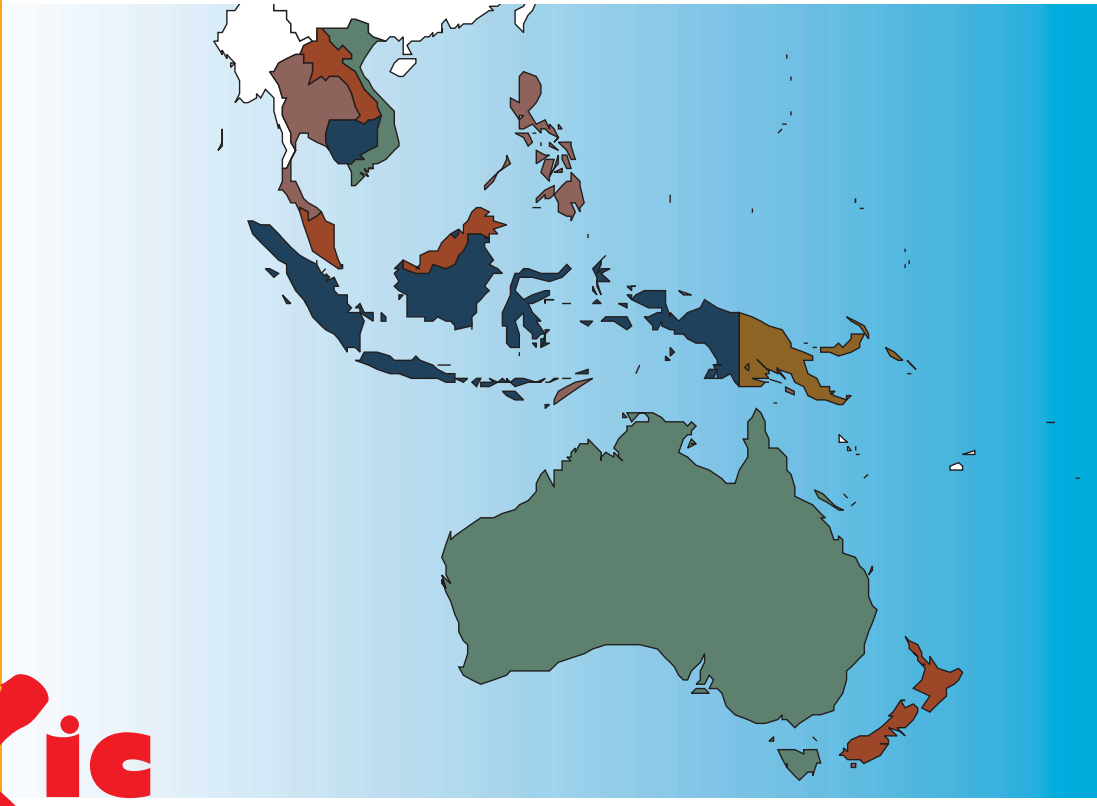
UNITED NATIONS

UNEP

United Nations
Environment Programme
Chemicals

South East Asia and South Pacific

REGIONAL REPORT



Regionally Based Assessment of Persistent Toxic Substances

December 2002

Global Environment Facility

UNITED NATIONS
ENVIRONMENT
PROGRAMME

UNEP

CHEMICALS

Regionally Based Assessment of Persistent Toxic Substances

Australia, Brunei, Cambodia, Indonesia, Lao People's Republic, Myanmar, Malaysia, New Zealand, Papua New Guinea, Philippines, Singapore, Thailand, Vietnam

SOUTH EAST ASIA AND SOUTH PACIFIC REGIONAL REPORT

DECEMBER 2002

GLOBAL ENVIRONMENT FACILITY

This report was financed by the Global Environment Facility (GEF) through a global project with co-financing from the Governments of Australia, France, Sweden, Switzerland and the United States of America.

This publication is produced within the framework of the Inter-Organization Programme for the Sound Management of Chemicals (IOMC).

This publication is intended to serve as a guide. While the information provided is believed to be accurate, UNEP disclaim any responsibility for the possible inaccuracies or omissions and consequences, which may flow from them. UNEP nor any individual involved in the preparation of this report shall be liable for any injury, loss, damage or prejudice of any kind that may be caused by any persons who have acted based on their understanding of the information contained in this publication.

The designations employed and the presentation of the material in this report do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations of UNEP concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The Inter-Organization Programme for the Sound Management of Chemicals (IOMC), was established in 1995 by UNEP, ILO, FAO, WHO, UNIDO and OECD (Participating Organizations), following recommendations made by the 1992 UN Conference on Environment and Development to strengthen cooperation and increase coordination in the field of chemical safety. In January 1998, UNITAR formally joined the IOMC as a Participating Organization. The purpose of the IOMC is to promote coordination of the policies and activities pursued by the Participating Organizations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.

Material in this publication may be freely quoted or reprinted but acknowledgement is requested together with a reference to the document. A copy of the publication containing the quotation or reprint should be sent to UNEP Chemicals.

UNEP
CHEMICALS

Available from:

UNEP Chemicals11-13, chemin des Anémones

CH-1219 Châtelaine, GE

Switzerland

Phone: +41 22 917 1234

Fax: +41 22 797 3460

E-mail: chemicals@unep.ch

http://www.chem.unep.ch

UNEP Chemicals is a part of UNEP's Technology, Industry and Economics Division

TABLE OF CONTENTS

PREFACE ..... **V**
EXECUTIVE SUMMARY ..... **VI**
1. INTRODUCTION **1**
1.2. OTHER PTS ASSESSMENT PROJECTS IN THE REGION 3
1.2.1. Existing Regional Assessments *3*
1.2.2. Inter-Regional Links and Collaboration *3*
1.2.3. National Programmes for PTS *4*
1.3. GENERAL DEFINITIONS OF CHEMICALS 5
1.3.1. Pesticides *5*
1.3.2. Industrial Compounds *9*
1.3.3. Unintended By-products *9*
1.3.4. Regional Specific Chemicals *10*
1.4. DEFINITION OF THE SOUTHEAST ASIA AND SOUTH PACIFIC REGIONS 16
1.5. PHYSICAL SETTING 17
1.5.1. Physical/Geographical Description *17*
1.5.2. Climate and Meteorology *18*
1.5.3. Region's Freshwater Environments *19*
1.5.4. Marine Environment *20*
1.5.5. Ecological Characteristics of the Region *21*
1.6. PATTERNS OF DEVELOPMENT/SETTLEMENT 22
1.7. REFERENCES 23
2. SOURCE CHARACTERISATION **25**
2.1. BACKGROUND INFORMATION 25
2.2. DATA COLLECTION 29
2.3. PESTICIDES 29
2.3.1. Aldrin *29*
2.3.2. Chlordane *29*
2.3.3. Dichlorodiphenyltrichloroethane (DDT) *29*
2.3.4. Dieldrin *30*
2.3.5. Endrin *30*
2.3.6. Endosulfan *31*
2.3.7. Heptachlor *31*
2.3.8. Hexachlorobenzene *31*
2.3.9. Mirex *31*

2.3.10. Pentachlorophenol (PCP) *32*
2.3.11. Toxaphene *32*
2.3.12. Hexachlorohexanes *32*
2.4. INDUSTRIAL CHEMICALS 33
2.4.1. Hexachlorobenzene (HCB) *33*
2.4.2. Polychlorinated Biphenyls (PCBs) *34*
2.5. UNINTENDED BY-PRODUCTS 35
2.5.1. Dioxins and Furans (PCDDs/PCDFs) *35*
2.5.2. Polycyclic Aromatic Hydrocarbons (PAHs) *38*
2.6. OTHER PTS OF EMERGING CONCERN IN REGION 38
2.6.1. Organotin Compounds *38*
2.6.2. Organomercury Compounds *39*
2.6.3. Organolead Compounds *39*
2.6.4. Chlor. Paraffins, Nonyl/Octyl-Phenols, Phthalates, PBBs and PBDEs *40*
2.7. HOT SPOTS 40
2.8. DATA GAPS 40
2.9. SUMMARY 41
2.10. REFERENCES 41
3. ENVIRONMENTAL LEVELS, TOXICOLOGICAL AND ECOTOXICOLOGICAL PATTERNS. 45
3.1. ENVIRONMENTAL LEVELS 45
3.1.1. Environmental Media: Air *45*
3.1.2. Environmental Media: Water *48*
3.1.3. Environmental Media: Sediment *52*
3.1.4. Environmental Media: Soil *53*
3.1.5. Environmental Media: Animals *54*
3.1.6. Environmental Media: Humans *56*
3.1.7. Environmental Media: Vegetation *59*
3.1.8. Data Gaps *61*
3.1.9. Conclusions *61*
3.2. SPATIAL AND TEMPORAL TRENDS 62
3.3. TOXICOLOGY OF PTS OF REGIONAL CONCERN 64
3.3.1. Overview of Harmful Effects *64*
3.3.2. National and Regional Human Health Reports *65*
3.3.3. Health Risk Assessment *69*
3.3.4. Risk Characterisation *72*
3.3.5. Data Gaps *72*
3.3.6. Conclusions *73*

3.4. ECOTOXICOLOGY OF PTS OF REGIONAL CONCERN 74
3.4.1. Overview of Harmful Effects 74
3.4.2. Ecological Databases and Laboratory and Field Studies 74
3.4.3. Observed lethal effects in the environment 79
3.4.4. Field Studies on Ecosystems 81
3.4.5. Ecological Risk Assessment Studies 82
3.4.6. Data Gaps 84
3.4.7. Conclusions 85
3.5. SUMMARY 85
3.6. REFERENCES 87
4. ASSESSMENT OF MAJOR PATHWAYS OF CONTAMINANT TRANSPORT 93
4.1. INTRODUCTION 93
4.2. REGIONALLY SPECIFIC FEATURES 93
4.2.1. Observations on the Properties of the PTS 93
4.2.2. Interhemispheric Mixing of PTS 94
4.3. OVERVIEW OF EXISTING MODELLING PROGRAMS AND PROJECTS 95
4.4. TRANSPORT PATTERNS OF PTS IN THE REGION 96
4.5. MODELLING THE TRANSPORT OF PTS IN THE REGION 97
4.5.1. The Study Area 97
4.5.2. Fugacity Modelling 98
4.5.3. Application of the Modelling Outcomes to Evaluation of Transport 101
4.5.4. Interpretation of the Modelling Outcomes 103
4.6. DATA GAPS 105
4.7. SUMMARY 105
4.8. REFERENCES 106
5. PRELIMINARY ASSESSMENT OF THE REGIONAL CAPACITY AND NEEDS 108
5.1. INTRODUCTION 108
5.2. MONITORING CAPACITY 108
5.2.1. PTS 108
5.2.2. Organometals 108
5.2.3. Dioxin Analysis 108
5.2.4. Human Health 109
5.3. EXISTING REGULATION AND MANAGEMENT STRUCTURES 109
5.3.1. National 109
5.3.2. Regional Initiatives 109

5.3.3. International *110*
5.4. STATUS OF ENFORCEMENT 113
5.5. ALTERNATIVES OR MEASURES FOR REDUCTION 115
5.5.1. ASEAN *115*
5.5.2. Australia *116*
5.5.3. New Zealand *116*
5.6. TECHNOLOGY TRANSFER 117
5.6.1. Integrated Pest Management *117*
5.6.2. Cleaner Production *117*
5.7. SUMMARY 117
5.8. REFERENCES 118
6. FINAL RESULTS AND RECOMMENDATIONS 119
6.1. MAIN RESULTS 119
6.1.1. Sources *119*
6.1.2. Levels/Effects *120*
6.1.3. Pathways and Transport *122*
6.1.4. Regional Capacity *122*
6.1.5. Regional Prioritisation of Chemicals *123*
6.2. RECOMMENDATIONS FOR FUTURE ACTIVITIES 124
6.2.1. Capacity Building and Assessment *125*
6.2.2. Information Management *125*
6.2.3. Capacity Building, Implementation and Monitoring *125*

PREFACE

In 2000, The United Nations Environmental Program asked The Marine Environment and Resources Foundation Inc. (MERF) to participate in a global assessment of PTS, and in particular, to produce a report on PTS for the Southeast Asia and South Pacific Region. This document is intended to meet that request. This report is one of twelve, which make up the global assessment.

The members of the Regional Team approved by UNEP and subsequently commissioned by MERF to produce the report were chosen on the basis of the following criteria:

- Each member should have extensive technical and scientific experience on PTS related subjects;
- Each member should be recognized and respected in their country and in the sub-region as competent in the PTS field;
- The members should come from differing countries to represent a cross-section of the region;
- Members should be selected to ensure that competence resides to undertake the writing of the various chapters of the regional report;
- Each member should be accessible by email and have internet access;
- Each member should have administrative and technical support of a recognizerecognised institution; and,
- Each member should be fluent in English.

The Team Members thus chosen, were as follows:

Regional Coordinator

Dr. Gil S. Jacinto, Director, Marine Science Institute, University of the Philippines, Diliman, Quezon City, Philippines

Team Members

Dr. Des W. Connell, Professor, School of Public Health, Griffith University, Nathan, Queensland, Australia;

Dr. Md. Sani Ibrahim, Associate Professor, School of Chemical Sciences, Universiti Sains Malaysia, Pulau Pinang, Malaysia; and,

Mr. Lim Kew Leong, Chief Engineer/Inspectorate, Pollution Control Department, Ministry of the Environment, Singapore.

Acknowledgements

As in many complex writing endeavours, this report is the product of many persons whose names do not appear in the cover. Also, this work would not have been possible without the assistance and support of the institutions where the team members are affiliated, and the help from members of the Regional Network who provided information on PTS chemicals within the region. The invaluable contributions from the participants at the two Regional Technical Workshops and the Regional Priority Setting Meeting are also gratefully acknowledged. Dr. Pythias Espino of the Institute of Chemistry, University of the Philippines Diliman, provided valuable support in uploading and validating PTS data into the project's web site.

The Global Environment Facility through UNEP Chemicals provided funds for the project.

EXECUTIVE SUMMARY

Following the recommendations of the Intergovernmental Forum on Chemical Safety, the UNEP Governing Council decided in February 1997 (Decision 19/13 C) that immediate international action should be initiated to protect human health and the environment through measures which will reduce and/or eliminate the emissions and discharges of an initial set of twelve persistent organic pollutants (POPs). However, in addition to the twelve substances identified and adopted under the Stockholm Convention of 2001, there are many other persistent toxic substances (PTS) that are of concern and satisfy the criteria for POPs. The sources, environmental concentrations and effects of these POPs are to be assessed.

The objective of this project was to deliver a measure of the nature and degree of damage or threat posed by PTS at national, regional and ultimately, global levels. Findings of the project will provide the Global Environment Facility (GEF) with a science-based rationale for assigning priorities for action among and between chemical related environmental issues. It will also determine the extent to which differences in priority exist among regions. The outcome of this project will be a scientific assessment of the threats posed by PTS to the environment and human health.

To achieve these results, the globe was divided into 12 regions namely: Arctic, North America, Europe, Mediterranean, Sub-Saharan Africa, Indian Ocean, Central and North East Asia (Western North Pacific), Southeast Asia and South Pacific, Pacific Islands, Central America and the Caribbean, Eastern and Western South America, Antarctica. The twelve regions were selected based on obtaining geographical consistency while trying to take into account the financial constraints of the project.

Region 8 (Southeast Asia and South Pacific) includes: Australia, Brunei Darussalam, Cambodia, Indonesia, Lao Peoples' Democratic Republic, Malaysia, New Zealand, Papua New Guinea, Philippines, Singapore, Thailand, and Viet Nam.

This report describes the assessment of PTS in Region 8. It focuses on the sources of PTS in the environment, their concentration levels and impact on biota, their transboundary transport, and examines the root causes of the problems. As an outcome, the capacity of the region to manage these problems has been evaluated.

The project has relied upon the collection and interpretation of existing data and information as the basis for the assessment. No research was undertaken to generate primary data, but projections were made to fill data/information gaps, and to predict threats to the environment.

Sources of PTS

Information on the importation, use and emissions of PTS is limited in the region. Much of the attention has been on regulatory measures to phase out or to ban the use of PTS pesticides. Except for DDT, endosulfan, mirex and lindane, many of the pesticides have been banned or have not been used for the last 10 years.

Emissions of PCDD/PCDFs and PAHs are widespread but have largely not been quantified. Major sources include forest and vegetation fires, open burning of wastes, releases from landfills and industrial processes. PCDD/PCDFs emissions from industrial sources are very much dependent on the technology in use while landfills, fires and open burning of domestic wastes are uncontrolled sources in some countries in the region. Regular and widespread occurrences of forest and bush fires are also major sources of PAHs and PCDD/PCDFs.

While the importation of PCBs has been banned in the region, many countries do not have or maintain national inventories of PCB-contaminated equipment (e.g. transformers).

Knowledge on the sources of other PTS (e.g. chlorinated phenols and PBDEs) is generally lacking in the region. This also includes organometallic compounds. Currently, leaded petrol and TBT in antifouling paints are being phased out.

Levels of PTS

The concentrations of most PTS in various environmental compartments (air, water, soil, sediments, and biota) were obtained from various sources, mainly published literature reports, project questionnaires and personal communications.

The levels of several PTS in air have been reported to be high in the Southeast Asian countries. In particular, DDTs, chlordanes, HCHs, and PCBs were found to be relatively high in air above coastal areas. High levels of DDTs and PCBs were found in soils throughout the region but some sites in Australia and Viet Nam were reported to be the most contaminated. However, studies of temporal trends revealed that the DDTs and several other chlorohydrocarbon pesticides are decreasing exponentially. Endosulfan was found in most sediment in the region, particularly in Malaysia, suggesting the recent use of this chemical because of its shorter persistence in the environment.

HCHs, particularly lindane, were found at high concentration levels in river waters in the region particularly Malaysia and Thailand. Other OCPs were also found in relatively high levels but showed a decreasing trend with time. Surface seawater was also found to contain high levels of HCHs particularly in seas around Southeast Asia.

The concentration levels of PTS in marine organisms, such as fishes and mussels, have been extensively studied. The Mussel Watch program reported the widespread presence of a whole spectrum of PTS in mussels collected from this region, although there were indications that the levels of PTS such as DDTs, HCHs and PCBs were declining.

PTS levels in humans have not been widely determined although Australia, New Zealand, and Singapore have undertaken population monitoring studies. New Zealanders have been found to have very low levels of PTS in blood and breast milk and could provide baseline values to compare with the region's human population. There is a definite lack of data on the human toxicological effects of PTS, which are of considerable importance for countries in this region. Data on levels of PTS in food and vegetables are available but not comprehensive. Most reports on PTS levels in food products reveal the presence of significant numbers of PTS in most samples and varied concentration levels.

Ecotoxicology and Toxicology

PCDDs/PCDFs were regarded to be of major concern in terms of their potential threat to human health and the ecosystem in general. Even though data on levels are scarce, estimates on release to the environment due to industrial and non-industrial activities indicated a significant input to the system. In view of widespread sources of unintentional releases coupled with high toxicity and accumulative properties, PCDD/PCDFs are possibly the most important PTS to be evaluated in the future. A greater effort should be focused on the reduction of unintentional releases of PCDD/PCDFs as well as monitoring of concentration levels.

The available evidence indicates that DDT concentration levels are falling in the region. However, DDT and related organochlorine pesticides may occur in significant concentrations and be implicated in such adverse human health effects as breast cancer and reduced bone density in women. There is also evidence that endosulfan has been widely used as a substitute for the banned pesticides. This substance has been shown to have significant effects on human health and the natural environment in this region.

A number of organochlorine compounds (DDTs, HCHs, chlordane and PCBs) occur in water and sediments throughout the region in concentrations that exceed guideline values for natural ecosystems. This would be expected to cause a reduction in the species diversity of natural aquatic systems in the region and other adverse effects.

The region has urban sources as well as natural sources, such as forest fires, which produce PAHs and particulates that will have adverse effects on human health.

Most countries in the region have phased out or are regulating the use of organochlorine pesticides, PCBs and organometals or organometallic compounds. As a result, the concentrations of some PTS are falling. However, a major regional health issue is concerned with the human health and adverse ecotoxicological effects resulting from the ongoing presence of PCDD/PCDFs in the environment of Viet Nam. This has resulted from the extensive use of 2,4,5-T herbicide, contaminated with PCDD/PCDFs during the Viet Nam war, mainly during the period from 1965-1970.

The analysis of major pathways and PTS transport into and out of the region suggests that the Southeast Asian sub-region of the Southeast Asia South Pacific region can be considered as a separate area in relation to transport of PTS due to the presence of ocean currents and atmospheric convergence zones around the equator. There is no evidence to suggest that Australia and New Zealand are sources of PTS that could be transported to other areas. On the other hand these countries do not seem to receive PTS in significant amounts from elsewhere.

Fugacity modelling indicates that the relatively high concentrations of HCHs in air and water in parts of the Southeast Asia region provide a reservoir for transport to other areas and that water movements are more important than atmospheric movement for PTS transport. The results suggest that transport out of the region would be to the north-east through the Kuroshio Current. The transport of PTS from Southeast Asia towards the south is inhibited by the equatorial ocean and atmospheric convergence located approximately on the equator.

While there are relatively large potential sources of DDT and PCBs in the region, fugacity modelling suggests that transport out of the region is not occurring on a significant scale. This analysis is based on results obtained in the period 1989 to 1991. The situation may have changed during the period up to the present time.

Capacity, Priorities and Needs

The assessments made in this report have been characterised by the limited amount of information available or accessible regarding sources, inventories, ecotoxicology, toxicology, and transport of PTS. Many developing countries in the region lack regulatory infrastructure (including national PTS registration and control schemes), appropriate legislation and regulations, enforcement mechanisms, and laboratory infrastructure for quality control and analysis of residual PTS. In addition, financial constraints make it difficult for countries to implement regulations and mechanisms that may already be in place. In contrast, Australia, New Zealand, and Singapore do not appear to be faced with such issues. Australia and New Zealand lead the countries in the region in monitoring, and minimising the use of or replacing the use of PTS. This includes the National Dioxins Program (Australia) and the Organochlorines Program in New Zealand. There is scope to transfer technology and experiences from these countries to the rest of the region.

A major output of the two regional workshops conducted in the course of this study was the prioritisation of a list of 25 persistent toxic substances for sources, environmental levels, ecotoxicological effects, human health effects, and data gaps. DDT and PCDD/PCDFs were considered to be of regional concern with respect to environmental levels, sources, ecotoxicological and health effects. Endosulfan is also of regional concern because of its continued use in many countries to replace organochlorine pesticides, and because of its known ecotoxicological effects. In many parts of the region, forest and vegetation fires are major sources of PAHs. While the short-term health risks from PAH exposure appear to be low, long-term exposure to PAHs may increase these risks especially if combined with urban emissions.

Based on the information gathered by the regional team, and the consultations made with various institutions and participants at the two regional workshops and the priority setting meeting under this project, a number of needs for the region have been identified and recommendations made. These fall under two main categories – capacity building and information management.

Under capacity building, a major need is to improve analytical facilities and methods for the determination of PTS, giving emphasis to compounds that are of the greatest cause of concern in the region. Associated with this, there is a need to develop a set of regional environmental quality guidelines to evaluate the significance of PTS levels in air, soil, waste, sediment, food and drinking water. These should relate environmental levels to the occurrence of significant adverse effects on human health and the natural environment. This could be part of an expanded set of environmental guidelines already initiated by ASEAN for the region.

Efforts should also be made by countries in the region to develop the software and hardware required for proper waste management, treatment, minimisation, and disposal facilities for PTS. It would be advantageous to use the tried and tested multilateral arrangement mechanisms in the region (e.g. ASEAN-Australia) to bring about projects/activities to support these needs.

The effort of UNEP to use the "toolkit" for PCDD/PCDFs could be expanded to include other countries in the region in addition to those where the method has been piloted (e.g. Brunei Darussalam, the Philippines, and Thailand). The procedure could also be developed further to take into account other priority PTS in the region.

Information management needs to include public information programs, improved handling and exchange of data, and also information on PTS. Policy makers in governments and developing countries need accessible information on strategies for improving capacity to regulate and implement best practices regarding PTS. If continued, the current effort to have a worldwide database on PTS sources, environmental levels, and national capacity, will benefit from the development of compatible national databases on PTS.

1. INTRODUCTION

Most chemicals find their way into the environment via various products and processes. Once in the environment, they can persist for long periods of time or break down into other chemicals with their own risk (EEA, 1998). They may also produce health or environmental effects when they act together with other natural or manufactured chemicals that are already in the environment.

Effective risk management for chemicals depends on tracking the pathways, fate and exposure implications of chemicals. Yet, data identifying the pathways, emissions, environmental fate and exposure as a base for risk assessment are available for very few chemicals.

Special attention has been given to the persistent toxic organic substances, which are widely found in the environment. These substances can travel through air, water and living organisms, be released into the environment in one part of the world, and, through a repeated process of release and deposit, be transported to regions far away from their original source (UNEP, 2000; EEA, 1998; UN ECE, 1998). They can become increasingly concentrated in the tissues of animals at higher levels of the food chain, such as predatory birds and mammals, including humans.

The result is that humans and wildlife are exposed in some cases to very complex mixtures of chemicals and, in many cases, we have only limited information concerning the harmful effects of these mixtures at environmental levels of exposure.

1.1. Overview of the RBA PTS Project

Following the recommendations of the Intergovernmental Forum on Chemical Safety, the UNEP Governing Council decided in February 1997 (Decision 19/13 C) that immediate international action should be initiated to protect human health and the environment through measures which will reduce and/or eliminate the emissions and discharges of an initial set of twelve persistent organic pollutants (POPs). Accordingly, an Intergovernmental Negotiating Committee (INC) was established with a mandate to prepare an international legally binding instrument for implementing international action on certain persistent organic pollutants.

These series of negotiations have resulted in the adoption of the Stockholm Convention in 2001. The initial 12 substances fitting these categories that have been selected under the Stockholm Convention include: aldrin, endrin, dieldrin, chlordane, DDT, toxaphene, mirex, heptachlor, hexachlorobenzene, PCBs, PCDD and PCDFs. Besides these 12, there are many other substances that satisfy the criteria listed above for which their sources, environmental concentrations and effects are to be assessed.

Persistent toxic substances can be manufactured substances for use in various sectors of industry, pesticides, or by-products of industrial processes and combustion. To date, their scientific assessment has largely concentrated on specific local and/or regional environmental and health effects, in particular "hot spots" such as the Great Lakes region of North America or the Baltic Sea.

There is a need for a scientifically-based assessment of the nature and scale of the threats to the environment and its resources posed by persistent toxic substances that will provide guidance to the international community concerning the priorities for future remedial and preventive action. The assessment will lead to the identification of priorities for intervention, and through application of a root cause analysis will attempt to identify appropriate measures to control, reduce or eliminate releases of PTS, at national, regional or global levels.
The objective of the project is to deliver a measure of the nature and comparative severity of damage and threats posed at national, regional and ultimately at global levels by PTS. This will provide the GEF with a science-based rationale for assigning priorities for action among and between chemical related environmental issues, and to determine the extent to which differences in priority exist among regions.

1.1.1.1. Project Activities and Expected Results

The project relies upon the collection and interpretation of existing data and information as the basis for the assessment. No research will be undertaken to generate primary data, but projections will be

made to fill data/information gaps, and to predict threats to the environment. The proposed activities are designed to obtain the following expected results:

1. Identification of major sources of PTS at the regional level;
2. Impact of PTS on the environment and human health;
3. Assessment of transboundary transport of PTS;
4. Assessment of the root causes of PTS related problems, and regional capacity to manage these problems;
5. Identification of regional priority PTS related environmental issues; and,
6. Identification of PTS related priority environmental issues at the global level.

The outcome of this project will be a scientific assessment of the threats posed by persistent toxic substances to the environment and human health. The activities to be undertaken in this project comprise an evaluation of the sources of persistent toxic substances, their levels in the environment and consequent impact on biota and humans, their modes of transport over a range of distances, the existing alternatives to their use and remediation options, as well as the barriers that prevent their good management.

1.1.1.2. Regional Divisions

To achieve these results, the globe is divided into 12 regions namely: Arctic, North America, Europe, Mediterranean, Sub-Saharan Africa, Indian Ocean, Central and North East Asia (Western North Pacific), Southeast Asia and South Pacific, Pacific Islands, Central America and the Caribbean, Eastern and Western South America, and Antarctica. The twelve regions were selected based on obtaining geographical consistency while trying to reside within financial constraints.

Region 8 (Southeast Asia and South Pacific) includes: Australia, Brunei Darussalam, Cambodia, Indonesia, Lao Peoples' Democratic Republic, Malaysia, New Zealand, Papua New Guinea, Philippines, Singapore, Thailand, and Viet Nam.

1.1.1.3. Management Structure

The project manager who is based at UNEP Chemicals in Geneva, Switzerland directs the project. A Steering Group comprising representatives of other relevant intergovernmental organisations along with participation from industry and the non-governmental community is established to monitor the progress of the project and provide direction for the project manager. A regional co-ordinator, assisted by a team of approximately 4 persons, heads each region. The co-ordinator and the regional team are responsible for promoting the project, the collection of data at the national level and carrying out a series of technical and priority setting workshops for analysing the data on PTS on a regional basis. Besides the 12 POPs from the Stockholm Convention, the regional team selects the chemicals to be assessed for its region with selection open for review during the various workshops undertaken throughout the assessment process. Each team writes the regional report for the respective region.

1.1.1.4. Data Processing

Data is collected on sources, environmental concentrations, human and ecological effects through questionnaires that are filled in at the national level. The results from this data collection, along with presentations from regional experts at the technical workshops, are used to develop regional reports on the PTS selected for analysis. A priority setting workshop with participation from representatives from each country results in priorities being established regarding the threats and damages of these substances to each region. The information and conclusions derived from the 12 regional reports will be used to develop a global report on the state of these PTS in the environment.

The project is not intended to generate new information but to rely on existing data and their assessment to arrive at priorities for these substances. The establishment of a broad and wide-ranging network of participants involving all sectors of society was used for data collection and subsequent evaluation. Close co-operation with other intergovernmental organisations such as UNECE, WHO, FAO, UNPD, World Bank and others was obtained. Most have representatives on the Steering Group Committee who monitor the progress of the project and critically review its implementation.

Contributions were garnered from UNEP focal points, national focal points selected by the regional teams, industry, government agencies, research scientists and NGOs.

1.1.1.5. Project Funding

The project costs approximately US$4.2 million funded mainly by the Global Environment Facility (GEF) with sponsorship from countries including Australia, France, Germany, Sweden, Switzerland and the USA. The project runs from September 2000 to April 2003 with the intention that the reports are presented to the first meeting of the Conference of the Parties of the Stockholm Convention projected for 2003/4.

1.2. Other PTS Assessment Projects In The Region

Assessment projects/initiatives related to PTS have been going on in the region and some of these are described below:

1.2.1. Existing Regional Assessments

1.2.1.1. Development of Environment Statistics in ESCAP Region

The broad aim of the project is to improve national capabilities of developing countries in the region for identifying, collecting, processing, analysing and utilising the data needed for formulating policies and programs for environment and sustainable development, as well as for monitoring and evaluating the progress made. The basic objectives of the project are to adopt a set of training materials on environment statistics and to provide the concerned officials with the available basic standard international methodological issues of environmental statistics through sub-regional training workshops (environmental statistics, and environmental and resource accounting) for East and Southeast Asia, South Asia, the Pacific islands and Central Asia during the years 2000-2001.

1.2.1.2. Global Environment Monitoring System (GEMS) Freshwater Quality Program

The GEMS/Water program is a multi-faceted water science program oriented towards understanding freshwater quality issues throughout the world. Major activities include monitoring, assessment, and capacity building. The implementation of the GEMS/Water program involves several United Nations agencies active in the water sector as well as a number of organisations around the world. Participants from Region 8 include: Cambodia (in progress), Indonesia, Laos (in progress), Thailand, Viet Nam (in progress) Australia, Malaysia, New Zealand, Philippines, and Papua New Guinea. Organic chemicals and contaminants being monitored include: p,p-DDT, o,p-DDT, p,p-DDD, o,p-DDD, p,p-DDE, o,p-DDE, lindane, alpha-BHC, mirex, aldrin, endrin, dieldrin, PCBs, atrazine, methiocarb, aldicarb, 2,4-D, and BHC.

1.2.2. Inter-Regional Links and Collaboration

1.2.2.1. ASEAN - Transboundary Haze

Transboundary haze pollution arising from land and forest fires continues to be the most prominent and pressing environmental problem facing ASEAN today. The HPA addresses the transboundary haze issue through the following objectives, namely (i) to fully implement the ASEAN Co-operation Plan on Transboundary Pollution with particular emphasis on the Regional Haze Action Plan (RHAP) by year 2001; (ii) to strengthen the ASEAN Specialised Meteorological Centre with emphasis on the ability to monitor forest and land fires and provide early warning on transboundary haze by year 2001; and (iii) to establish the ASEAN Regional Research and Training Centre for Land and Forest Fire Management by the year 2004. ASEAN Secretariat's RHAP-Co-ordination and Support Unit continuously monitors the haze situation on a day-to-day and region-wide basis and shares its findings through its website: the ASEAN Haze Action Online (www.haze-online.or.id).

1.2.2.2. ASEAN - Working Group on Multilateral Environmental Agreements

The purpose of the Working Group is to enhance co-operation between ASEAN member countries with regards to Multilateral Agreements on the Environment with a view to reaching a common

ASEAN approach, where appropriate, in the negotiation and implementation of multilateral environmental agreements. ASEAN member countries will also have the opportunity to:

(a) Strengthen the co-operation among each other in the implementation of existing international instruments or agreements in the field of the environment, taking into account in particular the needs of ASEAN. ASEAN countries need also to be provided with technical assistance in their attempts to enhance their national legislative capabilities in the field of environmental agreements,

(b) Identify and address issues and problems that prevent the ASEAN countries from participating in or duly implementing international environmental agreements or instruments and, where appropriate, to review or revise them with the purpose of further integrating environmental concerns into the development process;

(c) Promote and support the effective participation of ASEAN countries in the negotiation, implementation, review and governance of international environmental agreements or instruments, including appropriate provision of technical and financial assistance and other available mechanisms for this purpose;

(d) Exchange views and information on new or revised Multilateral Environmental Agreements; and,

(e) Upgrade ASEAN capacity for negotiations in Multilateral Environmental Agreements (MEAs).

1.2.2.3. Asia Toolkit Project on Inventories of PCDD/PCDFs Releases

This project is a key element of UNEP's capacity building program assisting countries in identifying their PCDD/PCDFs sources and releases. It supports the Stockholm Convention on Persistent Organic Pollutants where in Article 5 Parties to the Convention are requested to identify and quantify the release of by-products. The project, which is supported by the US Government, is piloting the Toolkit in five countries. Participants in this project in Region 8 are: Viet Nam, the Philippines and Brunei Darussalam.

1.2.3. National Programmes for PTS

1.2.3.1. Assessing National Management Needs forof PTS – Pilot Country Study

The Global Environment Facility (GEF) has approved a project preparation and development grant (PDF-B) for UNEP to prepare a project entitled "Assessing National Management Needs of Persistent Toxic Substances (PTS)." This project is wholly complimentary to the large-scale initiative of the PTS project, focussing on national level assessment of issues and problems, costs and alternatives for action.

At the national level, the objective for the participating countries is the development (or strengthening) of a Strategic Action Plan for the management of chemicals, particularly PTS (including POPs). At the global level, the objectives are two-fold: a) to produce widely applicable guidelines for assessing national level problems related to PTS and the needs of countries in terms of managing them (these guidelines will be produced on the basis of conducting eight or more country studies to address, and identify solutions to problems associated with persistent toxic chemicals in a few representative developing countries and countries in economic transition); and b) to produce a set of cost-norms for the set of enabling type activities that countries may have to execute in order to meet their obligations under a POPs Convention.

1.2.3.2. National Dioxins Program

In the 2001-02 Federal Budget, the Australian Government announced funding of $5 million over four years (2001-2005) for the National Dioxins Program to reduce dioxins and dioxin-like substances in the environment.

The key actions of the NDP will be implemented over three phases: *Phase One* – gather as much data as possible about levels of PCDD/PCDFs in Australia; *Phase Two* – assess the impact of

PCDD/PCDFs on human health and the environment; and *Phase Three* – in light of these assessed impacts, reduce and where feasible, eliminate releases of PCDD/PCDFs in Australia.

1.2.3.3. National Pollutant Inventory – Australia

The National Pollutant Inventory (NPI), first publicly available on the internet in early 2000, is an internet database designed to provide the community, industry and government with information on the types and amounts of certain substances being emitted to the environment. Australian industrial facilities, using more than a threshold amount for the substances listed on the NPI reporting list, are required to estimate and report emissions of these substances annually. PTS are included in the list. Environment Australia also estimates emissions from non-industry sources and facilities that are using less than the threshold amount for substances listed on the NPI.

1.2.3.4. The Organochlorines Program – New Zealand

The Ministry for the Environment's Organochlorines Program began in 1995 with the aim to: research levels of organochlorines in humans, food and in the environment; reduce industrial emissions of PCDD/PCDFs to air, land and water; clean up land contaminated with organochlorine residues; and manage the safe disposal of waste stocks of organochlorine chemicals. The Ministry has completed a series of investigations into levels of organochlorines in New Zealand. Detailed information is available in a series of research reports on organochlorines

(e.g., http://www.mfe.govt.nz/issues/waste/ocreports.htm).

1.3. General Definitions Of Chemicals

Substances that are persistent, bioaccumulative and possess toxic characteristics likely to cause adverse human health or environmental effects are called PTS (persistent and toxic substances). In this context, "substance" means a single chemical species, or a number of chemical species that form a specific group by virtue of (a) having similar properties and being emitted together into the environment; or (b) forming a mixture normally marketed as a single product. Depending on their mobility in the environment, PTS could be of local, regional or global concern (Wallack *et al.,* 1998).

A subclass of PTS, so called POPs (persistent organic pollutants), is a group of twelve compounds that have been selected, under the Stockholm Convention and which are prone to long-range atmospheric transport and deposition (Wallack *et al.,* 1998; UN ECE, 1996). These include aldrin, endrin, dieldrin, chlordane, DDT, heptachlor, mirex, toxaphene, hexachlorobenzene, PCBs, dioxins and furans. These will be considered in this regional assessment along with regional specific chemicals including HCH, PAHs, endosulphan, pentachlorophenol, organic mercury compounds, organic tin compounds, organic lead compounds, phthalates. PBDEs, HxBBs, chlordecone, octylphenols, nonylphenols and short chained chlorinated paraffins. The global extent of POPs became apparent with their detection in areas such as the Arctic, where they have never been used or produced, at levels posing risks to both wildlife (Barrie *et al.,* 1992) and humans (Mulvad *et al.,* 1996).

Persistent toxic substances include two main groups of pollutants, persistent organic pollutants (POPs) and organometallics. POPs are separated into three subgroups, pesticides, industrial compounds and unintended by-products. One compound, hexachlorobenzene, belongs to all three groups, pesticides (fungicide), industrial compounds (by-product) and unintended by-products.

The definitions presented here were agreed upon following consultations among the regional co-ordinators, their team members, and the program manager.

1.3.1. Pesticides

1.3.1.1. Aldrin

Chemical Name: 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-endo,exo-5,8-dimethanonaphthalene ($C_{12}H_8Cl_6$).

CAS Number: 309-00-2

Properties: Solubility in water: 27 µg/L at 25°C; vapour pressure: 2.3 x 10^{-5} mm Hg at 20°C; log K_{OW}: 5.17-7.4.

Discovery/Uses: It has been manufactured commercially since 1950, and used throughout the world up to the early 1970s to control soil pests such as corn rootworm, wireworms, rice water weevil, and grasshoppers. It has also been used to protect wooden structures from termites.

Persistence/Fate: Readily metabolised to dieldrin by both plants and animals. Biodegradation is expected to be slow and it binds strongly to soil particles, and is resistant to leaching into groundwater. Aldrin was classified as moderately persistent with a half-life in soil and surface waters ranging from 20 days to 1.6 years.

Toxicity: Aldrin is toxic to humans; the lethal dose for an adult has been estimated to be about 80 mg/kg body weight. The acute oral LD_{50} in laboratory animals is in the range of 33 mg/kg body weight for guinea pigs to 320 mg/kg body weight for hamsters. The toxicity of aldrin to aquatic organisms is quite variable, with aquatic insects being the most sensitive group of invertebrates. The 96-h LC_{50} values range from 1-200 µg/L for insects, and from 2.2-53 µg/L for fish. The maximum residue limits in food recommended by FAO/WHO vary from 0.006 mg/kg milk fat to 0.2 mg/kg meat fat. Water quality criteria between 0.1 to 180 µg/L have been published.

1.3.1.2. Dieldrin

Chemical Name: 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydroexo-1,4-endo-5,8-dimethanonaphthalene ($C_{12}H_8Cl_6O$).

CAS Number: 60-57-1

Properties: Solubility in water: 140 µg/L at 20°C; vapour pressure: 1.78 x 10^{-7} mm Hg at 20°C; log K_{OW}: 3.69-6.2. **Discovery/Uses:** It appeared in 1948 after World War II and was used mainly for the control of soil insects such as corn rootworms, wireworms and catworms.

Persistence/Fate: It is highly persistent in soils, with a half-life of 3-4 years in temperate climates, and bioconcentrates in organisms. The persistence in air has been estimated as 4-40 hrs.

Toxicity: The acute toxicity for fish is high (LC_{50} between 1.1 and 41 mg/L) and moderate for mammals (LD_{50} in mouse and rat ranging from 40 to 70 mg/kg body weight). However, a daily administration of 0.6 mg/kg to rabbits adversely affected the survival rate. Aldrin and dieldrin mainly affect the central nervous system but there is no direct evidence that they cause cancer in humans. The maximum residue limits in food recommended by FAO/WHO vary from 0.006 mg/kg milk fat and 0.2 mg/kg poultry fat. Water quality criteria between 0.1 to 18 µg/L have been published.

1.3.1.3. Endrin

Chemical Name: 3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-2,7:3,6-dimethanonaphth[2,3-b]oxirene ($C_{12}H_8Cl_6O$).

CAS Number: 72-20-8

Properties: Solubility in water: 220-260 µg/L at 25 °; vapour pressure: 2.7 x 10^{-7} mm Hg at 25°C; log K_{OW}: 3.21-5.34

Discovery/Uses: It has been used since the 1950s against a wide range of agricultural pests, mostly on cotton but also on rice, sugar cane, maize and other crops. It has also been used as a rodenticide.

Persistence/Fate: Is highly persistent in soils (half-lives of up to 12 years have been reported in some cases). Bioconcentration factors of 14 to 18,000 have been recorded in fish, after continuous exposure.

Toxicity: Endrin is very toxic to fish, aquatic invertebrates and phytoplankton; the LC_{50} values are mostly less than 1 µg/L. The acute toxicity is high in laboratory animals, with LD_{50} values of 3-43 mg/kg, and a dermal LD_{50} of 5-20 mg/kg in rats. Long-term toxicity in the rat has been studied over two years and a NOEL of 0.05 mg/kg bw/day was found.

1.3.1.4. Chlordane

Chemical Name: 1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene ($C_{10}H_6Cl_8$).

CAS Number: 57-74-9

Properties: Solubility in water: 56 µg/L at 25°C; vapour pressure: 0.98 x 10^{-5} mm Hg at 25 °C; log K_{OW}: 4.58-5.57.

Discovery/Uses: Chlordane appeared in 1945 and was used primarily as an insecticide for control of cockroaches, ants, termites, and other household pests. Technical chlordane is a mixture of at least 120 compounds. Of these, 60-75% are chlordane isomers, the remainder being related to endo-compounds including heptachlor, nonachlor, diels-alder adduct of cyclopentadiene and penta/hexa/octachlorocyclopentadienes.

Persistence/Fate: Chlordane is highly persistent in soils with a half-life of about 4 years. Its persistence and high partition coefficient promote binding to aquatic sediments and bioconcentration in organisms.

Toxicity: LC_{50} values from 0.4 mg/L (pink shrimp) to 90 mg/L (rainbow trout) have been reported for aquatic organisms. The acute toxicity for mammals is moderate with an LD_{50} in rats of 200-590 mg/kg body weight (19.1 mg/kg body weight for oxychlordane). The maximum residue limits for chlordane in food are, according to FAO/WHO between 0.002 mg/kg milk fat and 0.5 mg/kg poultry fat. Water quality criteria of 1.5 to 6 µg/L have been published. Chlordane has been classified as a substance for which there is evidence of endocrine disruption in an intact organism and possible carcinogenicity to humans.

1.3.1.5. Heptachlor

Chemical Name: 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene ($C_{10}H_5Cl_7$).

CAS Number: 76-44-8

Properties: Solubility in water: 180 µg/L at 25°C; vapour pressure: 0.3 x 10^{-5} mm Hg at 20°C; log K_{OW}: 4.4-5.5.

Production/Uses: Heptachlor is used primarily against soil insects and termites, but also against cotton insects, grasshoppers, and malaria mosquitoes. Heptachlor epoxide is a more stable breakdown product of heptachlor.

Persistence/Fate: Heptachlor is metabolised in soils, plants and animals to heptachlor epoxide, which is more stable in biological systems and is carcinogenic. The half-life of heptachlor in soil in temperate regions is 0.75 – 2 years. Its high partition coefficient provides the necessary conditions for bioconcentration in organisms.

Toxicity: The acute toxicity of heptachlor to mammals is moderate (LD_{50} values between 40 and 119 mg/kg have been published). The toxicity to aquatic organisms is higher and LC_{50} values down to 0.11 µg/L have been found for pink shrimp. Limited information is available on the effects in humans and studies are inconclusive regarding heptachlor and cancer. The maximum residue levels recommended by FAO/WHO are between 0.006 mg/kg milk fat and 0.2 mg/kg meat or poultry fat.

1.3.1.6. Dichlorodiphenyltrichloroethane (DDT)

Chemical Name: 1,1,1-trichloro-2,2-bis-(4-chlorophenyl)-ethane ($C_{14}H_9Cl_5$).

CAS Number: 50-29-3.

Properties: Solubility in water: 1.2-5.5 µg/L at 25°C; vapour pressure: 0.2 x 10^{-6} mm Hg at 20°C; log K_{OW}: 6.19 for *pp'*-DDT, 5.5 for *pp'*-DDD and 5.7 for *pp'*-DDE.

Discovery/Use: DDT appeared for use during World War II to control insects that spread diseases like malaria, dengue fever and typhus. Following this, it was widely used on a variety of agricultural crops. The technical product is a mixture of about 85% *pp'*-DDT and 15% *op'*-DDT isomers.

Persistence/Fate: DDT is highly persistent in soils with a half-life of up to 15 years and of 7 days in air. It also exhibits high bioconcentration factors (in the order of 50,000 for fish and 500,000 for bivalves). In the environment, the product is metabolised mainly to DDD and DDE.

Toxicity: The lowest dietary concentration of DDT reported to cause eggshell thinning was 0.6 mg/kg for the black duck. LC_{50} values of 1.5 mg/L for largemouth bass and 56 mg/L for guppy have been reported. The acute toxicity of DDT for mammals is moderate with an LD_{50} in rat of 113-118 mg/kg body weight. DDT has been shown to have an oestrogen-like activity, and possible carcinogenic activity in humans. The maximum residue level in food recommended by WHO/FAO range from 0.02 mg/kg milk fat to 5 mg/kg meat fat. Maximum permissible DDT residue level in drinking water (WHO) is 1.0 µg/L.

1.3.1.7. Toxaphene

Chemical Name: Polychlorinated bornanes and camphenes ($C_{10}H_{10}Cl_8$).

CAS Number: 8001-35-2

Properties: Solubility in water: 550 µg/L at 20°C; vapour pressure: 3.3 x 10^{-5} mm Hg at 25°C; log K_{OW} : 3.23-5.50.

Discovery/Uses: Toxaphene has been in use since 1949 as a non-systemic insecticide with some acaricidal activity, primarily on cotton, cereal grains, fruits, nuts and vegetables. It was also used to control livestock ectoparasites such as lice, flies, ticks, mange, and scab mites. The technical product is a complex mixture of over 300 congeners, containing 67-69% chlorine by weight.

Persistence/Fate: Toxaphene has a half-life in soil from 100 days up to 12 years. It has been shown to bioconcentrate in aquatic organisms (BCF of 4247 in mosquito fish and 76,000 in brook trout).

Toxicity: Toxaphene is highly toxic in fish, with 96-hour LC_{50} values in the range of 1.8 µg/L in rainbow trout to 22 µg/L in bluegill. Long-term exposure to 0.5 µg/L reduced egg viability to zero. The acute oral toxicity is in the range of 49 mg/kg body weight in dogs to 365 mg/kg in guinea pigs. In long-term studies NOEL in rats was 0.35 mg/kg bw/day, LD_{50} ranging from 60 to 293 mg/kg bw. For toxaphene, there is strong evidence of the potential for endocrine disruption. Toxaphene is carcinogenic in mice and rats and is of carcinogenic risk to humans, with a cancer potency factor of 1.1 mg/kg/day for oral exposure.

1.3.1.8. Mirex

Chemical Name: 1,1a,2,2a,3,3a,4,5,5a,5b,6-dodecachloroacta-hydro-1,3,4-metheno-1H-cyclobuta[cd]pentalene ($C_{10}Cl_{12}$).

CAS Number: 2385-85-5

Properties: Solubility in water: 0.07 µg/L at 25°C; vapour pressure: 3 x 10^{-7} mm Hg at 25°C; log K_{OW}: 5.28.

Discovery/Uses: The use in pesticide formulations started in the mid 1950s, largely focused on the control of ants. It is also a fire retardant for plastics, rubber, paint, paper and electrical goods. Technical grade preparations of mirex contain 95.19% mirex and 2.58% chlordecone, the rest being unspecified. Mirex is also used to refer to baits comprising corncob grits, and soya bean oil.

Persistence/Fate: Mirex is considered to be one of the most stable and persistent pesticides, with a half-life in soils of up to 10 years. Bioconcentration factors of 2,600 and 51,400 have been observed in pink shrimp and fathead minnows, respectively. It is capable of undergoing long-range transport due to its relative volatility (VPL = 4.76 Pa; H = 52 Pa m^3/mol).

Toxicity: The acute toxicity of mirex for mammals is moderate with an LD_{50} in rats of 235 mg/kg and dermal toxicity in rabbits of 80 mg/kg. Mirex is also toxic to fish and can affect their behaviour (LC_{50} (96 hr) from 0.2 to 30 mg/L for rainbow trout and bluegill, respectively). Delayed mortality of crustaceans occurred at 1 µg/L exposure levels. There is evidence of its potential for endocrine disruption and possibly carcinogenic risk to humans.

1.3.1.9. Hexachlorobenzene (HCB)

Chemical Name: Hexachlorobenzene (C_6Cl_6)

CAS Number: 118-74-1

Properties: Solubility in water: 50 µg/L at 20°C; vapour pressure: 1.09 x 10^{-5} mm Hg at 20°C; log K_{OW}: 3.93-6.42.

Discovery/Uses: It was first introduced in 1945 as fungicide for seed treatments of grain crops, and used to make fireworks, ammunition, and synthetic rubber. Today it is mainly a by-product in the production of a large number of chlorinated compounds, particularly lower chlorinated benzenes, solvents and several pesticides. HCB is emitted to the atmosphere in flue gases generated by waste incineration facilities and metallurgical industries.

Persistence/Fate: HCB has an estimated half-life in soils of 2.7-5.7 years and of 0.5-4.2 years in air. HCB has a relatively high bioaccumulation potential and long half-life in biota.

Toxicity: LC_{50} for fish varies between 50 and 200 µg/L. The acute toxicity of HCB is low with LD_{50} values of 3.5 mg/g for rats. Mild effects on the [rat] liver have been observed at a daily dose of 0.25 mg HCB/kg bw. HCB is known to cause liver disease in humans (porphyria cutanea tarda) and has been classified as a possible carcinogen to humans by IARC.

1.3.2. Industrial Compounds

1.3.2.1. Polychlorinated biphenyls (PCBs)

Chemical Name: Polychlorinated biphenyls ($C_{12}H_{(10-n)}Cl_n$, where n is within the range of 1-10).

CAS Number: Various (e.g. for Aroclor 1242, CAS No.: 53469-21-9; for Aroclor 1254, CAS No.: 11097-69-1)

Properties: Water solubility decreases with increasing chlorination: 0.01 to 0.0001 µg/L at 25°C; vapour pressure: 1.6-0.003 x 10^{-6} mm Hg at 20°C; log K_{OW}: 4.3-8.26.

Discovery/Uses: PCBs were introduced in 1929 and were manufactured in different countries under various trade names (e.g. Aroclor, Clophen, Phenoclor). They are chemically stable and heat resistant, and were used worldwide as transformer and capacitor oils, hydraulic and heat exchange fluids, and lubricating and cutting oils. Theoretically, a total of 209 possible chlorinated biphenyl congeners exist, but only about 130 of these are likely to occur in commercial products.

Persistence/Fate: Most PCB congeners, particularly those lacking adjacent unsubstituted positions on the biphenyl rings (e.g. 2,4,5-, 2,3,5- or 2,3,6-substituted on both rings) are extremely persistent in the environment. They are estimated to have half-lives ranging from three weeks to two years in air and, with the exception of mono- and di-chlorobiphenyls, more than six years in aerobic soils and sediments. PCBs also have extremely long half-lives in adult fish, for example, an eight-year study of eels found that the half-life of CB153 was more than ten years.

Toxicity: LC_{50} for the larval stages of rainbow trout is 0.32 µg/L with a NOEL of 0.01 µg/L. The acute toxicity of PCB in mammals is generally low and LD_{50} values in rats of 1 g/kg bw. IARC has concluded that PCBs are carcinogenic to laboratory animals and probably also for humans. They have also been classified as substances for which there is evidence of endocrine disruption in an intact organism.

Unintended By-products

1.3.3.1. Polychlorinated dibenzo-p-dioxins (PCDDs) and Polychlorinated dibenzofurans (PCDFs)

Chemical Name: PCDDs ($C_{12}H_{(8-n)}Cl_nO_2$) and PCDFs ($C_{12}H_{(8-n)}Cl_nO$) may contain between 1 and 8 chlorine atoms. PCDD/PCDFs have 75 and 135 possible positional isomers, respectively.

CAS Number: Various (2,3,7,8-TetraCDD: 1746-01-6; 2,3,7,8-TetraCDF: 51207-31-9).

Properties: Solubility in water: in the range 0.43 – 0.0002 ng/L at 25°C; vapour pressure: 2 – 0.007 x 10^{-6} mm Hg at 20°C; log K_{OW}: in the range 6.60 – 8.20 for tetra- to octa-substituted congeners.

Discovery/Uses: They are by-products resulting from the production of other chemicals and from the low-temperature combustion and incineration processes. They have no known use.

Persistence/Fate: PCDD/PCDFs are characterised by their lipophilicity, semi-volatility and resistance to degradation (half-life of TCDD in soil of 10-12 years) and long-range transport. They are also known for their ability to bio-concentrate and biomagnify under typical environmental conditions.

Toxicity: The toxicological effects reported refer to the 2,3,7,8-substituted compounds (17 congeners) that are agonist for the AhR. All the 2,3,7,8-substituted PCDDs and PCDFs plus coplanar PCBs (with no chlorine substitution at the ortho positions) show the same type of biological and toxic response. Possible effects include dermal toxicity, immunotoxicity, reproductive effects and teratogenicity, endocrine disruption and carcinogenicity. At the present time, the only persistent effect associated with PCDD/PCDFs exposure in humans is chloracne. The most sensitive groups are foetuses and neonatal infants.

Effects on the immune systems in the mouse have been found at doses of 10 ng/kg bw/day, while reproductive effects were seen in rhesus monkeys at 1-2 ng/kg bw/day. Biochemical effects have been seen in rats down to 0.1 ng/kg bw/day. In a re-evaluation of the TDI for PCDD/PCDFs (and planar PCB), the WHO decided to recommend a range of 1-4 TEQ pg/kg bw, although more recently the acceptable intake value has been set monthly at 1-70 TEQ pg/kg bw.

1.3.4. Regional Specific Chemicals

1.3.4.1. Hexachlorocyclohexanes (HCH)

Chemical Name: 1,2,3,4,5,6-hexachlorocyclohexane (mixed isomers) ($C_6H_6Cl_6$).

CAS Number: 608-73-1 (γ-HCH, lindane: 58-89-9).

Properties: γ-HCH: solubility in water: 7 mg/L at 20°C; vapour pressure: 3.3 x 10^{-5} mm Hg at 20°C; log K_{OW}: 3.8.

Discovery/Uses: There are two principal formulations: "technical HCH", which is a mixture of various isomers, including α-HCH (55-80%), β-HCH (5-14%) and γ-HCH (8-15%), and "lindane", which is essentially pure γ-HCH. Historically, lindane was one of the most widely used insecticides in the world. Its insecticidal properties were discovered in the early 1940s. It controls a wide range of sucking and chewing insects and has been used for seed treatment and soil application, in household biocidal products, and as textile and wood preservatives.

Persistence/Fate: Lindane and other HCH isomers are relatively persistent in soils and water, with half-lives generally greater than 1 and 2 years, respectively. HCH are much less bioaccumulative than other organochlorines because of their relatively low liphophilicity. On the contrary, their relatively high vapour pressures, particularly of the α-HCH isomer, determine their long-range transport in the atmosphere.

Toxicity: Lindane is moderately toxic for invertebrates and fish, with LC_{50} values of 20-90 µg/L. The acute toxicity for mice and rats is moderate with LD_{50} values in the range of 60-250 mg/kg. Lindane was found to have no mutagenic potential in a number of studies but possesses an endocrine disrupting activity.

1.3.4.2. Chlorinated Paraffins (CPs)

Chemical Name: Polychlorinated alkanes ($C_xH_{(2x-y+2)}Cl_y$). They are manufactured by chlorination of liquid n-alkanes or paraffin wax and contain from 30 to 70% chlorine. The products are often divided into three groups depending on chain length: short chain ($C_{10} – C_{13}$), medium ($C_{14} – C_{17}$) and long ($C_{18} – C_{30}$) chain lengths.

CAS Number: 108171-26-2

Properties: They are largely dependent on the chlorine content. Solubility in water: 1.7 to 236 µg/L at 25°C; vapour pressure: 6.78 x 10^{-2} to 8.47 x 10^{-9} mm Hg at 20°C; log K_{OW}: in the range from 5.06 to 8.12.

Discovery/Uses: The largest application is as a plasticiser, generally in conjunction with primary plasticisers such as certain phthalates in flexible PVC. The chlorinated paraffins also impart a number of technical benefits, of which the most significant is the enhancement of flame retardant properties and extreme pressure lubrication.

Persistence/Fate: CPs may be released into the environment from improperly disposed metal-working fluids or polymers containing chlorinated paraffins. Loss of chlorinated paraffins by leaching from paints and coatings may also contribute to environmental contamination. Short chain CPs with less than 50 % chlorine content seem to be degraded under aerobic conditions. The medium and long chain products are degraded more slowly. CPs bioaccumulate and both uptake and elimination are faster for the substances with low chlorine content.

Toxicity: The acute toxicity of CPs in mammals is low with reported oral LD_{50} values ranging from 4 - 50 g/kg bw, although in repeated dose experiments, effects on the liver have been seen at doses of 10 – 100 mg/kg bw/day. Short-chain and mid-chain grades have been shown, in laboratory tests, to show toxic effects on fish and other forms of aquatic life after long-term exposure. The NOEL appears to be in the range of 2–5 µg/L for the most sensitive aquatic species tested.

1.3.4.3. Chlordecone

Chemical Name: Decachlorooctahydro-1,3,4-metheno-2H-cyclobuta(cd)pentalen-2-one ($C_{10}Cl_{10}O$). Also known as Kepone.

CAS Number: 143-50-0

Properties: Solubility in water: 7.6 mg/L at 25°C; vapour pressure: < 3 x 10^{-5} mmHg at 25°C; log K_{OW}: 4.50.

Discovery/Uses: Chlordecone is released to the atmosphere as a result of its manufacture and use as an insecticide. Chlordecone also occurs as a degradation product of the insecticide mirex. It is used to control the Colorado potato beetle, rust mite on non-bearing citrus, and potato and tobacco wireworm on gladioli and other plants. Chlordecone was formerly registered for the control of rootborers on bananas. Non-food uses included wireworm control in tobacco fields and bait to control ants and other insects in indoor and outdoor areas. It has been used as a fungicide against apple scab and powdery mildew.

Persistence/Fate: The estimated half-life in soils is between 1-2 years, whereas in air it is much higher, up to 50 years. It is not expected to hydrolyse or biodegrade in the environment. Direct photodegradation and evaporation from water are considered insignificant processes. General population exposure to chlordecone occurs mainly through the consumption of contaminated fish and seafood.

Toxicity: Workers exposed to high levels of chlordecone over a long period (more than one year) showed harmful effects on the nervous system, skin, liver, and male reproductive system. These workers were probably exposed mainly through touching chlordecone, although they may have inhaled or ingested some as well. Animal studies with chlordecone have shown effects similar to those seen in people, as well as harmful kidney effects, developmental effects, and effects on the ability of females to reproduce. There are no studies available on whether chlordecone is carcinogenic in people. However, studies in mice and rats have shown that ingesting chlordecone can cause liver, adrenal gland, and kidney tumours. Very highly toxic for some species such as Atlantic menhaden, sheepshead minnow or donaldson trout with LC_{50} values between 21.4 – 56.9 µg/L.

1.3.4.4. Endosulfan

Chemical Name: 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide ($C_9H_6Cl_6O_3S$).

CAS Number: 115-29-7.

Properties: Solubility in water: 320 µg/L at 25°C; vapour pressure: 0.17 x 10^{-4} mm Hg at 25°C; log K_{OW}: 2.23-3.62.

Discovery/Uses: Endosulfan was first introduced in 1954. It is used as a contact and stomach insecticide and acaricide in a great number of food and nonfood crops (e.g. tea, vegetables, fruits, tobacco, cotton) and it controls over 100 different insect pests. Endosulfan formulations are used in commercial agriculture and home gardening and for wood preservation. The technical product contains at least 94% of two pure isomers, α- and β-endosulfan.

Persistence/Fate: It is moderately persistent in the soil environment with a reported average field half-life of 50 days. The two isomers have different degradation times in soil (half-lives of 35 and 150 days for α- and β-isomers, respectively, in neutral conditions). It has a moderate capacity to adsorb to soils and it is not likely to leach to groundwater. In plants, endosulfan is rapidly broken down to the corresponding sulphate. On most fruits and vegetables, 50% of the parent residue is lost within 3 to 7 days.

Toxicity: Endosulfan is highly to moderately toxic to bird species (Mallards: oral LD_{50} 31 - 243 mg/kg) and it is very toxic to aquatic organisms (96-hour LC_{50} rainbow trout 1.5 µg/L). It has also shown high toxicity in rats (oral LD_{50}: 18 - 160 mg/kg, and dermal: 78 - 359 mg/kg). Female rats appear to be 4–5 times more sensitive to the lethal effects of technical-grade endosulfan than male rats. The α-isomer is considered to be more toxic than the β-isomer. There is strong evidence of its potential for endocrine disruption.

1.3.4.5. Hexabromobiphenyl (HxBB)

Chemical Name: Hexabromobiphenyl ($C_{12}H_4Br_6$).

CAS Number: 59536-65-1

Properties: Solubility in water: 0.6 µg/L at 25°C; vapour pressure: 10^{-7} mm Hg at 20°C; log K_{OW}: 6.39.

Discovery/Uses: The production of polybrominated biphenyls (PBBs) began in 1970. HxBB was used as a fire retardant mainly in thermoplastics for constructing business machine housing and industrial (e.g. motor housing) and electrical (e.g. radio and TV parts) products. Smaller amounts were used as a fire retardant in coating and lacquers and in polyurethane foam for auto upholstery.

Persistence/Fate: HxBB is strongly adsorbed to soil and sediments and usually persist in the environment. HxBB resists both chemical and biological degradation. HxBB has been found in several sediment samples from the estuaries of large rivers and has been identified in edible fish.

Toxicity: Few toxicity data are available from short-term tests on aquatic organisms. The LD_{50} values of commercial mixtures show a relatively low order of acute toxicity (LD_{50} range from > 1 to 21.5 g/kg body weight in laboratory rodents). Oral exposure of laboratory animals to PBBs produced body weight loss, skin disorders, nervous system effects, and birth defects. Humans exposed through contaminated food developed skin disorders, such as acne and hair loss. PBBs exhibit endocrine disrupting activity and possible carcinogenicity to humans.

1.3.4.6. Pentachlorophenol (PCP)

Chemical Name: Pentachlorophenol (C_6Cl_5OH).

CAS Number: 87-86-5.

Properties: Solubility in water: 14 mg/L at 20°C; vapour pressure: 16 x 10^{-5} mm Hg at 20°C; log K_{OW}: 3.32 – 5.86.

Discovery/Uses: It is used as an insecticide (termiticide), fungicide, non-selective contact herbicide (defoliant) and particularly, as a wood preservative. It is also used in anti-fouling paints and other materials (e.g. textiles, inks, paints, disinfectants and cleaners) as an inhibitor of fermentation. Technical PCP contains trace amounts of PCDDs and PCDFs.

Persistence/Fate: The rate of photodecomposition increases with pH ($t_{1/2}$ 100 hr at pH 3.3 and 3.5 hr at pH 7.3). Complete decomposition in soil suspensions takes >72 days and half-lives in soils of 23-178 days have been reported. Although enriched through the food chain, it is rapidly eliminated after exposure ceases ($t_{1/2}$ = 10-24 h for fish).

Toxicity: It has been proved to be acutely toxic to aquatic organisms and have adverse effects on human health. PCP exhibits off-flavour effects at very low concentrations in aquatic foodstuffs. The 24-h LC_{50} value for trout was 0.2 mg/L, while chronic toxicity effects were observed at concentrations down to 3.2 µg/L. Mammalian acute toxicity of PCP is moderate-high. LD_{50} oral values in rats ranging from 50 to 210 mg/kg bw have been reported. LC_{50} ranged from 0.093 mg/L in rainbow trout (48 h) to 0.77-0.97 mg/L for guppy (96 h) and 0.47 mg/L for fathead minnow (48 h).

1.3.4.7. Polybrominated diphenyl ethers (PBDEs)

Chemical Name: Polybrominated diphenyl ethers ($C_{12}H_{(10-n)}Br_nO$, where n = 1-10). As in the case of PCBs the total number of congeners is 209, with predominance in commercial mixtures of the tetra-, penta- and octa-substituted isomers.

CAS Number: Various (PeBDE: 32534-81-9; OBDE: 32536-52-0; DeBDE: 1163-19-5)

Properties: Solubility in water: 0.9 ng/L at 25°C (PeBDE); vapour pressure: 3.85 x 10^{-3} to <10^{-7} mmHg at 20-25 °C; log K_{OW}: 4.28 - 9.9.

Discovery/Uses: Since the 1960s, three commercial PBDE formulations have been in production. The pentabrominated product is used principally to flame retard polyurethane foams in furniture, carpet underlay and bedding. Commercial octa is a mixture of hexa- (10-12%), hepta- (44-46%), octa- (33-35%) and nonabromodiphenyl (10-11%) ethers. It is used to flame retard a wide variety of thermoplastics and is recommended for injection moulding applications such as high impact polystyrene (HIPS). The deca product (a single congener) is used predominantly for textiles and denser plastics such as housings for a variety of electrical products, in particular TVs and computers.

Persistence/Fate: Data on environmental fate, although limited, suggest that biodegradation is not an important degradation pathway, but that photodegradation may play a significant role. They have already been found in high concentrations in marine birds and mammals from remote areas. The half-lives of PBDE components in rat adipose tissue vary between 19 and 119 days, the higher values being for the higher brominated congeners.

Toxicity: The available data suggest that the lower (tetra- to hexa-) PBDE congeners are likely to be carcinogens, endocrine disruptors, and/or neurodevelopmental toxicants. Studies in rats with commercial PeBDE indicate a low acute toxicity via oral and dermal routes of exposure, with LD_{50} values > 2000 mg/kg bw. In a 30-day study with rats, effects on the liver could be seen at a dose of 2 mg/kg bw/day, with a NOEL at 1 mg/kg bw/day. The toxicity to *Daphnia magna* has also been investigated and LC_{50} was found to be 14 µg/L with a NOEC of 4.9 µg/L. Although data on toxicology are limited, they have potential endocrine disrupting properties, and there are concerns over the health effects of exposure.

1.3.4.8. Polycyclic Aromatic Hydrocarbons (PAHs)

Chemical Name: PAHs are a group of compounds consisting of two or more fused aromatic rings.

CAS Number: (various CAS numbers for individual PAHs)

Properties: Solubility in water: 0.00014 -2.1 mg/L at 25ºC; vapour pressure: from 0.0015 x 10^{-9} to 0.0051 mmHg at 25°C; log K_{OW}: 4.79-8.20.

Discovery/Use: Most of these are formed during incomplete combustion of organic material and the composition of PAHs mixture vary with the source(s) and also due to selective weathering effects in the environment.

Persistence/Fate: Persistence of the PAHs varies with their molecular weight. The low molecular weight PAHs are most easily degraded. The reported half-lives of naphthalene, anthracene and benzo(e)pyrene in sediment are 9, 43 and 83 hours, respectively, whereas for higher molecular weight PAHs, their half-lives are up to several years in soils/sediments. The BCFs in aquatic organisms frequently range between 100-2000 and increase with increasing molecular size. Due to their wide distribution, the environmental pollution by PAHs has aroused global concern.

Toxicity: The acute toxicity of low PAHs is moderate with an LD_{50} of naphthalene and anthracene in rats of 490 and 18,000 mg/kg body weight respectively, whereas the higher PAHs exhibit higher

toxicity and LD_{50} of benzo[a]anthracene in mice is 10 mg/kg body weight. In *Daphnia pulex*, LC_{50} for naphthalene is 1.0 mg/L, for phenanthrene 0.1 mg/L and for benzo(a)pyrene is 0.005 mg/L. The critical effect of many PAHs in mammals is their carcinogenic potential. The metabolic action of these substances produces intermediates that bind covalently with cellular DNA. IARC has classified benz[a]anthracene, benzo[a]pyrene, and dibenzo[a,h]anthracene as probable carcinogens to humans. Benzo[b]fluoranthene and indeno[1,2,3-c,d]pyrene were classified as possible carcinogens to humans.

1.3.4.9. Phthalates

Chemical Name: They encompass a wide family of compounds. Dimethylphthalate (DMP), diethylphthalate (DEP), dibutylphthalate (DBP), benzylbutylphthalate (BBP), di(2-ethylhexyl)phthalate (DEHP)($C_{24}H_{38}O_4$) and dioctylphthalate (DOP) are some of the most common.

CAS Numbers.: 84-74-2 (DBP), 85-68-7 (BBP), 117-81-7 (DEHP).

Properties: The physico-chemical properties of phthalic acid esters vary greatly depending on the alcohol moieties. Solubility in water: 9.9 mg/L (DBP) and 0.3 mg/L (DEHP) at 25°C; vapour pressure: 3.5×10^{-5} (DBP) and 6.4×10^{-6} (DEHP) mm Hg at 25°C; log K_{OW}: 1.5 to 7.1.

Discovery/Uses: They are widely used as plasticisers, insect repellents, and solvents for cellulose acetate in the manufacture of varnishes and dopes. Vinyl plastic may contain up to 40% DEHP.

Persistence/fate: They have become ubiquitous pollutants, in marine, estuarine and freshwater sediments, sewage sludges, soils and food. Degradation ($t_{1/2}$) values generally range from 1-30 days in soils and freshwaters.

Toxicity: The acute toxicity of phthalates is usually low: the oral LD_{50} for DEHP is about 25-34 g/kg, depending on the species; for DBP reported LD_{50} values following oral administration to rats range from 8 to 20 g/kg body weight; in mice, values are approximately 5 to 16 g/kg body weight. In general, DEHP is not toxic for aquatic communities at the low levels usually present. In animals, high levels of DEHP damaged the liver and kidney and affected the ability to reproduce. There is no evidence that DEHP causes cancer in humans but it has been reported as an endocrine disrupting chemical. The EPA proposed a Maximum Admissible Concentration (MAC) of 6 µg/L of DEHP in drinking water.

1.3.4.10.Nonyl- and Octyl-phenols

Chemical Name: NP: $C_{15}H_{24}O$; OP: $C_{14}H_{22}O$.

CAS Number: 25154-52-3 (NP).

Properties: Solubility in water: 6.3 µg/L (NP) at 25°C; vapour pressure: 7.5×10^{-4} mm Hg at 20°C (NP); log K_{OW}: 4.5 (NP) and 5.92 (OP).

Discovery/Uses: NP and OP are the starting material in the synthesis of alkylphenol ethoxylates (APEs), first used in the 1960s. These compounds are highly effective cleaning agents or surfactants that have been widely used in a number of industrial sectors including textiles, pulp and paper, paints, adhesives, resins and protective coatings. Alkylphenols can also be used as plasticisers, stabilisers for rubbers, lube oil additives, and the alkylphenol phosphite derivatives can be used as UV stabilisers in plastics.

Persistence/Fate: NP and OP are the end degradation products of APEs under both aerobic and anaerobic conditions. Therefore, the major part is released to water and concentrated in sewage sludges. NPs and t-OP are persistent in the environment with half-lives of 30-60 years in marine sediments, 1-3 weeks in estuarine waters and 10-48 hours in the atmosphere. Due to their persistence they can bioaccumulate to a significant extent in aquatic species. However, excretion and metabolism are rapid.

Toxicity: NP and OP have acute toxicity values for fish, invertebrates and algae ranging from 17 to 3000 µg/L. In chronic toxicity tests the lowest NOEC are 6 µg/L in fish and 3.7 µg/L in invertebrates. The threshold for vitellogenin induction in fish is 10 µg/L for NP and 3 µg/L for OP (similar to the lowest NOEC). Alkylphenols are endocrine disrupting chemicals also in mammals.

1.3.4.11.Organotin compounds

Chemical Name: Organotin compounds comprise mono-, di-, tri- and tetrabutyl and triphenyl tin compounds. They conform to the following general formula $(n\text{-}C_4H_9)_nSn\text{-}X$ and $(C_6H_5)_3Sn\text{-}X$, where X is an anion or a group linked covalently through a hetero-atom.

CAS Number: 56-35-9 (TBTO); 76-87-9 (TPTOH)

Properties: Solubility in water: 4 mg/L (TBTO) and 1 mg/L (TPTOH) at 25°C and pH 7; vapour pressure: 7.5 x 10^{-7} mm Hg at 20°C (TBTO) 3.5 x 10^{-8} mmHg at 50ºC (TPTOH); log K_{OW}: 3.19 - 3.84. In seawater and under normal conditions, TBT exists as three species in seawater (hydroxide, chloride, and carbonate).

Discovery/Uses: They are mainly used as antifouling paints (tributyl and triphenyl tin) for underwater structures and ships. Minor identified applications are as antiseptic or disinfecting agents in textiles and industrial water systems, such as cooling tower and refrigeration water systems, wood pulp and paper mill systems, and breweries. They are used as stabilisers in plastics and as catalytic agents in soft foam production. They are also used to control the shistosomiasis in various parts of the world.

Persistence/Fate: Under aerobic conditions, TBT takes 1 to 3 months to degrade, but in anaerobic soils may persist for more than 2 years. Because of the low water solubility it binds strongly to suspended material and sediments. TBT is lipophilic and tends to accumulate in aquatic organisms. Oysters exposed to very low concentrations exhibit BCF values from 1000 to 6000.

Toxicity: TBT is moderately toxic and all breakdown products are even less toxic. Its impact on the environment was discovered in the early 1980s in France with harmful effects in aquatic organisms, such as shell malformations of oysters, imposex in marine snails and reduced resistance to infection (e.g. in flounder). Molluscs react adversely to very low levels of TBT (0.06-2.3 ug/L). Lobster larvae show a nearly complete cessation of growth at just 1.0 ug/L TBT. In laboratory tests, reproduction was inhibited when female snails exposed to 0.05-0.003 ug/L of TBT developed male characteristics. Large doses of TBT have been shown to damage the reproductive and central nervous systems, bone structure, and the liver bile duct of mammals.

1.3.4.12.Organomercury compounds

Chemical Name: The main compound of concern is methyl mercury (CH_3Hg^+).

CAS Number: 22967-92-6

Properties: Solubility in water: 0.1 g/L at 21°C ($HgCH_3Cl$) and 1.0 g/L at 25ºC ($Hg(CH_3)_2$); vapour pressure: 8.5 x 10^{-3} mm Hg at 25°C ($HgCH_3Cl$); log K_{OW}: 1.6 ($HgCH_3Cl$) and 2.28 ($Hg(CH_3)_2$).

Production/Uses: There are many sources of mercury release to the environment, both natural (volcanoes, mercury deposits, and volatilisation from the ocean) and human-related (coal combustion, chlorine alkali processing, waste incineration, and metal processing). It is also used in thermometers, batteries, lamps, industrial processes, refining, lubrication oils, and dental amalgams. Methyl mercury has no industrial uses; it is formed in the environment by methylation of the inorganic mercurial ion mainly by microorganisms in the water and soil but also by non-microbial routes.

Persistence/Fate: Mercury released into the environment can either stay close to its source for long periods, or be widely dispersed on a regional or even worldwide basis. Not only are methylated mercury compounds toxic, but highly bioaccumulative as well. The increase in mercury as it rises in the aquatic food chain results in relatively high levels of mercury in fish consumed by humans. Ingested elemental mercury is only 0.01% absorbed, but methyl mercury is nearly 100% absorbed from the gastrointestinal tract. The biological half-life of mercury is 60 days.

Toxicity: Long-term exposure to either inorganic or organic mercury can permanently damage the brain, kidneys, and developing foetus. The most sensitive target of low level exposure to metallic and organic mercury following short or long-term exposures appears to be the nervous system.

1.3.4.13.Organolead compounds

Chemical Name: Alkyllead compounds may be confined to tetramethyllead (TML, $Pb(CH_3)_4$) and tetraethyllead (TEL, $Pb(C_2H_5)_4$).

CAS Number: 75-74-1 (TML) and 78-00-2 (TEL).

Properties: Solubility in water: 17.9 mg/L (TML) and 0.29 mg/L (TEL) at 25°C; vapour pressure: 22.5 and 0.15 mm Hg at 20°C for TML and TEL, respectively.

Discovery/Uses: Tetramethyl and tetraethyllead are widely used as "anti-knocking" additives in petrol. The release of TML and TEL are drastically reduced with the introduction of unleaded petrol in the late 1970s in USA followed by other parts of the world. However, leaded petrol is still available and is likely to contribute to the emission of TEL, and to a lesser extent TML, to the environment.

Persistence/Fate: Under environmental conditions such as in air or in aqueous solution, dealkylation occurs to produce the less alkylated forms and finally inorganic lead. However, there is limited evidence that under some circumstances, natural methylation of lead salts may occur. Minimal bioaccumulations were observed for TEL in shrimps (650x), mussels (120x), and plaice (130x), and for TML in shrimps (20x), mussels (170x), and plaice (60x).

Toxicity: Lead and lead compounds have been found to cause cancer in the respiratory and digestive systems of workers in lead battery and smelter plants. However, tetra-alkyllead compounds have not been sufficiently tested for the evidence of carcinogenicity. Acute toxicity of TEL and TML are moderate in mammals and high for aquatic biota. LD_{50} (rat, oral) for TEL is 35 mg Pb/kg and 108 mg Pb/kg for TML. LC_{50} (fish, 96hrs) for TEL is 0.02 mg/kg and for TML is 0.11 mg/kg.

1.4. Definition of the Southeast Asia and South Pacific Regions

The Southeast Asian sub-region comprises the countries of Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam. The sub-region remains very diverse in terms of economic development, political systems, ethnicity, culture, and natural resources. Singapore, for example, is an OECD country and Brunei Darussalam, an oil-rich microstate. Myanmar, Lao People's Democratic Republic, and Cambodia are essentially agrarian economies; while Malaysia, Thailand, the Philippines, Indonesia, and Viet Nam are rapidly industrialising. The diversity of the region is also reflected in the Human Development Index of its member countries, which range through high to medium to low.

More than half the land area in Southeast Asia is under forest cover and of the remainder only a small area is under permanent pasture and around 18 per cent is cultivated. The population density is high at 104 persons per square kilometre (compared with the Asia-Pacific average of 90 persons per square kilometre) but the availability of arable land is also higher, at 18 per cent, compared with the regional average of 15 per cent (FAO/RAPA, 1993; ESCAP, 1993a and 1993b).

The Southeast Asian sub-region has a per capita forest cover of 0.48 hectares and also the highest absolute deforestation rates with continental and insular Southeast Asia losing around 1.3 and 1.9 million hectares a year, respectively (FAO/RAPA,1993). In the early 1990s, Indonesia alone had a deforestation rate of 0.6 million hectares per year (around 0.5 per cent of its forest cover), while Malaysia, Myanmar, the Philippines and Thailand each lost more than 300,000 hectares a year, representing 2.0, 1.3, 4.0 and 4.0 per cent of their forest cover, respectively, for the period 1981-1990. About 980,000 hectares of forest area were depleted between 1989 and 1993 in Thailand alone (Government of Thailand, 1994). Cambodia, Lao PDR and Viet Nam each lost in excess of 100,000 hectares per year, representing 1.0, 0.9 and 1.6 per cent of their total forest cover, respectively, for the period 1981-90 (FAO, 1995).

The Pacific sub-region has the highest per capita forest cover at 5.88 hectares per person and the lowest rate of deforestation at around 130,000 hectares per year, of which 113,000 hectares are removed in Papua New Guinea alone. This country also has the highest forest cover in the entire region, at 9.42 hectares per capita (FAO/RAPA, 1993).

Domestic sewage, industrial effluents, and run-off from land-based activities, such as agriculture and mining are major causes of water pollution in countries in the Southeast Asia-Pacific region. As much as 70 per cent of the waste effluent discharged into the Pacific Ocean is untreated (Fuavo, 1990). Over 40 per cent of marine pollution in the region is derived from land-based activities (via riverine discharge) and maritime transport contributes a further 12 per cent (Weber, 1993).

The increased use of agro-chemicals in this region also contributes to marine pollution. Fertiliser consumption in the Asia and the Pacific region rose 74 per cent, from 33.3 million tonnes to 57.8 million tonnes, over the period 1982–92 (ESCAP, 1995a). The use of pesticides to enhance agricultural productivity appears to be increasing, especially in the developing countries in the region.

The disposal of domestic and industrial waste is given relatively low priority in many countries; only around 70 per cent of the waste in urban municipal areas is collected and, of that, only about 5 per cent is treated (ESCAP, 1995b). Solid waste disposal is a particular problem in the small island states because of their limited land area. In some of these countries solid waste has been used for land reclamation, resulting in contamination and pollution of surrounding coastal areas. Some Governments are in the process of taking measures to treat wastewater. For example, the Government of Thailand has agreed in principle to establish a Central Waste Water Management Authority to consolidate policies and institutions to deal with this matter. The Government is also envisaging a role for private investments in setting up treatment plants (Government of Thailand, 1994). In Singapore, 36 industries were prosecuted in 1993 for discharging acidic effluents into the sewers (ASEAN, 1995). In addition, facilities for handling wastes and ensuring stringent enforcement of standards have improved significantly.

The terrestrial, freshwater and marine environments throughout this area exhibit considerable variation in climate, meteorology and physical geography.

1.5. Physical Setting

1.5.1. Physical/Geographical Description

The Southeast Asian countries covered in this report extend from latitude 30° north to 11° south and longitudes 92° east to 142° east. Only Lao PDR is landlocked, all others having direct access to the sea.

Southeast Asia consists of those continental margins and offshore archipelagos of Asia lying south of China and east of India. Continental Southeast Asia includes Thailand, the Lao PDR, Cambodia, and Viet Nam. Archipelagic Southeast Asia consists of Singapore at the tip of Peninsular Malaysia and the two sprawling archipelagic states of Indonesia and the Philippines. It also includes Malaysia, comprising West Malaysia (the Malay Peninsula) and East Malaysia (northern portion of the island of Borneo). The Sultanate of Brunei Darussalam is on the northern coast of Borneo between the two East Malaysian states of Sabah and Sarawak. Overall, Southeast Asia extends more than 3,300 km from north to south and 5,600 km from east to west.

Papua New Guinea is located in southeastern Asia. It consists of a group of islands including the eastern half of the island of New Guinea between the Coral Sea and the South Pacific Ocean, east of Indonesia.

Australia, as an island continent with a long coastline, has many different marine and estuarine environments. The northern, far north-eastern and most of the western coasts of the continent, the Great Australian Bight and Australia's External Territories in the Indian Ocean, South Pacific, Southern Ocean and Antarctica are among the least-polluted places on earth. However, even the most remote regions show traces of persistent global pollutants.

New Zealand lies in the southwest Pacific Ocean and comprises two main and a number of smaller islands. Their combined area of 270,500 sq km is similar to the size of Japan or the British Isles. The main islands, the North and South Islands, are separated by Cook Strait, which at its narrowest point is 20 km wide. The administrative boundaries of New Zealand extend from 33° to 53° south latitude, and from 160° east to 173° west longitude.

1.5.2. Climate and Meteorology

The tropical climate in Southeast Asia and Papua New Guinea is greatly influenced by tropical monsoons mostly originating in the South China Sea. The climatology of the summer and winter circulation is shown in Figure 1.4.1. Southern Thailand, Peninsular Malaysia and Indonesia are influenced by the Andaman Sea and the Indian Ocean. In addition, parts of continental Asia are subject to cold fronts from China. Semi-temperate climate prevails in the continental high plateau and mountains.

Consequently, the countries in the region have a diverse range of ecosystems. The relative humidity in the region is high, ranging from 70% to 90% with average annual temperatures for most locations ranging from 25°C to 30°C. Temperature inversions are common. When air is stable and sources of air pollutants are present, concentrations of pollutants may increase due to poor dispersion, causing hazy mornings, which normally clear by mid-afternoon.

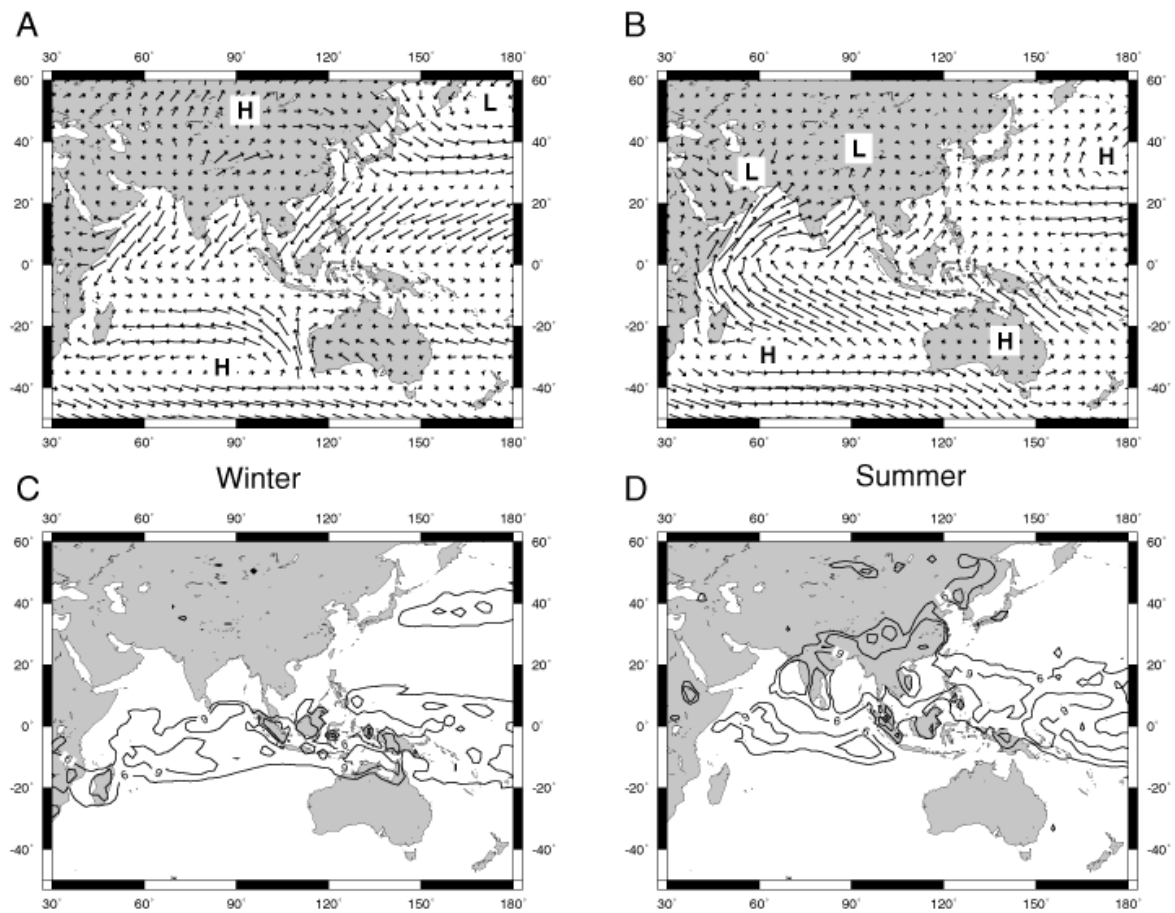


Figure 1.4.1. Climatology of the summer and winter monsoon circulation. Surface winds for the **(A)** winter (January) and **(B)** summer (July) seasons along with areas of high (H) and low (L) pressure, and precipitation (6 and >9 mm/day contours) for the **(C)** winter (January) and **(D)** summer (July) seasons. The pressure gradients and resulting wind and precipitation patterns reflect the land-sea heating contrasts, which are a function of solar radiation, elevation, and land surface boundary conditions. Monthly data for 1990-1997 from NOAA NCEP-NCAR CDAS-1 (Kalnay *et al.,* 1993).

The Southwest monsoon begins in May and ends in September or October. During this period, most rain falls over Thailand, Cambodia, Lao PDR, Viet Nam and parts of the western coastal districts of Sumatra and Peninsular Malaysia and the central and northern islands of the Philippines. During the monsoon, strong winds and rain help dilute and remove air pollutants from the atmosphere. The Northeast monsoon from October to February brings steady north-easterly winds from the interior of Asia. It is cool and dry in the northern parts of Thailand, Lao PDR, and Cambodia, and as the wind

blows over the South China Sea, it picks up moisture from the sea and deposits it as rain on the east coast of Viet Nam and Peninsular Malaysia, bringing about the wettest season for this area.

However, winds also carry pollutants and deposit them as ‘acid rain’ or particulate matter in soil and water bodies, often a considerable distance from the sources. These geographical conditions help explain why transboundary haze pollution from land and forest fires can be so severe in the region: winds can quickly transport them over much of the populated areas of ASEAN member countries and beyond.

Australia’s climate is generally arid to semi-arid; temperate in the south and east; tropical in the north. New Zealand is temperate with sharp regional contrasts. January and February are New Zealand's warmest months and July is normally the coldest. Average temperature ranges from 8°C in July to 17°C in January - but summer temperatures occasionally reach the 30s in many inland and eastern regions. The mean average rainfall varies widely - from less than 400 mm in Central Otago to over 12,000 mm in the Southern Alps.

Cyclones. Tropical cyclones, or typhoons, are common in the Asia-Pacific region. They occur most frequently over the north-west Pacific, just east of the Philippines, during June and November with an average of 30 typhoons a year, i.e. about 38 per cent of the world total (ESCAP, 1995a). Overall, the Philippines, Bangladesh and Viet Nam suffer most frequently from major events.

Earthquakes. The Asia-Pacific region alone has recorded 70 per cent of the world’s earthquakes measuring 7 or more on the Richter scale, at an average rate of 15 events per year (ESCAP, 1995a). The Philippines, which lies between two of the world’s most active tectonic plates, experiences an average of five earthquakes per day, most of which are imperceptible (ESCAP, 1995a). In New Zealand, an average of 200 perceptible earthquakes occur each year, of which at least one exceeds 6 on the Richter scale (ESCAP, 1995a). The frequency of earthquakes for some countries in the region may have implications on the siting of storage facilities for PTS.

1.5.3. Region’s Freshwater Environments

Lake eutrophication is a significant, but localised, concern in a number of countries in Southeast Asia. A survey by the United Nations Environment Program/International Lake Environment Committee (UNEP/ILEC) showed that 54 per cent of the lakes in this sub-region were suffering from eutrophication problems (UNEP, 1994). The inland water bodies of the sub-region are also affected by the presence of pathogenic agents, and many rivers carry enhanced nutrient and pollutant loads resulting from changes in land use, industrialisation and urbanisation.

1.5.3.1. Groundwater

In the small island countries, groundwater resources are suffering from severe salinisation due to the intrusion of seawater. In Thailand, the rapid lowering of the water table by excessive extraction of groundwater has caused the shallow aquifers in Bangkok to become contaminated with salt water from the nearby ocean. Over-extraction of groundwater reserves has also caused land subsidence in some cities, such as Bangkok and Jakarta. In Bangkok, for example, land has subsided by 0.5–0.6 metres in some places over the last 20–25 years; this in turn has aggravated problems of flooding in the city (ESCAP, 1995a).

With current levels of population growth, demand for water will increase in each sector throughout the region up to and beyond the next century. Freshwater availability of less than 1000 cubic metres of water per capita per year indicates water scarcity. Singapore can already be considered as short of freshwater.

Different measures are being taken by many countries in the region to meet the growing demands for water and to safeguard water quality. Such measures include water reuse and recycling, seawater desalinisation, demand-side management, inter-basin transfers, leak detection programs, differential payment rates, legislation (e.g. environmental impact assessment (EIA), water and effluent standards), protection of wetlands and use of economic incentives. Many countries including Malaysia, New Zealand, and Singapore, employ economic incentives and economic instruments (such as the "polluter pays principle", tax rebates, tax write-offs, etc.) to encourage industries to reduce water pollution.

1.5.3.2. Rivers

Major river systems include the Chao Phraya (Thailand), the Mekong (marking much of the Thailand-Lao PDR border and traversing Cambodia and Viet Nam) and the shorter, eastward flowing Red River (Song Hong), which reaches the Gulf of Tonkin further north, near the Chinese border. These river systems flow through broad alluvial plains and fertile deltas, where intensive rice agriculture sustains dense populations and large cities. No comparably large river systems exist in the islands in the Southeast Asian region. Closest in length are the large meandering rivers of Borneo, the world's third largest island. The other major Indonesian and the Philippine islands are, unlike the mainland, volcanic. Their topsoils support an intensive rice-dominated agriculture.

The Murray and Darling Rivers, the longest river system in Australia, form the Murray-Darling Basin covering more than one million square kilometres or 14 per cent of the mainland area. Most of Australia's rivers that feed estuaries contain impoundments or dams to provide water for urban supply, intensive agriculture or power generation. This has major impacts on the hydrological patterns and occurrence of above-ground and below-ground flows of water.

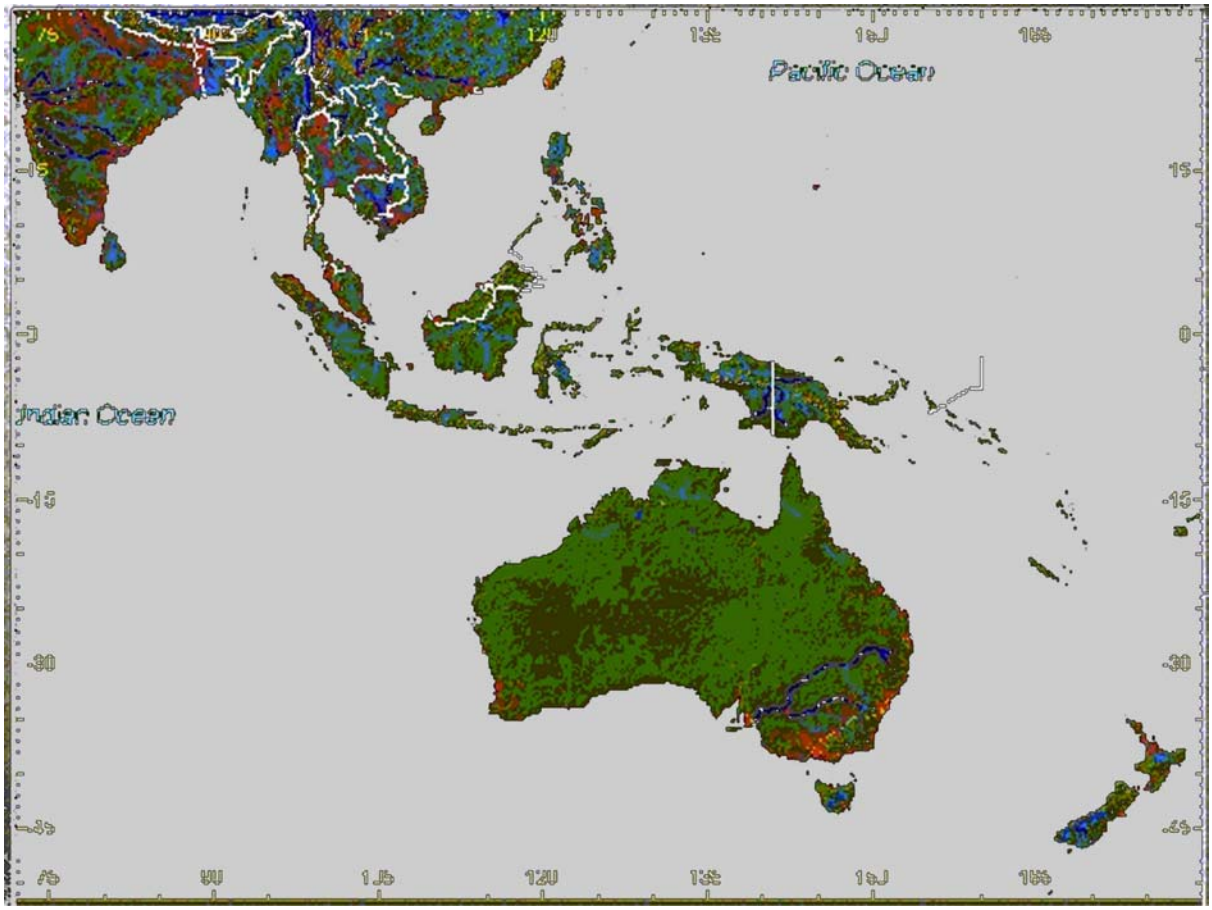


Figure 1.4.2. Countries in Region 8 showing major river systems (light and dark blue lines).

1.5.4. Marine Environment

The countries in the Southeast Asian region border the Andaman Sea, the Gulf of Thailand, the South China Sea, and the Pacific Ocean. The boundary of the Andaman Sea to the north is the Ayeyarwady River delta; to the east Peninsular Myanmar, Thailand and Malaysia; to the west the Andaman and Nicobar Islands; and to the south Sumatra and the Strait of Malacca. Huge volumes of runoff water from Myanmar flow into the Andaman Sea during the summer monsoon and may have implications on the transport of PTS from that river basin.

The South China Sea is a semi-enclosed sea and is bounded on the east by the Philippines and Borneo; in the south-west it merges with the Gulf of Thailand; and on the west it is separated from the Gulf of Tonkin by Hainan Island. The total sea area is 2.32 million sq km and is a major shipping

lane. Major ports on or near the South China Sea include Manila, Singapore, Bangkok, Ho Chi Minh City, and Hai Phong. The principal rivers draining into it are the Mekong and the Xi Jiang.

The Gulf of Thailand has an area of about 320,000 sq km and is an inlet of the South China Sea lying between Peninsular Malaysia on the west and the Southeast Asian mainland to the north and east. It is bounded mainly by Thailand (south-west through north), Cambodia, and southern Viet Nam (to the north-east). Main harbours include Bangkok and Chanthaburi (Thailand), Kompong Som (Cambodia) and Rach Gia (Viet Nam). The four major rivers of Thailand (Mae Klong, Tha Chin, Chao Phraya and Bang Pakong) drain into the Upper Gulf. The discharge and possible transport of PTS into these semi-enclosed seas from agricultural activities and densely populated urban areas have not been quantified.

The Strait of Malacca, which is located between Peninsula Malaysia and the Island of Sumatra Indonesia, is a busy shipping route between west and east Asia transporting mainly oil and gas from the Middle East to east Asia, particularly Japan. More than often, oil spill and sludge dumping have been sighted and reported.

Australia, as an island continent with a long coastline, has many different marine and estuarine environments. Most of these are far removed from the major population centres and are little affected by human activities. The northern, far north-eastern and most of the western coasts of the continent, the Great Australian Bight and Australia's External Territories in the Indian Ocean, South Pacific, Southern Ocean and Antarctica are among the least-polluted places on earth. However, even the most remote regions show traces of persistent global pollutants.

Two major ocean boundary currents - the East Australian Current and the Leeuwin Current - influence the east and west coasts of the continent respectively. The strength, seasonality and southward extension of both these currents are highly variable and their flow can influence coastal and ocean conditions along the south of the continent. Most of Australia’s rivers that discharge to estuaries contain dams that affect environmental flows.

1.5.5. Ecological Characteristics of the Region

The Indo-West Pacific is the key area for shallow water marine biodiversity. Coastal habitat loss and degradation, combined with increased sediment, nutrient and pollutant discharge (including PTS) into coastal areas, are major causes of concern particularly for the insular countries of the region. The rates of loss of coral reef and mangrove habitats in this region are amongst the highest in the world. Thailand alone has lost about 0.2 million hectares of mangrove forest during the period 1961–93 (Government of Thailand, 1994). However, the impacts of such unsustainable practices on regional biodiversity are difficult to quantify.

Southeast Asia is home to about half of the world’s terrestrial and marine biodiversity, which in the tropical forest of the sub-region remains largely undocumented (World Bank, 1992). Around 30 per cent of the world’s coral reefs are situated within the sub-region, with the seas around the Philippines, Indonesia, and Malaysia constituting the centre of marine biodiversity. Some of the last remaining intact expanses of mangroves also occur in Southeast Asia.

The rainforests of Southeast Asia contain more than 25,000 species of flowering plants, equivalent to about 10 per cent of the flora of the world. The region as a whole encompasses two thirds of the world’s flora. Almost all the nations in the region (with the exception of Singapore and Brunei Darussalam) are heavily dependent on direct harvesting of natural products.

Australia has evolved in relative isolation for at least the past 50 million years. This has resulted in a rich diversity of unique life forms. For example, 85 per cent of the flowering plants, 84 per cent of the mammals, 45 per cent of the birds, 89 per cent of the reptiles and 93 per cent of our frogs in the country are endemic. Of the 600 inshore species of finfish in the southern temperate zone, about 85 per cent are found only in Australian waters (SOE Australia, 1996).

Areas like the Great Barrier Reef, the species-rich rainforests of northern Queensland and the Southwest Botanical Province of Western Australia (with over one-third of Australia’s plant species, of which 70 per cent are endemic) are internationally recognised major centres of biodiversity.

New Zealand's biodiversity is more primitive in character than that of many other countries, having a limited representation of higher plants and animals (e.g. angiosperms and mammals), but a high representation of older plants and animals (e.g. mosses, liverworts, ferns, flatworms, snails, spiders, wingless crickets, solitary bees, leiopelmid frogs, sphenodon reptiles and ratite birds). Many species are endemic (found only in New Zealand) (SOE New Zealand, 1997).

1.6. Patterns of Development/Settlement

The total land area of the Southeast Asia sub-region is more than 435 million hectares, representing about 3 per cent of the total land surface of the earth, although the region is home to about 520 million people, or about 11 per cent of the world population. The average population has been growing at a rate of 1.5 per cent, representing the second highest growth rate in the Asian and Pacific Region. An average of 39 per cent of the population is urban, and urbanisation is growing at 3.5 per cent. Projections indicate that by 2050, there will be three megacities (with a population of more than 10 million) in Southeast Asia: Jakarta, Manila, and Bangkok.

Atmospheric pollution. Data for air pollution levels in each Southeast Asian country are limited. However, the high concentration of industries in the urban centres of the region especially in the two largest cities of Metro Manila and Jakarta, indicates the high air pollution potential. Vehicular emissions, particularly in Jakarta, Bangkok and Metro Manila, also contribute largely to the poor ambient air quality of these cities. However, since the 1997 financial decline, traffic congestion in the major cities has also been reduced. For example, between 1996 and 1999 automotive production in Thailand fell by 55 per cent and sales fell 63 per cent (Brown, 1999). Nevertheless, growth trends in air pollution are being observed in many cities. For example, Malaysia's urban centres have not yet reached critical levels of air pollution although traffic congestion and consequent vehicular emissions are fast becoming a problem in Kuala Lumpur and elsewhere.

The developing countries of Asia and the Pacific region have been developing more rapidly than all other developing countries in the world for the last three decades; this trend is likely to continue in the future. One of the more important implications of economic growth in the region has been the increased demand for energy and attendant emissions.

The Asia and the Pacific region, excluding Australia and New Zealand, accounted for 21 per cent of the world's primary commercial energy demand in 1992. A growth in energy demand of 3.6 per cent per year for the whole region was maintained between 1990 and 1992, compared with an average growth of 0.1 per cent for the whole world (ADB, 1994). The region also accounts for about 41 per cent of the global consumption of coal in 1993 (EIA, 1995). The rapid growth in energy demand, and especially the reliance on coal, has led to a significant increase in the emissions of air pollutants wherever appropriate technology interventions are not made (such as scrubbers).

Vehicular emissions are a significant problem in all major cities but also in small cities like Port Moresby. The government of the Philippines is attempting to address this issue through plans to limit the number of vehicles on the road. Similar measures are also being taken in Thailand. Significant penalties are imposed on violators. In several countries, including the Philippines, unleaded petrol has been introduced widely and new vehicles are required to be able to run on this fuel.

Land degradation. The sub-region suffers from soil erosion and contamination. For Southeast Asian countries, erosion mostly takes the form of surface water erosion, which contributes to the loss of topsoil (Van Lynden and Oldeman, 1997). Problems are most acute in the Philippines, Thailand, Viet Nam, Malaysia, Indonesia, Cambodia, and Lao People's Democratic Republic, where water erosion impacts an average of 20 per cent of the total land areas. Thailand and Cambodia also suffer from the impacts of land contamination, where soil fertility declines have affected a total of 36.5 million hectares (Van Lynden and Oldeman, 1997).

Forest fires. The indiscriminate clearing of land for pulpwood and oil palm plantations is fuelled by the high demand for paper and palm oil products throughout the world. The traditional way of clearing land in most of the Southeast Asia sub-region is by fire. The activity has led to devastating cross border impacts to habitat corridors, and has caused significant transboundary air pollution problems with particulates, smoke, and haze. The haze from forest fires that engulfed Indonesia,

Malaysia, Singapore, Brunei Darussalam, and to a lesser extent the Philippines, in mid 1997, and intermittently hereafter, has been observed as one of the worst episodes of air pollution in recent world history. An estimated 70 million people were affected, 9 million hectares of land and forest in Indonesia were damaged, and total cost was estimated at US$9 billion (ASEAN, 2000).

The geographic location and the topography of Australia mean that almost all vegetation types in the country are fire prone. There are few high mountains and no truly alpine regions. In 1974-75, lush growth of grasses and forbs following exceptionally heavy rainfall in the previous two years provided continuous fuels through much of central Australia and in this season fires burnt over 117 million hectares or 15 per cent of the total land area of the continent. In 1967, fires burned 264,000 hectares in Southern Tasmania, 61 lives were lost and more than 1700 homes were destroyed. In 1983, 15 major fires in South Australia burnt out 160,000 hectares, killed 28 people and destroyed 383 homes. In the same year, eight major fires in Victoria burnt out 183,000 hectares. In 1994, in New South Wales, more than 800 fires burnt more than 800,000 hectares (Yearbook Australia, 1995).

Water pollution. Pollution by chemicals of inland and coastal waters by mining and agricultural wastes, and by domestic sewage is an area of concern in most ASEAN countries and Papua New Guinea. Of relevance to the assessment of PTS was a 1992 study in Australia to scientifically evaluate the effluent quality of the 17 licensed Victorian coastal outfalls discharging treated or untreated sewerage into Bass Strait (McKenzie and Goudey, 1993). The report concluded that it can not be assumed that because an effluent is only of the domestic type, persistent toxicants are not a problem, since all the effluent samples in this study analysed contained heavy metals, surfactants and phenols.

1.6.References

ADB. 1994. *Energy Indicators of Developing Member Countries of ADB*. Energy and Industry Department. Manila.

ADB/IUCN (1994) Biodiversity Conservation in the Asia and Pacific Region: Constraints and Opportunities. *Proceedings of a Regional Conference*. 6-8 June 1994. Manila.

ASEAN Secretariat (1995) ASEAN State of the Environment 1995.

ASEAN Secretariat (2001) Second ASEAN State of the Environment Report 2000. 211 p.

ASEAN Haze Action Online. www.haze-online.or.id.

Barrie L. A., Gregor D., Hargrave B., Lake R., Muir D., Shearer R., Tracey B., Bidleman T. F. (1992) Arctic contaminants: sources, occurrence and pathways. The *Science of the Total Environment* 122, 1-74.

Brown, (1999). Introduction to shared environmental problems. Chapter 17, 3.356,

www.unescap.org/enrd/environment/ activities/ES/SOE/CH17.PDF

EEA (1998) EEA's second multiannual report on Europe's Environment produced in 1998: Europe's Environment: The Second Assessment.

EIA. (1995) International Energy Annual*:* 1993. Energy Information Agency, U.S. Department of Energy, Washington.

ESCAP (1993a) Asia-Pacific in Figures 1993. Bangkok.

ESCAP (1993b) Population Data Sheet 1993. Bangkok.

ESCAP (1995a) State of the Environment in the Asia-Pacific, 1995. Bangkok.

ESCAP (1995b) Preparatory Meeting for the Ministerial Conference on Environment and Development in Asia Pacific. Bangkok.

FAO (1995) *Forest Resource Assessment: 1990: Global Synthesis*. FAO Forestry Paper No. 124. (FAO). Rome.

FAO/RAPA (1993) *Selected Indicators of Food and Agriculture Development in the Asia and Pacific Region:1982-92*. Publication 1993/26, Bangkok.

Fuavo, V. (1990) Areas of Environmental Concerns in the South Pacific Region. SPREP. GESAMP (IMO, FAO, UNESCO, WMO, WHO, IAEA, UN, UNEP). 1991. Joint group of experts on the scientific aspects of marine protection, reducing environmental impacts of coastal aquaculture. Reports and Studies No 47. FAO. Rome.

Government of Thailand (1994) Thailand State of the Environment Report. Bangkok.

Kalnay, E., *et. al.,* (1993) The NCEP/NCAR CDAS/Reanalysis Project. NMC Office Note 401. Available from NOAA/NCEP Development Division, Washington DC 20233.

McKenzie, J.A. and Goudey, R. (1993) Assessment of coastal discharges for their potential environmental impact. EPA SRS 91/006.

Mulvad, G., Pedersen, H.S., Hansen, J.C., Dewailly, E., Jul, E., Pederson, M.B., Bjerregaard, P., Malcolm, G.T., Deguchi, Y. and Middaugh, J.P. (1996) Exposure of Greenlandic Inuit to organochlorines and heavy metals through the marine food-chain: an international study. *The Science of the Total Environment* **186**, 137-139.

New Zealand. (2002) The Organochlorines Programme. http://www.mfe.govt.nz/issues/hazardous/contaminated/organochlorines.html.

SOE Australia (1996) State of the Environment, Australia.

SOE New Zealand (1997) State of the Environment, New Zealand.

UN ECE (1996) The Dirty Dozen. http://www.unece.org/spot/s01.htm

UN ECE (1998) Convention on long-range transboundary air pollution. http://www.unece.org/env/lrtap/pops_h1.htm

UNEP (1994) *Environmental Data Report 1993-94.* United Nations Environmental Programme. Oxford.

Van Lynden, G.W.J. and Oldeman, L.R. (1997) The assessment of the status of human-induced soil degradation in South and South-east Asia. United Nations Environment Programme (UNEP), Food and Agricultural Organization of the United Nations (FAO), International Soil Reference and Information Centre (ISRIC), Wageningen, The Netherlands (digital map and data sets). The China Food maps were produced with the IIASA LUC-GIS from ASSOD database and vector files

Wallack, H. W., Bakker, D.J., Brandt, I., Brostrom-Lundén, E., Brouwer, A., Bull, K. R., Gough, C., Guardans, R., Holoubek, I., Jansson, B., Koch, R., Kuylenstirna, J., Lecloux, A., Mackay, D., McCutcheon, P., Mocarelli, P. and Taalman, R. D. F. (1998) Controlling persistent organic pollutants - What next? *Environmental Toxicology and Pharmacology* **6**, 143-175.

Weber, P. C. (1993) Abandoned Seas. Worldwatch Paper 116. Washington.

World Bank. (1992) Bhutan Trust Fund for Environmental Conservation. Project Document.

Yearbook Australia (1995) Yearbook Australia 1995. Canberra.

2. SOURCE CHARACTERISATION

2.1. Background Information

The main sources of PTS in the 12 countries under Region 8 can be broadly grouped into agricultural and industrial/urban related sources. Agricultural related sources include use and disposal of agricultural pesticides, open burning of biomass for land clearing activities and the disposal of agricultural wastes. Industrial/urbanisation related sources include stationary, diffuse and mobile sources. Examples of stationary sources are industrial plants with large fuel or waste combustion equipment such as power stations, steel mills, waste incinerators and sanitary landfills.

With increasing urbanisation of the countries in the region, vehicular sources of emissions are of increasing concern. In general, point sources such as emissions from industrial stacks or exhaust pipes of vehicles are more amenable to direct regulatory controls such as emission limits, mandatory use of cleaner fuel and use of pollution control equipment or devices. Diffuse sources such as smouldering fires from landfills, open burning of solid wastes or biomass, and contaminated run-offs from agricultural areas may also be controlled or managed to minimise such releases of PTS into the environment. Approaches include the establishment of appropriate regulatory framework, institutional capacity and environmental infrastructures.

During the last few years, progress has been made in raising the awareness of many countries in the region on the need for emission inventories of PTS. However there is still a lack of comprehensive source and emission inventories of PTS in most of the countries of the region with the exception of Australia and New Zealand. For example, Australia and New Zealand have in place emission inventories for PCDD/PCDFs. Several other countries such as Brunei Darussalam, Philippines and Thailand are compiling PCDD/PCDFs inventories under an UNEP/GEF sponsored project to assist countries in the implementation of the Stockholm Convention. Such inventories could help decision makers develop appropriate control strategies for PTS.

Even though source inventories are often unavailable or incomplete, countries in the region have already taken regulatory and administrative measures to prevent or minimise emissions of many of the PTS, especially the organochlorine pesticides (OCP). Table 2.1 contains a summary of such measures taken by countries in the region to prevent or control PTS emissions.

Table 2.1. Regulatory controls[1] on key PTS pesticides

	Aldrin	Chlordane	DDT	Dieldrin	Endosulfan	Endrin	Heptachlor	HCB	Mirex	PCP	Toxaphene	HCH
Australia	Banned in 1995	Banned	Banned by 1987	Banned		Banned	Banned in 1995	Banned	Severely restricted		Banned in 1960s	HCH isomers – banned. Lindane allowed under authorisation by Dept. of Agri., Fisheries and Forestry
Brunei Darussalam	Banned in 1980	Banned in 1980	Banned in 1980	Banned in 1980		Banned in 1980	Banned in 1980	Banned in 1980	Banned in 1986	Banned in 1986	Banned in 1980	
Cambodia	Banned in 1992	Banned	Banned	Banned	Restricted	Banned	Banned	Banned	Restricted	Restricted	Banned	Banned
Indonesia	Never registered for use	Banned in 1992	Banned	Banned in 1992		Never registered for use	Never registered for use	Banned	Banned	Banned in 1980	Banned in 1980	HCH isomers – banned. Lindane – not registered
Laos	Banned in 1992	Banned	Banned in 1992	Banned in 1992		Banned in 1992	Banned in 1992		Banned		Banned in 1992	
Malaysia	Banned in 1994	Banned in 1998	Banned in 1999	Banned in 1994		Withdrawn by company	Banned in 1990	Never registered	Banned	Banned in 2000	Banned	Registration under review
New Zealand	Banned in 1985	Banned in 1992	Banned in 1988	Banned in 1988		Banned in 1976	Banned in 1971	Banned in 1972	Banned in 1988	Banned in 1991	Banned in 1979	Banned in 1989
Papua New Guinea	Banned in 1990	Banned in 1999	Restricted	Banned in 1990	Not registered	Banned in 1990	Restricted	Banned in 1990	Banned in 1990	Banned in 1990	Banned in 1990	Lindane used in agriculture, all other isomers banned
Philippines	Banned in 1989	Restricted	Restricted	Banned in 1989		Banned from import in 1989	Banned in 1989	Restricted	Restricted	Banned. Only allowed for use in wood treatment	Banned in 1989	Banned in 1989
Singapore	Banned in 1985	Severely restricted 1985; banned 1999	Banned in 1985	Banned in 1985	Not registered	Severely restricted in 1985. Banned in 1995	Banned in 1985	Restricted in 1985	Banned in 1985	Restricted in 1985. Banned in 1995	Banned in 1985	Banned in 1985, not used
Thailand						Banned in 1981	Banned in 1988 (AG). Banned in 1995 (PH)	Banned in 2001	Banned in 1995	Banned in 1995 (AG). Banned in 2000 (PH)	Banned in 1983	HCH-mixed isomers are banned. Lindane banned 2002. Lindane import and use in public health requires import and production registration and import licence

Viet Nam	Banned in 1992	Banned in 1992	Banned in 1992	Banned in 1992	Banned in 1992	Banned in 1992	Banned in 1992	Import under conditions imposed by Ministry of Agriculture and Rural Development	Banned in 1995	Banned

[1] Based upon country contributions to UNEP and submissions at regional technical meetings. Banned refers to pesticides for which all registered uses have been prohibited or for all requests for registration or equivalent actions.

2.2. Data Collection

Data on sources of PTS in the region are collected via the following:

(a) UNEP/GEF Questionnaires under the Project;

(b) Papers and other contributions from country experts at the first and second regional technical workshops held in February and April 2002 and during the Regional Priority Setting Meeting in August 2002

(c) Published papers and documents

2.3. Pesticides

2.3.1. Aldrin

Aldrin has been used in several countries in the region. For example, aldrin was used to control termites in urban areas of Australia (Australian Academy of Technological Sciences and Engineering, 2002; Miller *et al*., 2002). It has been used in the Philippines as a pesticide for golf courses (Greenpeace, 2000). In New Zealand, aldrin was used to control horticultural pests such as wireworm, soldier fly and blackvine weevil and in limited quantities to control household spiders. It was also used in the control of ectoparasites in sheep (Ministry for the Environment, New Zealand, May 2001).

Most countries in the region have introduced regulatory and administrative measures to ban the use of aldrin. A summary of the regulatory control instituted by countries in the region is shown in Table 2.1.

There is no known manufacturing facility for aldrin in the region. In most of the countries of the region, bans or restrictions on the use of aldrin have been in effect for more than 10 years. There is no available inventory on the import and use of aldrin in the region with the exception of Thailand that was reported to have imported about 1 ton of aldrin in 1988 but has since ceased such import (Boon-Long, 1997). There appears to be no significant continuing source of aldrin emissions to the air, water or land in the region.

2.3.2. Chlordane

Chlordane has been used in the region as an insecticide for control of pests such as termites, cockroaches, ants and wood boring beetles to protect buildings and structures. It was also used in the timber industries as treatment against termites and borers and as an insecticide in glues used for manufacture of plywood and laminated timber.

Most countries in the region have introduced regulatory controls to ban the use of chlordane. A summary of the regulatory controls in countries of the region is listed in Table 2.1.

There is no known manufacturing facility for chlordane in the region. In many countries in the region, chlordane was permitted for use till recent years. There is however a lack of available inventories on the import and use of chlordane in countries in the region with the exception of Thailand which was reported to have imported about 150 tonnes of chlordane in 1996 but has since ceased such import (Boon-Long, 1997). As the ban on import and use of chlordane came into force only in recent years, there could still be continuing sources of chlordane releases from soil or sediments in the region from recent and perhaps continuing applications of chlordane. There is, however, a lack of emission inventories of chlordane in the region.

2.3.3. Dichlorodiphenyltrichloroethane (DDT)

DDT has been used extensively in the region for malaria control since the 1950s. It was also used in agricultural pest control on pests such as corn grasshopper, cotton ball worm and tobacco insect pests. It was found to be highly effective for malaria control and helped decrease the mortality rate from malaria in countries in the region. For instance in Thailand, the mortality rate has decreased from 200/100,000 in 1951 to 1/100,000 in 1993 (Boon-Long, 1997). In 1994, Thailand was reported to

have imported about 100 tons of DDT but since then no import of DDT was reported (Boon-Long, 1997).

In general, countries in the region have banned the use of DDT. For instance, Brunei banned DDT in 1985 and now uses substitutes such as Dursban and Resigen (Lee, 2002). In Malaysia, DDT has not been permitted to be imported, manufactured or used or sold in the country, except for purposes of research or education (PIC Database: Import Decision by Country), since May 1999. The use of DDT was prohibited on New Zealand farmlands in 1970, and its sale for all other purposes, e.g. borer bombs, was banned / deregistered in 1989 (Ministry for the Environment, New Zealand, 1998). PNG allows the use of DDT for malaria control only while in the Philippines, import of DDT for malaria vector control is subject to special permit from the Department of Health (PIC Database: Import Decision by Country).

A summary of the regulatory controls instituted by countries in the region on DDT is shown in Table 2.1. There is no known manufacturing facility for DDT in the region. There is, however, a lack of available inventories on the import and use of DDT in most countries in the region. In Australia, DDT usage peaked at 3500 tons in 1973 and was phased out totally by 1988. Tables 2.3.1 and 2.3.2 show the quantity of DDT imported and used in Viet Nam respectively.

Table 2.3.1. Imports of DDT- Viet Nam

Years	Quantity (tons)	Type of DDT
1957-1979	14,847	DDT 30%
1976-1980	1800	DDT 75%
1977-1983	4000	DDT 75%
1981-1985	600	DDT 75%
1984-1985	1733	DDT 75%
1986	262	DDT 75%
1986-1990	800	DDT 75%

Source: Medicine Preventive Department, Ministry of Health – 1998

Table 2.3.2. DDT usage in Viet Nam

Year	Quantity (kg)
1992	237,748
1993	33,935
1994	151,675

Source: Medicine Preventive Department, Ministry of Health – 1998

2.3.4. Dieldrin

Dieldrin was used in the region as an agricultural insecticide and in the timber processing industry for wood treatment in the 1970s and 1980s. It has also been used for control of cotton pests in conjunction with DDT in the 1960s. It has since been banned from use in most countries in the region. A summary of the regulatory controls instituted by countries in the region is listed in Table 2.1.

There is no known manufacturing facility for dieldrin in the region. In many countries of the region, the ban or restriction on the use of dieldrin has been in effect for more than 10 years. There is no available inventory on the import and use of dieldrin in the region. There appears to be no significant continuing source of dieldrin releases to the air, water or land in the region.

2.3.5. Endrin

Endrin has been used in the region as an insecticide, rodenticide and avicide. It has been banned from use by most countries of the region.

A summary of the regulatory controls instituted by countries in the region is listed in Table 2.1.

There is no known manufacturing facility for endrin in the region. In many countries of the region, the ban or restriction on the use of endrin has been in effect for more than 10 years. There is no available inventory on the import and use of endrin in the region.

2.3.6. Endosulfan

Endosulfan is used for cotton and other crops in several countries in the region. It has been used as a substitute for organotin compounds against the golden kuhol (snail), which was devastating rice-fields. Its use has been severely restricted or controlled in countries with this pest problem. In Australia, the National Registration Authority (NRA 02/5) had in September 2002 introduced new conditions to stop the use of endosulfan on Brussel sprouts and certain leafy vegetables as well as ban the use of treated fodder for livestock. The National Registration Authority for Agricultural and Veterinary Chemicals, Australia indicated that about 900 tonnes per year of endosulfan was imported for use in Australia (NRA, 1998). A review published in 2002 indicated that the quantity of endosulfan imported for use in Australia has reduced to about 500 tonnes per year (Australian Academy of Technological Sciences and Engineering, 2002).

In many countries of the region endosulfan is still in use. There is, however, no available inventory on the import and use of endosulfan in the region. As the use of endosulfan is ongoing, there would be continuing releases to air, soil or sediments in the region.

2.3.7. Heptachlor

Heptachlor was used in the region to protect soil and seeds against soil infestation and to control insect pests in crops. Most countries of the region have banned its use. In PNG, heptachlor is restricted to use against subterranean termites only.

A summary of the regulatory controls instituted by countries in the region is shown in Table 2.1.
There is no known manufacturing facility for heptachlor in the region. In many countries of the region, the ban or restriction on the use of heptachlor has been in effect for more than 10 years. There is no available inventory on the import and use of heptachlor in the region except for Thailand which was reported to have imported 87 tons of heptachlor in 1988 but has since ceased such import (Boon-Long, 1997). There appears to be no significant continuing source of heptachlor releases to the air, water or land in the region.

2.3.8. Hexachlorobenzene

Hexachlorobenzene was used briefly in small quantities in Australia and New Zealand in the 1960s and 1970s. Countries in the region have since either banned it or it has never been registered for use in agriculture. There are, however, pesticides in which HCB is a contaminant or by-product and the use of such pesticides could also be a source of HCB emissions.

There is no known manufacturing facility for hexachlorobenzene in the region. In many countries of the region, the ban or restriction on the use of hexachlorobenzene has been in effect for more than 10 years. There is no available inventory on the import and use of hexachlorobenzene in the region. There appears to be no significant continuing source of hexachlorobenzene releases to the air, water or land in the region from agricultural use.

2.3.9. Mirex

Mirex is still used under licence in small quantities as bait for termites in northern Australia and research is underway to find a suitable alternative. Australia has been granted an exemption to continue using mirex for five years from the date of the Stockholm Convention's entry-into-force (Australian Academy of Technological Sciences and Engineering, 2002). It has either been banned or was not used in most countries of the region.

A summary of the regulatory controls instituted by countries in the region is listed in Table 2.1.

There is no known manufacturing facility for mirex in the region. In many countries of the region, the ban or restriction on the use of mirex has been in effect for more than 10 years. There is no available inventory on the import and use of mirex in the region. There appears to be no significant continuing source of mirex releases to the air, water or land in the region.

2.3.10. Pentachlorophenol (PCP)

The sodium salt of pentachlorophenol (sodium pentachlorophenate (NaPCP)) was used in the region in fungicides, herbicides and other preparations. PCP was used as a fungicide extensively in sawmills in New Zealand in the treatment of freshly cut timber (mainly *Pinus radiata*). PCP was also used to a relatively minor extent by the pulp and paper industry, in mushroom culture, and in home gardens to control moss and algae. The use of PCP in the timber industry ceased in 1988, and it was withdrawn from sale / deregistered in 1991 (Ministry for the Environment, New Zealand, 2002). It was estimated that around 5000 tonnes of PCP have been used in the timber industry in New Zealand over a 35 to 40 year period (Ministry for the Environment, New Zealand, 1998).

Indonesia banned the use of PCP and its salts in 1980. In Malaysia, PCP has not been permitted to be imported, manufactured or used or sold in the country except for purposes of research or education since 1 January 2000 (PIC Database, Import Decision by Country). Singapore banned its use in 1995, while in the Philippines the use of PCP is restricted to wood treatment by FPA-accredited wood treatment plants. In Thailand, PCP was banned in 1995.

A summary of the regulatory controls instituted by countries in the region is listed in Table 2.1.

There is no known manufacturing facility for PCP in the region. In many countries of the region, PCP has been restricted or banned from use. There is no available emission inventory on PCP in the region.

2.3.11. Toxaphene

In Australia, toxaphene was registered briefly in the early 1960s for control of grasshoppers (Harrison, 1997). Only small quantities were used. In New Zealand, the single toxaphene-based product, registered for field-testing only, was withdrawn by the registrant in 1968 (PIC Database, Import Decision by Country). Countries in the region have introduced regulations to ban its use.

A summary of the regulatory controls instituted by countries in the region is listed in Table 2.1.

There is no known manufacturing facility for toxaphene in the region. In many countries of the region, it has not been in use or has been banned for more than 10 years. There appears to be no significant continuing source of toxaphene releases to the air, water or land in the region.

2.3.12. Hexachlorohexanes

Lindane, a form of hexachlorohexanes, was used as an insecticide in agriculture for the control of lice on cattle and grass grub in pasture, and for insect control on vegetables and in orchards in New Zealand (Ministry for the Environment, New Zealand, 1998). The use was progressively restricted under a permit system and its sale for use was banned in 1989 (Ministry for the Environment, New Zealand). It may still be in use for palm oil and coconuts in Malaysia (Othman and Palasubramaniam, 2001). Currently, its pesticide board is in the process of reviewing the registration of all products containing lindane (PIC Database, Import Decision by Country). Indonesia banned the use of lindane in 1991.

A summary of the regulatory controls instituted by countries in the region is listed in Table 2.1.

There is no known manufacturing facility for hexachlorohexanes in the region. There is, however, no available emission inventory of lindane or other hexachlorohexanes in the region.

2.4. Industrial Chemicals

2.4.1. Hexachlorobenzene (HCB)

HCB was previously used as a fungicide for seed grain. It is also produced as an unintentional 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 also a by-product in waste streams of chlor-alkali plants, wood preserving plants, waste incineration and pesticide manufacturing plants (Greenpeace).

In Australia, HCB was used as a fungicide in the past but now it is no longer used for such a purpose. Point sources of HCB emissions include aerospace industry, sanitary services, agricultural chemicals manufacture and industries involved in the manufacture of solvents and pesticides, wood-preserving plants and municipal waste incinerators (Environment Australia, 2001). Diffuse sources include small incinerators and agricultural run-offs. There are no known mobile sources of HCB.

Most of the countries in the region have banned the import and use of HCB.

A summary of the regulatory controls instituted by countries in the region is listed in Table 2.4.1.

Table 2.4.1. Control on PTS (industrial chemicals)

Country	HCB	PCBs
Australia	• Importation of the chemical is prohibited unless specifically approved by the Government. • All uses discontinued (dates vary from state to state) since 1987. • No remaining uses allowed.[1]	• National management plan for managing PCB wastes implemented.[1]
Brunei Darussalam	• Banned since 1980[2]	• Not manufactured or commercially produced • Importation not permitted since early 1980s.[4]
Cambodia	• No information available	• No information available
Indonesia	• Banned[2]	• Bans the import and use of PCBs in 1994[2]
Laos	• Banned[2]	• Banned[1]
Malaysia	• Import, manufacture, sale or use is banned.[2]	• Import of PCBs is banned[3]
New Zealand	• All uses and products banned in 1972 • No uses allowed.[3]	• Use of PCBs prohibited since 1 Jan 1994[3]
Papua New Guinea		• Current status of the chemical in the country is unclear. Requesting assistance from exporting countries in providing addresses of companies/agencies in Papua New Guinea to which PCB is being imported.[1]

Philippines	• Restricted use[3]	• Import, manufacture and industrial uses of PCBs is restricted[3]
Singapore	• Banned in 1985 [5]	• Import banned in 1980 • Mandatory phasing out and disposal of all old electrical transformers implemented [5]
Thailand	• Banned in 1980[6]	• Import banned in 1975[6]
Viet Nam	• National law bans substance for all uses in 1992[2]	• Restricted use[1]

Sources: [1] Food & Agriculture Organisation, [2] Ibrahim (2002b)

[3] Greenpeace, NZ, [4] Hanafi (2000)

[5] National Environment Agency, Singapore (2001) [6] Boon-Long (1997)

Despite the regulatory controls on its use, there are likely to be continuing sources of HCB emissions into the air in the form of unintentional by-products from industrial processes. There is, however, no available HCB emission inventory in the region.

2.4.2. Polychlorinated Biphenyls (PCBs)

PCBs comprise a group of 209 different congeners. Around half of this number has 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.

PCBs are not manufactured in the region. Countries in the region have generally banned the import and use of PCBs or equipment containing PCBs. Hence, the likelihood and amount of PCBs entering the environment in the region depend largely on the management and disposal of old electrical equipment containing PCBs.

Australia has a national management plan for managing PCB wastes. Any waste that contains PCBs at 50 mg/kg or more is classified as a scheduled waste. Under the plan, PCBs have been removed from sensitive areas such as schools and hospitals. From 1993-1998, approximately 5700 tonnes of PCB were destroyed (Connell *et al.*, 1999).

In New Zealand, PCBs were used in electrical equipment since the 1930s, mainly in transformers and capacitors. They were also used as heat exchange fluids, as paint additives, in carbonless copy paper and in plastics. The use of PCBs has been prohibited in New Zealand since 1 January 1994 under its Toxic Substances Regulations. Most of the old stocks of PCBs have been shipped overseas for destruction (Ministry for the Environment, New Zealand, 1998).

Malaysia has banned the import of PCBs since 1995. Since then it has been used mainly in electrical equipment such as transformers and capacitors. A total of 5.28 tonnes of PCB wastes has been disposed safely at an integrated treatment and disposal facility for hazardous waste in the country since 1998 (Hashim, 2001). Prior to this, destruction of PCB wastes was carried out at approved facilities in developed countries with consent from the relevant authorities.

Singapore has prohibited the import and use of PCBs and PCB-containing equipment such as electrical transformers since 1980. A waste management program was put in place to phase out and ensure proper disposal of old electrical equipment containing PCBs or PCB contaminated dielectrics. The transformers and electrical equipment containing PCBs or PCB contaminated dielectrics were collected and disposed at approved high-temperature disposal facilities located in other countries. By 1998, only 4 retrofilled transformers remained and these are to be phased out and disposed of by the end of 2002 (National Environment Agency, Singapore, 2001).

Indonesia banned the import and use of PCBs in 1994. There is, however, no available information on an existing inventory of PCBs.

In the Philippines, the import and industrial uses of PCBs are restricted under a Chemical Control Order but not banned. However, concerns had been expressed over the inadequate storage and disposal facilities for stocks of PCBs in older transformers and capacitors (Newbold, 2001).

In Cambodia, according to a report released by the Ministry of Industry, Mine and Energy (MIME), PCBs are still used in old electrical transformers, although new transformers without PCBs are replacing the old ones gradually. The Cambodian Electricity Authority has, however, stopped the import of transformers and transformers with PCBs. PCBs were reported to have been recycled and reused as lubricant in sewing machines in garment factories (Sokha, 2002).

In Thailand, the import of PCBs was banned in 1975. Capacitors and transformers containing PCBs and also PCB wastes were exported for disposal overseas. The PCB inventory for Thailand is shown in Table 2.4.2 (Chareonsong, 2002a).

Table 2.4.2. PCB inventory of Thailand

	No. of Units	Total Weight of Units (tons)	Total Weight of Metallic Parts (tons)	Total Weight of Liquids (tons)
Total units	849	3403	2544	858
Total no. of transformer capacitors (unknown dielectric)	16	12		
Transformers 100% PCB	15	47	32	15
Transformers (unknown dielectric)	711	3045	2277	768
PCB > 50 ppm	15	36	27	9
Transformers retrofilled	1	2.7	1.3	1.4
Transformers < 50 ppm	72	278	207	71
Dry transformers	20	29	29	
Transformers > 30 years	64	420	303	116

2.5. Unintended by-products

2.5.1. Dioxins and Furans (PCDDs/PCDFs)

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are commonly referred to as dioxins and furans or collectively as “dioxins”. PCDD/PCDFs 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 PCDD/PCDFs released to the environment include waste incineration, landfill fires, open burning of biomass, organochlorine production processes and PVC production.

There are two countries in the region with published emission inventories for PCDD/PCDFs. In addition, three countries in the region have embarked on UNEP/GEF-funded projects to establish PCDD/PCDFs emission inventories. An Environment Australia study estimated that PCDD/PCDFs emissions in Australia range from 150 g TEQ/year to 2300 g TEQ/year. Sources of PCDD/PCDFs include prescribed burning, bush fires, residential wood fires, sinter production, coal and oil

combustion, metal production, medical waste incinerators, and cement production (Environment Australia, 1998).

In New Zealand, the major industrial emitters of PCDD/PCDFs were identified as uncontrolled landfill fires (10 –15 g ITEQ/yr), followed by industrial and agricultural coal combustors (0.034 – 4.0 g I-TEQ/yr), clinical, pathological and quarantine waste incinerators (0.38 – 3.5 g I-TEQ/yr) and industrial wood combustors (0.85 – 2.4 g I-TEQ/yr). Non-industrial and natural sources, namely domestic wood burning, domestic waste burning and uncontrolled fires (forest, scrub and grass fires, structure fires and vehicle fires) also contributed significantly to PCDD/PCDFs emissions. The total annual emissions to air, land and water for 1998 were estimated to be in the range 41 to 109 g I-TEQ (Buckland *et al*., 2000).

The leachate or seepage from landfills and dumps can contain PCDD/PCDFs. Data from five landfills in New Zealand showed that such PCDD/PCDFs released ranged from 7.5 to 221 pg I-TEQ/L. The New Zealand inventory (Buckland *et al.*, 2000) subdivided the range into 14 to 48.3 pg I-TEQ/L for small and medium landfills and 7.5 to 221 pg I-TEQ/L for large landfills. The total annual emissions to land for 1998 were in the range 26 – 54 g I-TEQ.

Brunei Darussalam has embarked on a UNEP-funded project to establish its national PCDD/PCDFs inventory. Major PCDD/PCDFs sources include its two medical waste incinerators (0.0019 g TEQ/yr), uncontrolled burning such as forest fires (0.022 – 0.050 g TEQ/yr) and vehicles, especially those running on diesel fuel and leaded petrol (0.075 g TEQ/yr) (Ibrahim, 2002a).

The Philippines has screened 7,300 industries in Metro Manila and 706 industries have been pre-selected as potential sources of PCDD/PCDFs (Philippines, 2001).

In Thailand, a preliminary source inventory of PCDD/PCDFs has been compiled as shown in Table 2.5.1.

Table 2.5.1. **Preliminary source inventory of dioxins and furans in Thailand**

	Source Categories	Annual Release (g TEQ/yr)				
		Air	Water	Land	Product	Residue
1	Waste incineration	247.2	0	0	0	30
2	Ferrous and non-ferrous metal production	20.04	0	0	0	1
3	Power generation and heating	40.2	0	0	0	0
4	Production of mineral products	10.0	0	0	0	0.14
5	Transportation	7.3	0	0	0	0
6	Uncontrolled combustion processes	632.3	0	0	0	292
7	Production of chemicals and consumer goods	0.4	1.35	0	8.4	382
8	Miscellaneous	27.2	0	0	0	0
9	Disposal / Landfilling	0	0	0	0	0

Source: Chareonsong (2002b)

The most likely sources of PCDD/PCDFs emissions in the region are from industrial and non-industrial sources. These include waste incineration, industrial processes, open burning of domestic solid wastes, landfill fires, forest fires and other open burning of biomass.

The amount of PCDD/PCDFs emissions from waste incineration and industrial processes depends very significantly on the technology and type of pollution control equipment used. The UNEP toolkit

(UNEP, 2001) showed that a low technology combustion process with no APC system would have an emission factor of 3500 μg TEQ/t of waste materials burnt compared with 0.5 μg TEQ/t for high technology combustion with an advanced APC system. The latest APC systems such as the catalytic bag filters have been shown to reduce emissions to less than 0.1 μg TEQ/t of waste burnt.

Landfills for domestic wastes could also be major sources of PCDD/PCDFs emissions if such landfills are not designed and constructed to prevent landfill fires and smouldering. The UNEP toolkit gave an emission factor of 1000 μg TEQ/t of wastes burnt in landfill fires (UNEP, 2001).

Forest fires and burning of vegetation are also major sources of PAH and PCDD/PCDFs emissions to air and land in the region. A conservative estimate based upon satellite images of the 1997 forest fire episode in Southeast Asia was 60 Tg of biomass burnt. This value does not include possible burning of below ground biomass such as peat fires (Liew, 1998). The UNEP toolkit gave emission factors of 30 μg TEQ/t and 5 μg TEQ/t for burning of agricultural residues and forest fires respectively (UNEP, 2001).

Several countries in the region have imposed regulatory controls to ban open burning of biomass and agricultural wastes. Singapore and Malaysia have regulations that prohibit or restrict open burning of wastes. In Malaysia, open burning activities are supervised and must cease if the Air Pollutant Index exceeds 100 (Tan, 2002). In Singapore, open burning is prohibited at all times under the Environmental Pollution Control (Prohibition of the Use of Open Fires) Regulations.

Singapore has also under its Environmental Pollution Control (Air Impurities) Regulations stipulated and enforced stringent emission limits to control the emissions of PCDD/PCDFs from industrial plants and processes. Under the regulations, all waste incinerators commissioned before 2001 have to comply with a limit of 1.0 ng TEQ/Nm^3. All incinerators commissioned after 2001 have to comply with an emission limit of 0.1 ng TEQ/Nm^3 for PCDD/PCDFs emissions. Such incinerators have installed advanced APC systems to meet the regulatory requirements. A preliminary estimate shows the total annual emissions to air in Singapore are about 20 g I-TEQ/year (Lim, 2002).

In Viet Nam, the extensive use of PCDD/PCDFs-contaminated herbicides during the Viet Nam War was reported to be a major source of PCDD/PCDFs emissions. Based on Major Research Instrumentation (MRI) documents (1967), the NAS (1974) and Young (1988), the United States National Academy of Science published data on herbicides used during the Viet Nam war as shown in Table 2.5.2 (Le *et al.*, 1999).

Table 2.5.2. Major herbicides and pesticides used in Operation Ranch Hand 1962-1971

Herbicides and pesticides	Formula	Spraying quantity (gallons)	Year
Agent Purple	2,4-D and 2,4,5-T	145,000	1962-1964
Agent Blue (Phytar 560-G)	Cacodylic acid	1,124,307	1962-1971
Agent Pink	2,4,5-T	122,792	1962-1964
Agent Green	2,4,5-T	8208	1962-1964
Agent Orange	2,4-D and 2,4,5-T	11,261,429	1965-1970
Agent Orange II			
Agent White (Tordon-101)	2,4-D; Picloram	5,246,502	1965-1971

Source*:* US. NAS - 1997

An estimated total of about 170 kg of TCDD was reported to have been applied (Le, 2002).

2.5.2. Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are compounds consisting of two or more fused aromatic rings, which are strongly suspected to be carcinogenic and mutagenic (Cooke and Dennis, 1998). They are commonly found in the environment. The bulk of PAHs comes from incomplete combustion of organic matter, such as in fuel combustion, coke production, oil refining, aluminium production and open fires. It is evident that such sources of PAHs are found widely in the region.

Point sources of PAHs include fossil fuel power plants, coal tar production plants, bitumen and asphalt production plants, paper mills and aluminium production plants. Diffuse sources are asphalt roads, road tar, coal tar, fires from forest and residential heating, manufacture and use of preserved wood and motor vehicles exhausts. The total PAH content in diesel has been reported to be 4 to 7% but can be higher than this depending on the feedstock.

Except for Australia, there is no readily available emission inventory of PAHs. According to Environment Australia (2001), total PAH emissions from residential firewood combustion are about 625 tonnes/year, based on US emission factors. Among the various PAH congeners, anthracene, fluoranthene, naphthalene and pyrene have been identified in wood heater emissions (Chesterman, 1984) while for open fireplace emissions, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, indeno(c,d)pyrene and pyrene were identified (Freeman and Cattell, 1990).

Other emission data reported in the Environment Australia report 2001 are as follows:

Metal product manufacturing	0.0696 tonne/year
Waste disposal	0.0126 tonne/year
Petroleum, coal, chemical & associated product manufacturing	0.0609 tonne/year

Forest and vegetation fires can also be a major source of PAHs. In Brunei Darussalam, during the 1998 haze episode, the total PAH concentration was found to be between 1 and 33.8 $\mu g/m^3$ (Muraleedharan *et al.,* 2000). A study conducted to measure PAH emitted from vehicles shows a total PAH concentration of 1.076 ng/m^3.

It was reported that benzo(a)pyrene concentrations in particulate matter from the 1997 forest fire episode were 15.3 $\mu g/m^3$ and 1.05 $\mu g/m^3$ for two cities in the region respectively (Kunii, 1998).

Average level of total PAHs (14 compounds, including benzo(a)pyrene) measured along a roadside near the University of Brunei Darussalam in the year 2000 was 1.08 ng/m^3. The recommended ambient air quality guideline for benzo(a)pyrene (annual average) is 0.25 ng/m^3 (Lee , 2002).

2.6. Other PTS of emerging concern in region

2.6.1. Organotin Compounds

Organotin compounds are used as active ingredients in anti-fouling agents, fungicides, insecticides and bactericides. In the region, organotin compounds have been used in both the industrial and agricultural sectors in the past 30 years. They have been used as PVC stabilisers, biocides and industrial catalysts. Tributyltins (TBT) were used widely for pleasure boats, large ships and vessels, docks and fishing nets, lumber preservatives and slimicides in cooling systems, and as an effective antifouling agent in paints. Its derivatives, dibutyltin (DBT) and monobutyltin (MBT), were mostly used as stabilisers in polyvinyl chloride and as catalysts in the production of polyurethane foams, silicones, and in other industrial processes.

Triphenyltin compounds were used extensively in the Philippines against golden snails in rice fields and in fishponds (Philippines, 1996). Studies on the Philippine environment have shown the presence of organotin contaminants in the different environmental compartments such as marine sediments (Prudente *et al.,* 1994), fish (Prudente *et al.,* 1997), mussels (Prudente *et al.,* 1999), soils and sediments (Lee *et al.,* 1997).

The main sources of organotins in this region are considered to be antifouling paints, ship-scraping activities in some areas and sewage disposal (Allsopp and Johnston, 2000). There is, however, no available inventory of organotin emissions in the region.

2.6.2. Organomercury Compounds

There are many sources of mercury releases to the environment, both natural (volcanoes, mercury deposits, and volatilisation from the ocean) and human-related (coal combustion, chlorine alkali processing, gold refining, and metal processing). The mercury from these sources may be discharged into rivers, river mouths and ultimately to the sea. In the aquatic environment, mercury cycling encompasses the microbial transformation to methylmercury (MeHg). MeHg has a relatively high bioaccumulation and biomagnification capacity and exhibits high toxicity, which has led to the WHO adopting preventive measures, and to several countries establishing seafood standards.

In Papua New Guinea, a study revealed that inhabitants of the Lake Murray region in the remote Western Province of Papua New Guinea have among the highest recorded level of mercury in hair for people not directly exposed to human-made mercury concentrations. The diet of the inhabitants was largely based upon fish and high mercury concentrations were found in a common local fish species (PEAK, 2000).

In a Singaporean study conducted to determine the mercury (total, inorganic and organic) concentration in scalp hair of individuals not occupationally exposed to mercury, it was found that the average mercury level in hair was 5.7 ppm, with inorganic and organic mercury contents at 2.7 ppm and 3.0 ppm respectively. One suspected cause of having mercury content in individuals, not occupationally exposed to mercury, could be through their dietary pathway. Foods, typically fish and other seafood, could be both the reservoir and source of mercury found in humans (Foo *et al.,* 1988).

The annual loading of mercury to the Gulf of Thailand was reported to be about 5.4 metric tons (Thailand, 2001).

Mercury is widely used in gold mining in the Philippines. Since 1995, high mercury contents have been found in blood samples from more than 20 people living near the Palawan Quicksilver Mine, Philippines. The US Geological Survey is working with biomedical researchers from the U.S. and the Philippines to determine the source and pathway of mercury to humans in this area (USGS, 2000).

2.6.3. Organolead Compounds

Organolead compounds are organic molecules that contain one or more lead atoms. Alkyl-lead compounds such as tetramethyllead (TML) and tetraethyllead (TEL) were widely used as "anti-knocking" additives in leaded petrol. The release of TML and TEL was drastically reduced with the introduction of unleaded petrol. However, leaded petrol is still available which contributes to the emission of TEL and to a lesser extent TML to the environment. Very little alkyl-lead is emitted from petrol combustion. The primary source is direct emission through evaporation during refining, blending, transport and filling of leaded petrol.

Lead and lead compounds may be released to the land, water and air from mining activities, manufacturing industries, transport and smelting operations. Diffuse sources include contaminated soil near lead refineries and waste sites, lead-containing pesticides and lead pellets from spent ammunition. Vehicles running on leaded fuels and lawnmowers constitute mobile sources.

Air emissions of lead and mercury from various sources in Melbourne, Australia are shown below (EPA (Victoria), 1998):

	Concentration in tonnes/year	
	Lead and compounds	Mercury and compounds
Motor vehicles	184	--
Industry	3.4	0.033
Domestic/commercial	1.1	0.015

Several countries such as Brunei Darussalam, New Zealand and Singapore have phased out the use of leaded petrol. Indonesia has targeted to phase out leaded petrol by January 2003. Similarly, Australia is phasing out leaded petrol.

Data from Thailand showed that blood lead levels in children are falling as leaded petrol is phased out (EHP, 2002).

A study on heavy metal concentrations in surface sediments from Manila Bay and its inflowing rivers found that lead was present in relatively high concentrations in offshore sediments (66 – 137 µg/g in Pasig River and 11-220 µg/g in Bulacan rivers) (Prudente *et al.,* 1994). The relatively high metal concentrations in the rivers were mainly attributed to the discharge of wastes from industries.

2.6.4. Chlor. Paraffins, Nonyl/Octyl-Phenols, Phthalates, PBBs and PBDEs

Chlorinated paraffins are used extensively in industrial cutting oils, in particular in the manufacture of automobiles and automobile parts. They are also used in paints, adhesives and sealants. Nonyl- and octyl phenol derivatives are used in industrial processes such as pulp and paper manufacture, textile manufacture as well as in detergents and other household cleaning products. Phthalates are used as plasticisers in PVC products as well as in cosmetics. Polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) are used as flame retardant additives in products such as furniture, thermal insulation for buildings and housing for electronic and electrical equipment.

The use of these PTS in manufacturing processes as well as in products and articles used in the region indicate that the emissions of these PTS into the environment of the region could be significant. However, there is in general a lack of data on emission inventories of these PTS in the region.

2.7. Hot Spots

Hot spots refer to areas where PTS have been used or stored in large quantities and where significant concentrations of PTS are present in the environment of the area.

In the southern part of Viet Nam, between 1962 and 1971, Agent Orange and other herbicides were sprayed for defoliation. Approximately 18 million gallons of Agent Orange were sprayed. Soil samples from a site at Ben Hoa Air Base, a former Agent Orange storage facility, showed elevated PCDD/PCDFs levels (Schecter *et al*., 2001).

A study by Hatfield Consultants Ltd reported elevated PCDD/PCDFs levels in soil at a former airbase at Aluoi Valley in Thua Thien Hue province of Viet Nam. The study also suggested that soils in the vicinity of former facilities related to the Agent Orange spraying program may also have elevated dioxin levels (Searcy, 2002).

High levels of DDT have been found at former cattle dip sites in Australia. About 1,700 former cattle dip sites in northern NSW, Australia await remediation (Miller *et al.*, 2002).

2.8. Data Gaps

In general, there are limited data available on inventories of PTS emissions in the region. There are also limited data available on industrial, agricultural and other activities to allow estimates of emissions of PTS to be made. Emission inventories on PCDD/PCDFs are the most available. There are currently two countries with published inventory and three other countries have embarked on projects to establish their PCDD/PCDFs inventories. Estimates based on activity data and emission limits have also been made in one country. Two countries in the region have established inventories on PCB-filled or contaminated transformers, which are the major source of PCBs in the region.

Most of the pesticides listed as PTS have been banned or are not widely used in recent years in the region with the exception of endosulfan. Although no emission inventory is available for the PTS pesticides, the trend of decreasing environmental levels reported in some countries indicates that the emissions of these pesticides are generally declining. There is also a lack of reliable data on emission inventories of other emerging PTS of concern such as nonyl- and octyl-phenols, PBBs, PDBE and phthalates.

More work is needed to establish comprehensive PTS inventories in countries of the region. The UNEP/GEF project to establish PCDD/PCDFs inventories in three selected countries in the region is a key step forward.

2.9. Summary

In summary, there are limited data available on import, use and inventory of PTS emissions in the region. Regulatory and other measures have been taken to phase out or ban the use of most of the PTS pesticides in the region. Many of these pesticides with the exceptions of DDT, endosulfan, mirex and lindane have been banned or were not used in many of the countries of the region for more than 10 years. Mirex is used only in very limited quantities in Australia (termite baits) while DDT, endosulfan and lindane are still in use in some countries of the region.

The sources of by-products emissions such as PCDD/PCDFs and PAHs are widespread in the region and include emissions from both industrial and non-industrial sources. These include forest and vegetation fires, open burning of wastes, releases from landfills and industrial processes.

The amount of PCDD/PCDFs emissions from industrial processes, including waste incineration is highly dependant on the technology and type of pollution control equipment adopted, ranging from 3500 μg TEQ/t of wastes burnt for plants with no pollution control equipment to 0.5 μg TEQ/t of waste burnt for plants with advanced pollution control equipment. Landfills for domestic wastes as well as open burning of domestic wastes are also major sources of PCDD/PCDFs emissions. Landfill fires emit 1000 μg TEQ/t of wastes burnt while open burning of domestic wastes emit 300 TEQ/t of wastes burnt. Such sources need close monitoring and control to reduce their emissions.

Forest fires and burning of vegetation are also major sources of PAH and PCDD/PCDFs emissions in the region. A conservative estimate of biomass burnt based upon satellite images of the 1997 forest fire episode in Southeast Asia was 60 Tg excluding burning of below ground biomass such as peat fires. At least two countries in the region, Malaysia and Singapore, have taken regulatory measures to prohibit open fires and open burning of wastes.

PCBs are also of concern even though countries of the region have banned the import of PCBs. In many countries the existing stocks of old PCB filled electrical equipment are not closely monitored and managed. Many of the countries in the region lack adequate PCB waste management programs and facilities to monitor and ensure proper storage, handling and disposal of the PCB filled or contaminated equipment. Inventories of old PCB filled or contaminated electrical equipment are available only in two countries.

Leaded petrol is still in use in many countries of the region and could be a source of organolead emissions due to direct emissions from evaporation during transport, filling/refilling operations, storage and handling of the leaded fuel. Organotin compounds are used in agriculture as well as in antifouling paints on ships.

Phthalates, PDBE, nonyl- and octyl-phenols are known to be used in the region as raw materials, intermediates and in finished industrial and consumer products. There is, however, a lack of quantitative data on their import, use and emission inventories.

2.10 References

Allsopp, M. and Johnston, P. (2000) Unseen Poisons in Asia, A Review of POPs Levels in South and Southeast Asia and Oceania. Greenpeace, Mar 2000.

Australian Academy of Technological Sciences and Engineering (2002) *Pesticide Use in Australia*. 2002.

Boon-Long, J. (1997) Managing POPs in Thailand. *Proceedings of the Sub-Regional Awareness Raising Workshop on Persistent Organic Pollutants*, Bangkok, Thailand, 25-28 Nov 1997.

Buckland, S.J., Ellis, H.K. and Dyke, P.H. (2000) New Zealand Inventory of Dioxin Emissions to Air, Land and Water and Reservoir Sources. Organochlorines Programme, Ministry for the Environment, Wellington, NZ, March 2000.

Chareonsong, P. (2002a) PCB Inventory in Thailand. *UNEP/GEF 1st Technical Workshop for Region 8,* Singapore, 6-8 February 2002.

Chareonsong, P. (2002b) PCDD/PCDF Source Inventory in Thailand. *UNEP/GEF 1st Technical Workshop for Region 8*, Singapore, 6-8 February 2002.

Chesterman, R.B. (1984) *Emissions from Wood Burning Heaters*. Tasmania, Dept of Environment.

Connell, D.W., Miller, G.J., Mortimer, M.R., Shaw, G.R. and Anderson, S.A. (1999) Persistent lipophilic contaminants and other chemical residues in the Southern Hemisphere. *Critical Reviews in Environmental Science and Technology* **29** (1), 47.

Cooke, M. and Dennis, A.J. (1998) Polynuclear Aromatic Hydrocarbons: A Decade of Progress.

EHP (2002) World's Children Threatened. *Environmental Health Perspectives* Volume 110, Number 6, June 2002.

Environment Australia (2001) Air Toxics and Indoor Air Quality in Australia. Environment Australia Report, 2001.

Environment Australia (1998) Sources of Dioxins and Furans in Australia: Air Emissions 1998.

EPA (Victoria) (1998) Air Emissions inventory - Port Philip Region, Melbourne. Publication 632.

Foo, S.C., Ngim, C.H., Phoon, W.O. and Lee, J. (1988) Mercury in scalp hair of healthy Singapore residents. The *Science of the Total Environment* **72**, 113-122.

Freeman, D.J. and Cattell, F.C.R. (1990) Woodburning as a source of atmospheric polycyclic aromatic hydrocarbons. *Environmental Science and Technology* **24** (10), 1581-1585.

Greenpeace (2000) US Toxic Legacies: Toxic Hotspots in Subic and Clark, 29 Feb 2000 http://www.greenpeace.org/~toxics/toxfreeasia/documents/clarksubic.html

Greenpeace New Zealand (2000) Greenpeace Calls on the New Zealand Government to Clean up its Act.

http://www.greenpeace.org.nz/gpnz1/campaigns/Toxics/pressreleases/toxicnewsdetail.asp?offset=20&PRID=76

Greenpeace, NZ: Status of the Dirty Dozen in New Zealand

http://www.greenpeace.org/nz/gpnz1/campaigns/Toxics/dirtydozen.htm

Greenpeace: Down to Zero, POPs Listed by UNEP

http://archive.greenpeace.org/~toxics/downtozero/POPs/unep-list.html

Hanafi, H.H. (2000) Information Paper on PCBs, *Subregional Workshop on Identification and Management of Dioxins/Furans and PCBs*, Seoul, Jul 2000.

Harrison, S. (1997) Organochlorines in Australia. Department of Primary Industries & Energy Commonwealth of Australia. *Proceedings of the Subregional Awareness Raising Workshop on Persistent Organic Pollutants (POPs)*, Bangkok, Thailand, 25-28 November 1997. http://www.chem.unep.ch/pops/POPs_Inc/proceedings/bangkok/HARRISON.html

Hashim, H. (2001) Malaysia Country Report on Polychlorinated Biphenyl (PCBs) http://www.cacpk.org/cacpk/cacpk-en/ann/pop_06.htm

Ibrahim, R.H.A. (2002a) PCDD/PCDF Source Inventory in Brunei. *UNEP/GEF 2nd Technical Workshop for Region 8*, Penang, Malaysia, 17 - 19 Apr 2002.

Ibrahim, S. (2002b) Status of PTS in Region 8. *UNEP/GEF 2nd PTS Working Group Technical Workshop,* Penang, Apr 2002.

Kunii, O. (1998) A Case Study in the 1997 Forest Fires in Indonesia. *WHO Health Guidelines for Vegetation Fire Events at Peru*, 6-9 Oct 1998.

Le, K.S. (2002) Agent Orange in the Vietnam War. *GEF: Regionally Based Assessment of Persistent Toxic Substances First Technical Working Group*, Singapore, 6-8 February 2002.

Le, T.B.T., Nguyen, N.S., Nguyen, K.K. and Le, B.T. (1999) Persistent Organic Pollutants in Vietnam. *Proceedings of the Regional Workshop on the Management of Persistent Organic Pollutants (POPs)*, Hanoi, Vietnam, 16-19 March 1999.

Lee D.B., Prudente, M.S., Tanabe, S. and Tatsukaw, R. (1997) Organochlorine residues in soils and sediments from Manila Bay and nearby provinces, Philippines. *Toxicology and Environmental Chemistry* **60**, 171-181.

Lee, H.L. (2002) Particulate PAH Concentration in Brunei - A Preliminary Study. *UNEP/GEF 1st PTS Technical Working Group Meeting on Sources and Concentrations*, Singapore, 6- 8 Feb 2002.

Liew, S.C. (1998) A Study of the 1997 Forest Fires in Southeast Asia using SPOT Quicklook Mosaics. *International Geoscience and Remote Sensing Symposium*, Seattle, Jul 1998.

Lim, K.L. (2002) Sources of PTS. *UNEP/GEF 1st PTS Technical Working Group Meeting on Sources and Concentrations*, Singapore, 6- 8 Feb 2002.

Miller, G.J., Connell, D.W. and Anderson, S.M. (2002) Persistent Toxic Substances in Australia. *Prepared for 1st Technical Working Group Meeting, Region 8, GEF-UNEP Project on Global Assessment of Persistent and Toxic Substances*, 6-8 Feb, 2002, Singapore.

Ministry for the Environment, New Zealand (1998) Reporting on Persistent Organochlorines in New Zealand, September 1998 http://www.mfe.govt.nz/issues/waste/organochlorines/reporting_on_organochlorines.pdf

Ministry for the Environment, New Zealand (2001) Serum Study: A summary of the Findings, May 2001.

http://www.mfe.govt.nz/issues/waste/organochlorines/Serum_study_summary_of_findings.pdf

Ministry for the Environment, New Zealand (2002) Investigating Persistent Organochlorines in New Zealand.

http://www.chem.unep.ch/pops/indxhtms/NZBrochure.html

Muraleedharan T.R, Radojevic, M., Waugh, A. and Caruana, A. (2000) Chemical characterisation of the haze in Brunei Darussalam during the 1998 episode. *Atmospheric Environment* **34**, 2725-273, 2000.

National Environment Agency, Singapore: Pollution Control Department (2001).

Newbold, R. (2001) Philippines Finally Acts on Poisonous US Legacy, May 15, 2001.

NRA (1998) The NRA Review of Endosulfan 1998. The National Registry Authority (Australia).

Othman, A.B. and Palasubramaniam, K. (2001) Country Report for Malaysia. *PAC Meeting*, pg. 6, 2001.

PEAK (2000) Mercury Bioaccumulation in Papua New Guinea, PEAK 2000 Annual Report, *Research News,* Issue 8, February 2001.

Philippines (1996) Philippine Case Study: A Developing Country's Perspective on POPs. *IFCS Meeting on POPs*, Manila, Philippines, 17 – 19 Jun, 1996.

Philippines (2001) Philippines' Country Paper. *Presented at the Kickoff Workshop of the Asia Toolkit Project on Inventories of Dioxin and Furan Releases*, Hanoi, Vietnam, 1 – 4 Oct 2001.

PIC Database: Import Decision by Country

http://www.fao.org/pic/Country.htm

Prudente, M.S., Ichibashi, H. and Tatsukawa, R. (1994) Heavy metal concentrations in sediments from Manila Bay, Philippines and inflowing rivers. *Environmental Pollution* **86**, 73-83.

Prudente, M.S., Kim, E.Y., Tanabe, S. and Tatsukawa, R. (1997) Metal levels in some commercial fish species from Manila Bay, Philippines. *Marine Pollution Bulletin* **34**, 671-674.

Prudente, M., Ichihashi, H., Kan-atireklap, S., Watanabe, I. and Tanabe, S. (1999) Butyltin, organochlorines and metal levels in green mussel, Perna viridis L. from the coast water of the Philippines. *Fisheries Sciences* **65**, 441-447.

Schecter, A., Dai, L.C., Papke, O., Prange, J., Constable, J.D., Matsuda, M., Thao, V.D. and Piskac, A.L. (2001) Recent dioxin contamination from Agent Orange in residents of a southern Vietnam city. *Journal of Occupational and Environmental Medicine* **43** (5), 435-443.

Searcy, C. (2002) Agent Orange in Vietnam – An Overview. *Indochina News* Spring, 2002.

Sokha, C. (2002) Persistent and Toxic Substance Management in Cambodia. *UNEP/GEF 1st Technical Workshop for Region 8*, Singapore, 6 – 8 February, 2002.

Tan, E. (2002) New Law on Open Burning, *New Straits Times (Malaysia)*, 11 Jan 2002.

Thailand (2001) Mercury Assessment in Thailand. Pollution Control Department, Bangkok, Thailand, Oct 2001.

UNEP (2001) Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases. Prepared by UNEP Chemicals, Geneva, Switzerland, Draft 2001.

USGS (2000) Mercury Contamination in Philippines. US Geological Survey, Nov 14, 2000.

3. ENVIRONMENTAL LEVELS, TOXICOLOGICAL AND ECOTOXICOLOGICAL PATTERNS.

3.1. Environmental Levels

Monitoring of persistent toxic substances in the region has been conducted since the late 1960s to the early 1970s. The use and environmental levels of DDT were reported in Australia as early as 1972 (Australian Academy of Science, 1972). Because of worldwide reports on ecotoxicological effects of several chlorinated pesticides and their wide occurrence in environmental media, several countries in the region have started monitoring programs for PTS. This has led to the prohibited use and banning of certain PTS chemicals (see Table 2.1).

A few major monitoring programs have been completed within the region including the Mussel Watch Program - Marine Pollution Monitoring in Asian Waters (Tanabe *et al*., 2000), EDC Pollution Monitoring in the East Asian Coastal Hydrosphere (Coastal Hydrosphere, 2000), New Zealand Organochlorine Programs (Ministry for the Environment, New Zealand, 1998) and the comprehensive work of Tanabe on the marine environment in Japan and Asian countries. A number of countries are conducting PTS monitoring in agricultural and marine products, drinking water, human population and the environment. However, due to lack of expertise and resources, most countries in this region are unable to conduct comprehensive monitoring programs for PTS in the environment. Highly toxic PCDD/PCDFs pose a great challenge to these countries in terms of monitoring and reducing emissions. Hot spots such as those found in Viet Nam would be of global concern as most PTS may be transported over long distances.

Efforts made on capacity building through several projects in this region have improved the capability of the developing countries. The Asean-Canada Cooperative Program on Marine Science and the Environmental Monitoring and Governance of EDC Pollution in the East Asian Coastal Hydrosphere were involved in training local scientists and providing funds to acquire monitoring equipment. The Japanese Society for the Promotion of Science (JSPS) has also contributed to capacity building for PTS monitoring in participating countries.

Currently, a considerable amount of data is available on the environmental levels of most PTS, which has been collected mainly through the above-mentioned programs. Data on the marine environment are the most reported, reflecting the geographical nature of the region , which has extensive coastlines and significant maritime activities. Due to high technical requirements for the analysis of PCDD/PCDFs, few data are available on their environmental concentrations and where available, these are mainly from New Zealand and Australia. However, a parallel program initiated by UNEP is being conducted to estimate the release of PCDD/PCDFs to the environment through several industrial and human activities (Asia Toolkit Project on Inventories of Dioxin and Furan Releases).

3.1.1. Environmental Media: Air

Iwata *et al*. (1993) provide one of the most important works on the levels of PTS in air. They measured the concentration of several PTS in air as well as surface water from various oceans in 1989-90. Iwata and co-workers determined the distribution of PTS and the role of the ocean in the long-range atmospheric transport and fate of these PTS on a global scale. They found that concentrations of these PTS were higher in the Northern Hemisphere than in the Southern Hemisphere. In particular, the levels of DDTs, chlordanes, HCHs, and PCBs were relatively high in air above the coastal areas of the Indian Sub-continent and Southeast Asian countries. For example, they reported a level of 580 pg/m^3 of total DDT in air above the Strait of Malacca and as high as 1300 pg/m^3 of total HCHs in air above the South China Sea. The distributions of DDTs and PCBs in air are illustrated in Figures 3.1.1 and 3.1.2 taken from Iwata *et al.* (1993).

In a continuing effort, Iwata and co-workers reported the geographical distribution of persistent organochlorines in air, water, and sediments in Region 8 and determined their implications on global distribution from lower latitude sources (Iwata *et al.,* 1994). Air samples from urban and rural areas in India, Thailand, Viet Nam, Solomon Islands, Japan, Taiwan, and Australia were analysed for several persistent organic pollutants. Extremely high levels of HCHs were found in the Indian city of Calcutta

(11 x 10^6 pg/m^3) and Hue in Central Viet Nam (12 x 10^6 pg/m^3). Other areas showed much lower levels of HCHs in air. DDTs in air were found in high concentrations in Indochina but only trace amounts were found in Australia and other Southeast Asian countries. Similar distribution was observed for chlordane in air over these regions. High concentrations of PCBs in air were found in almost all the areas monitored ranging from 17,000 pg/m^3 (Perth) to 700 pg/m^3 (Viet Nam).

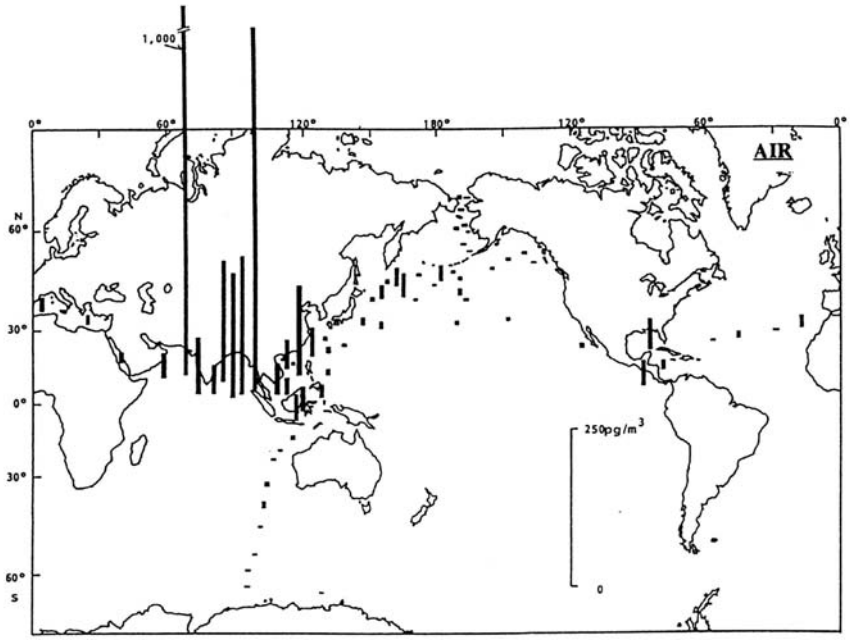


Figure 3.1.1. Distribution of DDT concentrations in air (Iwata *et al.,* 1993)

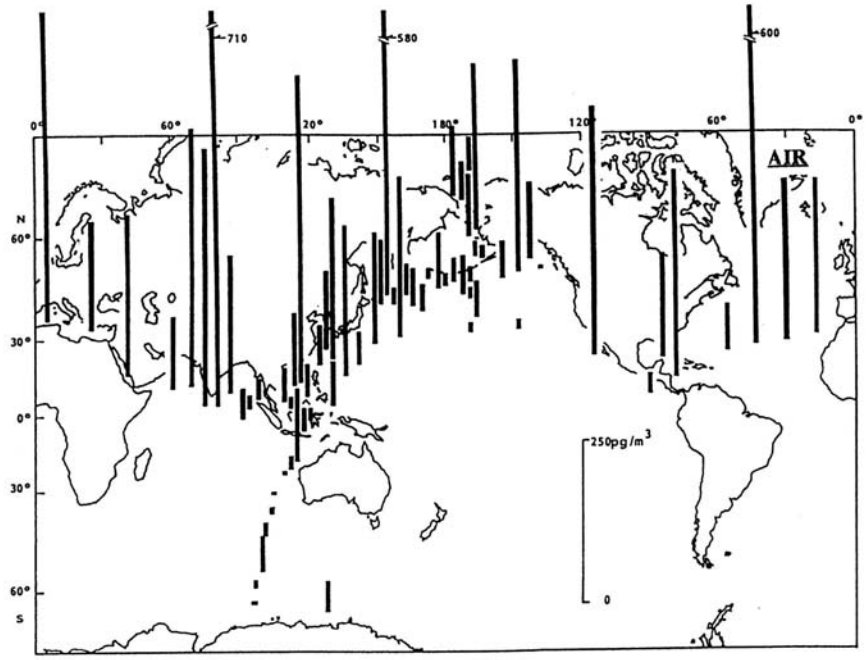


Figure 3.1.2. Distribution of PCB concentrations in air (Iwata *et al.,* 1993)

Table 3.1.1 summarises the levels of DDTs, HCHs, chlordanes, and PCBs in air over selected areas in Region 8. Figure 3.1.3 shows the relatively high concentrations of total HCHs and PCBs in air over Region 8.

Table 3.1.1. Levels of PTS in air for several cities in Region 8 (Iwata *et al.,* 1994)

Cities	DDTs (pg/m^3)	HCHs (pg/m^3)	Chlordanes (pg/m^3)	PCBs (pg/m^3)
Thailand rural areas	35 –3600	280-390	27 – 190	N.A.
Bangkok, Thailand	800	120	2500	3500
Hanoi, Viet Nam	1900	740	66	710
Hue, Central Viet Nam	2400	12×10^6	340	800
Ho Chi Minh City, Viet Nam	1700	220	31	830
Solomon Islands	1300	260	250	2300
Cronulla, NSW	14	350	390	3900
Hobart, Tasmania	8.8	450	30	4700
Melbourne, Victoria	21	380	130	8000
Perth, WA	22	900	650	17,000

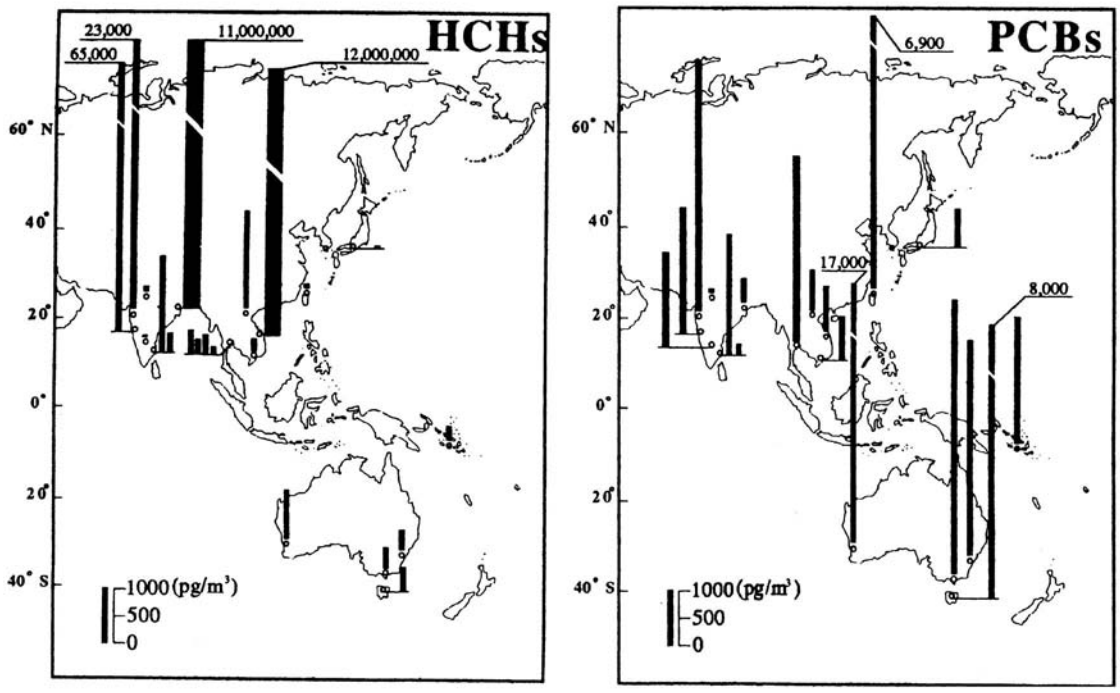


Figure 3.1.3. Distribution of HCHs and PCBs in air over rivers and estuaries in Region 8 (Iwata *et al.,* 1994)

The Ministry for the Environment, New Zealand started a national Organochlorine Program in 1995 and one of the environmental media monitored was air over several cities and rural areas throughout the country (Ministry for the Environment, New Zealand, 1998). In the 1996-1997 sampling period, they reported low levels of PCDD/PCDFs, PCBs and OCPs. PCDD/PCDFs levels were in the range of 0.94 – 31.7 fg I-TEQ /m^3 of air in the rural areas and between 6.15 – 262 fg I-TEQ /m^3 of air in the urban areas. An industrial site monitored showed relatively high levels of PCDD/PCDFs of up to 1170 fg I-TEQ /m^3 of air. However, these concentrations were more than 100 fold lower than reported for air in Japan and other developed countries. PCB concentrations in the same sampling areas also showed a similar trend with higher levels in the air of urban areas (29.9 – 129 pg/m^3) than rural areas (4.99 – 30.0 pg/m^3). These levels were much lower than the levels obtained in Australian cities (3900

– 17,000 pg/m^3) (see Iwata *et al.*, 1994). OCPs were also detected in all samples and the most abundant were lindane, HCB, dieldrin and DDT. However, the concentration levels were mostly below 50 pg/m^3 which are among the lowest concentrations of OCPs in air when compared globally.

The Pollution Control Department of Thailand has monitored the levels of organolead compounds in air over the City of Bangkok since 1992. High levels of organolead were reported, increasing temporally from 170 ng/m^3 in 1992 to 330 – 4750 ng/m^3 in 1997. However, there was a decrease to 240 ng/m^3 in 1998 (Pollution Control Department, 1998).

3.1.2. Environmental Media: Water

3.1.2.1. Freshwater

Most PTS are not very soluble in water but may also occur adsorbed on suspended solids. A few studies have been reported on the levels of PTS in water either from continuous monitoring programs or assessment studies. The Water Department of Singapore has monitored concentrations of several PTS in lake, river and processed water for drinking (National Environment Agency, Singapore, 2002). Specified numbers of samples (9 – 60 samples per year) were analysed for aldrin, chlordane, DDTs, dieldrin, and heptachlor to ensure the safe level for human consumption.

Tanabe and co-workers reported the concentrations of DDTs, HCHs, chlordanes, and PCBs in freshwater from several Asian countries and Australia (Iwata *et al.*, 1994). Extremely high concentrations of HCH were found in one Malaysian river (900 ng/L) while other areas in Region 8 showed much lower levels of HCH (0.08 – 22 ng/L). Concentrations of HCH in water in Australia were found to be low (0.079 – 0.87 ng/L) in the 20 areas studied. DDTs were found to be abundant in inland waters of most countries in Region 8. Particularly high levels of DDT were found in municipal sewage in Ho Chi Minh City, Viet Nam (25 ng/L). Chlordanes were found to be generally low in most parts of the region ranging from 0.002 to 2.8 ng/L. PCBs were found in significant amounts in most parts of the subcontinent countries while the oceanic countries had lower levels of PCB in the inland water systems. Table 3.1.2 summarises the levels and distribution of these PTS in Region 8.

Table 3.1.2. Levels of PTS in water for several countries in Region 8 (Iwata *et al.*, 1994)

Cities	No. of Locations	DDTs (ng/L)	HCHs (ng/L)	Chlordanes (ng/L)	PCBs (ng/L)
Thailand	5	0.23 – 2.50	0.18 – 75.00	0.18 – 1.30	0.24 – 4.40
Viet Nam	7	0.29 – 25.00	1.90 – 19.00	0.05 – 1.00	0.57 – 8.00
Malaysia	1	1.70	900.00	2.10	0.45
Australia	20	0.001 – 1.10	0.08 – 0.87	0.01 – 1.20	0.05 – 2.20

A more recent study on the levels of PTS in freshwater was reported for several rivers (Table 3.1.3) in Northern Peninsular Malaysia (Tan, 2001). Contrary to the 1994 report (Iwata *et al.,* 1994), the author found that most OCPs including HCHs were at relatively low levels in the river water suggesting isolated contamination of samples collected from nearby rivers in the earlier studies. However, Tan (2001) reported that PAHs and phthalate esters were exceptionally high. The levels of DDT were comparable to those found by Iwata and co-workers in the same study.

Thailand has monitored several PTS since the early 1980s and data are available in the Agricultural Department of Thailand annual reports. The data are summarised in Table 3.1.4 together with data on neighbouring Malaysian rivers. There were no significant changes in concentrations of several PTS such as aldrin, DDT, dieldrin and heptachlor over the two decades of monitoring river waters throughout Thailand. Heptachlor seemed to peak in 1995 even though it was already banned in 1981. It is likely that heptachlor was present at about 10% in the chlordane formulation used for termite control. Constant levels of several PTS in Thailand and Malaysia suggested continuous input even though the chemicals had been banned from import.

Table 3.1.3. Mean concentration (ng/L) of PTS in several rivers in West Malaysia (Tan, 2001)

Location	No. Samples	Aldrin	DDT	Dieldrin	Endosulfan	Endrin	HCH	Heptachlor	PAHs	Phthalates	Phenols
Sg. Perak	9	N.D.	10.22	N.D.	3.44	N.D.	N.D.	0.44	175.2	8706	114.2
Sg. Juru/ Sg. Perai	6	0.43	3.22	1.85	2.47	0.83	8.88	0.4	1544	8241	3559
Sg. Muda	5	1.04	1.76	0.4	6.86	4.94	2.02	0.22	1227	2593	482.8

Table 3.1.4. Temporal distribution of PTS concentrations (ng/L) in freshwater in Thailand and Malaysia *

Year	Aldrin	DDT	Dieldrin	Endosulfan	Endrin	Heptachlor	Organic Mercury Compound	Organic Lead Compounds
1977							30-270	7360
1983	100		80		2	80		
1984	235		<116				13,800	
1985						30-380		
1986						3		
1987			18.2 & 4620					
1988	12-16				2			38,700
1989	53		110					
1990	100	330	160			20		
1991		0 – 193*	0 – 47*	0 – 313.3*		0-118.7*		
1992							220	
1993	-	530					760	
1994	490				40	50		
1995	40-710	10-370			<10	9460		
1996						120		
1997						117.9		
1998	0 – 1.1 *	0.4 – 9.0*	0 – 3.3*	0.2-4.9*	0.2 – 2.2*	120 0 – 0.7*		47,800
1999	0.2 – 3.4 *	0.9 – 3.1*	0 – 1.1*	90-210 1.0 – 25.2*	3.9 – 6.6*	0 – 0.4*		
2000	N.D.	0 – 25*	N.D.	0 – 13*	N.D.	0 – 4*		

Under the Environmental Monitoring and Governance of EDC Pollution in the East Asian Coastal Hydrosphere program, vast amounts of data were collected on the levels of endocrine disrupting chemicals including several PTS in inland water and seawater. Valuable data on OCPs for Philippines, Thailand, Indonesia, Viet Nam, and Malaysia were made available at their website

(Coastal Hydrosphere, 2000) from recent surveys in 1999 and 2000. These are summarised in Table 3.1.5. Most of the OCPs were found in inland waters, generally, in the parts per trillion (ppt) levels except in Malaysia, where the levels of HCHs, particularly lindane, were found to be extremely high.

Table 3.1.5. Concentration levels of PTS (ng/L) in freshwater from several Southeast Asian countries (Coastal Hydrosphere, 2000)

Countries	Year	ΣHCH	Heptachlor	Aldrin	Endosulfan	Dieldrin	Endrin	ΣDDT
Indonesia	1999	23.97	-	-	-	6.67	6.39	-
	2000		-	-	-	-	-	-
Malaysia	1999	-	-	-	-	-	-	-
	2000	16,582	5.82	3.31	434.79	21.51	-	35.35
Philippines	1999	7.17	-	4.84	-	-	-	-
	2000	9.85	1.80	5.15	2.40	0.96	10.69	4.35
Thailand	1999	5.7	-	N.D.	-	-	3.40	-
	2000	16.0	-	9.6	-	-	-	-
Viet Nam	1999	13.30	-	-	-	-	-	4.87
	2000	-	-	-	-	-	-	3.56

In the report "Organochlorines in New Zealand - Ambient Concentrations of Selected Organochlorines in Rivers", several PTS including PCDD/PCDFs, PCBs and several OCPs were monitored. From the 1996 studies on several rivers in New Zealand, they found no PTS in the river water samples (limit of detection was 2 pg/L for 2,3,7,8-TCDD, 0.01 – 0.6 ng/L for PCB congeners, and <2 ng/L for most OCPs). However, PCDDs/PCDFs were found in some fish samples collected in the rivers while PCBs and DDTs were found in almost all fish samples collected. However, the concentration levels of these PTS in the fish samples were very low and near the detection limit.

3.1.2.2. Seawater

The concentrations of PTS in seawater are difficult to measure due to their very low levels and difficulties in collecting samples. Iwata *et al.* (1993) surveyed the PTS levels in surface seawater of several seas and oceans in this region from the south near Antarctica through Southeast Asia, and the Pacific Rim to Alaska in the north. The studies were conducted concurrently with the studies on the concentrations of PTS in air over the oceans. The spatial distribution of HCHs, DDTs, PCBs are shown in Figures 3.1.4, 3.1.5 and 3.1.6.

The concentrations of PTS in several selected seas and oceans are summarised in Tables 3.1.6 and 3.17. Seawater samples contained high levels of HCHs, mainly lindane, suggesting high and extensive usage in catchments. Other PTS levels were comparable with other parts of the world.

Table 3.1.6. Mean concentration (pg/L) of PTS in surface seawater in Region 8 (Iwata *et al.*, 1993)

Sampling Location	Total HCHs	Total Chlordanes	Total DDT	Total PCBs
East China Sea	580	13	16	17
South China Sea	480	12	6.9	17
Strait of Malacca	480	9.4	6.4	20
Celebes Sea	280	5.1	2.6	20
Java Sea	58	2.8	5.6	22
Eastern Indian Ocean	94	7.5	2.1	21
Southern Ocean	36	4.2	1.0	8.3

Table 3.1.7. Concentration levels (ng/L) of PTS in seawater from several S.E. Asian Countries (Coastal Hydrosphere, 2000)

Countries	year	ΣHCH	Heptachlor	Aldrin	Endosulfan	Dieldrin	Endrin	ΣDDT
Indonesia	1999	42.19				11.82	6.04	
	2000							
Philippines	1999	11.11						
	2000	10.1	1.9	7.3	6.1	1.2	11.8	7.4
Thailand	1999	15.30		4.63			4.35	
	2000	14.25		15.3				3.72
Viet Nam	1999	13.30*						49.27
	2000	-						

* lindane only

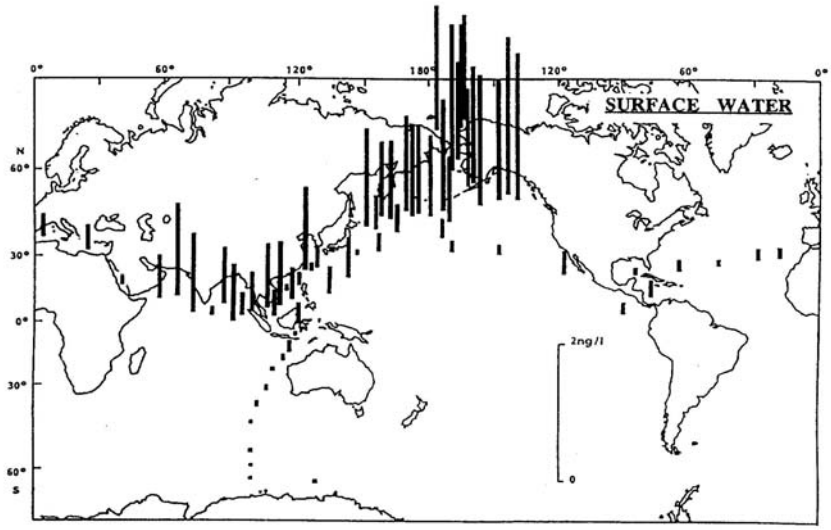


Figure 3.1.4. Distribution of total HCH concentrations in surface seawater (Iwata *et al.,* 1993)

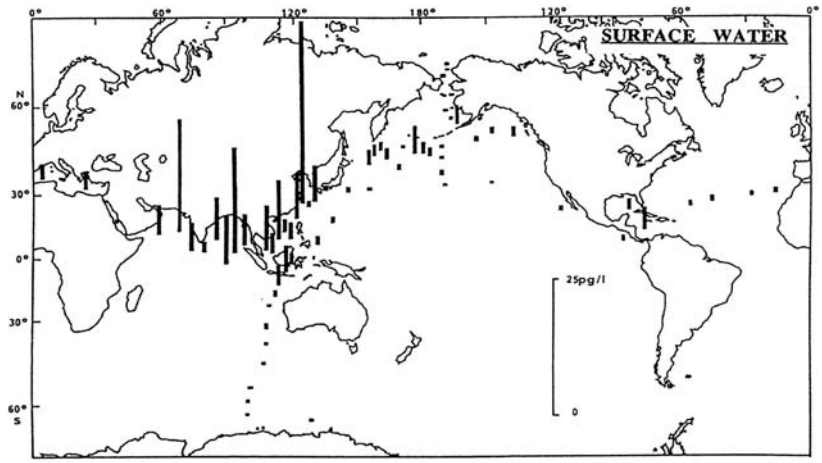


Figure 3.1.5. Distribution of total DDT concentrations in surface seawater (Iwata *et al.,* 1993)

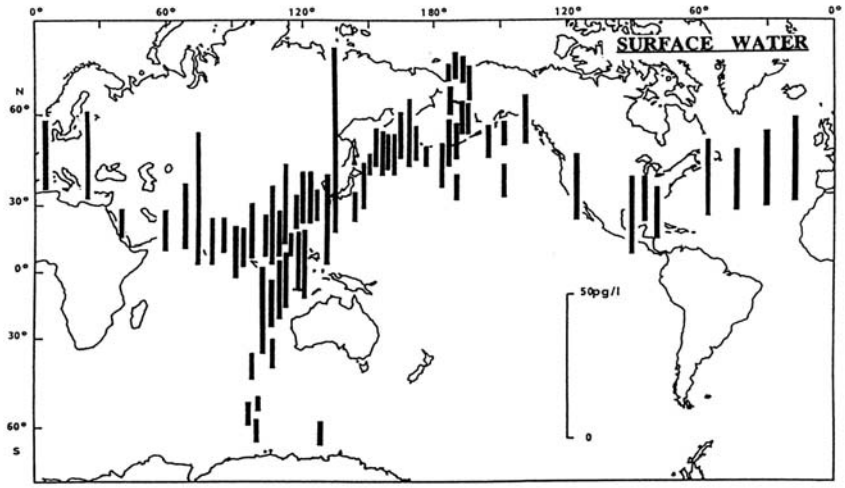


Figure 3.1.6. Distribution of total PCBs concentrations in surface seawater (Iwata *et al.*, 1993)

Another source of environmental data on PTS was from the EDC in Coastal Hydrosphere projects undertaken by the United Nations Universities Programs. Even though the data are limited, they are more recent (1999-2000) and should provide a better idea of the current status of PTS in seawater around Region 8 (Coastal Hydrosphere, 2000). The sampling areas were nearer to the shore compared with the study by Iwata *et al*. (1993), which were mostly offshore deepwater zones. Therefore, the concentration levels obtained in the more recent studies were 1000-fold higher, but similar proportions of PTS in seawater were found in both studies. The major constituents of PTS were the HCHs particularly near the Indonesian coast. High concentrations of DDT were found off the coast of Viet Nam.

Endocrine disrupting PTS (phthalates, alkylphenols, bisphenol A (BPA) and organochlorine insecticides) have been measured in rivers and estuaries in Viet Nam. Generally, levels of phthalates, alkylphenols and BPA ranged from ng/L to tens of ng/L. Residues of DDTs in river and estuary water were from 3 to 8 ng/L and in sediment from 100 to 400 µg/kg dry weight (Chieu *et al*., 2002).

3.1.3. Environmental Media: Sediment

Due to the low water solubility of most PTS, sediments and soils are the natural sinks or deposition matrices for PTS upon release to the environment. Tonnes of the PTS that have been applied through agricultural activities as well as vector control are likely to remain deposited in these sediments with minimal breakdown and natural decomposition due to the long half-lives of most PTS. For example, with a half-life of 10 –15 years for DDT and longer for DDE, there is more than 10% of the total DDT released still in the environment since it was banned in the 1970s. High levels of PTS remain in contaminated sediments while PTS are still deposited in uncontaminated sediments through air and water dispersion.

Quite a number of studies have been reported on PTS levels in sediments - marine sediment, coastal sediment, or inland water sediment (rivers and lakes). A study by Iwata *et al.* (1994) on PTS levels in sediments from rivers and estuaries is a good indication on the status of PTS in sediments in this region. These data are summarised in Table 3.1.7. DDT levels in sediment samples from the region were generally low even though one or two of the sites showed extremely high levels of DDT. For example, one site in Australia showed a level of 1700 µg/kg while most of other parts of the country showed DDT levels of less than 20 µg/kg. Similarly, three sites out of eighteen in Viet Nam showed high levels of PCBs (630 µg/kg) and DDTs (790 µg/kg), indicating hot spots in the country.

Table 3.1.7. Level of PTS in sediment (µg/kg) from several different locations in Region 8 (Iwata *et al.,* 1994)

Cities	No. of Locations	DDTs	HCHs	Chlordanes	PCBs
Indonesia	4	3.4 – 42	0.04 – 0.10	0.16 – 38	5.9 – 220
Thailand	4	4.8 – 170	0.48 – 3.1	1.4 – 210	11 – 520
Viet Nam	18	0.37 – 790	0.43 – 12	0.07 – 20	0.18 – 630
Malaysia	1	1.8	0.18	1.0	<5.0
Papua New Guinea	3	4.7 – 130	0.17 – 0.34	0.75 – 4.1	3.3 – 54
Solomon Islands	2	9.3, 750	<0.33, 2.2	0.53, 3.9	1.1, 5.0
Australia	19	0.08 – 1700	0.02 – 17	0.17 – 230	0.49 - 790

The levels of PTS in sediments from Malaysian rivers in a more recent report showed similar concentrations (Tan*,* 2001), as shown in Table 3.1.8. In an earlier report, Cullen and Connell (1992) summarised studies on PTS levels in sediments in Australia carried out in the 1970s and 1980s. DDT levels varied greatly, from not detectable to 50,000 µg/kg, while PCBs were found in marine sediments at concentrations of up to 1300 µg/kg. These high levels of DDT were attributed to the large number of cattle tick-dip sites throughout Australia, which are still considered hot spots in some parts of the country (Connell *et al.*, 1999; Miller *et al.,* 2002).

Table 3.1.8. Levels of PTS in Sediments in Malaysia (µg/kg) (Tan, 2001)

Location	Year	Aldrin	Endosulfans	HCHs	Heptachlor
Sg. Muda	1998	0.25	1.67	0.93	0.13
Strait of Malacca	1998	0.14	0.32	0.61	0.23
Sg. Bernam	1994	0.05	0.96	3.52	1.28
Sg. Selangor	1994	0.06	5.35	4.03	0.98

The levels of several organochlorines in sediment samples from New Zealand were very low compared with other industrialised countries (Scobie *et al.,* 1999). Concentrations of PCDD/PCDFs in sediments were in the range of 0.081 – 2.71 ng I-TEQ /kg. Non-detectable values were included as half LOD values while low values of 0 – 1.38 ng I-TEQ /kg were obtained when the non-detectable values were excluded. PCBs were also detected in the sediments but were less frequent than in shellfish. The sum of 25 congeners was in the range of 0.12 – 8.80 µg/kg DW for sediment samples with PCB cogeners 153 and 138 more frequently detected. Dieldrin and DDTs were the most frequently detected in sediments with concentration ranges of <0.05 – 0.38 µg/kg and <0.01 – 3.29 µg/kg, respectively.

3.1.4. Environmental Media: Soil

The Cattle Tick Dip Site Management Committee in Australia released data on levels of DDT in contaminated sites (Miller *et al.,* 2002). From the various types of soils analysed, DDT levels were found to be as high as 106 mg/kg in some areas. These soils were also found to contain chlordane and dieldrin in low concentrations (not detected to 2 µg/kg). However, DDT levels showed a declining trend since DDT usage was banned in 1987 in Australia.

A more recent work in the Philippines (Lee *et al.,* 1997) reported chlordane, DDT, HCB, and HCH levels as shown in Table 3.1.9. DDT, HCB and HCH levels were found to be higher in the urban soils while chlordane and PCB were relatively high in the river sediments. Agricultural soils were almost free of these PTS.

Table 3.1.9. Levels of PTS (µg/kg) in soils from the Philippines (Lee *et al.*, 1997)

Type of Soil	No. Samples	Chlordane		DDT		HCB		HCH		PCB	
		mean	range	mean	range	mean	range	mean	range	mean	range
Agricultural	10	8.5	0.04 - 20	49	1.2 - 200	6.6	0.1-19	1.7	0.1-5.2	<1.0	<1.0
Urban	10	240	33 - 510	370	50 - 1100	78	15-160	72	12-190	100	28-200
River	5	580	110 - 760	250	99 - 350	2.8	0.6-4.5	13	6.4 - 190	330	31-440

Buckland *et al*. (1998) summarised the results of a detailed New Zealand study on ambient concentrations of selected organochlorines in soils. Concentrations of PCDD/PCDFs (including half LOD values for non-detectable congeners) were typically in the range 0.17 – 1.99 ng I-TEQ /kg for forest and grassland soil, 0.17 – 0.90 ng I-TEQ /kg in agricultural soil and 0.26 – 6.67 ng I-TEQ /kg in urban soil. PCBs were not found in forest, grassland and agricultural soils in New Zealand. A limited number of PCB congeners were found in urban soils, with provincial soils in the range of 0.30 – 3.38 µg/kg and metropolitan soils in the range of 0.23 – 9.74 µg/kg. For all soils, PCB TEQ levels were calculated to be in the range of 0.065 – 1.33 ng TEQ /kg which were an order of magnitude lower than the PCDD/PCDFs I-TEQ levels for the same soil type.

Organochlorine pesticide residues found commonly in the soils were chlordanes, HCB, dieldrin, and DDTs. These residues never exceeded 1.0 µg/kg in the forest and agricultural soils. However, urban soils contained maximum concentrations of 1.22 µg/kg (HCB), 42.1 µg/kg (dieldrin), 1.72 µg/kg (chlordane), and 340 µg/kg (DDTs).

3.1.5. Environmental Media: Animals

The concentration levels of PTS in animals such as fishes and other marine organisms have been extensively studied for this region. Most data were from fairly recent studies covering almost all of the PTS listed plus a few of the regional specific PTS. Some of the data on mussels are from the Mussel Watch program while others are from individual studies reported by marine scientists throughout this region. The data on PTS levels in mussels would provide an interesting comparison on the distribution of PTS in mussels in Region 8 as well as with other regions in the world. Table 3.1.10 summarises levels of PCBs, DDTs and HCHs in mussel species (either *P. viridis* or *Mytilus* sp.) collected in this region. A decrease in concentration levels of PTS such as DDTs and HCHs in the green mussels over time was observed in most areas with the 1980s data significantly higher than the more recent findings.

The levels of PTS in various species of fish in Region 8 are summarised in Table 3.1.11. The levels of chlordane, HCB and PCBs are relatively low, mostly in the sub-ppb levels except for DDTs, which were in the ppb range. Fish samples collected in Australia seem to have high levels of these PTS compared with other parts of the region particularly PCBs which were more than 5 times higher. Hexachlorobenzene was detected in all the samples but at a much lower concentration.

Hossain (2001) conducted a recent study on the levels of organochlorine pesticides (OCPs) in marine biota to assess the level of PTS and to look into bioamplification effects of these OCPs in the Strait of Malacca. All samples were collected in offshore or coastal areas of the West Coast of West Malaysia. The results are summarised in Table 3.1.12. Most of the results are comparable with other studies in this region as well as other parts of the world. Total DDT was relatively low and decreasing compared with earlier studies in Malaysian marine biota. An interesting observation was that coastal species such as cockles, mussels and shrimps contained higher levels of aldrin, HCH and heptachlor probably because of export from rivers and inland waters where agricultural activities were intensive.

Table 3.1.10. Levels of PTS (µg/kg wet wt.) in green mussels (*Perna viridis,* L.)

Location	Year	PCBs	DDTs	HCHs	References
Hong Kong Coast	1983	9.6-300	14-320	4.8-34	Phillips (1985)
East Java, Indonesia	1984		100–520	0–30	Boon *et al.* (1989)

Indian Coast	1988–89		2.8–40	4.3–16	Ramesh *et al.* (1990)
Gulf of Thailand	1989	-	0.39-7.41	<0.02-0.19	Siriwong *et al.* (1991)
Penang, Malaysia	1990		-	180.9	Rohani *et al.* (1992)
Australia	1991	<10	<1.0–2.0		Burt and Ebell (1995)
Gulf of Thailand	1991	-	0.74–5.38	<0.02–0.09	Ruangwises *et al.* (1994)
Gulf of Thailand	1994	0.17–12	1.3–38	<0.01–0.09	Kan-atireklap *et al.* (1997)
Gulf of Thailand	1995	<0.01-20	1.3–15.0	<0.01–0.43	Kan-atireklap *et al.* (1997)
Indian Coastal water	1994-95	0.31-15	0.93-40	1.5-12	Kan-atireklap *et al.* (1998)
Philippines	1994-97	0.69-36	0.19–4.20	<0.01–0.19	Prudente *et al.* (1999)
Papua New Guinea	1994-97		-	0.0–0.19	Prudente *et al*. (1999)
Viet Nam	1997	0.2-3.4	2.7-340	0.04-0.1	Monirith *et al.* (2000)
Cambodia	1998	<0.05-5.1	0.25-1.6	0.01-0.03	Monirith *et al.* (2000)
Malaysia	1998	0.1-5.1	0.2-5.7	0.01-0.15	Monirith *et al.* (2000)
West coast, Malaysia	1998-99		0.00-7.8	0.32–11.28	Hossain (2001)
Indonesia	1998	0.2-2.7	0.1-3.1	0.1-0.1	Monirith *et al.* (2000)
Philippines	1998	0.4-14.2	0.1-1.0	0.03-0.06	Monirith *et al.* (2000)

Table 3.1.11. Mean concentrations of PTS (µg/kg wet wt.) in several species of fish in Region 8

Countries	Lipid (%)	PCBs	DDTs	HCHs	CHLs	HCB	References
Australia	3.4	55	22	0.34	51	4.2	Kannan *et al.* (1995)
Cambodia	5.3	0.36	8.1	0.08	0.11	0.09	Monirith *et al.* (1999)
Thailand	5.3	1.6	6.2	0.82	2.6	0.24	Kannan *et al.* (1995)
Viet Nam	1.9	10	26	1.8	0.11	0.05	Kannan *et al.* (1995)
Indonesia	3.0	2.6	28	0.73	0.45	0.05	Kannan *et al.* (1995)
Papua New Guinea	0.68	7.5	0.43	0.57	0.37	0.03	Kannan *et al.* (1995)

Table 3.1.12. Levels of PTS in several species of marine organisms (µg/kg) in Malaysia (Hossain, 2001)

Marine Species	Concentration range of PTS (µg/kg wet wt.)						
	Aldrin	DDT	Dieldrin	Endosulfan	Endrin	HCH	Heptachlor
Blood cockle (*Anadara granosa*)	0.02-2.5	0.04-1.24	0.01-0.7	0.10-3.25	ND-3.25	0.74-10.23	0.27-3.54
Cat fish (*Arius* sp.)	0.2-2.5	0.1-3.2	0.02-0.5	0.3-0.8	0.1-5.4	0.9-5.9	0.3-8.2
Green mussel (*Perna viridis*)	0.02-15.7	ND-7.8	ND-0.9	ND-2.6	ND-9.1	0.32-11.28	0.1-14.6
Jew fish (*Pennahia* sp.)	ND-9.5	0.1-6.0	0.02-0.9	0.3-3.8	0.1-6.2	2.7-7.1	0.9-5.7
Mullet (*Valamugil* sp.)	ND-2.2	0.01-4.9	0.02-0.8	0.5-1.8	ND-13.0	0.3-8.3	0.1-5.2

Schrimp (*M. monoceros*)	0.2-26.5	0-4.1	ND-0.6	ND-0.6	ND-2.7	3.3-35.8	3.5-36.1
Seabass (*Lates calcarifer*)	0.5-8.0	0-0.5	ND-1.0	0.01-3.4	ND-9.1	1.7-5.1	0.7-21.7

Large marine mammals such as whales and dolphins are at the top of the marine food-chain. Therefore, bioaccumulative and bioamplification effects of PTS may be estimated from concentration data on these organisms. A group from Australia reported PTS levels in these mammals. Table 3.1.13 summarises this report. The levels for PCDD/PCDFs were in the sub-ppt levels and only the large beaked whale contained 1-3 ppt of PCDD/PCDFs. However, other PTS such as DDT, PCBs and HCB were high as expected.

Table 3.1.13. Level of PTS in marine mammals in Australia (µg/kg, wet weight) (Miller *et al.*, 1999)

Species	Chlordane	DDTs	Dieldrin	PCDD	PCDF	HCB	Heptachlor	PBB	PCB
Beaked whale	60	720	80	0	0.00126	160	20	0	390
Andrew's beaked whale	60	2500	40	0.00116	0.00287	180	0	110	800
Bottlenose dolphin	60-140	980-3340	140-260	0.0 - 0.00068	0.00015-0.00262	80-160	0.0 - 40	180 - 410	1200 - 3300
Pilot whale	60-100	700-1180	0-160	0.0 - 0.00053	0.00037-0.00177	80-220	0.0 - 20	0	340 - 600
Fin whale	20	0	0	0.00027	0	20	0	0	0
Leopard seal	340	1540	280	0.00093	0.00027	80	0	0	820

Minh *et al.* (2000) reported the PCB levels in a number of marine mammals from the North Pacific and Asian coastal waters and an assessment of isomer specific accumulation and toxicity of various PCB congeners. The levels of total PCBs (2.4-8.6 µg/kg wet weight) in two dolphin species found in Mindanao Sea, Philippines were lower than most dolphin species found elsewhere in the world. This is equivalent to 36-45 pg/g TEQ for the PCBs congeners detected.

In the New Zealand Organochlorine Program (Scobie *et al.,* 1999), the survey on shellfish collected from the estuaries showed very low levels of PCDD/PCDFs, PCBs, OCPs and chlorophenols in these samples. Concentrations of PCDD/PCDFs were in the range 0.015 – 0.26 ng I-TEQ /kg wet weight with the higher chlorinated congeners most abundant. PCBs were detected in most shellfish samples where the sum of 25 congeners was in the range 0.11 – 12.9 µg/kg wet wt. Aldrin and HCHs were not detected in the shellfish samples but DDTs and dieldrin were found at the concentration ranges of <0.01 – 2.77 µg/kg and <0.02-0.56 µg/kg wet weight respectively.

Terrestrial biota have not been widely studied. There are a few studies reported in Australia but most of these studies were conducted prior to 1990. For example, the king brown snake (reptile) was reported to have a 50 µg/kg level of aldrin in a 1973 study. Cats and Tasmanian devils had DDT levels as high as 15,200 µg/kg and a maximum dieldrin level of 4300 µg/kg. Surveys of cattle in 1980-1982 reported relatively high levels of DDT in the fatty tissues and other parts of the mammals in the range 120 – 76,500 µg/kg, and a maximum concentration of 490 µg/kg for dieldrin. Extensive Australian monitoring of livestock has shown a major decline in pesticide residues to negligible or not detected levels (see Miller *et al*., 1999). More studies should be made to assess the levels of PTS in terrestrial animals, particularly livestock.

3.1.6. Environmental Media: Humans

Studies on humans were difficult in terms of sample collections. The media normally used are human milk and blood and rarely human tissue. Human milk samples limit the study to the postnatal female population, while analysing blood samples requires the detection limit to be the lowest available. Live

human tissue is almost impossible to obtain. However, with advances in analytical techniques, a blood sample of only two mL is sufficient to monitor the level of PTS in the human population. For instance, a study was conducted in Singapore on the levels of DDT in humans where 89 subjects were screened (National Environment Agency, Singapore, 2002). It was reported that the mean DDT level was 2 µg/kg with the range from not detected to 9 µg/kg. Under the same program, blood lead and mercury were found to be 66 and 5.57 µg/L.

New Zealand undertook a nation-wide study on the levels of PTS in human blood (Ministry for the Environment, New Zealand, 2001). In the 1996-97 study, a total of 1834 blood samples were taken from New Zealanders aged 15 years and over from all over New Zealand. The average PCDD/PCDF concentrations were 12.8 ng TEQ /kg of serum fat with concentrations increasing with age. PCB concentrations also increased with population age with an average concentration of 79 µg/kg of fat. DDE, dieldrin and β-HCH were the most frequently detected OCPs. The average concentration of DDE increased from 646 µg/kg (fat) for the 15-24 years age group to 1780 µg/kg (fat) in the over 65 years old population with the average of 1080 µg/kg (fat) across all age groups. The average dieldrin concentration was 14.2 µg/kg (fat).

Australia conducted a comprehensive program of monitoring PTS levels in human milk. Started in the 1970s, the program reported studies in several states in Australia and this is summarised in Table 3.1.14. DDT and HCB were found to be high in human milk collected in Queensland in 1974. A more recent study in Victoria in 1994 showed lower concentrations of some PTS in human milk. Isomers of PCBs were also found in some of the milk fats at µg/kg levels.

Table 3.1.14. Levels of PTS in human milk fat in Australia (µg/kg)(Miller *et al.*, 1999)

Location	Years	No. Samples	DDTs		Dieldrin		HCB		HCHs		Heptachlor	
			Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Victoria	1994	60	960[1]	150-3900[1]								
		60	225[2]	6-960[2]	159	13-190	411	16-7600	108	3-480	61	5-150
W Australia	1991	128	800	30-4000	50	15-250	100	0-6000	-	-	20	0-170
Queensland	1974	121	8500	500-30,400	29	2-100	190	50-23,000	190	50-1790	-	-

[1] ppDDT

[2] ppDDE

In a very recent report (Dwernychuk *et al.,* 2002), direct measurements of PCDD/PCDFs were reported in several media including human blood and breast milk collected in villages in Aluoi Valley of central Viet Nam. The study attempted to correlate the effect of Agent Orange aerially sprayed in the valley to the apparent food chain transfer of PCDD/PCDFs from contaminated soil to cultured fish pond sediments to fish and duck tissues and finally to humans. The report described southern Viet Nam as PCDD/PCDFs reservoirs, which should be seriously treated as hot spots for PCDD/PCDFs contamination.

In the report, four communes were selected where pooled blood samples from a number of donors were collected and divided into gender and two age groups (25 years and above and below 25 years old). Analysis was conducted for a number of important congeners of PCDD and PCDF and total I-TEQ calculated. Percent of TCDD was also calculated based on the total I-TEQ to indicate the significant presence of this compound. A So is a village on the site of the former US Special Force base while Houng Lam is adjoining A So. Hong Thuong commune is at the centre of Aluoi Valley while Hong Van commune is to the north and received the fewest aerial applications of Agent Orange.

The study revealed that high levels of PCDD/PCDFs were found in the lipids of human blood samples from the A So population with total I-TEQ ranging from 16.6 – 45.9 pg/g I-TEQ (see Table 3.1.15). Lower levels were found in blood samples from Huong Lam and Hong Thuong and relatively lower levels of PCDD/PCDFs were found in blood samples from the least affected area of Hong Van. This study clearly showed the accumulation of PCDD/PCDFs in village populations following aerial spraying of dioxin-contaminated Agent Orange during the Viet Nam war in the 1960s and 1970s.

The study also looked into the levels of PCDD/PCDFs in human breast milk from lactating primaparous females from the sample area to estimate the daily intake of PCDDs and PCDFs by infants. Results are summarised in Table 3.1.16.

Table 3.1.15. Level of TCDD and total I-TEQ (pg/g, lipid wt.) in pooled whole human blood from Aluoi Valley, Viet Nam (Dwernychuk *et al.*, 2002)

Commune and donor (years of age)	No. in pool	TCDD	Total I-TEQ	TCDD as % of total I-TEQ
A So				
Males (> 25)	48	41	45.9	89.3
Males (< 25)	30	31	35.0	88.6
Females (>25)	44	16	18.3	87.4
Females (< 25)	41	14	16.6	84.3
Huong Lam				
Males (> 25)	31	17	25.6	66.4
Males (< 25)	33	9.0	19.8	45.5
Females (> 25)	29	5.3	22.0	24.1
Females (< 25)	27	N.D.	10.0	-
Hong Thuong				
Males (> 25)	43	21	32.3	65.0
Males (< 25)	27	8.6	15.1	57.0
Females (> 25)	37	12	24.6	48.8
Females (< 25)	25	7.6	11.5	66.1
Hong Van				
Males (> 25)	37	N.D.	5.41	-
Males (< 25)	40	N.D.	7.67	-
Females (> 25)	27	N.D.	5.95	-
Females (< 25)	37	N.D.	3.53	-

Table 3.1.16. PCDDs and PCDFs in human breast milk from lactating primaparous females, Aluoi Valley, Viet Nam (pg/g) (Dwernychuk *et al.*, 2002)

Commune	Donor age	TCDD	Total I-TEQ	TCDD as % of total I-TEQ
A So				
	22	5.5	6.15	89.4
	20	19.0	21.9	86.8
	18	18	18.7	96.3
	23	16	18.8	85.1
Huong Lam				

	23	12	14.6	82.2
	19	8.3	10.2	81.4
	28	2.9	10.6	27.4
	21	5.8	9.33	62.2
Hong Thuong				
	17	11	17.2	64.0
	21	8.7	12.6	69.0
	22	7.7	9.73	79.1
	19	11	18.5	59.5
Hong Van				
	20	3.3	5.07	65.1
	23	2.2	3.85	57.1
	20	5.0	13.2	37.9
	19	1.4	2.99	46.8

3.1.7. Environmental Media: Vegetation

Kannan *et al*. (1992) reported the levels of several PTS in foodstuffs collected from several locations in Viet Nam. Staple foods and meats constituting the dietary intake of an average Vietnamese population were analysed for PCBs, HCHs, DDTs, HCB, aldrin, dieldrin, and heptachlor. The results are summarised in Table 3.1.17. All the foodstuffs analysed contained residues of the PTS monitored. PCBs were found in high concentrations in meat products particularly animal fat, shellfish and crabs. HCHs were generally low except in caviar samples reaching up to 290 µg/kg. DDTs were also found to be high in products containing high fat content, especially animal fats. Other PTS were in the sub-ppb levels.

In a similar study, Kannan *et al.* (1994) reported the levels of PTS in foodstuffs from Australia, Papua New Guinea and the Solomon Islands. The results are summarised in Table 3.1.18 (Australia), Table 3.1.19 (Papua New Guinea) and Table 3.1.20 (Solomon Islands). Similar trends were observed in these samples, with high fat products containing high PTS. PCBs were high in meat products and fishes but generally low in cereals and vegetables.

Table 3.1.17. Concentration of PTS (µg/kg wet wt) in foodstuffs collected in Viet Nam (Kannan *et al.*, 1992)

Food Item	No. of Samples	PCBs	HCHs	DDTs	HCB	Aldrin	Dieldrin	Heptachlor
Rice	3	0.32	4.3	2.0	0.03	0.19	0.26	0.13
Pulses	6	4.0	5.0	1.9	0.04	<0.1	0.08	0.07
Oil	1	21	29	67	1.2	4.2	26	0.79
Butter	2	17	49	7.2	5.0	<0.1	2.2	8.13
Animal fat	3	61	70	130	0.41	1.5	5.3	2.44
Meat	2	18	17	48	0.11	0.16	1.3	0.35
Fishes	16	10	1.8	26	0.05	0.12	0.17	0.12
Prawn	1	6.6	1.5	1.7	0.03	0.03	0.25	0.15
Shellfish	1	15	2.8	7.2	0.04	0.09	0.40	0.12

Crab	1	59	1.4	78	0.17	0.13	0.38	0.33
Caviar	3	51	200	90	3.8	0.81	7.9	0.32

Table 3.1.18. Level of PTS in foodstuffs (µg/kg wet wt) collected from several locations in Australia (Kannan *et al*., 1994)

Food Item	No. of samples	PCBs	HCHs	DDTs	HCB	Aldrin	Dieldrin	Heptachlor
Cereals	5	0.62	0.44	0.82	0.01	0.03	1.6	0.23
Pulses	5	1.4	0.28	2.4	0.02	2.8	1.8	0.75
Oils	8	6.5	0.89	2.1	0.07	0.15	4.2	1.8
Beverages	2	2.3	0.66	0.66	0.03	0.1	0.55	0.31
Vegetables	5	0.40	0.16	3.3	0.01	0.01	0.9	0.07
Fruits	3	0.28	0.10	0.13	0.01	<0.0.01	0.37	0.03
Dairy products	9	4.1	6.0	5.9	0.55	0.89	13	13.33
Meat	17	11	1.4	13	0.46	0.30	5.1	2.02
Fishes	37	55	0.34	22	4.2	0.77	9.5	1.1

Table 3.1.19. Level of PTS in foodstuffs (µg/kg wet wt) collected from several locations in Papua New Guinea (Kannan *et al*., 1994)

Food Item	No. of Samples	PCBs	HCHs	DDTs	HCB	Aldrin	Dieldrin	Heptachlor
Cheese	1	4.4	1.1	6.2	0.43	<0.01	2.2	1.4
Pork fat	1	45	7.5	24	0.40	0.3	4.3	0.13
Chicken	1	124	9.8	29	0.2	<0.01	2.2	0.31
Striped mullet	6	3.3	0.85	0.51	0.04	0.12	1.2	0.07
Tilapia	3	1.9	0.47	0.09	0.01	<0.10	0.1	0.09
Mud crab	3	8.6	0.64	0.79	0.03	0.45	0.32	0.26
Oyster	1	16	0.33	0.34	0.02	2.1	0.73	0.17

Table 3.1.20. Level of PTS in foodstuffs (µg/kg wet wt) collected from several locations in the Solomon Islands (Kannan *et al*., 1994)

Food Item	No. of Samples	PCBs	HCHs	DDTs	HCB	Aldrin	Dieldrin	Heptachlor
Pork	1	17	2.2	130	0.14	<0.10	3.0	0.68
Chicken	1	5.2	0.64	4.4	0.06	1.0	2.9	0.22
Greenspotted kingfish	4	6.6	0.79	11	0.03	<0.10	0.65	0.14
Indian mackerel	3	1.1	0.37	2.2	0.01	<0.10	0.18	0.07
Snapper	3	3.0	0.43	1.3	0.01	<0.10	0.12	0.12

3.1.8. Data Gaps

Region 8 may be divided into the developed countries of Australia, New Zealand, and Singapore, with the rest being developing countries. Extensive work has been carried out to assess the levels of PTS in various environmental media in Australia and New Zealand but minimal studies have been made to determine the environmental concentrations of PTS in other parts of the region. Without additional technical and financial support, very few data can be made available on concentrations of PTS for this region particularly in Southeast Asia. There is definitely a lack of data on concentrations of PTS in air and seawater and very few data on the levels of PTS in humans except for New Zealand. Some of the concentration data may be available in the form of annual reports of government departments or agencies in most countries but these could not be readily accessed or made available to the public. Efforts should be made to fill the data gap in order to have a clearer picture of the status of PTS in this region where almost all of these chemicals have been banned a number of years ago but are still found in the environment.

Monitoring of PCDD/PCDFs is difficult and most of the countries in this region are not capable of undertaking environmental studies by themselves. This issue should be one of the priorities for this region where the focus should be made to assess the sources and monitor the concentrations of PCDD/PCDFs. Continuous efforts should also be made to monitor the levels of PTS in foodstuffs to ensure safe dietary consumption.

Other PTS of emerging concern such as chlorinated paraffins, nonylphenols, octylphenols and organometallic compounds have received minimal attention. Very little information on concentration levels of these chemicals is available and there has been very little effort to monitor these PTS (Coastal Hydrosphere, 2000).

3.1.9. Conclusions

Generally, levels of PTS in the region in most media appear to be elevated when compared with other parts of the world. However, reported studies showed declining trends in PTS particularly those OCPs that have been banned from use. PCB, DDTs, HCHs, endosulfan and chlordane seemed to be the focus of most monitoring studies where their concentration levels were found to be significant. Other PTS were either low in concentration or were not studied. Little information is available in the region on PTS of emerging global concern such as organotin, organolead, chlorinated paraffins and alkyl phenols. PCDD/PCDFs are starting to be determined in some countries but the lack of technical expertise and funds constrain monitoring studies in most countries.

PTS were found relatively high in air, water, and sediments in most parts of the region. For example, HCHs were found to be extremely high (12,000,000 pg/m^3) in air over Central Viet Nam and PCBs were found to be high in air over Perth, Western Australia (17,000 pg/m^3). Lindane was found at an exceptionally high level in one location in a Malaysian river water sample (900 ng/L) in 1994 while neighbouring Thailand recorded a concentration range of 0.18-75.0 ng/L from the same study. Levels of DDTs and PCBs in sediments from almost all countries in the region were found to be above sediment quality values of 1.6 and 23 µg/kg respectively.

PTS in biota, particularly marine organisms, have been widely studied and reported. The concentration levels varied among types of animals, OCPs and locations. The Mussel Watch program provides most of the data on PCBs, DDTs, and HCHs levels in the bivalve (P*erna viridis*), and generally ranged from not detectable to very contaminated. Fishes collected from various countries in this region showed significant amounts of PCBs, DDTs, HCHs, and chlordanes but were generally lower than the maximum residual limits.

PCDD/PCDFs apparently pose the greatest threat to humans and the environment. Even though information on concentration levels of PCDD/PCDFs are scarce, estimates on releases of these compounds from industrial and human activities (using the UNEP toolkit) coupled with bioaccumulation and persistence data, indicated high risk situations. Without immediate intervention, PCDD/PCDFs can cause the greatest damage among the PTS to human health and the environment. From very recent reports, PCDD/PCDFs in certain regions in Viet Nam may be considered hot spots as it was well documented that several million gallons of Agent Orange contaminated with TCDD

were sprayed widely in the country during the Viet Nam war. It was reported that high concentrations of PCDD/PCDFs were measured in blood and human milk of Vietnamese living in areas directly affected by the aerial spraying of Agent Orange.

3.2. Spatial And Temporal Trends

The distribution of selected PTS in air in several cities in the region is shown in Figure 3.2.1. Relatively high PCBs in air were found over Australian cities and very low concentrations of DDT. On the other hand, high concentrations of DDT were found in the air of the cities in Viet Nam and other cities in Southeast Asia. Figure 3.2.2 shows the distribution of selected PTS in freshwater as reported by Iwata *et al.* (1994). HCHs seem to predominate in the Southeast Asian region particularly in Malaysia but it may be misleading due to the fact that only a single sample was collected in the case of Malaysian water. Thailand and Viet Nam also showed high levels of HCHs in their river waters, probably due to the extensive use of lindane for vector control and plant protection. DDT was found to be relatively high in the Solomon Islands while the Australian inland water showed almost equal distribution of the four PTS although at much lower concentrations compared with the Southeast Asian waters.

The distribution of selected PTS in surface seawater in the seas and oceans in Region 8 is illustrated in Figure 3.2.3. High concentrations of HCH were found in all samples of surface seawater indicating the importance of this PTS in the environment even though it is not listed in the top twelve PTS for this region.

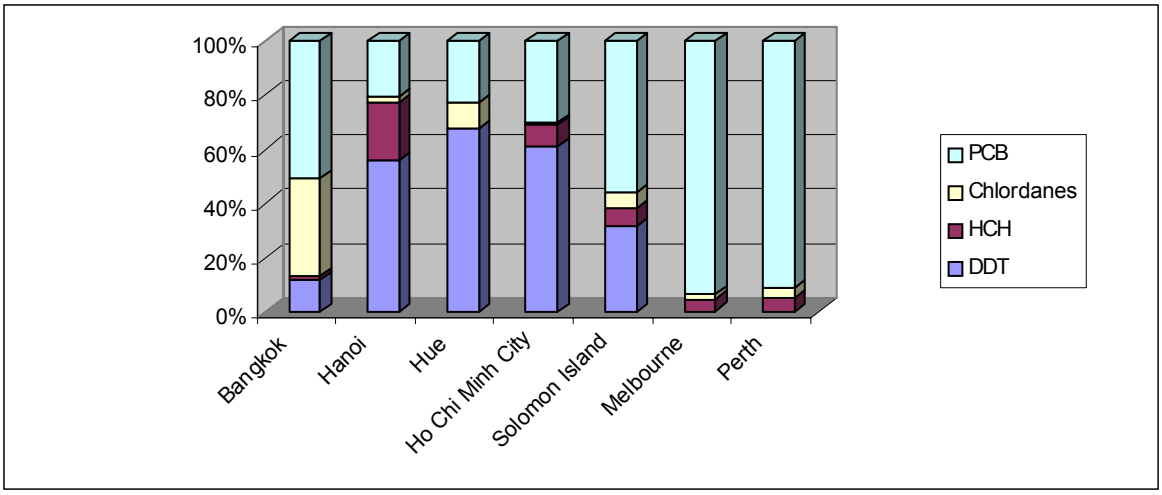


Figure 3.2.1. Distribution of selected PTS in air over several cities in Region 8

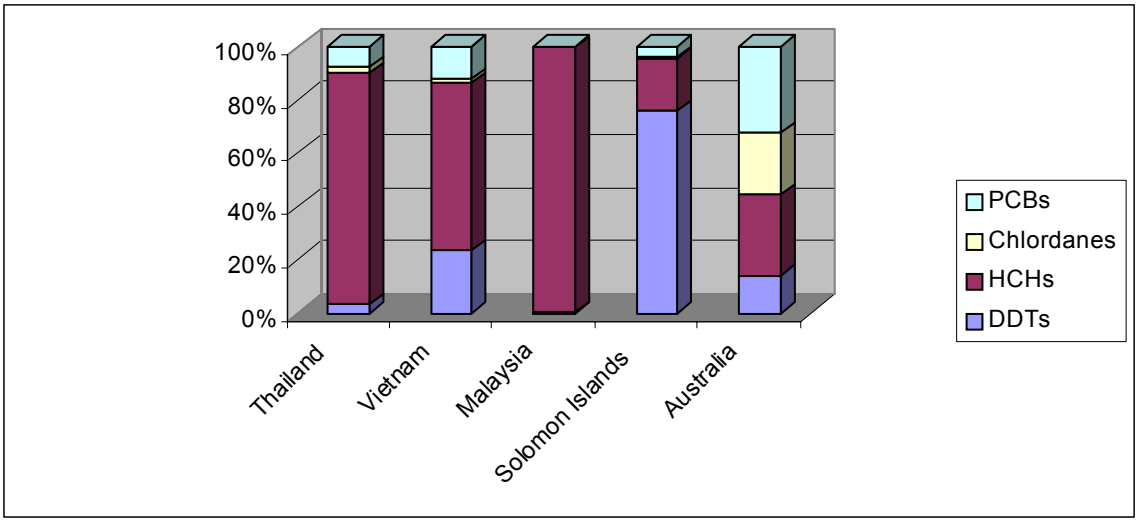


Figure 3.2.2. Distribution of selected PTS in freshwater from several countries in Region 8

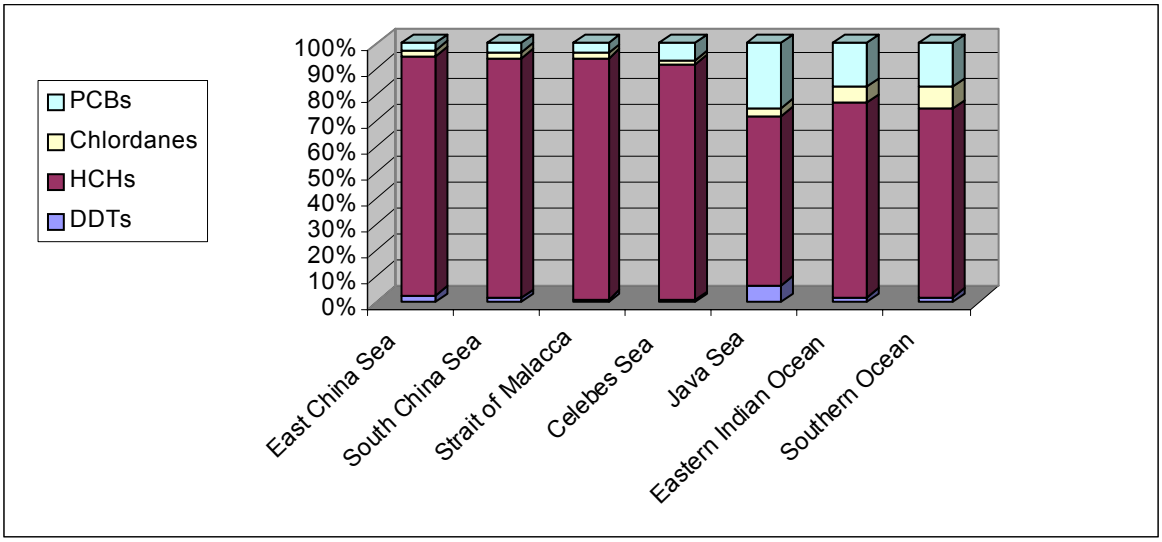


Figure 3.2.3. Distribution of selected PTS in surface seawater in Region 8

The aquatic biota were found to contain most of the PTS in relatively high concentrations compared with other parts of the world. Figure 3.2.4 shows the distribution of selected PTS in several species of fishes caught near-shore in various countries in this region. DDTs seem to be the dominant contaminant measured in fish samples collected in SE Asian countries. Fishes from Australia contain similar proportions of PTS where their concentration levels were slightly higher than those fish found in other parts of the region.

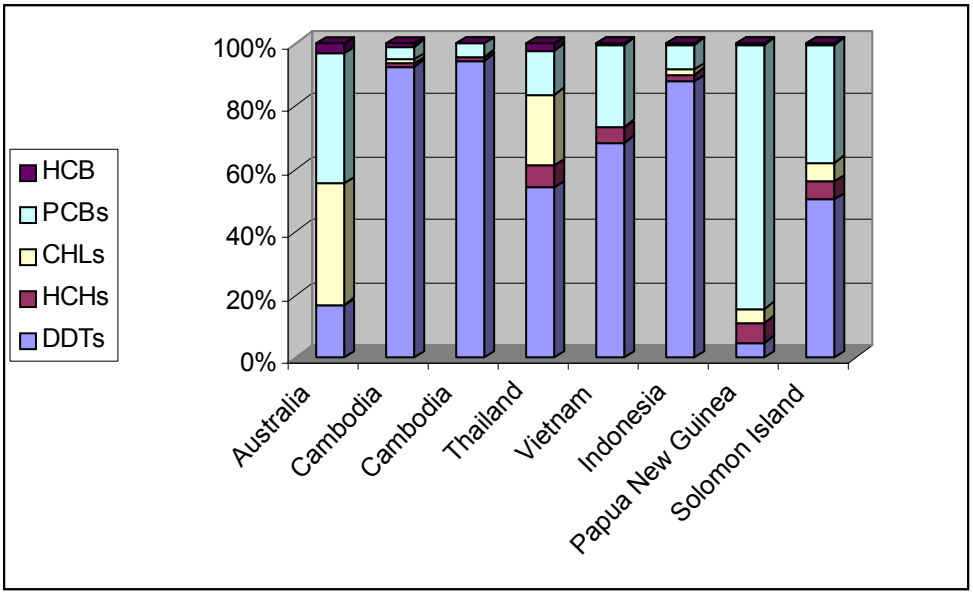


Figure 3.2.4. Distribution of selected PTS in several species of fishes from countries in Region 8

Most of the data available on the levels of PTS in this region are temporally scattered and it is difficult to determine trends in various media. Overall, the levels of most PTS appear to be decreasing with time. PCDD/PCDFs may not be decreasing but there has been little monitoring to date in this region. More effort needs to be focused on the PCDD/PCDFs.

3.3. Toxicology Of PTS Of Regional Concern

3.3.1. Overview of Harmful Effects

3.3.1.1. General

The primary hazard of PTS relates to their capacity to be readily absorbed into the human body via inhalation, the digestive system and/or through the skin. This tends to be related to their lipid solubility. Once absorbed, PTS are readily distributed through the body and tend to accumulate in fatty tissues, including human milk. Biotransformations or metabolic processes (e.g. liver) may also produce active and toxic metabolites.

Persistent toxic substances (PTS) are known to pose potential adverse health effects, including cancers, reproductive disorders, development deformities and learning disabilities in both humans and wildlife (UNEP/GEF, 2001).

Generally, PTS exposures occur in humans at low doses and toxic effects are difficult to diagnose (e.g,. the use of biomarkers and clinical tests such as for chronic lead effects). In addition, synergistic effects are possible when PTS occur together which cannot be taken into account. Health risks are also difficult to estimate because of uncertainties about assumptions of cause-effect relationships between low-level exposures to PTS and adverse effects observed in human populations. In particular there is often a lack of information on children who can be the most susceptible group in a population. In a regional context, health effects or risks for specific PTS exposures among local or national populations are reported for relatively few countries (e.g. dioxins in Viet Nam, organochlorines in Australia, lead in Malaysia and mercury in the Philippines).

3.3.1.2. Genotoxic Effects

Genotoxicity is concerned with genetic damage. One of the main health implications of toxicity to the gene is carcinogenesis, if the damage carries through to the offspring of the cell that is initially assaulted (Rodricks, 1994). Not only can genetic damage increase the risk of cancer development, it can cause cell death or abnormalities. There is limited information and often mixed results for genotoxic effects following exposure to OCPs including chlordane, dieldrin, heptachlor epoxide and HCB.

Most organochlorine pesticides (including cyclodienes), PCDD/PCDFs and PCBs are classified as probable human carcinogens (B2) by the US-EPA and the International Agency for Research on Cancer (IARC), based on animal feeding studies. Human data tend to be inadequate.

3.3.1.3. Oestrogenic Effects

An environmental endocrine disrupting chemical (EDC) may cause disruption of central nervous system-pituitary integration of hormonal and sexual behavioural activity, female and male reproductive system development and thyroid function. In addition, EDCs may play a role in the induction of breast, testicular and prostate cancers. Evidence for endocrine disruption exists for DDT (DDE metabolite).

3.3.1.4. Developmental and Reproductive Toxicity

Most organochlorines have shown developmental effects in children due to pre- and postnatal exposure. Organochlorines accumulate in body tissues and any exposure prior to pregnancy (placental transfer) can contribute to the overall maternal body burden and result in exposure to the developing individual (e.g., human milk via lactation). The major observations in children with pre- and postnatal exposure to organochlorines include effects on the CNS and immune system and neurological effects such as abnormal behaviour and susceptibility to seizures. Increased post-natal mortality may also occur. Structural skeletal changes have also been observed following prenatal exposure. Skeletal malformations, cleft palate, webbed foot, open eyes and extra ribs have been observed in experimental animals exposed to, for example, dieldrin.

Lactational exposure to organochlorines (e.g. HCB) is also of concern due to the rapid transfer of the chemical through breast milk. Observations include skin lesions, weakness and convulsions in

exposed infants. HCB effects in older children resulted in development of atrophied hands and fingers, short stature, pinched faces and osteoporosis in the hands and other arthritic changes.

Chemicals from a wide range of chemical classes (e.g. insecticides, herbicides, fungicides, plasticisers, surfactants, organometallics and halogenated polyaromatic hydrocarbons) have been shown to induce developmental toxicity via the endocrine system. The strongest evidence of human effects involves developmental neurotoxicity in children exposed to PCBs (Casarett and Doull's Toxicology, 6th Edition).

DDT causes toxicity to unborn animals but not birth defects in experimental animals. Studies indicate that oestrogen like effects on the developing reproductive system occur. DDT is suspected of causing spontaneous abortion in humans and cattle. It is not known whether this is related to the reproductive system toxicity of DDT or the developmental toxicity.

3.3.2. National and Regional Human Health Reports

3.3.2.1. General

Health studies related to the use of PTS in the region are limited and tend to reflect specific issues (e.g. mercury poisoning from gold mining) or episodes (e.g. herbicide spraying in Viet Nam war) rather than results from national reviews. This can be reasonably expected as environmental levels or exposures for common PTS in most countries of the region are relatively unknown while health priorities are generally directed towards the assessment and treatment of communicable diseases.

Despite shifts toward broader health programs and community knowledge, clinical and epidemiological expertise on PTS is in early stages of development. Available health reports on PTS from within the region indicate the diverse range of reported effects on the region's people.

3.3.2.2. Herbicide Spraying (2,4,5-T and Dioxins)

Reproductive and carcinogenic effects such as liver cancer have been associated with the large scale spraying of 2,4,5-T herbicide, together with contaminating PCDD/PCDFs, by the US military during the Second Indochina war period from 1962 to 1971 (see Westing, 1984). About 10 percent of the land area of Viet Nam was sprayed, mainly between the years 1965 to 1970 (Phuong *et al.,* 1989). Since this period the 2,4,5-T would be expected to have effectively disappeared due to degradation while the contaminating PCDD/PCDFs would remain in significant concentrations (e.g., see Schecter *et al*., 2002).

Constable and Hatch (1985) reviewed the reproductive effects of herbicide exposure in Viet Nam, particularly unpublished studies by Vietnamese researchers. The studies conducted in North Viet Nam reported a consistent association between presumptive parental exposure to herbicides, prior to or at conception and congenital defects in children born, particularly for abnormalities such as anencephaly and orofacial defects. These reviewers noted that the strengths of the association demonstrated in the data varied among studies. No association with molar pregnancy was documented while miscarriage rates were conflicting. In the case of South Viet Nam, where both sexes were at risk of exposure, studies indicated increases in miscarriage, stillbirths, molar pregnancy and birth defects among couples previously exposed to herbicides. An association between molar pregnancy and herbicide exposure was considered very suggestive.

Phuong *et al.* (1989a) compared reproductive anomalies in women living in a herbicide sprayed area (Thanh Phong Village) and non-herbicide sprayed area (Commune No. 10, first district on Ho Chi Minh City), 1952 to 1981. As shown in Table 3.3.1, the pooled data indicate that the incidence of hydatidform mole and congenital malformations was significantly higher ($p < 0.005$) for the herbicide-exposed group than the unexposed one. The dates of specific pregnancies were not reported.

Table 3.3.1. Frequency of occurrence of reproductive anomalies between herbicide exposed area (Thanh Phong) and non-exposed area (Commune 10) Viet Nam (1952-1981)

	Thanh Phong		Commune 10		
Congenital Anomalies	81/7327	1.1%	29/6690	0.43%	p <0.005
Hydatidiform Mole	54/7327	0.73%	26/6690	0.38%	p <0.005

From Phuong *et al.* (1989a)

Vietnamese studies on carcinogenic effects from herbicide or PCDD/PCDFs exposures appear to be limited.

Cordier *et al.* (1993) conducted a case control study to investigate risk factors for hepatocellular carcinoma (HCC) among male cases in two hospitals in Hanoi, North Viet Nam between 1989 and 1992. One hospital treated Vietnamese veterans and the other civilians from all the provinces of North Viet Nam.

Hepatocellular carcinoma is considered one of the most frequent cancers in males in Southeast Asia, including Viet Nam. As well, Vietnamese studies have claimed that an increased risk of liver cancer had been observed among persons exposed to herbicides in the south of Viet Nam during the Second Indochina war (Westing, 1984).

This study confirmed the major role of hepatitis B virus infection in HCC and showed an association with other factors such as alcohol consumption and chemical exposure (i.e. agricultural use of organophosphorus pesticides (30 L/yr or more) and military service in the south of Viet Nam for 10 years or more). The authors supported the hypothesis that phenoxyacid herbicides may act as tumour promoters and TCDD through immunosuppression.

More recently, Schecter *et al.* (2001) have reported substantially higher blood levels of TCCD (up to 271 parts per trillion) in a cohort of 19 out of 20 persons living in Bien Hoa, near a former Agent Orange spraying base, 1962-1970, than in a pooled sample from 100 residents of Hanoi (2 parts per trillion) used for comparison. These authors suggest that current and past exposure are related to food chain contamination via river-sediment-fish-people (see also Schecter *et al.,* 2002). Other blood levels of TCDD in Vietnamese exposed to Agent Orange are given in Table 3.1.15.

3.3.2.3. Smoke Haze, Particulates and PAHs

Airborne particulate matter is a key air pollutant of health concern in urban and rural areas throughout the region especially for chronic respiratory disorders. Aside from indoor air pollution from cooking and heating using wood and fossil fuels, emissions from urban sources (e.g. Bangkok, Thailand), forest fires (e.g. Australia) and biomass burning for clearing of land for agriculture, plantations and resettlement (e.g. Indonesia) are important health and environmental issues for the region. In particular, smoke haze episodes resulting from biomass burning have affected countries such as Malaysia, Singapore and Indonesia.

During the late summer and early autumn of 1997, large scale mass burning in Indonesia in an El Nino year resulted in a widespread dense smoke haze which spread as far as the Philippines to the north-east and the SE Asian mainland (including areas of Viet Nam, Thailand and Malaysia) to the north and north-west. Daily PM_{10} concentrations ($\mu g/m^3$, 24hr average) monitored at Kuala Lumpur during August-November 1997 reached a peak value of over 400 $\mu g/m^3$ and at least 23 daily readings of over 150 $\mu g/m^3$.

US-EPA air monitoring (Indonesia and Malaysia) of PM_{10}, $PM_{2.5}$ and constituents such as PAHs in the smoke haze from SE Asia biomass fires (1997) identified increased risk of adverse health effects (e.g. respiratory symptoms, hospital admissions of the elderly, those with pre-existing chronic cardiorespiratory disease and asthmatic persons) among local populations in Kuala Lumpur and in Indonesia. Short-term increases in PM_{10} levels, mainly $PM_{2.5}$, were about 250 $\mu g/m^3$ above background levels.

Short-term PAH exposures were considered a low health threat but repeated prolonged exposures over several weeks or months every few years could result in cumulative doses associated with increased health risks (e.g. cancer) (Pinto *et al.,* 1998).

Panther *et al.* (1999) have shown that seasonal exposures to PAHs are significant for local populations in tropical urban environments from both urban pollution and biomass burning. Higher levels of PAHs are usually associated with biomass burning compared with urban emissions.

There is little information on effects of PAH in urban air, generated by motor vehicles, on human health. Estimates from Great Britain indicate that most of the PAHs in urban air are derived from motor vehicles (Lim *et al.,* 1999) and are associated with the PM_{10} fraction.

3.3.2.4. Organochlorine Insecticides

Regional reports on health effects from PTS or POPs have tended to identify adverse human health and environmental impacts from pesticide use, often from occupational exposures. In developing countries of the region, large proportions of populations and women live in rural areas where risks of pesticide exposure are elevated. In Australia and New Zealand, urban and rural exposures to organochlorines have been significant.

For developing countries, a Philippine case study describes the nature of pesticide poisoning cases documented by the Philippine General Hospital and the National Poisons Control and Information Service.

A review of admitted cases of poisoning at the Philippine General Hospital, Manila, showed that before the implementation of the intensive food production program in the 1960s, only 3% of the acute poisoning cases were caused by pesticides (mostly organochlorines). By 1974, pesticides ranked among the top four etiologic agents of acute suicide poisonings with about 18% mortality rate. By 1990, the cases of organochlorine poisonings increased significantly with a mortality rate of 29.7%.

A descriptive study of 47 male and 23 female patients with aplastic anemia referred during the period January 1979 – December 1981 was undertaken at the Philippine General Hospital. Insecticides, which were either organophosphates or organochlorines, were implicated in 21 patients.

In 1988, a retrospective study of mortality statistics in Central Luzon linked occupational exposure to insecticides to a marked increase in rural male mortality in Central Luzon.

In 1992, the results of a prospective study were released comparing the health status of farmers exposed to pesticides in the province of Nueva Ecija and those who had not been exposed in the province of Quezon. Eye, skin, nail, pulmonary, renal and neurological problems were found to be significantly associated with pesticide exposure (Philippines, 1996).

Since 1992, the pesticide use has generally declined in the Philippines with a shift towards sustainable agricultural activities (e.g. ICM). Endosulfan was the most widely used of the PTS over the last three decades. This pattern of use and poisoning is likely to be reflected in most countries where records exist.

In a Singaporean study, DDT levels detected in blood serum samples from males were found to be higher than those from females, probably due to their higher intake of meat products. In comparison, DDE, a metabolite of DDT and being oestrogen-like, was higher in the females than in males as a result of the biotransformation from DDT to DDE in females. This was possibly implicated in the occurrence of breast cancer in women. The sources of DDT and DDE found in Singaporeans was likely through consumption of imported dietary products containing DDT and DDE residues as a result of bioconcentration through the food chains, especially fish and aquatic products (Anon, 2002).

Australian research has identified significant statistical associations between organochlorine insecticide levels in serum and adverse biological or biochemical effects in groups of subjects. For example, in the case of patients with chronic fatigue syndrome, patients with unexplained and persistent fatigue had significantly higher levels of DDE compared with control subjects and had different specific blood cell responses to organochlorines compared with controls (Dunstan *et al.,* 1995; 1996).

Beard et al. (2000) investigated the relationship between serum levels of DDE and bone mineral density in 68 sedentary women. These women reported an adequate dietary intake of calcium. However, reduced bone mineral density was correlated significantly with age ($r = -0.36$, $p = 0.004$) as well as with increases in the log of DDE levels in serum ($r = -0.27$, $p = 0.03$). Hormone replacement therapy was also identified as another predictor variable. The authors suggested that past community exposures to DDT might be associated with reduced bone mineral density in women.

Women in this study were selected from northern New South Wales where DDT was extensively used in cattle dips and significant residues remain (see Miller *et al.,* 1999).

3.3.2.5. Organometallics

Lead

Community health studies on organic lead exposures in the region are related to urban emissions of total lead from the use of lead additives in petrol. Various monitoring programs on urban pollution in most countries (e.g. Indonesia, Thailand, Malaysia, Philippines, Australia and New Zealand) have implicated airborne lead exposure and elevated blood levels, mainly among children.

Air monitoring in countries such as Australia and New Zealand has shown that the phasing out of the use of tetraethyl lead in petrol has resulted in significantly decreased levels of airborne lead exposure in major urban areas.

In Singapore, surveys on lead levels in blood samples were carried out from 1995 to 1997 to assess the measures used to reduce environmental lead pollution. The results revealed that age was a significant factor in blood level. The older age group (>50 years old) had significantly higher blood lead levels than the young adults (<30 years old). This could be due to the bioaccumulation of lead in the adipose and skeletal tissue in the human body. However, the study showed that there was a definite reduction in the blood lead levels as a result of the introduction of unleaded petrol in 1991 and the control of lead content in paint in 1993 (Anon, 2002).

Organomercury

Health effects on children exposed to mercury from small-scale gold mining and refinery activities in Tagum, Davao del Norte, about 1545 km south of Manila, in the Philippines have been investigated (Akagi *et al.,* 2000). In this case, methylmercury has been associated with total mercury levels in blood and hair. Of the 163 children, 10 (6.13%) had elevated total mercury blood levels. For methylmercury, only one child exceeded the WHO limit. Of the 163 children, 3.07% had elevated total mercury hair levels while ME-Hg was elevated in one child. On physical examination, abnormalities were found in all 163 children with the following five predominant abnormalities: under-height, gingival discoloration, underweight, adenopathy and dermatologic abnormalities. The investigators however, did not offer any specific conclusions. Mercury is widely used in the region in gold mining, including Papua New Guinea and Indonesia, and similar adverse effects would be expected in these countries. The role of methylmercury in small-scale gold mining exposures in the tropical areas of the region is unclear.

Organic mercury in hair appears to be significant in Singaporeans. A study on the levels of mercury (total and organic) in scalp hair of individuals not occupationally exposed to mercury found that the average total mercury level in hair was 5.7 µg/g (ppm), with inorganic and organic mercury contents at 2.7 µg/g and 3.0 µg/g, respectively. Other than factors such as gender, age, ethnicity and artificial hair waving, the levels were considered to also reflect intake from food (typically fish and other seafood) and from the environment (Anon, 2002).

Organotin

Adverse health effects from exposure to organotins have been reported in the Philippines. Organotin compounds (e.g. triphenyl tin) have been used extensively as molluscides against the golden snail in rice fields and in fish ponds. These compounds are known to be highly toxic when absorbed in the body and can cause severe skin irritations. Organotins as a group are associated with chronic effects such as immune and reproductive disorders and swelling of the spinal cord and brain (Philippines, 1996).

During the early part of 1989, the problem of controlling the damaging effects of golden apple snail triggered the increased usage of organotin compounds in rice-farming communities. Several newspapers reported the death of 20 women in Isabela, allegedly exposed to organotin-contaminated irrigation water. In spite of the lack of direct evidence in this particular case, a suspension order on the importation and use of organotin compounds was issued by the Government in October 1989. However, the use of endosulfan as an unofficial alternative chemical to control snails was reported to be responsible for the largest number of poisoning cases with fatalities in the country (Philippines, 1996).

3.3.3. Health Risk Assessment

3.3.3.1. General

Few health risk assessments on PTS are available for the Southeast Asia Region although risk assessment practices are developing as part of project assessments (e.g. contaminated land). The risk assessment process usually follows the four-step framework developed by the United States Environmental Protection Agency (US-EPA), i.e. hazard identification, dose-response assessment, exposure assessment and risk characterisation.

The approach can be applied to models that deal with either carcinogenic or non-carcinogenic effects. However, the dose-response assessment for a hazardous chemical (e.g. carcinogen) may support a non-threshold response or alternatively, a threshold or safety factor approach. The latter approach tends to be favoured by European Governments and the World Health Organisation.

3.3.3.2. Organochlorines

Health risks for the Australian population from exposure to organochlorine pesticides (OCPs) have been estimated as part of a national case study. Miller *et al.* (2002) have derived estimates of total exposures to OCPs for the general public and special risk groups by combining data on dietary intake estimates with likely levels of intake from environmental sources: air, drinking water, soils and dusts. From this information, health risk levels for the Australian population and sub-population groups have been estimated for a range of potential exposures (exposure scenarios).

The dietary intake of organochlorine pesticides is considered the main source of exposure for the general population in Australia and in many other countries. From the 1970s, the Australian Market Basket Surveys (AMBS) of foods have shown a progressive decline in organochlorine pesticides detected in food. Since 1976, there has been an exponential decrease in DDT and dieldrin intake in the Australian diet, as indicated for DDT in Figure 3.3.1. In contrast to other organochlorine pesticides, there has been an increase in total endosulfan intakes between 1992 and 1996 surveys, which reflects use (e.g. crops).

Australian estimates of average daily intakes (µg/kg body weight/day) for different human population groups have been compared with acceptable daily intakes (ADI), as recommended by the WHO/FAO or adopted by the Australian and New Zealand Food Authority, and also reference doses (RfD) for non-carcinogenic effects (US-EPA). Table 3.3.2 presents risk estimates for OCP exposures in the case of the Australian population. The health risks for exposure to OCPs in the Australian population are estimated to be low to negligible for adults and children, based on 1996 data. The infant diet, however, indicated elevated DDT intake mainly due to breast feeding.

If a non-threshold is assumed, the lifetime carcinogenic risk for dieldrin intake was calculated to be between 1 in a hundred thousand and 1 in a million, and lower than 1 in a million for DDT and total heptachlor.

Other regional estimates of dietary intake of organochlorines are given in Table 3.3.3 for Viet Nam, Thailand and Papua New Guinea. Average daily intakes are below available ADIs while Vietnamese values are elevated compared with others. Exposure scenarios for the eating of seafoods in the region suggest that risk estimates increase significantly for common OCP residues found in seafoods from urban areas (see Table 3.3.4).

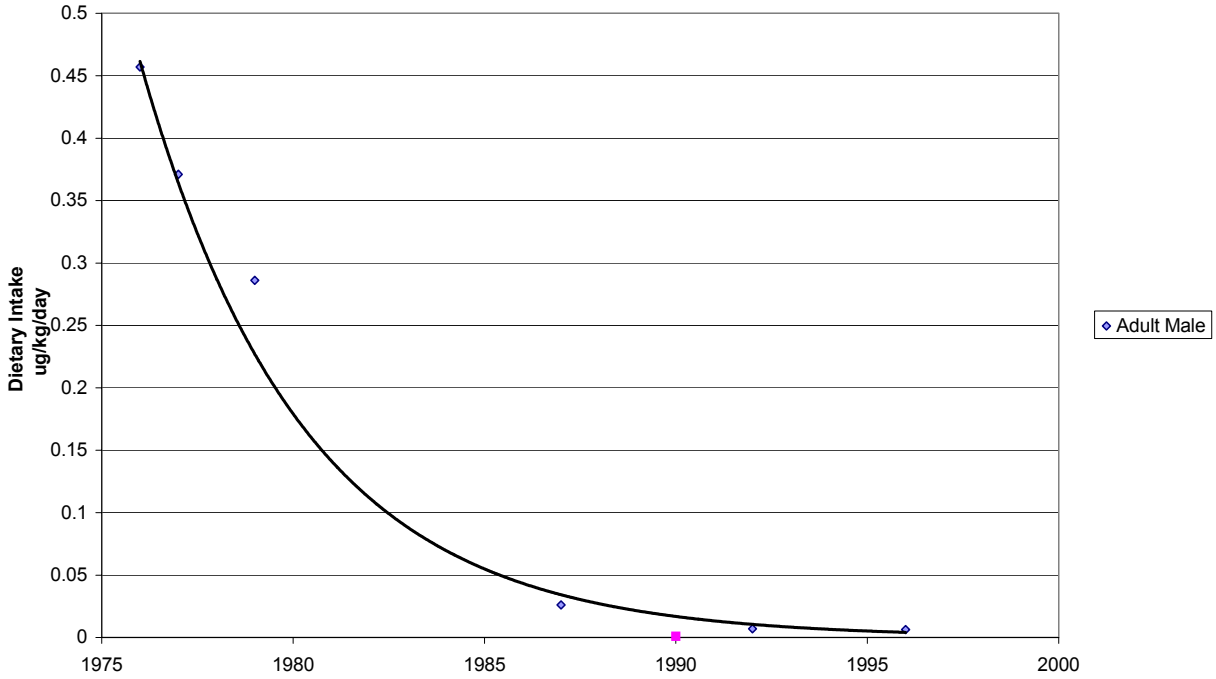


Figure 3.3.1 Trend in Estimated Dietary Intake of Total DDT for Australian Adult Males

Table 3.3.2. Health risks from total daily intake of organochlorine pesticides for the Australian population

Pesticide	Period	Persons	Daily Intake[1] (µg/kg bw/day)	ADI (µg/kg bw/day)	RfD (µg/kg bw/day)	Ratio ADI	Ratio RfD	Lifetime Risk Estimate
Total DDT	1996 – current	Adults	0.007	2	0.5	<0.1	<0.1	$<1x10^{-6}$
		Children	0.009			<0.1	<0.1	$<1x10^{-6}$
Dieldrin		Adults	0.003	0.1	0.05	<0.1	<0.1	$5x10^{-5}$
		Children	0.004[+]			<0.1	(0.08)	$6x10^{-5}$
Total Heptachlor		Adults	0.0006	0.5*	(0.5)	<0.1	<0.1	$<1x10^{-6}$
		Children	0.002		0.013*	<0.1	<0.1 – 1.5*	$<1x10^{-6}$

[1] air, water, soil and food

[+] two year old

* heptachlor epoxide

RfD = reference dose (US-EPA)

Source: Miller *et al.* (2002a)

Table 3.3.3. Comparison of average daily dietary intakes of organochlorines (µg/person/day) in Region 8 countries with ADIs

Organochlorines	Viet Nam[1]	Thailand[1]	Papua New Guinea[a]	ADIs	
				FAO/WHO[1] 1989	ANZFA[2] 1996
PCBs	3.7	1.5	1	-	-
HCHs	5.4	2.2	0.2	-	-
Lindane	0.90	0.28		600	780
DDTs	19	4.2	0.5	1200	120
HCB	0.10	0.08	0.01	-	-
Aldrin + dieldrin	0.55	12	0.1	6.0	6
Heptachlor + heptachlor epoxide	0.25	0.08	0.02	30	30

[1] Kannan *et al.*(1992); [2] ANZFA (1998); [a] estimates only – 2000g diet/day; PTS data from Table 3.1.19. Person – 60 kg body weight

Table 3.3.4. Hypothetical risk estimates for consumption of seafoods from major urban estuaries of region

Pesticide	Person - Adult	Estimated Daily Intake	ADI	RfD	Ratio ADI	Ratio RfD	Added Lifetime Carcinogenic Risk Estimate
		µg/kg bw/day	µg/kg bw/day				
Total DDT	60kg	0.7	2	0.5	0.35	1.4	2.4×10^{-4}
Dieldrin	60kg	0.33	0.1	0.05	3.3	6.6	5×10^{-3}
Chlordane	60kg	0.07	0.5	0.5	0.14	0.14	2.3×10^{-5}

Average seafood intake: 200g/day; total DDT 0.2 mg/kg; dieldrin 0.1 mg/kg; chlordane 0.02 mg/kg, wet weight tissues

See also Miller *et al.* (2002a)

3.3.3.3. Dioxins

Humans are estimated to be exposed to "background" levels of dioxin-like compounds (including PCBs) in the order of 3-6 pg TEQ/kg body weight/day or body burden levels of 40 to 60 ppt in lipid. This is much higher than the US-EPA risk specific dose estimate (1×10^{-6} risk or one additional cancer in one million exposed) of about 0.01 pg TEQ/kg bw/day. "True" risks are likely to be less (US-EPA 1994 Dioxin Reassessment).

In a recent South Vietnamese survey, Bien Hoa residents were found to contain dioxin-like TEQ levels in blood ranging from 8.59 ppt to 301 ppt in lipid (Schecter *et al.,* 2001). The US-EPA has concluded that some adverse health effects may occur at or within one order of magnitude of average background TEQ intake or body burden levels (equal to 3-6 to 60 pg TEQ/kg body weight/day or 40-60 to 600ppt in lipid).

Potential risks to the health of the Melbourne community in Australia were characterised for emissions of PCDD/PCDFs from Nufarm Limited, an agricultural chemicals manufacturer in Laverton North, a suburb of Melbourne (Carlo and Sund, 1993). The exposure assessment used exaggerated assumptions to estimate both total daily exposure (203 pg total toxic equivalents of PCDDs and PCDFs, or 2.9 pg TEQ/kg body weight) and daily exposure attributable to Nufarm (56.4 pg, or 0.80 pg TEQ/kg body weight) under a worst-case scenario. The risk characterisation section found that exposures under 20 pg/kg body weight per day should not induce the aryl hydrocarbon hydroxylase system, which appears to be the starting point for PCDD and PCDF toxicity. The authors concluded that the general population exposure to PCDDs and PCDFs in Melbourne was within the range of acceptable daily intakes that are currently used.

3.3.4. Risk Characterisation

For most people, current intakes of OCPs indicate a safe level in terms of acceptable daily intakes or US reference doses. Lifetime carcinogenic risks (US-EPA model) are also estimated to be conservatively low, although uncertainties would exist for persons exposed to higher intakes in the 1960s and 1970s. (Risk levels of 1 in 100,000 or 1,000,000 are assumed to be low.)

In the case of PCDD/PCDFs, cancer risk estimates for general population exposures may be as high as 10^{-4} or 10^{-3} (upper bound limits) (US-EPA 2000 Dioxin Reassessment). Risks for specifically exposed groups, such as some South Vietnamese, could be 10 to 100 times higher than for background exposures. Some possible toxicological effects such as endocrine disruption continue to be uncertain, particularly for DDT or DDE, dieldrin and PCDD/PCDFs exposures. Contaminated soils, seafoods and private drinking waters can still cause abnormal to excessive intakes of persistent organochlorines where exposure is uncontrolled.

Breast-fed infants appear to be a sensitive group exposed to low levels of DDT and its metabolite DDE and some other residues (e.g. dieldrin and PCDD/PCDFs). Limited human milk studies in the region indicate breast-fed children can be exposed to levels above the acceptable daily intakes for OCPs. Risks for breast fed babies are inconclusive.

Recent studies of breast cancer patterns in women (e.g. USA and The Netherlands) have shown a statistical association with organochlorine residues, such as dieldrin (see Hoyer *et al.,* 1998). Again, there is considerable scientific and medical debate because some other studies indicate no significant association (e.g. Krieger *et al.,* 1994; Zheng *et al.,* 1999). Plausible toxicity mechanisms exist (Shekhar *et al.,* 1997) to the extent that this issue may be important for long-term health risks in Australian women, for example, given a past history of elevated DDT, DDE and dieldrin exposures in the 1970s and 1980s. Breast cancer incidence in Australia has significantly increased (AIHW, 1998) consistent with the usual delay or latency period between exposure and effect for carcinogens.

The role of organochlorine pesticides as a risk factor in breast cancer has been examined in a preliminary Australian study. Taylor *et al.* (1999) found that levels of organochlorine pesticides were higher in breast adipose tissue taken from women with breast cancer compared with women with benign breast conditions. DDE levels were significantly different between malignant and benign tissues.

Studies of plasma levels of organochlorines and breast cancer risks have tended not to support the hypothesis that exposure to DDT (or DDE) and PCBs increases the risk of breast cancer (e.g. Hunter *et al.,* 1997). However, Foo (2002) has reported a significant association for breast cancer in a Singaporean population with oestrogen metabolism and total DDT levels.

While current risk models suggest low health risks for exposure to organochlorines (e.g. Australia), the significance of past exposures for higher risk groups such as children may be underestimated along with specific health effects, e.g. endocrine disruption.

3.3.5. Data Gaps

The information gathered by the Philippines General Hospital in Manila has been valuable in evaluating human health effects. There is a need to have databases, perhaps focused on hospitals, where data on the occurrence of mortalities and illness as well as possible causes are recorded. This

provides a fundamental source of information on human health, which can be used to assess trends and significance of particular diseases in the population.

Epidemiological investigations of specific communities, which are known to be exposed to PTS, are necessary. These studies should aim to establish the linkage between human health and exposure to PTS. Examples include the relationship between the health of the Vietnamese community and the occurrence of PCDD/PCDFs; the possible effects of the PAH and airborne particulates originating from forest fires and urban areas on highly exposed urban communities; the effects of DDT on fish-consuming communities; the effects of mercury on communities involved with gold mining and so on.

It is also valuable to seek to identify problems associated with PTS exposures, which may emerge in the future. Included in this category are potential problems such as the effects of endosulfan on rural communities and the potential effects of endocrine disrupting substances such as DDT and its metabolite, DDE.

3.3.6. Conclusions

Harmful effects and health risks from chronic exposures to PTS of regional concern, such as DDT, PAH and PCDD/PCDFs, are difficult to characterise because of limited data sources and case studies which examine relations between exposure levels and measured effects. Regional differences between developing and developed countries are also apparent in health concerns about long-term risks (e.g. carcinogenic) from low-level PTS exposures in the diet and environment. Large rural populations in developing countries have experienced episodes of short-term poisoning from pesticide use and heavy metal exposures while disease vector control involves large-scale applications of insecticides including DDT. DDT residues in Singapore and Australia have been implicated in breast cancer and reduced bone density in women.

The majority of countries have phased out or are regulating the use of organochlorine pesticides, PCB and organometallics. Recent developments in National Poison Information Centres (e.g. Malaysia and Philippines) have meant better community access to information on POPs and PTS, poisoning statistics and surveys of exposed populations. In some countries (e.g. Australia, New Zealand and Singapore) environmental agencies are co-ordinating national surveys and reports on PTS such as PCDD/PCDFs emissions and organochlorines.

Regional health issues associated with PTS include the large-scale PCDD/PCDFs contamination of South Viet Nam during the Second Indochina War. Vietnamese and other studies show elevated incidences of dioxin (TCDD) in blood and birth defect anomalies among exposed populations including war veterans. Exposure to herbicide spraying is also identified as a risk factor in increased incidences of hepatocellular cancer in some Vietnamese males (e.g. war veterans). Hot spots of PCDD/PCDFs contamination remain (e.g. Bien Hoa) including abnormal levels of blood PCDD/PCDFs.

By-products from biomass burning in tropical areas (e.g. Indonesia) have produced sub-regional impacts in the form of smoke haze, excessive levels of PM_{10} and $PM_{2.5}$ (~ 250 $\mu g/m^3$) for periods of days, and associated PAHs. Health risks from PAHs appear to be low in the short-term but long-term exposure may be significant when combined with urban emissions of PAHs (e.g. vehicles, wood and fossil fuel combustion). Endosulfan and several other organochlorine pesticides are implicated in the occurrence of adverse health effects, particularly in rural communities. This requires further evaluation.

The phasing out of organochlorine pesticides in Australia demonstrates that dietary and environmental exposure to PTS can be reduced to low levels of health risks for the general population. However, special risk groups and susceptible populations need to be protected by regional health agencies or authorities.

The conclusions outlined above relate to areas where some information is available. There is no information available on such PTS as HCB, phthalates, nonyl phenols and brominated fire retardants. It cannot be concluded that these types of PTS produce no adverse health effects.

3.4. Ecotoxicology Of PTS Of Regional Concern

3.4.1. Overview of Harmful Effects

In general terms, there are four major properties, which govern the behaviour of a chemical in the environment and effects on biota. These are:

1. bioaccumulation,

2. environmental persistence,

3. toxicity, and

4. endocrine disruption capacity

Briefly, bioaccumulation can result in the occurrence of relatively high concentrations of PTS in organisms, particularly aquatic organisms. These is evidence for this effect in the region with levels of up to 520 µg/kg of DDT and 180.9 µg/kg in mussels in the region (see Table 3.1.10) compared with mean seawater levels of up to 0.016 ng/L of DDTs and 0.580 ng/L of HCHs, as shown in Table 3.1.6. With each compound this represents a concentration increase of tens of thousands with DDT and several hundred with HCH. Similar effects would be expected throughout the region with most of the PTS and aquatic organisms. Environmental persistence is a characteristic of many of the PTS and the wide occurrence of several PTS in the region is consistent with this property. Toxic effects, in the form of fish kills, have been observed in parts of the region associated with harmful levels of PTS. Effects from endocrine disrupting activity require detailed investigations to evaluate and there have been limited investigations in the region. However, the occurrence of sufficient levels in organisms and the environment would be expected to initiate these effects.

3.4.2. Ecological Databases and Laboratory and Field Studies

Relationship of observed environmental levels to guidelines

The existing guidelines for environmental media can be used to evaluate the potential for adverse effects in natural systems. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality, 2000 (ANZECC, 2000) were selected for use as a comparison with existing levels in the environment. These were selected for the following reasons:

1. These guidelines are applicable to two countries in the region - Australia and New Zealand;
2. The guidelines apply to the tropical region of Australia and may be applicable to the rest of the region, which is in the tropical zone; and,
3. The guidelines are set up on a probabilistic framework and thus have the capability of wider application than many other guidelines, which are set up in a single value.

The guidelines for the PTS in water (see levels reported in Section 3.1 of this report) are shown in Table 3.4.1 (ANZECC, 2000). These are described as 'trigger values' and have been developed in terms of the percentage of species, which can be protected in the aquatic system. This probabilistic approach allows a wider application of the guidelines to evaluate different levels of effect in aquatic systems resulting from different levels of exposure. The guidelines have been developed to evaluate a sustained exposure to toxicants or chronic toxicity. The approach utilises a probability distribution of toxicity endpoints and attempts to protect a predetermined percentage of species, usually 95%. This level of protection is applied to ecosystems, which could be described as slightly to moderately disturbed. With aquatic systems of high conservation value the highest level of protection (99%) is appropriate. This high level of protection is also recommended for systems influenced by bioaccumulative chemicals, such as DDT, PCBs and so on. All of the chemicals in Table 3.4.1 are highly bioaccumulative, except endosulfan, and thus the higher levels of protection may be applicable when considering the effects of PTS in this region.

Table 3.4.1. Water quality guidelines for PTS in freshwater – trigger values (μg/L) for level of protection as percentage of species

Compound	99%	95%	90%	80%
Chlordane	0.03	0.08	0.14	0.27
DDT	0.006	0.01	0.02	0.04
Endosulfan	0.03	0.2	0.6	1.8
(marine waters)*	0.005	0.01	0.02	0.05
Lindane	0.07	0.2	0.4	1.0
PCBs				
Aroclor1242	0.3	0.6	1.0	1.7
Aroclor1254	0.01	0.03	0.07	0.2

From ANZECC, 2000.

* this guideline is for endosulfan in marine waters

The trigger values have been compared with the levels of the PTS in water reported in Table 3.1.2 of this report. The measured levels of chlordane and the PCBs are below the 99% protection trigger value for all countries in the region with the highest levels of chlordane a factor of 10 less than the 99% trigger value. This suggests that these substances do not pose a significant threat to the water component of the aquatic environment in this region, although more evidence would be needed to establish this clearly. However, the trigger values do overlap with the measured values for DDT and HCH for several countries as shown in Figure 3.4.1. Levels for DDT are exceeded at the 90% protection level in the Solomon Islands and Viet Nam, which represents a higher level of potential damage to the aquatic ecosystem than the 99% level, which would be an appropriate level of protection. In addition the levels of HCH exceed the 99% protection level in Thailand.

It is noteworthy that the trigger values have been mainly set for freshwater and the waters involved in this evaluation include estuarine, marine and freshwater. There are values for marine waters set for endosulfan as shown in Table 3.4.1 and the levels are generally lower than the freshwater values suggesting that the levels for the other substances in marine waters may be lower than those reported in Table 3.4.1. Endosulfan has not been included in this analysis since there are limited data on its occurrence in the region. There are some data on river water in Malaysia in Table 3.1.3, which range from 0.00247 to 0.00344 μg/L. These can be compared with the trigger values in Table 3.4.1, which are considerably higher than this value. Thus, the evidence indicates that DDT and HCH are at levels in parts of the region that may be damaging to the water component of the aquatic ecosystem.

The PTS, for which levels are reported, are highly accumulative in sediments. Levels in this medium would be expected to reflect the levels in the environment in general since these chemicals are sorbed to soil and are transferred with stormwater run-off to aquatic areas where they accumulate. The Australian and New Zealand Fresh and Marine Water Quality Guidelines (ANZECC, 2000) include guidelines for PTS in sediments as shown in Table 3.4.2. These values are reported as the Interim Sediment Quality Guidelines (ISQS) with high and low values which correspond to a statistical probability of effects at the 10 and 50% level when tested against one or two species of amphipods. The low ISQS value is the trigger value for evaluation of biological effects and the high value indicates that there is the need for further evaluation and possibly toxicity testing. Since the presence of organic carbon influences the availability of organic toxicants, all the values are normalised to 1.0% organic carbon.

The trigger values have been compared with the measured values reported by Iwata *et al.,* 1994, and the results are shown diagrammatically in Figures 3.4.2 and 3.4.3. The concentrations have been adjusted to 1.0% organic carbon so that they are comparable with the trigger values. The data indicate that DDT, HCH, chlordane and PCBs are widely distributed throughout sediments in the region at concentrations that exceed the trigger values. Perhaps DDT could be singled out as causing the most

serious contamination since it has levels that exceed the trigger value in all countries except Malaysia for which there is a limited amount of data. Also the data suggest that New Zealand is probably the least contaminated since only DDT exceeds the trigger value in this country. It is particularly noteworthy that in many countries the relatively high concentration quality guideline, ISQG-high in Table 3.4.2, has been exceeded. Endosulfan has not been analysed in this way because the sediment data are limited to that in Table 3.1.8. Thus, the information available indicates that contamination of sediments by DDT, HCH, chlordane and PCBs at relatively high levels is widespread throughout the region.

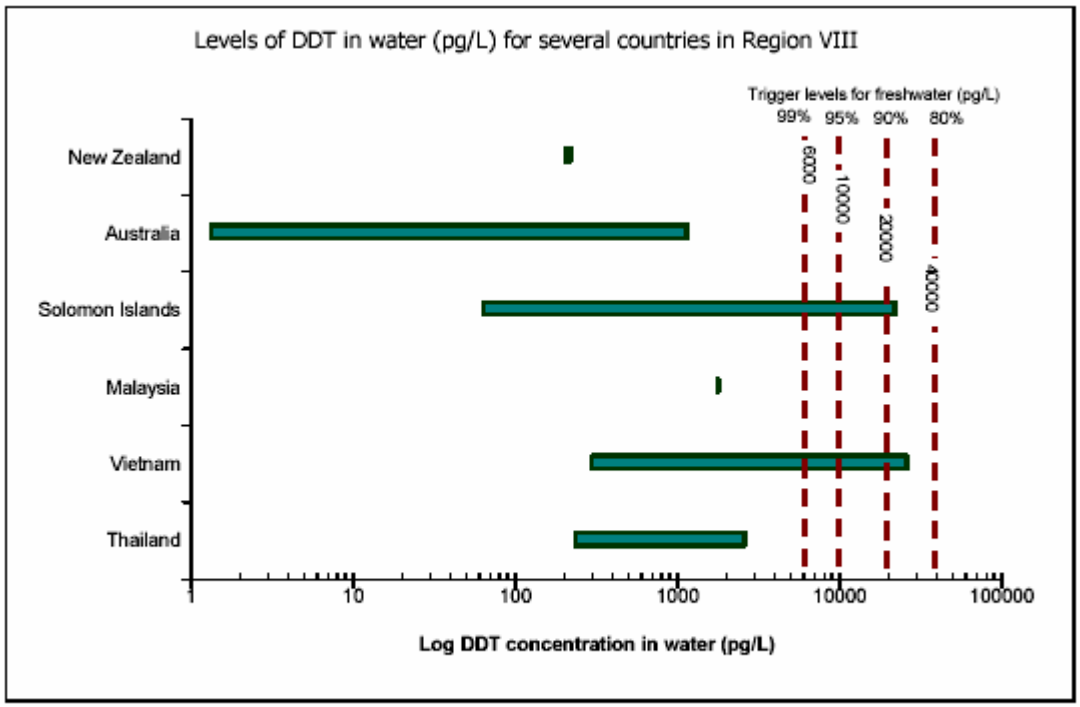
Table 3.4.2. Sediment quality guidelines for PTS (µg/kg dry weight*)

Compound	ISQG – Trigger Value	ISQG – high
Chlordane	0.5	6.0
Total DDT	1.6	46.0
Endosulfan	Na	na
Lindane	0.32	1.0
PCBs	23.0	na

From ANZECC, 2000

* adjusted to 1.0% organic carbon

The U.S. National Academy of Sciences and the National Academy of Engineering (NAS-NAE, 1973) have set maximum levels for the occurrence of some PTS in fish. These are needed to protect fish-eating wildlife and can be used to evaluate the levels of PTS in fish in Tables 3.1.11 and 3.1.12. These levels are set at 1000 µg/kg wet weight DDT, 100 µg/kg wet weight HCH and 100 µg/kg wet weight dieldrin. A few exceedances can be noted but they are insufficient to establish a general pattern.



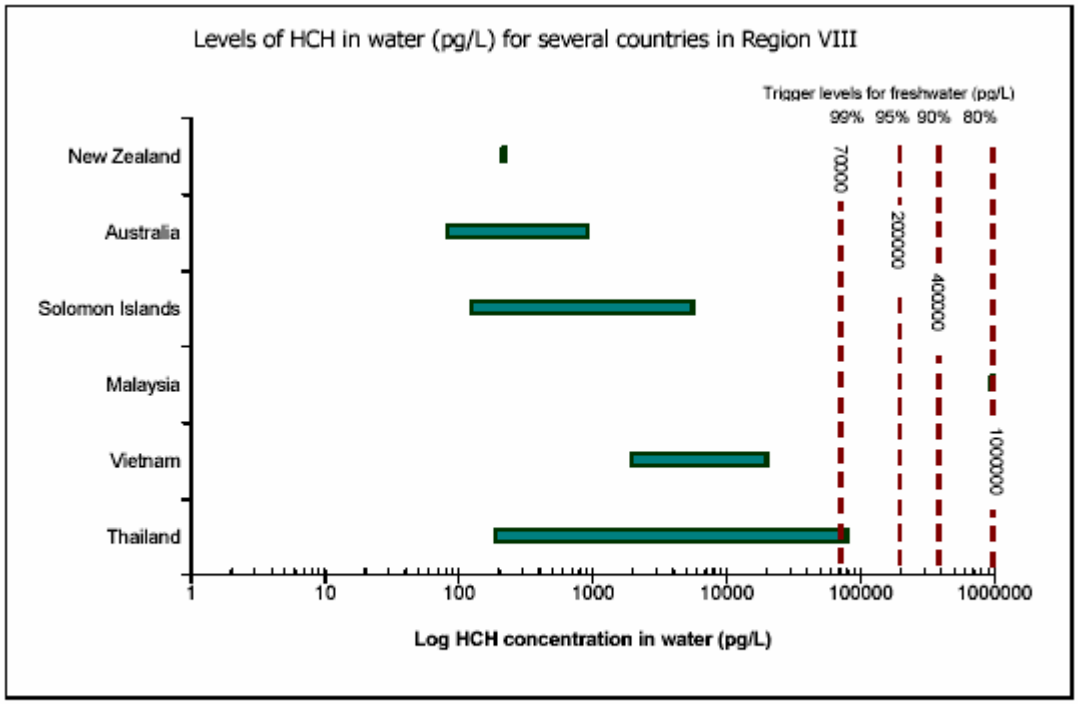
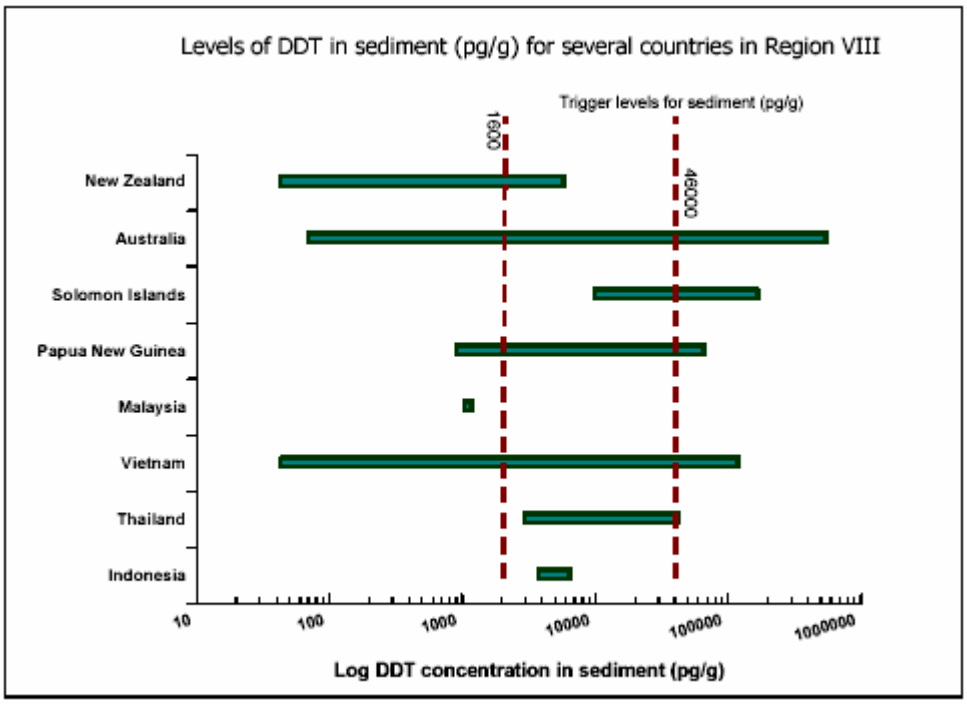


Figure 3.4.1. Comparison of concentrations of some PTS in water in the region (as bars) with trigger values from ANZECC (2000)

Source: Iwata *et al.* (1994)



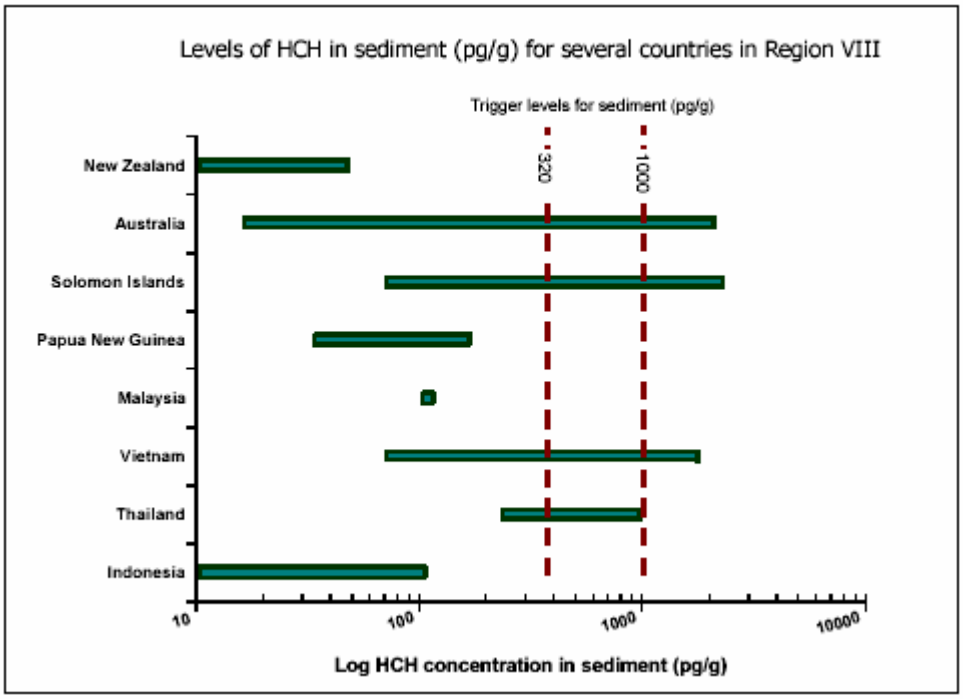
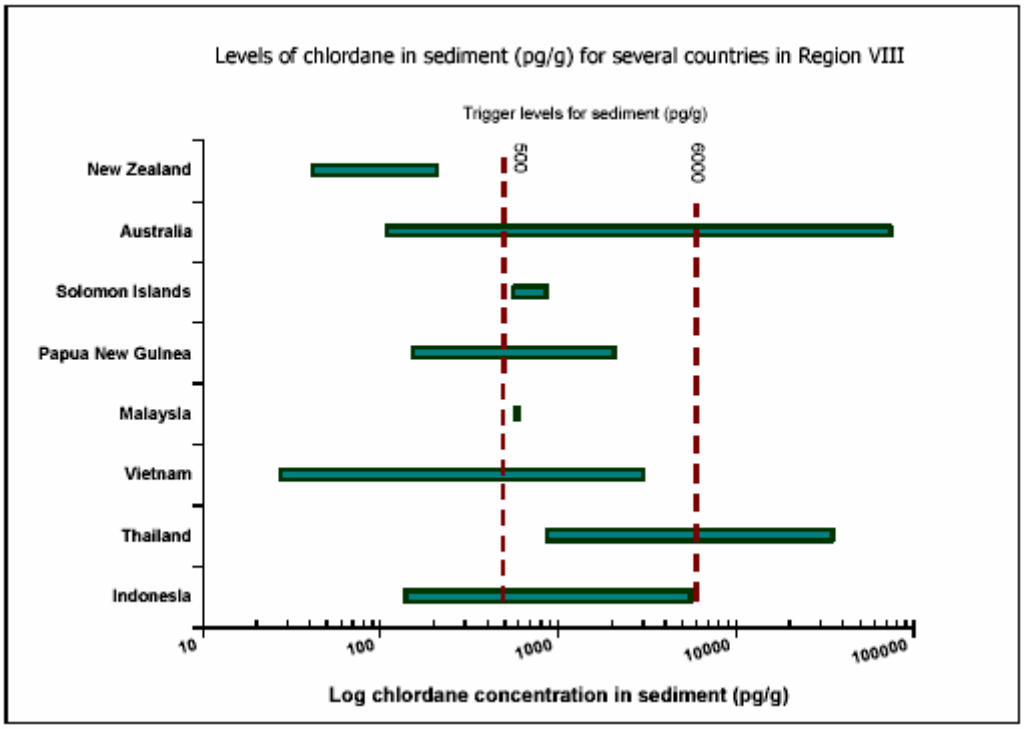


Figure 3.4.2. Comparison of measured sediment concentrations normalised to 1% organic carbon dry weight in countries of the region (as bars) with ANZECC (2000) trigger values

Source: Iwata *et al.* (1994).



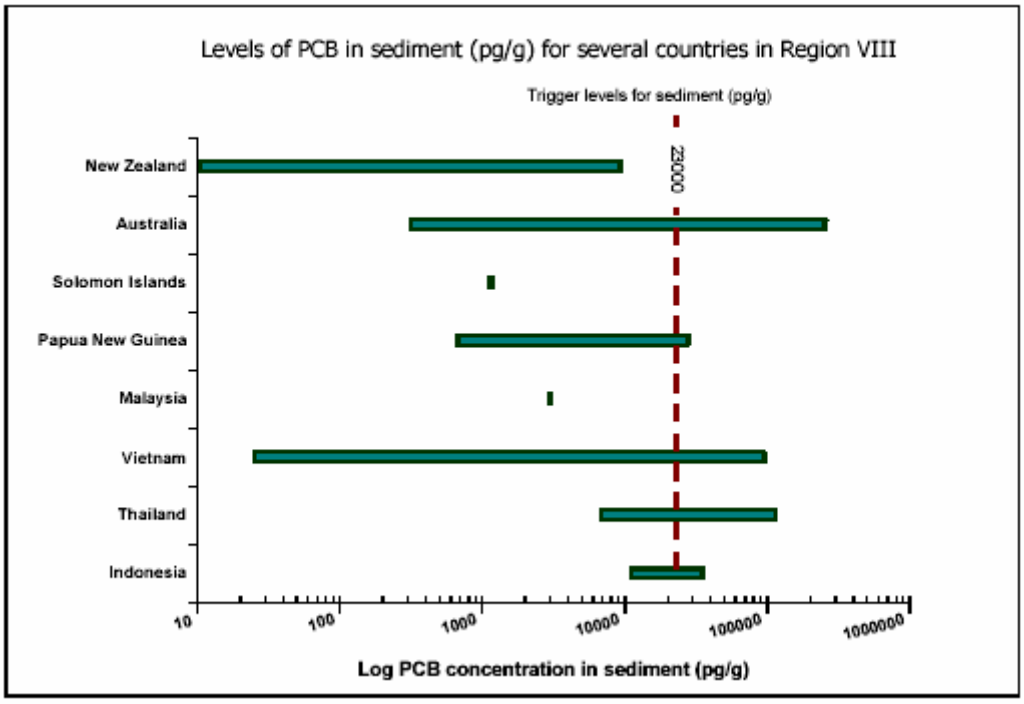


Figure 3.4.3. Comparison of measured sediment concentrations normalised to 1.0% organic carbon dry weight in countries of the region (as bars) with ANZECC (2000) trigger values Source: Iwata *et al.* (1994)

3.4.3. Observed lethal effects in the environment

In the past, many fish kills were associated with the use of many of the PTS pesticides that were in common use. However endosulfan has replaced many of the organochlorine pesticides in the region and the usage of these has declined or in many areas ceased. In general, endosulfan is less persistent in the environment and residues are relatively much lower.

The most dramatic and visible ecological effect has been the increase in the number of fish kills (Sunderam *et al.,* 1992). Sunderam *et al.* (1992) have found that endosulfan is highly toxic to Australian native and introduced fish as well as overseas fish. The State Pollution Control Commission of New South Wales has reported that there are frequent occurrences of fish kills in cotton growing areas of the state during the season when this pesticide is used. However, they report that these incidences occur on occasions and under conditions when reports on them are unlikely. Thus, there is probably considerable under-reporting of these incidents (Whyte and Conlon, 1983). The reporting of fish kills throughout the region is suspected to be at a low level compared with the actual incidence. Endosulfan is a powerful fish toxicant and levels of 0.3 µg/L, or higher, are likely to cause fish kills in natural waters throughout the region (Whyte and Conlon, 1983).

During the Viet Nam war (1961 to 1971), a large quantity of defoliants, particularly 2,4-D and 2,4,5-T containing PCDD/PCDFs, was sprayed into the Vietnamese environment. Hoang (2002) has reported that large areas of forest were destroyed and have not recovered up to the present time. In addition there have been losses of flora and fauna associated with the forest.

Aquatic Biota – Sublethal Effects

The residues of pesticides detected in fish from Australian waters have been summarised by noting the maximum levels detected in the Australian environment in each decade as shown in Table 3.4.3 (Miller *et al.,* 1999 and Connell *et al.,* in press).

The first observation that can be made is that DDT has occurred the most consistently in fish from the 1960s to the present time with maxima at relatively high levels. Also the maximum levels in each decade exceed the maximum residue limit (MRL) for use of marine fish for human food. This can be expected to reflect the relatively heavy usage of DDT, its persistence in the environment and its strong bioconcentration capacity. Dieldrin also has a somewhat similar profile in that it occurs consistently from the 1970s to the present time in maximum concentrations exceeding the MRL. All the other pesticides have a less consistent pattern of occurrence, but all of those listed have maxima during some decades that exceed the MRL (Miller *et al.,* 1999).

Table 3.4.3. Maximum concentrations (µg/g, wet weight muscle) of pesticides measured in fish in the Australian environment (marine, estuarine and inland)

Compound	1960s	1970s	1980s	1990s	MRL ** (µg/g)
Total DDT	6.3	40.3	3.10	2.4	1.00
HCH	-	8.8	2.5	0.041	1.00
Dieldrin	-	0.37	3.10	0.23	0.10
Aldrin + Dieldrin	-	-	0.046	0.046	0.10
Aldrin	-	0.140	1.75	-	0.10
HCB	-	0.02	0.66	3.00	0.10
Heptachlor + heptachlor epoxide	-	<LOD	4.9	0.059	0.05
Total chlordane	-	-	0.72	1.70	0.05

From Miller *et al.* (1999) and Connell *et al.* (in press).

** MRL, maximum residue limits in food and animal feedstuffs, 30 June, 1994, Commonwealth Department of Human Services and Health

The trends in the data seem to be for a maximum level of DDT and dieldrin to occur generally in the 1970s and 1980s with a decline since that period (see Table 3.4.3). Somewhat similar data have been produced for other aquatic biota. However, the data are limited and this trend is not always apparent. Many pesticides have shown a trend towards continuing occurrence in the 1990s. Although the concentrations are lower in the later years the range of pesticides is greatest during the 1990s. This

probably reflects the frequency of monitoring, analytical chemistry capability and other factors (Miller *et al.,* 1999).

The biological significance of these pesticide residues in aquatic biota is difficult to interpret. However, growth reduction has been reported by Mortimer and Connell (1995) for Australian crab species when sub-lethal levels of chlorohydrocarbon residues were present in lipid tissues. This and other sublethal effects, such as lack of breeding success that has been observed with birds, have probably occurred and may be still occurring in the region.

3.4.4. Field Studies on Ecosystems

3.4.4.1. Terrestrial Ecosystems

As a result of the use of defoliants 2,4-D and 2,4,5-T during the Viet Nam war, 1961 to 1971, Dang (2002) has reported that the forest faunal ecosystem remains adversely affected. The diversity or composition of the wildlife has been reduced by 30% of the total number of species, with important species such as elephant (*Elephas maximus*), banteng (*Bos gaurus*), samba deer (*Cervus unicolour*) and Elds deer (*Cerbus eldi*) being particularly reduced.

3.4.4.2. Aquatic Ecosystems

A wide range of ecological investigations has been conducted on the longer term ecological effects of the use of endosulfan in Australia. These are largely focused on the cotton growing areas where usage is most intensive. A recent and typical investigation was conducted by Leonard *et al.* (1999) into the effects of local usage of endosulfan in growing cotton on the ecosystem of the Namoi River in New South Wales. They found that the concentrations of endosulfan in the river were closely related to the depletion of a range of invertebrate fauna. Field investigations on residues and biota in East Java also implicate endosulfan as having a detrimental effect on aquatic biota in the region (Gorbach *et al.,* 1971).

There is little doubt that endosulfan usage in cotton growing is having a detrimental effect on the fish populations and the aquatic ecosystem in Australia. It could be expected that there are similar effects occurring in other parts of the region.

3.4.4.3. Effects of Endocrine Disrupting Chemicals

Chieu et al. (2002) carried out a comprehensive investigation of endocrine disrupting chemicals on the river and estuarine environment of Viet Nam. A range of PTS was identified including the DDTs, which were found to be of declining importance.

There is a limited amount of data available on the occurrence of PTS, particularly pesticides, in birds in Australia (Miller *et al.,* 1999). Although the data are limited, the concentrations of DDT appear to be the highest ranging from <0.01 to 519 µg/g (fat) with HCB next in concentration ranging from <0.01 to 8.62 µg/g (fat), HCH next with concentrations ranging from <0.001 to 1.61 µg/g (fat), and dieldrin with lowest concentrations ranging from <0.0006 to 0.82 µg/g (fat) assuming 10% fat content. Levels in the 1970s and 1980s were in the range <0.01 up to 519 µg/g in fat. If the birds contained 10% fat, then this would be equivalent to <0.001 to 52 µg/g wet weight. It has been calculated (McEwan and Stephenson, 1979; Brown, 1978) that a 20% reduction in shell thickness would be sufficient to cause a significant adverse effect on a bird population. Also the total DDT concentration that would cause this in various bird species ranges from about 10 to 200 µg/g wet weight (Brown, 1978). Since the concentrations in Australian birds ranged from <0.001 to 52 µg/g wet weight during the 1970s and 1980s, these data support the egg shell effects observed in the peregrine falcon, and suggest that DDT was affecting egg shell thickness in bird populations in Australia during this period.

The association between DDT usage and declining populations of carnivorous birds is well known (Mellanby, 1967). This has been attributed to an adverse effect on the endocrine system leading to a residue induced imbalance in calcium metabolism resulting in shell thinning and loss of eggs as well as other behavioural abnormalities.

In Australia, the peregrine falcon (*Falco peregrinus*) has been intensively examined to determine if shell thinning was occurring as a result of DDT usage (Olsen and Olsen, 1979) and having an adverse

effect on the endocrine system. The falcon is a cosmopolitan bird of prey that is known in North America, Europe and elsewhere as well as Australia. Its numbers have fallen and this was attributed to DDT usage. The CSIRO has examined eggs of known age from museums, private collections and so on from many different parts of Australia. The results are shown in Figure 3.4.4. The results indicate a decline in egg shell thickness during the period of introduction and usage of DDT and an adverse effect on breeding success would be expected as a result.

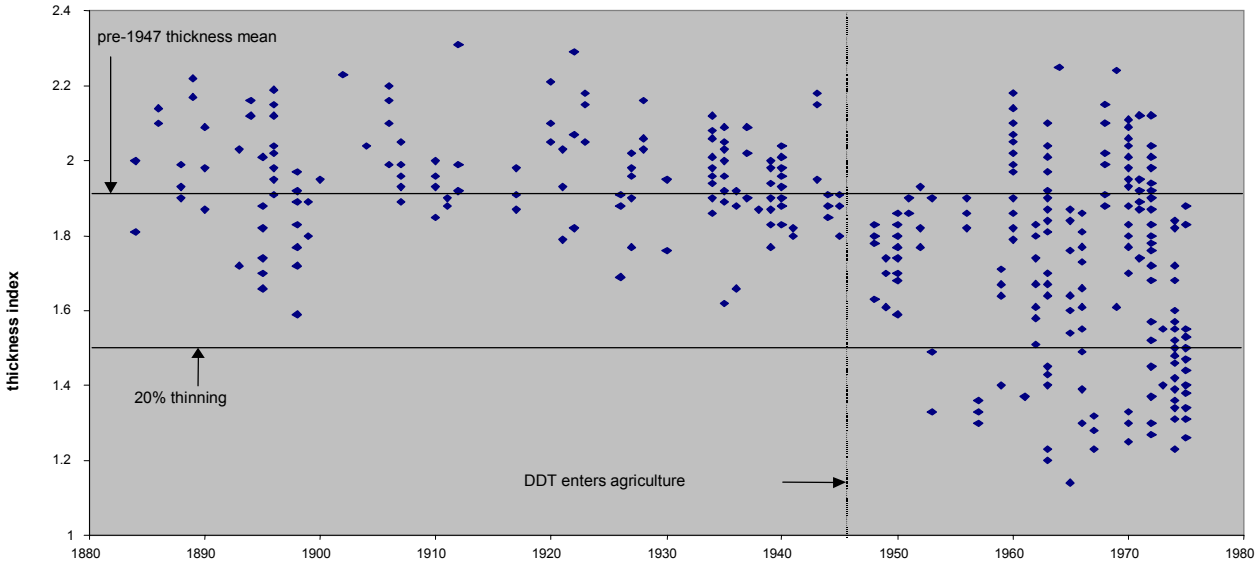


Figure 3.4.4: This figure indicates how the thickness of peregrine falcon (*Falco peregrinus*) egg shells has changed. Each spot represents the thickness of an egg shell. Before 1947, no shells were 20 per cent thinner than the pre-pesticide mean but after 1947, a substantial proportion of the eggs, collected from all over the continent, were more than 20 per cent thinner. The use of DDT in agriculture started about 1947.

Source: Anon, 1979; Olsen and Olsen, 1979

Redrawn from Connell (1981)

The superimposition of male sex organs on female gastropods is described as imposex. This occurs as a result of disruption of the endocrine system. There are a number of examples of the development of imposex with gastropods as a result of exposure to tributyl tin (TBT) compounds used in the boating industry in Australia (Reitsema and Spickett, 1999). Investigations by Tanabe *et al*. (2000) have revealed TBT occurs in higher concentrations than the chlorohydrocarbon contaminants in mussels from tropical coastal waters in Asia, including the Southeast Asia and Oceania region. Increasing usage suggests increasing contamination and possible imposex effects.

The use of TBT in antifouling paints has been associated with imposex (male genitalia or characters imposed on females) in whelks and other gastropod molluscs throughout the Southeast Asian Region (Singapore, Malaysia, Indonesia, Thailand, Australia and New Zealand) (Ellis and Pattisina, 1990; Pandey and Evans, 1996; Bech, 1999; Hashimoto *et al.,* 1998; Foale, 1993; Swennen *et al.,* 1997; Nias *et al.,* 1993; and Smith, 1996).

There was a significant decline in imposex levels in dogwhelks in an area of New Zealand following a ban on the use of TBT antifouling on pleasure craft (Smith, 1996).

3.4.5. Ecological Risk Assessment Studies

Animals at the top of the food web such as mammals and birds can accumulate high levels of DDT and dieldrin in their body fats. Chronic population effects such as the thin egg shell effect have been observed in peregrine falcons and acute effects, e.g. fish kills after spraying or from pesticide waste disposal, have been widely reported.

A well-recognised problem in studying the effects of toxic chemicals on wildlife, however, is that it is often difficult to document sub-lethal and lethal effects on wildlife in the field. At the same time, it is also difficult to link cause and observed effect, especially when toxic residues cannot be directly measured or the situation is complicated by other contaminants.

It is useful to identify which major living systems in the environment and species are most at risk even though any previous level of loss or damage is unknown. An approach used here is to indicate the relative level of environmental risk posed by each of the common organochlorine pesticides. It should be kept in mind that the concentrations of these PTS are in decline as outlined above and that the levels of risk are also in decline. A risk evaluation can be achieved by a risk scoring method using the relationship:

RISK = EXPOSURE X TOXICITY

A relative risk score can be calculated simply by assigning different values of exposure levels and toxicity to particular groups of animals and plants. Exposure periods can also be considered a factor but for environmental chemicals this is ongoing and continuous and so has not been considered. These scores are based on literature reviews and available data.

Biological Diversity

Potential risks for biological diversity from the use of organochlorine pesticides can be evaluated as in Table 3.4.4. While this is a qualitative exercise it still provides a basis for the comparison of risks due to the different biota and PTS. Current risks for these pesticides are primarily related to residues of DDT and dieldrin with invertebrates, birds and fish species.

Risks to marine and land plants are considered to be low while there is a medium risk with mammals. The exposure patterns and the susceptibility of the biological species are somewhat similar for the whole region.

Table 3.4.4. Environmental risk ratings for organochlorine pesticide impacts on biodiversity in the region

Key Issue(s)	Current Status	Potential Risks from Pesticides*
1. Plants		
Marine plants Habitat modification and loss; pollution; natural events – floods and cyclones	• Extensive loss of seagrasses; localised loss of mangroves throughout Region. • Historical herbicide spraying – Viet Nam	Low
Freshwater plants Habitat modification and loss	Species threatened; siltation of rivers	?
Land plants Clearance; habitat modification and forest loss	• Many species endangered or vulnerable. • Agriculture	Low
2. Invertebrates		
Marine invertebrates Habitat modification and loss; harvesting of edible species; competition from marine pests	Reduction in population size of exploited species; Indo-Pacific; seagrass losses; wetlands, estuaries; coral reefs under threat of development	Medium to high
Freshwater invertebrates Habitat modification and loss	Insufficient information to assess	Medium to high
Land invertebrates	Massive reduction in population size of	Low to medium

• Habitat modification and loss • Agriculture	affected species.	
3. Vertebrates		
Amphibia and Reptiles • Declines in some frog populations • Exploitation and habitat loss	Insufficient information for assessment. Frog species	?
Marine fish Harvesting of edible species	• Many important species overexploited • Estuaries and wetlands under threat	Medium to high
Freshwater fish Habitat modification and loss, competition and predation from introduced species	Generally in poor condition; many species endangered	High
Birds Habitat modification and loss; predation from feral animals	Some species disappearing, others threatened; a few increasing their range	Medium to high
Mammals Habitat modification and loss; competition with and predation by feral animals; hunting	• Several species lost, others threatened; a few increasing in numbers and range • Marine mammals uncertain	Medium
4.Genetic Diversity Habitat fragmentation and loss	• Some species show reduced genetic diversity • Inadequate data	Uncertain?

* refers to organochlorine pesticides; other pesticides may also be significant

3.4.6. Data Gaps

Of particular value to the management of PTS in the region would be the availability of a set of guideline values for the ecotoxicological significance of the levels of PTS that occur in environmental media. The use of most guidelines developed elsewhere is inappropriate in the region since it is a tropical area with features such as coral reefs that have received limited attention in other countries. It would be of greatest benefit if such guidelines were applicable to all countries in the region. This would enable a co-ordinated approach to be taken to maximise the use of scarce resources and improve the applicability of the guidelines. A precedent has been set in this area by ASEAN who has established guideline values for several water quality parameters.

Ecotoxicological investigations are needed in specific situations where PTS exposure of natural systems occurs at a significant level. DDT and several other PTS are declining in many areas and there has been an associated increase in the use of endosulfan. However, DDT is a persistent substance and will continue to be of concern because of its ecotoxicological effects, particularly the endocrine disrupting capacity of its metabolite, DDE. Investigations of this are needed as well as temporal changes. Current evidence on the effects of endosulfan indicates potential major effects but the evidence is limited and the initiation of ecotoxicological investigations at this stage would be appropriate. This substance has very high toxicity to fish and other aquatic organisms, which indicates that aquatic systems should be the highest priority.

3.4.7. Conclusions

Ecotoxicological effects of PTS, particularly organochlorine pesticides, have not been quantified in the region and field studies of effects on non-target species are relatively few compared with results on monitoring for residual and bioindicator concentrations. As a result of comparison of environmental levels with guidelines from Australia and New Zealand, the potential ecotoxicological effects are estimated to be high where exposure exists. Currently there are no water and sediment quality guidelines in the region except for Australia and New Zealand. The value of such guidelines is illustrated by this application. Residual levels of DDTs, HCHs, PCBs and chlordane in waters and sediments have been measured in the ranges of known adverse effects. A difference in the potential adverse effects in the water and sedimentary components of the aquatic ecosystem has been observed with a higher level of potential effects indicated with the sedimentary system. The distribution of risk areas has not been mapped because of inadequate information but is believed to be mainly confined to major urban and intensive agriculture catchments.

In a geographical sense, the more remote parts of the region have extremely little data available on the occurrence of pesticides in the environment and wildlife. The limited data available suggest that DDT and dieldrin are declining in concentration but significant levels still occur in some locations. Evidence now available suggests that urban areas, in particular sewage, may be a major source of the PTS including pesticides.

In Viet Nam the effects of residues of defoliant usage, such as PCDD/PCDFs, in the Viet Nam war during 1961 to 1971 on terrestrial ecosystems have been severe and are continuing at the present time although the residues appear to be in decline. As residues decline (e.g. biodegrade) and contamination is thus remediated, recovery of adversely affected ecosystems is probable providing replacement pesticides or other pollutants do not increase environmental risks. This may be occurring with endosulfan as outlined below.

Endosulfan has been identified as a major PTS, which has a continuing effect on the natural ecosystems in the region. This substance is expected to increase in importance as the ongoing banning of the organochlorine pesticides continues. It has an acute effect in the form of fish kills and long-term effects on the structure of aquatic ecosystems where it is used. In addition there are examples of endocrine disrupting activity in marine gastropod populations as a result of exposure to TBT. DDT and its metabolite DDE have had a detrimental effect on the breeding success of some bird populations in the past and this is possibly continuing although these effects would be expected to decline as the use and levels of DDT in the region decline.

There are no ecotoxicological investigations available on PTS such as HCB, phthalates and brominated fire retardants but this cannot be interpreted as evidence of an absence of effects due to these substances.

3.5. Summary

The concentration levels of most PTS in various environmental compartments were mainly extracted from published literature reports, with some information from the project questionnaires database and several personal communications. The POPs have been considered in detail and residual levels in air, water, sediments, and biota have been summarised. The prioritisation exercise during the two technical workshop meetings for the region placed DDTs, dieldrin and PCDD/PCDFs as of regional concern with limited concern for chlordane, endosulfan, HCHs, PAHs, and PCBs.

The levels of several PTS in air were reported to be high in the Southeast Asian countries. DDT, HCH and PCB were exceptionally high in a few countries such as Viet Nam, Australia, and Thailand. HCHs, particularly lindane, were found at high concentration levels in river waters in the region particularly Malaysia and Thailand. Other OCPs were also found in relatively high levels in this region but showed a decreasing trend with time. The surface seawater in the region was found to contain high levels of HCHs particularly in seas around Southeast Asia. PTS in sediments and soil seem to be the main source of the PTS in the region where sediments and soils act as sinks for these PTS. High levels of DDTs and PCBs were found in soil all over the region but Australia and Viet Nam were reported to be the most contaminated. However, temporal trend studies revealed that these

chemicals are decreasing exponentially. Endosulfan was found in most sediments in the region particularly in Malaysia suggesting the recent use of this chemical.

The concentration levels of PTS in marine organisms, such as fishes and mussels, have been extensively studied. The Mussel Watch program reported widespread presence of a whole spectrum of PTS in mussels collected from this region. However, there were indications that the levels of PTS such as DDTs, HCHs and PCBs were declining. Many PTS were found to occur in fish species collected in the region but the concentration levels were generally lower than the allowable limit. Marine mammals such as whales and dolphins have been reported to have high concentrations of DDTs, HCB and PCBs. However, data on terrestrial biota are lacking and efforts should be made to correct this situation particularly in relation to domestic animals.

Due to difficulties in sample collection and analyses, studies on PTS levels in human tissues have not been widely reported. A few more developed countries such as Australia, New Zealand, and Singapore have undertaken population monitoring studies. New Zealand has a comprehensive program of population studies, which may be used as a model for other countries. However the levels of a number of PTS in blood and breast milk of New Zealanders studied were found to be very low. Australia reported decreasing levels of DDTs and HCB in human milk while Singapore reported low levels of DDT in population studies. There is a definite lack of data on the human toxicological effects of PTS, which is of considerable importance for countries in this region.

Data on levels of PTS in food and vegetables are available but not comprehensive. Such data are important for human health risk assessment and dietary intake estimations. Complete and up-to-date information should be gathered on PTS concentration levels in various food products for each country. Most reports on PTS levels in food products reveal the presence of significant numbers of PTS in most samples with varied concentration levels. Even low levels of PTS in food should not be taken lightly due to the bioaccumulative nature of these chemicals.

PCDD/PCDFs were found to be of major threat to the human health and the ecosystem in general. Even though data on PCDD/PCDFs levels are scarce, estimates of releases to the environment due to industrial and human activities indicated a significant input to the system. Through unintentional release coupled with high toxicity and accumulative properties, PCDD/PCDFs are possibly the most important PTS to be evaluated in the future. A greater effort should be focused on the reduction of unintentional release of PCDD/PCDFs as well as monitoring of concentration levels.

Most countries in the region have phased out or are regulating the use of organochlorine pesticides, PCB and organometallics. As a result, the concentrations of some PTS are falling. However, a major regional health issue is concerned with the human health and adverse ecotoxicological effects resulting from the ongoing presence of PCDD/PCDFs in the environment of Viet Nam. This has resulted from the extensive use of 2,4,5-T herbicide contaminated with PCDD/PCDFs during the Viet Nam war principally in the period from 1965-1970. Elevated concentrations of TCDD in the blood, birth defects and the induction of cancer have been reported in exposed human populations. In addition natural ecosystems have exhibited adverse effects with up to 30% reductions in the number of species present in the terrestrial ecosystems. Ongoing investigations are needed in the affected areas to evaluate recovery and any specific actions needed.

The available evidence indicates that DDT concentrations are falling in the region. However, DDT and related organochlorine pesticides may occur in significant concentrations and be implicated in such adverse human health effects as breast cancer and reduced bone density in women. At the same time, reduced use of organochlorine pesticides has resulted in increased use of endosulfan. This substance has emerged as a substance, which may have significant effects on human health and the natural environment.

A range of organochlorine compounds (DDT, HCH, chlordane and PCB) occur in water and sediments throughout the region in concentrations, which exceed guideline values for natural ecosystems. This would be expected to cause a reduction in the species diversity of natural aquatic systems in the region and other adverse effects. This confirms the need for control and management of PTS so that environmental concentrations can be reduced to acceptable levels.

The region has urban sources as well as natural sources, such as forest fires, which produce PAHs and particulates, which have adverse effects on human health. Human health investigations are needed in specific situations where exposure is most acute. These should aim to establish the relationship between exposure and adverse effects so that management guidelines can be established to protect human health.

There is a need for a set of environmental quality regional guidelines to evaluate the significance of the occurrence of PTS in air, soil, waste, sediment, food and drinking water. These should relate environmental levels to the occurrence of significant adverse effects on human health and the natural environment. This could be part of an expanded set of environmental guidelines initiated by ASEAN for the region. The region has a substantially tropical climate and other unique features which suggest that guidelines developed elsewhere will not be appropriate.

3.6. References

AIHW (1998) *Australia's Health*. Australian Institute of Health and Welfare, Australia.

Akagi, H., Castillo, E.S., Cortes-Maramba, N., Francisco-Rivera, A.T. and Timbang, T.D. (2000) Health assessment for mercury exposure among schoolchildren residing near a gold processing and refining plant in Apokon, Tagum, Davao del Norte, Philippines. The *Science of the Total Environment* **259**, 31-43.

Anon (1979) DDT, thin eggshells and an Australian falcon. *Ecos* **20**, 8.

Anon (2002) Country Paper by Singapore. *Prepared for 2nd Technical Workshop for Region 8, GEF-UNEP Project on Global Assessment of Persistent and Toxic Substances*, 17-19 April, 2002, Penang, Malaysia.

ANZECC (2000) *Australian and New Zealand Guidelines for Fresh and Marine Waters*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, 2000.

ANZFA (1998) *The Australian Market Basket Survey 1996*. Australia New Zealand Food Authority, Canberra.

Australian Academy of Science (1972) *The Use of DDT in Australia*. Australian Academy of Science, Report No 14, Canberra.

Beard, J., Marshall, S., Jong, K., Newton, R., Triplett-McBride, T., Humphries, B. and Bronks, R. (2000) 1,1,1-trichloro-2,2-*bis* (p-chlorophenyl)-ethane (DDT) and reduced bone mineral density. *Archives of Environmental Health* **55** (3), 177-180.

Bech, M. (1999) Increasing levels of tributyltin-induced imposex in muricid gastropods at Phuket Island, Thailand. *Applied Organometallic Chemistry* **13** (10), 799-804.

Boon, J., Everaarts, J., Sumarno, I., Nelissen, P., Stefels, J. and Hillebrand, M. (1989) Cyclic organochlorines in epi-benthic organisms from coastal waters around East Java, Indonesia. *Netherlands Journal of Sea Res*earch **5**, 23-39.

Brown, A.W.A (1978) *Ecology of Pesticides in the Environment*. John Wiley and Sons, New York.

Buckland, S., Ellis, H. and Salter, R. (1998) Organochlorines in New Zealand: Ambient concentrations of selected organochlorines in soils. Organochlorines Programme Ministry for the Environment Report, 1998.

Burt, J.S. and Ebell, G.F. (1995) Organic Pollutants in mussels and sediments of the coastal waters off Perth, Western Australia. *Marine Pollution Bulletin* **30**, 723-732.

Carlo, G.L. and Sund, K.G. (1993) Assessment of dioxin-related health risks for the Melbourne metropolitan area. *Australian Journal of Public Health* **17** (2), 162-168.

Casarett and Doull's Toxicology 6th Ed (2001) C.D. Klaassen (Ed.) McGraw-Hill Medical Publishing Division, New York.

Chieu, L.V., Hoai, P.M., Lieu, T.T., Le, H.M., Dung, H.M., Tuyen L.H. and Viet, P.H. (2002) Distribution and behaviour of endocrine disrupting chemicals in rivers and estuary environment from Vietnam. *Paper, Research Centre for Environmental Technology and Sustainable Development (CETASD).*

Coastal Hydrosphere (2000) http://landbase.hq.unu.edu/Monitoring/MonitoringtheEnvironment.htm

Connell, D.W (1981) *Water Pollution: Causes and Effects in Australia and New Zealand*. 2nd Edition. University of Queensland Press, St Lucia.

Connell, D.W., Miller, G.J., Anderson, S.A. (in press) Chlorohydrocarbons pesticides in the Australian marine environment after banning in the period from 1970s to 1980s. *Marine Pollution Bulletin.*

Connell, D.W., Miller, G.J., Mortimer, M.R., Shaw, G.R. and Anderson, S.A. (1999) Persistent lipophilic contaminants and other chemical residues in the Southern Hemisphere. *Critical Reviews in Environmental Science and Technology* **29** (1), 47.

Constable, J.D. and Hatch, M.C. (1985) Reproductive effects of herbicide exposure in Vietnam: Recent studies by the Vietnamese and others. *Teratogenesis, Carcinogenesis and Mutagenesis* **5**, 231-250.

Cordier, S., Thuy, L.T.B., Verger, P., Bard, D., Dai, L.C., Larouze, B., Dazza, M.C., Quinh, H.T. and Abenhaim, L. (1993) Viral infections and chemical exposures as risk factors for hepatocellular carcinoma in Vietnam. *International Journal of Cancer* **55**, 196-201.

Cullen, M. and Connell, D.W. (1992) Bioaccumulation of chlorohydrocarbon pesticides by fish in the natural environment. *Chemosphere* **25**, 1579.

Dang, H.H. (2002) An assessment of forest mammal population change in Ma Da and A Luoi areas form 1980 to 2000 under the effects of Agent Orange-dioxin sprayed by United States of America's army during the war in Vietnam. *Summaries- Vietnam- United States Conference on Human Health and Environmental Effects on Agent Orange/Dioxin*, Hanoi, Vietnam, page 107.

Dwernychuk, L.W., Hoang, D.C., Hatfield, C.T., Boivin, T.G., Tran, M.H., Phung, T.D. and Nguyen, D.T. (2002) Dioxin reservoirs in southern Viet Nam – A legacy of Agent Orange. *Chemosphere* **47**, 117-137.

Dunstan, R.H., Donohoe, M., Taylor, W., Roberts, T.K., Murdoch, R.N., Watkins, J.A. and McGregor, N.R. (1995) A preliminary investigation of chlorinated hydrocarbons and chronic fatigue syndrome. *The Medical Journal of Australia* **163**, 294-297.

Dunstan, R.H., Roberts, T.K., Donohoe, M., McGregor, N.R., Hope, D., Taylor, W.G., Watkins, J.A., Murdoch, R.N. and Butt, H.L. (1996). Bioaccumulated chlorinated hydrocarbons and red/white blood cell parameters. *Biochemical Molecular Medicine* **58** (1), 77-84.

Ellis, D.V. and Pattisina, L.A. (1990) Widespread neogastropod imposex: A biological indicator of global TBT contamination? *Marine Pollution Bulletin* **21** (5), 248-253.

Foale, S. (1993) An evaluation of the potential of gastropod imposex as a bioindicator of tributyltin pollution in Port Phillip Bay, Victoria. *Marine Pollution Bulletin* **26** (10), 546-552.

Foo, S.C. (2002) Serum DDT and DDE in Singapore Population. 1st Technical Working Group Meeting, Region 8, South-East Asia and South Pacific, 6-8 February, 2002, Singapore.

Gorbach, S., Haarring, R., Knauf, W. and Werner, H.J. (1971) Residue analyses and biotests in rice fields of East Java with Thiodan. *Bulletin of Environmental Contamination and Toxicology* **6**, 193-199.

Hashimoto, S., Watanabe, M., Noda, Y., Hayashi, T., Kurita, Y., Takasu, Y. and Otsuki, A. (1998) Concentration and distribution of butyltin compounds in a heavy tanker route in the Strait of Malacca and in Tokyo Bay. *Marine Environmental Research* **45** (2), 169-177.

Hoang, D. C. (2002) Health and Environmental Problems in Vietnam after War. *Summaries- Vietnam-United States Conference on Human Health and Environmental Effects on Agent Orange/Dioxin,* Hanoi, Vietnam, page 2.

Hossain, M.M. (2001) Fate of organochlorine pesticide residues (OCPs) in sediment and in the marine food chain. Ph D. Dissertation, Universiti Sains Malaysia.

Hoyer, A.P., Grandjean, P., Jorgensen, T., Brock, J.W. and Hartvig, H.B. (1998) Organochlorine exposure and risk of breast cancer. *Lancet* **352** (9143), 1816-1820.

Hunter, D.J., Hankinson, S.E., Laden, F., Colditz, G.A., Manson, J.E., Willett, W.C., Speizer, F.E. and Wolff, M.S. (1997) Plasma organochlorine levels and the risk of breast cancer. *New England Journal of Medicine* **337** (18), 1253-1258.

Iwata, H., Tanabe, S., Sakai, N. and Tatsukawa, R. (1993) Distribution of persistent organochlorines in the oceanic air and surface seawater and the role of ocean on their global transport and fate. *Environmental Science and Technol*ogy **27**, 1080.

Iwata, H., Tanabe, S., Sakai, N., Nishimura, A. and Tatsukawa, R. (1994) Geographical distribution of persistent organochlorines in air, water and sediments from Asia and Oceania, and their implications for global redistribution from lower latitudes. *Environmental Pollution* **85**, 15.

Kan-atireklap S., Yen, N.T.H., Tanabe, S. and Subramanian, A.N. (1998) Butyltin compounds and organochlorine residues in green mussels (Perna viridis L.) from India. *Toxicology and Environmental Chemistry* **67**, 409-424.

Kan-atireklap, S., Tanabe, S., Sanguansin, J., Tabucanon, M.S. and Hungspreugs, M. (1997) Contamination by butyltin compounds and organochlorine residues in green mussels (Perna Viridis, L) from Thailand Coastal Waters. *Environmental Pollution* **97**, 79-89.

Kannan, K., Tanabe, S., Quynh, H.T., Hue, N.D. and Tatsukawa, R. (1992) Residue pattern and dietary intake of persistent organochlorine compounds in foodstuffs from Vietnam. *Archives of Environmental Contamination and Toxicology* **22**, 367-374.

Kannnan K., Tanabe S., Williams R. J. and Tatsukawa R. (1994) Persistent organochlorine residues in foodstuffs from Australia, Papua New Guinea and the Solomon Islands: contamination levels and human dietary exposure. *The Science of the Total Environment* **153**, 29-49.

Kannan, K., Tanabe, S. and Tatsukawa, R. (1995) Geographical distribution and accumulation features of organochlorine residues in fish in tropical Asian and Oceania. *Environmental Science and Technology* **29**, 2673-2683.

Krieger, N., Wolff, M.S., Hiatt, R.A., Rivera, M, Vogelman, J. and Orentreich, N. (1994) Breast cancer and serum organochlorines: a prospective study among white, black, and Asian women. *Journal of National Cancer Institute* **86** (8), 589-599.

Lee, D.B., Prudente, M.S., Tanabe, S. and Tatsukawa, R. (1997) Organochlorine residues in soils and sediments from Manila and nearby provinces, Philippines. *Toxicology and Environmental Chemistry* **60**, 171-181.

Leonard, A.W., Hyne, R.V., Lim, R.P. and Chapman, J.C. (1999) Effect of endosulfan runoff from cotton fields on macroinvertebrates in the Namoi River. *Ecotoxicology and Environmental Safety* **42**, 125.

Lim, L.H., Harrison, R.M. and Harrad, S. (1999) The contribution of traffic to atmospheric concentrations of polycyclic aromatic hydrocarbons. *Environmental Science and Technology* **33**, 3538-3542.

McEwan, E.L. and Stephenson, G.R. (1979) *The Use and Significance of Pesticides in the Environment*. John Wiley and Sons.

Mellanby, K. (1967) *Pesticides and Pollution*. Fontana New Naturalist, London.

Miller, G.J., Anderson, S.A. and Connell, D.W. (1999) *Report on Organochlorine Pesticide (OCP) Levels in Australia*. Envirotest, Prepared for Environment Australia, Canberra.

Miller, G.J., Connell, D.W. and Anderson, S.M. (2002) Persistent Toxic Substances in Australia. *Prepared for 1st Technical Working Group Meeting, Region 8, GEF-UNEP Project on Global Assessment of Persistent and Toxic Substances,* 6-8 Feb, 2002, Singapore.

Miller, G.J., Connell, D.W. and Anderson, S.M. (2002a) Health Risk Assessment of Persistent Toxic Substances in Australia. *Prepared for 2nd Technical Working Group Meeting, Region 8, GEF-UNEP Project on Global Assessment of Persistent and Toxic Substances*, 17-19 April, 2002, Penang, Malaysia.

Minh, T.B., Nakata, H., Watanabe, M., Tanabe, S., Miyazaki, N., Jefferson, T.A., Prudente, M. and Subramanian, A. (2000) Isomer-specific accumulation and toxic assessment of polychlorinated biphenyls, including coplanar congeners, in cetaceans from the North Pacific and Asian Coastal Waters. *Archives of Environmental Contamination and Toxicol*ogy **39**, 398-410.

Ministry for the Environment, NZ (2001) Serum Study: A summary of the Finding. www.mfe.govt.nz/issues/waste/organo.htm

Ministry for the Environment, NZ (1998) Reporting on Persistent Organochlorines in New Zealand, Ministry for the Environment New Zealand Report, 1998.

(www.mfe.govt.nz/issues/waste/organochlorines/reporting_on_organochlorines.pdf)

Monirith, I., Nakata, H., Tanabe, S. and Tana, T.S. (1999) Persistent Organochlorine Residues in Marine and Freshwater Fish in Cambodia. *Marine Pollution Bulletin* **38**, 604-612.

Monirith, I., Nakata, H., Watanabe, M., Takahashi, S., Tanabe, S. and Tana, T.S. (2000) Organochlorine contamination in fish and mussels from Cambodia and other Asian Countries, in *Mussel Watch: Marine Pollution Monitoring in Asian Waters*, Ed. S. Tanabe, 129-136.

Mortimer, M.R. and Connell, D.W. (1995) A model of the environmental fate of chlorohydrocarbon contaminants associated with Sydney sewage discharges. *Chemosphere* **30**, 2021.

NAS-NAE (1973). National Academy of Sciences and National Academy of Engineering, Water Quality Criteria, 1972, US EPA Report R3-73-033, US Environment Protection Agency, Washington, DC.

National Environment Agency, Singapore, Country report of PTS, *UNEP-GEF 1st PTS Working Group Technical Workshop*, Singapore, Feb 2002.

Nias, D.J., McKillup, S.C. and Edyvane, K.S. (1993) Imposex in *Lepsiella vinosa* from southern Australia. *Marine Pollution Bulletin* **26** (7), 380-384.

Olsen, P. and Olsen, J. (1979). Eggshell thinning in the Peregrine Falcon, *Falco peregrinus* in Australia. *Australian Wildlife Research* **6**, 15.

Pandey, E. and Evans, S.M. (1996). The incidence of imposex in gastropods from Indonesian coastal waters. *Asian Marine Biology* **13**, 53-61.

Panther, B.C., Hooper, M.A. and Tapper, N.J. (1999) A comparison of air particulate matter and associated polycyclic aromatic hydrocarbons in some tropical and temperate urban environments. *Atmospheric Environment* **33**, 4087-4099.

Phuong, N.T.N., Thuy, T.T. and Phuong, P.K. (1989) An estimate of reproductive abnormalities in women inhabiting herbicide sprayed and on-herbicide sprayed areas in the south of Vietnam, 1952-1981. *Chemosphere* **18** (1-6), 843-846.

Phuong, N.T.N., Thuy, T.T. and Phuong, P.K. (1989a) An estimate of differences among women giving birth to deformed babies and among those with hydatidiform mole seen at the Ob-Gyn Hospital of Ho Chi Minh City in the south of Vietnam. *Chemosphere* **18** (1-6), 801-803.

Pinto, J.P., Grant, L.D. and Hartlage, T.A. (1998) Report on U.S. EPA Air Monitoring of Haze from S.E. Asia Biomass Fires. EPA/600/R-98/071. U.S. Environmental Protection Agency.

Philippines (1996) Philippine Case Study: A Developing Country's Perspective on POPs. *IFCS Meeting on POPs*, 17-19 June, 1996, Manilla, Philippines.

Phillips, D.J.H. (1985) Organochlorines and trace metals in green-lipped mussels Perna viridis from Hong Kong water: a test of indicator ability. *Marine Ecology Progress Ser*ies **21**, 251-258.

Pollution Control Department Thailand Report (1998).

Prudente, M., Ichihashi, H., Kan-atireklap, S., Watanabe, I. and Tanabe, S. (1999) Butyltin, organochlorines and metal levels in green mussel, Perna viridis L. from the coast water of the Philippines. *Fisheries Sciences* **65**, 441-447.

Ramesh, A., Tanabe, S., Subramaniam, N.A. and Venugopalan, K.V. (1990) Persistent organochlorine residues in green mussels from coastal waters of South India. *Marine Pollution Bull*etin **12** (20), 587-590.

Rohani, I., Chan, S.M. and Ismail, I. (1992) Organochlorine pesticides and PCBs residues in some Malaysian shell fish. *Paper presented at the National Seminar on Pesticides in Malaysia Environment*, Kuala Lumpur.

Reitsema, T.J. and Spickett, J.T. (1999) Imposex in Morula granulata as a bioindicator of tributyl tin (TBT) contamination in the Dampier Archipelago, Western Australia. *Marine Pollution Bulletin* **39**, 280.

Rodricks, J. V. (1994) *Calculated Risks. The Toxicity and Human Health Risks of Chemicals in Our Environment*. Cambridge University Press, Cambridge.

Ruangwises, S., Ruangwises, N. and Tabucanon, M.S. (1994) Persistent organochlorine pesticide residues in green mussels (Perna viridis) from the gulf of Thailand. *Marine Pollution Bulletin* **28**, 351-355.

Schecter, A., Dai, L.C., Papke, O., Prange, J., Constable, J.D., Matsuda, M., Thao, V.D. and Piskac, A.L. (2001) Recent dioxin contamination from Agent Orange in residents of a southern Vietnam city. *Journal of Occupational and Environmental Medicine* **43** (5), 435-443.

Schecter, A., Pavuk, M., Dai, L.C., Constable, J.D., Papke, O., Ryan, J.J., Furst, P., Malisch, R., Olie, K., Gross, M., Matsuda, M., Raisanen, S. and Toniolo, P. (2002) Collaborative USA-Vietnamese Agent Orange Research from 1968 to 2002.

Scobie, S., Buckland, S., Ellis, H. and Salter, R. (1999) *Organochlorines in New Zealand: Ambient concentrations of selected organochlorines in estuaries*. Organochlorines Programme Ministry for the Environment Report, 1999.

Shekhar, P.V., Werdell, J. and Basrur, V.S. (1997) Environmental estrogen stimulation of growth and estrogen receptor function in preneoplastic and cancerous human breast cell lines. *Journal of National Cancer Institute* **89** (23), 1774-1782.

Siriwong, C., Hironaka, H., Onodera, S. and Tabucanon, M.S. (1991) Organochlorine pesticides residues in green mussel (Perna viridis) from the gulf of Thailand. *Marine Pollution Bulletin* **32**, 362-365.

Smith, P.J. (1996) Selective decline in imposex levels in the dogwhelk *Lepsiella scobina* following a ban on the use of TBT antifoulants in New Zealand. *Marine Pollution Bulletin* **32** (4), 362-365.

Sunderam, R.I.M., Cheng, D.M.H. and Thompson, G.B. (1992) Toxicity of endosulfan to native and introduced fish in Australia. *Environmental Toxicology and Chemistry* **11**, 1469 – 1476.

Swennen, C., Ruttanadakul, N., Ardseungnern, S., Singh, H.R., Mensink, B.P. and Ten Hallers-Tjabbes, C.C. (1997) Imposex in sublittoral and littoral gastropods from the Gulf of Thailand and Strait of Malacca in relation to shipping. *Environmental Technology* **18** (12), 1245-1254.

Tanabe, S., Prudente, M.S., Kan-atireklap, A. and Subramanian, A. (2000) Mussel watch: marine pollution monitoring of butyltins and organochlorines in coastal waters of Thailand, Phillipines and India. *Ocean and Coastal Management* **43**, 819-839.

Tan, E.C. (2001) Development of analytical method for persistent organic pollutants in fresh water using solid phase extraction. Ph.D Dissertation, Universiti Sains Malaysia.

Taylor, C.M., Henderson, M.A., Scurry, J., Venter, D., Probert, W. and Fairclough, R.J. (1999) Are organochlorine pesticides a risk factor for breast cancer? *Environmental Health Review – Australia*. May 1999. 35.

UNEP/GEF (2001) Regionally Based Assessment of Persistent Toxic Substances. United Nations, Geneva.

US-EPA (2000) Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds – Parts I and II. United States Environmental Protection Agency.

Westing, A.H. (Ed.) (1984) *Herbicides in War. The Long Term Ecological and Human Consequences*. Taylor and Francis, London. pp. 3-24.

Whyte, R.J. and Conlon, M.L. (1983) Cotton Growing and the Environment. Technical Report prepared for the State Pollution Control Commission, Sydney.

Zheng, T., Holford, T.R., Mayne, S.T., Ward, B., Carter, D., Owens, P.H., Dubrow, R., Zahm, S.H., Boyle, P., Archibeque, S. and Tessari, J. (1999) DDE and DDT in breast adipose tissue and risk of female breast cancer. *American Journal of Epidemiol*ogy **150**, 453-458.

4. ASSESSMENT OF MAJOR PATHWAYS OF CONTAMINANT TRANSPORT

4.1. Introduction

Substances having environmental persistence and occurring widely in ecosystems have been generally described as persistent lipophilic contaminants (PLCs), persistent organic pollutants (POPs) or persistent toxic substances (PTS). For a toxic substance to be transported and become widely distributed in the global environment, particularly in the air and water, remote from specific sources, it must have specific properties related to volatility, usually measured as the Henrys Law constant, solubility in fat, measured as the octanol/water constant, and environmental persistence, measured as the half-life in air, soil and water.

Most of the substances in this group are the semivolatile and persistent chlorohydrocarbon pesticides, such as DDT, HCHs, dieldrin and chlordane, and industrial chlorohydrocarbons such as the PCBs and HCB. These substances have been detected throughout environmental compartments and have been found to be bioaccumulative in lipid-containing tissues in some of the first investigations of environmental contaminants (Woodwell *et al.,* 1971). In addition, there have been combustion product residues detected, consisting principally of the PCDD and the PCDF, which share the persistent, lipophilic and bioaccumulative properties of the chlorohydrocarbons (Rappe *et al.,* 1978).

Thus, currently the following substances are usually considered to be globally important PTS with the potential for regional transport: chlordane, DDT, dieldrin, endrin, heptachlor, HCB, HCHs including lindane, mirex, PCBs, PCDD, PCDF and toxaphene. In recent years, residues of such substances as the PAHs, endosulfan, atrazine and many other substances have been detected in many sectors of the environment and share many of the attributes of PLCs (e.g. Yang *et al.*, 1991).

Investigations and studies in the 1980s and 1990s have identified long-range transport, primarily in the Northern Hemisphere, as a mechanism that is important in the distribution of PTS. Recent studies have focused on the global distribution and hypotheses such as the "grasshopper effect" have been proposed to explain the nature of the distribution of some PTS from lower to higher latitudes (e.g. equatorial to polar regions) (Mackay and Wania, 1995).

The significance of the usage patterns and distributions of PTS and other related compounds within countries and geographical regions of the Southeast Asian and South Pacific region remains much less clear. The evaluation of transboundary transport is a major objective of the UNEP-PTS project. An outline of how this could be carried out has been provided by Wania as prepared for UNEP-Chemicals (WECC Wania Environmental Chemists Corp, 2001).

Basically this approach uses fugacity modelling to evaluate the distribution processes and obtain some estimation of the inputs into and out of a region. Fugacity is not a new concept but Macka*y* first applied it to modelling the behaviour of chemicals in the environment in 1979 (see Mackay and Paterson, 1981). Fugacity is related to pressure and can be conceived as the "escaping tendency" of a substance from any given phase and for a single substance will vary from phase to phase. Chemicals tend to partition from phases in which they have a high fugacity to those where their fugacity is low. When equilibrium is attained the fugacities in each phase are equal as are the "escaping tendencies".

4.2. Regionally specific features

4.2.1. Observations on the Properties of the PTS

In considering regionally specific features some observations on the occurrence of the PTS relevant to transboundary movement in the region can be made. It is difficult to make valid comparisons of concentrations of the PTS in the different parts of the region due to a lack of data and differences in such factors as: (1) specific local contamination situations; (2) latitude; (3) the nature of the sample taken; and (4) the sampling time. By considering these factors and taking into account investigations on a broader geographical scale, it is possible to make comparisons and evaluate trends with different substances that are relevant to transboundary transport.

4.2.1.1. Hexachlorobenzene (HCB) and Hexachlorocyclohexane (HCH)

The global occurrence of HCB in plant biomass was investigated by Calamari *et al.* (1991). These authors observed that polar areas are higher in HCB than tropical areas. This is presumably due to the volatility of HCB and its consequent movement towards the poles, with condensation in the colder regions.

In the case of the HCHs, the available data suggest an influence of latitude on concentrations in both the abiotic environments, and plant biomass. The usage of HCH in the tropics (Iwata *et al.*, 1993), especially in India and some countries in Southeast Asia, appears to be responsible for the relatively higher concentrations of HCH in tropical areas. Simonich and Hites (1995) have shown that a correlation exists between latitude and concentrations of HCH and HCB in tree bark samples. In addition, it has been shown (Calamari *et al.*, 1991; Iwata *et al.*, 1993) that much higher levels of the HCHs occur in the Northern Hemisphere. This is obviously due in part, at least, to extensive sources of input with areas such as the Arabian Sea and Bay of Bengal having concentrations of HCHs in atmospheric samples of over 10,000 pg/m^3 (Iwata *et al.*, 1993).

The levels of HCHs in the ocean atmosphere and hydrosphere around Australia and the Southern Ocean have been shown to be significantly lower than those in the Southeast Asia region (Tatsukawa *et al.*, 1990) for an eleven year period to 1985. In contrast, however, are the findings of Weber and Montone (1990), and Kurtz and Atlas (1990). Weber and Montone (1990) found that the levels of HCHs were of the same order of magnitude in air over the Southern Ocean as in other world oceans.

4.2.1.2. Polychlorinated Biphenyls (PCBs)

The levels of PCBs in various sample types appear to depend largely on the influence of local sources of contamination. The cases of PCB contamination observed in the region seem to be hot spots related to local sources that are principally urban areas. PCBs in general are less volatile than HCHs and HCB and consequently are less influenced by the global distillation process and tend to remain reasonably close to the source. It has been estimated, however, by Tanabe and Tatsukawa (1986), that the Northern Hemisphere ocean environment contains about 150,000 tons of PCBs which is about two thirds of the global load.

4.2.1.3. DDT

A similar situation is observed with DDT as with the PCBs where obvious hot spots occur, in particular in several areas and countries in the tropical part of the region.

4.2.1.4. Endosulfan

This substance does not seem to be globally distributed since it has not been reported from locations remote from sources and concentrations are generally location specific and depend on local usage patterns (Gregor and Gummer, 1989).

4.2.2. Interhemispheric Mixing of PTS

The effects of atmospheric circulation patterns and oceanic currents are important in understanding the role of transboundary movement patterns on the distribution of PTS both in the region and the globe. For instance, it is widely accepted that global distillation is a major process involved in the deposition of volatile PTS such as the HCHs at the poles (Wania and Mackay, 1996). Barrie *et al.* (1992) however, have concluded that both the atmosphere and the ocean currents are the major transport mechanisms that must operate in conjunction with global distillation for the movement of PTS.

Important findings from the work of Levy (1990) are: atmospheric transport in the east-west direction will increase with height; air parcels will subside in the tropics; and air passing between hemispheres will rise in the tropics and be exposed to precipitation produced by the lifting of the moist tropical air. In the Southern Hemisphere, particularly Australia and New Zealand, the prevailing winds are the south-easterly trades which blow towards the equator. Little interhemispheric mixing occurs due to the presence of Hadley cells over the tropics (Levy, 1990). The thermally directed Hadley cells produce a strong upward flux in the tropics and subsiding flux in the subtropics, with little interhemispheric mixing as a consequence.

It appears that as a general rule, PTS are lifted in the atmosphere in the tropics, and move polewards due to atmospheric and water movements and exhibit the global distillation effect. However, because of the presence of Hadley cells in the tropics and very low north-south velocities, little interhemispheric mixing occurs. Irrespective of season, on a global basis, the major feature is a converging surface flow in the tropics that is coupled to a vigorous rising motion in the region that results in strong precipitation. This region has been called the intertropical convergence zone (ITCZ) (Levy, 1990) and forms a strong barrier to transport of chemicals between the hemispheres. This would be expected to have a major influence on the movement of PTS in the Southeast Asia South Pacific resulting in little movement from Australia and New Zealand to Southeast Asia and vice versa. Thus it would be expected that bush and forest fires would produce smoke haze that would not be subject to movements across the equator.

The effect of ocean currents on transport between Southeast Asia and Australia and New Zealand has the potential to be important through direct movement and through flux of contaminants between the atmosphere and ocean surface water (Iwata *et al.*, 1993). The potential for interhemispheric mixing varies between PTS. For instance, HCH concentrations in surface water are highest in the high latitudes of the Northern Hemisphere (Iwata *et al.*, 1993), and significant mixing would not be expected to occur. In contrast, the highest levels of DDTs are in surface water in tropical Asia (Iwata *et al.*, 1993; Iwata *et al.*, 1994), and offer a potential for transport south in the region.

A consideration of the ocean currents of the world indicates that the major currents in the Southern Hemisphere circulate in an anticlockwise direction and in a clockwise direction in the Northern Hemisphere. The Pacific, Atlantic and Indian equatorial counter currents run along the equator. This situation does not facilitate significant mixing of Northern and Southern Hemisphere waters in the region leading to a division of the region into two sub-regions roughly separated by the equator. Within these sub-regions, contaminants would be expected to have substantially independent movement patterns.

4.3. Overview of existing modelling programs and projects

Connell and Hawker (1986) have used a fugacity model at the first level, i.e. without accounting for any other factors than the partitioning characteristics, to calculate the distribution of chemicals in the Canberra environment as shown in Table 4.3.1.

Table 4.3.1. Hypothetical distribution and concentration of some representative chemicals in the Canberra environment (adapted from Connell and Hawker, 1986)

	DDT		Hexachlorobiphenyl	
	μg/kg*	% moles#	μg/kg*	% moles#
Air	4.6×10^{-3}	0.4	1.0×10^{-1}	7.5
Water	4.9×10^{-3}	5×10^{-2}	2.0×10^{-4}	2×10^{-3}
Soil	47.5	86.7	44.5	80.0
Suspended sediments	142	0.2	134	0.2
Sediment	142	12.7	134	11.7
Aquatic biota	376	2×10^{-3}	354	2×10^{-3}
Vegetation	151	0.6	141	0.6

* In a single phase

Percentage distribution of the compound between all phases.

The results indicate that the soil and atmosphere are the major repositories on a mole percentage basis. On a concentration basis, the largest values for the selected compounds are found in the aquatic biota and vegetation with the highest concentrations being consistently found in the aquatic biota.

A more advanced fugacity model (Mackay and Wania, 1995) which takes into account additional environmental factors including degradation and advection has been used to model the PTS in discharges in Victoria Harbour, Hong Kong (Connell *et al.*, 1998) and in the oceanic discharges offshore from Sydney, Australia (Mortimer and Connell, 1996).

4.4. Transport Patterns of PTS in the Region

The concentrations reported in the atmosphere by Iwata *et al.* (1994) can be taken as a general indication of the presence of a PTS in the associated land area during the period of the survey, 1989-1991, as shown in Figure 4.4.1. This indicates that relatively high concentrations of HCHs were present in Calcutta, India (11,000 μg/m^3) and also Viet Nam (12,000 μg/m^3). Iwata *et al.* (1994) suggest this is probably due to the use of these substances in mosquito control for public health purposes. Atmospheric DDT and CHL levels were highest in India and generally lower elsewhere in the region. PCBs exhibited a distribution suggesting an association with urban areas in the region.

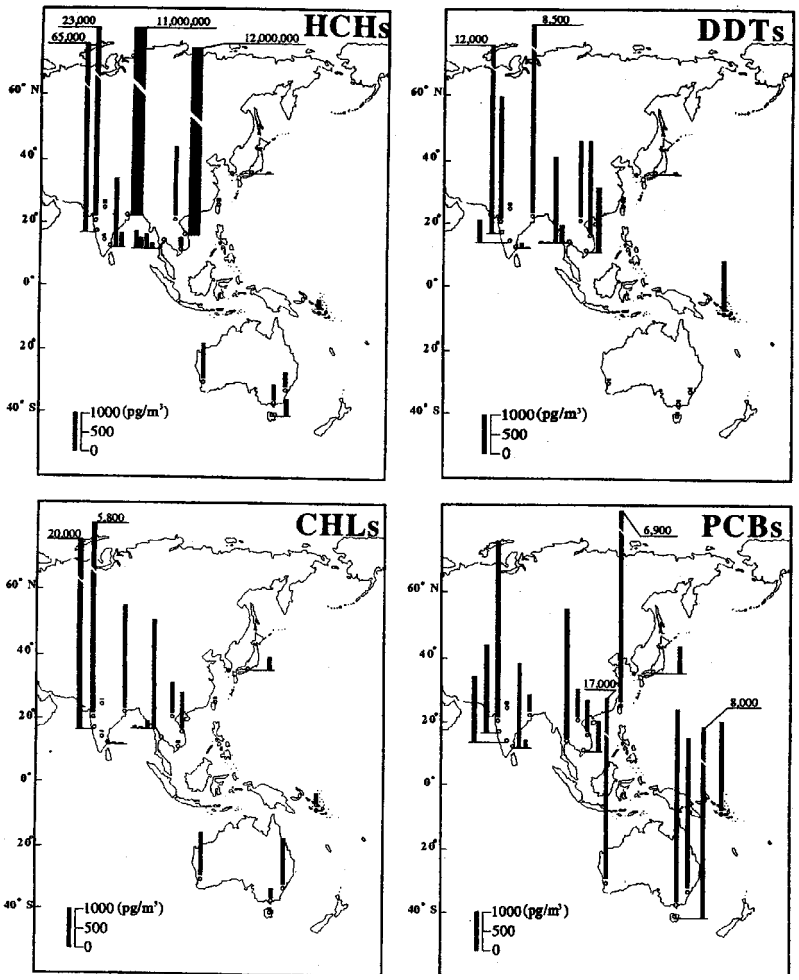


Figure 4.4.1. Distributions of persistent toxic substances in river and estuarine air from the eastern and southern Asia and Oceania region
From Iwata *et al.* (1994)

The water and air movements are the most significant for the transport of PTS in the region. The atmospheric distributions indicate relatively high concentrations of HCH in the Southeast Asia region and thus potential for transport out of this area. The water concentrations found by Iwata *et al.* (1994) in the Southeast Asia South Pacific region are shown in Figure 4.4.2. Several relatively high concentrations are attributed to the Southeast Asia region with Selangor, Malaysia reported to have

1,900,000 pg/L HCH, Ayutthaya, Thailand, 75,000 pg/L HCH as well as 25,000 pg/L DDTs with 8000 pg/L PCBs reported for Hui, Viet Nam.

The movements of aquatic biota such as fish and birds do not make a significant contribution to the overall movement patterns of PTS. This is illustrated by the data in Table 4.3.1 where aquatic biota contain a total percent of 0.002 of two common PTS. However, fish and birds can accumulate relatively high concentrations of PTS and then move outside the region where this may exhibit adverse effects.

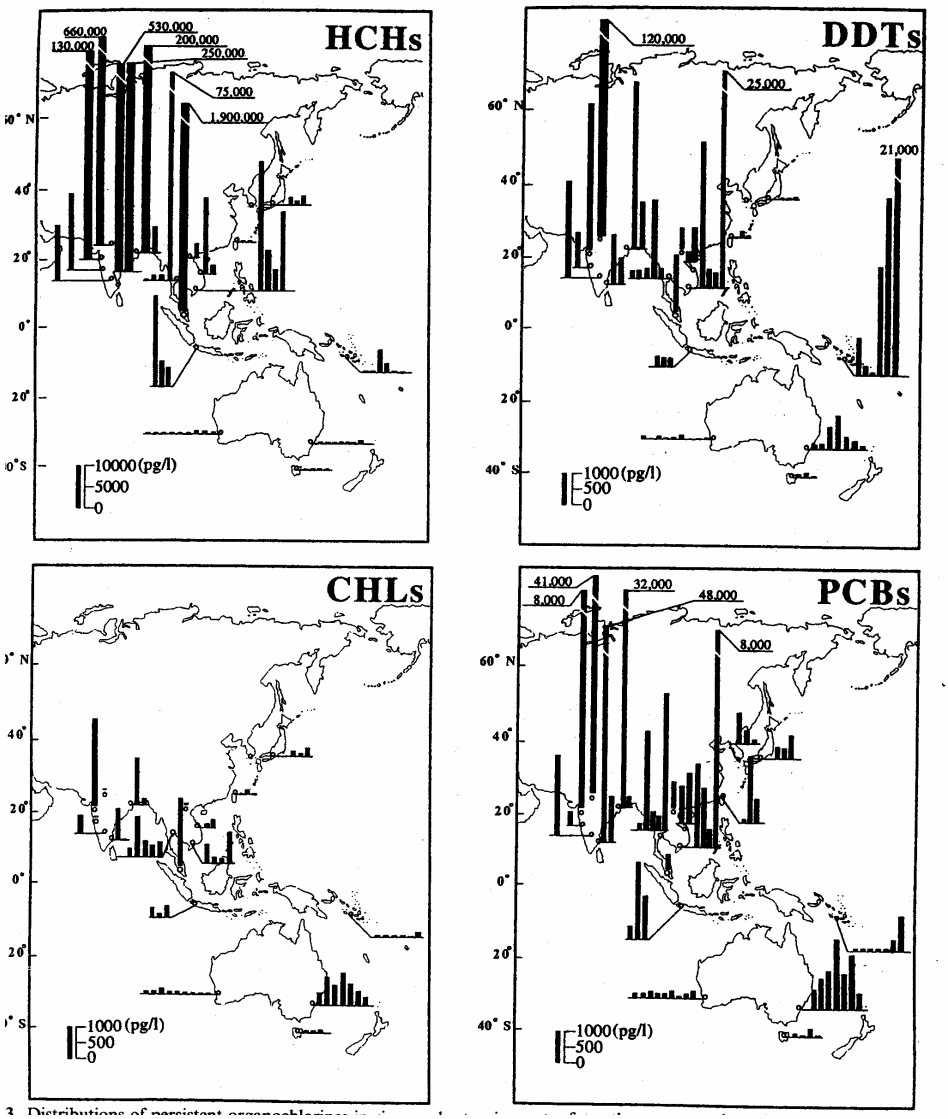


Figure 4.4.2. Distributions of persistent toxic substances in river and estuarine water from the eastern and southern Asia and Oceania region
From Iwata *et al.* (1994)

4.5. Modelling the Transport of PTS in the Region

4.5.1. The Study Area

As outlined above, the Southeast Asia South Pacific Region comprises two sub-regions in terms of the movement of air and water. The atmospheric tropical convergence zone and the equatorial convergence zone of the ocean currents effectively divide the region into two separate sub-regions, which can be referred to as the Southeast Asia sub-region and the Australia New Zealand sub-region.

In section 4.4, Southeast Asia was identified as having the potential to transport PTS out of the region into other regions, particularly those to the north-east. For these reasons, Southeast Asia has been subject to evaluation of the patterns of movement of PTS using fugacity modelling techniques basically as suggested by Wania (WECC Wania Environmental Chemists Corporation, 2001).

The study area covers South Esat Asia and surrounding water areas as shown in Figure 4.5.1 with the dimensions and volumes of the various environmental compartments as compiled in Table 4.5.1

Figure 4.5.1. Map of the Southeast Asia study area used in the fugacity modelling.

4.5.2. Fugacity Modelling

Fugacity modelling was developed by Mackay and co-workers and has been the subject of a series of papers and books (e.g. Mackay *et al.,* 1992). The models used in previous investigations were an equilibrium model described as a Level I model and a steady state non-equilibrium model described as a Level III model. These have been used successfully in previous investigations based on offshore Sydney, Australia (Mortimer and Connell, 1996) and Victoria Harbour, Hong Kong (Connell *et al.,* 1998). Both the Level I and Level III models have been applied to the study area in order to develop an understanding of the movements and distributions of the PTS in this area.

The models which were applied to the study area, in Figure 4.5.1, were the equilibrium Level I model based on the PTS distributing into air, water, sediment, suspended sediment, aquatic biota, soil and

terrestrial vegetation and a Level III model also based on environmental distribution with consistent discharges to and emissions from the study area and contaminant degradation to form a steady state.

Discharges to the study area could be expected to arise from a divergent set of sources including use in agriculture, emissions from urban areas, sources in other regions and so on. The information on these sources is extremely limited and is insufficient to allow quantification. Losses are principally due to advection and chemical degradation by environmental processes such as oxidation and hydrolysis. Total discharges and losses to the study area were estimated using the Level III model.

Table 4.5.1. Dimensions of the compartments in the model

Compartment	Subcompartment	Volume (m^3)	Depth, h (m)	Area, A (m^2)
air	air	1.21×10^{16}	1000	1.21×10^{13}
water	water	1.714×10^{14}	20	8.57×10^{12}
	suspended sediment	1.00×10^{6}		
	biota (fish) (lipid content 5%)	2.00×10^{5}		
soil	soil (organic matter 5%)	3.53×10^{11}	0.1	3.53×10^{12}
bottom sediment	solids (organic matter 10.3%)	2.536×10^{11}	0.01	8.57×10^{12}
vegetation	grassland and pasture crops (lipid content 1%)	1.13×10^{10}		9.02×10^{11}
	forest (lipid content 1%)	2.40×10^{10}		1.92×10^{12}
	total	3.53×10^{10}		2.82×10^{12}

The models used were based on the approach used by Mackay *et al.* (1992) and developed in a spreadsheet format as described previously in Mortimer and Connell (1996) and Connell *et al.* (1998). The model area is shown in Figure 4.5.1 and has the dimensions as shown in Table 4.5.1 while the environmental variables used are shown in Table 4.5.2. The PTS modelled and their physicochemical characteristics are shown in Table 4.5.3. Where mixtures are involved, such as PCB1254, average characteristics have been used while with others the major typical component has been used as the basis of the characteristics. Of course the model will be sensitive to changes in these characteristics and so the accuracy of these data is important in obtaining a representative operation of the model.

Input to the model also included the total amount of the substance in the whole system, which was obtained by running the model at Level I to obtain the proportion of the contaminant in the sediments as compared to the whole system. The amount was obtained by multiplying the average concentration in the sediment by the volume of sediment, from Table 4.5.1, and the proportion in the whole system to obtain the total amount in the system (see Table 4.5.4).

Table 4.5.2. Values for environmental variables used in the fugacity model

Variable	Value Used	Source
Aerosol volume fraction	2×10^{-11} volume of air	Mackay *et al.* (1992)
Air advection (wind)	23 km/h net removal rate	Collated data
Biota (fish) weight per unit area	89 kg/hectare	
Suspended sediment concentration	13.1 g/m^3	Collated data
Suspended sediment density	1500 kg/m^3	Mackay *et al.* (1992)
Bottom sediment active layer	0.01 m solids	Mackay *et al.* (1992)

Bottom sediment burial rate	solids residence time in active layer of 5 x 10^4 h	Mackay *et al.* (1992)
Aerosol deposition	6 x 10^{-10} m/h	Mackay *et al.* (1992)
Sediment deposition	5 x 10^{-7} m/h	Mackay *et al.* (1992)
Sediment resuspension	2 x 10^{-7} m/h	Mackay *et al.* (1992)
System temperature	28^0 C	Collated data
Annual rainfall	2.2 m/year	Collated data

Table 4.5.3. Physicochemical properties and degradation rates of PTS contaminants used in the fugacity model

Compound	Log K_{ow}	Molecular weight (g/mo1)	Melting point (^{o} C)	Aqueous solubility[a] (g/m^3)	Vapour pressure[b] (Pa)	Half-life Air (h)	Water (h)	Sediment (h)
Chlordane	6.00	409.8	106[c]	0.056[c]	0.000459[c]	28.5[d]	19500[d]	20000d
DDT	6.36	354.5	108.5[e]	0.0031[e]	0.00002[e]	97.4[d]	4280[d]	78800[d]
Hexachloro-benzene	6.18	284.8	230[h]	0.005[h]	0.0023[h]	17000[h]	55000[h]	55000[h]
Lindane (δ-HCH)	3.61	290.8	113	7.3	0.00005	51	3050	3050
PCB (Aroclor 1254)	6.40	327	i	0.043[j]	0.0000294[j]	1700[h]	55000[h]	55000[h]

[a] Solubility of solid at 25° C except where indicated, [b] Vapour pressure of solid, at 25° C except where indicated, [c] Mean of cis- and trans- forms, from Howard (1991), [d] Mean value of range in Howard *et al*. (1991), [e] Mackay (1991), [f] Howard *et al*. (1991), [g] At 20° C, from Howard (1991), [h] Mackay *et al*. (1992), [i] Compound is a viscous liquid at relevant temperature, [j] At 20° C.

Table 4.5.4. Measured concentrations and calculated total amounts of PTS in the regional environment

Compound	Mean Sediment Concentration * (µg/kg)	Percent of Total **	Amount in Sediment (kgx10^6)	Total Amount (kgx10^6)
Chlordane	20.8	49.1	3.5	7.2
DDT	69.8	13.3	149.0	112.3
HCH	1.74	2.3	0.4	16.2
PCB	112.0	13.2	24.0	182.0

* From averages based on Iwata *et al*. (1993)

** Calculated using a Level I model.

The parameters obtained as above were entered into the model and the results of the model calculations are shown in Table 4.5.5. The distributions agree with the properties of the compounds. HCH, which has the highest aqueous solubility, has the largest proportion of the substance in the aqueous phase with lesser proportions in the other phases. The other compounds, chlordane, DDT and the PCBs are much less soluble in water and have much higher solubility in lipids and organic matter. These substances have a much lower proportion in the aqueous phase and relatively higher proportions in the sediments and soil. The concentrations of the PTS calculated by the model are shown in Table 4.5.5 and are in reasonable agreement with the observed concentrations. The agreement between the predicted and observed concentrations suggests that the model provides a reasonable evaluation of the behaviour of the substances in the Southeast Asian environment.

Table 4.5.5. Model predictions of distributions and regional water concentrations *

Compound	Distribution (% amount)					Regional Water Concentrations (pg/L)	
	Air	Water	Sediment	Soil	Vegetation	Observed **	Calculated
Chlordane	0.02	2.0	49.1	40.5	8.2	482 (45-21,000)	833
DDT	0.05	0.8	13.3	78.0	7.9	1,054 (190-25,000)	5020
HCH (Lindane)	0.002	82.6	2.3	13.6	1.4	26,800 (180-1,900,000)	74,600
PCB	0.29	0.48	13.2	77.9	7.9	1,850 (380-8000)	6450

* Calculated using a Level I fugacity model

** Regional averages based on the data in Iwata *et al*. (1993) for freshwater, estuarine water and seawater

4.5.3. Application of the Modelling Outcomes to Evaluation of Transport

The data in Table 4.5.4 indicate that even though the concentrations of PTS are relatively low, there are significant total amounts of these PTS in the Southeast Asian environment. There are almost equal amounts of DDT and PCB residues present totalling HCH (16.2 x 10^6 kg) and 112.3 x 10^6 kg (DDT) and 182.0 x 10^6 kg (PCB) as well as lesser quantities of chlordane (7.2 x 10^6 kg). This would be expected to reflect, to some extent, the usage of these substances in the study area. These data are in general accord with the data on production of these PTS throughout the world produced by Voldner and Li (1995).

The data in Table 4.5.6 record some of the concentrations in seawater measured throughout the world. These values are somewhat lower than the values in Table 4.5.5 since these data include inland aquatic areas, which have considerably higher values than seawater. The average and single concentrations available for the South China Sea, Strait of Malacca and the Celebes Sea, which are marine areas throughout the study area, show a relatively limited range of values. However it is important to identify the movements of seawater in the study area to obtain a clearer picture of the transport of PTS out of the area.

Table 4.5.6. Concentrations of PTS in seawater in the Southeast Asia study area and elsewhere

Sampling Location	HCHs (pg/L)		Chlordanes (pg/L)		DDTs (pg/L)		PCBs (pg/L)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
North Pacific (n=8)	250	75-550	7.6	3.8-14	1.2	0.3-2.8	24	9.1-63
North Pacific (Phillipines)	nr		9		2		30	
South China Sea (n=6)	480	73-910	12	1.9-21	6.9	3.5-12	17	9.6-33
Strait of Malacca (n=1)	480		9.4		6.4		20	
Celebes Sea (n=1)	280		5.1		2.6		20	
Java Sea (n=1)	58		2.8		5.6		22	
Eastern Indian Ocean (n=5)	94	54-170	7.5	2.4-15	2.1	1.3-4.3	21	9.7-42
Southern Ocean (n=5)	36	23-54	4.2	2.4-5.6	1	0.6-1.5	8.3	4.6-10
North Atlantic (n=4)	140	80-170	5.5	4.1-8.3	0.8	0.7-0.9	26	21-29

From Iwata *et al*. (1993) and Iwata *et al*. (1994)

Since the air and water phases contain PTS in solution, the transport of these substances is going to relate to water and air currents in the study area. Thus, an important variable to be considered in evaluating the transport of PTS is the advective flow of air and water in the study area. A typical air flow was derived from collated data from the region and used in the model as shown in Table 4.5.2. Water movements in the South China Sea are of particular importance since this area is close to the region of highest contamination and is subject to systematic patterns of oceanic water movement leading to discharges from the South China Sea to the Pacific Ocean. Chen *et al* 2001) studied water movements in the South China Sea and the results obtained are shown in Table 4.5.7.

Of particular importance in these data is the surface movements of the Kuroshio Current, which partially enters the South China Sea during the wet season under the influence of the persistent winds of the south-west monsoon. This movement displaces water already containing contaminants in the South China Sea into the Taiwan Strait and also into the Bashi Strait. This latter water movement passes into the Pacific Ocean and moves towards the north-east as shown in Figure 4.5.2 joining the main Kuroshio current. A more limited movement of a somewhat similar pattern seems to occur in the dry season but this has not been taken into account since the quantities are too small to allow appropriate quantification. In these considerations the movements of the surface waters (to a depth of 350m) are of prime importance since the contaminants will be contained in these waters. However it should be kept in mind that movements of subsurface waters occur in this system but these are not relevant to these calculations.

The surface advective movement during the wet season was quantified by averaging the movement into the South China Sea, the Kuroshio at +12.8 x 10^6 m^3/second, and the South China Sea (Bashi Channel) movement out of the basin, - 13.9 x 10^6 m^3/second, and assuming the upper 6 m of the 350 m depth of water contains the contaminant to give 8.04 x 10^8 m^3/ hour. This was entered into the Level III model spreadsheet as the water advective flow. There is no doubt there are other flows of a sustained nature out of the study area but insufficient information is available on them to allow an entry into the model. This indicates that the advective flow out of the study area will most likely be underestimated.

Table 4.5.7. Sea surface (to 350 m depth) flows in the South China Sea Basin*

(Chen *et al.*, 2001)

Zone/Origin	Net Flow (m^3x10^6)	
	Dry Season**	Wet Season***
River Inflow	+0.03	+0.08
Sanda Shelf	-3.0	+1.8
Mindoo Strait	+1.0	+0.2
Taiwan Strait	-0.2	-0.5
South China Sea (Bashi Channel)	-1.8	-13.9
Kuroshio	+4.7	+12.8
Sunda Shelf	-1.8	-2.0
Malacca Strait	0	0

* positive signs indicate movement into the South China Sea and negative the opposite

** the period from November to April when the north-east monsoon occurs

*** the period from May to October when the south-west monsoon occurs

The parameters, as outlined above, were entered into the Level III model and the calculated results are shown in Table 4.5.8. By comparison with the discharges to the area, it can be seen that the advective losses of PTS due to movement of both water and air account for only a small proportion of the losses from the study area. This could be higher if more advective flows through the area could be identified but, under any circumstances, will not account for the losses from the area due to degradation. The data also indicate that advective losses due to water movement are much greater than those due to air movements. This is particularly true with HCH, which has a comparatively high loss rate from the study area due to water movements. In addition the data show that HCH transport in water, and overall, exceeds the other PTS, probably due to its greater water solubility. Although DDT and the PCBs have major quantities present as residues in the environment in the area, these substances seem to have a much lesser tendency to be transported out of the area than the HCH.

4.5.4. Interpretation of the Modelling Outcomes

The data of Iwata *et al.* (1993) show a chain of consistent HCH air and water concentrations extending from the South China Sea to the north Pacific Ocean, running with the Kuroshio Current, which agrees with the results above. On the other hand the pattern of distribution of DDT found by these researchers does not indicate significant movement from the South China Sea and this is also indicated by the modelling results. The patterns of chlordane and PCB distribution are somewhat similar and differ from those already considered in that there is a consistent distribution of chlordane and PCB concentrations throughout most of the world.

The data produced by this modelling suggests that chlordane and the PCBs have little capacity for transregional transport and this pattern arises due to the ubiquitous nature of chlordane and PCB contamination. PCB contamination is associated with numerous uses and generally originates from urban areas. The air and water concentrations of most of the PTS generally exhibit a drop to relatively low concentrations, starting from the equator and moving into the Southern Hemisphere. However while this pattern is apparent with chlordane and the PCBs in the atmosphere, it is not apparent with the water concentrations. The reasons for this are unclear. With this exception the overall pattern of PTS concentrations is in agreement with the presence of a barrier to movement due to the oceanic and atmospheric convergence zones around the equator.

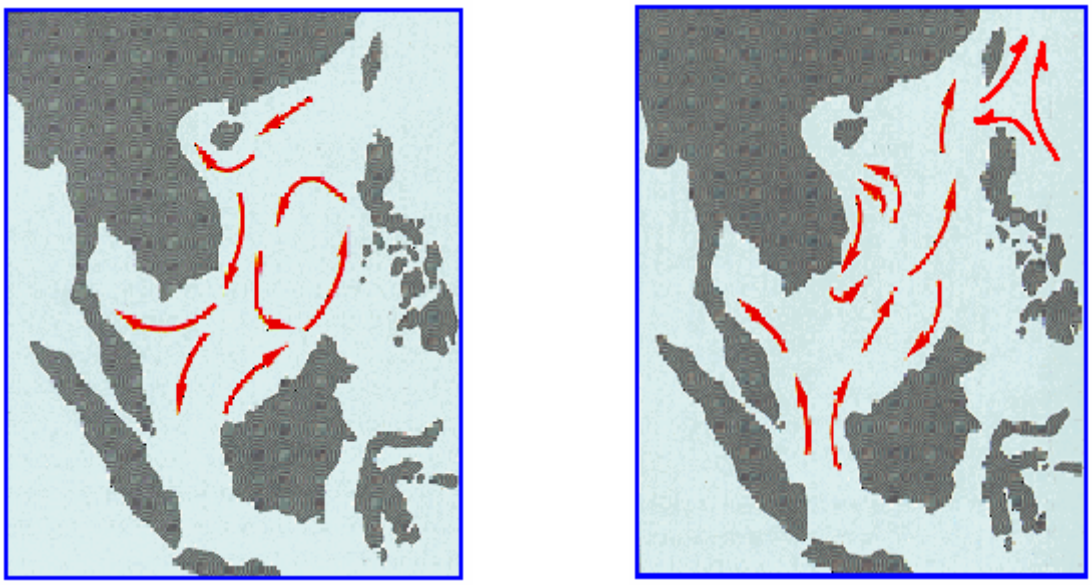
The total quantities of the PTS in the study area have been quantified as shown in Table 4.5.4. However the data are insufficient to quantify the discharges and losses to the study area but these can

be estimated using the Level III model as shown in Table 4.5.8. Discharges introduce substances that are not currently in the partitioning system and occur as a result of the following processes:

- agricultural usage
- urban discharges
- emissions from disposal of waste chemicals
- emissions from urban wastes
- industrial emissions
- transport in air and water from other regions
- other processes

These are difficult to quantify and only possible total discharges are shown in Table 4.5.8. However some general observations can be made regarding transport from other regions. These data indicate that the water phase is the major medium for the advective movement of PTS in the environment. There are relatively high concentrations of some PTS in the South Asia region to the west of Southeast Asia as shown in Figures 4.4.1and 4.4.2. In addition there are ocean currents that run from west to east in the Bay of Bengal, which may transport PTS into the study area. But the route for water currents into the South China Sea is very limited. The Malaysian Peninsula and Sumatra provide a land barrier with only the Malacca Strait available for entry of ocean currents. The data in Table 4.5.7 indicate that there is little flow of seawater through this strait. Thus this is no major water route for water from the west to enter the South China Sea. This suggests that transport of PTS from South Asia would be limited.

Losses from the study area are also difficult to measure directly but can be estimated overall as presented in Table 4.5.8. Losses are principally due to degradation of the compounds by hydrolysis and oxidation but advection is also important as well as other processes.



North-east monsoon (dry season) South-west monsoon (wet season)

Figure 4.5.2. Diagrammatic illustration of the flows of seawater in the South China Sea in the different seasons

Table 4.5.8. Calculations of discharges* into and advective losses from the study area

Compound	Total Residue (kgx10^6)	Calculated Discharges Into Study Area (kg/day)	Calculated Water Advective Losses (kg/day)	Calculated Atmospheric Advective Losses (kg/day)
Chlordane	7.2	3190	16	1.9
DDT	112.3	620	97	0.56
HCH	16.2	3040	1442	0.007
PCB	182.0	19,400	125	1.00

* Calculated using a Level III model

4.6. Data Gaps

- Data are needed to quantify the inputs, uses and disposal of PTS in individual countries and the region. Information is very limited and insufficient to allow quantification.
- Better information on movements of seawater, and other pathways, in the region should be obtained to provide a clearer picture.
- Current data on levels and distribution of PTS in environmental media in the region are needed to update effects of bans on some PTS and provide a comprehensive baseline on PTS.

4.7. Summary

This analysis leads to the following conclusions regarding PTS transport in the Southeast Asia and South Pacific region:

- The Southeast Asia sub-region of the Southeast Asia and South Pacific region can be considered as a separate area in relation to transport of PTS due to the presence of ocean current and atmospheric convergence zones around the equator.
- There is no evidence for Australia and New Zealand as sources of PTS that could be transported to other areas.
- Fugacity modelling indicates that the relatively high concentrations of HCH in air and water in parts of the Southeast Asia region provide a reservoir for transport to other areas.
- Fugacity modelling also indicates that water movements are more important than atmospheric movements for PTS transport and these favour transport out of the region towards the north-east in the Kuroshio Current.
- Transport of PTS out of Southeast Asia towards the south is inhibited by the equatorial ocean and atmospheric convergence located approximately on the equator.
- The “global distillation” effect favours movement of HCH to the north-east.
- There are relatively large potential sources of DDT and PCBs in the region but fugacity modelling suggests that transport out of the region is not occurring on a significant scale and this is supported by the existing environmental data.

- Due to the lack of a water current route there is probably little transport of PTS from South Asia, where high contamination occurs, to Southeast Asia.

This analysis is based on results obtained in the period 1989 to 1991. The situation may have changed during the period up to the present time, as the uses of the PTS modelled have been banned, restricted or phased out in the region.

4.8. References

Barrie, L.A., Gregor, D., Hargrave, B., Leke, R., Muir, D., Shearer, R., Tracey, B. and Bidleman, T. (1992) Arctic contaminants: sources, occurrence and pathways. *The Science of the Total Environment* **122**, 1-5.

Calamari, D.C., Bacci, E., Focadi, S., Gaggi, C., Morosini, M. and Vighi, M. (1991) Role of plant biomass in the global environmental partitioning of chlorinated hydrocarbons. *Environmental Science and Technology* **25**, 1489-1492.

Chen, C.A., Wang, S.L., Wang, B. and Pai, S. (2001) Nutrient budgets for the South China Sea basin. *Marine Chemistry* **75**, 281-300.

Connell, D.W. and Hawker, D. (1986) Predicting the distribution of persistent organic chemicals in the environment. *Chemistry in Australia* **53**, 428-431.

Connell, D.W., Wu, R.S.S., Richardson, B.J., Lam, P.K.S., Leung, K. and Connell, P.A. (1998) Fate and risk evaluation of persistent organic contaminants and related compounds in Victoria Harbour, Hong Kong. *Chemosphere* **36**, 2016-2030.

Gregor, D.J. and Gummer, W.D. (1989) Evidence of atmospheric transport and deposition of organochlorine pesticides and polychlorinated biphenyls in Canadian Arctic snow. *Environmental Science and Technology* **23**, 561-566.

Howard, P.H. (1991) *Handbook of Environmental Fate and Exposure Data for Organic Chemicals – Volume III, Pesticides.* Lewis Publishers, Chelsea, Michigan.

Howard, P.H., Boethling, R.S., Jarvis, W.F., Meylan, W.M. and Michalenko, E.M. (1991) *Handbook of Environmental Degradation Rates.* Lewis Publishers, Chelsea, Michigan.

Iwata, H., Tanabe, S., Sakai, N. and Tatsukawa, R. (1993) Distribution of persistent organochlorines in the oceanic air and surface seawater and the role of ocean on their global transport and fate. *Environmental Science and Technology* **27**, 1080-1084.

Iwata, H., Tanabe, S., Sakai, N., Nishimura, A. and Tatsukawa, R. (1994) Geographical distribution of persistent organochlorines in air, water and sediments from Asia and Oceania, and their implications for global redistribution from lower latitudes. *Environmental Pollution* **85**, 15-18.

Kurtz, D.A. and Atlas, E.L. (1990) Distribution of hexacyclohexanes in the Pacific Ocean Basin, air and water, 1987. In *Long Range Transport of Pesticides.* Kurtz, D.A. (Ed.), Lewis Publishers, Michigan 143-146.

Levy, H. (1990) Regional and global transport and distribution of trace species released at the earth's surface. In *Long Range Transport of Pesticides.* Kurtz, D.A. (Ed.), Lewis Publishers, Michigan 83-87.

Mackay, D. (1991) *Multimedia Environmental Models. The Fugacity Approach.* Lewis Publishers, Chelsea, Michigan.

Mackay, D. and Paterson, S. (1981) The fugacity approach for calculating near source toxic substance concentrations and partitioning in lakes. *Canadian Journal of Water Pollution Research* **16**, 59-70.

Mackay, D. and Wania, F. (1995) Transport of contaminants to the Arctic: partitioning processes and models. The *Science of the Total Environment* **25**, 160-161.

Mackay, D., Shiu, W.Y. and Ma, K.C. (1992) *Illustrated Handbook of Physical-chemical Properties and Environmental Fate for Organic Chemicals, Volume I – Monoaromatic Hydrocarbons, Chlorobenzenes, and PCBs.* Lewis Publishers, Chelsea, Michigan.

Mortimer, M. and Connell, D.W. (1996) Environmental distribution of chlorohydrocarbons contaminants associated with Sydney sewage discharges. *Marine Pollution Bulletin* **33**, 160-167.

Rappe, C., Marklund, S., Buser, H.R. and Bosshard, H.P. (1978) Formation of polychlorinated dibenzo-p-dioxins (PCPDs) and dibenzofurans (PCDFs) by burning or heating chlorophenates. *Chemosphere* **7**, 269.

Simonich, S.L. and Hites, R.A. (1995) Global distribution of persistent organochlorine compounds. *Science* **269**, 1851.

Tanabe, S. and Tatsukawa, R. (1986) Distribution, behaviour and load of PCBs in the oceans. In *PCBs and the Environment, Vol.1.* Waid, J.S., (Ed.), CRC Press, Boca Raton, Fl., 143.

Tatsukawa, R., Yamaguchi, Y., Kawano, M., Kannan, N. and Tanabe, S. (1990) Global monitoring of organochlorine insecticides - an 11 year case study (1975-1985) of HCHs and DDTs in the open ocean and hydrosphere. In *Long Range Transport of Pesticides.* Kurtz, D.A. (Ed.), Lewis Publishers, Michigan, 127.

Voldner, E.C. and Li, Y-F. Global use of selected persistent organochlorines (1995) *The Science of the Total Environment* **160/161**, 201-210.

Wania, F. and Mackay, D. (1996) Tracking the distribution of persistent organic pollutants. *Environmental Science and Technology* **30**, 390A-393A.

Weber, R.R. and Montone, R.C. (1990) Distribution of organochlorines in the atmosphere of the South Atlantic and Antarctic Oceans. In *Long Range Transport of Pesticides,* Kurtz, D.A. (Ed.), Lewis Publishers, Michigan. 185.

WECC Wania Environmental Chemists Corporation (2001) Pers. comm.

Woodwell, G.M., Craig, P.P. and Johnson, H.A. (1971) DDT in the biosphere: Where did it go? *Science* **174**, 1101.

Yang, S.Y.N., Connell, D.W., Hawker, D.W. and Kayal, S.I. (1991) Polyaromatic hydrocarbons (PAH) in air, soil and vegetation in the vicinity of an urban roadway. T*he Science of the Total Environment* **102**, 229.

5. PRELIMINARY ASSESSMENT OF THE REGIONAL CAPACITY AND NEEDS

5.1. Introduction

All the twelve countries of Region 8 have signed the Stockholm Convention, 10 have signed or ratified the Basel Convention, and 6 have signed the Rotterdam Convention. In general, countries have also introduced regulatory and administrative measures to ban or regulate the use of pesticides, with the exception of endosulfan. Although no emission inventory is available for the PTS pesticides, the trend of decreasing environmental levels reported in some countries indicates that the emissions of the PTS pesticides are generally declining.

Generally, there are limited available data on PTS emissions in the region. This also applies to available data on industrial, agricultural and other activities to allow estimates of emissions of PTS to be made. Only Australia and New Zealand have emission inventories for PCDD/PCDFs. However, Brunei Darussalam, the Philippines and Thailand are compiling PCDD/PCDFs inventories under an UNEP/GEF sponsored project to assist countries in the implementation of the Stockholm Convention.

There is also a paucity of data on PTS concentrations in various media, and ecological or ecotoxicological effects. Except for the work of Iwata *et al.* (1993) and the attempt in this report to model the transport of PTS, no other studies are available to quantify the movement of PTS within and outside the region.

5.2. Monitoring Capacity

5.2.1. PTS

Information obtained on PTS in Region 8 indicates that there are some data regarding concentrations in various environmental media but only on a limited number of PTS mainly organochlorine pesticides. However, the more developed countries in the region (e.g. Australia and New Zealand) have generated relatively comprehensive data on levels of PTS in their respective countries. Where information has been acquired in the developing countries, it has often been with the assistance of researchers in countries where the infrastructure and expertise are more advanced.

Even less information is available regarding ecological and human health effects of PTS within countries in the region. The situation also reflects the low priority given to this area for a number of possible reasons. These include limited expertise and capability, possible liabilities and related disincentives to gathering the information, and the perception that this type of information can be costly with little benefit to governments or to the public.

What is generally lacking is a systematic, targeted, and reliable monitoring effort on the sources, transport and potential effects of PTS on a region-wide and temporal basis. Such an effort, if in place, could provide feedback to governments on the effectiveness of efforts to abide by PTS-related conventions that most countries in the region have signed or ratified.

5.2.2. Organometals

A special case exists for the organometallics. Few spatial or temporal trends are apparent in the existing data, largely due to poor temporal or spatial coverage or to irresolvable artefacts in the data. Such artefacts appear to be related to differences in sampling, analytical, and reporting protocols.

5.2.3. Dioxin Analysis

Currently, New Zealand has established a capability in the region to analyse for PCDD/PCDFs. Australia has recognised a future need to analyse environmental and food samples for the presence of dioxins and furans also. AGAL has developed and implemented a plan to establish such a capability in its Sydney facility. The laboratory, tentatively named the Australian Ultra Trace Laboratory, has

third party technical accreditation through the National Association of Testing Authorities. Malaysia, Singapore, and Thailand have also started to set up PCDD/PCDFs laboratories but may not yet be ready to analyse levels in environmental samples.

5.2.4. Human Health

There have been very few health studies related to the use or exposure to PTS in the region. Those available tend to reflect specific issues (e.g. mercury poisoning from gold mining) or episodes (e.g. spraying of Agent Orange during the Viet Nam war). In addition, a major study was conducted in 1996-1997 to measure the concentrations of PCDD, PCDF, PCBs and organochlorine pesticides in serum from a cross-sectional survey of the adult New Zealand population (Buckland *et al.,* 2001). There is very little information on temporal trends of PTS in humans. Monitoring of PTS in blood over the next decade is essential to establish whether risk management strategies for POPs are effective. Existing data for organometallics do not allow a valid estimate of spatial and temporal trends of current exposures.

5.3. Existing Regulation and Management Structures

For many of the developing countries in the region, government responsibility for the environment, more specifically for PTS, rests with environment ministries, with a division or a unit in another ministry, with independent environment agencies or with departments created to assist the environment ministries (e.g. Ministry of Agriculture under which is a Pesticide Authority).

Most of the environmental institutions are relatively small and suffer from limited staffing and financial resources. Command and control is the main environmental policy instrument of countries. Strategic environmental planning, legislation and regulatory standards and planning procedures are the most commonly used tools for environmental control. The least used instruments are those related to economic incentives. In addition, environmental institutions often have no power to audit the environmental performance of sectoral institutions. In response, they are attempting to strengthen performance by developing additional tools or by improving existing ones.

There is a modest level of participation by the developing countries of the region in PTS-related international agreements. In most cases, the reason for non-implementation is inadequate professional and administrative expertise and resources that are necessary to develop domestic legislation. In addition, there appears to be a need to find an appropriate mix of command and control mechanisms, economic instruments, and moral persuasion to consider PTS issues.

5.3.1. National

Table 2.1 summarises information on the legal status of PTS in each of the countries in the region. As expected, most of the chemicals are those included in the Stockholm Convention. No similar overview of the metals was available.

5.3.2. Regional Initiatives

A number of regional initiatives related or relevant to PTS were described in Section 1.2.1. Other initiatives are described below.

1) The ASEAN Strategic Plan of Action on the Environment, Strategy 7 promotes environmentally sound management of toxic chemicals and hazardous wastes, and control of transboundary movement of hazardous wastes. The main activities under this strategy are the establishment of regional guidelines for assessing highly polluting industries and the safe handling of potentially harmful chemicals entering the ASEAN region, and the strengthening of the information network on the transboundary movement of toxic chemicals and hazardous waste (ASEAN, 1994). (http://www.eapap.unep.org/apeo/Chp2h-energy.html)

2) ASEAN Agreement on Transboundary Haze. Transboundary haze pollution arising from land and forest fires continues to be the most prominent and pressing environmental problem facing ASEAN today. The HPA addresses the transboundary haze issue through the following objectives, namely (a) to fully implement the ASEAN Co-operation Plan on Transboundary Pollution with particular

emphasis on the Regional Haze Action Plan (RHAP) by year 2001; (b) strengthen the ASEAN Specialised Meteorological Centre with emphasis on the ability to monitor forest and land fires and provide early warning on transboundary haze by year 2001; and (c) establish the ASEAN Regional Research and Training Centre for Land and Forest Fire Management by the year 2004. ASEAN Secretariat's RHAP-Coordination and Support Unit continuously monitors the haze situation on a day-to-day and region-wide basis and shares its findings through its website: the ASEAN Haze Action Online (http://www.haze-online.or.id).

5.3.3. International

Persistent toxic substances are covered by several international agreements or arrangements that form an important focus for political efforts aimed at reducing impacts on the region's environment and its ecosystems. The following have particular relevance to the UNEP assessment of the region.

International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978, (MARPOL 73/78)

The MARPOL Convention is a combination of two treaties adopted in 1973 and 1978. It covers all technical aspects of pollution from ships, except the disposal of waste into the sea by dumping, and applies to ships of all types. The Convention has five annexes covering oil, chemicals, sewage, garbage, and harmful substances carried in packages, portable tanks, freight containers, etc.

WHO Environmental Health Criteria

Over the past twenty years, the WHO has published an extensive list of environmental criteria for many of the PTS discussed in this assessment. These criteria provide quantitative guidance for human concentrations including PTDI, TDI and TWI values.

Stockholm Convention on Persistent Organic Pollutants

This convention was adopted at the December 2000 meeting of the intergovernmental negotiating committee for an international legally binding instrument for implementing international action on certain persistent organic pollutants in Johannesburg. The objective of this Convention is to protect human health and the environment from persistent organic pollutants. The selected list of POPs is of direct relevance to the UNEP assessment of PTS. The Convention was opened for signatures on 23 May 2001 to 22 May 2002. In this region all countries have signed the Convention. As of August 2002, Viet Nam has ratified the Convention (Table 5.1).

Basel Convention

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted in 1989 and entered into force on 5 May 1992. The Convention is the response of the international community to the problems caused by the annual worldwide production of hundreds of millions of tonnes of wastes. These wastes are hazardous to people or the environment because they are toxic, poisonous, explosive, corrosive, flammable, eco-toxic, or infectious.

This global environmental treaty strictly regulates the transboundary movements of hazardous wastes and provides obligations to its Parties to ensure that such wastes are managed and disposed of in an environmentally sound manner. The main principles of the Basel Convention are:

- Transboundary movements of hazardous wastes should be reduced to a minimum consistent with their environmentally sound management.
- Hazardous wastes should be treated and disposed of as close as possible to their source of generation.
- Hazardous waste generation should be reduced and minimised at source.

IMO Convention on the Control of Harmful Antifouling Systems on Ships

International Convention on the Control of Harmful Anti-fouling Systems on Ships

(Adoption: 5 October 2001; Entry into force: 12 months after 25 States representing 25% of the world's merchant shipping tonnage have ratified it)

A new IMO convention will prohibit the use of harmful organotins in anti-fouling paints used on ships and will establish a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems. The International Convention on the control of harmful anti-fouling systems on ships was adopted on 5 October 2001 at the end of a five-day Diplomatic Conference held at IMO Headquarters in London. Under the terms of the new Convention, Parties to the Convention are required to prohibit and/or restrict the use of harmful anti-fouling systems on ships flying their flag, as well as ships not entitled to fly their flag but which operate under their authority and all ships that enter a port, shipyard or offshore terminal of a Party.

The Rotterdam Convention

In March 1998, 95 governments finalised the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. The Convention will enable the world to monitor and control the trade in very dangerous substances. It will give importing countries the power to decide which chemicals they want to receive and to exclude those they cannot manage safely. If trade does take place, requirements for labelling and provision of information on potential health and environmental effects will promote the safe use of these chemicals. Six pesticides out of the nine initial POP pesticides are subject to the Rotterdam Convention. In the region, Australia, Indonesia, New Zealand, the Philippines, and Singapore have signed the final act of the Convention. Thailand has gone through the accession process of the Convention.

The PIC list includes the following 22 hazardous pesticides: 2,4,5-T, aldrin, captafol, chlordane, chlordimeform, chlorobenzilate, DDT, dieldrin, dinoseb, 1,2-dibromoethane (EDB), fluoroacetamide, HCH, heptachlor, hexachlorobenzene, lindane, mercury compounds, certain formulations of monocrotophos, methamidophos, phosphamidon, methyl-parathion, parathion. The industrial chemicals are: crocidolite, polybrominated biphenyls (PBB), polychlorinated biphenyls (PCB), polychlorinated terphenyls (PCT), tris (2,3 dibromopropyl) phosphate. In addition to the 27 chemicals listed in Annex III of the Convention and carried forward from the original, voluntary PIC procedure, the Intergovernmental Negotiating Committee has added the pesticides: binapacryl, ethylene dichloride, ethylene oxide and toxaphene to the interim PIC procedure.

The Waigani Convention

The Waigani Convention – Convention to Ban the Importation into Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement and Management of Hazardous Wastes within the South Pacific Region. Ten countries including Australia, New Zealand and the South Pacific Forum Island countries ratified the convention that entered into force on 21 October 2001.

Table 5.1. Ratification of international conventions related to PTS by countries in Region 8.

Conventions	Australia		Brunei Darussalam		Cambodia		Indonesia		Lao PDR		Malaysia		New Zealand		Papua New Guinea		Philippines		Singapore		Thailand		Viet Nam	
	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R
Basel Convention on the Control of the Transboundary Movements of Hazardous Wastes and their Disposal (1989)		05 Feb 1992 (a)				02 Mar 1991		20 Sep 1993 (a)				08 Oct 1993 (a)		20 Dec 1994		01 Sep 1995 (a)		21 Oct 1993		02 Jan 1996 (a)		24 Nov 1997		13 Mar 1995 (a)
Rotterdam Convention on the Prior Informed Consent (PIC) - 1998		6 Jul 1999						11 Sep 1998						11 Sep 1998				11 Sep 1998				19 Feb 2002 (a)		
Stockholm Convention on Persistent Organic Pollutants (POPs) - 2001		23 May 2001		21 May 2002		23 May 2001		23 May 2001		5 Mar 2002		16 May 2002		23 May 2001		23 May 2001		23 May 2001		23 May 2001		22 May 2002		23 May 2001		22 Jul 2002
Waigani Convention* (1995)		16 Sep 1995												16 Sep 1995		16 Sep 1995								

Notes: S: Signature; R: Ratification; a: Accession; A: Acceptance; AA: Approval; Sc: Succession

*Regional agreement stopping hazardous and radioactive waste from moving around the Pacific. It also makes sure that regional waste is safely managed. Ten countries including Australia, New Zealand and the South Pacific Forum Island countries ratified the convention and entered into force on 21 October 2001.**Source**: Pollution Control Department 2002. ASEAN Achievements and Future Directions in Pollution Control. Ministry of Science, Technology, and Environment, Bangkok, Thailand. 72 pp.

5.4. Status of Enforcement

Some countries in the region have developed mechanisms to monitor and ensure the enforcement of PTS-related guidelines and/or laws.

Malaysia. The Government administers control of hazardous substances such as PTS and wastes through the prohibition of imports and exports. The Pesticides Board has control over formulation, use and sales of pesticides while the Department of Environment (DOE) has carried out checks on releases from unintentional production of PCDD/PCDFs from waste facilities. This task is possible due to the availability of PCDD/PCDFs analytical facilities at the Department of Chemistry and the Doping Control Centre. Enforcement of provisions related to safe treatment and disposal of hazardous wastes is made possible with the setting up of an integrated hazardous waste treatment and disposal facility and waste recovery facilities in the country.

Singapore. (http://www.chem.unep.ch/pops/POPs_Inc/proceedings/bangkok/HOCK.html)

All imports of hazardous chemicals are monitored electronically through the Tradenet System, which requires traders to make import declarations on the types and quantities of hazardous chemicals they are importing.

Officers from the National Environment Agency (NEA), a statutory board under the Ministry of the Environment, Singapore also carry out audit checks to ensure the safe storage and handling of hazardous chemicals at the factories and chemical warehouses. Surprise road checks are also carried out jointly with the Traffic Police and Fire Safety Bureau to ensure that hazardous chemicals are transported with the necessary approval and in accordance with prescribed licensing and technical requirements. The enforcement system is complemented by dialogues, training courses and workshops to review, brief and train management and operational personnel in industries, including drivers on regulatory requirements and technical measures to prevent and minimise emissions and leaks or accidental releases during storage, transport and use.

Thailand. (http://www.chem.unep.ch/pops/POPs_Inc/proceedings/bangkok/JBLPAPER.html)

The Pollution Control Department (PCD), formerly part of the Office of National Environment Board, has developed policies, strategies and action plans in protecting the environment and other living systems. Recommendations have been made concerning environmental quality standards with regard to the control of pollution and also toxic chemicals as protective measures under the Enhancement and Conservation of National Environmental Quality Act 1975, 1978 and as amended in 1992.

The Ministry of Industry (MOI) has established quality standards and control for industries and factories involved with chemicals, particularly those generating hazardous or toxic chemicals under the provision of the Factory Act 1969, 1978 and the amended 1992 and of the Hazardous Substance Act 1967, 1973 and the amended 1992.

The Ministry of Agriculture and cooperatives (MOA) has the authority to control hazardous substances in agriculture (pesticides) under the Hazardous Substances Act 1967, 1973 and the amendment of 1992.

Under the same Act, the Ministry of Public Health (MPH) also controls the toxic substances used as consumer products and some purposes for human health.

The MOI, MOA and MPH issue a list of hazardous substances in the Ministerial Notification periodically following the evaluation of such substances, either old or newly introduced. In addition, the PCD, MOA and MPH have done a great deal of monitoring and analysis of residues of chemicals including POP chemicals.

Papua New Guinea. Chemicals are regulated principally under the Environmental Contaminants Act, and to a lesser extent under the Environmental Planning Act and the Water Resources Act, all under the responsibility of the Department (now Office) of Environment and Conservation. A new strategic plan and a new environmental regulatory framework have been developed, and a new Environmental Act (2000) was passed by the National Parliament. These should strengthen chemical and waste management in PNG.

Australia. (http://www.npi.gov.au/about/faqs.html)

National Strategy for the Management of Scheduled Waste

The National Strategy was endorsed by the Australian and New Zealand Environment and Conservation Council (ANZECC) in 1993 and provides for the safe management and disposal of scheduled wastes. An important outcome of the National Strategy was the development of the three national plans for Scheduled Waste:

1) Organochlorine Pesticides Management Plan – July 1999;

2) Polychlorinated Biphenyls Management Plan – revised July 1999; and

3) Hexachlorobenzene Waste Management Plan – November 1996.

More information on the National Strategy for the Management of Scheduled Waste and copies of the plans can be found at:

http://www.ea.gov.au/industry/chemicals/swm/index.html

Environment Protection and Heritage Council (EPHC)

The EPHC was formed following changes to natural resource and environment related Ministerial Councils and agreed to by the Council of Australian Governments in June 2001.

EPHC was created by amalgamating the National Environment Protection Council, the environment protection components of the ANZECC[1], and Heritage Ministers' Meetings. The natural resource management components of ANZECC were transferred to the newly created Natural Resource Management Ministerial Council (NRMMC).

A comprehensive National Profile of Chemicals Management Infrastructure in Australia was published by Environment Australia in 1998 and can be found at:

http://www.ea.gov.au/industry/chemicals/infrastructure.html.

Commonwealth, State and Local government authorities all have responsibilities in relation to chemicals management in Australia. These responsibilities span health, agricultural, environment protection, workplace relations and transport portfolios. Responsibilities among spheres of government are generally aligned with stages in the lifecycle of chemicals. Commonwealth agencies are responsible for substance assessment and product registration, including conditions up to point of sale. Jurisdictions are responsible for management beyond the point of sale, which may include enforcing recommendations made at the assessment stage. Jurisdictions are also responsible for regulating the storage, handling and disposal of chemicals and chemical wastes.

In Australia chemicals are generally assessed and registered under separate schemes according to their end use – industrial, agricultural/veterinary, therapeutic or food-related.

Industrial Chemicals

The National Industrial Chemicals Notification and Assessment Scheme (NICNAS) was established under the Industrial Chemicals (Notification and Assessment) Act 1989, and operates within the Therapeutic Goods Administration in the Commonwealth Health and Ageing portfolio.

Around 40,000 chemicals that were in use in Australia before the inception of NICNAS are listed in the Australian Inventory of Chemical Substances. All industrial chemicals not on the Inventory are regarded as new to Australia. They must be assessed by NICNAS before they can be manufactured in, or imported into, Australia. Proponents must supply detailed information on the chemical's properties, including its exposure effects and methods of safe handling in the workplace.

Agricultural and Veterinary Chemicals

The Agricultural and Veterinary Chemicals (Administration) Act 1992 and the Agricultural and Veterinary Chemicals Code Act 1994 (the Agvet Code) established a national scheme for the

assessment and registration of Agvet chemicals (active constituents) and products, through the National Registration Authority (NRA). The NRA operates within the Commonwealth Agriculture, Fisheries and Forestry portfolio. All Agvet products new to Australia must be assessed and registered or permitted by the NRA before they can be sold, supplied, distributed or used in Australia. NRA reviews registered chemicals and products in response to new information. It also manages quality assurance programs that monitor the ongoing safety and performance of registered products.

Proponents must supply information on the product's properties, including its chemistry and manufacture, toxicology, metabolic studies, proposed use pattern and resulting residues, maximum residue limits, overseas registration details, exposure effects, methods of safe handling in the workplace, safety information to be provided on the label, Material Safety Data Sheets, environmental impacts including bioaccumulation and mobility in soil, degradation and leachability, ecotoxicology and trade aspects.

Therapeutic Goods

Any product for which therapeutic claims are made must be entered in the Australian Register of Therapeutic Goods (ARTG) before the product can be supplied in Australia. The ARTG is maintained by the Therapeutic Goods Administration, operating within the Commonwealth Health and Ageing portfolio. Its role is to assess and register therapeutic goods (including substances and devices).

Factors in the assessment process include the strength of the product, its efficacy, side effects, potential harm through prolonged use, toxicity and the seriousness of the targeted medical condition. The requirements for inclusion of therapeutic goods in the ARTG can include conditions on advertising, labelling requirements including warnings, and product appearance.

Food Additives

Food additives are prohibited unless they are expressly permitted in the Australia New Zealand Food Standards Code. Most food additives are assessed by Food Standards Australia New Zealand (FSANZ) established under the Australia New Zealand Food Standards Act 1991, although some are assessed by NICNAS. FSANZ operates within the Commonwealth Health and Ageing portfolio.

Applications for approval of food additives are submitted with a package of information addressing issues such as public health and safety and any trade implications. If the additive is approved for use, FSANZ recommends an amendment to the Code.

5.5. Alternatives or Measures for Reduction

5.5.1. ASEAN

To support the implementation of the Basel Convention, several ASEAN member countries (Indonesia, Malaysia, Philippines, Singapore, Thailand, and Viet Nam) have prepared legislation to fulfil obligations following their accession to the Convention. Thailand established the Hazardous Substances Act (HAS) in 1992, resulting in the creation of the Hazardous Substance Board to oversee control of the import/export, manufacturing, storage, transport, use and disposal of hazardous substances. Singapore has enacted the Hazardous Waste (Control of Import, Export and Transit) Act and its Regulations in March 1998. Malaysia enacted in 1993 a Customs measure for hazardous wastes (Prohibition of Import/Export, Amendment No. 2) giving priority to strengthening the information network on transboundary movement of hazardous wastes and encouraging implementation of cleaner product concepts and market-based instruments. Regional training programs and capacity building activities for the management of hazardous wastes were held in Bali, Indonesia in 1996.

In addition, several countries (Brunei Darussalam, Thailand, the Philippines, and Viet Nam) have completed or are soon to complete a National Dioxin Inventory in their respective jurisdictions as part of the Asia Pacific Regional Dioxin Pilot Project.

5.5.2. Australia

5.5.2.1. National Dioxins Program

In the 2001-02 Federal Budget, the Commonwealth Government announced funding of $5 million over four years (2001-2005) for the National Dioxins Program to reduce dioxins and dioxin-like substances in the environment.

The key actions of the NDP will be implemented over three phases: Phase One - gather as much data as possible about levels of PCDD/PCDFs in Australia; Phase Two - assess the impact of PCDD/PCDFs on human health and the environment; and Phase Three - in light of these assessed impacts, reduce and where feasible, eliminate releases of PCDD/PCDFs in Australia.

The data gathering and consolidation phase of the program will run from mid 2002 through to mid 2003 and aims to: determine the levels of PCDD/PCDFs in the environment and the Australian population; standardise sampling, analyses and reporting of PCDD/PCDFs data nationally; and compare Australian and international concentrations.

Up to $2.5 million has been allocated for Phase One with much of the work to be carried out through contracts let by the Commonwealth to well respected scientific organisations and companies. More information on the National Dioxins Program can be found at:
http://www.ea.gov.au/industry/chemicals/dioxins/

5.5.2.2. ChemCollect

ChemCollect is a nationally coordinated, free collection scheme for the collection and safe disposal of unwanted and de-registered agricultural and veterinary chemicals from farms. These chemicals, particularly the persistent organochlorine pesticides (OCPs) otherwise pose a risk to the environment, human health and markets for our agricultural products. The $27 million program is being funded on a 50/50 basis between the Commonwealth, States and Northern Territory Governments. ChemCollect was conducted from 1999-2002. More information on the ChemCollect Program can be found at: http://www.ea.gov.au/industry/chemicals/swm/farm.html

5.5.2.3. ChemClear

To ensure that stocks do not build up again, the agriculture and veterinary chemicals industry has agreed to institute ChemClear - an ongoing industry-funded program for regular collections of registered farm chemicals which are otherwise non-returnable. ChemClear will begin in 2004 after ChemCollect has finished (2002-2003) in each State. The ChemClear scheme will deal with most unwanted farm chemicals apart from unregistered chemicals including organochlorine compounds.

5.5.2.4. Industry Waste Reduction Scheme

ChemCollect and ChemClear are complemented by the agricultural and veterinary chemical Industry Waste Reduction Scheme, which has two objectives: 1) the reduction of the amount of packaging at source by encouraging manufacturers to adopt alternative containers such as bulk or re-fillable packs, new packaging technology such as water soluble sachets, and new formulations such as gel packs and granules; and 2) ensuring that non-returnable crop protection and animal health chemical containers have a defined route for disposal that is socially, economically and environmentally acceptable.

The scheme aims to reduce the weight of container packaging by 32% and the weight of containers currently going to landfill by 68% by 2001. An estimated four million non-returnable agricultural chemical containers are sold every year to farmers in Australia. A key initiative under this scheme is the drumMUSTER program. drumMUSTER is a national industry program for the collection and recycling of empty, cleaned farm chemical containers. Managed by Agsafe, it is a joint initiative of Avcare, the National Farmers Federation, the Veterinary Manufacturers and Distributors Association and the Australian Local Government Association.

5.5.3. New Zealand

The Ministry of Environment's Organochlorines Program began in 1995 with the aim to: a) research levels of organochlorines in the country's human population, food, and environment; b) reduce industrial emissions of PCDD/PCDFs to air, land and water; c) clean up land contaminated with

organochlorine residues; and d) manage the safe disposal of waste stocks of organochlorine chemicals. Among the actions taken to reduce hazards are: a) PCBs are withdrawn from service and use of materials containing PCBs above 50 ppm are banned; b) all POP pesticides have been deregistered (i.e. illegal to use without a permit) and there are initiatives in some regions in the country to collect and destroy waste pesticides from the rural sector; and c) regulations are being developed to control PCDD/PCDFs emissions from industrial sources and ambient environmental criteria are being developed.

5.6. Technology Transfer

5.6.1. Integrated Pest Management

Health and environmental concerns associated with pesticide use have motivated development of integrated pest management (IPM) programs around the world. However, the adoption of IPM practices in developing countries in the region appears to vary considerably and leaves room for public policies that would encourage adoption. While support for such programs may be justified on their productivity effects alone, a significant share of the benefits may be missed if environmental gains are ignored (Cuyno *et al.,* 2000). Thus, the need is for more empirical work to estimate the value of environmental benefits of IPM.

The application of IPM includes the search for alternative management approaches against pests and diseases. The need for such alternatives for POP pesticides is obvious. As five of the nine POP pesticides are used against termites, FAO, UNEP and the Global IPM Facility recently conducted (Geneva, February 2000) a joint workshop to recommend strategies for managing termites in agriculture and constructions. The objectives of this workshop included the identification of new management approaches and not simply the replacement of a POP pesticide by another chemical.

5.6.2. Cleaner Production

The United Nations Environment Program has defined cleaner production as "the continuous application of an integrated environmental strategy to process products and services to increase efficiency and reduce risks to humans and the environment." The idea is that industrial processes can often be improved in ways that not only reduce the amount of waste, and therefore pollution, but also save or make money for the company or agency. The Australian and New Zealand Environment and Conservation Council produced a draft national strategy for cleaner production.

5.7. Summary

Limited information appears to be available or accessible regarding sources, inventories, ecotoxicology, toxicology, and transport of PTS due to a number of reasons. These include: the lack of capability and resources to analyse for PTS, the absence of or the limited resources to undertake such work and to track generated information, and even the reluctance of some governments to make available such information. The notable exceptions are Australia and New Zealand where national pollutant inventories are ongoing and much of the information is made available. Most of the monitoring on PTS levels and toxicity and ecotoxicology have focused on mainly POPs and may reflect the limited analytical capabilities and the high costs for such analyses.

Many developing countries lack regulatory infrastructure including national PTS registration and control schemes, appropriate legislation regulations, enforcement mechanisms, and laboratory infrastructure for quality control and analysis of residual PTS. In addition, financial constraints make it difficult for countries to implement regulations and mechanisms that may be in place. Australia, New Zealand, and Singapore do not appear to be faced with such issues.

Countries in the region have already taken regulatory and administrative measures to ban or restrict the importation, and prevent or minimise emissions of many of the PTS, especially the organochlorine pesticides (OCP). In addition, most countries have developed mechanisms to monitor and ensure the enforcement of PTS-related guidelines and/or laws.

Australia and New Zealand lead the countries in the region in monitoring, and minimising the use of or replacing the use of PTS. This includes the National Dioxins Program (Australia) and the Organochlorines Program in New Zealand. There is scope to transfer technology and experiences from these countries to the rest of the region.

5.8. References

ASEAN (1994) Network on the Transboundary Movement of Toxic Chemicals and Hazardous Waste. http://www.eapap.unep.org/apeo/Chp2h-energy.html

ASEAN Haze Action Online. http://www.haze-online.or.id

Australia. National Strategy for the Management of Scheduled Waste. http://www.npi.gov.au/about/faqs.html

Australia. National Strategy for the Management of Scheduled Waste.

http://www.ea.gov.au/industry/chemicals/swm/index.html

Australia. National Profile of Chemicals Management Infrastructure. http://www.ea.gov.au/industry/chemicals/infrastructure.html

Australia. National Dioxins Program. http://www.ea.gov.au/industry/chemicals/dioxins

Australia. ChemCollect Program. http://www.ea.gov.au/chemicals/swm/farm.htm

Boon-Long, J. (2001) Managing POPs in Thailand. In: Proceedings of the Workshop on sustainable approaches for pest and vector management and opportunities for collaboration in replacing POPs pesticides, Bangkok, March 6 - 10, 2000.

Buckland, S.J., Bates, M.N., Garrett, N., Ellis, H.K. and van Maanen, T. (2001) *Concentrations of selected organochlorines in the serum of the non-occupationally exposed New Zealand population*. Organochlorines Programme. Ministry for the Environment, May 2001.

Cuyno, L.C.M., Norton, G.W. and Rola, R. (2000) *Economic Analysis of Environmental Benefits of Integrated Pest Management*: A Philippine Case Study, IPM CRSP Working Papers Series.

Iwata, H., Tanabe, S., Sakai, N. and Tatsukawa, R. (1993) Distribution of persistent organochlorines in the oceanic air and surface seawater and the role of ocean on their global transport and fate. *Environmental Science and Technol*ogy **27**, 1080.

Koh, K.H. (2001). Control of Hazardous Chemicals in Singapore. In: Proceedings of the Workshop on sustainable approaches for pest and vector management and opportunities for collaboration in replacing POPs pesticides, Bangkok, March 6 - 10, 2000.

Pollution Control Department (2002) *ASEAN Achievements and Future Directions in Pollution Control*. Ministry of Science, Technology, and Environment, Bangkok, Thailand. 72 pp.

6. FINAL RESULTS AND RECOMMENDATIONS

Chapters 2, 3, 4 and 5 have subsections that identify data gaps and provide summaries with respect to the sources, levels, ecotoxicology, and toxicity of PTS in the region. Technical/institutional capacities to address PTS issues have also been considered. The following sections present the key findings.

The main results have been selected from the previous chapters. The selection is subjective; hence, the interested reader is encouraged to refer to the full record in each chapter. The 'Recommendations for Future Activities' are general statements, which are not found in the preceding text.

6.1. Main Results

6.1.1. Sources

There are limited available data on import, use and inventory of PTS emissions in the region. Regulatory and other measures have been taken to phase out or ban the use of most of the PTS pesticides. Many of these pesticides with the exceptions of DDT, endosulfan, mirex and lindane have been banned or were not used in many of the countries of the region for more than 10 years. Mirex is used only in very limited quantities in Australia while DDT, endosulfan and lindane are still in use in some countries of the region.

The sources of by-product emissions such as PCDD/PCDFs and PAHs are widespread in the region and include emissions from both industrial and non-industrial sources. These include forest and vegetation fires, open burning of wastes, releases from landfills and industrial processes.

The amount of PCDD/PCDFs emissions from industrial processes, including waste incineration is highly dependant on the technology and type of pollution control equipment adopted, ranging from 3500 μg TEQ/t of wastes burnt for plants with no pollution control equipment to 0.5 μg TEQ/t of waste burnt for plants with advanced pollution control equipment. Landfills for domestic wastes as well as open burning of domestic wastes are also major sources of PCDD/PCDFs emissions. Landfill fires emit 1000 μg TEQ/t of wastes burnt while open burning of domestic wastes emit 300 μg TEQ/t of wastes burnt. Such sources need close monitoring and control to reduce their emissions.

Forest fires and burning of vegetation are also major sources of PAH, PCDD/PCDFs emissions in the region. A conservative estimate of biomass burnt based upon satellite images of the 1997 forest fire episode in Southeast Asia was 60 Tg excluding burning of below ground biomass such as peat fires. At least two countries in the region, Malaysia and Singapore, have taken regulatory measures to prohibit open fires and open burning of wastes.

PCBs are also of concern even though countries of the region have banned the import of PCBs. In many countries the existing stocks of old PCB filled electrical equipment are not closely monitored and managed. Many of the countries in the region lack adequate PCB waste management programs and facilities to monitor and ensure proper storage, handling and disposal of the PCB filled or contaminated equipment. Inventories of old PCB filled or contaminated electrical equipment are available only in two countries.

Leaded petrol is still in use in many countries of the region and could be a source of organolead emissions due to direct emissions from evaporation during transport, filling/refilling operations, storage and handling of the leaded fuel. Organotin compounds are used in agriculture as well as in antifouling paints on ships.

Phthalates, PDBE, nonyl- and octyl-phenols are known to be used in the region as raw materials, intermediates as well as in finished industrial and consumer products. There is, however, a lack of quantitative data on their import, use and emission inventories.

6.1.2. Levels/Effects

6.1.2.1. Levels

Generally, levels of PTS in most environmental media were on the high side when compared with concentrations in other parts of the world. However, an assessment of available reports indicates declining trends in PTS, particularly for those OCPs that have been banned from use. PCB, DDTs, HCHs, endosulfan and chlordane seemed to be the focus of most monitoring studies where their concentration levels were found to be significant. Other PTS were either low in concentration or were not studied. Little information is available in the region on PTS of emerging global concern such as organotin, organolead, chlorinated paraffins, PBDEs and alkyl phenols. PCDD/PCDFs are starting to be determined in some countries but the lack of technical expertise and funds restrict their monitoring studies.

PTS were found at relatively high levels in air, water, and sediments in most parts of the region. For example, HCHs were found to be extremely high (12,000,000 pg/m^3) in air over Central Viet Nam and PCBs were found to be high in air over Perth, Western Australia (17,000 pg/m^3). Lindane was found at an exceptionally high level in one location in Malaysian river water (900 ng/L) in 1994 while neighbouring Thailand recorded a concentration range of 0.18-75.0 ng/L from the same study. Levels of DDTs and PCBs in sediments were found to be above the trigger value of 1.6 and 23 µg/kg in almost all countries in the region.

PTS in biota, particularly marine organisms, have been widely studied and reported. The concentration levels varied among types of animals, OCPs and locations. The mussel watch program provides most of the data on PCB, DDT, and HCH levels in the bivalve (P*erna viridis*), and generally ranged from not detectable to highly contaminated. Fishes collected from various countries in this region showed significant amounts of PCBs, DDTs, HCHs, and chlordanes but were lower than the maximum residue limits.

PCDDs/PCDFs apparently pose the greatest threat to humans and the environment. Even though information on concentration levels of dioxin and furan are scarce, estimates on releases of these compounds from industrial and human activities (using the UNEP toolkit) coupled with bioaccumulation and persistence data revealed high risk situations. Without immediate intervention, PCDD/PCDFs can cause the greatest damage amongst the PTS to human health and the environment. From very recent reports, PCDD/PCDFs in certain regions in Viet Nam may be considered hot spots as it was well documented that several million gallons of Agent Orange contaminated with TCDD were sprayed in the country during the Viet Nam war. It was reported that high concentrations of PCDD/PCDFs were measured in blood and human milk of Vietnamese living in areas directly affected by the aerial spraying of Agent Orange.

6.1.2.2. Toxicology

Harmful effects and health risks from chronic exposures to PTS of regional concern, such as endosulfan, PCDD/PCDFs and other organochlorines, are difficult to characterise because of limited data sources and case studies which examine relations between exposure levels and measured effects. Regional differences between developing and developed countries are also apparent in health concerns about long-term risks (e.g. carcinogenic) from low-level PTS exposures in the diet and environment. Large rural populations in developing countries have experienced episodes of short-term poisoning from pesticide use and heavy metal exposures while disease vector control involves large-scale applications of insecticides including DDT.

The majority of countries have phased out or are regulating the use of organochlorine pesticides, PCBs and organometallics. Recent case studies and surveys have concentrated on longer term health risks (e.g. reproductive, developmental and carcinogenic) and monitoring of biological indicators (e.g. lead in blood and hair) of urban and industrial exposures.

Recent developments in National Poison Information Centres (e.g. Malaysia and Philippines) have meant better community access to information on POPs and PTS, poisoning statistics and surveys of exposed populations. In some countries (e.g. Australia, New Zealand and Singapore) environmental agencies are co-ordinating national surveys and reports on PTS such as PCDD/PCDFs emissions and organochlorines.

Regional health issues associated with PTS include the large-scale PCDD/PCDFs contamination of South Viet Nam during the Second Indochina War. Vietnamese and other studies show elevated incidences of PCDD (TCDD) in blood and birth defect anomalies among exposed populations including war veterans. Exposure to herbicide spraying is also identified as a risk factor in increased incidences of hepatocellular cancer in some Vietnamese males (e.g. war veterans). Hot spots of PCDD/PCDFs contamination remain (e.g. Bien Hoa) including abnormal levels of blood PCDD/PCDFs.

By-products from biomass burning in tropical areas (e.g. Indonesia) have produced sub-regional impacts in the form of smoke haze, excessive levels of PM_{10} and $PM_{2.5}$ (~ 250 $\mu g/m^3$) for periods of days, and associated PAHs. Health risks from PAHs appear to be low in the short-term but long-term exposure may be significant when combined with urban emissions of PAHs (e.g. vehicles, wood and fossil fuel combustion). Endosulfan and several other organochlorine pesticides are implicated in the occurrence of adverse health effects, particularly in rural communities. This requires further evaluation.

The phasing out of organochlorine pesticides in Australia demonstrates that dietary and environmental exposure to PTS can be reduced to low levels of health risks for the general population. However, special risk groups and susceptible populations need to be protected by regional health agencies or authorities.

The conclusions outlined above relate to areas where some information is available. There is no information available on such PTS as HCB, phthalates, nonyl phenols and brominated fire retardants. It cannot be concluded that these substances produce no adverse health effects.

6.1.2.3. Ecotoxicology

Ecotoxicological effects of PTS, particularly organochlorine pesticides, have not been quantified in the region and field studies of effects on non-target species are relatively few compared with results on monitoring for residual and bioindicator concentrations. As a result of comparing environmental levels with guidelines from Australia and New Zealand, the potential ecotoxicological effects are estimated to be high where exposure exists. Currently, there are no water and sediment quality guidelines in the region except for Australia and New Zealand. The value of such guidelines is illustrated by this application.

Residual levels of DDTs, HCH, PCBs and chlordane in waters and sediments have been measured in the ranges of known adverse effects. A difference in the potential adverse effects in the water and sedimentary components of the aquatic ecosystem has been observed with a higher level of potential effects indicated with the sedimentary system. The distribution of risk areas has not been mapped because of inadequate information but is believed to be mainly confined to major urban and intensive agriculture catchments.

In a geographical sense, the more remote parts of the region have extremely little data available on the occurrence of pesticides in the environment and wildlife. The limited data available suggest that DDT and dieldrin are declining in concentration but significant levels still occur in some locations. Evidence now available suggests that urban areas, in particular sewage discharges, may be a major source of the PTS, including pesticides.

In Viet Nam the effects of residues such as PCDD/PCDFs from defoliant use, in the Viet Nam war during 1961 to 1971, on terrestrial ecosystems have been severe and are continuing at the present time although the residues appear to be in decline. As residues decline (e.g. biodegrade) and contamination is thus remediated, recovery of adversely affected ecosystems is probable, providing that replacement pesticides or other pollutants do not increase environmental risks, as may be occurring with endosulfan.

Endosulfan has been identified as the major PTS that has a continuing effect on the natural ecosystems in the region. It has an acute effect in the form of fish kills and long-term effects on the structure of aquatic ecosystems where it is used. In addition, there are examples of endocrine disrupting activity as a result of TBT exposure to marine gastropods. DDT and its metabolite DDE have had a detrimental effect on the breeding success of some bird populations in the past and this is

possibly continuing, although these effects would be expected to decline consistent with the declining amounts of DDT use and levels in the regional environment.

There are no ecotoxicological investigations available on PTS such as HCB, phthalates and brominated fire retardants but this cannot be interpreted as evidence of an absence of effects due to these substances.

6.1.3. Pathways and Transport

The analysis and modelling of available data on PTS has pointed to a number of conclusions regarding PTS pathways and transport in the Southeast Asia and South Pacific region.

The Southeast Asia sub-region of the Southeast Asia South Pacific region can be considered as a separate area in relation to transport of PTS due to the presence of ocean current and atmospheric convergence zones around the equator. There is no evidence for Australia and New Zealand as sources of PTS that could be transported to other areas.

Fugacity modelling indicates that the relatively high concentrations of HCHs in air and water in parts of the Southeast Asia region provide a reservoir for transport to other areas. Fugacity modelling also indicates that water movements are more important than atmospheric movements for PTS transport and these favour transport out of the region towards the north-east in the Kuroshio Current.

Transport of PTS out of Southeast Asia towards the south is inhibited by the equatorial ocean and atmospheric convergence located approximately on the equator and the "global distillation" effect favours movement of HCH to the north-east.

There are relatively large potential sources of DDT and PCBs in the region but fugacity modelling suggests that transport out of the region is not occurring on a significant scale and this is supported by the existing environmental data. Due to the lack of a water current route there is probably little transport of PTS from South Asia, where high contamination occurs, to Southeast Asia.

This analysis is based on results obtained in the period 1989 to 1991. The situation may have changed during the period up to the present time.

6.1.4. Regional Capacity

In addition to funding and technical support from multilateral and bilateral sources to address PTS, it is essential to consider how to make the best use of existing systems and resources in the countries in the region. It is important to recognise that recipient countries should be given technical support that is both practical and useful within the framework of their socio-economic and climatic situation.

It is important that there be close co-operation and co-ordination of efforts among donor agencies. In turn, in order to fully benefit from such efforts, recipient countries should work closely with donor agencies, from inception to finalisation of technical assistance projects related to PTS.

Adequate and efficient regional co-operation and sharing of information and expertise among recipient countries are also essential.

Countries in the region should be encouraged to participate in ongoing efforts to promote the implementation of the Rotterdam Convention organised by FAO and UNEP. This will provide opportunities to take part in regional awareness-raising workshops aimed at informing Designated National Authorities (DNAs) about the major elements of the Rotterdam Convention on PIC and to discuss the changes to the voluntary PIC procedure under the new rules of the Convention.

Analytical capability for the analysis of PTS can be enhanced through existing mechanisms including possible links with the Asia Pacific Metrology Program (APMP) that is primarily responsible for developing international recognition of the measurement capabilities of the region's national and territorial measurement laboratories. APMP has been operating in the Asia-Pacific since its inception as a Commonwealth Science Council initiative in 1977. In addition, training workshops and regional interlaboratory comparison initiatives of the International Atomic Energy Agency (IAEA) and the Intergovernmental Oceanographic Commission (IOC) can be expanded to include PTS. In the region,

analytical proficiency studies are regularly carried out by the National Residue Survey in Australia and laboratories in the region can be encouraged to link with this effort.

Countries in the region can be encouraged to take better advantage of activities being conducted by the International Program on Chemical Safety (IPCS), a co-operative mechanism of UNEP, ILO and WHO, aimed to establish the scientific health and environmental risk assessment basis for safe use of chemicals (normative functions) and to strengthen national capabilities for chemical safety (technical co-operation). Under the program of "emerging issues", IPCS has started to give attention to "Integrated Health and Environmental Risk Assessment." At the April 2001 workshop held on this subject, case studies were presented on persistent organic pollutants (POPs) in humans and wildlife, tributyltin and triphenyltin compounds in humans and wildlife, and organophosphorus compounds in the environment.

In addition, there are regional mechanisms for co-operation on the environment and pollution control. These include the ASEAN Ministerial Meeting on the Environment (AMME), the ASEAN Senior Officials on the Environment (ASOEN), and the ASEAN Haze Technical Task Force. Previous successful initiatives on the marine environment between ASEAN and Australia (e.g. ASEAN-Australia Marine Science Program) indicate that a multilateral regional mechanism can be undertaken again, perhaps to include New Zealand. Australia and New Zealand are certainly capable and could provide support to ASEAN in addressing PTS concerns. This could include training and information exchange; PTS risk reduction programs, and monitoring, research and development. Moreover, there appears to be a need to harmonise criteria values for PTS for the protection of human and environmental health in the region (which is largely tropical) and this could be initiated also as a regional program.

6.1.5. Regional Prioritisation of Chemicals

A major output of the two regional workshops conducted in 2002 was the prioritisation of a list of 25 persistent toxic substances for sources, environmental levels, ecotoxicological effects, human health effects, and data gaps. Each PTS was assessed by the participants of the two workshops (principally invited scientific and technical representatives from the various countries) based on its source, ecotoxicological effects from exposure, human effects from exposure, and data gaps. Each substance was scored "0" if it was considered of least concern; "1" if it was of limited concern; and "2" if it was of regional concern. The scores given to the chemicals by the participants were tallied and subsequently grouped in order of priority. The prioritisation was further refined and validated by the participants in plenary sessions.

The results of the prioritisation are summarised in Table 6.1.

Table 6.1. Prioritisation of PTS in Region 8

		Sources	Levels	Ecotox-Efffects	Human Effects	Data Gaps
PRIORITY	**Regional Concern**	DDT Dioxins Endosulfan Furans PAH PCB	DDT Dieldrin Dioxins	Endosulfan Dioxins DDT	DDT Dioxins PAH	Atrazine Chlorinated Paraffins Nonylphenols Octylphenols
	Limited Concern	Atrazine Dieldrin Org-Pb Org-Sn	Chlordane Endosulfan Furans HCH PAH PCB	Chlordane Dieldrin Nonylphenols	Chlordane Dieldrin Endosulfan Org-Pb Org-Hg	Dioxins Furans PBDE PCP Phthalates

	Least Concern	Aldrin Chlordane Chlordecone Chlorinated Paraffins Endrin HCH Heptachlor HCB Mirex Nonylphenols Octylphenols Org-Hg PBDE PCP Phthalates Toxaphene	Aldrin Atrazine Chlordecone Chlorinated Paraffins Endrin Heptachlor HCB Mirex Nonylphenols Octylphenols Org-Pb Org-Hg Org-Sn PBDE PCP Phthalates Toxaphene	Aldrin Atrazine Chlordecone Chlorinated Paraffins Endrin Furans HCH Heptachlor HCB Mirex Octylphenols Org-Pb Org-Hg Org-Sn PAH PBDE PCB PCP Phthalates Toxaphene	Aldrin Atrazine Chlordecone Chlorinated Paraffins Endrin Furans HCH Heptachlor HCB Mirex Nonylphenols Octylphenols Org-Sn PBDE PCB PCP Phthalates Toxaphene	Aldrin Chlordane Chlordecone DDT Dieldrin Endosulfan Endrin HCH Heptachlor HCB Mirex Org-Pb Org-Hg Org-Sn PAH PCB Toxaphene

Among the PTS, DDT and PCDD/PCDFs were considered to be of regional concern with respect to environmental levels, sources, ecotoxicological and health effects.

While banned in many countries in the region, DDT (used primarily for malaria control) along with a range of organochlorine compounds (e.g. HCHs, chlordane and PCBs) still occurs in water and sediments throughout the region in concentrations that exceed guideline values for natural ecosystems. This would be expected to cause a reduction in the species diversity of natural aquatic systems in the region and other adverse effects. Moreover, DDT residues in Singapore and Australia have been implicated in breast cancer and reduced bone density in women.

PCDD/PCDFs were found to be of major threat to the human health and the ecosystem in general. Even though data on PCDD/PCDFs levels are scarce, estimates on release to the environment due to industrial and human activities indicated a significant input to the system. Through unintentional release coupled with high toxicity and accumulative properties, PCDD/PCDFs are possibly the most important PTS to be evaluated in the future.

Endosulfan was also of regional concern because of its continued use in many countries, replacing many of the organochlorine pesticides. For instance, Australia imported 900 tons of endosulfan in 1998 although this was reduced to 500 tonnes in 2002. Studies have also shown adverse ecotoxicological and human health effects from endosulfan exposure.

The health risks from PAHs appear to be low in the short-term but long-term exposure may be significant when combined with urban emissions of PAHs (e.g. vehicles, wood and fossil fuel combustion). In many parts of the developing and developed countries in the region, forest fires and burning of vegetation are major sources of PAHs to air and land.

6.2. Recommendations For Future Activities

Emission sources of PTS that still exist in the region are causing considerable uncertainties in emission estimates for the region. Information on PTS concentrations in various environmental media, toxicology, ecotoxicology, and transport are also limited and would need to be acquired to further assess the importance and priorities to be given to PTS.

Based on the information gathered by the regional team, and the consultations made with various institutions and participants at the two regional workshops and the priority setting meeting under this project, a number of needs for the region have been identified and recommendations made:

6.2.1. Capacity Building and Assessment

1. More data on PTS sources, concentrations, ecotoxicology, and toxicity are needed. The effort of UNEP to use the "toolkit" for PCDD/PCDFs could be expanded to include other countries in the region, in addition to those where the method has been piloted (e.g. Brunei Darussalam, the Philippines and Thailand). The procedure could also be developed further to take into account other priority PTS in the region.

2. Resources are required to improve analytical facilities and methods for the determination of PTS, giving emphasis to compounds that are of the greatest cause of concern in the region. This entails more trained personnel and the acquisition of appropriate analytical facilities and the funds to maintain and operate these. A major effort associated with improving analytical capability for PTS needs to set in place quality assurance and quality control activities among laboratories. This will include the regular use of reference standards and/or certified reference materials, regional training programs and intercomparison exercises, a registration system for laboratories, and the identification of reference laboratories in the region for specific PTS. There would be merit in using the tried and tested multilateral arrangement mechanisms in the region (e.g. ASEAN-Australia) to bring about projects to support this need.

3. Support should also be provided to research and government institutions, especially in developing countries, to undertake epidemiological studies (levels and effects in humans), ecotoxicological studies (levels, pathways and effects in organisms) and modelling of transport processes. Models are essential in assessing the sensitivity of individual or linked processes, which in turn can be instructive in assigning priorities to complex research questions. In particular, models have not been used to their fullest in the area of terrestrial/freshwater pathways and other complex questions, including evaluation of the relative importance of processes, estimation of transport fluxes, and assessment of remedial measures.

6.2.2. Information Management

1. Public information programs are needed to allay public concern, to raise awareness about the risks associated with exposure to PTS, and about the role they have to play to prevent further contamination of the environment.
2. In addition, improved handling and exchange of data and information on PTS are required. If continued, the current effort to have a worldwide database on PTS sources, environmental levels, and national capacity, will benefit from the development of compatible national databases on PTS. For a number of countries in the region, it would not necessarily mean starting again but building upon already existing environmental databases.
3. Policy makers in governments and developing countries require accessible information on strategies for improving the capacity to regulate and implement best practices regarding PTS. Some of these efforts are already in place, particularly for pesticides.

6.2.3. Capacity Building, Implementation and Monitoring

1. Efforts should also be directed for countries in the region to consider the software and hardware required for proper waste management, treatment, waste minimisation, and disposal facilities for PTS. Funding is required to support PTS-related activities within countries. This includes resources to develop National Implementation Plans for POPs/PTS, obtain inventories of PTS, as well as capability-building. Health ministries in the region should also be involved in PTS-related initiatives and programs.

2. A better assessment of PTS movement through "informal" channels between and among countries in the region is also needed. Even if many countries have signed or ratified the Rotterdam Convention on Prior Informed Consent (see Table 2.1), which among others alerts developing countries to bans and severe restrictions on pesticides and chemicals that are traded internationally and helps them stop certain unwanted imports, there appears to be continued illegal traffic of PTS and the possible movement of PTS-contaminated food.

3. There is a need for a set of regional environmental quality guidelines to evaluate the significance of the occurrence of PTS in air, soil, waste, sediment, food and drinking water. These should

relate environmental levels to the occurrence of significant adverse effects on human health and the natural environment. This could be part of an expanded set of environmental guidelines initiated by ASEAN for the region. The region has a substantially tropical climate and other unique features which suggest that guidelines developed elsewhere will not be appropriate.

Available from:
UNEP Chemicals
11-13, chemin des Anémones
CH-1219 Châtelaine, GE
Switzerland

Phone : +41 22 917 1234
Fax : +41 22 797 3460
E-mail: chemicals@unep.ch
http://www.chem.unep.ch

UNEP Chemicals is a part of UNEP's Technology, Industry and Economics Division

Printed at United Nations, Geneva
GE.03-00157–January 2003–500
UNEP/CHEMICALS/2003/8