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GREENPEACE

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EXECUTIVE 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, particularly combustion processes. Several POPs, notably certain organochlorine pesticides such as DDT and technical grade HCH, have been completely banned in industrialised countries and banned from agricultural use in most less industrialised countries. However, due to the persistence of these pesticides, high levels remain in many regions of the globe. Moreover, in some less industrialised countries, including Latin America, organochlorine pesticides, particularly DDT, are still used in sanitation campaigns against vector borne diseases such as malaria. In addition, illegal use of organochlorine pesticides often cannot be ruled out.

This report draws together published scientific literature on levels of POPs in the environment and in animals and humans of Latin America. The report reveals that there is a great lack of research on levels of POPs in Latin America in comparison to countries of the Northern Hemisphere. An overall insight into the state of contamination of Latin America is therefore impossible. However, available research does at least highlight the state of POPs contamination in some regions of Latin America.

WHAT ARE POPs?

POPs encompass many different and varied groups of man-made chemicals. Some POPs have been listed 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. They are:

- dioxins and furans - chemicals that are formed as unintentional by-products of combustion and processes involving the manufacture, use and disposal of organochlorines. For example, they are produced as by-products of municipal

waste incineration and other types of incineration, 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 – a chemical used as a pesticide and in the manufacture of pesticides and produced as an unwanted by-product of various industrial processes involving organochlorines.
- Organochlorine pesticides, including- 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 global 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 somewhat less persistent but are none 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. Consequently, POPs can 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 and even attain high levels in remote regions, such as the arctic.

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 LATIN AMERICA

Persistent organochlorine pesticides have been used for agriculture in Latin America over the past few decades although agricultural use is generally now illegal. Particularly large quantities have been used in Mexico for growing cash crops. In more recent years, the use of organochlorine pesticides has been restricted to public health programs against diseases such as malaria. In this regard, Mexico is by far the biggest user of the pesticide DDT in Latin America followed by Brazil with other countries using lower quantities.

This report reviews data on POPs in Latin America from the scientific literature, (mainly that published in the english language). Literature was identified mainly from the BIDS ISI scientific database. The studies that are reviewed can only be seen to be representative of the particular region studied and can by no means be considered to be representative of each country as a whole since so little research is available.

Detailed comparisons between POPs levels found in a study with other studies is difficult because of inconsistencies in laboratory methods used and different laboratory quality control standards. Nevertheless, comparison between studies can give insight into the state of contamination of an area and whether levels of POPs are considered to be high or low. Current levels of organochlorine pesticides in Latin America reflect both past and current uses.

COASTAL ENVIRONMENT

Several studies reported on POPs levels in coastal lagoons, water and sediments and fish/shellfish. The majority of this research was limited to assessment of DDT levels in Mexico and the Gulf of Mexico.

Sediments in the aquatic and marine environment act as an ultimate sink for POPs. Notably high levels of DDT in estuarine or lagoon sediments were found in certain regions of northwest Mexico (16,600 ppb, dry weight), in northern Gulf of Mexico (1600 ppb), and in Nicaragua (270 ppb). In Mexico, the high levels of DDT were a consequence of its use for vector control and in Nicaragua it was due to extensive DDT use for cotton production over many years. Lower levels of DDT were reported for sediments in Brazil, Argentina, El Salvador, and other regions of Nicaragua, Mexico and the Gulf of Mexico. For fish and shellfish, comparatively high levels of DDT (>100 ppb wet weight) were again evident in certain regions of northwest Mexico, the Gulf of Mexico and Nicaragua.

PCBs were detected in estuarine and lagoon sediments from several Latin American countries. Particularly high levels were found in estuarine sediments in El Salvador (1137 ppb). Levels of PCBs in fish/shellfish were comparatively high (>100 ppb wet weight) in the Gulf of Mexico, Nicaragua, Argentina and Chile. The levels in fish/shellfish were within a similar range to those reported for marine fish from Australia (range 0.22 to 720 ppb) and were generally higher than those reported for Southeast Asian countries (0.38 to 110 ppb).

OCEANIC ENVIRONMENT

A global survey of oceanic air and seawater in 1993 detected several organochlorines in the Caribbean Sea and Gulf of Mexico. In general, organochlorine concentrations in air in northern and southern oceans have remained constant in recent years despite bans on their use in many regions. In seawater, DDT was detected at comparatively low concentrations from the Caribbean Sea and the Gulf of Mexico.

Fish and Shellfish

Few data was available on levels of POPs in marine biota from the open oceans. DDT was found to be the most common contaminant in fish and shellfish taken from the Gulf of Mexico. Levels of PCBs in squid were considerably lower in animals taken from waters of the Southern Hemisphere compared with the Northern Hemisphere. Similarly organotin levels were also considerably lower in squid from Southern Hemisphere waters, including waters off Peru and Argentina.

Marine Mammals

Only a few studies were found in the literature on levels of POPs in marine mammals of Latin America. Research on bottlenose dolphins from the Gulf of Mexico revealed high concentrations of chlordane compounds and dieldrin in blubber of these animals. Levels of DDT were similar to levels in dolphins from the Atlantic coast of the US and were in the same range as levels in Burmeister's porpoises from Argentine waters. A study on brominated flame retardants in marine mammals showed that levels found in dolphins from the Gulf of Mexico were similar to levels found in marine mammals in the Northern Hemisphere.

AQUATIC ENVIRONMENT

A limited number of studies reported that several organochlorine pesticides were detectable in surface water, sediments and/or fish and shellfish in aquatic environments of Brazil, Mexico, Honduras, Argentina, Uruguay and Chile. Chemicals included DDT, heptachlor and heptachlor epoxide, dieldrin, aldrin and lindane.

Comparison of POPs levels in the aquatic environment of Latin America with other countries showed that levels were in general not considered to be high in most regions that were studied. However, there were some very notable exceptions:

- In the Ipojuca river basin in Brazil, extremely high levels of heptachlor were evident in river water (up to 57.8 ppb) in 1995/6 which clearly exceeded legal limits (10 ppb). It was inferred that the cause of this was the use of heptachlor in public health programmes. Levels of total HCH (maximum of 3760 ppt) in water also exceeded legal limits in this region.

- In an intensive agricultural region of the Choluteca river Basin in Honduras, very high levels of dieldrin were found (40 ppb) that according to the study exceeded US EPA water standards.

- In the Biobio river basin in Chile, notably high concentration of DDT (up to 2788 ppb) and lindane (up to 773 ppb wet weight) were detected in fish. The lindane levels were among the highest values ever reported in the world and reflected the massive use of lindane-based pesticides in the area

- In the Rio de La Plata in Argentina, comparatively high levels of PCBs were evident in water and fish. Levels were similar to those reported for the Great Lakes.

Assessment of the concentration of POPs in drinking water in Latin America was almost non-existent in the scientific literature. Researchers expressed concern about the lack of information on levels of POPs in groundwater of Mexico that is used for drinking water. Serious groundwater contamination with the organochlorine pesticides 2,4-D and 2,4,5-T was found in Mexico at the Yucatan peninsula. At La Lima, Honduras, high levels of lindane and chlordane were found in drinking water that were above WHO standards.

TERRESTRIAL ENVIRONMENT

Air, Soil and Vegetation

The scientific literature was almost devoid of studies on levels of POPs in air, vegetation and soil of Latin America. One study was available for Mendoza, Argentina which monitored levels of organochlorine pesticides in pine needles from urban parks as an indirect way of assessing air pollution. High levels of DDT and HCH were found in comparison to rural areas of Argentina and to levels found in Germany. This implied that localised air pollution from insecticide spraying had occurred where the high levels in pine needles were detected. A study on municipal compost from different regions of Brazil found that levels of dioxins were similar to levels in German compost, while levels of PCBs were lower.

Birds

Several studies were published on levels of POPs in birds for Mexico, one study for Chile and none for other Latin American countries. Evidence of egg shell thinning due to high levels of DDE was found in Mexican birds of prey from the 1950s to the 1980s. No studies on this subject were available for the 1990s, but a recent study warned that birds in Chiapas state in Mexico may be at significant risk of DDT accumulation due to its continued use in this region. A range of other organochlorine pesticides were detectable in resident and migratory birds of Mexico in the 1980s and 90s and birds from central Chile in the 1990s.

Food

POPs are detectable in foodstuffs from all over the world. In Latin America, research on POPs in food was scarce and was limited to research in Argentina and Mexico. Limits set by the World Health Organisation (WHO) and Food and Agricultural Organisation (FAO) as "safe" levels for POPs in food were exceeded for DDT in cheese samples taken in Mexico and milk in Argentina. Milk from Mexico and Argentina also greatly exceeded regulatory limits for heptachlor. In Mexico, total HCH levels in milk exceeded the recently set limit for HCH and meat samples exceeded regulatory limits for DDT and HCH. These results imply that exposure to POPs via food in Mexico and Argentina may be high, but far more research is needed to clarify whether this is the case in general since current research is so limited.

Humans

Measurable quantities of POPs are present in human tissues worldwide. In Latin America, research on POPs in human tissues over the past 15 years or so are limited to a handful of studies, most of which focused on DDT in Mexico and Brazil.

One study in Rio de Janeiro, Brazil, 1992 found levels of dioxins and PCBs in breast milk were at the lower end of the range of those found in Western countries.

For DDT and its breakdown product DDE, the highest levels in human milk have been reported for Asia, Africa and Latin America. In various regions of Mexico and Brazil, DDE levels found in human milk were high (>2.5 ppm lipid) compared to most countries. This was almost certainly due to the continued use of DDT in these countries. In addition, very high levels of DDT have been found in pesticide sprayers from Brazil, Mexico and Venezuela. Levels of total DDT in adipose tissue of pesticide sprayers from Mexico were 6-fold higher than the general population while blood levels of Brazilian sprayers were 4.7-fold greater than levels in non- exposed workers.

Other organochlorine pesticides including dieldrin, HCB and heptachlor epoxide were found in human milk from Mexico and Brazil at concentrations that were within the range of those found in other countries. However, this gives no room for complacency because these chemicals are persistent, bioaccumulative and toxic. In addition, the developing young are particularly vulnerable to the impacts of such chemicals and they are passed from the mothers body to the developing foetus in the womb and to the nursing infant via breast milk.

Regulatory authorities use the concept of acceptable daily intakes of chemicals in food in an attempt to protect public health. The ADI is the amount of a chemical that can be taken in on a daily basis in the diet that is considered to be safe. If the ADI is applied to human milk taken in by the nursing infant, calculations showed that the ADI is exceeded for several POPs in many countries. In Latin America, calculations show that the ADI for the breast-fed infant was exceeded for DDT in two regions of Mexico and for dieldrin in two regions of Brazil. It is, of course, questionable how the ADI is applicable to the nursing infant because ADIs are calculated for a 70 kg adult taking in food over a whole lifetime. However, since the infant is more vulnerable than the adult to chemical exposure, it has been argued that the ADI should definitely not be exceeded for infants. It is therefore of great concern that the ADI is exceeded through intake of human milk in Latin America. Nevertheless, it is very important to note that breastfeeding is highly recommended by experts because of the many advantages it conveys.

CONCLUSIONS

- Published scientific studies clearly show that POPs contaminate terrestrial, aquatic and marine environmental media throughout Latin America. However, published research on levels of POPs in Latin America is extremely limited. This is both in terms of the quantity of research that is available and the number of POPs that have been researched. The majority of research has been generated in Mexico and secondarily in Brazil with little or no research in other countries. Data are mainly limited to investigations of levels of a few organochlorine pesticides. Only a few studies on dioxins are available in the whole of Latin America and research on brominated flame retardants is limited to one study on marine mammals.

- Notably high levels of some organochlorine pesticides are evident in some regions of Latin American countries which relate to past and/or present uses. Levels of DDE in human milk in Mexico and Brazil indicated that exposure of the general population is high in some regions.

- It is almost certain that POPs which are released in tropical Latin America not only cause local contamination problems but may also contribute to pollution in areas of the world far away from their source. For instance, studies on rivers and sediments in other tropical areas (Asia) 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. Transfer to air has wider implications for the global environment. Semi-volatile and persistent POPs such as HCB and HCH appear to be redistributed from tropical point sources to colder regions on a global scale.

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 unintentional generation of POPs as by-products, on an international/global basis 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 a national, 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. . Strict timelines must be applied to achieve this goal.

- 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.

- Community Right to Know legislation provides a means to give citizens and the general public the tools to prevent and reduce industrial pollution, and protect themselves and their environment. Public access to information must exist at all levels of industrial production - from production processes to food and product ingredient labelling.

- 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 all pops and all other hazardous substances to the environment will need to be taken both at a regional level 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 other 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 1998). 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 some less industrialised 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 1998), Latin America and Asia. 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. 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. 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 areas in Latin America. It is probable that the tropical climate facilitates the rapid dissipation of POPs to air and water from agricultural areas of the tropics.
Indeed, research has shown that transfer of chemicals to the atmosphere is much greater in tropical areas (eg. Tanabe 1991).

A survey of levels of organochlorines in air water and sediments from Asia and Oceania also indicated that chemicals released in the tropics are dispersed rapidly through air and water and are retained less in sediments (Iwata *et al.,* 1994). 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 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 global atmosphere 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), far from their sources.

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 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. Perhaps the most extensive review of temporal trends of POPs in the global environment is given by 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 (see Allsopp *et al.*, 2000b). In Latin America, available data on levels of these chemicals in human tissues are very limited and it is not possible to determine whether levels have decreased over recent years. 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. 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. 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 resulting in particularly high tissue levels.

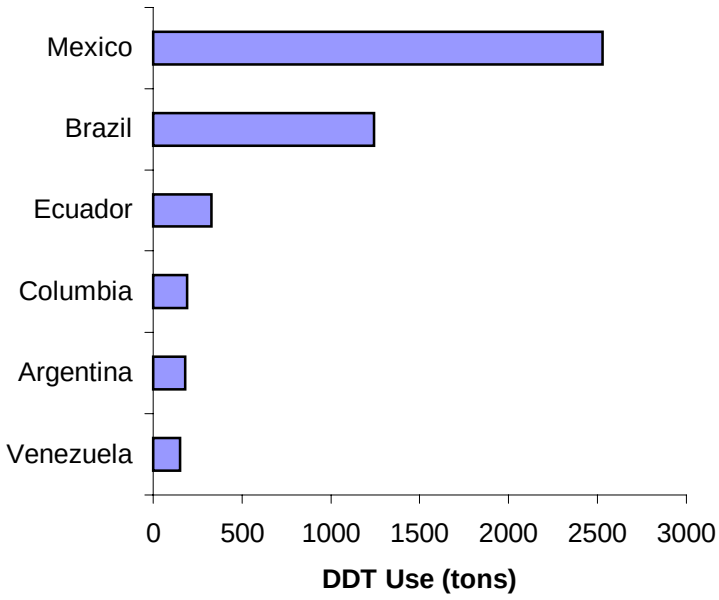
Data on temporal trends of organochlorines in the marine environment indicate that marine pollution by these compounds will not decline unless strict regulations are imposed on their use throughout the world. In the terrestrial environment, human populations in some less industrialised countries are 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, Loganthan and Kannan (1994) reported that 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.

3 POPS IN LATIN AMERICA

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. According to Nair *et al.,* (1996), DDT is used in less industrialised countries primarily due to cost-benefit efficacy and broad spectrum toxicity of this pesticide. In a number of less industrialised countries, DDT and other organochlorines are recommended by national and international health organisations to control mosquitoes, 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 world-wide (Lopez-Carillo *et al.,* 1996, Rivero-Rodriquez *et al.,* 1997). The total global use of DDT may be as great in the 1990s as it was in the 1970s (Smith 1999).

DDT and most other organochlorine pesticides have been banned from agricultural use in Latin America for some years (eg. Castillo 1998, Paratori 1998, Scribano 1998). However, DDT may still be used against malaria in some countries although efforts have been underway in recent years to use alternatives. Figure 1 shows the extent of use of DDT against malaria for the year's 1993/4 in Latin American countries.

Figure 1: DDT use in malaria prevention programmes in some Latin American countries 1993-1994 (after López-Carillo et al., 1996)



Mexico was the greatest user. However, Smith (1999) notes that there are plans in Mexico to reduce DDT usage over the next 5 years and eliminate it by 2007. In Brazil, according to Torres *et al.*, (1997), DDT was used during the 1990s against malaria and against termites for wood protection. However, in 1996, DDT was completely prohibited in an internal directive of the National Health Foundation for Public Health in Brazil and in 1998, the Federal Government also announced the complete ban of DDT use in Brazil. Aldrin, heptachlor-epoxide and dieldrin have also been banned during the 1990s although HCB is still permitted for use by the Health Ministry (C.C.P. Loiola, personal communication).

Organochlorine pesticides that are still permitted for use in some Latin American countries include endosulfan and lindane.

The following report presents information concerning levels of POPs in Latin America. Searches of the scientific literature, (mainly literature documented in the english language), were conducted. The most obvious observation to emerge from the literature search was that research on POPs in Latin American countries is extremely limited in quantity. Considerably fewer data is available for Latin America than for industrialised regions such as Japan, USA and Europe. The lack of data is even apparent in very recent years when it may be expected that there would have been increasing scientific interest and concern on this issue. The reason for the lack of data is unknown, but Albert (1996) points out that, at least for Mexico, research on persistent pollutants in different environmental media has never been a priority for the Mexican science and technology authorities. Therefore, most research scientists have a very low interest in it, which, in turn, results in a lack of sufficient and reliable information. Kammerbauer and Moncada (1998), noted that, for Central America, there is an increasing use of pesticides for cash-crop production. Note that data on levels of POPs in the environment are important to give 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. It is difficult however to give detailed comparisons of levels of POPs reported by different studies. This is due *inter alia* to differences in the scientific methods and quality control 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.

4 COASTAL ENVIRONMENT

The coastline of Central and South America stretches approximately 47,000 km. There are many rare wetland habitats on this long coastline, from tropical lagoons, coral reefs and mangrove swamps in the north, to marine bird and mammal breeding grounds in the south. The quality of the water, air and sediment of these coastal areas are of great importance, not only for the species that live and breed in them, but also for the ecosystem function. Coastal ecosystems include some areas with the world's highest net primary productivity per unit area, mangrove swamps. They provide treatment processes for small amounts of pollution, and physical coastal protection. Man impacts on these areas through activities that may take place far inland, as well as more direct impact through clearance of mangroves, the setting up of resorts for tourists, road building and other activities is increasing. Just offshore from a number of tropical countries in Latin America lie coral reefs. These are among the world's oldest (5,000 – 10,000 years old) and most diverse and productive ecosystems, the marine equivalent of a tropical rain forest. A single reef may contain 3,000 species of coral and these systems support at least one-third of all marine fish species. Coral reefs reduce the energy of incoming waves and help in coastal protection. Nonetheless they are being destroyed or damaged. The greatest threats to these systems come from deforestation, construction, agriculture and poor land management, often far away from the coast (Miller, 1992). Rapid, and uncontrolled, 'development' has taken place in Latin America over the last 20 to 30 years and extensive impacts on the coastal marine environment are already clear.

Pollution of coastal waters is a problem affecting all the littoral countries of Latin America. Many large rivers (e.g. the Amazon and the Plate) drain vast areas of the continent. Contaminants from the land are often transported to the coast dissolved in river water, as suspended colloidal particles or adsorbed onto sediment. In addition the majority of the population of Latin America live on, or close to, the coast. This human burden adds to the terrestrial input of pollutants to coastal systems, making them some of the most threatened ecosystems worldwide. Although pollutants undoubtedly also reach the coast from the open ocean, ocean sources constitute only a very minor input in comparison with terrestrial sources.

There are a number of causes to which this environmental degradation can be attributed,some of which involves pollution by POPs:

- sewage discharges
- industrial discharges to rivers and the sea
- agricultural and other run-off
- inputs from aquaculture
- mining

Once in the marine environment there are a number of fates for these compounds. They may be metabolised by resident biota and removed by this process, they can be degraded by micro-organisms, accumulated in tissues, volatilised into the atmosphere, oxidised by light from the sun or sink to the bottom and be adsorbed by sediments or particulates (McMillin & Means 1996). In a study on the Mississippi River plume and the Gulf of Mexico, McMillin & Means (1996) concluded that the concentrations of all herbicides analysed were highest closest to the shore and that concentrations fell with increasing distance from shore and depth of water. The presence of herbicides in

detectable concentrations represents continuous transport of huge amounts of material from riverine systems into the ocean. Moreover, the small number of compounds usually analysed represents only a fraction of the total metabolites and degradation products of applied compounds with potentially adverse effects on aquatic systems (McMillin & Means 1996).

There has been a considerable amount of scientific research into the coastal areas of the Gulf of Mexico (USA and Mexico) and into environmental pollution of the Pacific coast of Mexico. Unfortunately the literature on coastal systems in other Latin American littoral states is, at best, patchy, and at worst, non-existent. Consequently in this review of POPs in coastal regions of Latin America a number of countries are poorly represented. This does not mean that there is no pollution on these coasts, but simply that few research data are available in the open literature for these countries.

4.1 Coastal lagoons, water and sediments

The contamination of the coastal and marine environment, particularly sediment, is an increasing concern in many coastal areas of Latin America. Sediments may act as a reservoir for a number of different contaminants, including POPs, even when the water above them meets the appropriate water quality criteria. As these toxicants leach into the water column, or are ingested by sediment dwellers, they can become mobilised in the food chain and impact on biota at every trophic level (Lewis *et al.*, 2000).

Agricultural, industrial and domestic wastewater can be responsible for impacting on sediments in near-coastal areas, and this is of particular concern where few environmental controls, or effluent treatment plants, exist. In Latin America it has been estimated that 98% of wastewaters are discharged untreated.

This section discusses POPs contamination of the coastal environment in different countries and areas of Latin America. Most data were available, however, for Mexico and the Gulf of Mexico.

4.1.1 Mexico:

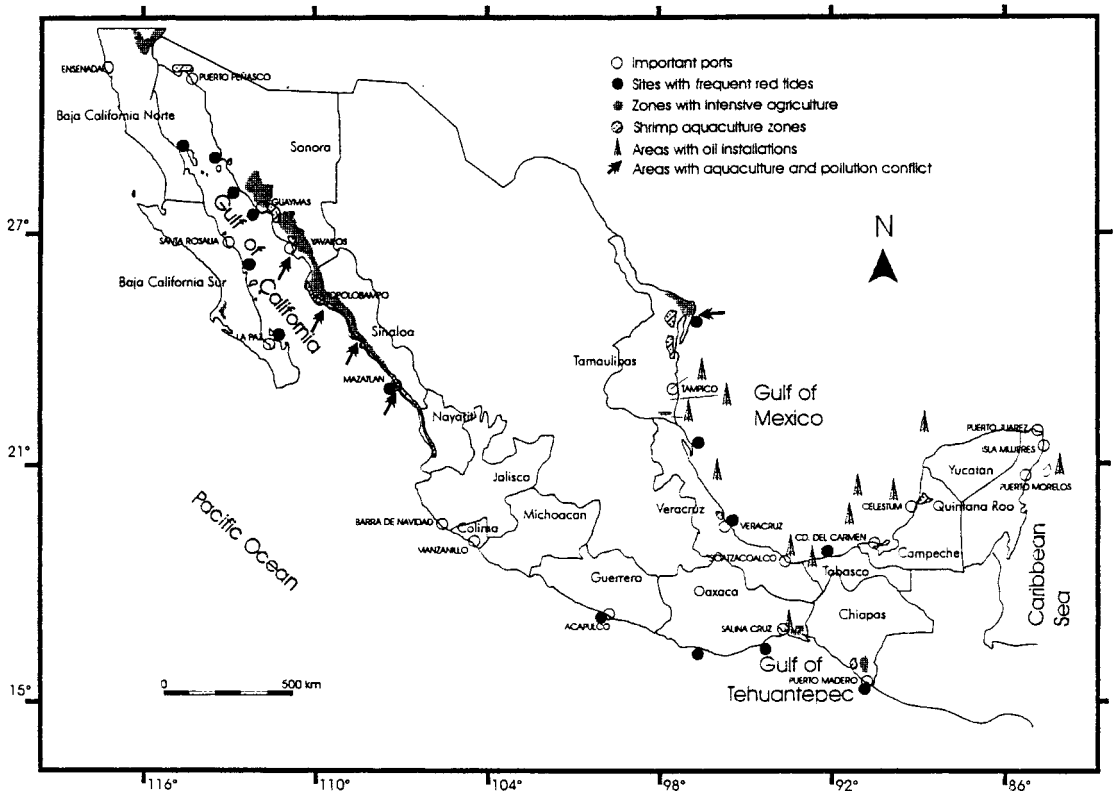
Mexico has one of the longest coastlines of all Latin American countries, at 9,330 km. Both Pacific and Gulf coast have a variety of wetland ecosystems, in particular coastal lagoons which are home to a variety of organisms (Fig 1). In recent years shrimp farming, primarily for export, has become established, putting further environmental pressure on these threatened systems.

The lagoon wetlands of north-western Mexico are an important area for wildlife containing many wetland habitat types including mangrove swamps, salt-marsh, intertidal pools, fresh-water lagoons and brackish and seawater systems. These habitats have a rich and complex food web and there is already evidence that this is being disturbed by anthropogenic activity as mangroves are cut down and salt-marsh ‘reclaimed’ for agriculture (Páez-Osuna *et al*, 1998).

These coastal ecosystems of northwest of Mexico are being heavily impacted by agricultural pollution. In the nearby river valleys there are 2 million hectares (ha) of irrigated agricultural land. Runoff from agriculture into these rivers eventually drains into a system of coastal lagoons. The lagoons themselves border an enclosed area of

ocean, the Gulf of California, a finger of water that extends between the mainland of Mexico and Baja California, and which is a major breeding ground for humpback whales (Fig 2).

Figure 2: Sites of coastal aquaculture in Mexico indicating areas threatened by pollution (from Páez-Osuna et al., 1998)



4.1.1.1 ***DDT***

For sediments, levels of total DDT of around 100 ppb or greater could be considered to be comparatively high. Since 1991 DDT use in Mexico has been permitted only for public health campaigns. Nonetheless the compound continued to be detected in a number of environmental media. Levels in sediments detected in various studies in Mexico have not found especially high concentrations although there are exceptions. DDT has been detected in sediments from lagoons in the northwest of Mexico (Table 4.1) (Albert, 1996). Up to 17.67 ng g^{-1} (ppb) of DDE was detected in Terminos lagoon. This is one of the highest reported values for a DDT compound in the Mexican northwest, although 16.4 ng g^{-1} (ppb) of ΣDDTs was found in the Huizache-Caimanero lagoons system nearby (Table 4.1).

A study on POPs in sediments from a lagoon system draining into the Gulf of Mexico reported that DDT was the major organochlorine pesticide found (2.24 ppb) (Table 4.1) (Albert, 1996). Unfortunately such low residues were not consistently found. Near the Laguna Verde nucleoelectric station, an area where DDT had been used for vector control, DDT was detected in lagoon sediment at concentrations up to 16,600 ppb. DDT was the contaminant found at the highest concentrations (Albert, 1996). This

value for DDT is the highest reported in the literature on persistent pollutants in sediments Latin America.

Table 4.1: Mean or range of concentrations of DDT and its metabolites in sediment from coastal areas of Latin America (ppb)

COUNTRY	AREA	DDD	DDE	DDT	ΣDDTs	Reference
Argentina	Rio de la Plata		50.6-100	19.3-21.2	100	Colombo *et al* 1995
El Salvador	Acajutla	6-49	5-99	5-49	0-76	Michel & Zengel 1998
Mexico	Terminos lagoon	0-0.55	0-17.67			Paez-Osuna *et al* 1998
	Palizada river				0.37-1.45	Gold-Bouchot *et al* 1995
	Terminos lagoon	0.45-0.55	0.24-17.67			Gold-Bouchot *et al* 1993
	Bay of Chetumal				1.43	Norena-Barroso *et al* 1998
	Huizache-Caimanero lagoon				16.4	Albert 1996
	Yavaros				7.62	Albert 1996
	Carmen lagoon		0.15	1.47		Albert 1996
	Machona lagoon		0.26	1.47		Albert 1996
	Alvarado lagoon		1.78	2.24		Albert 1996
	Laguna verde			16,600		Albert 1996
Nicaragua	Estero Real lagoon	0.33-0.50	4.9-7.7	0.098-0.24	5.94-8.76	Carvalho *et al* 1999
	Estero Padre Ramos lagoon	0.06-0.20	0.39-3.8	0.06-0.11	0.61-4.28	Carvalho *et al* 1999
	San Juan del Sur lagoon	0.21-2.6	1.4-6.2	0.68-1.2	2.4-11.45	Carvalho *et al* 1999
	Esteros Naranjo-Pasao Caballos	0.093-28.8	0.41-220	0.15-32.2	0.71-270.5	Carvalho *et al* 1999
USA	N Gulf of Mexico	1-17	1-32	1-18	1-44	Macauley *et al* 1999
	N Gulf of Mexico		0.64			McMillin & Means 1996
	N Gulf of Mexico				6.19	Wade *et al* 1988
	N Gulf of Mexico	2.1	1.1	1.47	6.18	Sericano *et al* 1990
	N Gulf of Mexico	17.7	3.71	5.97	32	Sericano *et al* 1990

4.1.1.2 Other Organochlorine Pesticides

A study of the Huizache-Caimanero lagoon system in north west Mexico (Pacific coast) found that declining shrimp aquaculture success might be due to increasing pollution of the system by POPs carried into it by runoff from municipal sites and agricultural land (Galindo *et al.*, 1997). A number of organochlorine pesticides have been detected in these lagoon systems. Highest concentrations (second to DDT) were for aldrin (9.02 ppb) in Terminos lagoon and total HCHs (10.45 ppb) in Yavaros lagoon (Table 4.2) (Albert, 1996; Galindo *et al.*, 1997).

In the Mexican state of Chiapas, on the Pacific coast, aldrin was found at concentrations up to 150.71 ppb in lagoon sediments (Table 4.2). Heptachlor and heptachlor epoxide were also detected. Heptachlor was used intensively on cotton crops in this region, although increasing pest resistance to the compound led to the phasing out of cotton growing in 1986. Heptachlor was deregistered in Mexico in 1991. According to Albert (1996), the continued presence of heptachlor compounds in lake sediments suggests continued use of heptachlor despite legislative efforts to limit its use; a matter of particular concern in crops for domestic consumption where very little regulation of pesticides is enforced on farmers.

Residues of chlordane, lindane, aldrin and dieldrin have been found in the sediment and water of various coastal lagoons in Sinaloa on the Mexican Pacific coast as a result of

runoff from nearby agricultural regions (see Albert 1996). Metabolic studies on shrimp showed that concentrations appeared to be high enough to affect shrimp respiration and to increase stress on benthic biota (Table 4.3) (Reyes *et al.,* 1996).

On the Gulf Coast, in the Candelaria-Palau lagoon system, concentrations of and endrin (260.72 ppb) and endosulfan sulphate were highest, but the most frequently found persistent organochlorine pollutants were heptachlor epoxide, α-HCH and γ-HCH. In the Palizada del Este system the most frequently detected POPs were β-HCH and heptachlor and the highest concentrations were of endrin (7.82 ppb) (Table 4.2) and endrin aldehyde (Albert, 1996). As with DDT, endrin has been banned in Mexico since 1991. Endosulfan use was restricted in 1991 (although it later reappeared on the list of registered pesticides) (Albert, 1996).

A study carried out on coastal lagoon sediments near the Laguna Verde nucleoelectric station (also on the Gulf of Mexico coast) found α-HCH and aldrin most frequently in the samples taken (Albert, 1996). Heptachlor and heptachlor epoxide were also detected frequently (Albert, 1996).

Table 4.2: Mean or range of concentrations of organochlorine pesticides and PCBs in sediment from coastal areas of Latin America (ng g^{-1})(ppb)

COUNTRY	AREA	Aldrin	α-HCH	β-HCH	δ-HCH	Lindane	ΣHCHs	Alpha-chlordane	Gamma-chlordane	Total-chlordane	Dieldrin	Endosulfan	Endrin	HCB	Heptachlor	Heptachlor epoxide	Total heptachlors	Mirex	Cis-nonachlor	Trans-nonachlor	Oxychlordane	Toxaphene	PCB	Reference
Argentina	Rio de la Plata																						0.05-54.2	Colombo 1995
Brazil	Mapele										1.90		6.38	1.84										Tavares 1999
	Madre Deus													0.11										Tavares 1999
	Acupe		0.32																					Tavares 1999
	Muta		11.10								4.76		46.50											Tavares 1999
El Salvador	Acajutla																						400-1,137	Michel & Zengel 1998
Honduras	Zamorano Valley		33								3	7			5									Kammerbauer & Moncada 1998
Mexico	Terminos lagoon	0-9.02				0-0.57																		Paez-Osuna 1998
Mexico	Palizada river	0.25					0.04-0.35				0.35-2.29		0.39-2.34	0.18-0.67			0.08-0.26							Gold-Bouchot 1995
Mexico	Terminos lagoon	0.27-9.02				0.57								0.32										Gold-Bouchot 1993
Mexico	Bay of Chetumal						1.46																2.96	Norena-Barroso *et al* 1998
Mexico	Yavaros	1.85					10.45				5.85				5.4									Albert 1996
Mexico	Candelaria-Palau												260.72											Albert 1996
Mexico	Carmen lagoon	0.7	0.12	0.5		0.24					6.84		2.73		5.19	0.19								Albert 1996
Mexico	Machona lagoon	1.15	0.09	0.62		0.28					0.59		4.91		2.3	0.27								Albert 1996
Mexico	Alvarado lagoon	2.11	0.47	1.86		0.85					2.05		7.82		3.91	0.86								Albert 1996
Mexico	Chiapas state lagoons	150.71																						Albert 1996

COUNTRY	AREA	Aldrin	α-HCH	β-HCH	δ-HCH	Lindane	ΣHCHs	Alpha-chlordane	Gamma-chlordane	Total-chlordane	Dieldrin	Endosulfan	Endrin	HCB	Heptachlor	Heptachlor epoxide	Total heptachlors	Mirex	Cis-nonachlor	Trans-nonachlor	Oxychlordane	Toxaphene	PCB	Reference
Nicaragua	Estero Real lagoon	0.02	0.014-0.022	0.009-0.016		0.085-0.22					0.004-30.33		0.024-0.071	0.041-0.058	0.006-0.758					0.013-0.044		6.2-9.3		Carvalho *et al* 1999
Nicaragua	Estero Padre Ramos lagoon		0.01			0.027-0.066					0.013-0.593		0.009-0.016	0.004-0.017	0.004-0.012					0.007-0.017				Carvalho *et al* 1999
	San Juan del Sur lagoon		0.010-0.037	0.016-0.11		0.027-0.028					0.021-0.022		0.007-0.011	0.028-0.031	0.005-0.006							2.4-2.7		Carvalho *et al* 1999
	Chinandega lagoons										1.23													Carvalho *et al* 1999
	Esteros Naranjo-Pasao Caballos	0.004-0.083	0.004-0.21	0.006-0.17		0.015-1.0					0.049-53.7	0.013-0.11	0.026-2.9	0.006-1.1	0.004-65.4					0.014-2.0		13-800		Carvalho *et al* 1999
USA	N Gulf of Mexico	0-1	0-3	<1-2	<1-1	0-3	<1-6	0-3	0-5		0-3	3.00	0-7	0-23	0-<1	0-12		0-3	0-3	0-3	0-3	0.00	1-299	Macauley 1999
	N Gulf of Mexico										3.10			0.28										McMillin 1996
	Gulf of Mexico																						33.70	Lewis *et al* 2000
	N Gulf of Mexico					0.03				0.46	0.25						0.04	0.06					9.84	Wade *et al* 1988
	N Gulf of Mexico	0.03				0.05		0.26			0.26			0.11	0.04	0.04		0.07		0.21			4.2	Sericano *et al* 1990
	N Gulf of Mexico	0.08				0.07		1.18			0.36			0.25	0.05	0.08		0.18		0.8			5.4	Sericano *et al* 1990

Table 4.3: Concentration or range of concentrations of DDT and metabolites found in Latin American fish and shellfish (ppb). Values are wet weight, unless otherwise specified.

COUNTRY	Species	DDD	DDE	DDT	ΣDDTs	Reference
Argentina (Rio de la Plata)	Asiatic clam (lipid)		5,900-15,500	3,700-12,100	26,400-42,900	Colombo *et al* 1995
	white croaker (*Micropogonias furnieri*) - gonad lipid female	34.43	122.38	62.75		Lanfranchi *et al* 1998
	white croaker (*Micropogonias furnieri*) - gonad lipid male	17.05	42.24	14		Lanfranchi *et al* 1998
	white croaker (*Micropogonias furnieri*) - subcutaneous fat female	0.66	2.11	0.48		Lanfranchi *et al* 1998
	white croaker (*Micropogonias furnieri*) - subcutaneous fat male	15.07	48.02	10.88		Lanfranchi *et al* 1998
	white croaker (*Micropogonias furnieri*)-liver lipid female	9.69	20.77	6.08		Lanfranchi *et al* 1998
	white croaker (*Micropogonias furnieri*)-liver lipid male	12.99	44.26	9.99		Lanfranchi *et al* 1998
	Asiatic Clam		48.2-100	19.3-21.2	100	Sericano *et al* 1995
(Hudson)	Bivalves				210	Sericano 1995
Brazil	Clams		0.2-44			Tavares 1999
(Fortaleza)	Bivalves				130	Sericano *et al* 1995
(Recife)	Bivalves				120	Sericano *et al* 1995
Chile (Valparaiso)	Bivalves				140	Sericano *et al* 1995
Ecuador (Guayacil)	Bivalves				160	Sericano *et al* 1995
El Salvador	Oyster		26-99	457	26-589	Michel & Zengel 1998
	Bivalves				180	Sericano 1990(a)
Gulf of Mexico	Amber jack (*Seriola dumerili*)		49	6		Giam 1978
	Blue crab (*Callinectes sapidus rathpun*)		6-11	1		Giam 1978
	Cabbage head jellyfish		0.1	<0.1		Giam 1978
	Catfish (*Galeichthys felis*)		7	3		Giam 1978
	Catfish (*Galeichthys felis*)		3	0.3		Giam 1978
	Catfish (*Galeichthys felis*)		8	0.5		Giam 1978
	Catfish (*Galeichthys felis*)		8	0.5		Giam 1978
	Catfish (*Galeichthys felis*)		7	<0.1		Giam 1978
	Clams				20	Kennicut 1988
	Crab				16	Kennicut 1988
	Croaker (*Micropogon undulatus*)		6	<0.1		Giam 1978
	Croaker (*Micropogon undulatus*)		7	3		Giam 1978
	Drum fish (*Pogonias cromis*)		8	<0.1		Giam 1978
	Eel (*Anguilla sp*)		5	2		Giam 1978
	Fish				18.2	Kennicut 1988
	Fish & shrimp				62	Kennicut 1988
	Fish & shrimp				10	Kennicut 1988
	Fish, crab & oyster				49	Kennicut 1988
	Grouper				19	Kennicut 1988
	Mesopelagic fish				10	Kennicut 1988
	Morey eel (*Muraena sp*)		11	<0.1		Giam 1978
	Oyster				15	Kennicut 1988
	Oyster				25	Kennicut 1988
	Plankton				7	Kennicut 1988
	Plankton				1	Kennicut 1988
	Pompano (*Trachinotus carolinus*)		4	0.4		Giam 1978

COUNTRY	Species	DDD	DDE	DDT	ΣDDTs	Reference
Gulf of Mexico	Ribbon fish (*Equetus lanceolatus*)		18	6		Giam 1978
	Sand trout (*Cynoscion nothus*)		2	<0.1		Giam 1978
	Sand trout (*Cynoscion nothus*)		2	<0.1		Giam 1978
	Sand trout (*Cynoscion nothus*)		2	1		Giam 1978
	Sand trout (*Cynoscion nothus*)		2	0.7		Giam 1978
	Shark (*Carcharinus falciformis*)		37-83	<0.1-50		Giam 1978
	Shrimp				2	Kennicut 1988
	Shrimp (*Squilla empusa*)		8	1		Giam 1978
	Skate (*Raja texana*)		7	<0.1		Giam 1978
	Spade fish (*Chaetodipterus faber*)		7-14	0.1-1.0		Giam 1978
	Spade fish (*Chaetodipterus faber*)		5	5		Giam 1978
	Starfish (*Luidia clathrata*)		5	4		Giam 1978
	Sting ray (*Sasytis sabina*)		0.3			Giam 1978
	Trout (*Cynoscion nebulosus*)		4	0.5		Giam 1978
Honduras (Zamorano)	Mussel			43		Kammerbauer & Moncada 1998
Mexico	Oyster (*Crassostrea corteziensis*)	<2.5	18-22			Paez-Osuna 1998
	Oyster (*Cassostrea corteziensis*)					Paez-Osuna 1998
	Clam			300		Paez-Osuna 1998
	Clam	16.8				Gold-Bouchot 1993
	Mussel				1.44	Gold-Bouchot 1995
	Mussel	4.09				Gold-Bouchot 1993
	Oyster				0.39	Gold-Bouchot 1995
	Oyster	1.85				Gold-Bouchot 1993
	Oyster	1.28				Gold-Bouchot 1993
	Oyster				1.49	Gold-Bouchot 1995
	Oyster (*Crassostrea virginica*)	1.55				Paez-Osuna 1998
(Western)	Melaniris balsanus		8.77	2.63		Albert 1996
(Blanco river)	Oreochromis niloticus (lipid)		135,800	1,947,170		Albert 1996
	Callenectus sp. (lipid)			732,210		Albert 1996
	Penaeus sp.(lipid)		205,510	1,383,300		Albert 1996
	Carp (*Cyprinus carpio*)		1,723.4	5.6		Albert 1996
	Shrimp				0.25	Gold-Bouchot 1995
	Tilapia sp.		3,687.4	38.3		Albert 1996
(Tampico)	Mussel				100	Sericano *et al.*, 1990(a)
(Laguna del Ostion)	Mussel				170	Sericano *et al* 1990(a)
(Puerto Madero)	Mussel				130	Sericano *et al* 1990(a)
(Bahía Ventosa)	Mussel				180	Sericano *et al.*, 1990(a)
(Alvarado lagoon)	Oyster (*Crassostrea virginica*)			1.64		Albert 1996
(Baja California)	Oyster (*Crassostrea gigas*)				15.5	Albert 1996
(Baja California)	Oyster (*Crassostrea gigas*)				12.1	Albert 1996
(Baja California)	Oyster (*Crassostrea gigas*)				15.6	Albert 1996
(Baja California)	Oyster (*Crassostrea gigas*)				21.5	Albert 1996
(Baja California)	Oyster (*Crassostrea gigas*)				47.7	Albert 1996
(Baja California)	Oyster (*Crassostrea gigas*)				45.9	Albert 1996
(Baja California)	Mussel (*Mytilus californianus*)		6.46	1.78		Albert 1996
(Carmen lagoon)	Oyster (*Crassostrea virginica*)		4.17			Albert 1996
(Machona lagoon)	Oyster (*Crassostrea virginica*)			5.6		Albert 1996

COUNTRY	Species	DDD	DDE	DDT	ΣDDTs	Reference
Mexico (Mazatlan, Sinaloa)	*Crassostrea corteziens*		22			Albert 1996
Nicaragua (Isla de Aserradores)	Bivalves				200	Sericano *et al* 1995
USA (Alabama)	Mussel				160	Sericano *et al* 1995
(Choctachobee Bay)	Mussel				960	Sericano *et al* 1995
(St Andrew's Bay)	Mussel				150	Sericano *et al* 1995
(N. Gulf of Mexico)	Catfish				0-15	Macauley 1999
(N. Gulf of Mexico)	Croaker (*Micropogon undulatus*)				0-11	Macauley 1999
(N. Gulf of Mexico)	Hardhead catfish				14-400	McCain *et al* 1996
(N. Gulf of Mexico)	Oyster				44	Wade *et al* 1988
(N. Gulf of Mexico)	Oyster	18	17.7	1.8	45	Sericano *et al* 1990(a)
(N. Gulf of Mexico)	Oyster	25	29	1.5	68	Sericano *et al* 1990(a)
(N. Gulf of Mexico)	Oyster	27	26	2.1	68	Sericano *et al* 1990(a)
(N. Gulf of Mexico)	Oyster	29	31	2.5	80	Sericano *et al* 1990(a)
(N. Gulf of Mexico)	Oyster	2.13	17.3	1.77		Sericano *et al* 1990(b)
(N. Gulf of Mexico)	Oyster	25	29.4	1.49		Sericano *et al* 1990(b)
(N. Gulf of Mexico)	Oyster (*Crassostrea corteziensis*)	<1.4-<2.5	18-22			Sericano *et al* 1995
(N. Gulf of Mexico)	Shrimp				0-1	Macauley 1999
Venezuela (Morrocoy National Park)	Tree-oyster (*Isognomon alatus*)	<0.32-<1.1	<0.4-<1.2	0.52-2.2		Jaffe *et al* 1998

4.1.1.3 ***PCBs***

Only one reported value for PCB residues in sediment was found in the literature. Sediment in the Bay of Chetumal on Mexico's Gulf Coast was analysed and found to contain 2.96 ppb of ΣPCBs (Table 4.2) (Norena-Barroso *et al.*, 1998).

4.1.2 **Gulf of Mexico**

The Gulf of Mexico and the Caribbean Sea are bordered by a number of other countries in addition to Mexico. Inputs of pesticides and other pollutants to the Gulf of Mexico are heavily influenced by discharges from terrestrial sources in North America. The Mississippi River discharges into this water mass and non-point agricultural run-off of pesticides from the Mississippi River drainage basin is a major concern in considering the environmental health of the Gulf (McMillin & Means 1996). It also receives approximately 3,700 wastewater discharges from the US alone. The impact of these discharges on the condition of the sediments and their biota is thought to be significant (Lewis *et al.*,2000). Estuaries, particularly those of rivers draining large watersheds, such as the Mississippi (USA) and the Plate (Argentina) are often the most polluted areas of any coastline.

In a study undertaken as part of the 'Mussel Watch' pollutant biomonitoring programme, sediments from unpolluted coastal areas of the northern Gulf of Mexico were examined. The sediments were found to contain generally low levels of chlorinated pesticides, with the majority being below detection limits. Although use of chlorinated pesticides has largely been banned in the United States, there are reports that their use continues (illegally) in Louisiana (McMillin & Means, 1996).

4.1.2.1 *DDT*

Total DDT concentrations in sediments in the northern part of the Gulf of Mexico exceeded 1,600 ppb in about 12% of samples according to McMillin & Means (1996). Macauley *et al.,* (1999) found ΣDDT residues in sediment reaching 44 ppb as the highest individual value for this compound found in their study, although other researchers (Wade *et al.,* 1998) found up to 454 ppb DDT in sediment from the same area.

4.1.2.2 *Other Organochlorine Pesticides*

Dieldrin concentrations exceeded 0.02 ppb in 43% of sediment samples taken from the northern Gulf of Mexico, and endrin exceeded this value in 23% of samples (McMillin & Means, 1996). Total chlordanes concentrations were three orders of magnitude greater and exceeded 500 ppb in 4% of sediments analysed in the northern Gulf of Mexico. Although it is calculated that less than 2% of atrazine applied to agricultural land in the Mississippi river basin will eventually be discharged into the sea, stream loads near the US Gulf coast were estimated at up to 2,000 kg day^{-1} in 1989. In 1993 mass transport of atrazine was reported to peak at 7,110 kg day^{-1} during summer flooding in 1993, an estimated 80% increase over discharges in 1991 (McMillin & Means, 1996). This is of particular concern when the reported phytotoxicity of atrazine to submerged vascular plants occurs at concentrations in the region of 5 ppb (McMillin & Means, 1996).

4.1.2.3 *PCBs*

PCBs from the US Gulf of Mexico coast ranged from 5-50 ppb, although some sites exhibited higher individual values. PCBs were found in one sample at a concentration of 189 ppb (Wade *et al.,* 1988). These concentrations were similar to those reported in another study by Sericano *et al.,* (1990b). The highest individual value (299 ppb) was reported by Macauley *et al* (1999) from the US Gulf coast (Table 4.2).

4.1.3 Nicaragua

Nicaragua has coastline totalling 910 km, bordering the Pacific Ocean and the Caribbean Sea. A wide band of marshy wetlands, known as the Mosquito coast, faces the Caribbean Sea. The vast majority of Nicaragua's foreign exchange earnings comes from the export of its agricultural produce including coffee, sugar, cotton, bananas and seafood.

Nicaragua has been reported as one of the biggest pesticide importers and users in Central America. DDT, lindane, dieldrin and toxaphene have been deployed by farmers and for vector control (Carvalho *et al.,*1999). The Pacific coast of Nicaragua has many coastal lagoons, semi-enclosed water bodies from which POPs can be slow to flush. The intensive use of pesticides, particularly for growing cotton, has led to the degradation of these coastal water bodies (Carvalho *et al.,* 1999).

4.1.3.1 *DDT*

High levels of total DDTs (270 ppb) were found in coastal lagoon sediment of Estero Naranjo-Pasao Caballos in the Chinandega region on the Pacific coast, an area where there has been extensive use of pesticides for cotton production over many years (Carvalho *et al.,* 1999). Concentrations of total DDTs measured in the Naranjo-P.

Caballos lagoon system are much higher than concentrations reported from other lagoons in the area (4.28-11.45 ppb) where contamination is thought to be at a background level (probably from aerial deposition rather than local application). These lower values are in the same range as those from similar environments in the American continent (Table 4.1) where residues in sediment are usually lie in the concentration range 0-50 ppb (Carvalho *et al.,* 1999).

4.1.3.2 Other Organochlorine Pesticides

Lagoon sediments from the Pacific coast of Nicaragua showed the presence of a wide variety of pollutants including HCB, α-HCH, β-HCH, lindane, heptachlor, aldrin, dieldrin, endosulfans, chlordane and toxaphene as well as PCBs (Table 4.2). As with DDT, the highest concentrations of other organochlorine pesticides were found in the coastal lagoon system of the Chinandega district. Toxaphene was found in 9 of 13 samples taken and reached a maximum concentration of 1,420 ppb in a single sample, with an average value of 800 ppb (Table 4.2) (Carvalho *et al.*,1999). Toxaphene application rates as high as 31 kg ha^{-1} have been reported in the past, until the early 1990s when local production of toxaphene was discontinued and use dropped gradually. In the Chinandega lagoon system, endosulfan residues (up to 1.23 ppb) were higher than in the other lagoons under investigation. Endosulfan use in Nicaragua is relatively recent, and it has been deployed for pest control in coffee, vegetable and pulse crops (Carvalho *et al.,* 1999).

4.1.4 El Salvador

El Salvador lies solely on the Pacific coast of the Central American isthmus and has a relatively short (307 km) coastline compared with some other Latin American nations. As with most other Central American countries, exports consist largely of agricultural produce and these generate the majority of foreign exchange. There are also a number of coastal lagoons and wetlands where shrimp aquaculture is practised. There is, however, a paucity of information on levels of POPs in coastal ecosystems and only one report on environmental contaminants in these areas was found.

4.1.4.1 DDTs

Levels of DDD (49 ppb), DDE (99 ppb) and DDT (49 ppb) were found in the estuary near the town of Acajutla. ΣDDTs (76 ppb) were quite high.

4.1.4.2 PCBs

Two mud samples taken from near Acajutla near the border with Guatemala had accumulated PCB concentrations (1,137 ppb) one order of magnitude greater than similar samples from California. These represent the highest individual values for PCBs reported in sediments from Latin America. Such high concentrations of PCBs are of environmental concern given the potential toxicity of these compounds (Michel & Zengel, 1998).

4.1.5 Brazil

Brazil is the largest country in Latin America and has a coastline that stretches 7,491 km along the South Atlantic from its border with French Guiana in the north to Uruguay in the south. There is a considerable amount of heavy industry, and forty deep water ports, on the Brazilian coast and environmental pollution, particularly in

such coastal cities as São Paulo, the world's second largest conurbation (17 million inhabitants) is a growing concern. It is surprising, therefore, that only two substantive reports on POPs in coastal ecosystems were found in the literature, both concerning Todos os Santos.

Todos os Santos is the largest bay along the Brazilian coast with a surface area of 1,100 km^2. There has been increasing urbanisation, industrial growth and exploitation of its natural resources particularly since the 1960s. By 1990 approximately 200 industries lined its shores (Porte *et al.,* 1990). The Bay's natural resources are coming under increasing environmental pressure from both industrial and agricultural pollutants.

4.1.5.1 ***DDT***

A recent study quantified the presence of organochlorine pesticides in Todos os Santos sediments (Tavares *et al.,* 1999). The results of this study were particularly interesting in light of Brazil's banning of organochlorine insecticides in 1985, (although exceptions are in existence for disease vector control). Of the compounds analysed, DDT and its metabolites (Tavares *et al.,* 1999) were found in the highest concentrations both in molluscs and sediments (Tables 4.1 & 4.3).

Reported concentrations of DDT+DDE in Todos os Santos sediments collected in 1994/5 had risen 15-fold on average since previous sampling had taken place in 1985. Tavares *et al.,* (1999) demonstrated that DDT was present in some sediment samples, particularly in the eastern part of the bay close to an industrial centre; in the north-west, near a sugar cane plantation and a pulp mill; and in the southwest where palm oil is grown. Here p,p'-DDT reached concentrations up to 22 ppb. In Mutá p,p'-DDT concentrations of 34 ppb were found. Using the ratio of DDT/DDE the authors calculated that DDT use had taken place a number of times after 1990, despite the ban on its use. They suggested that the chemicals may have been obtained from old government stock or through smuggling (Tavares *et al.,* 1999).

4.1.5.2 ***Organochlorine Pesticides***

The same study of Todos os Santos included analysis for other organochlorine compounds. At some sites significant concentrations of endrin and dieldrin were found in sediments. Lindane was also found in sediments at several sites although concentrations were low. Highest concentrations of all organochlorines studied were found in sediments from the area of Mutá, close to an oil palm plantation (Table 4.2) (Tavares *et al.,* 1999).

4.2 Coastal Biota

The deleterious effects of pesticides to biota are well documented and can result in poor reproductive success in both marine and coastal species. Crustaceans and fish, in particular, appeared to be very sensitive to the presence of organochlorines (Páez-Osuna *et al.,* 1998) and the conflicting resource demands of agricultural and shrimp aquaculture are liable to become more severe unless measures are taken to restrict inputs of pesticides to agricultural watersheds, particularly near the coast.

The native fauna of Latin American wetlands come under combined pressure from these conflicting economic activities and are thus doubly threatened.

The use of sentinel organisms is now an accepted method for long term monitoring of environmental pollution. The 'Mussel Watch' programme uses predominantly mussels (usually *Mytilus* sp.) and oysters to monitor selected pollutants in coastal environments, but mussels and oysters do not occur regularly in tropical waters (Porte *et al.*, 1990) where other bivalve species are used in order to acquire data.

4.2.1 Mexico

It has already been mentioned that the lagoon systems of the Mexican coasts, both Pacific and Gulf of Mexico, are important for fisheries and more recently for aquaculture. The inputs of POPs into these lagoons is not only of concern for the natural habitat, therefore, but also commercially and with regard to human health. Benthic (bottom) feeders and omnivorous species are perhaps the most directly exposed and accumulate significant concentrations of POPs, although species high in the food chain also accumulate POPs through biomagnification. Recently the shrimp fisheries in the Mexican state of Sinaloa (Fig. 1) have been experiencing increasing mortality (Reyes *et al.,* 1996) and it is thought that high concentrations of these compounds may be responsible for this. Sinaloa is one of the predominantly agricultural areas in Mexico's north west region and pesticides are used here extensively for crop protection (Reyes *et al.,* 1996).

4.2.1.1 DDTs

The presence of DDT compounds in shrimp for human consumption is clearly a concern for both shrimp farmers and potential consumers, particularly in the light of reports of increased shrimp mortality in the Sinaloa region. Investigations, however, gave rise to measurable quantities of DDE only amongst the DDT compounds, and this was found only in the exoskeleton. Residues were at their highest during the dry season when agricultural residues are more highly concentrated (Albert, 1996).

DDT and its derivatives have been found in bivalves from the north-west Mexican coast (Páez-Osuna *et al.,* 1998; Reyes *et al.,* 1996). But only low levels of DDT (<2.5 ppb) were found in organisms collected from the lagoon systems around the increasingly industrial town of Mazatlán (Table 4.3) (Martin & Gutierrez-Galindo, 1989).

The highest concentrations of DDT in Mexican biota were measured in Tampico (100 ppb), Laguna del Ostion (170 ppb), Puerto Madero (130 ppb) and Bahía Ventosa (180 ppb) (Table 4.3) (Sericano *et al.,* 1990a).

4.2.1.2 Other Organochlorine Pesticides

Residues of chlordane, lindane, aldrin, dieldrin have been found in shrimp in various coastal lagoons in Sinaloa as a result of runoff from nearby agricultural regions. These compounds were present at concentrations that could affect shrimp respiration and increase stress and it could be that combinations of pollutants were the root cause of reported increases in shrimp mortality (Reyes *et al.,* 1996). Heptachlor and

heptachlor epoxide have also been detected in bivalves from the NW Mexican coast (Table 4.4) (Albert, 1996; Gold-Bouchot *et al.*, 1995) .

A study carried out on crustaceans (*Penaeus vannamei*) and fish (*Lutjanus novemfasciatus*) from one coastal lagoon in Chiapas State, Mexico found five OC compounds in the fish (heptachlor, heptachlor epoxide, endosulfan, endosulfan sulphate and aldrin) and none in the shrimp tissues, although δ-HCH and heptachlor were found in the exoskeleton as had been the case with DDT. Similarly too, heptachlor was found at the highest concentrations in fish during the dry season (Albert, 1996).

Table 4.4: Range of concentrations or concentrations of organochlorine pesticides and PCBs found in Latin American non-mammalian biota (ng g^{-1})(ppb). Values are in wet weight, unless otherwise stated.

COUNTRY	Species	Aldrin	α-HCH	β-HCH	δ-HCH	Lindane	ΣHCHs	Cis-chlordane	trans-Chlordane	ΣChlordane	DEHP	Dieldrin	Endosulfan	Endrin	HCB	Heptachlor	Heptachlor epoxide	Σheptachlor	Mirex	cis-Nonachlor	trans-Nonachlor	Oxychlordane	Toxaphene	PCBs	Reference
Argentina (Rio de la Plata)	Asiatic clams (lipid)		1,000-11,500	600-3,700		1,900-20,200	3,600-35,300	4,700-12,400	19,000-32,900	37,700-59,100					200-2,600	2,000-7,200	3,800-7,000				3,900-7,400			500-11,600	Colombo *et al.*, 1995
	Asiatic clams																							0.01-871.3	Colombo *et al* 1997
	White croaker (*Micropogonias furnieri*) - gonad lipid female	138.65	43.19	77.93	72.61	186.85		30.67	62.13			50.55		18.78	60.88	115.18	131.3				30.67			34,647.90	Lanfranchi *et al* 1998
	White croaker (*Micropogonias furnieri*) - gonad lipid male			53.85	62.05	38.55		7.17	20.96			16.34		10.49	9.45	16.99	131.65				3.8			523.3	Lanfranchi *et al* 1998
	White croaker (*Micropogonias furnieri*) – subcutaneous fat female		0.19	0.57	0.4	1.14		0.26	0.6			0.59		0.24	0.16	0.24	0.75			0.32	0.08			472.8	Lanfranchi *et al* 1998
	White croaker (*Micropogonias furnieri*) – subcutaneous fat male		4.23	13.02	9.17	25.93		5.85	13.71			13.38		5.56	3.59	5.56	17.21			7.22	1.76			472.8	Lanfranchi *et al* 1998
	White croaker (*Micropogonias furnieri*)-liver lipid female		2.3	8.83	2.06	11.2		2.98	9.83			21.59		6.54	1.39	1.95	3.49			1.69	1.6			177.6	Lanfranchi *et al* 1998
	White croaker (*Micropogonias furnieri*)-liver lipid male	53.1	5.9	8.46	10.1	20.47		13.93	18.22			8.28		6.7	7.28	17.53	18.94			4.54				4,317	Lanfranchi *et al* 1998
Brazil	Mussel					0.54									0.59										Tavares *et al.*, 1999
	Mussel					0.12									0.12										Tavares *et al.*, 1999
	Mussel	5.27																							Tavares *et al.*, 1999

COUNTRY	Species	Aldrin	α-HCH	β-HCH	δ-HCH	Lindane	ΣHCHs	Cis-chlordane	trans-Chlordane	ΣChlordane	DEHP	Dieldrin	Endosulfan	Endrin	HCB	Heptachlor	Heptachlor epoxide	Σheptachlor	Mirex	cis-Nonachlor	trans-Nonachlor	Oxychlordane	Toxaphene	PCBs	Reference
El Salvador	Oyster															146								405	Michel & Zengel 1998
Gulf of Mexico	Amber jack (*Seriola dumerili*)										3													68	Giam *et al.*, 1978
	Blue crab (Callinectes sapidus rathpun)										3-20													10-20	Giam *et al.*, 1978
	Cabbage head jellyfish										1													1	Giam *et al.*, 1978
	Catfish (*Galeichthys felis*)										<1													41	Giam *et al.*, 1978
	Catfish (*Galeichthys felis*)										<1													9	Giam *et al.*, 1978
	Catfish (*Galeichthys felis*)										4													12	Giam *et al.*, 1978
	Catfish (*Galeichthys felis*)										8													11	Giam *et al.*, 1978
	Catfish (*Galeichthys felis*)										<1													20	Giam *et al.*, 1978
	Clam											2.9													Kennicut *et al.*, 1988
	Crab											2.1													Kennicut *et al.*, 1988
	White croaker (*Micropogon undulatus*)										<1													28	Giam *et al.*, 1978
	White croaker (*Micropogon undulatus*)										3													23	Giam *et al.*, 1978
	Drum fish (*Pogonias cromis*)										1													55	Giam *et al.*, 1978
	Eel (*Anguilla sp*)										2													15	Giam *et al.*, 1978
	Fish																							11	Kennicut *et al.*, 1988
	Fish											15.2												203	Kennicut *et al.*, 1988
	Fish & shrimp																							66	Kennicut *et al.*, 1988
	Fish & shrimp																							25	Kennicut *et al.*, 1988
	Fish, crab & oyster											9													Kennicut *et al.*, 1988
	Grouper																							33	Kennicut *et al.*, 1988
	Mesopelagic fish																							25	Kennicut *et al.*, 1988
	Molluscs & fish																		139						Kennicut *et al.*, 1988

COUNTRY	Species	Aldrin	α-HCH	β-HCH	δ-HCH	Lindane	ΣHCHs	Cis-chlordane	trans-Chlordane	ΣChlordane	DEHP	Dieldrin	Endosulfan	Endrin	HCB	Heptachlor	Heptachlor epoxide	Σheptachlor	Mirex	cis-Nonachlor	trans-Nonachlor	Oxychlordane	Toxaphene	PCBs	Reference
Gulf of Mexico	Morey eel (*Muraena sp.*)										3													77	Giam *et al.*, 1978
	Oyster											0.9											200	55	Kennicut *et al.*, 1988
	Oyster											8.9													Kennicut *et al.*, 1988
	Plankton																							95	Kennicut *et al.*, 1988
	Plankton											12												84	Kennicut *et al.*, 1988
	Pompano (*Trachinotus carolinus*)										2													6	Giam 1978
	Ribbon fish (*Equetus lanceolatus*)										4													20	Giam 1978
	Sand trout (*Cynoscion nothus*)										9													11	Giam 1978
	Sand trout (*Cynoscion nothus*)										<1													10	Giam 1978
	Sand trout (*Cynoscion nothus*)										1													6	Giam 1978
	Sand trout (*Cynoscion nothus*)										2													8	Giam 1978
	Shark (*Carcharinus falciformis*)										<1-2													94-4,300,000	Giam 1978
	Shrimp											1.8													Kennicut 1988
	Shrimp (*Squilla empusa*)										8													10	Giam 1978
	Skate (*Raja texana*)										8													22	Giam 1978
	Spade fish (*Chaetodipterus faber*)										4-20													35-670	Giam 1978
	Spade fish (*Chaetodipterus faber*)										2													33	Giam 1978

COUNTRY	Species	Aldrin	α-HCH	β-HCH	δ-HCH	Lindane	ΣHCHs	Cis-chlordane	trans-Chlordane	ΣChlordane	DEHP	Dieldrin	Endosulfan	Endrin	HCB	Heptachlor	Heptachlor epoxide	Σheptachlor	Mirex	cis-Nonachlor	trans-Nonachlor	Oxychlordane	Toxaphene	PCBs	Reference
Gulf of Mexico	Starfish (*Luidia clathrata*)										135													1	Giam 1978
	Sting ray (*Sasytis sabina*)										12													10	Giam 1978
	Trout (*Cynoscion nebulosus*)										4													23	Giam 1978
Honduras	Fish	3	3			11						10	3	197		270									Kammerbauer & Moncada 1998
Mexico	Oyster (*Crassostrea.corteziensis*)																							(101) 2.8-3.1	Paez-Osuna 1998
	Oyster (*Crassostrea.corteziensis*)																							(153) 3.9-4.3	Paez-Osuna 1998
	Clam					1.21																			Gold-Bouchot 1993
	Mussel (*M.strigata*)												140												Paez-Osuna 1998
	Mussel (dry wt.)	0.98								23.08		0.29	8.23	5.32	1.68									7.56	Gold-Bouchot 1995
Mexico	Mussel (dry wt.)					1.25																			Gold-Bouchot *et al.*, 1993
	Oyster (dry wt.)	0.98								104		0.29	111	5.32	1.97			0.63						12.99	Gold-Bouchot *et al.*, 1993
	Oyster (dry wt.)	5.26				0.66																			Gold-Bouchot *et al.*, 1993
	Oyster (dry wt.)	6.56				0.45								56.7											Gold-Bouchot *et al.*, 1993
	Oyster (dry wt.)	0.54								12.13			9.84	8.36	1.04			0.17						2.77	Gold-Bouchot *et al.*, 1993
	Oyster (*Crassostrea virginica*)	5.92				0.55																			Paez-Osuna *et al.*, 1998
	Shrimp (dry wt.)					0.08				0.54		0.28	0.94	0.44	1.18									0.74	Gold-Bouchot *et al.*, 1995
	Shrimp (*P.vannamei; P stylirostris*)						0.11-1.71					0.62-3.87													Paez-Osuna *et al.*, 1998
(Alvarado lagoon)	Oyster (*Crassostrea virginica*)	6.61		2.08									1.22	7.95			2.91	2.17							Albert 1996
(Alvarado lagoon)	Oyster (*Crassostrea virginica*)												14.93												Albert 1996

COUNTRY	Species	Aldrin	α-HCH	β-HCH	δ-HCH	Lindane	ΣHCHs	Cis-chlordane	trans-Chlordane	ΣChlordane	DEHP	Dieldrin	Endosulfan	Endrin	HCB	Heptachlor	Heptachlor epoxide	Σheptachlor	Mirex	cis-Nonachlor	trans-Nonachlor	Oxychlordane	Toxaphene	PCBs	Reference
(Alvarado lagoon)	Oyster (*Crassostrea virginica*)												17.65												Albert 1996
(Carmen lagoon)	Oyster (*Crassostrea virginica*)	2.56		0.62									0.83	1.5			2.1	2.49							Albert 1996
(Machona lagoon)	Oyster (*Crassostrea virginica*)	1.61		0.97									8.78	10.61			1.71	3.24							Albert 1996
(Mazatlan Sinaloa)	Oyster (*Crassostrea corteziens*)																								Albert 1996
US (northern Gulf of Mexico)	Catfish	0-23				0-15	0-6	0-4				0-84	0-3	0-12		0-49	0-4		0-73		0-4		0-836	0-63	Macauley *et al.*, 1999
	White croaker (*Micropogon undulatus*)	0-3				0-1	0-82	0-9				0-28	0-2	0-24		0-2	0-4		0-94		0-6		0-5325	0-95	Macauley *et al.*, 1999
	Hardhead catfish									14-55														55-1,700	McCain *et al* 1996
US (northern Gulf of Mexico)	Oyster					0.98				20.7		8.44				2.96			1.25					172	Wade *et al* 1988
	Oyster							10.9		24.1						0.51	2.71				10				Sericano *et al* 1993
	Oyster							14.1		29.5						0.54	3.3				11.6				Sericano *et al* 1993
	Oyster							9.76		21.7						0.49	2.44				8.98				Sericano *et al* 1993
	Oyster							7		16.3						0.78	1.25				7.29				Sericano *et al* 1993
	Oyster							5.81		15.3						1.34	2.63				5.55				Sericano *et al* 1993
	Oyster							11.4		25.4						0.58	2.95				10.5				Sericano *et al* 1993
	Oyster							10.2		24.2						0.74	1.5				11.8				Sericano *et al* 1993
	Oyster							7.74		19.4						1.36	2.57				7.72				Sericano *et al* 1993
	Oyster	0.28				1.04		10.9				8.64			0.32	0.51	2.71		1.4		10			173	Sericano *et al* 1990(b)
	Oyster	0.34				1.74		14.1				6.08			0.36	0.54	3.3		1.38		11.6			134	Sericano *et al* 1990(b)
	Oyster																							100-630	Sericano *et al* 1995
US (northern Gulf of Mexico)	Shrimp	0-5				0-0	0-4	0-2				0-2	0-3	0-13		0-8	0-4		0-45		0-1		0-0	0-15	Macauley 1999
Venezuela (Morrocoy National Park)	Tree-oyster (*Isognomon alatus*)							<0.13-<0.45	<0.22-<0.74											<0.21-<0.72	<0.12-<0.40	<0.25-<0.83		1.8-12	Jaffe *et al* 1998

4.2.1.3 *PCBs*

PCBs have been detected in biota from Sinaloan lagoons (Albert, 1996) and at the other end of the Mexican Pacific coast, low levels of PCBs (3-4 ppb) were found in bivalves from an estuary near Mazatlán (Martin & Gutierrez-Galindo, 1989). The city has a growing population which had reached nearly half a million by the beginning of the 1990s and is located at the mouth of the estuary. The estuary itself is less than 1 km wide and has a length of approximately 15 km. It receives most of its freshwater inputs from urban and agricultural runoff (Martin & Gutierrez-Galindo, 1989). Mazatlán has a number of industries, but relatively few organochlorine pesticides or PCBs were found in the organisms gathered in the estuary (Martin & Gutierrez-Galindo, 1989).

On the Gulf coast, oysters from the Laguna Madre had significantly elevated levels of PCBs (110 ppb) when compared with other sites in Latin America (Sericano *et al.*, 1995).

4.2.2 Gulf of Mexico and the Caribbean Sea

The Gulf of Mexico is bordered by two mainland nations, the USA in the north and Mexico in the west. South of this lies the Caribbean Sea, along the coast of which lie Belize, Honduras, Nicaragua, Costa Rica, Panama, Colombia and Venezuela. As with the literature on sediments, however, the majority of research appears to have taken place on the US and Mexican coasts, with only scattered information on residues in biota from the other littoral nations bordering the Caribbean Sea.

A number of studies on organochlorine pesticide residues in fish and shellfish have taken place on the US Gulf Coast. Generally, reported residue levels were relatively low in the majority of areas, although where industry is found e.g. Tampa Bay, or around the Mississippi delta, considerably elevated concentrations of POPs have been detected. Scientists continue to express concern for the well-being of aquatic ecosystems in the Gulf of Mexico despite improved legislative controls on the release of toxins to the environment (McMillin *et al.*, 1996; Giam *et al.*, 1978).

Contaminant concentrations in fish and shellfish in the northern Gulf of Mexico (Tables 4.3 & 4.4) were reported as being low for all pesticides tested (McMillin & Means, 1996). The persistence of these compounds and their known carcinogenic and reproductive effects, however, engender continued concern for the well-being of aquatic ecosystems in the Gulf of Mexico (McMillin & Means, 1996).

In the northwestern Gulf of Mexico in areas bordering the continental United States samples of biota from the Mississippi delta were the most highly contaminated and contained generally higher concentrations of all pollutants than did samples from elsewhere along the Gulf coast (Giam *et al.*, 1978).

Tampa Bay is the largest estuary in Florida with waters discharging into the northern Gulf of Mexico. Two major cities (Tampa and St Petersburg) lie on the estuary and are responsible for discharging a variety of wastes into the Bay. The number of

aquatic biota of certain species in the bay has been declining, including spotted seatrout and bait shrimp, but it has not so far been clear why this should be the case. It has been speculated that loss of habitat (sea grass) may be a factor in this (McCain *et al.,* 1996). If so, this could be an indirect result of pesticide pollution as some organochlorine compounds are toxic to this species.

4.2.2.1 ***DDT***

In the Gulf of Mexico, organisms affected by agricultural run-off contained the highest concentrations of DDT. Overall residues had, however, fallen to one fifth of former levels (from a mean of ~50 ppb to ~10 ppb) in the six year period between the two research projects (1971-1978) (Giam *et al.,* 1978; Albert, 1996). Other later studies, however, have indicated that such encouraging figures are not true for the whole Gulf coast. Generally, biota from polluted areas such as Mobile Bay, Alabama (160 ppb), Choctachobee (960 ppb) and St Andrew's Bays, Florida (150 ppb) had elevated DDT concentrations (approximately 2 times background for the area). Elevated tissue residues were also detected in biota from Brazos River and Galveston Bay (Texas) and the Mississippi river (Louisiana) (McCain *et al.,* 1996). One of the highest average total DDT concentrations from the whole of the US Gulf of Mexico coast was found in samples from close to the mouth of the Mississippi River (160 ppb) which drains a large part of continental USA (Table 4.3).

Oysters accumulated DDT at 10-20 times the rate of surrounding sediments giving rise to concentrations generally in the range <1-10 ppb, although very high concentrations, up to 4,000 ppb, were detected in individual samples (Wade *et al.,* 1988).

4.2.2.2 ***Organochlorine Pesticides***

Having undertaken a study examining DDT in mussels in 1990, Sericano *et al.,* (1993) undertook a further study as part of the 'Mussel Watch' programme in 1993. This later study examined the same organisms but for different organochlorine compounds and also compared values over time. In 1986 concentrations for total chlordane ranged from 2-175 ppb with a mean value of 24.1 ppb. During 1987 the overall average value for chlordane had increased to 29.5 ppb (range 2.12-590 ppb). In 1988 the total chlordane average concentration had dropped again to 21.7 ppb (1.29-132 ppb). This trend continued during 1989 (16.3 ppb range 1.37-159 ppb) and 1990 (15.3 ppb range <1-69.4 ppb) (Table 4.4) (Sericano *et al.,* 1993). Highest residues were, not unsurprisingly, found in oysters collected near highly populated urban areas. Mean concentrations more than three times the average were measured in samples from Galveston Bay, Texas; Mississippi Sound, Mississippi; and Choctawhatchee, Tampa and Charlotte Bays in Florida, all densely populated areas. This may well reflect the fact that, since 1975 most chlordane use in the US has been restricted to underground termite control in houses (Table 4.4) (Sericano *et al.,* 1993).

In the northern Gulf of Mexico the majority of sites studied for POPs residues in mussels and other bivalves show concentrations of chlordane-related compounds (comprising α-chlordane, trans-nonachlor, heptachlor and heptachlor epoxide) in the range 2.8-9.6 ppb. The highest residues were found (up to 76 ppb) near highly populated areas which tended to be to the east of the Mississippi delta. Generally the

concentrations appear to be falling over time as legislative restrictions on these compounds begin to make an impact (Sericano *et al.,* 1995).

The highest concentrations of dieldrin were detected in Gulf of Mexico fish and shellfish affected by agricultural runoff (Table 4.4) (Albert, 1996).

4.2.2.3 *PCBs*

Fifteen sites on the northern Gulf of Mexico coast showed concentrations of PCBs in bivalves higher than 100 ppb (range 100-630 ppb) (Sericano *et al.,* 1995). In general, oysters were found to accumulate PCBs 10 to 20 times more strongly than the surrounding sediments. Typical concentrations in fish ranged from 10-200 ppb wet weight in fish, although unusually high concentrations of 4,000 ppb PCBs were found in a shark (Table 4.4) (Wade *et al.,* 1988). Other researchers have reported ranges of 72-90 ppb in Gulf of Mexico organisms (Albert, 1996). As with bivalves, fish from the more polluted areas exhibited elevated PCB concentrations in their tissues. Red Drum (*Scieaenops ocellatus*) in particular exhibited elevated levels of PCBs, at least 2.5 times higher than those found in other species examined during the study. This was thought to be as a result of its predatory feeding strategies. Generally the most polluted fish were collected from the most industrially impacted region of the Bay, near the town of Hillsborough, and the level of contamination was correlated with contamination of the bottom sediments in the area (McCain *et al.,* 1996).

4.2.2.4 *Organotin Compounds*

Organotins are a group of organometallic compounds first synthesised in the 1930s to protect the hulls of boats and ships from attaching marine organisms (Tanabe, 1999). Vessels and boats coated with TBT are the main source of TBT in the aquatic environment (Cantillo *et al.,* 1997). TBT is actively toxic to many aquatic species, but, more importantly, very low concentrations of TBT can exert sublethal effects on reproduction causing a decline in populations. Highest concentrations of TBT occur in marinas, harbours and shipping channels. Field observations indicate that where TBT concentrations are in excess of 0.1 ppb, marine macrofauna are often absent altogether (Stewart & de Mora, 1990). TBT is strongly bioaccumulated probably as it is highly lipophilic with bioaccumulation factors ranging from 1,000 to 30,000 and has been observed in a number of marine biota including mussels, oysters, salmon, scallops, algae and eelgrass (Stewart & de Mora, 1990).

In southern Florida on the Gulf of Mexico coast levels of TBT in mussels have been decreasing since the 1988 passage of the Organotin Paint Control Act. Higher concentrations still tend to be found at sites with high human populations, but continue the overall downward trend in concentrations continues (Cantillo *et al.,* 1997).

4.2.3 Honduras

In Honduras, as with much of the remainder of central America, agricultural policies are oriented towards increasing exportable cash crops. This is concomitant with increasing use of agricultural pesticides. In 1996 Honduras imported about 11,000 tons of biocides as compared with half of that amount in 1992. The huge increase in land under cultivation has led to potential resource conflicts where agricultural runoff

is carried into the estuarine waters of the Gulf of Fonseca on the Pacific coast border with El Salvador (Kammerbauer & Moncado, 1998).

4.2.3.1 ***DDT***

Kammerbauer and Moncado (1998) reported DDT concentrations averaging 43 ppb in bivalves from the Zamorano valley (Table 4.3).

4.2.3.2 ***Organochlorine Pesticides***

Heptachlor (270 ppb) and endrin (197 ppb) were the most common contaminants of fish tissue at concentrations 10-100 times that of other organochlorine pesticides analysed in a study by Kammerbauer and co-workers (1998).

4.2.4 **Nicaragua:**

4.2.4.1 ***DDT***

Nicaraguan bivalves taken as part of the 'Mussel Watch' biomonitoring exercise contained some of the highest residues of DDT found in Latin American samples. The samples collected from Isla de Aserradores contained 200 ppb of DDTs (Table 4.3) (Sericano *et al.,* 1990a).

90% of fish samples taken from the coastal lagoons of Nicaragua contained DDT (as compared with 17% of sediment samples) which suggested to the researchers that bioaccumulation of this compound was taking place (Carvalho *et al.,* 1999).

4.2.5 **Venezuela**

Venezuela lies on the north coast of the South American continent and borders both the Caribbean Sea and the Atlantic Ocean. Its coastline stretches for 2,800 km. The country is rich in natural resources such as petroleum, natural gas, coal, iron, gold, bauxite, zinc and diamonds. The extraction of these resources can impact heavily on coastal ecosystems. The one study on coastal pollution found in the literature, however, measures POPs residues in wetlands that are part of a national park, and, therefore, in a relatively undisturbed part of the coast. It is not surprising, therefore, that relatively low concentrations of pollutants were determined, and these levels should not be taken as representative of levels of contamination in enezuela as a whole.

A study on the concentrations of chlorinated pesticides and PCBs in the flat tree-oyster from the Morrocoy National Park in Venezuela detected several pollutants. Chlorinated pesticides were detected at very low concentrations, some of the lowest measured on the coast of mainland South America (Table 4.4) (Jaffé *et al.,* 1998).

4.2.5.1 ***DDT***

DDT and its degradation products were occasionally detected in flat tree-oysters from the Morrocoy National Park in concentrations up to 2.2 ppb (Table 4.3) (Jaffé *et al.,* , 1998).

4.2.5.2 *Other Organochlorine Pesticides*

Components of technical chlordanes such as γ- and α-chlordane were occasionally detected in flat tree-oysters taken from the Morrocoy National Park in Venezuela in concentrations up to 2.2 ppb (Jaffé *et al.,* 1998). These values are similar to data reported from other locations in Venezuela taken as part of the International Mussel Watch Program (Jaffé *et al.,* 1998) and compare favourably with the remainder of Latin America where values were generally in the region of 20 ppb (Table 4.4).

4.2.5.3 *PCBs*

The highest PCB concentration reported in flat tree-oysters from the Morrocoy National Park was 12 ppb. This value was similar to concentrations found in organisms in other parts of Venezuela (Jaffé *et al.,* 1998) and not dissimilar from residues found in other parts of Latin America (Table 4.4).

4.2.6 El Salvador

4.2.6.1 *DDT*

There were detectable levels of DDT and its degradation products in both oysters and sediments collected near Acajutla in El Salvador. p,p'-DDE was the only compound consistently detected in all samples. In general levels of total DDT in oysters were within twice the background level of similar species from California (50 ppb), although one sample contained 10 times this amount (Michel & Zengel, 1998).

This contrasts strongly with the a study by Sericano *et al* (1990a) who reported that some of the highest values of DDTs in Latin America (180 ppb) were found in bivalves from El Salvador (Table 4.3).

4.2.6.2 *Organochlorine Pesticides*

A study of organochlorine pesticides in oysters and sediments near Acajutla in El Salvador found that concentrations were generally below detection limits (Table 4.4) (Michel & Zengel 1998). Heptachlor was found in oysters from Las Flores at 146 ppb (Michel & Zengel, 1998).

4.2.6.3 *PCBs*

The study by Michel & Zengel (1998) reported that PCBs were generally below detection limits in samples taken near Acajutla, except for one oyster sample containing 405 ppb, comparable with the median concentration in mussels from harbours and bays in southern California (Michel & Zengel, 1998).

4.2.7 Brazil

4.2.7.1 *DDT*

The same study that examined DDE/DDT ratios in sediments in Todos os Santos Bay also investigated this ratio in crabs and bivalves. DDT and metabolites had the highest residues in these organisms, up to 49 ppb (Table 4.3). The researchers regarded the residues found as being average for the South American continent (Tavares *et al.,* 1999). There has, however, been a 15-fold increase in DDT residues in benthic biota in parts of the Bay as a result of anti-malarial campaigns utilising DDT, and consumption of edible mollusc species can lead to human intakes of DDT

up to 589 ppb day^{-1}. The researchers also cited illegal use of DDT as being partially responsible for increased DDT residues in resident biota (Tavares *et al.,* 1999).

Bivalves collected from Fortaleza (130 ppb) and Recife (120 ppb) in Brazil contained some of the highest DDT residues found in bivalves collected as part of the 'Mussel Watch' biomonitoring exercise in Latin America (Sericano *et al.,* 1995).

4.2.7.2 Other Organochlorine pesticides

High levels of PCBs were found in bivalves from Recife (280 ppb) and Guanabara Bay (210 ppb) in Brazil (Sericano *et al.,* 1995).

4.2.8 Argentina

The Rio de la Plata (River Plate) is the second largest river draining the South American continent (after the Amazon) with a basin of more than 3 million km^2. The estuary itself is heavily populated. More than one third of the population of Argentina (~33 million) live on the 80 km stretch between Buenos Aires and La Plata City. The heavily industrialised area near La Plata is an important source of chlorinated compounds and the fishes and bivalves in the estuary reflect this heavy loading (Colombo *et al.,* 1995).

Marine teleost (bony fish) species are particularly susceptible to reproductive disruption through the presence of organochlorine compounds in the gonads. The viability of the hatch is reduced and this can lead to a long term decline in numbers, followed eventually by extinction of the species in that area (Lanfranchi *et al.,* 1998). There is concern that the commercially important species of white croaker (*Micropogonias furnieri*) is declining in the Rio de la Plata in Argentina at Samborombón Bay. Catches have declined considerably over recent years and it was feared that high levels of organochlorine compounds might be affecting white croaker reproduction. Analyses of white croaker tissue found that organochlorine compounds were accumulating in the liver, gonads and subcutaneous fat of this species (Table 4.4) (Lanfranchi *et al.,* 1998). Samborombón Bay receives discharge waters from both industrial and agricultural areas and water-borne chemicals are dispersed throughout the estuary by tidal currents and prevailing winds (Lanfranchi *et al.,* 1998).

4.2.8.1 DDT

During the period 1986 to 1993 there was a considerable drop (to approximately one-third) in DDT residues in Asiatic clams in the Rio de la Plata (Colombo *et al.,* 1995), although residues reported in this report were still relatively high at 100 ppb for ΣDDTs (Table 4.3).

4.2.8.2 Other Organochlorine Pesticides

Total chlorinated pesticide concentrations in Rio de la Plata Asiatic Clams (7-315 ppb) (Table 4.4) are very much greater than those reported for bivalves from unpolluted areas in Brazil (1.2-5.6 ppb) which may be representative of baseline values due solely to atmospheric transport (Colombo *et al.,*1995). Levels of lindane in the same species did not decrease over the period from 1986-1993 (Colombo *et al.,* 1995).

4.2.8.3 *PCBs*

Total PCB concentrations in Rio de la Plata Asiatic clams (up to 11,600 ppb lipid) (Table 4.4) are very much greater than those reported for bivalves from unpolluted areas in Brazil (2.5-10 ppb) which may be representative of baseline values due solely to atmospheric transport (Colombo *et al.,* 1995).

Poor embryological viability is associated with the presence of high levels of PCBs in fish eggs, and it is likely that the high values found in the tissues of the white croaker could be affecting reproduction in this species. Their tissues contained detectable residues of 25 PCBs in livers and gonads and 18 in skin and subcutaneous fat. Total tissue PCB concentrations ranged from 20.7 to 363.8 ppb wet weight and from 177 to 34,647 ppb lipid (Lanfranchi *et al.,* 1998).

Two sites on the coast of Argentina, Hudson (3,800 ppb) and Atalaya (1,500 ppb) exhibited significantly elevated concentrations of PCBs in mussels (Sericano *et al.,* 1995).

4.2.9 Remainder of Latin America

4.2.9.1 *DDT*

In Central and South America total DDT in bivalve samples show a similar range to that found in the northern Gulf of Mexico, although the distribution is less uniform and there are more locations with concentrations over 100 ppb, particularly in tropical and sub-tropical South America. Some of the highest concentrations of DDT in bivalve tissue were measured Guayaquil (160 ppb) in Ecuador, Valparaiso (140 ppb) in Chile and Hudson (210 ppb) in Argentina (Table 4.3) (Sericano *et al.,* 1995).

4.2.9.2 *Organotin compounds*

TBT is associated at very low concentrations with the induction of imposex (or pseudohermaphrodatism) on female dioecious gastropods. Imposex is currently documented in over 118 species of 63 genera worldwide. In southern Chile populations of *Nucella crassilabrum* are found throughout the intertidal rocky shore. Muricids including *Concholepas concholepas, Thais chocolata,* and *C. giganteus* are collected both for local consumption and for export. Imposex was found to be widespread in open coastal areas and regions of limited boating activity as well as in harbour facilities (Gooding *et al.,* 1999).

4.2.9.3 *PCBs*

High PCB concentrations were found at Commander's Bay (440 ppb) in Aruba; Punta Arenas (170 ppb) in Chile; Arroyo Parejas (130 ppb) in Argentina; and Callao (120 ppb) in Peru. The lowest PCB concentrations in mussels were, in general, found in Central America (Sericano *et al.,* 1995).

5 MARINE ENVIRONMENT

5.1 Air

POPs have often been detected in open ocean systems. It is thought that atmospheric transport processes are responsible for between 80-99% of the loadings found in major oceans such as the Atlantic and Pacific. Globally, riverine transport is a minor factor, impacting mainly coastal areas. (Bidleman, 1999).

This section discusses POPs in air, seawater and marine mammals. Very few data appeared to be available on levels of POPs in air and seawater and research was mainly focussed on the Gulf of Mexico.

5.1.1 DDT

A 1980 study reported that concentrations of ΣDDT in Gulf of Mexico air were similar to those reported for air over the North Atlantic (Giam *et al.*, 1980). Indeed, organochlorine concentrations in the air above both southern and northern oceans have remained constant even in recent years despite bans on their use in most of the Northern Hemisphere (Loganathan & Kannan, 1994), and in restrictions and bans in most countries of the Southern Hemisphere.

Table 5.1: Mean concentration of DDTs and chlorinated pesticides in open ocean air around Latin America (pg m^{-3})

Area	Contaminant								Reference
	DDE	DDT	ΣDDTs	α-HCH	Lindane	ΣHCHs	trans-Nonachlor	ΣPCBs	
Caribbean Sea	6.4	4.6	13	96	27	120	0.2	320	Iwata *et al* 1993
Gulf of Mexico	9.1	22	48	61	16	78	<0.2	160	Iwata *et al* 1993

5.1.2 Other Organochlorine Pesticides

In general HCH levels were highest both in air and seawater when compared with residues of other organochlorine pesticides, although levels were considerably higher in the northern rather than the Southern Hemisphere, as would be expected due to the greater landmasses and industrialisation in the north. In general HCH residues are thought to move primarily from air into seawater, suggesting an eventual oceanic sink for these compounds (Iwata *et al.*, 1993b).

5.2 Seawater

The Gulf of Mexico occupies a basin which is bounded to the north by the US and to the south by the island of Cuba. It connects by the Yucatan strait to the Caribbean

Sea and through the Straits of Florida to the Atlantic Ocean. The Gulf has a surface area of approximately 564,000 km^2 of which 35% is comprised by the relatively shallow waters overlying the continental shelf (Darnell & Defenbaugh, 1990). The Gulf of Mexico receives over two-thirds of the run-off from the continental US and is a semi-enclosed water body. Semi-closed and coastal seas exhibit the slowest clearance rates for organochlorine compounds of all ocean types.

5.2.1 DDT

Iwata and co-workers analysed DDTs in air and seawater from various oceans around the world during 1989-1990. Total DDT was detected in much lower concentrations around Latin America, but also consistently through all the ocean areas surveyed, including those around Latin America. It was also clear that DDT concentrations in air and seawater fell rapidly with increasing distance from land based point sources. Increased relative concentrations of p,p'-DDT at lower latitudes was indicative of higher usage of DDT in tropical areas. p,p'-DDT was the most abundant component in the atmosphere of the South Atlantic and Southern Oceans (Table 5.2) (Iwata *et al.*, 1993a).

Table 5.2: DDT and metabolites in seawater around Latin America (ng ml^{-1})(ppb)

		Contaminant			
Country	Area	DDE	DDT	ΣDDTs	Reference
None	Caribbean Sea	0.500	2.600	3.900	Iwata *et al* 1993
None	Gulf of Mexico			0.006	Sauer *et al* 1989
Mexico	Yavaros Lagoon			7.620	Paez-Osuna *et al* 1998
	Huizache-Caimanero Lagoon			16.400	Paez-Osuna *et al* 1998
	Huizache-Caimanero Lagoon			0.076-1.195	Galindo *et al* 1997
	Coastal			0.03-11	Sauer *et al* 1989
	Agricultural drainage into Gulf of California	0.152	0.388		Albert 1996

Very low concentrations of ΣDDT (0.006 ppb) were detected in open waters of the Gulf of Mexico (Table 5.2) (Sauer *et al.*, 1989).

5.2.2 Other Organochlorine Pesticides

HCB was present in samples of seawater microlayer (a thin 'skin' that floats on the sea surface and that frequently contains the highest concentrations of fat soluble pollutants) from the Gulf of Mexico (Iwata *et al.*, 1993a). Chlordane and nonachlor concentrations in open water have equalised over recent decades between northern and Southern Hemispheres, and this has been blamed on indiscriminate use and disposal of these substances in tropical countries (Iwata *et al.*, 1993a).

Lindane and Chlordane were detected in nearly all seawater filtrate samples taken from the Gulf of Mexico in concentrations of 0.02-0.15 ppt and 0.004-0.034 ppt respectively (Sauer *et al.*, 1989). Heptachlor epoxide (0.008-0.01 ppt) and dieldrin (0.004-0.024 ppt) were also detected but at lower concentrations (Table 5.3) (Sauer *et al.*, 1989). These values were considerably lower than those found at the Blake Plateau (Eastern US seaboard) (<7-80 ppt for all pesticides) and slightly lower than those found off the south-east US coast (<0.1-0.5 ppt) (Sauer *et al.*, 1989).

A uniform distribution of HCH was reported in surface waters of the Atlantic and was ascribed to continuous inputs of HCH from Africa and South America (Loganathan & Kannan, 1994).

5.2.3 PCBs

Cl_3-Cl_6 congeners of PCBs had been reported as reaching a maximum concentration of 28 ppt in one sample of Gulf of Mexico waters sampled between 1970 and 1980, although average concentrations were considerably lower at <0.002 ppt by 1989. This is considerably lower than previous average values for PCBs in the Gulf of Mexico which had reached concentrations of 1-10 ppt during the 1970s (Sauer *et al.*, 1989). Other studies, however, report a stabilisation of PCB congeners in Gulf of Mexico waters rather than a decrease (Table 5.3) (Iwata *et al.*, 1993).

5.3 Marine Biota

5.3.1 Fish and shellfish

Data on organochlorine concentrations in biota indicate that predator species in semi-enclosed seas and coastal regions are more contaminated with POPs than those found in the open ocean.

5.3.1.1 DDT

In samples of plankton and various species of fish, shrimp and oysters taken from the northern Gulf of Mexico, DDT and its metabolites are the most commonly found contaminants. Estuarine biota may have higher concentrations generally than pelagic organisms but there are large individual and interspecies variations in contaminant concentrations (Table 4.3) (Kennicut *et al.*, 1988). ΣDDT residues in the Gulf of Mexico did not exceed 50 ppb except in oysters from El Salvador where a maximum residue of 589 ppb was found for ΣDDT (Table 4.3) (Michel & Zengel 1998).

5.3.1.2 PCBs

The distribution of PCBs in the world's oceans was examined and concentrations of PCBs in squid livers from Southern Hemisphere waters were considerably lower than those found in the north by up to 62 times (Table 4.4) (Yamada *et al.*, 1997). No specific information was found for seas surrounding Latin America.

5.3.1.3 Organotin compounds

Levels of TBT in squid livers were measured in samples taken from around the South American coast (Yamada *et al.*, 1997). In waters off Peru, TBT concentrations were measured as trace-1 ppb and 8-18 ppb in waters of the South Atlantic off Argentina and an average of 1-4 ppb for the Southern Hemisphere generally. This compares with up to 279 ppb in the north western Pacific off Japan. Generally Southern Hemisphere open waters had very much lower concentrations of TBT than did those in the Northern Hemisphere by a factor of up to 279 times (Yamada *et al.*, 1997). The same study looked at the worldwide distribution of triphenyl tin (TPT), a product used as a pesticide among other applications. No TPT was detected in squid samples taken

from the Southern Hemisphere and it was calculated that the Northern Hemisphere was up to 260 times more contaminated with TPT (Yamada *et al.*, 1997).

5.3.2 Marine Mammals

POPs have been found in the tissues of marine mammals globally. Historically the highest levels of organochlorines in marine mammals have been found in blubber, liver and milk, which have a very high fat content and are, therefore, the natural repository for lipophilic organochlorine compounds (Ridgway & Reddy, 1995). Cetaceans (whales and dolphins) in particular have a thick layer of subcutaneous blubber and the majority of toxic organochlorines are distributed in this tissue. Once retained in such tissue the pollutants are not easily eliminated (Tanabe *et al.*, 1994). Considerable contamination of open ocean tropical waters has been measured as well as those at higher latitudes. Marine mammals, particularly cetaceans, bioaccumulate high concentrations of persistent organic pollutants (up to 10 million times the concentration in water) which they can pass on to their young through feeding (Tanabe *et al.*, 1994). Furthermore cetaceans are less able to metabolise these compounds than are other mammals, making them one of the most vulnerable target organisms for global organochlorine pollution (Tanabe *et al.*, 1994).

Most studies on levels of POPs in marine mammals have been conducted in the Northern Hemisphere. Several studies have also been conducted in the Southern Hemisphere in Asia and Oceania although studies published in the scientific literature for Latin America appear to be very limited in number and the geographical areas that are covered.

5.3.2.1 DDT

In stranded bottlenose dolphins from the Gulf of Mexico mature males had the highest concentrations of ΣDDTs, and mature females had consistently lower concentrations (Table 5.4) (Salata *et al.*, 1995).

Table 5.3: Mean or range of concentrations of chlorinated pesticides and PCBs in seawater around Latin America (ng ml^{-1})(ppb)

		Contaminant											
Country	Area	Aldrin	α-HCH	β-HCH	Lindane	ΣHCHs	ΣChordane	Dieldrin	Endrin	Heptachlor	Heptachlor epoxide	Trans-nonachlor	PCBs	Reference
None	Caribbean Sea	3.9	180		36	220						1.1	18	Iwata *et al* 1993
	Gulf of Mexico												<0.2-1.0	Sauer *et al* 1989
Argentina	Rio de la Plata		6.9-15.8	2-5.9	43.3-72.7	54.5-82.4	17.6-45.5			7.5-45.5	3.5-6.4			Colombo 1995
Mexico	Altata-Ensada del Pabellon Lagoon													Paez-Osuna *et al* 1998
	Yavaros Lagoon							5.85		5.4	4.29			Paez-Osuna *et al* 1998
	Huizache-Caimanero Lagoon	6.95			5.1					18.2	8.8			Paez-Osuna *et al* 1998
	Huizache-Caimanero Lagoon	0.076-1.195			0.059-2.604									Galindo *et al* 1997
	Agricultural drainage into Gulf of California		0.16		0.107			0.027	0.16					Albert 1995

Table 5.4: Concentration or range of concentrations of DDT and metabolites found in Latin American marine mammals (ppb, lipid weight)

COUNTRY/ AREA	Species	DDD	DDE	DDT	ΣDDTs	Reference
Gulf of Mexico	Bottlenose dolphin - blubber - Adult female		3,700 (600-14,000)	9 (<LoD-15)		Kuehl & Haebler 1995
	Bottlenose dolphin - blubber - Adult male		37,000 (15,000-78,000)	907 (2234-1,990)		Kuehl & Haebler 1995
	Bottlenose dolphin - blubber – foetus		2,800 (600-4,900)	39 (<LoD-76)		Kuehl & Haebler 1995
	Bottlenose dolphin - blubber – immature		12,000 (7,100-19,000)	1,400 (823-2,300)		Kuehl & Haebler 1995
	Bottlenose dolphin - blubber – suckling		7,200 (300-16,000)	681 (70-2,110)		Kuehl & Haebler 1995
N. Argentine waters	Burmeister's porpoises (female)		111-2,377	81-1,316	248-4,632	Corcuera *et al.*,
	Burmeister's porpoises (male)		587-5,641	398-2,605	1,316-8,543	Corcuera *et al.*,

Interestingly, older marine mammals (aged 15-33 years) had a lower uptake ratio of PCBs to ΣDDT s than younger animals. It was suggested that this may be due to the comparatively higher exposure of the older marine mammals during their young life when there would have been less restrictions on DDT use (Salata *et al.*, 1995).

5.3.2.2 *Organochlorine Pesticides*

Salata *et al.*, (1995) investigated OC pesticides in stranded bottlenose dolphins from the Gulf of Mexico. For some organochlorines, females had lower levels than males which may be expected if the females had given birth (Table 5.5) (Salata *et al.*, 1995). Particularly high concentrations of chlordanes (cis-chlordane 204 ppb; trans-chlordane 280 ppb), dieldrin (547 ppb) and trans-nonachlor (2,170 ppb) were found in blubber lipid, although another study by Kuehl & Haebler (1995), discussed below, found still greater concentrations. The two studies are not, however, directly comparable as no overall mean values are given in the latter report.

Kuehl and Haebler (1995) examined the carcasses of a number of bottlenose dolphins that had stranded on beaches on the Gulf of Mexico in an unusual mortality event in 1990. The levels of organochlorine pesticides found in the carcasses (Table 5.5) were similar to those found in bottlenose dolphins collected from the US Atlantic coast during another mass mortality event in 1987/88.

5.3.2.3 *PCBs, Dioxins and Brominated Flame Retardants*

Stranded bottlenose dolphins from the Gulf of Mexico were analysed for PCBs (Table 5.5) (Salata *et al.*, 1995). Mature males were found to have the highest concentrations of ΣPCBs, and mature females had consistently lower concentrations. The distribution of different congeners as a function of age supported the theory that higher chlorinated congeners are not readily transferred during parturition or through lactation (Salata *et al.*, 1995).

Kuehl and Haebler (1995) examined the carcasses of a number of bottlenose dolphins that had stranded on beaches on the Gulf of Mexico in an unusual mortality event in 1990. The levels of PCBs found in the carcasses (Table 5.5) were similar to those found in bottlenose dolphins collected from the US Atlantic coast during another mass

mortality event in 1987/88. It was suspected that the dolphins' high body burdens of accumulated immunosuppressive PCBs (along with other organochlorine compounds) may have overwhelmed the immune system as the dolphins were heavily infected by opportunistic micro-organisms (Kuehl & Haebler, 1995).

Only one study appears to have been undertaken with respect to levels of dioxins and furans (PCDD/Fs) in marine mammals. Jimenez and co-workers examined levels of PCDD/Fs in Southern Sea Lions, a species that are found along the Atlantic and Pacific coasts of South America from Peru to Tierra del Fuego and from Isla de Torres (off the coast of south east Brazil) to the Falkland Islands (Jimènez *et al.*, 1999). They found relatively low levels of PCDD/Fs in sea lions from both a polluted area and from an area with little industry which suggested that the animals were able to metabolise and eliminate at least some of these compounds (Jimènez *et al.*, 1999).

Research on the levels of brominated flame retardants in marine mammals globally is very limited. Studies showed levels of PBDEs in whales and dolphins from the Dutch coast in 1998 to range from 187 to 7700 ppb lw and in pilot whales from the Faroe Islands 843-3160 ng/g lw (reviewed by de Wit 1999). By comparison, levels in bottlenose dolphins from the Gulf of Mexico (up to 8000 ppb lw) were of a similar magnitude.

Table 5.5 : Range or concentrations of organochlorine pesticides and PCBs found in marine mammals around Latin America (ppb wet weight unless otherwise stated)

COUNTRY	Species	Contaminant																		Reference
		Aldrin	α-HCH	β-HCH	δ-HCH	Lindane	Cis-chlordane	Trans-chlordane	Chlorpyrifos	DEHP	Dieldrin	HCB	Heptachlor	Heptachlor epoxide	Mirex	Cis-nonachlor	Trans-nonachlor	Oxychlordane	ΣPCDD/F	PCBs	
Argentina (Mar del Plata)	Sea Lion (Otaria flavescens) -lipid																		0.01092		Jimenez *et al* 1999
(Punta Bermeja)	Sea Lion (Otaria flavescens) -lipid																		0.03755		Jimenez *et al* 1999
Chile	Bryde's whales	0.0048-0.0683				0.0003-0.0082					0.0010-0.0954										Pantoja *et al* 1985
	Fin Whales	0.0005				0.0003-0.0017					0.0005-0.0206										Pantoja *et al* 1985
Gulf of Mexico	Bottlenose dolphin – blubber - Adult female						48 (20-107)				390 (2-1,390)	254 (23-761)		520 (90-1,580)	94 (23-275)			108 (<LoD-369)		7,200 (1,500-18,000)	Kuehl & Haebler 1995
	Bottlenose dolphin – blubber - Adult male						340 (186-504)				1,080 (290-1,800)	292 (54-737)		5,020 (2,310-9,250)	502 (271-810)			714 (407-1,120)		93,000 (64,000-187,000)	Kuehl & Haebler 1995
	Bottlenose dolphin – blubber - foetus						52 (<LoD-38)				1,120 (76-167)	57 (48-66)		288(<LoD-424)	62(10-113)			97 (<LoD-177)		4,000 (2,200-5,800)	Kuehl & Haebler 1995
	Bottlenose dolphin – blubber - immature						689 (318-1,150)				1,550 (732-2,300)	3,360 (276-5,730)		4,390 (2,530-6,260)	215 (10-362)			464 (298-620)		49,000 (22,000-65,000)	Kuehl & Haebler 1995
	Bottlenose dolphin – blubber - suckling						364 (31-1,280)				949 (<LoD-3,120)	428 (191-786)		2,370 (<LoD-8,040)	164 (>LoD-551)			401 (<LoD-1,480)		21,000 (800-58,000)	Kuehl & Haebler 1995
N. Argentine waters	Burmeister's porpoises (female) – lipid																			562-3,874	Corcuera *et al.*,
	Burmeister's porpoises (male) - lipid																			1,941-5,574	Corcuera *et al.*,

5.3.2.4 *Organotin Compounds*

Organotins have been detected in the tissues of marine mammals (Tanabe 1999). Sites of highest concentration tend to be the in liver, kidney and blood rather than blubber. The highest concentrations of these pollutants appear in marine mammals caught in the Northern Hemisphere, and it seems that, so far, animals from the Southern Hemisphere are very much less contaminated (Tanabe, 1999).

A stranding event with bottlenose dolphins along the Gulf of Mexico coast gave Kannan and co-workers the opportunity to examine these cetaceans for organotin compounds. Total butyltins (mono- + di- + tri-butyltins) ranged in concentration in dolphin liver between 110 and 11,340 ppb (wet weight) with a mean value of 1,400 ppb. Residues were also found in blubber (630 ppb), kidney (~200 ppb), melon (190 ppb), heart (50 ppb) and brain (110 ppb). When these concentrations were compared with those found in the livers of spotted dolphin (360 ppb) and pygmy sperm whale (390 ppb), both offshore Atlantic species, residues in stranded bottlenose dolphins were found to be 3-4 times higher.

6 AQUATIC ENVIRONMENT

Pollution of the aquatic environment can occur through a variety of routes including direct discharges to watercourses, run-off from agricultural land and deposition of airborne contaminants. While there is a wealth of scientific data on levels of POPs in the aquatic environment for many countries of the Northern Hemisphere, by comparison extremely little has been published for Latin America. This is the case for surface water and groundwater, sediments in freshwater and aquatic biota.

Scientists have expressed concern about the potential contamination of groundwater by POPs in Latin America and the fact that few actual data on assessing such contamination have been published. For instance, in a review of persistent pesticides in Mexico, Albert (1996) notes that groundwater is an essential resource for large populations in Mexico yet the literature is virtually devoid of relevant information. In this review, Albert cites only one study that monitored pesticides in groundwater (Cabrera 1995). This study reported that groundwater from the Yucatan Peninsula in Mexico was contaminated by the residues of the persistent organochlorine pesticides 2,4,-D and 2,4,5-T. It was noted that this is a particularly serious case of environmental pollution since the groundwater was the only source of drinking water in the region and may be irreversibly contaminated. In another study, Mazari and Mackay (1993) report that in Mexico City, most of the drinking water is drawn from an underground aquifer which is threatened by contamination from several sources. These include contamination by synthetic halogenated organic solvents from electronics industries, and from dry cleaning and metal degreasing operations in which the halogenated solvent tetrachloroethylene is used. The study noted that concerted efforts are needed to locate and address the hot spots of existing contamination, since it is unlikely that new tighter regulations of drinking water quality will be successfully implemented for some time.

Studies published for several countries in Latin America have all reported the presence of persistent organochlorine contamination in surface waters, sediments and

freshwater fish and shellfish. Table 6.1 presents data on levels of POPs in surface waters of a few countries in Latin America and table 6.2 shows levels of POPs in sediments. Points of particular concern which noticeably stand out in these studies are the exceptionally high levels of heptachlor found in Ipojuca River in Brazil, and high levels of lindane in fish from the Biobio River in Chile.

6.1 DDT

6.1.1 Surface Water

Studies have reported levels of DDT in surface waters for Argentina, Uruguay, Honduras and Mexico. In Northwest Mexico, a study published in 1977, documented high concentrations of DDT in a agricultural drainage system (mean 540 ng/L, (ppt), (Albert and Armienta, 1977). The concentrations found in this study are comparable to levels that have been reported for rivers in Asia where DDT has also been used extensively (eg. Iwata *et al.,* 1994). There appear to be no recent data on levels of DDT residues in surface waters in Mexico, so it is not known whether such high levels still persist in any region. The lack of data on levels of DDT in the aquatic environment in Mexico is noteworthy given that DDT, as well as other organochlorine pesticides, have been used extensively used for a long time both in agriculture and for public health programs (Albert 1996).

Studies conducted during the past decade in Argentina and Uruguay found much lower DDT concentrations in river water (around 6 ppt). One of these studies was undertaken at the Rio de La Plata, Argentina (Colombo *et al* 1990). The other was conducted and at a number of sites along the Uruguay River that runs as a natural boundary alongside Argentina and Uruguay and eventually drains into the Rio de La Plata (Janiot *et al.,* 1994). DDT isomers were detected in surface water at most sites along the Uruguay River and at 7 out of 17 test sites in the region of the Rio de La Plata. An earlier study in Argentina also reported the presence of DDT in water samples taken from the Parana and Uruguay Rivers although at far higher concentrations (minimum for p,p' -DDE 90 ppt, maximum p,p'-DDT 5600 ppt) (Fenandez *et al.,* 1979). A recent study in Honduras found DDT residues in areas of the Choluteca River Basin, but at low detection frequencies, ranging from 6-10% of the total samples that were analysed. However, levels were reported to exceed USEPA standards (Kammerbauer and Moncada 1998).

6.1.2 Sediments

Sediments act as an ultimate sink for POPs brought into the aquatic environment from direct discharges, surface run-off and atmospheric fall-out. DDT was analysed and detected in sediments of the Rio de La Plata, (mean 6.1 ng/g dry weight (ppb) (Colombo *et al.,* 1990). Here, DDE and TDE isomers were predominant, suggesting the breakdown of DDT in sediments. In a study in Honduras, DDT was not detected in lagoon sediments, even though it was detected in water samples and was present in fish muscle (Kammerbauer and Moncada 1998). In Mexico, a study on sediment samples taken from the Palizada river basin in the Gulf of Mexico identified DDT (Gold-Bouchot *et al.,* 1993 and 1995).

Three studies reported on the Paraíba do Sul-Guandu River system in Brazil (Torres *et al.,* 1999, Brito *et al.,* 1999, Malm and Japenga 1997). This river is 1137 km in length and runs through the most industrialised part of the country in southeastern Brazil.

After this huge industrial centre, about 40% of the river water is pumped to a series of reservoirs before running on to form the Guandu river, the main drinking water source for Rio de Janeiro. Torres *et al.,* (1997) reported that total DDT levels in river sediments samples were between 20 and 200 ppb. DDT was present in 50% of samples with the highest levels being found near Volta Redonda. Levels of DDT within a similar range were also reported by Torres *et al.,* (1999). Torres et. al. (1997) commented that DDT has been used for decades against mosquitoes in Brazil. In the nearby Santana reservoir, a core sample was taken to investigate the historical occurrence of pollutants in sediments. In the upper most levels, reflecting recent deposition, levels of total DDT (3.67 ppb) were lower than in the river, (Malm and Japenga 1997). According to an abstract published from a conference, in the Funil reservoir, no organochlorine contaminants were detected (Brito *et al.,* 1999). Comparatively low DDT levels were identified in the Guandu river system (Torres *et al.,* 1999).

The Rato river system in Pará state in the northern region of Brazil is a tributary of the Tapajós river. This is an important gold mining area. Like other areas located in the Amazon river basin, malaria is endemic and government authorities spray DDT twice a year in houses and other buildings. Up to 68 ppb total DDT was detected in river sediments (Torres *et al.,* 1999). Another study published on this region by Torres suggested that DDT that is sprayed for malaria control reached the water system and was retained there in small tributaries (called "igarapés") (Torres *et al.,* 1998). These areas are very important for fish reproduction. It was suggested that such contamination of local biota may cause unpredictable environmental damage.

A study was undertaken on sediments of a small urban lake in San Pedro County, central Chile, to investigate the historical occurrence of organochlorine pesticides in the area (Barra *et al.,* 2000). The highest levels of DDT breakdown products were found in sediments that were dated as being representative of the years 1972 to 1978. DDT was not detected in sediments that represented the interval between 1984-1993. This may have reflected the ban of DDT in Chile in 1985. However, since 1993, increased levels of p,p'-DDT were found which suggests a new DDT source in the lake. Potential new sources include illegal use of DDT, domestic sewage discharge in the lake, or long-distance transport on air currents. The mean level of DDT in the sediments between 1993 to 1996 was 1.4 ppb. This is similar to levels found in pristine regions of the Northern Hemisphere, but lower than levels reported for urban lakes of the Northern Hemisphere. Another study in Chile, on fjords in the south of the country, reported levels of p,p'DDT between 0.2 and 0.3 ppb (Bonert and Estrada 1998).

6.1.3 Aquatic Biota

Comparison of concentrations of organochlorines in fish tissue between different studies is limited by differences in analytical methodology. In addition, the concentrations in fish may be partly dependent on the species in question. For example, some fatty fish species accumulate higher levels of organochlorines in their tissues than other fish. An accurate comparison of organochlorine levels is therefore difficult. A review of studies in different countries revealed levels of DDT in fish tissues were most often below 100 ng/g wet weight (ppb) (Allsopp *et al.,* 2000a and b). Notably high levels greater than 1000 ppb have been detected, for instance in USA and Australia. For Latin America, comparatively low DDT levels were noted in fish in

studies conducted in Chile and Argentina discussed below. However, data are very limited and the concentrations of DDT reported in these studies may not be representative of other regions in these countries.

High levels of DDT in fish were detected in a study on seven species of fish taken from the Blanco River and the Camaronera and Alvarado coastal lagoons in Veracruz State, Mexico (Albert *et al.,* 1988). Comparison with other data is, however, not possible because levels were reported on a fat basis rather than on a wet weight basis which is most often the norm. Concentrations of DDT residues up to 1947 μg/g lipid (ppm) were found. The highest concentrations were found in fish from coastal lagoons. It was suggested that this contamination of fish tissue occurred as a consequence of the intensive use of DDT for vector control in these coastal regions. A more recent study on fish from a coastal lagoon in Chiapas State, Mexico, also found DDE in fish tissues (Vázquez-Botello 1995). Shellfish (bivalves) from three coastal lagoons in the Gulf of Mexico were found to contain relatively low levels of DDT (highest mean concentration 5.6 ppb) (Botello *et al.,* 1994).

A study on the Biobio River in central Chile found DDT levels in fish were distributed fairly evenly along the length of the river except at Laguna Icalma, an area close to the source of the river, where levels were lower (Focardi *et al.,* 1996). Mean levels of DDT residues, (DDT + DDE), in muscle from two species of fish taken near to the source were 390 and 687 ppb. Levels in fish muscle at other sites along the river were higher, ranging from 832 to 2788 ppb.

In the Rio de La Plata, Argentina, DDT was detected in one bivalve (*Corbicula fluminea*) and a number of fish species (Colombo *et al.,* 1990). Total DDT concentrations ranged from 3 – 2200 ppb. Levels in biota were comparable to levels found for Lake trout in the Great Lakes.

Table 6.1. Mean and (Range) of Concentrations in ng/L (ppt) of Organochlorine Pesticides in Surface Waters

Location	Total DDT*	Heptachlor Epoxide	Heptachlor	Dieldrin	Lindane	Reference
Rio de La Plata, Argentina	6 (nd – 9.2)	1.9 (nd – 3.7)	nd	-	24.8 (nd-61)	Colombo *et al.,* 1990
Uruguay River, Uruguay and Argentina	6.7	1.3 (<1.2-3.2)	0.9 (<0.8-3.2)	2.7 (<2.6-7.2)	2.0 (0.9-10)	Janiot *et al.,* (1994)
Ipojuca River Basin, Brazil	-	-	(nd – 57,800)	-	-	Araujo *et al.,* (1998)
Choluteca River, Honduras	-	-	-	40,000	-	Kammerbauer and Moncada (1998)
Agricultural drainage system, Northwest Mexico	540 (33-2700)	-	-	27 (2-93)	160 (50-1880)	Albert and Armienta (1977)

nd denotes not detected, - denotes not reported.
* DDT values are not directly comparable since the number of DDT isomers used to calculate total DDT in varies between studies.

Table 6.2. Mean and (Range) of Concentrations ng/g dry weight (ppb) of Organochlorine Pesticides in Sediments

Location	Total DDT	Heptachlor	Heptachlor Epoxide	Lindane	Reference
Rio de La Plata, Argentina	6.1 (0.9-91.4)	-	0.6 (0.03-18.7)	0.2 (0.1-12.2)	Colombo *et al.,* 1990
Rato River, in the Tapajós river basin, Brazil	23.1	0.8	1.4	0.7	Torres *et al.,* (1999)
Paraíba do Sul-Guandu River system, Brazil	73.3	-	2.3	-	Torres *et al.,* (1999)
Lagoon sediments, Zamorano valley, Honduras	Nd	5.0	-	nd	Kammerbauer and Moncada (1998)
Urban Lake in San Pedro County, Central Chile (sediment samples representing years 1993-6	1.4	0.303	-	0.31	Barra *et al.,* 2000

6.2 Heptachlor and Heptachlor Epoxide

6.2.1 Surface Water

Table 6.1 shows that heptachlor and/or heptachlor epoxide were detectable in surface waters of Argentina and Uruguay (Janiot *et al.,* 1994, Colombo *et al.,* 1990), and in Brazil (Araujo *et al.,* 1998). In the Uruguay River (Janiot *et al.,* 1994) and in the Rio de La Plata (Colombo *et al.,* 1990), heptachlor was detected at low levels in samples and at some sampling sites not at all. Another study in the Choluteca River Basin of Honduras, showed that heptachlor was present at low concentrations in river, lagoon and well water in more than 20% of the samples assessed (Kammerbauer and Moncada 1998).

In contrast to the above studies, exceedingly high levels of heptachlor were detected at some sites in the Ipojuca River Basin in the Northeast State of Pernambuco, Brazil (Araujo *et al.,* 1998). Samples taken during 1995 and 1996 revealed levels of heptachlor/heptachlor epoxide at various sites along the river that were frequently in excess of the maximum limit (0.01 µg/L, i.e. 10 ng/L or ppt) established in the Brazilian Environmental Resolution CONAMA. Levels were notably high during the dry season at São Caetano (51,390 ppt) and Caruaru (57,800 ppt). At the time this study was published and according to the authors, heptachlor is used extensively in Brazil as a formicide (i.e. against ants). The authors concluded that it could therefore be inferred that a major source of the heptachlor contamination in the Ipojuca River was due to its use in public health programmes. No measurements were taken on levels of heptachlor in sediments and fish in this study.

6.2.2 Sediments

Heptachlor was monitored in sediments of the Rio de La Plata, Argentina (Colombo *et al.,* 1990) and in lagoon sediments in the Choluteca River Basin, Honduras.

Heptachlor epoxide was found at several sites on the Rio de La Plata (mean concentration 0.6 ppb), while heptachlor was detected at a somewhat higher concentration of 5.0 ppb in lagoon sediments in Honduras. In a small urban lake in central Chile, an average heptachlor concentration of 0.303 ppb was reported for sediments that were dated as representing the years 1993 to 1996 in an urban lake (Barra *et al.,* 2000). In southeastern Brazil, heptachlor epoxide was detected in sediments of the Paraíba do Sul-Guandu River system at levels of 0.2 to 4.0 ppb (Torres *et al.,* 1999) and at 3 to 4 ppb (Malm and Japenga 1997). In the Tapajós river basin in the northern part of the country levels of heptachlor epoxide ranged from 0.1 to 4.4 ppb and levels of heptachlor from 0 to 1.6 ppb.

In Mexico, a study on sediment samples taken from the Palizada river basin in the Gulf of Mexico reported the presence of heptachlor in some samples (Gold-Bouchot *et al.,* 1993 and 1995). In sediments of lagoons and rivers on the coast of Chiapas State, heptachlor and heptachlor epoxide were some of the main organochlorine pesticides identified (Vázquez-Botello 1995). The study noted that heptachlor was used for cotton in this region for many years until the crop was phased out in 1986. The use of heptachlor for agriculture in Mexico has not been registered since 1991 (Albert 1996).

6.2.3 Aquatic Biota

A study on fish from a coastal lagoon in Chiapas State, Mexico reported the presence of five organochlorine pesticides in fish tissue including heptachlor and heptachlor epoxide (Vázquez-Botello 1995). Heptachlor and heptachlor epoxide were also detected in bivalves from three coastal lagoons in the Gulf of Mexico (Botello *et al.,* 1994). Colombo *et al.,* (1990) reported the presence of heptachlor and heptachlor epoxide in aquatic biota from the Rio de La Plata, Argentina.

6.3 Dieldrin, Aldrin and Endrin

6.3.1 Surface Water

Levels of dieldrin, aldrin and endrin varied widely between studies in Latin America. A study on the Uruguay River reported that dieldrin and aldrin were occasionally encountered in samples (mean concentration 2.7 ppt), but otherwise were below the detection limit (Janiot *et al.,* 1994). An earlier study undertaken on the Uruguay and Parana Rivers also found aldrin and dieldrin in river water (Fernandez *et al.,* 1979). In Mexico, a study undertaken in 1977 also revealed the presence of dieldrin (mean concentration 27 ppt) (Albert and Armienta (1977). In this study levels of aldrin and endrin were noted to be higher than permissible levels for discharges into estuaries in Mexico. A study on the Ipojuca River Basin in Brazil reported that aldrin and endrin were apparent at trace levels in river water samples collected near to densely populated areas (Araujo *et al.,* 1998).

A more recent study on the Choluteca River Basin of Honduras reported extremely high levels of dieldrin (40,000 ppt) in river water with a detection frequency of 10-15% (Kammerbauer and Moncada 1998). Dieldrin and aldrin were also detected in well water and lagoon water at a frequency of 10-15%. The study noted that levels of aldrin and dieldrin in water from the Choluteca River Basin were not in compliance

with US EPA water standards. The concentration of dieldrin reported in river water in this study exceeds levels reported by studies for rivers in Asia by 3 orders of magnitude (see Allsopp *et al.*, 2000b). Different areas of the Choluteca River Basin in Honduras were sampled in the study and it was found that the highest levels of dieldrin and some other organochlorine pesticides were in Choluteca, an area of intensive crop export agricultural region. Somewhat lower levels were found in a moderately intensive agricultural region and the lowest levels in a traditional subsistence agricultural region. This is because intensive agriculture to produce cash crops for export uses the highest quantities of pesticides, although pesticides are also used by subsistence farmers. The study noted that most organochlorine pesticides were banned during the 1980s in Honduras.

6.3.2 Sediments

Few of the above studies on surface waters also investigated the occurrence of organochlorine pesticides in sediments. The study in the Choluteca River Basin in Honduras reported that dieldrin was detected in both lagoon sediments and in fish from the lagoons (Kammerbauer and Moncada 1998). A study on an urban lake in central Chile reported the presence of aldrin in sediments that were representative of the years 1993 to 1996. In Mexico, a study on sediment samples taken from the Palizada river basin in the Gulf of Mexico reported that aldrin, dieldrin and endrin were detectable in some samples (Gold-Bouchot *et al.*, 1993 and 1995). In sediments of lagoons and rivers on the coast of Chiapas State, aldrin was the main pesticide identified in samples (150.71 ppb) along with heptachlor and heptachlor epoxide (Vázquez-Botello 1995).

In southeastern Brazil, dieldrin was detected in the Paraíba do Sul-Guandu river system at levels ranging from 3.8 to 21.2 ppb (Torres *et al.*, 1999). In the Tapajós river basin in northern Brazil, dieldrin was detected at lower levels (0.1-1.4 ppb) and aldrin was also found (0.3 to 0.6 ppb).

6.3.3 Aquatic Biota

One study in on a coastal lagoon in Chiapas State, Mexico, reported the presence of aldrin in fish tissue (Vázquez-Botello 1995). Aldrin and endrin were also detected in bivalves from three coastal lagoons in the Gulf of Mexico (Botello *et al.*, 1994). Levels of aldrin (highest mean concentration 6.61 ppb dry weight and endrin (highest mean concentration 10.61 ppb dry weight) were documented. These values cannot be compared with levels recorded by studies from many other countries since levels are usually given on a wet weight rather than on a dry weight basis.

6.4 α-HCH and γ-HCH (Lindane)

6.4.1 Surface Water

In a study on the Uruguay River in Argentina and Uruguay, α-HCH and lindane were found to be the most commonly detected organochlorine pesticides (up to concentrations of 10 ppt, (Janiot *et al.*, 1994). Similarly, lindane was the most dominant organochlorine pesticide found in water from the Rio de La Plata in Argentina with concentrations ranging from 0.9 to 61 ppt (Colombo *et al.*, 1990).

Higher levels of total HCH (sum of HCH isomers), were detected in river water from the Ipojuca Basin in Brazil (Araujo *et al.*, 1998). Levels were highest (maximum 3760 ppt) in São Caetano, a region where heptachlor was also found to be particularly high (see section 6.2 above). In fact, the majority of samples taken in this study at different sites along the length of the river were found to exceed the maximum levels established by the Brazilian Environmental Resolution CONAMA (Araujo *et al* 1998). Another study, on the Choluteca River Basin in Honduras, reported high levels of γ-HCH, or lindane, (mean 5000 ppt) in spring water from the La Lima watershed which is used for drinking water (Kammerbauer and Moncada 1998). This exceeds the WHO limit from drinking water of 3 ppb (i.e. 3000 ppt).

6.4.2 Sediments

HCH isomers in sediments were identified by studies in Mexico, Chile, Honduras and Argentina. In Chile, a study on a small urban lake showed that both α- and γ-HCH were present in sediments which were dated as being representative of the years 1968 to 1996 (Barra *et al.*, 2000). Levels were the highest in sediments that related to most recent years. Concentrations for α-HCH and γ-HCH were 0.310 and 0.362 ppb respectively for 1993 to 1996. Levels were similar to those reported for sediments in the Rio de Plata, Argentina (see below). The study pointed out that lindane appears to be the most common organochlorine pesticide in drinking water, fog and river samples in Chile. Its use for agriculture in the country was banned in 1998.

In the Rio de La Plata, Argentina, lindane was detected in some sediment samples at a mean concentration of 0.2 ppb (Colombo *et al.*, 1990). In northern Brazil, lindane was detected at concentrations of 0.1 to 1.8 ppb in the Tapajós river basin. In Mexico, a study on sediment samples taken from the Palizada river basin in the Gulf of Mexico identified γ-HCH in some samples (Gold-Bouchot *et al.*, 1993 and 1995). In the Choluteca River Basin, Honduras, α-HCH was found to be present in both fish and lagoon sediments (Kammerbauer and Moncada 1998).

6.4.3 Aquatic Biota

With regard to levels of HCH isomers in fish, a study on the Biobio River in Chile reported extremely high concentrations of γ-HCH in fish muscle and liver at Nacimiento and Laja (Focardi *et al.*, 1996). In these regions, levels in fish muscle ranged from 59 to 773 ppb. The concentrations present were some of the highest values for lindane reported in fish tissues worldwide. Lindane was also found in fish from other regions on the river. Levels of other HCH isomers, α and β- HCH, were much lower than for lindane, in all cases below 1 ppb. The study noted that the almost exclusive presence throughout the Biobio basin of the γ-HCH isomer, with particularly high levels around Nacimiento and Laja, is evidence of the massive use of lindane-based pesticides in this area. This is due to the use of these pesticides for agriculture and forestry. It was also pointed out that since the river is the main source of water for all purposes, including drinking, the socio-economic aspects of pollution should also be considered.

In the Rio de La Plata, Argentina, lindane was detected in aquatic organisms at a mean level of 600 ppb of lipid. Since this figure is reported on a lipid basis, it cannot be compared to levels documented by many other studies which report on a wet weight basis.

6.5 Other Organochlorine Pesticides and PCBs

6.5.1 PCBs

PCBs were rarely analysed as part of studies on Latin American aquatic environments. One study that assessed levels of organochlorines in the Rio de La Plata, Argentina, reported the presence of PCBs in water (6.4-56.5 ppt), sediments and various species of fish and a bivalve (Colombo *et al.,* 1990). The study noted that levels in water and biota were similar to levels found in the Great Lakes, a region with known high PCB pollution. Total PCB concentrations in biota (0.01 to 1.6 μg/g (ppm) or 3.3-17.8 μg/g of lipids) did not exceed tolerance limits set for human consumption (2 μg/g). Nevertheless, levels in one fish species (1.2 to 1.6 μg/g) were quite high and the authors noted that consumption of such fish may represent a critical contamination pathway for humans. Another study, on the Palizada River area in the Southeast coast of the Gulf of Mexico, found PCBs (as Aroclor, 12.99 ppb, dry weight) in oysters (Gold-Bouchot *et al.,* 1993 and 1995).

A study on the Biobio river basin in central Chile, reported the presence of PCBs in fish tissue at several different sites along the river (Focardi *et al.,* 1996). The highest levels were recorded for fish species inhabiting the mouth of the river (up to a mean of 1.842 ppm fat, an area close to the towns of Concepcion and Talcauano. The highest levels of PCBs were therefore evident in a region close to industrialised areas. Similarly, the highest levels of HCB in fish (0.214 ppm fat) were observed in this industrialised region, although HCB was also detected in all fish sampled throughout the whole river basin.

In the Paraíba do Sul-Guandu River system in southeastern Brazil, PCBs were detected in river sediments at concentrations around 25 ppb. A slight increase was detected near to a steelworks (up to 60 ppb) (Torres *et al.,* 1997). Torres *et al.,* (1999) noted that the low levels of PCBs in sediments of the river were indicative of different small discharges along the watershed. A core sediment sample taken from the Santana reservoir nearby to investigate historical occurrence of POPs. Results showed levels of PCBs at 10.14 ppb in sediments close to the surface. However, there was an increasing concentration of PCBs with increasing depth of sediments which may reflect higher inputs of PCBs in the recent past (Torres *et al.,* 1997). In the Tapajós river basin in northern Brazil, PCBs were also detectable. The authors commented that the presence of lower chlorinated PCBs in most of the samples suggests atmospheric transport of these compounds.

6.5.2 Chlordane

A study in the Choluteca River Basin of Honduras reported that chlordane was evident in 6% of river water samples that were tested, and in 5-10% of well and lagoon water samples (Kammerbauer and Moncada 1998). The highest levels of total chlordane (defined as sum of chlordane, heptachlor, HE and *trans*-nonachlor) were found in the Choluteca river with nearly 250,000 ppt at a 17% detection rate. The Yeguare river system in Zamorano and the La Lima river had about a tenth of this concentration at lower detection frequencies. The levels of chlordane found in this study were above USEPA standards.

A study of the Rio de La Plata in Argentina reported that compound C, which is a hexachloro component of technical chlordane, was detected at several sites at what were considered to be relatively high concentrations (0.4-28 ppt). *Trans*-chlordane was also evident in sediments and in aquatic biota. A study on the Palizada River area in the Southeast coast of the Gulf of Mexico analysed several different species of aquatic biota (Gold-Bouchot *et al.,* 1993 and 1995). The study found that chlordane levels in mussels (23.08 ppb, dry weight, and PCB levels in oysters were higher than other organochlorine residues.

6.5.3 Toxaphene

The majority of studies on organochlorine pesticide levels in the environment rarely assess toxaphene. One study was located in the literature that investigated levels of toxaphene in Lake Xolotlan in Nicaragua (Calero *et al.,* 1992). The study reported that the principle source of pesticide contamination of this lake is from discharge of waste waters by a factory which had produced toxaphene since 1965. Toxaphene was not detected in water samples from the lake in this study, although a survey in 1990 did find toxaphene in water 200 meters from the factory discharge point (365 ppb). The study did detect very high levels of toxaphene in sediment near the factory discharge (359,000 ppb) and in one out of 6 fish from the lake at 428 ppb in muscle tissue.

6.5.4 HCB

Da Silva (1998), draws attention to past and present HCB contamination of the environment in certain regions of Baixada Santista in Brazil. HCB was reported to be present in river water, sediment and fish.

6.5.5 Endosulfan

Studies did not routinely test for the organochlorine pesticide endosulfan which is still currently in use for agriculture in many countries. In Honduras, Kammerbauer and Moncada (1998) noted that endosulfan was detectable in about 20% of river water samples and 5-10 % in well and lagoon water samples in the Choluteca River Basin. The authors noted as a comnparison that this was not in compliance with USEPA standards. Endosulfan was also present in lagoon sediments and in fish from the lagoons. In Mexico, endosulfan was detectable in fish from a coastal lagoon in Chiapas State (Vázquez-Botello 1995), and in bivalves (shellfish) from three coastal lagoons in the Gulf of Mexico (Botello *et al.,* 1995). In Brazil, endosulfan was detectable in the Tapajós river basin (Torres *et al.,* 1999).

7 TERRESTRIAL ENVIRONMENT

7.1 Air

Very few data were located in the scientific literature on levels of POPs in terrestrial air of Latin America. Kallenborn *et al.,* (1998) reported that concentrations of POPs in air of Antarctica, such as γ-HCH, PCBs and chlordane, may be influenced by long distance transport on air currents from Central and South America.

A study in Argentina made an assessment of airborne pollution by investigating the levels of various POPs in needles from conifer trees (Wenzel *et al.*, 1997). The needles of conifer trees take in air pollutants and therefore they can be used as indicators of atmospheric pollution. Samples of needles from pine trees were taken in 1994 from two urban parks in Mendoza, Argentina, and from forests in more remote regions near Potrerillos and Polvaredas. The results were compared to levels present in pine needles taken from an urban area and a remote site in Germany. In Argentina, peak levels of HCH isomers and DDT isomers in one of the urban parks were one to two orders of magnitude higher than peak levels in more remote regions of the country. They were also one to two orders of magnitude higher than levels found in Germany. The study noted that this indicated substantial recent input of these compounds into the air from local sources, possibly from insecticide spraying. Levels of PCBs in pine needles were of the same order of magnitude in Argentina and Germany. Levels of HCB were slightly higher in pine needles in Germany, most likely due to the greater degree of industrialisation in Germany, particularly combustion processes.

7.2 Vegetation

A few studies on concentrations of heavy metals in terrestrial plants of Latin America were located in the literature (Wiersma *et al.*, 1992 and 1990, Ginocchio 2000). However, no studies were found on POPs in vegetation. One study in Brazil investigated levels of dioxins and PCBs in compost (Grossi *et al.*, 1998). Compost is used as a soil conditioner and the study noted that testing it for contaminants is necessary to prevent the widespread distribution of pollutants. Samples of compost were taken from a total of 21 municipal solid waste composting plants that were situated in the States of São Paulo, Rio de Janeiro, Espirito Santo, Paraíba, Rio de Grande Norte, Rio do Sul, Amazonas and Distrito Federal (Brasilia). Levels of dioxins (PCDD/Fs) varied between 3 and 163 ng I-TEQ/kg, with an average of 42 ng I-TEQ/kg. The highest levels were evident in metropolitan areas where they averaged 57 ng I-TEQ/kg. The study noted that values were comparable to levels of dioxins found in compost in Germany. Levels of PCBs in the Brazilian compost ranged from 15 to 1690 μg total PCB/kg and averaged 373 μg total PCB/kg . This is around 3 times lower than average levels found in European compost of about 1000 μg total PCB/kg.

7.3 **Soil**

Many persistent organochlorines 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).

Only very few studies on levels of POPs in Latin American soils were located in the scientific literature and these focused on Brazil. This lack of data on soils has been noted by other authors including Mazari and Mackay (1993) who comment on the absence of data on POPs in Mexican soils.

Levels of dioxins and PCBs were investigated in soils from Brazil by Krass *et al.* (1995). The study reported that levels of dioxins and PCBs in soils from the Amazonian forest were very low (0.02 to 0.4 ng I-TEQ/kg, PCB 0.1 to 7.7 µg/kg). However, levels in soil near to industrial regions around Rio de Janeiro (up to 654 ng I-TEQ/kg) and São Paulo (up to 341 ng I-TEQ/kg) were much more highly contaminated due to industry.

According to a published abstract from a conference (Torres *et al.*, 1998) an investigation was made into levels of DDT in soil from the Tapajós river basin in the Brazilian Amazon. At the time of the study, the authors reported that several areas are sprayed with DDT in this region twice a year by Brazilian Health authorities to control malaria. Soil samples contained up to 922 ppb of DDT. Results also indicated that DDT and its metabolites reach the river system.

According to a published abstract from a conference (Vieira *et al.*, 1999), a study was carried out which investigated levels of DDT in tropical soil from Pau da Fome, Jacarepaguá in Rio de Janeiro, Brazil. The areas has endemic tegumental leishmaniasis and DDT was last sprayed in 1990. Soil samples taken closer to sprayed places (eg. Walls) had higher mean DDT and DDE concentrations (510.11 and 330.66 ng/g dry weight (ppb). DDT levels were lower in more distant sample points. The authors noted that despite the time elapsed since spraying, soil DDT concentrations were high. It was suggested that the bioaccumulation in farmyard animals may be a problem and this is currently under investigation.

The only other studies located in the literature on POPs in soils were experimental studies that assessed the behaviour of the pesticides DDT and atrazine in tropical soils (Langenbach *et al.*, 2000, Monteiro *et al.*, 1999, Andréa *et al.*, 1994, Espinosa-González *et al.*, 1994).

7.4 **Birds**

The accumulation of POPs in the tissues and eggs of birds is a reflection of contamination of the food chain by these pollutants. Research on POPs in birds is quite limited for Latin America. Several studies have been conducted in Mexico, and one study in Chile, but few data appear to be available for other countries. Studies

have focused largely on DDT and its isomers. In some instances, other organochlorine pesticides were also assessed.

A review of the literature on POPs in Mexican birds (Mora 1997), notes that a study by Kiff *et al.,* (1980) was the first to investigate egg-shell thinning in birds of prey in Mexico. This study reported that egg shells from bat falcons (*Falco rufigularis*) and aplomado falcons (*F. femoralis*) collected in northeast Mexico from 1954 to 1967 were 18 and 25% thinner respectively than eggshells collected before 1947 (that is, before DDT was used). All egg shells were found to contain DDE residues, a chemical that is associated with egg shell thinning. By 1977, eggshells of aplomado falcons in the state of Veracruz in Mexico still had high DDE residues (average 14.8 μg/g (ppm) wet weight, estimate assuming 5% lipid), which suggested that serious DDT pollution still occurred in Mexico in the late 1970s. Other research undertaken on eggs from various Mexican birds of prey collected between the mid-1950s and 1970 revealed the presence of several other organochlorine pesticides in eggs including chlordane, oxychlordane and heptachlor epoxide (reviewed by Albert 1996).

Research on the black vulture (*Coragyps atratus*) from the state of Chiapas, southeast Mexico, during the 1980s also revealed high levels of DDE in tissue samples (up to 118.1 ppm, on an extracted lipid basis) and evidence of egg shell thinning (reviewed by Albert 1996). High levels of α- and β-HCH were also found in the birds.

A few studies have been conducted during the 1980s on levels of POPs in both resident and migratory birds in Mexico. Eight species of resident birds from agricultural regions of northwest Mexico, (the Mexicali, Yaqui and Culiacá valleys), have been shown to contain several organochlorine pesticides in their tissues including DDT isomers, HCH, dieldrin, oxychlordane, heptachlor epoxide, endrin, and PCBs (Mora and Anderson 1991). DDE was present at the highest concentrations (0.009-26 ppm wet weight) and the authors considered that this may be a hazard for birds of prey that feed on such birds. Eggs from cattle egrets (*Bubulcus ibis*) in Mexicali Valley in the northwest also had high concentrations of DDE. HCB, endosulfan, dieldrin and PCBs were also detectable. Eggshell thickness was also reduced (Mora 1991).

Research in the US has led to the hypothesis that several migratory bird species which inhabit various areas of the US have elevated DDE tissue levels because they over-winter in Mexico or Latin America (reviewed by Mora 1997). However, to date, the data are limited and do not show a clear pattern of increased DDE accumulation in relation to over-wintering in Mexico, at least for birds from the southwest US (Mora 1997). For instance, a few studies on birds in northwest Mexico have shown they have similar DDE levels to birds in southwest US. A study on great-tailed grackles from east Mexico and southwest US in 1991 showed no differences in levels of DDE in birds from the two countries except for Veracruz state in Mexico where levels were lower. With regard to east Mexico, Mora (1997) draws attention to the continued use of DDT in the state of Chiapas for spraying houses against malaria and possibly in agriculture. Mora (1997) points out that this state is probably the one where most migrant species of birds may still be at risk from significant accumulation of DDT and DDE.

In central Chile, a study was conducted on birds and fish that inhabited the Biobio river Basin (Focardi *et al.,* 1996). HCB, PCBs, γ-HCH, DDT isomers and DDE were detected in various bird species at several sites along the river. As in fish, the highest levels of PCBs were found in birds living near to the mouth of the river. This is reflective of the urbanisation of this area. Mean PCB levels in muscle from different species at the mouth of the river were up to 4398 ppb. Similarly, HCB was also found at the highest levels (up to 152 ppb in muscle) near the mouth off the river. DDT and DDE contamination in bird tissues was evident along the length of the river. DDT levels between 500 and 2000 ppb were reported.Levels were generally lower in birds living near to the source of the river.

8 FOOD

Environmental pollution has led to the contamination of human food with POPs. Discharges and deposition of POPs to the aquatic environment ultimately results in fish becoming contaminated with POPs. Similarly, atmospheric deposition of POPs on soil and plants leads to their contamination and subsequent consumption by, for instance, cows, and results in contamination of milk and meat. In addition, the direct application of organochlorine pesticides leads to residues on crops. Contamination of the human food chain has also occurred when contaminated wastes have been mixed with livestock feedstuffs or directly with food intended for human consumption.

Organochlorines have been detected in foodstuffs from all over the world, including in fish, meat, dairy products, cereals and vegetables. Indeed, for the general population, the greatest exposure to POPs comes through consumption of food. Many studies have been conducted to assess the concentration of persistent organochlorines in various food types, but data are nonetheless limited. Data on Latin American foodstuffs are particularly limited as nearly all of these studies have been undertaken in Northern industrialised countries.

8.1 Dairy Products

Published scientific literature on POPs in dairy products was mainly limited to Mexico and Argentina. Results from three studies are given in table 8.1. Table 8.2 gives regulatory limits set for levels of organochlorines in milk and eggs.

Table 8.1: Organochlorine Residues in Milk (µg /kg fat, ppb) reported in Latin America

Country	Chemical	Milk	Butter	Cheese
Argentina	α-HCH	8.5[1]		
	γ-HCH	42.1[1]		
	HCB	6.8[1]		
	Total Heptachlors	54.9[1]		
	Aldrin + Dieldrin	38.8[1]		
	Chlordane (α+γ)	23.2[1]		
	Endosulfan (I+II)	16.9[1]		
	Total DDTs	990[1]		
Mexico	HCB	14[11]	16[2]	50[3]
	α-HCH	15[11]	17[2]	30[3]
	β-HCH	49[11]	78[2]	140[3]
	γ-HCH	30[11]	33[2]	10[3]
	Total HCH	94[11]	93[2]	140[3]
	P,p'-DDE	44[11]	33[2]	1380[3]
	Total DDTs	159[2]	49[2]	1420[3]
	Heptachlor	23[2]		
	Heptachlor expoxide	7[2]	35[2]	
	α-endosulfan	8[2]	15[2]	
	β-endosulfan	5[2]	3[2]	

References: [1]Maitre *et al.,* 1994; [2]Walizewski *et al.,* 1997; [3]Albert 1990

Table 8.2: FAO/WHO MRLs (ppb) for Milk and Eggs.

Chemical	Milk	Milk products with >2% fat (value expressed as µg/kg fat)	Eggs
Aldrin & Dieldrin	6	150	100
Chlordane	2	50	20
DDT	20	100	100
Endrin	0.8[a]	20	200[a]
Heptachlor	6	150	50
HCB	No MRL established or revoked	No MRL established or revoked	No MRL established or revoked
Lindane	10	250	100

Source: Joint FAO/WHO Food Standards Programme Codex Alimentarius Commission (1998). (a) FAO/WHO Codex Alimentarius 1993.

8.1.1 **DDT**

Cheese from two regions of Mexico was heavily contaminated with DDT and its metabolites after dairy production began on land previously used for growing cotton (Albert, 1990). The total DDT residue was calculated at 1420 ppb in samples from one region. The study reported that these residues were much greater than the advisory level for cheese set by WHO of 1000 ppb. The reported maximum residue limit for this substance in cheese has since been reduced to 50 ppb fat.

86 of 202 (43.5%) of milk samples from Mexico contained p,p'-DDT, o,p'-DDE and p,p'-DDE. DDT residues varied widely between samples from 10 ppb to 82 ppb. These levels do not exceed regulatory limits. 68% of the samples came from central-southern areas of the country. In Argentina, DDT residues in milk (990 ppb) exceeded the WHO/FAO MRL in all cases.

Butter samples from the state of Veracruz, Mexico were analysed and did not exceed WHO limits. The authors noted, however, that some caution should be exercised in interpreting this data as none of the samples were obtained through probabilistic sampling methods (López-Carillo *et al.*, 1996). Another study assessed levels of DDT and other organochlorines in butter from 23 countries around the world, including Mexico and Brazil (Kalantzi *et al.* 2000). Levels of total DDT in butter from Brazil (4.3 ppb fat) were similar to levels found in many other countries. However, levels in butter from Mexico (100 ppb fat) were higher than levels found in all other countries except for India (250 ppb fat). By comparison levels in New Zealand were 98 ppb fat, USA 25 ppb fat and UK 2.4 ppb fat.

8.1.2 **Heptachlor and Heptachlor Epoxide**

Total heptachlors were detected at a concentration of 54.9 ppb in milk from Argentina (See Table 8.1) (Maitre *et al.*, 1994; Wong and Lee, 1997). Milk in Mexico also exhibited high residues of heptachlor although the reported value was significantly lower than (approximately half) the value of that for milk in Argentina. The levels of DDT detected in milk form Argentina and Mexico are an order of magnitude greater than the MRL for heptachlor and its epoxide of 6.0 ppb (FAO/WHO 1998). These values contrasted strongly with those found in southern Asia. In Thailand and Vietnam heptachlor and heptachlor expoxide residues were consistently below 5 ppb (Tanabe *et al.*, 1991; Kannan *et al.*, 1992).

In a survey of butter samples in Argentina, 5.9% of samples analysed (n=146) exceeded safety limits for heptachlor (Lenardon *et al.*, 1994).

In Chile, Celis (1998) discusses research that was undertaken in the late which 1980s demonstrated that a proportion of cow's milk that was tested exceeded regulatory limits.

8.1.3 Aldrin and Dieldrin

There are few data in the literature on aldrin and dieldrin in dairy products. 3.4% of butter samples (n=146) analysed in Argentina exhibited residues in excess of guideline concentrations for aldrin/dieldrin (Lenardon *et al.*,1994). In Chile, Celis (1998) cited research from the late 1980s which showed that aldrin, dieldrin and endrin were detectable in cow's milk, in some instances at levels that exceeded regulatory limits.

8.1.4 Lindane and Other HCHs

A study undertaken in Veracruz, Mexico found that α-HCH residues were detectable in 92.0% of milk samples tested, at a mean concentration of 15 ppb. 63.3% of milk samples contained β-HCH at an average concentration of 49 ppb. Lindane (γ-HCH) was detected in 80% of samples at a mean concentration of 30 ppb. Total HCHs in milk were 94 ppb, close to the FAO/WHO tolerance limit in place at the time (100 ppb) (Waliszewski *et al.,* 1997). This MRL has since been reduced to 10 ppb (FAO/WHO 1998). The presence of these compounds in dairy products was thought to be as a result of lindane being used in Veracruz as a pesticide for livestock vector control programmes, and for the control of agricultural pests (Waliszewski *et al.*, 1997).

1.4% of butter samples analysed in Argentina (n=146) contained residues of HCH in excess of recommended limits (Lenardon *et al.,* 1994).

A study on levels of organochlorines in butter from 23 different countries worldwide reported levels of total HCH in Brazil (2.3 ppb fat) and Mexico (2.9 ppb fat). These levels were similar to levels found in several other countries and were in the mid-range of levels found in the whole study.

In Chile, Celis (1998) notes that research from the late 1980s demonstrated α- and β-HCH residues in cow's milk, in some cases at levels that exceeded regulatory limits.

8.1.5 PCBs

A study on PCB and organochlorine levels in butter from 23 different countries reported levels of total PCBs in Brazil 1.1 ppb and Mexico 1.2 ppb (Kalantzi *et al.* (2000). These levels were in the mid to lower range of levels reported for other countries. Levels of PCBs were generally lower in countries from the Southern Hemisphere than from the Northern Hemisphere.

8.2 Meat

In Chile, between 1981 and 1990, the Agricultural and Livestock Research Institute investigated the presence of organochlorine pesticides in food and soils. According to Paratori (1998), the study showed that the highest percentage of pesticide occurrence was found in the northern area of the country and the lowest in the southern region.

The most ubiquitous pesticides were lindane followed by DDT and dieldrin. In food, meat samples were found to contain heptachlor, dieldrin and α-chlordane that exceeded maximum residue limits.

Table 8.3 shows the results of this research on POPs levels in foods of Mexico and table 8.4 gives regulatory limits.

Table 8.3: Organochlorine Residues (ppb fat) in beef from Mexico.

Country	Chemical	Beef	References
Mexico	HCB	77[3]	Walizewski *et al.,* 1997
	α-HCH	132[3]	
	β-HCH	310[3]	
	γ-HCH	91[3]	
	p-p'-DDE	78[3]	
	Total DDTs	2545[3]	

Table 8.4: FAO/WHO MRLs (ppb fat) for Meat

Chemical	Meat (generic)	Poultry
Aldrin & Dieldrin	200	500
Chlordane	50	500
DDT	5000	-
Endrin	100	1000
Heptachlor	200	200
Lindane	2000	700

Source: Joint FAO/WHO Food Standards Programme Codex Alimentarius Commission (1993).

8.2.1 DDT

DDT and/or its metabolites were detected in 100% of meat samples analysed in Mexico (Waliszewski *et al.,* 1997). Mean total DDTs amounted to 2,545 ppb. The latest recommendations from the Codex Alimentarius Commission have introduced a reduced MRL of 500 ppb fat (FAO/WHO 1998). The Mexican meat samples, therefore, exhibited a mean concentration in excess of 5 times the Codex MRL.

8.2.2 HCB

Hexachlorobenzene was detected in 47% of bovine meat samples tested in the Veracruz region of Mexico (Waliszewski *et al.,* 1997). There are, at present, no FAO/WHO MRLs reported for this compound (FAO/WHO 1998).

8.2.3 Lindane and Other HCHs

The total HCH burden found in 165 meat samples taken in Veracruz, Mexico had a mean of 728 ppb which the author reported as being above the FAO/WHO guideline value (Waliszewski *et al.,* 1997). That it should be the mean value that exceeds the FAO/WHO figure is of particular concern, indicating widespread contamination of bovine meat in this region of Mexico.

8.3 Fruit, Vegetables And Other Crops

Pesticides are widely used in agriculture and horticulture to secure attained production and quality targets and for the control of weeds. Inevitably some residues remain on food crops when these methods are used (Dejonckheere *et al.,* 1996). Application of pesticides to growing crops is not, however, the only manner in which food items may become contaminated. In areas where public health pesticide use is prevalent for control of diseases such as malaria, the spraying of residential properties may result in concurrent contamination of food items.

Research that was located for POPs in crops of Latin America was very limited. According to Scribano *et al.,* (1998), a study in Paraguay in 1991 identified residues of several persistent organochlorine pesticides in 9 out of 10 horticultural products that were tested. Residues were lower than FAO Codex Alimentauris standards in all but one case. In Chile, according to Celis (1998), organochlorine pesticides were detected at low levels in fruit during the 1980s.

In Brazil endosulfan use is restricted by regulation to use on sugar cane and cocoa, where a bulk residue limit of 10 ppb has been established, and on coffee where an upper limit of 40 ppb in the beans has been set. One monitoring programme, however, reported endosulfan residues of 4 to 220 ppb in locally grown fruit and vegetables around the city of Belo Horizonte in the south of the country. Endosulfan has been detected in commercially produced strawberries, where up to 29% of samples were contaminated in a study covering the period 1983-1988. Strawberries from the Campinas region were also found to contain endosulfan with residues reaching a maximum concentration of 60 ppb. In a study on endosulfan residues on tomatoes, 28% of samples contained residues, although only one farmer admitted to using the product and a maximum residue of 510 ppb was detected (Araújo *et al.,* 1999).

8.4 PCB and dioxin food contamination incident - Brazilian lime waste

Use of contaminated citrus pulp pellets from Brazil in animal feed caused contamination of milk with dioxins in Germany towards the end of 1997 and beginning of 1998. Some milk had levels higher than nationally permitted. The citrus pulp was also used as animal feed in a total of 12 EU countries. The source of the contamination in the feed was found to arise from dioxin contaminated lime waste produced as a by-product by Solvay in Brazil. The waste lime is converted into a form which is then added to citrus pulp for animal feed. Details of this incident are discussed below.

An increase in concentrations of dioxins in milk and butter (from a baseline of about 0.6-0.7 pg ITEQ g^{-1} fat) was noted in Germany in September 1997 through routine monitoring. In March 1998, milk from a tanker that collected from some 70 farms was found to contain 7.4 pg ITEQ g^{-1} fat. This was in excess of the German standards (5.0 pg ITEQ g^{-1} fat) and so was unfit for sale. Subsequent investigations determined that the source of the contamination was Brazilian citrus pulp pellets (CPP) which could constitute up to 25% of cattle feed. The contaminated feed was taken off the market across Europe and the milk contamination abated (Malisch 1998a; Malisch,

Bruns-Weller *et al.*, 1998; Traag, Mengelers *et al.*, 1999). Beef was also contaminated, though no data are available (MacKenzie 1999). In 12 EU member states, approximately 92,000 tonnes of pulp pellets were either landfilled or destroyed (Malisch, Berger *et al.*, 1999).

Around 1.5 million tonnes of pulp pellets, with an estimated value of 200-300 million US$ are sold each year. Around 60% of this comes from Brazil (Malisch 1998a; Malisch, Berger *et al.*, 1999). The citrus pulp pellets are based on citrus pulp, peel and seeds (by-products of orange juice production) and contain approximately 2% lime, which absorbs some of the moisture and neutralises its natural acidity (EC 1999e; Malisch, Berger *et al.*, 1999).

Waste lime produced by Solvay in Brazil was identified as the most likely source of the contamination (MacKenzie 1999). In January 1999 representatives of the European Commission visited Brazil to investigate the source of the dioxin-contaminated lime. In the report on this trip (EC 1999e) one specific supplier, which, until 1996, had generated "lime milk" as a by-product of acetylene production, and had approximately 1 million tonnes still in storage, was identified as the source of the contamination. This waste was supplied to another company who "converted" it into hydrated lime and then sold it on to the citrus pulp producers.

The EC report did not name any of the companies involved, but they did report the maximum concentration of dioxins found in samples from their sites. The maximum concentration reported from lime from the "converter" was 15 270 ng ITEQ kg^{-1} dry matter and the maximum concentration reported from the company that supplied them with lime was 56 111 ng ITEQ kg^{-1} dry matter. A report by a German consulting firm (ERGO 1998) provides a detailed data set for samples analysed for ABECitrus, the Brazilian association of citrus producers. The sampling was also documented by the Brazilian Ministry of Agriculture. The ERGO report contains full analysis results for two samples with identical dioxin concentrations to the two described above. Examination of the sample data included in the ERGO report confirms that the "converter" was a company called Carbotex and that their supplier was indeed Solvay.

Comparison of dioxin congener profiles is always an important factor in determining the sources of dioxin contamination. ERGO (1998) reported that samples with a congener profile similar to the citrus pulp were found at the Carbotex site, but did not investigate the subject in detail. However, another consultants' report (CEGEQ 1999), found close similarities between the dioxin profile in citrus pulp analysed in Germany and that in several of the samples from the Solvay and Carbotex sites. They were even able to offer experimental evidence to explain that if the lime from Solvay were heated, as would happen during conversion and manufacturing of CPP, it could change the dioxin profile in a way that would explain some of the apparent discrepancies between samples.

CEGEQ also reported high concentrations of other toxic organochlorines in lime samples originating from Solvay. These included tetra-, penta-and hexa- chlorinated benzenes, PCBs, hydroxy-PCBs and polychlorinated diphenyl ethers. Chlorophenols were not found. Concentrations of PCBs were generally high in samples which were heavily contaminated with PCDD/Fs, though there was no very close correlation. PCB concentrations ranged up to 52 200 μg kg^{-1} in a sample from the Solvay site.

This same sample also contained the highest reported concentrations of chlorinated benzenes; 190 μg kg^{-1} (tetrachlorobenzenes), 3 000 μg kg^{-1} (pentachlorobenzene) and 4 800 μg kg^{-1} (hexachlorobenzene). The concentration of dioxins in this sample was 32 434 ng ITEQ kg^{-1}, among the highest reported during this incident. However, another sample from this report, also from the Solvay site, had the highest dioxin contamination of all: 56 390 ng ITEQ kg^{-1} (CEGEQ 1999).

In July 1998, the EC passed Directive 98/60/EC (EC 1998), which set a maximum limit of 500 pg ITEQ kg^{-1} in citrus pulp pellets for use in animal feed. This has been retained in a subsequent Directive and proposed Directive (EC 1999d; EC 1999g). Although the new EC regulations, and the safeguards instituted in Brazil (EC 1999f) will protect European food sources from any further contamination from this source, there was scope for considerable concern if this highly contaminated material were used for other purposes. For example, contaminated lime had been used for construction in Brazil (EC 1999e). Consequently, after protracted negotiations with the State Prosecutor and other interested parties, in December 1999, Solvay signed an agreement to clean up the site (Paolo 1999).

9 HUMANS

As a consequence of the persistent, lipophilic, bioaccumulative properties of many POPS, and tendency of some to biomagnify within food chains, long-term exposure to relatively small concentrations of these compounds leads to the accumulation of considerable deposits in animal and human tissues. Studies which have monitored levels of organochlorine POPs in human tissues provide scientific evidence that humans are exposed to these chemicals. Indeed research from numerous countries has demonstrated that measurable quantities of organochlorine pesticides, PCBs and PCDD/Fs are present in human adipose tissue, blood and breast milk (Jensen and Slorach 1991). Measuring levels of POPs in tissues can give an indication of human exposure to these environmental pollutants.

There are several problems which can hinder comparisons between studies which document the levels of organochlorines in human tissues. These problems arise from differences in the scientific methods which are used to measure the concentrations of contaminants. As a consequence, direct comparison of results between studies if difficult. However, in this report, a comparison of such studies is made because this can at least give an approximate indication of the variation in levels of organochlorine contaminants between different countries.

With regard to human milk, POPs that have accumulated in a woman's body during her lifetime pass to her nursing infant via breast milk. In some countries the levels of POPs in human milk are of great concern given the potential impacts on the infant. It is possible to determine whether Acceptable Daily Intakes (ADIs) of POPs in human milk are exceeded. The ADI is a value calculated by regulatory authorities for estimating whether levels in food are "safe". The applicability of ADIs to the breast-fed infant is questionable because ADIs are designed to prevent adverse health effects over a whole lifetime exposure in a 70 kg adult. Nevertheless, given that an infant is likely to be a more vulnerable life-stage than an adult to toxic insult from chemicals, it has been proposed that ADIs should be lower for infants, and, therefore that current ADIs should not be exceeded by breast-fed infants.

It has previously been calculated that ADIs set by US EPA and WHO for dioxins/furans are exceeded by breast-fed infants. A previous Greenpeace report has also noted that ADIs for some organochlorine pesticides are exceeded for human milk in some countries (Allsopp *et al.,* 1998). In this report, estimates of whether the current ADIs for organochlorine pesticides are exceeded are performed, based on mean levels of POPs found in breast milk. Levels recorded by some studies show that the ADI is for breast-fed infants is exceeded for DDT in Mexico and dieldrin in Brazil. It is of great concern that current ADIs are exceeded by breast-fed infants, even though the relevance of this to health is unknown. Indeed, it is questionable whether ADIs are protective of human health in general. However, it is very important to note that despite contaminants in human milk, experts recommend breast-feeding because of the many advantages it gives to the child (WHO 1996, MAFF 1997).Importantly, contamination of breast milk is not, therefore, a reason to overt breast-feeding, but an indication of the urgent need for the elimination of sources of contramination.

9.1 Dioxins (PCDD/Fs) and PCBs

The most comprehensive set of studies to date on the levels of PCDD/Fs and PCBs in human tissue from many countries was performed by the World Health Organisation (WHO) on breast milk samples in the late 1980s and early 1990s (WHO 1996). This research was undertaken to assess the exposure of infants to PCDD/Fs and PCBs through breast-feeding and the possible health risks of such exposure. The study covered many countries of eastern and western Europe, Canada and Pakistan. No South American countries were included in this study. In fact, there is only one study in the scientific literature on dioxins in human milk of Latin America (Paumgartten *et al.,* 2000). This study collected milk samples from 40 mothers who were resident in the urban area of Rio de Janeiro in 1992. The milk samples were pooled into one sample and then analysed. The concentration of dioxins in the milk was 8.1 pg TEQ/g milk fat (or ppt TEQ), and PCBs (total) was 0.15 μg/g milk fat. In comparison to levels of dioxins reported in the WHO study, the level of dioxins in the Brazilian study is relatively low. For instance, the highest dioxin levels reported for a small number of countries in the WHO study was 20 – 30 ppt TEQ while the majority of countries had levels of 10 – 20 ppt TEQ. Levels of 4 – 10 ppt TEQ, similar to the Brazilian study, were found in a few countries.

For PCBs, a previous study on milk samples collected from mothers in Porto Alegre, Brazil in 1987/88 reported that PCBs were below the detection limit (Beretta and Dick 1994). In the Rio de Janeiro study, PCBs were detectable. Both the WHO study and the Rio de Janeiro study monitored 6 marker PCBs (PCB-28, -52, -101, -138, -153, -180). A comparison of the results shows that the sum total of marker PCBs found in human milk in Brazil (104 ng/g fat, ppb), was at the lower end of the range of values for other countries documented by WHO.

Table 9.1 Mean Levels of Organochlorine Pesticides in Breast Milk on a Lipid Basis (ppm)

Country	p,p'DDT	p,p'DDE	Dieldrin	HCB	β-HCH	γ-HCH	Reference
Sao Paulo, Brazil Urban Rural	(Total DDT) 1.8 0.77				(Total HCH) 0.73 2.13		Sant'Ana *et al.,* (1989)
Sao Paulo, Brazil (1983/4)			Detected in 1 of 37 samples at 0.038			0.0344	Matuo *et al.,* 1992
Porto-Algre, Brazil (1987/88)	0.12	2.53	0.07	0.02	0.9	0.02	Beretta and Dick 1994
Rio de Janeiro, Brazil (1992)	0.18	1.52	0.023	0.012	0.27	0.005	Paumgartten *et al.,* 2000
Veracruz, Mexico (1994/5)	1.271	5.017		0.047	0.561	0.022	Waliszewski *et al.,* 1996b

9.2 DDT and DDE

9.2.1 General Population

DDT and its metabolites DDE and DDD are commonly found in human tissue samples, and have been reported as being the most widespread contaminant in human milk (Jensen and Slorach 1991). In many countries, despite being banned several years ago, DDT compounds continue to be found in human tissues, demonstrating the remarkable biological persistence of this chemical (Sonawane 1995). The isomers p,p'DDT and p,p'-DDE are the major contributors to total DDT concentrations in breast milk, the other isomers being present at much lower levels (ASTDR 1997).

Countries where very high levels of DDT and DDE are found in human tissue are those where DDT is still used in agriculture or to control vector-borne diseases such as malaria. It is therefore of no surprise that the highest levels in human milk have been recorded in Asia, Africa and South America. In western countries, DDE, the major breakdown product of DDT, is by far the greatest contributor to total DDT concentrations. However, in countries where DDT is still in use, DDE contributes less to the total, around 50%, whilst DDT compounds contribute more (Kalra *et al.*, 1994).

Research on levels of DDT in human tissues in Latin America after 1985 is fairly limited with most studies available for Brazil and Mexico (see below). In Costa Rica, according to Castillo (1998), earlier studies between 1980 and 1983 showed very high levels of DDT and its metabolites in human milk. In Chile, according to Paratori (1998), a study by the Public Health Institute of Chile in the early 1980s detected DDT and its metabolites in human milk samples and in cow's milk. As a result, the manufacture, sale and use of DDT have been prohibited since 1984. In 1989, the School of Public Health, University of Chile also detected DDT residues in breast milk. According to Celis (1998), research conducted in Chile in rural areas found DDT and its metabolites were present as contaminates of human milk.

Table 9.1 shows levels of DDT and DDE in human milk reported in studies for Brazil and Mexico. On a global basis, DDT levels greater than 1 ppm in human milk may be considered as high and such levels have only been recorded in a few countries (see Allsopp *et al.*, 1998). DDT levels reported for human milk in Mexico (1.27 ppm), (Waliszewski *et al.*, 1996b), are therefore relatively high. Similarly, with regard to worldwide levels of DDE, levels greater than 2.5 ppm in human milk may be regarded as comparatively high. Studies in Latin America therefore indicated that levels of DDE in both Brazil (2.53 ppm), (Beretta and Dick 1994), and Mexico (5.01 ppm), (Waliszewski *et al.*, 1996b) were high. A study on the impacts of DDT on the length of the lactation period in women from Comarca Lagunera in north Mexico found particularly high levels of DDE in breast milk (Gladen and Rogan 1995). Of the 229 women studied, 55% had DDE levels of 2.5 - 7.5 ppm, 23% had levels of 7.5- 12.5 ppm and 9% had levels equal to or even greater than 12.5 ppm. By comparison, in the US and some European countries DDE levels of less than 1 ppm have been reported, whilst other European countries have levels in the region of 1-2 ppm. Another study undertaken in Rio de Janeiro, Brazil, reported DDE levels (1.52) falling within the latter category (Paumgartten *et al.*, 2000).

Marked regional differences in levels of DDT and DDE in human milk are apparent in countries where DDT is still in use. For instance, higher levels of DDT and DDE were

found in human milk in suburban areas of Veracruz, Mexico, than in urban areas. This was reported to be due to the spraying of DDT in suburban areas for malarial control that resulted in inhalation of DDT vapours by mothers, causing extensive exposure and eventual elimination in breast milk. Levels of DDT and DDE in breast milk respectively were 0.422 and 2.709 ppm in urban Veracruz versus 2.460 and 8.253 ppm in the suburban area (Waliszewski *et al.,* 1996b). In non-agricultural and non-tropical areas of Mexico, such as Mexico city, DDT is still found to accumulate in human tissues but to a lesser degree. For example, mean breast milk levels of p,p'-DDE were reported to be 0.594 ppm (Lopez-Carillo *et al.,* 1996). This is 10-fold lower than human breast milk in the tropical area of Veracruz (mean 5.017 ppm).

Differences in DDT levels were also apparent between studies conducted in Porto Alegre, Brazil, (Beretta and Dick 1994), and Rio de Janeiro (Paumgartten *et al.,* 2000). For instance, levels of DDE were 2.53 ppm in Rio de Janeiro versus 1.52 ppm in Porto Algre. Other organochlorine pesticides in human milk were also lower in Rio de Janeiro. This study pointed out that since Brazil has a large variety of geographical scenarios, different degrees of industrialisation and different dietary habits, data for the population of Rio de Janeiro may not reflect the situation of the country as a whole.

9.2.2 Nursing Infants

If levels of total DDT in human milk exceed 3.8 mg/kg fat (ppm), then the ADI for the nursing infant is exceeded. One study in Veracruz, tropical Mexico reported levels of 5.017 ppm of DDE plus 1.27 ppm DDT (Waliszewski *et al.,* 1996b). The ADI is therefore exceeded in this region. The ADI for DDT has also been reported to be exceeded for nursing infants in some African and Asian countries (Allsopp *et al.,* 1998).

9.2.3 Occupational Exposure

Occupational exposure to DDT can result in very high tissue levels of DDT and DDE compounds. A study in Veracruz, Mexico, investigated adipose tissue levels of DDT compounds in a group of workers whose occupation involved spraying houses with DDT and other pesticides to control malaria vectors (Rivero-Rodriguez *et al.,* 1997). Comparisons were made with the general population of Veracruz state for whom adipose tissue levels may reflect direct exposure to the sanitation campaigns and exposure through diet, (mean p,p'-DDT concentration of 1.34 ppm, p,p'-DDE, 14.1 ppm and total DDT 15.65 ppm fat) (Waliszewski *et al.,* 1995). Adipose tissue levels of total DDT in the workers who sprayed DDT were found to be 6-fold higher than levels the general population (mean p,p'-DDT 31.0 ppm fat, p,p'-DDE 60.98 ppm fat, and total DDT 104.48 ppm fat) (Rivero-Rodriguez *et al.,* 1997)

A study was undertaken on 26 workers engaged in spraying DDT and HCH for controlling disease vectors in the city of São José do Rio Preto, São Paulo, Brazil (Minelli and Ribeiro 1996). The study found that DDT and DDE were significantly elevated in the blood of workers compared to an unexposed control group of workers. Mean concentrations of p,p'-DDE and p,p'-DDT in workers were respectively 64.3 and 13.5 μg/L (ppb) compared to 14.3 and 1.5 ppb in non-exposed workers. For mean total DDT, this amounted to a 4.7-fold greater level in the blood of workers compared to controls. The levels of DDE and DDT in the pesticide sprayers in this

Brazilian study were noted to be higher than levels found in the blood of workers in Honduras in a study conducted in 1989 (mean p,p'-DDE 42.5 ppb, p,p'-DDT 2.69 ppb). However, higher blood levels were reported for malaria control sprayers from Venezuela and for workers engaged in the vector control program of the State of Bahia, Brazil (see Minelli and Ribeiro 1996).

9.3 HCH isomers

9.3.1 General Population

Of the HCH isomers, β-HCH is the most persistent and is widespread in human milk on a global basis. Levels of β-HCH reported for Brazil and Mexico (0.27 – 0.561 ppm) are within the range of levels reported for other countries (see Allsopp *et al.*, 1998), and lower than levels reported for India and China (4-8 ppm). A study in Botucata, São Paulo, Brazil, observed that levels of total HCH (α, β, γ-HCH), in human milk were on average 3-fold higher in rural than in urban regions (Sant'Ana *et al.*, 1989). This was attributed to the use of HCH for agriculture in the rural region as well as house-spraying for rural endemic diseases. In Chile in 1989, a study conducted by the school of public health, University of Chile detected lindane residues in breast milk (Paratori 1998).

9.3.2 Nursing Infants

If levels of γ-HCH in human milk exceed 0.19 mg/kg fat (ppm), then the ADI for the nursing infant is exceeded. None of the Latin American studies reported levels in excess of this figure. This is not to say, however, that the contamination and exposure are not significant.

9.3.3 Occupational Exposure

A study was conducted on 26 workers engaged in spraying DDT and HCH for controlling vector-borne diseases in the city of São José do Rio Preto, São Paulo, Brazil (Minelli and Ribeiro 1996). Blood levels of β-HCH in workers (mean 31.8 ppb) were considerably higher than blood levels detected in unexposed workers (3.3 ppb). The levels in workers blood was higher than recorded for workers in Honduras in 1989 (see Minelli and Ribeiro 1996).

9.4 Other Organochlorine Pesticides

Other pesticides that were detectable in human milk from Latin America included dieldrin, HCB and heptachlor epoxide. Dieldrin was detected by three studies on Brazil and HCB was detected in Brazil and Mexico (see table 9.1). For dieldrin, levels reported for several countries worldwide are in the range of 0.01 to 0.1 ppm, and levels from Latin America fall within this range. Levels of HCB in human milk from Mexico and Brazil were at the lower end of the range of values for many other countries (see Allsopp *et al.*, 1998). In Chile in 1989, a study conducted by the School of Public Health, University of Chile, detected HCB residues in human milk (Paratori 1998).

Heptachlor epoxide was also recorded in human milk in Brazil in Rio de Janeiro, (0.008 ppm), (Paumgartten *et al.*, 2000), and in Porto Alegre (0.02 ppm), but not in Veracruz, Mexico (Waliszewski *et al.*, 1996b). These are similar to levels found in studies from other countries (see Allsopp *et al.*, 1998).

9.4.1 Nursing Infants

If levels of dieldrin plus aldrin in human milk exceed 0.19 mg/kg fat (ppm), then the ADI for the nursing infant is exceeded. All of the studies presented in table 9.1 for Brazil reported levels in human milk which exceed this value. For HCB and heptachlor epoxide the ADI is not exceeded.

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