, rubber and other plastics, varnishes, sealants and adhesives, leather treatment chemicals and as extreme pressure additives in lubricants and metal cutting oils (Campbell and McConnell 1980). It should be noted that it is not just the short chained chlorinated paraffins that are problematic but the whole group of chlorinated paraffins.

2. GLOBAL POLLUTION AND TRANSPORT OF POPS

Many POPs have become ubiquitous in the environment and can be detected at considerable levels even in remote regions such as the Arctic and Antarctic (e.g. Bidleman *et al.* 1993, Iwata *et al.* 1993). The contamination of remote regions occurs as a consequence of the long distance transport of POPs on air currents. Once in the atmosphere, POPs may be dispersed and transported across great distances on air currents before they are deposited on the earth's surface again. It is speculated that some POPs move through the atmosphere from warmer regions, where they are emitted, towards colder regions at higher latitudes. The hypothesis that explains how POPs move from warm regions to colder polar areas is known as global distillation or global fractionation. This is because once released to the environment, chemicals appear to become fractionated with latitude according to their volatility as they condense at different temperatures (Wania and Mackay 1993, Wania and Mackay 1996).

POPs are released into the environment, for example, from incinerator stacks to air, as industrial discharges to rivers, as pesticides sprayed onto crops and soil and as losses from a variety of consumer products. Subsequent movement of POPs between air, water, soil or vegetation depends on temperature, and on the physical and chemical properties of POPs. The global distillation hypothesis assumes that warmer temperatures favour evaporation of POPs from the Earth's surface to air, whereas cooler temperatures favour their deposition from air back onto soil, vegetation or water. The overall effect is that POPs volatilize to air in warmer climates and then condense and are deposited again on the Earth's surface in cooler climates. Researchers have suggested that POPs may migrate to the poles in a series of short hops by repeatedly undergoing the cycle of evaporation, transport and deposition (Wania and Mackay 1993). Others have suggested that the process is most likely to occur as a one-step process (Bignert *et al.* 1998). It has been noted that there are uncertainties about how the processes of exchange occur between air and soil/water / vegetation and that more research is needed (Addo *et al.* 1999).

It appears that the more volatile a chemical, the greater tendency it has to remain airborne and the faster and farther it travels on air currents towards remote polar regions. Conversely, chemicals of low volatility are unable to attain high atmospheric levels and are thus deposited close to where they are initially released. Therefore, POPs of higher volatility like α- and γ- HCH may migrate faster towards the poles than those of lower volatility like DDT which tend to remain closer to their source (Wania and Mackay 1993, Wania and Mackay 1996). Observations suggest that certain POPs such as HCBs and HCHs, preferentially deposit in polar latitudes, while DDT and others primarily deposit at lower latitudes (Wania and Mackay 1996). For example, a worldwide study of persistent organochlorines in tree bark found that the relatively volatile compounds HCB was distributed according to latitude, demonstrating a global distillation effect. Conversely, less volatile compounds such as endosulfan were not as effectively distilled and tended to remain in the region of use (Simonich and Hites 1995).

It is thought that POPs in polar regions mainly originate from industrial and other human activities in nearby countries. For example, studies show that sources of POPs pollution in the Arctic are most likely to come from mid-latitudes of the Northern Hemisphere such as Europe, Russia and North America (Barrie *et al.* 1989, Muir *et al.* 1997). However, the tropical countries are also responsible for spreading contamination to the polar regions, because some of these chemicals used in agriculture and public health like HCH, DDT and dieldrin are still consumed in considerable quantities in low latitude areas (Tanabe 1991). It should be noted that most of the global inventory of POPs will be not eventually reach polar regions but will be retained and/or undergo degradation close to their source or en route to polar regions. Nevertheless, levels in polar regions can still be very high.

2.1 Fate of POPs in Tropical Ecosystems

The tropical belt is characterised by high temperature and heavy rainfall. Some POPs such as persistent organochlorine pesticides are still used in tropical countries including some countries in South-Southeast Asia. It is probable that the tropical climate facilitates the rapid dissipation of POPs to air and water from agricultural areas of the tropics. A study in South India was undertaken to investigate the fate of the pesticide HCH in the tropical paddy environment (see Tanabe 1991). Concentrations of HCH isomers were measured in air, water, paddy soil and sediments and were compared to levels in Japan in order to compare the fate of HCH in a tropical and a temperate climate. Results showed that levels of HCH in air and water in India were higher than Japan but levels in soil and sediment were lower in India. Therefore, HCH was dissipated in air and water faster in the tropical climate of India than the temperate climate of Japan. In Japan, HCH was not volatized so rapidly and so became bound up in soil and sediments, thus attaining higher concentrations in these media than in India. The study showed that transfer of chemicals to the atmosphere is much greater in tropical areas. For instance, it was estimated that about 99.6% of HCH applied in the paddy area was removed to air and only 0.4% drained to the nearby estuary over a year. Furthermore, a large proportion of HCH that drained into the estuary was also removed to air and final calculations showed that only 0.1% of the HCH applied to the paddy field ultimately drained to the sea in this area.

A survey of levels of organochlorines in air water and sediments from Southeast Asia and Oceania also indicated that chemicals released in the tropics are dispersed rapidly through air and water and are retained less in sediments. The study showed that ratios of organochlorine concentrations in sediment and water phases were positively correlated with the latitude of sampling. This suggests that persistent, semi-volatile compounds released in the tropics including HCH and HCB tend to be redistributed on a global scale. DDTs, chlordanes and PCBs had a lower tendency of long range transport from the tropics than HCH and HCB (Iwata *et al.* 1994). The implications of using POPs in the tropics are thus not only of concern for the tropical environment but are also for the global environment. It is almost certain that the volatized residues from tropics disperse through the atmosphere in global terms and ultimately deposit into the open ocean environment including Arctic waters. Here, these chemicals may pose a threat to marine organisms, particularly marine mammals (Tanabe 1991).

2.2 Time Trends of POPs Levels in the Global Environment

A wide variety of sample types have been used to monitor levels and trends of organochlorine pollution in the environment. These include sampling of the environmental media air, water, sediments and soils and sampling of tissues of living organisms. A number of studies on the variation of levels of persistent organochlorines in the environment with time have been undertaken. Most have been for the Northern Hemisphere. These studies show the history of contamination in recent decades and can point to possible implications for the future (see Loganthan and Kannan 1994).

In the terrestrial environment, studies on human tissues have shown a decreasing trend of DDT in countries where a ban on the use of these compounds has been imposed since the 1970s. Levels of chlordane and HCH have also decreased. However, available data show that there has been no significant reduction in DDT and HCH levels in human tissues in India since the 1960s and 70s, a country where DDT is still in use. Levels of PCBs in human tissue display a different trend to other organochlorines. No significant decline has been reported in industrialised countries such as Japan and USA despite a ban on use. This implies a continued exposure to PCBs most likely because they continue to leach into the environment from where they are dumped in landfills. Moreover, in less industrialised developing countries such as tropical Southeast Asia, PCBs have also been used in imported electrical equipment and an increase in PCB levels in human tissue is predicted. In addition to human tissue, bird tissue has also been used to trace temporal trends of organochlorines. In industrialised countries of the Northern Hemisphere, a slow reduction in levels of DDT and PCBs have been documented with PCBs declining at the slowest rate. It has been suggested that it is now important to protect birds of the Southern Hemisphere given the continued use of DDT, since there was a decline in several bird populations of the Northern Hemisphere due to the previous usage of DDT in this area. Overall, it can be concluded from temporal trends of persistent organochlorines in humans and birds that reduction in the levels of these chemicals in the terrestrial environment is generally very slow (Loganathan and Kannan 1994).

Research on riverine fish has shown that levels of persistent organochlorines in fish tissue decline quite rapidly subsequent to banning of the compounds. This indicates the rapid clearance of organochlorines from rivers once discharges cease and possibly the short residence time of these chemicals in the water of rivers (Loganathan and Kannan 1994). Fish have a short life span and a low metabolic capacity to degrade organochlorines and consequently they become rapidly contaminated with these chemicals, but the rate of clearance of the chemicals is relatively fast. In contrast, organisms with long life spans and higher metabolic capacities, such as humans, become contaminated more slowly and have a slower clearance rate for persistent organochlorines (Loganathan and Kannan 1991).

The decline of organochlorines in riverine fish has been faster than declines in levels recorded in lake fish, for example, in the Great Lakes in the USA. Slower clearance rates are possibly due to the continuous atmospheric input of chemicals into lakes which originate from tropical areas. In marine fish of the Northern Hemisphere, the decline in

levels has been even slower and for more volatile chemicals such as HCH, a steady state in levels is reported (Loganthan and Kannan 1994).

The residence time of persistent organochlorines in the ocean environment appears to be very long. High levels of organochlorines have been detected in semi-enclosed coastal areas, even in recent years. Such coastal areas receive direct discharges from rivers and industrial/agricultural discharges and they become rapidly contaminated. The removal rate of organochlorines from semi-enclosed seas is slow and this places marine organisms at risk. In contrast to coastal semi-enclosed marine environments, the open ocean is contaminated more slowly by receiving inputs from atmospheric deposition and ocean dumping. Many organochlorines are detectable in coastal and open ocean environments and it is evident that the ocean acts as a sink for such chemicals from anthropogenic activities. A few studies have reported temporal trends of persistent organochlorines in ocean waters and marine organisms. Overall, these studies show that there has been no tendency of decline for organochlorines in the open-ocean environment and it continues to serve as a sink for the semi-volatile compounds used in the tropics such as HCH. It has also been noted that organochlorine concentrations in air above the southern and northern oceans have remained constant in recent years despite bans on their use in Northern Hemisphere countries (Loganthan and Kannan 1994).

Marine mammals residing in the open ocean environment have been shown to exhibit either a slow decline or no decline in levels of persistent organochlorines. Like humans, these animals have a long life span but they are less capable of metabolising such chemicals and have high amounts of fat in which the chemicals are stored. They are also at the top of the food chain. As such, marine mammals are subjected to long-term accumulation of organochlorines and they have very slow clearance rates of these chemicals. This places them at high risk from contamination and potential adverse effects from organochlorines.

Data on temporal trends of organochlorines in the marine environment indicate that marine pollution by these compounds may not decline unless strict regulations are imposed on their use throughout the world. In particular, marine mammals are considered to be at risk from this pollution. In the terrestrial environment, human populations in some less industrialised countries are exposed to high levels of organochlorines from food and air and this has maintained body levels of organochlorines at a steady state. Many less industrialised countries are presently being used as a dumping ground for hazardous pesticides because of having virtually no policy to check the influx of such chemicals. Tropical developing countries of the Southern Hemisphere have therefore become more contaminated in recent years. Despite this, no comprehensive contaminant monitoring programs, including long-term trend and toxicological studies, have been carried out in the Southern Hemisphere countries due to economic and political implications of such studies. It has been recommended that research on organochlorine trends is needed in tropical areas, semi-enclosed seas and in the open ocean environment (Loganthan and Kannan 1994).

3. POPS IN SOUTHEAST ASIA AND OCEANIA

Data on the extent of use of organochlorine pesticides in the global environment is very limited. A project on global uses of organochlorine pesticides has reported that many countries do not keep records on pesticides, whereas in other countries, such information is confidential (Voldner and Li 1995). The study reports that the compounds DDT, technical HCH, lindane and toxaphene are still legally used in several countries, and illegal use in some other countries is suggested. In a number of less industrialised countries, DDT and other organochlorines are recommended by national and international health organisations to control mosquitos, flies and lice which spread malaria, typhus, typhoid fever and cholera (Loganthan and Kannan 1994). The World Health Organisation currently recommends the use of DDT for malarial outbreaks, although public health experts do not uniformly endorse its use. DDT targets adult insects and cannot kill larvae and resistance of insects to DDT has occurred worldwide (Lopez-Carillo *et al.* 1996, Rivero-Rodriquez *et al.* 1997). DDT is used for malarial control in some tropical Southeast Asian countries. In India, DDT is also used in agriculture although it is use in this domain is restricted.

The following report presents levels of POPs in Southeast Asia and Oceania. Several surveys have been carried out on levels of POPs in environmental media and biota of this region. However, considerably less data is available for tropical Southeast Asian countries than industrialised countries such as Japan, USA and Europe. Data on levels of POPs in the environment gives insight into both the persistence of POPs from past uses and into whether such chemicals are still being used.

In this report, figures portraying levels of POPs in environmental media are given from different studies. There are, however, several problems that can hinder comparisons between studies that document the levels of POPs. These problems arise from differences in the scientific methods that are used to measure the concentrations of contaminants. For example, differences between studies may occur in sample collection, storage, preparation, the method used for chemical analysis, mathematical analyses and data interpretation (e.g. Thomas and Colborn 1992). A difference in the sensitivity of an analytical method for instance could affect whether or not a compound is detected. Since a number of differences in the methodologies occur in studies from various countries, results of these studies are not directly comparable. However, in the present report, a comparison of such studies is made because this can at least give an approximate indication of the variation in levels of POPs contaminants between different countries.

3.1 POPs in the Marine Environment

3.1.1 Air and Seawater

A survey of worldwide levels of organochlorines in air and seawater was undertaken in the early 1990s by Iwata et al (1993).

PCBs

Table 1 shows some of the results of levels of PCBs in air and seawater taken from the study by Iwata *et al.* (1993). The data show that levels of PCBs in air were higher in the Northern Hemisphere than the Southern Hemisphere (Iwata *et al.* 1993). On the other hand, levels of PCBs in seawater were more uniformly distributed throughout the Northern and Southern Hemispheres.

A possible explanation of the now uniform distribution of PCBs in the world's oceans, rather than higher concentrations in the Northern Hemisphere, could be the result of usage and disposal of PCBs in tropical countries. About 15% of PCBs have been reported to be held in less industrialised, developing countries whereas the majority were produced and used in industrialised countries of the Northern Hemisphere. It is likely that the current distribution pattern of PCBs in seawater points to a reduction of highly contaminated areas in industrialised countries and the expansion of PCB usage to the tropics during the 1980s.

Table 3.1 Range and Mean Concentration of PCBs in Air (pg/m^3) and Surface Seawater (pg/L) from Various Seas and Oceans

Location of Samples (north to south)	Concentration of Chlordane in Oceanic Air (pg/m^3)	Concentration of Chlordane in Surface Seawater (pg/L)
North Atlantic (n = 4)		
mean	290	26
range	72-600	21-29
Mediterranean (n = 2)		
mean	330	27
range	170-490	24-30
East China Sea (n = 3)		
mean	140	17
range	62-250	14-19
South China Sea (n = 5)		
mean	140	17
range	17-480	9.6-33
Strait of Malacca (n = 1)		
	30	20
Celebes Sea (n = 1)		
	22	20
Java Sea (n = 1)		
	36	22
Bay of Bengal and Arabian Sea (n = 7)		
mean	270	21
range	19-710	13-46
Eastern Indian Ocean (n = 5)		
mean	33	21
range	3.3-110	9.7-42
Southern Ocean (n = 5)		
mean	28	8.3
range	3.7-54	4.6-10

Source: Iwata *et al.* (1993)

DDT

Table 3.1 shows results for DDT levels in air and seawater taken from a global survey by Iwata *et al.* (1993). It revealed that the highest concentrations of DDT are currently found around the region of tropical Southeast Asia. This distribution pattern of DDT is different from that found until the 1980s in which a much higher level of DDT contamination was present in the mid-latitude ocean of the Northern Hemisphere. The change in distribution pattern reflects the ban or restriction of DDT usage in northern industrialised countries and hence lower levels in this region and the increased use of DDT in tropical Southeast Asia (Iwata *et al.* 1993).

Table 3.2 shows that both in air and seawater, the concentrations of DDT were higher in the Bay of Bengal, Arabian Sea, East China Sea and South China Sea compared to other oceans such as the North Atlantic and the Southern ocean. Results for air samples taken from the Java Sea (Indonesia) Celebes Sea (south of the Philippines) and Straits of Malacca (south west of Malaya) were also relatively high. The results imply the continued use of DDT in countries surrounded by these seas. For example, it is well known that DDT is still used in India. The use of DDT in China has also been suggested although its production here officially ceased in 1983. A particularly high level of DDT in air (1000 pg/m3) was found in the Arabian Sea, located off the west coast of India. By contrast, in the Southern Ocean (located around Antarctica) and eastern Indian Ocean (to the west of Australia) levels of DDT were relatively low. In these regions DDT levels were lower than those previously recorded in the early 1980s. This implies that the use of DDT in some countries of the Southern Hemisphere has decreased over the last decade (Iwata *et al.* 1993).

In addition to DDT levels providing insight to emission sources of this chemical, the ratio of DDT its breakdown product DDE can also serve as a guide to emission sources. High ratios of DDT to DDE in air (i.e. mostly DDT) were especially found around the seas and oceans near India and Southeast Southeast Asian countries. This indicates the presence of a significant source of DDT in tropical Southeast Asia now, since only a small amount of DDE is contained in commercial products (Iwata *et al.* 1993).

Table 3.2 Range and Mean Concentration of Total DDT in Air (pg/m^3) and Surface Seawater (pg/L) from Various Seas and Oceans

Location of Samples (north to south)	Concentration of DDT in Oceanic Air (pg/m^3)	Concentration of DDT in Surface Seawater (pg/L)
North Atlantic (n = 4)		
mean	8.7	0.8
range	4.1-17	0.7-0.9
Mediterranean (n = 2)		
mean	18	2.5
range	14-22	2.1-2.8
East China Sea (n = 3)		
mean	19	16
range	2.9-43	1.5-41
South China Sea (n = 5)		
mean	54	6.9
range	7.8-140	3.5-12
Strait of Malacca (n = 1)		
	580	6.4
Celebes Sea (n = 1)		
	37	2.6
Java Sea (n = 1)		
	39	5.6
Bay of Bengal and Arabian Sea (n=7)		
mean	250	10
range	42-1000	1.6-24
Eastern Indian Ocean (n = 5)		
mean	4.8	2.1
range	2.5-8.1	1.3-4.3
Southern Ocean (n = 5)		
mean	2.4	1.0
range	2.1-2.7	0.6-1.5

Source: Iwata *et al.* (1993)

Chlordane

In a global survey of chlordane residues in air and seawater, Iwata *et al.* (1993) noted that levels in air were higher in the Northern Hemisphere (<1.0 - 160 pg/m^3) than in the Southern Hemisphere (<0.5 - 14 pg/m^3). This result suggested that present emission sources of chlordane compounds are likely to be located in the Northern Hemisphere since air pollution generally indicates recent contamination. Levels in seawater were more uniform in the Northern and Southern Hemisphere.

Table 3.3 shows some results of chlordane levels in air and seawater from the survey by Iwata *et al.* (1993). Little was previously known about the distribution of chlordane compounds in the marine environment of the tropics. However, these results reveal that the levels of chlordane compounds in the Bay of Bengal and Arabian Sea off the coasts of India were several times higher than those found in a survey in 1976-77. This suggested

that there has been an increasing use of chlordane in more southerly areas of the globe. The southward expansion of chlordane usage is also supported by considering the ratio of the different chlordane compounds trans-nonachlor to trans-chlordane. The results suggest the continued use of chlordane in the region of South China Sea, Bay of Bengal and Arabian Sea. This implies emission sources of chlordane from southern tropical countries and Japan. Emission sources are also suggested for USA and Europe.

Table 3.3 Range and Mean Concentration of total Chlordane in Air (pg/m^3) and Surface Seawater (pg/L) from Various Seas and Oceans

Location of Samples (north to south)	Concentration of Chlordane in Oceanic Air (pg/m^3)	Concentration of Chlordane in Surface Seawater (pg/L)
North Atlantic (n = 4)		
mean	20	5.5
range	<1.0-43	4.1-8.3
Mediterranean (n = 2)		
mean	18	4.7
range	<1.0-35	5.4-4.0
East China Sea (n = 3)		
mean	35	13
range	7.9-70	3.9-22
South China Sea (n = 5)		
mean	46	12
range	8.1-160	1.9-21
Strait of Malacca (n = 1)		
	20	9.4
Celebes Sea (n = 1)		
	7.9	5.1
Java Sea (n = 1)		
	3.9	2.8
Bay of Bengal and Arabian Sea (n = 7)		
mean	30	9.5
range	<1.0-69	3.4-17
Eastern Indian Ocean (n = 5)		
mean	3.7	7.5
range	0.3-14	2.4-15
Southern Ocean (n = 5)		
mean	2.6	4.2
range	<0.5-5.9	2.4-5.6

Source: Iwata *et al.* (1993)

Organotins

Organotin compounds are used as active ingredients in anti-fouling agents, fungicides, insecticides and bactericides. One of the chemicals in this group, tributyltin (TBT) has been used as an antifouling agent in paints for boats, ships and aquaculture nets since the 1960s. It has been stated that TBT compounds are "probably the most toxic compounds ever deliberately introduced by societies into natural waters" (see King *et al.* 1989). In

the marine environment, TBT has been responsible for causing adverse effects on marine invertebrates, for example, shell thickening and other malformations in oysters and imposex in dog whelks and mud snails. Imposex is a condition in which male sexual characteristics develop in females and may cause infertility. TBT is also toxic to other organisms. Following concerns in recent years about the adverse effects of TBT on some marine organisms, some countries have restricted the use of TBT in anti-fouling paints to large vessels only and banned its use on boats less than 25 metres in length. Despite these limitations, the worldwide annual production of organotin compounds is increasing year by year suggesting that restrictions have not appreciably lessened the consumption of organotins worldwide (Kannan *et al.* 1995).

TBT is not persistent in most natural waters because it is susceptible to natural degradation processes and it absorbs onto particulate matter. It is however considerably more persistent in sediments, having an estimated half-life of 2.5 years (Hashimoto *et al.* 1998b), and in heavily contaminated sediments it becomes even more persistent (de Mora *et al.* 1989, Stewart and de Mora 1990). Levels in sediments are commonly 1000 times greater than levels in overlying waters (Stewart and de Mora 1990).

Scientific literature on levels of organotins in seawater and sediments of Southeast Asia and Oceania are very limited. Studies have been reported for coastal waters of New Zealand, Japan, India and in the Straits of Malacca (located south west of Thailand and Malaya, north east of Sumatera).

A study published in 1989 on levels of TBT in the marine environment of coastal Northland and Auckland, New Zealand, reported levels of TBT in seawater that were comparable to those found in European countries and North America in the late 1980s. The concentrations exceeded TBT levels that are thought to cause adverse effects in shellfish.

A study of levels of organotin compounds in the Port of Osaka, southeast Japan, found that levels in water had fallen between 1989 and 1996 (Harino *et al.* 1999). The decrease in levels most likely reflects the implementation of TBT regulation in 1990 in Japan to restrict its use on small boats. The levels of TBT in this area, and in an area tested in north east Japan, Otsuchi Bay (Harino *et al.* 1998), are nevertheless higher than levels associated with adverse effects in marine invertebrates such as imposex in dogwhelks. A study on organotin levels in Tokyo Bay, Japan, and a busy shipping route, the Strait of Malacca, in 1993 to 1996, found high levels of TBT and other organotins in these areas and somewhat lower levels in the Bay of Bengal (Hashimoto *et al.* 1998b). Results suggested there had been recent inputs of TBT in the Strait of Malacca, most probably from large vessels, and possibly inputs into Tokyo Bay from sewage discharges. The concentration of TBT in these regions was high enough to cause deleterious effects in marine invertebrates.

3.1.2 Marine Mammals

Studies suggest that the world's oceans, and particularly Arctic waters, act as a sink for POPs. Marine mammals are thus subjected to relatively high exposure to POPs because of this phenomenon but also for several other reasons. They accumulate high levels of organochlorines due to of their position in the food chain and because they have a thick layer of fat or blubber in which these chemicals can readily accumulate. In addition, considerable quantities of organochlorines are passed to the nursing young in milk as a consequence of the very high fat content of milk in these animals. Marine mammals are also susceptible to the bioaccumulation of organochlorines because they have a limited metabolic capacity to break them down. The combination of these factors results in very high concentrations of organochlorine residues in marine mammals and creates great concern about the toxicological impact of such chemicals in these animals. The striped dolphin, for example, has been shown to accumulate PCBs and DDT at concentrations about 10 million times those in surrounding water (Tanabe *et al.* 1994a).

Most studies on levels of organochlorines in marine mammals have been conducted in the Northern Hemisphere but a few studies are available for Southeast Asia and Oceania. These are discussed below.

Organochlorines

Time Trends
Two studies have investigated how the levels of organochlorines in marine mammals from Southeast Asian waters vary with time. In the first study, levels of organochlorines were measured in blubber taken from northern fur seals collected off the Pacific coast of northern Japan between 1971 and 1988 (Tanabe *et al.* 1994b). The highest levels of PCBs and DDT were found around 1976 and then declined somewhat through the 1980s. PCBs declined only very slowly and it was suggested that this result implies that there has been a continual input of PCBs into the marine environment. The study suggested that the trends of PCB resides in these animals is likely to reflect contamination on global terms rather than just PCB sources of Japan.

A second study of time trends of organochlorines in marine mammals was carried out on striped dolphins (*Stella coeruleoalba*) between 1978/9 and 1986 from remote water off the Pacific coast of Japan (Loganthan *et al.* 1990). The levels of PCBs and DDT in dolphin blubber remained the same during this time period whereas HCB and HCHs showed a significant decrease. The constant level of PCBs could reflect continued input into the marine environment from distant sources. DDT has been shown to decline in fish and marine animals inhabiting remote regions of the Northwestern hemisphere. The constant level in striped dolphins between 1978/9 and 1986 in this study suggests a continued input of DDT into the marine environment from tropical Pacific countries. It is not known whether the decline in HCH and HCB residues in dolphin blubber was due to a reduced use of these chemicals in the region.

Levels

Levels of organochlorines in 56 male marine mammals (11 different species) collected between 1980 and 1996 from the North Pacific, Indian Ocean and nearby seas has been reported (Prudente *et al.* 1997). The study included marine mammals collected in the Sea of Japan off the west coast of the country, from the Pacific near the east coast of Japan, from the Bay of Bengal off the east coast of India and the Mindanao Sea in the Philippines. Some of the results from this study showing levels of organochlorines in blubber of marine mammals in the Southeast Asian region are given in table 1.

In general the study showed that levels of organochlorines in marine mammals were somewhat higher in temperate waters (e.g. off the coast of Japan) than in tropical waters (e.g. off the coast of India and the Philippines). DDT was an exception to this in that similar levels were found in animals from tropical and temperate waters. The results suggest the continued discharge of chemicals in both the tropical and temperate regions studied.

Concentrations of both DDT and PCB residues found in tropical species were considered to be relatively high. DDT levels in marine mammals from the Bay of Bengal and the Philippines could be due to current usage of DDT in India and use of DDT for malaria control in the Philippines until it was phased out in the early 1990s. Moreover, the even higher levels found in temperate water species indicate that some species might potentially be at high risk from toxicological effects from these chemicals.

Levels of HCH in animals from tropical waters compared to those from temperate waters were lower. This could be due to the atmospheric transport of HCH from the tropics northwards. Levels of PCBs, chlordane and HCB in marine mammals inhabiting tropical waters were somewhat lower than species from mid-latitude temperate regions. The study concluded overall that serious contamination in tropical species of marine mammals by organochlorines by the present discharge of these chemicals in the tropics is reduced because of the rapid dissipation of these chemicals in tropical water bodies. Tragically, temperate and cold-water species appear to receive significant contamination and toxic effects of organochlorines released from the tropics due to long distance atmospheric transport of the chemicals.

A study was carried out on organochlorines in the Indo-Pacific hump backed dolphin and finless porpoise collected from Hong Kong coastal waters between 1993 and 1997 (Minh *et al.* 1999). Results of this study are presented alongside results from the above study (Prudente *et al.* 1997) in table 3.4. DDT concentrations in the animals were comparable to those found in marine mammals in the Southeast Asian region by the Prudente *et al.* (1997). It was suggested that the relatively high levels of DDT in the hump backed dolphin and finless porpoise are related to the usage of DDT in Hong Kong until 1989. In addition, results of the levels of DDE, the major breakdown product of DDT, compared to DDT levels was indicative of recent input of DDTs in the Hong Kong ecosystem. In agreement with the study in Southeast Asian waters by Prudente *et al.* (1997), it was noted in this study that levels of PCBs and DDT in the marine mammals from Hong Kong coastal waters were considered to be high and may present a toxicological risk.

Levels of HCH, chlordane and HCB in the hump-backed dolphin and finless porpoise from Hong Kong waters were also similar to levels found in Southeast Asian waters by Prudente *et al.* (1997).

A review of organochlorine levels in blubber of marine mammals collected from Australian waters throughout the 1980s and early 1990s has been reported (Kemper *et al.* 1994). Levels of organochlorines in Australian marine mammals were markedly lower than marine mammals from Southeast Asian tropical and temperate waters, from South Africa and from northern temperate waters. For example, total DDT in blubber of Australian marine mammals ranged from <0.05 to 28.4 μg/g wet weight which is lower than found in studies in Southeast Asian waters (6.8 to 66 μg/g wet weight). It should however be noted that detailed comparisons of levels of organochlorines are difficult to make between the Australian and Southeast Asian studies because of differences in the laboratory methods employed. Within Australian waters, the highest organochlorine levels were recorded for animals collected from near to Victoria.

A study of levels of organochlorines in Australian seals compared levels in their milk with those found in seal or sea lion milk from the California, the Arctic and Antarctic (Bacon *et al.* 1992). Similar to the review on Australian marine mammals by Kemper *et al.* (1997), this study also reported distinctly lower levels of some organochlorines in the marine mammals from Australia and Antarctica compared to animals from the Northern Hemisphere. For example, levels of DDE were 14 to 118 times lower in Australian/ Antarctic seals and levels of PCBs were also markedly lower.

A study of levels of dioxins (PCDD/Fs) in blubber of Hector's dolphins from coastal waters of New Zealand revealed that these chemicals were present in the animals (Buckland *et al.* 1990). Levels were in agreement with those in arctic ringed seals and, given the limited emission sources of dioxins in New Zealand, it was noted that their presence reflects the spread and accumulation of these chemicals in the global environment. No other studies were located in the scientific literature on levels of dioxins in marine mammals in Southeast Asia and Oceania.

Table 3.4 Range Concentrations (μg/g, wet weight) of organochlorines in the blubber of male marine mammals in Southeast Asia and Oceania

Species	Location	Year	No. of samples	Total PCBs	Total DDT	Total HCH	Total Chlordane	HCB	Reference
Dall's porpoise	Japan Sea	1989	3	22-30	38-66	5.7-7.8	4.9-6.6	0.74-2.1	Prudente et al. 1997
Baird's beaked whale	Wadaura, Chiba, Japan	1985-1989	3	8.0-12	6.8-14	0.03-0.34	0.6-1.3	0.16-0.56	Prudente et al. 1997
Striped dolphin	Off Sanriku, Japan	1992	5	26-49	30-48	0.24-1.7	4.1-6.6	0.12-0.26	Prudente et al. 1997
Melon-headed whale	Miyazaki, Japan	1982	3	51-55	50-65	0.14-0.40	2.1-2.8	0.26-0.38	Prudente et al. 1997

Species	Location	Year	No. of samples	Total PCBs	Total DDT	Total HCH	Total Chlordane	HCB	Reference
Risso's dolphin	Off Taiji, Japan	1991	5	76-130	9.0-52	0.16-0.43	6.2-15	0.14-0.27	Prudente et al. 1997
Fraser's dolphin	Off Taiji, Japan	1991	5	38-76	38-63	0.19-0.30	2.1-4.4	0.11-0.27	Prudente et al. 1997
Fraser's dolphin	Minanao Sea, Philippines	1996	1	7.3	35	0.21	0.71	0.05	Prudente et al. 1997
Spinner dolphin	Minanao Sea, Philippines	1996	2	6.2-9.2	30-55	0.22-0.25	0.75-1.1	0.05-0.06	Prudente et al. 1997
Spinner dolphin	Bay of Bengal, India	1990	3	0.77-2.0	16-33	0.07-0.17	0.07-0.32	0.01-0.02	Prudente et al. 1997
Hump backed dolphin	Bay of Bengal, India	1992	3	4.0-5.0	41-63	0.14-1.5	0.09-0.14	0.01-0.01	Prudente et al. 1997
Hump Backed Dolphin	Hong Kong coast	1993-1996	7	13-50	31-80	0.3-2.2	0.25-5.80	0.013-0.240	Minh et al. 1999

Organotins

A few studies have been published on organotins in marine mammals. Organotins have been found in the tissues of marine mammals from many different regions of the world, illustrating global contamination by these compounds. Studies show they accumulate in muscle, blubber, liver and kidney of whales and dolphins and also in hair and feathers of sea lions and water birds respectively (Kim *et al.* 1996, Iwata *et al.* 1994b). They are lipophilic, as are many organochlorines, but they accumulate to the greatest extent in the liver, hair and feathers, and this has been attributed to their protein-binding capacity (Tanabe 1999). Since they accumulate in marine mammals, these animals, as well as marine invertebrates, are noted as being appropriate indicators of marine contamination by organotins (Tanabe *et al.* 1998). Whales, dolphins and porpoises have been found to accumulate higher levels than sea lions. This appears to be caused by a greater metabolic capacity to degrade organotins in sea lions and their ability to excrete considerable amounts by shedding skin thereby losing organotin accumulated in hair (Kim *et al.* 1996, Tanabe 1999).

A study of levels of organotins in the livers of whales, dolphins and porpoises, collected between 1979 and 1996 from the North Pacific and Southeast Asian coastal waters has been reported (Tanabe *et al.* 1998). Higher levels of organotins were found to occur in coastal species compared to off-shore species. This distribution pattern was also observed in a study of squid from worldwide waters (see section 3.1.3), (Yamada *et al.* 1997). It probably reflects a greater contamination near coastal regions due to man's industrial and maritime activities. Similarly, another study showed that inland and coastal birds from Japan and Korea had higher levels of organotins in liver and kidney than open ocean birds from the North Pacific and south Indian Ocean. This was most likely because inland and coastal birds lived and fed closer to pollution sources (Guruge *et al.* 1997).

The study of organotins in marine mammals (Tanabe *et al.* 1998) showed that the highest levels of organotins were present in animals from Japanese coastal waters. The highest level (10,000 ng/g wet weight or 10 ppm) was found in finless porpoise from the Seto Inland Sea, Japan. Levels in other marine mammals from Japanese waters ranged from 110 to 5200 ng/g. The elevated concentrations of organotins marine mammals from Japan are comparable to the levels found in dolphins along the US Atlantic and Gulf coasts and Italian coastal waters. It is likely that high levels in marine mammals from these countries reflect the heavier use of organotins by industrialised countries. In Japan, the high levels may suggest intensive usage of organotins for shipping and aquaculture activities. Lower levels were found in marine mammals from less industrialised countries. For instance, relatively low levels were found in marine mammals from India (53-200 ng/g) and the Philippines (42-98 ng/g). Somewhat higher levels were found for animals from China (350 to 1200 ng/g) although levels were lower than Japan. The lowest level was found for marine mammals from the Antarctic (Tanabe 1999).

The data available for organotins in marine mammals indicate higher levels in animals from more industrialised countries, such as US, Italy and Japan compared to less industrialised Southeast Asian countries. This difference between countries could indicate significant and continuous inputs of organotins in the coastal waters of the industrialised countries and smaller usage in less industrialised ones. Based on current knowledge, the present contamination by organotins may pose a considerable toxic threat to some coastal species of whales, dolphins and porpoises. Future use of organotins is expected to increase in view of the increasing demand for paints in the Southeast Asia-Pacific (Tanabe 1999, Tanabe *et al.* 1998). Considering the major ecotoxicological threat posed by organotins in the aquatic environment, it is of great concern that input to coastal waters from industrialised nations continues, and that some of the less industrialised countries have no control acts or monitoring systems for usage and subsequent pollution by organotins.

3.1.3 Marine Fish

Organochlorines

Levels of organochlorines in muscle tissue from marine fish collected during 1989 to 1993 in eastern and southern Southeast Asia (India, Thailand, Vietnam, Indonesia, Papua New Guinea, the Solomon Islands and Australia), have been reported in a study by Kannan *et al.* 1995. A study on levels of organochlorines in marine fish from Cambodia has also been reported (Monirith *et al.* 1999). Data from these studies shows that in tropical Southeast Asian countries, DDT was the predominantly identified compound in fish and levels of other organochlorines were low. In general, the levels of organochlorines in fish from tropical Southeast Asia were found to be lower than those in fish of temperate regions. This is different to levels of some organochlorines in air and seawater (section 3.1.1) which are higher in the tropics than the mid-latitudes. On the other hand, the levels in fish were similar to levels found in sediments. The reason that fish from tropical latitudes accumulate lower concentrations of organochlorine compounds than fish from temperate regions may be explained by the shorter residence time of these compounds in the tropical environment. For instance, DDT, HCH,

chlordanes and HCB are likely to rapidly volatize in the tropical environment. Also, higher temperatures in the tropics could enhance the elimination rate of chemicals in fish (due to the influence of temperature on respiratory requirements of the fish), as the biological half-lives of compounds such as DDT are shorter at high temperature.

Studies on shellfish in Southeast Asian countries have found similar distribution patterns of organochlorines to those found in fish. Several studies have been conducted on levels of organochlorines and other contaminants in green mussel (*Perna viridis*), (Prudente *et al.* 1999, Kan-atireklap *et al.* 1997, Ramesh *et al.* 1990). These shellfish have a wide geographical distribution in the Southeast Asia-Pacific region and are grown as a commercially valuable seafood for worldwide markets. Studies on the levels of contaminants in mussels have been conducted to check contamination levels in the interests of public safety. In addition, mussels have also been used as bioindicators to assess the state of marine pollution by toxic contaminants and to understand the fate and effects of contaminants in tropical regions. The International Mussel Watch scheme has used mussels and other shellfish in the Southeast Asia-Pacific region for this purpose (Tanabe 1994c).

PCBs

Table 3.5 shows PCB concentrations in fish from several Southeast Asian countries reported in the study by Kannan *et al.* (1995) and levels in fish from Cambodian waters reported by Monirith *et al.* (1999). Levels in tropical Southeast Asian countries were considered to be low (range 0.38 to 110 ng/g wet weight). Amongst the tropical Southeast Asian countries levels of PCBs in Vietnamese fish were slightly higher. This may be due to the use of PCBs in electrical equipment imported from Australia up to the mid-1980s and possibly from weapons used during the second Indo-Chinese war (1961-71). The lowest levels among Southeast Asian countries were reported for Cambodia (Monirith *et al.* 1999).

In contrast to tropical Southeast Asian countries, levels of PCBs in fish from Australia are high (range 0.22 to 720 ng/g wet weight). The wide range of values indicates that there are specific sites of contamination in Australia. Like Australia, fresh inputs of PCBs around the coasts of New Zealand have also been shown to occur. The high PCB levels in Australian fish are comparable to those found in fish from Japan, another industrialised nation. Given that PCBs are still present in old electrical equipment in Australia it is assumed that continued inputs of PCBs into the environment will continue in the future (Kannan *et al.* 1995).

Table 3.6 shows levels of PCBs in green mussels collected from coastal waters of Thailand, India, the Philippines and Hong Kong. As in tropical fish, levels of PCBs are generally low. Higher levels within countries are associated with industrial areas, for instance, relatively higher levels within the Philippines were found for mussels taken from Manila Bay (Prudente *et al.* 1999).

DDT

In tropical Southeast Asia, limited data suggest that there has been a minor decline of DDT levels in fish in recent years (Kannan *et al.* 1995). Present concentrations of DDT in tropical Southeast Asian fish are currently 1 to 2 orders of magnitude lower than those reported for temperate developed countries at the time of maximum use of this compound. Nevertheless, the currently elevated levels of DDT in tropical Southeast Asian fish (see table 3.5) suggest its continued use in these regions. In Cambodia for example, levels in fish are low compared to other Southeast Asian countries, but even here, elevated levels in one region, Sihanouk Ville, imply recent input to the marine environment (Monirith *et al.* 1999). In Australia, levels of DDT in fish were comparable to, or higher than levels reported from tropical Southeast Asia. Another study from Australia on levels of DDT in fish (bream) from Homebush Bay reported very high levels of DDT (173-634 ng/g wet weight), (Office of Marine Administration, Sydney, Australia 1998). Levels in shellfish were also high. Reportedly, run off from soils contaminated with DDT by extensive use in the past continues to be a major source of this chemical to the aquatic ecosystem of Australia.

Levels of DDT found in green mussels in tropical Southeast Asia (see table 3.6) were within the range of levels found in tropical fish. An exception is Hong Kong where levels found in mussels in 1986 were notably high. It is not known whether such high levels are presently incurred in this region. In Thailand, past studies show that levels of DDT appear to have fallen in recent years and this may reflect the ban on its agricultural use in 1983. Nevertheless, mussel samples taken in 1995 in Thailand had considerable DDT levels in some areas and may indicate significant current sources in these locations due to DDT use for malaria vector control (Kan-atireklap *et al.* 1997). The lowest levels of DDT in green mussels were reported for the Philippines. Here, the use of organochlorines for agricultural purposes was halted in 1977 and usage of DDT for malaria control was phased out in 1992 (Prudente *et al.* (1999).

HCHs

Table 2 shows levels of HCH in fish from Southeast Asian countries given in the study by Kannan *et al.* (1995). The levels of HCH in fish were relatively low in all countries except India. Unlike fish from other Southeast Asian countries, levels of HCH in fish from India even exceeded levels of DDT making HCH the predominant contaminant in Indian fish. The HCH levels in fish from India reflect the continued use of HCH compounds in the country. HCH has however also been used in other Southeast Asian countries at least until the 1980s. The low level of HCH in fish tropical Southeast Asian countries is likely to be due to the rapid valorization of this compound in tropical latitudes.

Levels of different isomers of HCH differed among countries. α-HCH was the predominant isomer in fish from India and Thailand, and B-HCH was predominant in Vietnam, Papua New Guinea and Australia. The predominance of α-HCH in India and Thailand suggests the use of technical grade HCH in these countries. In other countries, Indonesia and the Solomon Islands, fish contained higher amounts of γ-HCH which

suggests the use of lindane in these areas. Indeed, reports have indicated the use of lindane in Indonesia, the Solomon Islands and Vietnam (Kannan *et al.* 1995).

As in tropical fish, levels of HCH in green mussels in tropical Southeast Asian countries (see table 3) were low except for India. In Thailand, g-HCH was the most prevalent HCH isomer in some locations and this may suggest the continuing use of lindane in Thailand (Kan-atireklap *et al.* 1997).

Chlordane

Table 3.5 shows levels of chlordane in Southeast Asian fish reported by Kannan *et al.* (1995). Levels were considered to be low in all countries studied. Similar to HCH compounds, the low accumulation of chlordanes in tropical Southeast Asian countries is likely due to the volatile nature of chlordanes and their subsequent long-distance transport towards colder regions. Interestingly, chlordane has been reported to be the predominant organochlorine pesticide in the aquatic environment in the USA, Japan and New Zealand. Increasing concentrations in Antarctica in recent years suggest that Australia may be an important source of these compounds to the South Pole region. Concentrations of chlordanes in fish collected from Australia were elevated compared to other Southeast Asian countries. Within Australia, levels in fish from several regions of Australia were comparable, except for Sydney where levels were higher, and suggest the widespread use of chlordane in this country (Kannan *et al.* 1995). A study of levels of organochlorines in fish from Homebush Bay, Sydney, Australia found extremely high levels of chlordane in fish (up to 970 ng/g wet weight) but not in mussels (Office of Marine Administration, Sydney, Australia 1998).

In concordance with results on tropical fish, levels of chlordane in green mussels in tropical Southeast Asian countries were low. A study in the Philippines noted that levels of chlordane were higher in mussels near urban locations compared to rural locations. This suggests that chlordane may be used partly against termites in more populated areas, similar to Japan (Prudente *et al.* 1999).

HCB, Aldrin and Dieldrin

Table 3.5 shows levels of dieldrin, aldrin and HCB in fish from Southeast Asian countries. HCB levels are considered to be low in fish from tropical Southeast Asian countries and were somewhat higher in Australia. HCB levels were also considered to be low in green mussels from Thailand (Kan-atireklap *et al.* 1997, Ruangwises *et al.* 1994) and the Philippines (Prudente *et al.* 1999). The presence of HCB in marine fishes may originate from pesticide formulations which contain HCB as an impurity, from incineration of municipal and industrial wastes and from various chlorination processes in which HCB is a by-product. HCB is likely to rapidly volatize in tropical regions and hence, like other semi-volatile chemicals such as DDT and HCHs, be short-lived in tropical waters.

Levels of aldrin and dieldrin in fish from Southeast Asia and Oceania were considered to be low even though these compounds have been used in recent years to control crop pests in India, Pakistan, Thailand, Malaysia, Indonesia and the Philippines and to control

termites in Australia (Kannan *et al.* 1995). However, a study of fish from Homebush Bay, Sydney Australia, found higher levels of dieldrin in fish (124-408 ng/g wet weight), (Office of Marine Administration, Sydney, Australia 1998).A study of levels of organochlorines in benthic (bottom-dwelling) invertebrates from coastal areas of Thailand and Malaysia found that levels of dieldrin were higher in Jeram, Malaysia, than Ao Ban Don and Pattani Bay, Thailand (Everaarts *et al.* 1991). Another study in Thailand found that levels of aldrin (0.2-0.92) and dieldrin (0.08-0.47 ng/g wet weight) in green mussels from the Gulf of Thailand were within the range of levels found in fish from tropical Southeast Asia (Ruangwises *et al.* 1994). These chemicals have been extensively used for termite control in Thailand, aldrin being used in greater amounts than dieldrin. Higher levels of dieldrin than aldrin in green mussels may occur because dieldrin is a persistent breakdown product of aldrin.

PCDD/Fs

Published scientific literature on levels of dioxins in fish from Southeast Asia appear to be very limited. Studies on dioxins in shellfishes taken from seas around Japan and Korea showed that levels from both countries are in the same range, suggesting a similar situation for both countries (Hashimoto *et al.* 1998). For example, levels of total PCDDs and PCDFs in shellfish from Tokyo Bay, Osaka Bay and Kii Channel in 1993 ranged from 25 to 97 pg/g wet weight and levels in oysters from several locations in Korea in 1996/7 ranged from 7.5 to 37.0 pg/g wet weight. Levels of PCDD/Fs for shellfish from Korea were higher in industrial areas compared to rural areas which this could be due to the impact of industrialization. Nevertheless, PCDD/Fs were also present in shellfish from more rural areas which implied that long distance transport of dioxins was also contributing to pollution in these marine animals. Congener profiles suggested that combustion sources, for example incineration, were possibly responsible for the occurrence of PCDD/Fs in the shellfish from both rural and urban areas of Korea. Similarly, a previous study in Japan on dioxins in blue mussels from Osaka Bay in 1987 indicated that municipal incinerators may be the main contaminant source of dioxins in these shellfish (Miyata *et al.* 1987a, 1987b). A study on seaweed collected from the Japanese coast found that dioxins were present in seaweed and the results suggested that combustion was the most likely source of these contaminants (Hashimoto and Morita 1995).

A study on fish from Homebush Bay, Sydney, Australia found levels of TCDD in fish of 41-81 pg/g (Office of Marine Administration, Sydney, Australia 1998). Another study in Australia on mussels from five sites along the Ninety Mile Beach, Victoria in 1992/4 detected PCDD/Fs in these shellfish (Haynes *et al.* 1995). The direct discharge of industrial, domestic and paper mill effluent into the area was not found to affect the levels of dioxins in mussels. It was therefore concluded that the discharge of effluent has negligible impact on the levels of dioxins in mussels.

Table 3.5 Range (in Parentheses) and Mean Concentrations of Organochlorines (ng/g wet weight) in Fish from Tropical Southeast Asia and Oceania[a]

Country	number of samples	PCBs	DDTs	HCHs	Aldrin and Dieldrin	Chlordanes	HCB
Cambodia		0.36 (0.05-1.2)	8.1 (0.51-25)	0.08 (0.01-0.22)		0.11 (0.03-0.04)	0.09 (<0.01-0.32)
India	48	3.5 (0.38-110)	15 (0.86-140)	28 (0.48-380)	3.1 (<0.1-15)	2.4 (<0.01-30)	0.07 (<0.01-0.55)
Thailand	17	1.6 (0.8-2.7)	6.2 (0.48-19)	0.82 (0.22-1.8)	3.7 (0.97-9.6)	2.6 (0.1-15)	0.24 (0.01-2.1)
Vietnam	19	10 (3.1-24)	26 (3.9-76)	1.8 (0.58-4)	0.29 (<0.1-1.1)	0.11 (<0.01-0.35)	0.05 (0.01-0.31)
Indonesia	5	2.6 (2-3.8)	28 (0.66-76)	0.73 (0.06-1.4)	1.2 (<0.1-2.3)	0.45 (0.24-0.69)	0.05 (0.01-0.18)
Papua New Guinea	13	7.5 (0.8-16)	0.43 (0.07-1.4)	0.57 (0.18-1.6)	1.3 (0.1-3.0)	0.37 (<0.01-2.1)	0.03 (<0.01-0.05)
Solomon Islands	10	3.6 (0.66-15)	4.8 (0.91-24)	0.53 (0.23-1.9)	0.32 (0.1-1.6)	0.57 (0.11-1.6)	0.02 (0.01-0.06)
Australia	37	55 (0.22-720)	22 (0.14-230)	0.34 (<0.01-2.1)	10 (0.12-55)	51 (0.06-720)	4.2 (<0.01-60)

[a]: DDT: p,p'-DDT + p,p'_DDE + p,p'-DDD + o,p'DDT. HCHs: α- + β- + γ- + δ- isomers. Chlordanes = *cis*-chlordane + *trans*-chlordane + *cis*-nonachlor + *trans*-nonachlor + oxychlordane.

Source: Kannan *et al.* (1995), Monirith *et al.* 1999

Table 3.6 Concentrations (ng/g wet weight) of Organochlorine Residues in Green Mussels Collected in Tropical Southeast Asian Countries

Location	PCBs	DDTs	Chlordanes	HCHs	HCB	Reference
Hong Kong (1986)	49-330	50-520		53-100		Phillips 1989
Thailand (1994/5)	<0.01-20	1.2-38	0.25-5.9	<0.01-0.33	<0.01-0.12	Kan-atireklap et al. 1997
South India (1988/9)	0.66-7.1	2.8-40		4.3-16		Ramesh et al. 1990
Philippines (1994-1997)	0.69-36	0.19-4.2	0.15-9.5	<0.01-0.19	<0.01-0.04	Prudente et al. 1999

Organotins

A survey of levels of organotins in fish taken in 1990 to 1992 in Southeast Asia and Oceania has been reported (Kannan *et al.* 1995b). The study found that organotins (TBT and other compounds) could be detected in most of the samples tested and this suggested that organotins a were widespread across this area of the world. Detrimental effects of

marine invertebrates have been reported here. For instance, studies in Australia and New Zealand suggested extensive contamination and detrimental effects of TBT on oyster culture in Oceania in the early 1990s (Kannan *et al.* 1995b). Imposex in the oyster borer has also been found. This species is reported to be in decline in New Zealand possibly due to TBT (Stewart *et al.* 1992). A ban on TBT paints for small boats has reportedly been successful in protecting local shellfish industries in Oceania although the need for monitoring in different shellfish and fish species continues. The widespread occurrence of imposex in marine invertebrates has also been recorded in Singapore, Malaysia and Indonesia suggesting the use of TBT in Southeast Asia (see Kannan *et al.* 1995b). A study undertaken on several species of marine invertebrates (gastropods) in the Gulf of Thailand and the Strait of Malacca found a high incidence of imposex (Swennen *et al.* 1997). The occurrence of imposex was related to distance to the main shipping routes linking it with TBT from shipping in the region. The main sources of organotins in Southeast Asia and Oceania are considered to be antifouling paints, intensive ship-scrapping activities in some areas and sewage disposal.

Higher levels of organotins in fish and shellfish from coastal regions compared to open waters have been reported worldwide (Hung *et al.* 1998, Yamada *et al.* 1997). This is assumed to be due to a larger input into coastal waters from industrial sources and boats.

On a global scale, the highest levels of organotins in fish have been found for Japan, the US, Canada (Kannan *et al.* 1995b). A worldwide survey of organotin compounds in squid livers collected in 1991-3 from coastal and open waters reported higher levels were present in the Northern Hemisphere than the Southern Hemisphere (Yamada *et al.* 1997). The highest levels were detected off Japan (17-279 ng/g). By comparison levels were lower in the East China Sea (7-49 ng/g), and in the Indian Ocean off Australia (13 ng/g). There has been concern about the levels of TBT around the coastal waters of Japan regarding its toxicological effects of marine life. Extremely high levels have been detected in the Horseshoe Crab (up to 5000 ng/g wet weight). Levels are 2-10 times higher than those found in marine fish and there is concern that accumulations of organotins in horseshoe crabs may pose a serious risk to their survival (Kannan *et al.* 1995c).

A survey was conducted on organotin levels in fish from Southeast Asia and Oceania by Kannan *et al.* (1995b). Table 3.7 shows results of total butyltin levels in fish muscle from the countries that were studied. The highest levels were found in fish from Australia, Bangladesh and India. Elevated concentrations of organotins in fish from Bangladesh could be related to ship-scrapping activities in the coastal areas. Comparable levels of organotins were observed for Thailand, Indonesia and Taiwan. Concentrations of organotins recorded for Vietnam, Papua New Guinea and the Solomon Islands were relatively low and suggest ship traffic and boating activities are a minimum around these countries. The overall range of organotin levels between countries from Southeast Asia and Oceania is high which suggests the presence of localised sources of contamination. The main sources are likely to be anti-fouling paints, ship-scrapping and sewage disposal. In addition, the World's major ship building industries are located in Southeast Asian countries such as South Korea and Japan and butyltin pollution in waters near the

Southeast Asia-Oceania region may also originate from these activities (Kannan *et al.* 1995b).

Table 3.7 Concentrations of Butyltin residues (ng/g wet weight) in fish muscle from Southeast Asia and Oceania

Country	Total Butyltins*
India	ND-79
Bangladesh	0.47-190
Thailand	2.9-16
Vietnam	ND-1.7
Indonesia	0.41-19
Taiwan	0.49-18
Australia	ND-47
Papua New Guinea	ND-9.0
The Solomon Islands	0.2-1.4

* Total butyltin is the sum of tri-butyltin (TBT) + Mono-butyltin (MBT) + di-butyltin (DBT).
Source: Kannan *et al.* (1995b)

3.2 POPs in the Terrestrial Environment

3.2.1 Soil

Many organochlorine POPs have a high affinity for soils and are retained in this environmental medium. Such POPs may be taken up by plants and by grazing animals and hence reach the human food chain. They may also be washed in run-off from the land into watercourses. In tropical regions characterised by heavy rainfall, soil erosion can be severe and eroded soils end up as sediments in rivers. Contaminated soils may therefore cause significant pollution of waterways in the tropical countries (e.g. Abdullah 1995). There have been few studies on the fate of POPs in agricultural ecosystems, particularly soils (Thao *et al.* 1993). Only a handful of studies have been published on levels of POPs in Southeast Asia and Oceania and these are limited to levels of some organochlorine pesticides, PCBs and PCDD/Fs.

A survey of levels of DDT, HCH and PCBs in cultivated and non-cultivated soils from Vietnam, Thailand and Taiwan has been reported (Thao *et al.* 1993). Similarly, a survey was undertaken on levels of DDT and HCH in three districts of India from 1992 to 1994 (Kumari *et al.* 1996), and on DDT in soils of the Indo-Gangetic plain in 1991/2 (Kulshrestha *et al.* 1996). A few studies have been reported on organochlorines in soil in Australia and new Zealand (see Bodo 1996).

DDT

Table 3.8 gives levels of DDT present in soils in Southeast Asian countries. Levels in Thailand were rather low and similar levels were found at different locations. DDT was banned from agricultural use in Thailand in 1983. The results suggest that small quantities of DDT are used for vector control in places such as urban and suburban areas from where they are dissipated by aerial deposition giving a uniform distribution of DDT

residues across the country. Levels of DDT in soils from Thailand are similar to those from Indonesia (up to 20 ng/g, mean value of 1.2 ng/g) and Malaysia (4.7 to 5.8 ng/g, mean value 5.3 ng/g) in studies undertaken in the 1980s (Thao *et al.* 1993).

Levels of DDT residues in soils from Taiwan were somewhat higher than those found in soils from Thailand. DDT use was prohibited in Taiwan in 1975, but the levels found indicate its previous use in both agricultural and vector control. Levels of DDT in Vietnam and India are high compared to other tropical countries. Levels in Vietnamese soils are similar to levels found in soils of Japan in 1970 (16-1400 ng/g, mean value of 330 ng/g). In paddy field soils from the two countries levels are comparable. In Vietnam, most of the samples taken in agricultural areas revealed relatively low DDT levels but very high levels were found in a few samples. This suggests the sporadic use of DDT for agricultural purposes or sampling at locations close to where DDT was used for vector control. It is likely that DDT was heavily used in Vietnam during the late 1970s and early 1980s and levels found in soil in the early 1990s suggest its continued use (Thao *et al.* 1993).

In India, DDT continues to be used for vector control but was banned from agricultural use in 1993. Levels of DDT and the isomers of DDT found in rice growing areas and rainfed areas of Rohtak in Haryana, northern India, reflected its use up until the early 1990s. These levels are not expected to rise in the future because of restrictions on agricultural use (Kumari *et al.* 1996). In the area of the Indo-Gangetic Plain, northern India, levels of DDT were high due to past agricultural uses on crops and sanitation campaigns in which mud houses in villages, drains and potholes are regularly sprayed during the rainy season. It was noted that some farmers still use DDT for crops despite the ban because of its low cost and effectiveness (Kulshrestha *et al.* 1996). In addition to these studies from northern India which show that soil is contaminated by DDT, the contamination of soils with DDT in southern India has also been shown to be widespread (see Bodo 1996). Cotton fields were shown to have the most heavily contaminated soils followed by tea, fruit and vegetables. Contamination of rice fields was low by comparison.

Studies undertaken in Oceania show that DDT residues are still present in soils despite a ban on its use. In New South Wales soils, Australia, DDT was still prevalent in soils of fruit and vegetable growing areas (see Bodo 1996). On South Island, New Zealand studies on an agricultural experimental station between 1950 and 1970 showed significant levels of DDT remained in soil. In 1990, levels were still very high (about 1000 to 2000 ng/g). The levels have decreased since 1965 (2600-6400 ng/g). The high levels of DDT in New Zealand reflect its past use from 1947 to 1970 when DDT was extensively applied to pastures to control grass grub damage.

HCH

Data presented in table 3.8 shows that soil is contaminated at relatively low levels in Thailand, Taiwan and Vietnam compared to India where levels are very high. In Thailand, low concentrations of HCH in soil reflect the fact that production and importation of HCH were banned in 1980. Levels of HCH in Taiwan and Vietnam reflect

its former use in agriculture and for public health purposes. In Vietnam, levels of individual isomers of HCH in samples suggest the previous use of technical grade HCH and in some areas the use of lindane (γ-HCH) probably for vector control. In India the use of HCH in agriculture has been restricted since 1993 but not banned. Levels found in studies in northern India (Kulshrestha *et al.* 1996, Kumari *et al.* 1996) are very high and comparable levels have also been found in soils from south India (Ramesh *et al.* 1991).

Very little information on HCH residues in soils of Oceania was found in the scientific literature. In Australia, the presence of HCH residues were detected in pasture, sugar cane and banana plantation soils (see Bodo 1996).

Table 3.8 Concentrations (ng/g dry weight) of total DDT and total HCH in Soils from Southeast Asia

Location	Total DDT	Total HCH	Reference
India (3 sites in Hayana, northern India)	up to mean value of 45	up to mean value of 134	Kumari et al. 1996
India (River Ganga plain, northern India)	range of mean values 27 - 337	range of mean values 14 - 158	Kulshrestha et al. 1996
Taiwan	range 2.4 – 78	range 0.09 – 55	Thao et al. 1993
Thailand	range 0.61-98	range 0.07-1.6	Thao et al. 1993
Vietnam	range 0.73-1300	range 0.33-4.8	Thao et al. 1993

Other Pesticides

The use of pesticides is reported to be increasing in several Southeast Asian countries including Thailand (Tonmanee and Kanchanakool 1999, Tayaputch 1996), the Philippines (Heong *et al.* 1994) and Malaysia (Abdullah 1995). Many persistent organochlorine pesticides have been banned in these countries but reportedly, endosulfan continues to be used in Thailand and the Philippines (Tayaputch 1996, Heong *et al.* 1994), and the residues of banned organochlorine pesticides can still be detected in Southeast Asian soils. Research has shown that pesticide use does not necessarily increase yields and in many cases may be unnecessary (e.g. Heong *et al.* 1994). Governments in several Southeast Asian countries have opted to lessen the dependence of pesticides by starting to encourage sustainable agricultural practices and implement Integrated Pest Management (IPM) programmes. This has been reported to be occurring in Korea (Kim 1999), Thailand (Tayaputch 1996) and the Philippines (Bajet and Tejada 1995).

In Australia, residues of formerly used organochlorine pesticides can be found in soil. For example, heptachlor in land used for dairy and crop rotations and dieldrin in sugar cane and banana soils. Results of a study on the decay of heptachlor, *trans*-chlordane and dieldrin suggest that such pesticides will continue to contaminate soil and surface waters for some years because levels decline only slowly (see Bodo 1996).

PCBs and PCDD/Fs

Higher levels of PCBs and PCDD/Fs would be expected in industrialised countries and areas compared non-industrialised countries and rural regions. A survey of PCBs in soils

in Southeast Asia reported levels for Thailand (1.1-6.2 ng/g), Vietnam (0.61-320ng/g) and Taiwan (1.6 to 960 ng/g), (Thao *et al.* 1993). Levels in Thailand were notably low most probably because the sampling areas used were not industrialised. In Vietnamese soils, the majority of samples were at levels of <40 ng/g, with the higher levels being in industrialised areas. One sample showing very high concentrations of PCBs was not near to industrialised facilities. Possible reasons for this high level could be due to PCB contamination of herbicides that were sprayed during the war by the USA or due to contamination from warfare equipment/weapons some of which were connected with the usage and disposal of PCBs. In Taiwan, levels of PCBs were higher than in Vietnam, the majority of samples being <100 ng/g. The highest levels were found in industrialised areas. Levels were comparable to those from the USA and Canada during the early period of the 1970s and similar to those found presently in Japan.

In China, elevated levels of PCBs (7.1 ng/g) and PCDD/Fs (18.1-34.3 ng/kg) were reported to occur in soils of the Ya-er lake area (Wu *et al.* 1997). The presence of these contaminants in the area was attributed to production of pentachlorophenol (PCP). PCP use is banned in many industrialised countries but China produces about 5000 tons of PCP annually for application in the prevention of blood fluke and as a wood preservative for making sleepers for railways. A study of PCDD/Fs in soil from two regions of Japan found elevated levels of PCDD/Fs in Tokyo, an industrialised city (1608 pg/g), and in paddy field soils of lake Kasumigaura (2071 pg/g), (Sakurai *et al.* 1996). Levels of PCDD/Fs in paddy field soils are suspected to arise from impurities contained in a pesticide, CNP, and possibly also from pollution from incinerators. Another study near to Fukuoka City, Japan found soils contaminated with PCBs and PCDD/Fs in paddy fields (PCDD/Fs 103,000 pg/g) and this was attributed to a nearby municipal waste incinerator (Ohsaki *et al.* 1995). A study in New Zealand found generally very low levels of PCDD/Fs (13.1 – 372 pg/g) in agricultural soils except for one sample in which the high level was attributed to past herbicide uses (Buckland *et al.* 1998). Levels in urban soils were higher (50.6 – 2850 pg/g), but it was noted that the levels in New Zealand soils were markedly lower than levels in other industrialised countries.

3.2.2 Air

Levels of persistent organochlorines in air in Southeast Asia and Oceania were measured in a study by Iwata *et al.* (1994). Table 3.9 shows the results of this study. Concentrations of DDT and HCH were found to be higher in the lower latitudes around the tropics than in higher latitudes. For HCH, some samples in India and Vietnam were very high whereas levels in Thailand, Solomon Islands, Japan, Taiwan and Australia were lower and more comparable. Another study also found high levels in Delhi, India (up to 21.797 x 10^3 pg/m^3) in 1980 to 1982 (Kaushik *et al.* 1987). The highest levels were detected from August to December and it is likely that this is due to HCH use in mosquito control programmes in the preceding three months. Iwata *et al.* (1994) noted that high HCH concentrations measured in Calcutta, India, suggested the prevalence of mosquito control programmes in urban areas of the tropics. For DDT, Iwata et al (1994) reported that higher levels were apparent in some cities in India, Thailand, Vietnam and the Solomon Islands than Japan, Australia, USA and some European countries. High levels of DDT (4 to 232000 pg/m3) were also reported in Delhi, India by Kaushik *et al.* (1987). It was

noted that such high levels may originate both from mosquito control programmes and from a DDT factory in the city.

Concentrations of chlordane in air varied between cities in tropical Southeast Asia. Particularly high concentrations were found in some urban areas in the tropics including Goa, Bombay, Calcutta in India and Bangkok, Thailand. Levels in other countries were similar or lower levels than levels in Japan and Australia. Iwata *et al.* (1994) noted that levels of chlordane found in urban air in tropical Southeast Asia were considerably higher than levels in open ocean air from the region. This strongly suggests the significant usage of chlordane in the tropics.

The study by Iwata *et al.* (1994) revealed that there was a wide variation in the levels of PCBs in air between different locations in Southeast Asia and Oceania (74 to 4600 pg/m3), although comparable levels were observed over the whole region. High concentrations in some areas indicated that there are sporadic emission sources of PCBs in the tropics and other regions. A recent study was carried out on PCB levels in air near to a site used to store capacitors in a suburb of Bangkok, Thailand (Watanabe *et al.* (1996). The study detected PCB concentrations of 35 to 1400 ng/m3. This is far higher than levels found in the city air in Bangkok (3.5 ng/m3), (Iwata *et al.* 1994). It was estimated that about one quarter of the atmospheric contamination was due to the stored capacitors and the remainder was due to PCBs which had leaked into soils and subsequently volatized. Significant valorization was attributable to high temperatures typical of the tropics. It was suggested that the study findings called for pertinent measures to control the indiscriminate usage and dumping of PCBs in capacitor storage sites in Bangkok. It was also noted that equipment containing PCBs dumped improperly in the tropics leads to large and rapid dispersal of PCBs into the atmosphere and consequently contributes to global contamination (Watanbe *et al.* 1996).
PBDE's were reported to be present in air samples taken near metal recycling plants in Japan and Taiwan (see de Wit 1999). However, no other data were located on PBDEs in other countries of Southeast Asia and Oceania.

Table 3.9 Concentrations (pg/m^3) of organochlorines in air from Southeast Asia and Oceania

Location	Remarks	Total HCH	Total DDT	Total Chlordane	PCB
INDIA					
Ranjit Hotel, Maharaja Ranjit Singh Road, Delhi	urban area	89	20	5.7	74
C.A.S., Porto Novo, Tamil Nadu	paddy field	1800	8.0	26	190
Habibulla Road, Madras	urban area	340	52	15	2200
Woodland Hotel, No.5 Sampangi Tank Road, Bangalore	urban area	13	270	20	1700
Hotel Golden Goa, Panaji, Goa	sub-urban area	65,000	7400	20,000	2300
Citizen Hotel, Juhu Beach, Bombay	urban area	23,000	1700	5800	4600
Great Eastern Hotel, Old Court house Street, Calcutta	urban area	11 x 10 (6)	4100	2700	420

Location	Remarks	Total HCH	Total DDT	Total Chlordane	PCB
THAILAND					
Ayutthaya	rural area	390	20	45	-
Si Racha	rural area	280	20	27	-
Minburi	rural area	340	2200	190	-
Sol Phiboonwattana, Rama VI Rd, Bangkok	urban area	120	460	2500	3500
VIETNAM					
Thong Nhat Hotel, Quan Hoan Kiem, Hanoi	urban area	1800	710	66	710
Huong Giang Hotel, Hue	Sub-urban area	12 x 10 (6)	880	340	800
Cuu Long Hotel, Ton Duc Thang, Ho Chi Minh	urban area	220	-	31	830
SOLOMON ISLANDS					
Panatina, Honiara, Guadalcanal	suburban area	260	920	250	2300
JAPAN					
Osaka Bay, Osaka	urban area	190	<2.0	330	700
TAIWAN					
Ming-fu Hotel, Taipei	urban area	470	81	270	6900
AUSTRALIA					
Victoria Hotel, Melbourne, Victoria	urban area	380	13	130	8000
Department of Lands Parks and Wildlife, Hobart, Tasmania	sub-urban area	450	5.5	30	4700
Fisheries Research Institute, Cronulla, NSW	sub-urban area	350	5.0	390	3900
Marine Research Laboratories, Perth, WA	beach	900	14	650	17,000

Source: Iwata *et al.* (1994)

3.2.3 Surface Waters

A survey of concentrations of organochlorines in surface waters in 1989 to 1991 was carried out in several countries from Southeast Asia and Oceania (Iwata *et al.* 1994). Results of levels of organochlorines in river water from this survey are presented in table 3.10. Results of concentrations in river water from other studies undertaken on rivers in Southeast Asia and Oceania are also given in table 3.10. Although results between the different studies are not directly comparable because of differences between laboratories and analytical methods, the data do provide an approximate indication of concentrations of organochlorines in surface waters from different countries.

In general, levels of DDT and HCH in river water were higher in the tropics than countries in the mid-latitudes. This pattern was also seen in levels of these chemicals in air in Southeast Asia and Oceania (section 3.3.2).

DDT

In a survey of DDT concentrations in river water in Southeast Asia and Oceania, Iwata *et al.* (1994) detected the highest concentration of DDT (120ng/l) in river water for Delhi,

India. Other studies have also found very high levels of DDT in India, for example in the Ganges river as shown in table 3.10 (Nayak *et al.* 1995, Agnihotri *et al.* 1994). High levels of DDT were also detected in Malaysian rivers (up to 190 ng/l), (Tan and Vijayletc 1994) and in one river from the Solomon Islands (21 ng/l), (Iwata *et al.* 1994). In Thailand, Indonesia, Taiwan and Australia levels were significantly lower.

A review of studies on DDT contamination in surface waters in India showed that research was lacking on organochlorines in surface waters from the south of India. It reported that studies in the north of India indicated that the highest levels are generally observed in the Ganges basin (Bodo 1996). In particular research has shown high concentrations in the Ganges at Farrukhabad, an area of intensive agricultural activity, where run-off from fields may contribute to elevated levels (Agnihotri *et al.* 1994). Concentrations recorded at Varanasi were highly variable but included some samples with notably high levels. It was suggested that the use of DDT in public health activities may be responsible for the high levels (Nayak *et al.* 1995). Very high levels of DDT (80-49,700ng/l) were reported in lakes in the Jaipur area south of Delhi, Rajasthan state in 1985-87 (see Bodo 1996). Similarly, a study of 5 lakes in a remote region at the southern extremity of lesser Himalayan zone in the Kumaun region of Uttar Pradesh, reported high levels of DDT (mean values 6054-31,336 ng/l), (Dua *et al.* (1998). It was suggested that high contamination of the lakes resulted from illegal uses of DDT in agriculture in the surrounding region. It was also noted that the lakes were the only source of water for drinking and domestic use and that levels exceeded WHO maximum permissible limits of DDT (1000ng/l) for drinking water. A study of water contamination in rural ponds of Uttar Pradesh state, northern India, reported high levels of DDT in ponds (mean values 620-4480 ng/l), (Dua *et al.* 1996). The study noted that such rural ponds are the major water source for animals, agriculture and other domestic uses.

Table 3.10 shows that levels of DDT in were high in some rivers of Peninsular Malaysia. Levels in four out of twenty-five rivers studied were particularly high and exceeded 100 ng/l (Tan and Vijayelchumy 1994). The study suggested that higher levels were present in rivers that flowed through major rice-growing areas in the west and levels were lower in rivers near the east coast. It is possible that such high levels are due to the previous widespread use of DDT for a malaria eradication programme in these regions. However, in a review of POPs in Southeast Asian surface waters, Bodo (1996) noted that the differences in concentrations of DDT between east and west rivers may be artifacts of the sampling methods used in the study because sampling failed to adequately represent annual usage cycles of pesticides. Not all isomers of DDT were measured in the study and Bodo (1996) estimates that if they had been measured the total DDT concentrations would be approximately double those given. The ratio of the p,p'-DDT isomer to p,p'-DDE which were measured in the study gave a result which suggested there were fresh inputs of DDT to Malaysian rivers.

Relatively high levels of DDT were detected in the Solomon Islands and Vietnam. In Vietnam data came from DDT concentrations measured in a paddy field, mangroves and urban canals but not in river waters (Iwata *et al.* 1994). In the Solomon Islands levels of

3.5-21 ng/l were found in both an agricultural area and residential areas indicating the extensive use of DDT for agriculture and public health.

Lower levels of DDT (mainly <1 ng/l) were detected in rivers from Thailand, Indonesia, Taiwan and Australia (Iwata *et al.* 1994). Sampling for Taiwan was very limited and it is not known whether it is representative of other regions in the country. Another study in Thailand suggested that DDT levels have declined since restrictions were imposed in 1988 (see Bodo 1996). Only very limited data were available for Japan where levels of DDT in the Yodo river (2.3-3.3 ng/l) and Lake Biwa (9ng/l) were moderate (Bodo 1996).

HCH

In a survey of levels of organochlorines in rivers from Southeast Asia and Oceania, Iwata *et al.* (1994) found the highest levels of HCH were apparent in Delhi India (see table 3.10). High levels were also detected in other surface waters of Bombay, Madras and Calcutta and it was noted that Indian pesticide manufacturing firms have all been producing large quantities of HCHs in these cities. A review of studies on organochlorines in surface waters in India indicated that data shows that HCH is widely used across India (Bodo 1996). Sites in the Ganges watershed, including Farrukhabad, Varanasi and Jaipur lakes, appear to be most highly contaminated although this may simply be an artifact of sampling data because of more extensive sampling in these regions. Even remote areas have been found to be contaminated, for example, in an upland area, Naintal, Uttar Pradesh, a survey of 5 lakes found high contamination of HCHs (up to mean 4831 ng/l) and suggested local agriculture may contribute to the high levels (Dua *et al.* 1998). A study of rural ponds in Uttar Pradesh state also reported high levels of HCH (mean of 13 ponds 2940 ng/l), (Dua *et al.* 1996). In South India, high levels of HCH were detected in the Periyar River (up to 1125ng/l), (see Bodo 1996), and Vellar river (530 ng/l), (Iwata *et al.* 1994).

High levels of HCH were also detected in rivers from Malaysia (Tan and Vijayaletchumy 1994). Table 3.10 shows that significant concentrations were also found in some rivers/lakes from Thailand, Vietnam and the Solomon Islands. A study in Thailand suggested that HCH has declined in the Chao Phraya river since restrictions were imposed in 1988 (see Bodo 1996). Iwata *et al.* (1994) have commented on the proportions of different HCH isomers for the locations studied. Higher proportions of the α-isomer were recorded for Thailand, Vietnam, Indonesia, Taiwan and Japan which implies the usage of technical grade HCH. On the other hand, the γ-isomer predominated in Malaysia, Solomon Islands and Australia, where the usage of lindane might still be expected.

PCBs

PCBs were not widely different in surface waters of countries assessed by Iwata *et al.* (1994) in Southeast Asia and Oceania (see table 3.10). The distribution of PCBs was also found to be quite uniform in oceanic air and seawater (see section 3.1.1). Industrialised countries such as Japan have been major point sources of PCBs and there was a highly contaminated belt of PCBs in the mid latitude of the northern hemisphere until the beginning of the 1980s. The present distribution of PCBs across tropical Southeast Asia

suggests there has been a southward expansion of PCB usage due to the exportation of these chemicals from the mid-latitudes. For instance, some tropical countries such as Vietnam, have imported transformers and capacitors containing PCBs from industrialised nations. Subsequent disposal of this equipment on landfills would result in contamination of tropical air and water (Iwata *et al.* 1994).

Other POPs

Iwata *et al.* (1994) observed that chlordane concentrations fairly uniform in rivers from several Southeast Asian countries and Australia (see table 3.10). Originally, chlordane was primarily used in mid-latitude countries of the northern hemisphere, including Japan. However, the present distribution of chlordane across tropical countries indicates there has been export of chlordane from mid-latitude countries to lower latitude nations. High residues of chlordanes in Southeast Asia and Australia may be due to their application as termiticides. A study in the vicinity of Saga city in Japan reported levels of chlordane in river water from <0.2 ng/l up to 9 ng/l in 1987/88 (Hirai and Tomokuni 1989). Chlordane was used as a termiticide in Japan up to 1986 when it was banned.

There are only a limited number of studies which have analysed levels of aldrin and dieldrin in rivers from Southeast Asia and Oceania. A study in Thailand reported that aldrin and dieldrin had high frequencies of occurrence in water samples taken from different locations along the Chao Phraya river in Thailand (Boonyatumanond *et al.* 1997). Concentrations of aldrin (3.6-5.0 ng/l) and dieldrin (1.1-7.7 ng/l) were reported. In India, aldrin (nd-99 ng/l) and dieldrin (nd-49 ng/l) were detected in the river Ganges at Farrukhabad (Agnihotri *et al.* 1994). In Australia, dieldrin was found to be widespread in the Ovens and King rivers, Northeast Australia with levels up to 1.21 ng/l (McKenzie-Smith *et al.* 1994). This reflected previous widespread use of dieldrin in the areas studied.

Endosulfan is an organochlorine pesticide that is still used in many countries. Data on levels of endosulfan in surface waters of Southeast Asia and Oceania are sparse. The presence of this pesticide in river water was reported for the Ganges river at Farrukhabad, India at levels up to 232 ng/l (Agnihotri *et al.* 1994), and at Varanasi (83-66,516 ng/l), (Nayak *et al.* 1995). In a study of 25 rivers in Peninsular Malaysia, endosulfan was detected in 17 rivers (0.4 to 310 ng/l). Residues were higher in rice-growing areas. It is still a widely used pesticide in the paddy fields of Malaysia.

Data on organotin pollution of surface waters is very limited. One study of the Ganga Plain in the Kanpur-Unnao industrial region in northern India reported organotin contamination in waters of the Pandu river, Ganges River and Ganda Nala (Ansari *et al.* 1998). High concentrations of organotins were related to discharges of industrial wastes in this region. Various organotins were found including TBT.

PBDEs were reported to be detectable in Japanese rivers (see de Wit 1999). Research on PBDEs in the environment has only begun to be generated more recently and no other studies on PBDE's in surface waters of Southeast Asia and Oceania were located.

Table 3.10 Concentrations (pg/L) of organochlorines in river water from Southeast Asia and Oceania

Location	Remarks	HCH	DDT	Chlordane	PCB	Reference
INDIA						
Yamuna River, Delhi	urban area	660,000	120,000	<8.0	41,000	Iwata et al. 1994
Vellar River, Porto Novo, Tamil Nadu	paddy field	530,000	870	<8.0	1500	ibid.
Cooum River, South Beach Road Bridge, Madras	urban area	250,000	1600	1000	48,000	ibid.
Ulsoor Lake, Bangalore	urban area	13,000	3100	540	2600	ibid.
Mandovi River Tributary, Panaji, Goa	sub-urban area	18,000	1100	35	450	ibid.
Hooghly River, Babu Ghat, Calcutta	urban area	6200	1500	180	340	ibid.
River Ganges, Varanasi		105,000-99,000,000	135,000-143,000,000			ibid.
River Ganges, near Farrukhabad	intensive agricultural area	22,000-1,119,000	nd-832,000			ibid.
THAILAND						
Chao Phraya River, Ayutthaya	paddy field	75,000	340	210	<240	ibid.
Chao Phraya River, Chao Saming Prai Pier, Bangkok	urban area	-	310	440	580	ibid.
Chao Phraya River Estuary, Bangkok	urban area	180	230	180	450	ibid.
VIETNAM						
Phuloc Lake, Phu Da, Thua Thien	paddy field	18,000	290	210	1200	ibid.
MALAYSIA						
River Sg.Perlis		30,000	33,000			Tan and Vijayletchumy (1994)
River Sg.Kedah		50,000	42,000			ibid.
River Sg.Merbok		32,000	35,000			ibid.
River Sg. Muda		60,000	69,000			ibid.
River Sg. Perai		65,000	48,000			ibid.
River Sg. Jura		54,000	52,000			ibid.
River Sg. Perak		9400	25,000			ibid.
River Sg. Bernam		320,000	190,000			ibid.
River Sg. Selangor		280,000	110,000			ibid.
River Sg. Klang		1100	9500			ibid.
River Sg. Linggi		2700	7800			ibid.
River Sg. Melaka		3900	74,000			ibid.
River Sg. Muar		nd	122,000			ibid.
River Sg. Batu Pahat		nd	100,000			ibid.
River Sg. Tebrau		1400	59,000			ibid.
River Sg. Johor		nd	65,000			ibid.
River Sg. Mersing		4000	88,000			ibid.
River Sg. Pontian		7700	44,000			ibid.

Location	Remarks	HCH	DDT	Chlordane	PCB	Reference
River Sg. Pahang		900	10,000			ibid.
River Sg. Kemaman		6100	300			ibid.
River Sg. Kerteh		2300	100			ibid.
River Sg. Dungun		300	100			ibid.
River Sg. Terengganu		1100	200			ibid.
River Sg. Besut		200	nd			ibid.
River Sg. Kelantan		500	1100			ibid.
INDONESIA						
Ciliwung River, JI. Gunung Sahari, Jakarta	urban area	3100	270	71	380	Iwata et al. 1994
Ciliwung River, Ancol, Jakarta	urban area	5200	220	260	2100	ibid.
Ciliwung River, Bogor	rural area	22,000	190	240	1300	ibid.
SOLOMON ISLANDS						
Nggurambusu River, Komundi, Paripao, Guadalcanal	rural area	180	1200	14	<50	Iwata et al. 1994
Mbalisuna River, Karoururu, Tadhimboko, Guadalcanal	agricultural farm area	120	290	12	<50	ibid.
Ngalimbiu River, Mbaravuli, Ghaombata, Guadalcanal	agricultural farm area	5300	3500	17	<50	ibid.
Lungga River, Lungga, Ghaombata, Guadalcanal	rural area	230	62	23	<50	ibid.
Mataniko River, Honiara, Guadalcanal	urban area	340	21,000	140	1100	ibid.
TAIWAN						
Keelong River, Yung-shan Water Pumping Station, Taipei	urban area	240	190	110	2100	Iwata et al. 1994
AUSTRALIA						
Parramata River, Sydney, NSW	urban area	670	130	330	620	Iwata et al. 1994
Parramata River, Chiswick, NSW	sub-urban area	490	210	1100	950	ibid.
Parramata River, Meadowbank, NSW	sub-urban area	500	700	840	1200	ibid.
Cooks River, Sydney airport, NSW	sub-urban area	660	410	950	1100	ibid.
Georges River, Rocky Pt. NSW	sub-urban area	250	320	410	1700	ibid.
Swan River, Fremantle, WA	sub-urban area	150	55	51	140	ibid.
Canning River, Melville, WA	urban area	230	14	72	150	ibid.
Swan River, Perth, WA	urban area	180	68	150	180	ibid.
Swan River, Bassendean, WA	sub-urban area	140	16	55	120	ibid.
Swan River, Swan, WA	rural area	140	30	54	120	ibid.
Murray River, Pinjarra, WA	rural area	600	11	32	140	ibid.
Derwent River, Norfolk Bridge, Hobart, Tasmania	rural area	85	19	46	93	ibid.

Location	Remarks	HCH	DDT	Chlordane	PCB	Reference
Derwent River, Boyer Paper Mill, Hobart, Tasmania	rural area (paper mill drain)	110	37	33	<50	ibid.
Derwent River, Prince of Wales Bay, Hobart, Tasmania	urban area	79	110	68	240	ibid.
Derwent River, Macquarie Point, Hobart Tasmania	urban area	110	1.6	<6.0	<50	ibid.

3.2.4 River and Estuarine Sediments

Sediments act as an ultimate sink for POPs brought into the aquatic environment from direct discharges, surface run-off and atmospheric fall out. A study of sediments from inland and estuarine waters in Southeast Asia and Oceania was carried out by Iwata *et al.* (1994). Results are presented in table 3.11. The study noted that levels of DDT, HCH, chlordane and PCBs did not vary widely between countries. This result is different from levels of persistent organochlorines in air and surface waters which were higher in the tropics than, for instance, in Japan and Australia (section 3.3.2 and 3.3.3). It is suggested that the more uniform distribution of organochlorines in sediment samples can be explained by their rapid evaporation from water to the atmosphere due to high temperatures in the lower latitudes. This has the effect of protecting sediments from severe contamination in the tropics.

Direct comparison of data on levels of organochlorines on sediments (table 3.11) between different studies is difficult because of differences in laboratories and methods of analysis. In addition, the carbon content of sediments can affect the retention of POPs in the sediments and this cannot be taken into account on a direct comparison of data. However, the data presented in table 3.11 can at least give an indication of levels in sediments, and Iwata *et al.* (1994) note that there was no significant difference in carbon content between the mid- and low-latitude regions in their study. Studies revealed very high levels of DDT and HCH were apparent in some sediment samples from rivers in India and China. A study on Hong Kong coastal sediments also reported high levels of DDT, HCH and PCBs in some areas, for example, Victoria Harbour (Richardson and Zheng 1999). It was concluded that substances such as PCBs, DDT and HCHs in Hong Kong sediments were the result of trace discharges in stormwaters, sewage, industrial waste, agricultural run off and were of long term significance to the health of Hong Kong waters. A study on organochlorine pesticides in sediments of the Red River Delta, North Vietnam, in 1996 indicated that DDT was being used in the valley of the Red River (Nhan *et al.* 1998). The study commented that DDT is banned for agricultural use in Vietnam but that it has been used recently for malarial control. Furthermore, with recent liberalisation of the agrochemicals market, there has been a tendency towards the application of cheaper pesticides and there are concerns that some banned organochlorine pesticides, including DDT, may be available to farmers and result in widespread environmental contamination. In Australia, extremely high levels of DDT and chlordane were found in sediments from Homebush Bay, Sydney (Office of Marine Administration, Sydney Australia 1998).

Few studies were available in the scientific literature on levels of PCDD/Fs in sediments. Levels of PCDD/Fs in rivers in northern Taiwan (0.03 to 4.7 pg TEQ/g) were lower than those found in a survey of twelve rivers in Japan (<0.02 to 24 pg TEQ/g), (Aozasa *et al.* 1997). A survey of marine sediments around Korea found that levels were higher in the southern sea and east sea than the Yellow Sea. Data on congener profiles in the sediment samples suggested that pentachlorophenol (PCP) used in agriculture was the source of some of the contamination (Ok *et al.* 1999). Similarly, a study of PCDD/Fs in sediments of Tokyo Bay and Kasumigaura Lake Basins in Japan also reported that a large part of the dioxin pollution in aquatic sediment is caused by past pesticide use in paddy fields, largely PCP. It is expected that most of the dioxins emitted in past pesticide impurities still exist in agricultural soil and they will continue to flow into water bodies and pollute sediment in the future (Masunaga *et al.* 1998). In China, the pesticide sodium-PCP has been used widely to control schistosomiasis and residues of dioxins in lake sediments were found to be higher in areas that had been sprayed with the pesticide (Jiang *et al.* 1997). Although past PCP use in Japan is a known source of dioxins, the present production of dioxins is deemed to be combustion, contributing to over 90% of the dioxins produced (Masunga *et al.* 1998).

Table 3.11 Concentrations (ng/g dry) of organochlorines in river and estuarine sediments from Southeast Asia and Oceania

Location	Remarks	HCH	DDT	Chlordane	PCB	Reference
INDIA						
Cooum River, Madras	urban area	1.6	20	1.4	4.8	Iwata et al. 1994
Adayar River, Madras	urban area	22	450	47	420	Iwata et al. 1994
Mandovi River Estuary, Panaji, Goa	sub-urban area	3.8	73	6.4	170	Iwata et al. 1994
Mandovi River Estuary, Panaji, Goa	sub-urban area	0.58	8.0	0.47	6.8	Iwata et al. 1994
River Kaveri, Tamil Nadu, South India	agricultural area	85.9	3.0			Rajendran and Subramanian (1999)
River Kaver, Tamil Nadu	agricultural area	84.8	1.87			Rajendran and Subramanian (1999)
River Coleroon, Tamil Nadu	agricultural area	14.2	1.83			Rajendran and Subramanian (1999)
VIETNAM						
Lo Giang River, Duyen Hai	Paddy field and mangrove	0.45	1.0	0.15	2.2	Iwata et al. 1994

Location	Remarks	HCH	DDT	Chlordane	PCB	Reference
CHINA						
River Daliaohe		0.65	0.2		1.9-2.7	Wu et al. 1999
River Luanhe		0.2	-		1.4	ibid.
River Haihe		9.3	105		2.9-3.5	ibid.
River Huanghe		3.0	-		0.7-2.4	ibid.
River Changjiang		0.6	0.2		3.0-9.5	ibid.
River Huangpujiang		2.9	1.3		19.9	ibid.
River Qingtangjiang		0.7	0.1		12.8	ibid.
River Mingjiang		4.2-9.4	6.9-13.1		not analysed	ibid.
River Jiulongjiang		0.49	5.2		0.45-1.15	ibid.
River Zhujiang		72.5	11.1		not analysed	ibid.
HONG KONG						
near shore sediments		0.1-16.7	0.3-14.8		n/d-97.9	Richardson and Zheng (1999)
INDONESIA						
Ciliwung River JI. Gunung Sahari, Jakarta	urban area	0.035	42	38	220	Iwata et al. 1994
Ciliwung River, Ancol, Jakarta	urban area	0.071	26	8.0	140	Iwata et al. 1994
Ciliwung River, Bogor	residential area (muddy)	0.099	13	0.49	79	Iwata et al. 1994
Ciliwung River, Bogor	residential area (sandy)	0.058	3.4	0.16	5.9	Iwata et al. 1994
SOLOMON ISLANDS						
Mbokokimbo River, Komlonga, Reko, Guadalcanal	rural area	2.2	9.3	0.53	1.1	Iwata et al. 1994
Mataniko River, Honiara, Guadalcanal	urban area	<0.33	750	3.9	5.0	Iwata et al. 1994
JAPAN						
Osaka Bay	urban area (estuary)	4.5-6.2	2.5-12	0.66-2.1	63-240	Iwata et al. 1994
TAIWAN						
Keelong River, Yung-shan water pumping station	urban area	0.79	10	5.6	230	Iwata et al. 1994

Location	Remarks	HCH	DDT	Chlordane	PCB	Reference
AUSTRALIA						
Homebush Bay, Sydney		-	749-1,487,732	<0.5-80,016	-	Office of Marine Administration Sydney Australia (1998)
Cooks River, Sydney airport, NSW	sub-urban area	2.5	51	30	120	Iwata et al. 1994
Swan River, Bassendean, WA	sub-urban area	0.72	7.4	6.4	13	Iwata et al. 1994
Harvey Estuary, Dawensville, WA	rural area	-	0.078	0.31	0.69	Iwata et al. 1994
Murray River, Pinjarra, WA	rural area	0.045	0.77	8.5	0.85	Iwata et al. 1994
Derwent River, Prince of Wales Bay, Hobart, Tasmania	urban area	17	58	43	470	Iwata et al. 1994
Derwent River, Newtown Bay, Hobart, Tasmania	urban area	0.29	13	0.75	7.3	Iwata et al. 1994

3.2.5 Humans

The greatest exposure to POPs in humans is via food intake. Other pathways of exposure are inhalation and dermal contact. Measuring levels of POPs in human tissue is one of the most accurate and precise ways of assessing exposure to these environmental pollutants. Levels of POPs are most commonly monitored in blood, breast milk or adipose tissue.

PCDD/Fs

In comparison to available data on PCDD/F and PCB levels in human milk in industrialised countries of the Northern Hemisphere (see Allsopp *et al.* 1998), there is little data for countries in Southeast Asia and Oceania. Table 3.12 shows concentrations of PCDD/Fs published in the scientific literature for this region. PCB concentrations are not given because there are differences between studies in the analysis of PCBs that makes comparison difficult.

Levels of PCDD/Fs are low in Cambodia, Thailand, Pakistan and the north of Vietnam (in the 1980s) compared to Japan and New Zealand (in the 1990s). This can be attributed to the fact that levels of these chemicals are generally lower in less industrialised countries. Indeed previous studies have noted that PCDD/F levels in human tissue/milk are low in less industrialised compared to industrialised countries (e.g. WHO 1996).

Levels of PCDD/Fs in New Zealand (average 17.3 ppt TEQ) and Japan (15.3 ppt TEQ) are somewhat lower than the highest levels found in some industrialised countries of the Northern Hemisphere (20 to 30 ppt TEQ), but similar to countries eastern Europe (WHO 1996).

Levels of PCDD/Fs in the south of Vietnam in the 1980s are high (26 ppt TEQ) and are similar to those found in industrialised countries of the Northern Hemisphere. Studies have indicated that the high levels of PCDD/Fs in this region are not only attributed to more industrialisation in the south of the country than the north, but also to the spraying of a herbicide, Agent Orange, during the war (Dai *et al.* 1995). It has been found that Agent Orange was contaminated with PCDD/Fs. It was sprayed over 10% of mid and southern Vietnam between 1962 to 1971. A study on blood samples taken from people from South Vietnam the early 1990s has revealed that high levels of PCDD/Fs have persisted in humans 20 years after the spraying of Agent Orange. It has also been shown that Vietnamese soldiers from the north of the country who were in the south during the war have high levels of PCDD/Fs in their tissues which reflects exposure to Agent Orange during the war (Schecter *et al.* 1992).

A study on levels of organochlorines in adipose tissue from humans in Korea reported that levels of PCDD/Fs averaged 283 pg/g (Kang *et al.* 1997). Levels were lower than those of other industrialised countries such as Japan (2560 pg/g), but similar to levels reported for China (300 pg/g).

Table 3.12 Mean PCDD/F Levels in Human Milk (on a Lipid Basis) in Southeast Asia and Oceania

Country	Area	Number of Samples	ppt lipid TEQ [PCDD/F]	Reference
Cambodia	Phnom Penh	8	3	Schecter et al. 1991
Japan	Fukuoka	125	16.1	Nakagawa et al. 1999
Japan	Western Japan	95	15.3	Iida et al. 1999
New Zealand	Auckland, Christchurch Northland, North Canterbury	38	16.5 18.1	Bates et al. 1994
Pakistan	Lahore	14	3.9	
Thailand	Bangkok	10	3	Schecter et al. 1991
Vietnam	Hanoi (North) Dong Nai (South)	30 11	9 26	Schecter et al. 1991

DDT

In human milk, the isomers p,p'-DDT and p,p'-DDE are the major contributors to the total sum of DDT compounds (DDT + DDE + DDD) and levels of the o,p'-DDT and p,p'-DDD isomers are much lower. Table 3.13 lists the mean concentrations of DDT in human milk in various countries from Southeast Asia and Oceania. In some studies listed in the table, total DDT is taken to be the sum of p,p'-DDT + p,p'-DDE, whereas in others it is the sum of these plus other isomers. The levels given by different studies listed in table 3.13 are therefore not directly comparable but they do give an approximation of DDT levels in the various countries.

Table 3.13 shows that levels of DDT in human milk are generally higher in tropical Southeast Asian countries (Cambodia, India, Thailand, Vietnam) compared to other

regions (Australia, Japan, New Zealand, Solomon Islands). An exception is Hong Kong where levels measured in 1985 were also high. The comparatively low concentrations of DDT in human milk from Australia, Solomon Islands and Japan are similar to levels found in some countries of Europe and North America. DDT has been banned in such countries for some years and levels have been shown to gradually decline in human milk over this time (e.g. Loganthan *et al.* 1993). On the other hand, DDT has been used more recently or is still being used in some tropical Southeast Asian countries and this is reflected in the higher levels of DDT in human milk from these countries. Usage patterns of DDT were also apparent within countries. For example, there was a marked regional difference for two regions studied in India. Women residing in Fairidkot, a cotton growing area where DDT was used, had higher levels of DDT in their milk than women from the urban community of Ludhiana (Kalra *et al.* 1994).

A study of organochlorine levels in human adipose tissue in Korea in 1994/5 reported a mean level of 1.1 μg/g (on a lipid weight basis), (Kang *et al.* 1997). DDT has been banned in Korea since the 1970s. The concentrations found in Korea were lower than levels in adipose tissue reported for Japan in 1986/7 (2.4 μg/g) and the south of Vietnam in 1991 (4.9 μg/g).

Table 3.13 Mean Concentrations of DDT in Human Milk (on a Lipid Basis) in Southeast Asia and Oceania

Country	Area/Date	Number of Samples	DDT Compounds Measured	Mean Concentration of DDT Compound (μg/g fat or ppm)	Reference
Australia	Perth (1991) Victoria	128 60	total DDT p,p'-DDT	0.8 (median) 0.225	Stevens et al. 1993 Quinsey et al. 1995
Cambodia	Phnom Penh (1985-7)	8	p,p'-DDE + p,p'DDT	6.615	Schecter et al. 1991
Hong Kong	(1985)	25	total DDT	13.800	Smith 1999
India	Punjab Fairidkot	40 58	p,p'-DDT	7.18 13.81	Kalra et al. 1994
Japan	Fukuoka (1994-6)	125	total DDT	0.345	Nakagawa et al. 1999
New Zealand	North (1988) South	21 17	total DDT	1.1 3.1	Bates et al. 1994
Papua New Guinea	(1990)	41	total DDT	0.89	Smith 1999
Thailand	Bangkok (1985-7)	10	p,p'-DDE + p,p'-DDT	6.277	Schecter et al. 1991
Vietnam	Hanoi (north) (1985-7) Dong Nai (south)	2 11	p,p'-DDE + p,p'-DDT	15.25 16.66	Schecter et al. 1991

Other Organochlorines

With the exception of DDT, data on levels of other organochlorine pesticides in human tissues is scarce. Table 3.14 gives the mean concentrations of dieldrin, HCB, β-HCH and chlordane compounds in a few countries from Southeast Asia and Oceania. Levels of oxychlordane and dieldrin are far higher in Australia than in the tropical Southeast Asian countries of Thailand and Vietnam. This most likely reflects the widespread use of these compounds for termite control in Australia. A recent study in Australia reported significantly higher levels of dieldrin, oxychlordane and heptachlor epoxide (HE) in the breast milk of women who resided in houses that had previously been sprayed with the pesticides for termite control (Sim *et al.* 1998). The association was greatest for heptachlor. This could be due to its high volatility and therefore greater potential for inhalation and absorption than for dieldrin and oxychlordane. The report suggested that the associations found between high breast milk concentrations of dieldrin, chlordane and HE and termite control of residences have important implications when considering the public health impact of further restrictions of these pesticides as termiticides.

In Japan, a study on trends of organochlorines in human adipose tissue showed the levels of chlordane increased up until the mid 1980s when the use of chlordane as a termiticide was banned (Loganthan *et al.* 1993). In India, dieldrin has been banned since 1975 and a recent study in Delhi showed that levels of aldrin and dieldrin in human milk, blood and adipose tissue were low in comparison with Australia (Nair *et al.* 1992).

The alpha, beta and gamma isomers of HCH have been detected in human breast milk. Technical grade HCH is an insecticide that is composed of different isomeric forms including the latter three isomers. β-HCH is more persistent than α-HCH and γ-HCH and is more slowly cleared from the body. Consequently, β-HCH is the most ubiquitous isomer found in human milk. Table 3.14 shows concentrations of β-HCH that have been reported in human milk in Australia and a few Southeast Asian countries. Levels are lowest in Cambodia and Thailand suggesting little use of HCH in these countries. Extremely high levels have been recorded in human milk in India (4.37-8.83 ppm). A previous study also noted high levels of around 6 ppm for India and China. This reflects the widespread usage of HCH in these countries.

Table 3.14 Mean Concentrations of organochlorine Pesticides in Human Milk on a Lipid Basis (ppm) in Southeast Asia and Oceania

Country	Chlordane Compound	Dieldrin	HCB	β-HCH	Reference
Australia Victoria	oxychlordane 0.13	0.159	0.411	0.345	Quinsey et al. 1995
Cambodia Phnom Penh	-	0.004	0.002	0.074	Schecter et al. 1991
India Delhi Ludhiana Fairidkot				 8.83 4.37 8.20	 Banerjee et al. 1997 Kalra et al. 1994
Thailand Bangkok	oxychlordane 0.051	0.058	0.003	0.095	Schecter et al. 1991
Vietnam Hanoi (north) Dong Nai (South)	 oxychlordane 0.002 0.016	 0.005 0.002	 0.011 0.007	 0.836 0.23	 Schecter et al. 1991

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