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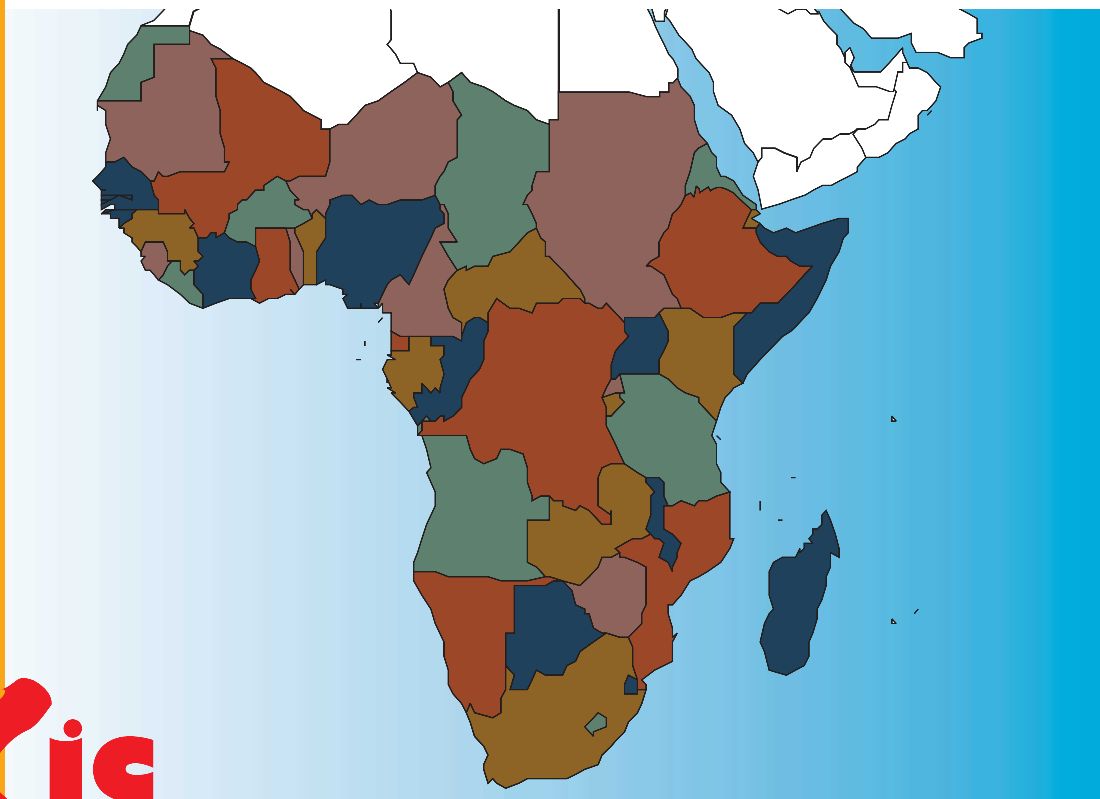

Regionally Based Assessment of Persistent Toxic Substances

December 2002

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PROGRAMME

CHEMICALS

Regionally Based Assessment of Persistent Toxic Substances

Angola, Benin, Botswana, Brunei Darussalam, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo (Brazzaville), Cote d'Ivoire, Democratic Republic of Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Guinea-Bissau, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe

SUB-SAHARAN REGIONAL REPORT

DECEMBER 2002

GLOBAL ENVIRONMENT FACILITY

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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.

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PREFACE

This report is the product of the collective efforts of the Regional Team Members of the UNEP/GEF Regionally Based Assessment of Persistent Toxic Substances (RBA PTS) Project for Region V, Sub-Sahara Africa. It forms part of a global assessment of Persistent Toxic Substances (PTS) as sub-Sahara Africa is one of the twelve regions designated by the United Nations Environment Programme (UNEP) for this purpose.

Composition of the Regional Team

The Regional Team established within the framework of the project with the following as members prepared the report:

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Data Collection and Report Preparation

African experts in academia, research institutes government and non-governmental organizations (NGOs) provided data existing in the region mainly through the completion of dedicated questionnaires designed by GEF/UNEP for the study. The data collected was supplemented with data from published literature, research reports, technical reports as well as personal communication from experts in the region.

The draft report prepared by the Regional Team Members was presented and reviewed at the Technical Workshops on Sources Characterisation, Impact and Transport of PTS, held in Mombasa, Kenya 29 July - 2 August 2002 and attended by the network of regional experts. The revised draft report was presented to the Regional Priority Setting Meeting held in Nairobi, UNEP, Kenya, during 30 October to 02 November 2002. The inputs from the workshops and the meeting are reflected in this report.

ACKNOWLEDGEMENT

Several people and organisations contributed immensely towards the preparation of this report. The invaluable assistance from members of the Regional Network of Experts who provided information on PTS chemicals within the region is gratefully acknowledged. The invaluable contributions from the participants at the Regional Technical Workshops and the Regional Priority Setting Meeting are also profoundly appreciated. Funds for the project were provided by the GEF through UNEP Chemicals without which the implementation of this important regional study would have been impossible. The provision of enabling environment and logistic support for the successful completion of the latter stages of the project, including the finalisation of this regional report, by Mr. Ahmed Djoghlaf, Director Division of GEF Co-ordination, UNEP, Nairobi; Dr. Walter Jarman, Programme Officer, GEF Coordinating Office, UNEP, Nairobi, Kenya and his able assistants, Miss Jackline Oduor and Ms. Theresa Lowe are gratefully acknowledged.

The contributions of Mr. Raphael Dakouri Zadi, Coordinateur du Project POPs & PCB, Ministere de L'environement et du Cadre De Vie, Service Autonome Des Affaires Internationales, (20bp 650 Abidjan 20, Cote d'Ivoire; zadid@aviso.ci) in coordinating data collection from some countries including assistance during the Technical Workshops, Regional Priority Setting Meeting and finalisation of the report are acknowledged.

The special contribution of Mr. Paul Whylie, the PTS Project Manager at UNEP, Geneva for rendering total support towards the success of the project in spite of daunting difficulties is profoundly appreciated.

EXECUTIVE SUMMARY

INTRODUCTION

Forty Seven sub-Saharan African countries including Madagascar and six small island states constitute Region V, the largest of the twelve regions, for the Regionally Based Assessment (RBA) of Persistent Toxic Substances (PTS) in a global project funded by GEF/UNEP. This assessment of PTS is a major milestone as no comprehensive database on hazardous chemicals exists in the region.

PTS SOURCES

The identifiable main sources of PTS in the region are agricultural use of pesticides, production and imports, vector control, stocks of obsolete and expired pesticides, industrial sources (manufacture, mining and electricity) and not the least as by-products of combustion including open burning of waste.

Pesticides

Pesticides constitute one of the major sources of PTS in Region V. Except for atrazine produced in South Africa, PTS pesticides are generally imported and not produced in Region V but pesticide formulation plants exist in many countries of the region. Sub-Sahara Africa imports less than 5% in terms of value of total pesticides import of the world. Twenty-two RBA Region V countries each import more than $5 million worth of pesticides annually.

During the technical workshops, the regional experts identified the most widely used PTS pesticides for Region V as mainly organochlorine pesticides namely: DDT, Endosulfan, Chlordane, Lindane (HCH), Heptachlor, Toxaphene, HCB and Aldrin; as well as Atrazine. The workshops also noted the possibility and likelihood of illegal trade and use of PTS pesticides (including DDT) in the region. Based on pesticide import data (FAO), South Africa, Nigeria, Cote D'Ivoire, Kenya, Ethiopia, Ghana, Sudan, Tanzania, Mozambique and Mali are the highest users of pesticides in the region.

A serious problem facing the region now is the issue of stocks and reservoirs of obsolete discarded and banned PTS pesticides. The FAO estimates that there might be more than 40 000 tons, perhaps even much more, of these chemicals stocked or discarded over many parts of Africa. Some of these chemicals were donations from developed countries.

Industrial PTS Chemicals

The major industrial PTS chemicals of concern in the region are adjudged to be the following: PCBs (mainly from electricity generating industry), HCB (also a PTS pesticide), pentachlorophenol (PCP) and phthalates. Data is lacking on the use and import of PTS industrial chemicals in the region. This data gap will be addressed perhaps when most of the countries have carried out "National Chemical Profile" study being driven by the Intergovernmental Forum on Chemical Safety (IFCS).

Industrial output and electricity generation have been used as criteria to rank countries on the production of PTS especially PCBs and Dioxins from industrial sources. Accordingly the countries releasing the largest PTS emissions are South Africa, Nigeria, Zimbabwe, Ghana, Kenya, Democratic Republic of Congo, Zambia, Cote D'Ivoire, Sudan and Cameroon in that order.

Other Sources Of PTS

The PTS of concern in this category are polyaromatic hydrocarbons and dioxins/furans.

Although not quantified, the main source categories are:

PAHs – exhaust emission from combustion of fossil fuels in vehicles and electrical generating sets.

Dioxins and furans – Waste (domestic, hospital, industrial) burning is possibly the least known factor in the production of PCDD/Fs in Africa. A large amount of accidental and deliberate combustion is taking place, including the burning of rubber tyres as well as stripping insulation of copper wires and cables. Waste combustion could potentially be the largest source of dioxins and furans in Africa. Moreover, burning of sugar cane fields, a common practice in sugar producing countries, could also contribute to the formation of dioxins.

Based on population figures (2001 estimates), waste production (tons/day), air releases (mg TEQ), and burned residue (mg TEQ) respectively; the largest potential emitters of dioxins into the environment from waste burning, a common practice in the region, are: Nigeria, Ethiopia, Democratic Republic of Congo (DRC), South Africa, Tanzania, Sudan, Kenya, Uganda, Ghana, and Mozambique respectively. A daily TEQ production of around 60g (21360 g TEQ/year) for dioxins and furans for Region V has been estimated. This would equate to 0.0003 g TEQ/year per capita, but only for uncontrolled domestic waste combustion, not including industrial or any other anthropogenic or natural sources, which were not taken into consideration. This lack of information therefore constitutes a major data gap.

Ranking Of PTS Sources By Countries

At the technical workshops, the experts from the countries present were asked to score the PTS as released from sources according to levels of concern for that specific country. The experts were asked to rank from 0 for no concern, to 3 for major concern. Some country experts did indicate however, that their scoring was indicative only, but the combined scores from the countries gave a good indication of the overall level of relative concern. The country experts rated the unintentional production of dioxins/furans as well as the problem of PCBs, as the highest concern for most countries. DDT, Atrazine, Endosulfan and Lindane were ranked as the most important PTS pesticides. Organic lead was the organometallic compound that caused the most concern. For almost all of these compounds, significant data gaps were also indicated.

ENVIRONMENTAL LEVELS, TOXICOLOGICAL AND ECOTOXICOLOGICAL CHARACTERISATION

Experts from only 16 countries out of 47 of the region provided data concerning PTS (about 3000 filled questionnaires) in the environment. These data are relative to the levels and trends of PTS in environmental media and clinical samples. Toxicological data are generally lacking for the region. Moreover, air, as an environmental compartment was not given the required attention by most of the countries of the region in general.

Concentrations Of PTS In Abiotic Compartments Of The Environment (Highlight Of Hotspots: Trend Analysis)

Sub-Sahara is mainly an agricultural continent and it has been using pesticides for pest and disease control for more than 50 years. Except for South Africa and Zimbabwe, no systematic pesticide monitoring/analysis exists in all the countries of the region. These two countries account for more than two thirds of the filled questionnaires gathered for the region. A big data gap therefore exists in the region as far as levels of PTS in the environment are concerned.

The data gathered have been grouped according to the period of analysis: 1970 - 1979, 1980 - 1989 and 1990 - 2002 respectively for the purpose of trend analysis. During the 1970 - 1979 period, only seven PTS were reported (DDT, dieldrin, endosulfan, Lindane, toxaphene, PCBs and HCB) whereas in the second period (1980 - 1989), the period of awareness, banning and/or restriction, this number increased to nine (DDT, dieldrin, endosulfan, Lindane, toxaphene, PCBs, HCB, heptachlor and atrazine). DDT, Lindane, endosulfan, dieldrin, PCBs and HCB were common to both periods. During the third period (1990 - 2002) new chemicals of agricultural, construction and industrial use, viz. endrin, chlordane, PAHs (pyrene), and nonylphenols were detected in the region. PCBs and HCB were detected since the 1970’s in South Africa and Zimbabwe in water, vegetation and animals at relatively high levels.

Concentrations Of PTS In Biotic Media

From the data gathered through filled questionnaires, the trend of concentration observed in Sub-Sahara Africa for PTS is DDT> PCBs> toxaphene. These same data apparently indicate that humans were less directly exposed than animals and vegetation to PTS during the period 1970 - 2002. However the main risk remains the food-web contamination. The occurrence of relatively high levels of DDT, PCBs and dioxins/furans in adipose tissues and blood of occupationally exposed persons is of immense concern. Equally disturbing is the high levels of HCB, Lindane and endosulfan in human breast milk in the region, in view of WHO's vigorous campaign that mothers breast milk is best for children. It has been established by studies in South Africa that Organochlorine Pesticides (OCPs) can be transferred to infants *via* breast milk. Thus infants are being exposed to these xenobiotics while the toxicological hazards and risks have not been studied in many sub-Sahara African countries.

Evidence Of Harmful Effects

Many cases of accidental or intentional release of large amounts of PTS (for fishing or hunting) causing severe stress to the environment and humans have been reported in the region. For example, the accidental release of organochlorine pesticides (OCPs) in large quantities had caused massive fish kills in many countries, such as Senegal, Nigeria and Kenya. Cases of people suffering from diseases as a result of exposure to organochlorine insecticides while selling, mixing or spraying these were reported in Wad Medani, Sudan. However there is data gap on PTS contaminated sites and hotspots.

RANKING OF PTS CHEMICALS ON ENVIRONMENTAL LEVELS, TOXICOLOGICAL AND ECOTOXICOLOGICAL CHARACTERISATION BY COUNTRIES

At the technical workshops, the country experts rated dioxins and PCBs of highest concern in regard to their levels in the environment. Among the PTS pesticides, it was DDT that was of highest concern followed by endosulfan, atrazine, Lindane, aldrin, dieldrin, chlordane and heptachlor respectively. A similar pattern of response was obtained for data gaps, that is, dioxins; PCBs and DDT were the chemicals that the experts considered of highest priority.

DATA GAPS

At the technical workshops, the experts considered the following list as the major data gaps/issues that need to be addressed:

- PTS atmospheric concentrations in the countries of the region
- PTS levels in sediments of the major lakes, *e.g.* Tana, Victoria, Chad, etc. and the marine environment
- Dioxins and furans in environmental compartments and humans (analytical data exist only in South Africa),
- Systematic studies of the food-web contamination and biomagnifications
- The effect of burning crop residues, *e.g.* cotton, sugarcane, etc.
- Effect of improper burning of wastes
- The long-term effect of the accumulated stocks of obsolete PTS on the environment and health of the human and animal populations near them
- The effect of the emissions from the chimneys of the sugar and cement factories on the human and animal populations in their areas and the vicinity, at least within 50 km from the sites, where some eventually deposit
- Concentrations of PAHs and organometallics (mercury and tin) in environmental media and biota.

ASSESSMENT OF MAJOR PATHWAYS OF CONTAMINANTS TRANSPORT

Atmospheric Transport

The uniqueness of the African continent in terms of secondary drift and temperature inversions is significant in determining the environmental fate of PTS. These conditions can influence the behaviour of PTS. For example air monitoring data in Zimbabwe and Malawi showed that hot temperatures volatilise sprayed DDT into pockets of hot air and could drift down stream. DDT can condense on the ground when the temperatures are low. The distillation and condensation of PTS on top of cold mountains, like the Kilimanjaro, could also take place, although no data from Africa exists to confirm this.

It is not known whether Africa is a source or sink of global PTS. Current thinking is that the presence of the Inter-Tropical Convergence Zone will prevent atmospheric transport of PTS to the north and vice versa. However, whether Africa acts as a source of PTS to the Antarctic is not known.

In this context, the Island states are particularly vulnerable to this atmospheric mode of contamination by PTS. For the region there is big data gap concerning atmospheric transport of PTS and therefore underscores the importance of modelling here.

Food Web

Monitoring data from Chapter 3 of the report indicate that DDT and PCBs in fish were two of the PTS most often encountered since 1970s in the region including the marine environment. The data also indicate widespread PTS contamination of fruits, vegetables, major cereals, foodstuffs of animal origin, as well as fish and fish products, breast milk and dairy products. Fish that constitutes the major source of animal protein for coastal, lacustrine and riparian populations of Region V is thus an indirect source of exposure to PTS for these populations.

Coastal And Marine Environment

Since most of the socio-economic activities of Region V are associated with rivers and other water bodies apart from land, it is expected that significant amounts of PTS are transported across boundaries and released into lakes, seas and oceans. The magnitude of this input is unknown for the region, but it is likely to be significant and therefore constitutes another major data gap.

Terrestrial Aspects

The aspect of the behaviour of PTS in Region V soil types again constitutes a major data gap. Results obtained from other parts of the world may not be valid for Region V as the soil type and climatic conditions are very different.

PRELIMINARY ASSESSMENT OF THE REGIONAL CAPACITY AND NEEDS

In Region V, it is regrettable that whereas most of the national legislations are either general or fragmentary in nature and non-specific to PTS, some countries do not have any laws regarding hazardous chemicals. It will be important that national legislations are enacted and/or harmonised to deal with hazardous chemicals in general and PTS in particular.

A major constraint towards the sustainable management of these hazardous chemicals is the lack of and/or weak enforcement of regulations. For the region to contribute effectively in the global effort to reduce PTS, there is need to establish and/or strengthen existing institutions and legal framework through capacity building and putting in place necessary mechanisms for compliance monitoring and enforcement.

Alternatives And/Or Measures For Reduction Of PTS

Due to lack of adequate knowledge about the newly developed alternatives, some farmers undercover are still using PTS pesticides in the region. This calls for aggressive awareness raising amongst these small-scale farmers of the innovations and the effects of the PTS in order to convince them of the need to turn to the alternatives. The development of alternative chemicals to replace PTS has however started, though still on a small scale in the region. In some East African countries for example, most of the banned PTS pesticides (organochlorines) have been replaced by pyrethrums; some of which are locally manufactured and formulated. Some international research institutions in Africa are implementing alternatives to PTS pesticides in agriculture and vector control. For example, Integrated Pest Management (IPM) and Integrated Vector Management (IVM) have been developed and are currently being implemented in some parts of Region V along with the rest of the world. Another example is the potential use of the extract of the Neem tree to control agricultural pests and some fungal diseases instead of the conventional pesticides.

RECOMMENDATIONS

Existing environmental data gaps should be filled as a matter of priority as meaningful policy interventions to protect humans and the environment from risk of exposure to PTS cannot be achieved in a data vacuum. Environmental monitoring of PTS levels at the national level in soils, water, sediments, biota, air, livestock and human blood/breast milk is essential for identifying all the hot spots for remedial action to reduce health risks to humans.

The pathways and fate of PTS in the region should be studied, so that the critical pathways can be identified, followed by the evaluation of the relative impact of processes, estimation of transport fluxes, and assessment of remedial measures. Information is lacking in this critical area.

Capacity building needs in the region deserve priority action to ensure global success of the recent Stockholm Convention on POPs and other international regulations for the environmentally sound management of PTS and other hazardous chemicals. Regionally based research including development of an ecotoxicological database on the African environment is important. Training African experts in the use of models for sound chemicals management and environmental protection is also advantageous to the region and the international community.

1 INTRODUCTION

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 are: Aldrin, Endrin, Dieldrin, Chlordane, DDT, Toxaphene, Mirex, Heptachlor, Hexachlorobenzene, PCBs, Dioxins and Furans. Beside 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.

1.1.1 Objectives

There is a need for the 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.

1.1.2 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:

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

1.1.3 Methodology

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), South East 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 reside within financial constraints.

1.1.4 Management Structure

The Project Manager who is situated at UNEP Chemicals in Geneva, Switzerland directs the project. A Steering Group comprising of 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 Coordinator (RC) assisted by a team of approximately 4 persons controls each region. The Regional Coordinator and the Regional Team (RT) are responsible for promoting the project, the collection of data at the national level and to carry 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.

1.1.5 Data Processing

Data is collected on sources, environmental concentrations, human and ecological effects through questionnaires that are filled 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 its 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 cooperation with other intergovernmental organizations such as UNECE, WHO, FAO, UNPD, World Bank and others was obtained. Most have representatives on the Steering Group Committee that monitors the progress of the project and critically reviews its implementation. Contributions were garnered from UNEP focal points, UNEP POPs focal points, national focal points selected by the regional teams, industry, government agencies, research scientists and NGOs.

1.1.6 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 between September 2000 to April 2003 with the intention that the reports be presented to the first meeting of the Conference of the Parties of the Stockholm Convention projected for 2003/4.

This report provides a regional review of the production, use, environmental impacts and environmental transport of the group of chemicals known as Persistent Toxic Substances (PTS). The report is based on existing information only, and did not involve any additional research. The information for the report was assembled by the Regional Team Members on the basis of information supplied from a wide range of people throughout the region (the Regional Network) and beyond. The recommendations given in the report on regional priorities and future needs were developed during the Regional Technical Workshops and the Regional Priority Setting Meeting.

1.2 SCOPE OF SUB- SAHARA AFRICA REGIONAL ASSESSMENT

The chemicals included in this review were the 12 chemicals covered under the Stockholm Convention on Persistent Organic Pollutants (POPs), plus several other PTS chemicals. The 12 POPs are aldrin, chlordane, DDT, dieldrin, dioxins, endrin, furans, hexachlorobenzene (HCB), heptachlor, toxaphene, mirex and polychlorinated biphenyls (PCBs). Information was also obtained on other PTS chemicals: endosulfan, hexachlorocyclohexane (HCH), phthalate esters, polyaromatic hydrocarbons (PAHs), pentachlorophenol, organic lead, organic tin and organic mercury. Other chemicals considered for inclusion in the survey were, atrazine, chlordecone, hexabromobiphenyl, polybrominated biphenyl ethers, chlorinated paraffins, octylphenols, and nonylphenols.

1.2.1 Existing Assessments

Up to now, there has been no comprehensive regional assessment of organic pollutants in sub-Sahara Africa. This UNEP/GEF assessment is therefore both a landmark and an important source of regional database on persistent toxic substances (PTS). A previous sub-regional assessment of POPs (a subset of PTS), excluding dioxins and furans, in West and Central Africa (WACAF) and East Africa (EAF), had been undertaken in the past, especially in the early 1980s to the early 1990s. This was done under the aegis of the UNEP Regional Seas Programme. The assessments, which were limited to selected countries in WACAF and EAF, began with equipping selected laboratories and training national experts in the countries selected in the analysis of chlorinated hydrocarbons and heavy metals. The landlocked countries were excluded.

The FAO attempted for the first time in the early 1990s, under the aegis of the Committee of Inland Fisheries of Africa (CIFA), to collate the levels of chlorinated hydrocarbons (CHCs), specially organochlorine pesticides (OCPs) and PCBs in water, sediments and biota in Africa, and which was published as a chapter in the publication " *Review of pollution in the African aquatic environment* '' (Osibanjo *et. al.* 1994). This remains the only existing Regional Assessment of CHCs in the region before this report.

1.2.2 Methodology

Information on the PTS chemicals was obtained through various means. Data on current production and use was solicited from the relevant government agencies within the region. Heavy reliance was placed on CIA Fact book, Internet, and where this failed, all other data were obtained from published papers and reports. Additional information was obtained through searches of the published literature and through direct contacts with researchers, government agencies and the regional network of experts. All of the information collected from the above sources were entered into a series of standard questionnaires, which were provided by UNEP Chemicals for this purpose. The data was also entered into the UNEP PTS database in Geneva (which is accessible online www.unep.org; password required) to facilitate processing and analysis, and also to allow for future updating and review.

The regional team members were responsible for promoting the project, collection of data at the national level and, analysing the data on PTS on a regional basis. Data and information were collected on sources, environmental concentrations, human and ecological effects through questionnaires that were filled at the national level in the 47 countries of the region. Each regional team member was responsible for data collection in at least 6 countries. The regional team held organizational meetings and were responsible for filling the data from about 3000 questionnaires returned on to the UNEP PTS database.

The data gathering was aimed at obtaining information on all the chemicals mentioned in 1.1above. However, as can be seen later in Chapter 3, data was not available on some of the chemicals, already indicating a significant data gap, although this does not preclude their existence within the region. The potential for this and the need for appropriate regional investigations, are discussed later in this report.

All the collected data, reviewed in the regional report, were analysed for technical accuracy and completeness during the Regional Technical Workshops and the Regional Priority Setting Meeting. This report incorporates the inputs from the participants during the Regional Technical Workshops and the Regional Priority Setting Meeting. The recommendations given in Chapter 6 were based on the earlier comments made during the

Regional Technical Workshops, which were further enriched and endorsed by the Regional Priority Setting Meeting.

1.3 PTS DEFINITIONS AND PROPERTIES

The substances assessed in this report are as follows: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, PCBs, dioxins, furans, chlordecone, hexabromobiphenyl, HCH (lindane), PAHs, PBDE, chlorinated paraffins, endosulfan, atrazine, pentachlorophenol, organic mercury compounds, organic tin compounds, organic lead compounds, phthalates, octylphenols and nonylphenols. All the substances in the PTS list under study were adopted for the region with the assumption that some or all of the chemicals must have been used at one time or the other for specific purposes. The regional survey data is meant to be used as benchmark for identifying PTS existing in the region. The non-identification of a PTS is however considered as a data gap, rather than non-existence of the chemical in the region as searches were conducted for all the chemicals.

Summary of physico-chemical properties, including eco-toxicological and safety data, on each of the PTS chemicals is given below.

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 metabolized 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 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 varies 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 used mainly for the control of soil insects such as corn rootworms, wireworms and cat worms.
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 in 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 varies 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 °C; 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 50s 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}: 6.00.
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 promotes binding to aquatic sediments and bioconcentration in organisms.
Toxicity: LC_{50} 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 rat 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: Sol. 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 is in temperate regions 0.75 – 2 years. Its high partition coefficient provides the necessary conditions for bioconcentrating 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 *p,p*'-DDT, 5.5 for *p,p'*-DDD and 5.7 for *p,p'*-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% *p,p'*-DDT and 15% *o,p'*-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 50000 for fish and 500000 for bivalves). In the environment, the product is metabolized mainly to DDD and DDE.
Toxicity: The lowest dietary concentration of DDT reported to cause egg shell thinning was 0.6 mg/kg for the black duck. LC_{50} 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 estrogen-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 levels 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: Sol. 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 nonsystemic 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 76000 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 exists a 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,2,2,3,3a,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 bait comprising corncob grits, soya bean oil, and mirex.
Persistence/Fate: Mirex is considered to be one of the most stable and persistent pesticides, with a half-life is soils of up to 10 years. Bioconcentration factors of 2600 and 51400 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 rat 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_6H_6). **CAS Number:** 118-74-1
Properties: Sol. 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 of 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 rat of 1 g/kg bw. IARC has concluded that PCB 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.

1.3.2.2 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. Dioxins and furans 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/Fs are characterized by their lipophilicity, semi-volatility and resistance to degradation (half life of TCDD in soil of 10-12 years) and to long-range transport. They are also known for their ability to bio-concentrate and biomagnify under typical environmental conditions.
Toxicity: The toxicological effects reported refers 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 dioxin exposure in humans is chloracne. The most sensitive groups are fetus 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 dioxins, furans (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.

1.3.3 Regional Specific

1.3.3.1 Atrazine

Chemical Name: 2-Chloro-4-(ethlamino)-6-(isopropylamino)-s-triazine ($C_{10}H_6Cl_8$).
CAS Number: 19-12-24-9
Properties: Solubility in water: 28 mg/L at 20°C; vapour pressure: 3.0 x 10^{-7} mm Hg at 20°C; log K_{ow}: 2.34.
Discovery/Uses: Atrazine is a selective triazine herbicide used to control broadleaf and grassy weeds in corn, sorghum, sugarcane, pineapple, christmas trees, and other crops, and in conifer reforestation plantings. It was discovered and introduced in the late 50's. Atrazine is still widely used today because it is economical and effectively reduces crop losses due to weed interference.
Persistence/Fate: The chemical does not adsorb strongly to soil particles and has a lengthy half-life (60 to >100 days). Atrazine has a high potential for groundwater contamination despite its moderate solubility in water.
Toxicity: The oral LD50 for atrazine is 3090 mg/kg in rats, 1750 mg/kg in mice, 750 mg/kg in rabbits, and 1000 mg/kg in hamsters. The dermal LD50 in rabbits is 7500 mg/kg and greater than 3000 mg/kg in rats. Atrazine is practically nontoxic to birds. The LD50 is greater than 2000 mg/kg in mallard ducks. Atrazine is slightly toxic to fish and other aquatic life. Atrazine has a low level of bioaccumulation in fish. Available data regarding atrazine's carcinogenic potential are inconclusive.

1.3.3.2 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: sol. 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 principle 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 vapor 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 resulted to have no mutagenic potential in a number of studies but an endocrine disrupting activity.

1.3.3.3 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 non-food 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 sulfate, 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 a strong evidence of its potential for endocrine disruption.

1.3.3.4 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 insecticide (termiticide), fungicide, non-selective contact herbicide (defoliant) and, particularly as wood preservative. It is also used in anti-fouling paints and other materials (e.g. textiles, inks, paints, disinfectants and cleaners) as 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, other authors reports half-life in soils of 23-178 days. Although enriched through the food chain, it is rapidly eliminated after discontinuing the exposure ($t_{1/2}$ = 10-24 h for fish).
Toxicity: It has been proved to be acutely toxic to aquatic organisms and have certain effects on human health, at the time that exhibits off-flavour effects at very low concentrations. The 24-h LC_{50} values for trout were reported as 0.2 mg/L, and chronic toxicity effects were observed at concentrations down to 3.2 µg/L. Mammalian acute toxicity of PCP is moderate-high. LD_{50} oral in rat 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).

1.3.3.5 Polycyclic Aromatic Hydrocarbons (PAHs)

Chemical Name: PAHs is a group of compounds consisting of two or more fused aromatic rings. **CAS Number:** Various
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 it increases 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 rat of 490 and 18000 mg/kg body weight respectively, whereas the higher PAHs exhibit higher toxicity and LD_{50} of benzo(a)anthracene in mice is 10mg/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 produce intermediates that bind covalently with cellular DNA. IARC has classified benz[a]anthracene, benzo[a]pyrene, and dibenzo[a,h]anthracene as probable carcinogenic to humans. Benzo[b]fluoranthene and indeno[1,2,3-c,d]pyrene were classified as possible carcinogens to humans.

1.3.3.6 Organomercury compounds

Chemical Name: The main compound of concern is methyl mercury ($HgCH_3$). **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 volatilization 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.
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 world-wide 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.

1.3.3.7 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, and 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.

1.3.3.8 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 a 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 are 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 varies 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 1mg/kg bw/day. The toxicity to *Daphnia magna* has also been investigated and LC_{50} was found to be 14 □g/L with a NOEC of 4.9 □g/L. Although data on toxicology is limited, they have potential endocrine disrupting properties, and there are concerns over the health effects of exposure.

1.3.3.9 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 Nos.:** 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, 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 they have been reported as endocrine disrupting chemicals. The EPA proposed a Maximum Admissible Concentration (MAC) of 6 µg/L of DEHP in drinking water.

1.3.3.10 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 60s. 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 is 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.

1.3.3.11 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 sea water 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 also used as stabilisers in plastics and as catalytic agents in soft foam production. It is 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.

1.3.3.12 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 in 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 depending 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 are bioaccumulated 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.

1.3.3.13 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. As a fungicide against

apple scab and powdery mildew former use and to control the colorado potato beetle, rust mite on non-bearing citrus, and potato and tobacco were worm 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.
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 will not be expected to hydrolyse, or biodegrade in the environment. Also direct photodegradation is not significant similarly as evaporation from water. General population exposure to chlordecone occurs mainly through the consumption of contaminated fish and seafood.
Toxicity: Workers who were 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 tumors. Very highly toxic for some species such as Atlantic menhaden, sheepshead minnow or donaldson trout with LC50 between 21.4 – 56.9 μg/L.

1.3.3.14 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 gasoline. The release of TML and TEL are drastically reduced with the introduction of unleaded gasoline in late 70’s in USA and followed by other parts of the world. However, leaded gasoline is still available which contribute to the emission of TEL and to a less 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 to 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 has 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 SUB-SAHARA AFRICA REGION

Sub-Sahara Africa is the second largest of the earth’s seven continents, and with the adjacent islands covers about 21,787, 284 sq. km, or about 20% of the world's total land area. It is also the largest of the 12 regions in the UNEP PTS project, comprising about 47 independent African countries. A map of Sub-Sahara Africa is shown Figure 1.1. Algeria, Egypt, Libya and Morocco are excluded as these countries belong to the Mediterranean Region under the project. For the purposes of this project, the region was considered to include the following countries and island states: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo (Brazzaville), Cote d’Ivoire, Democratic Republic of Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Guinea-Bissau, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia and Zimbabwe.

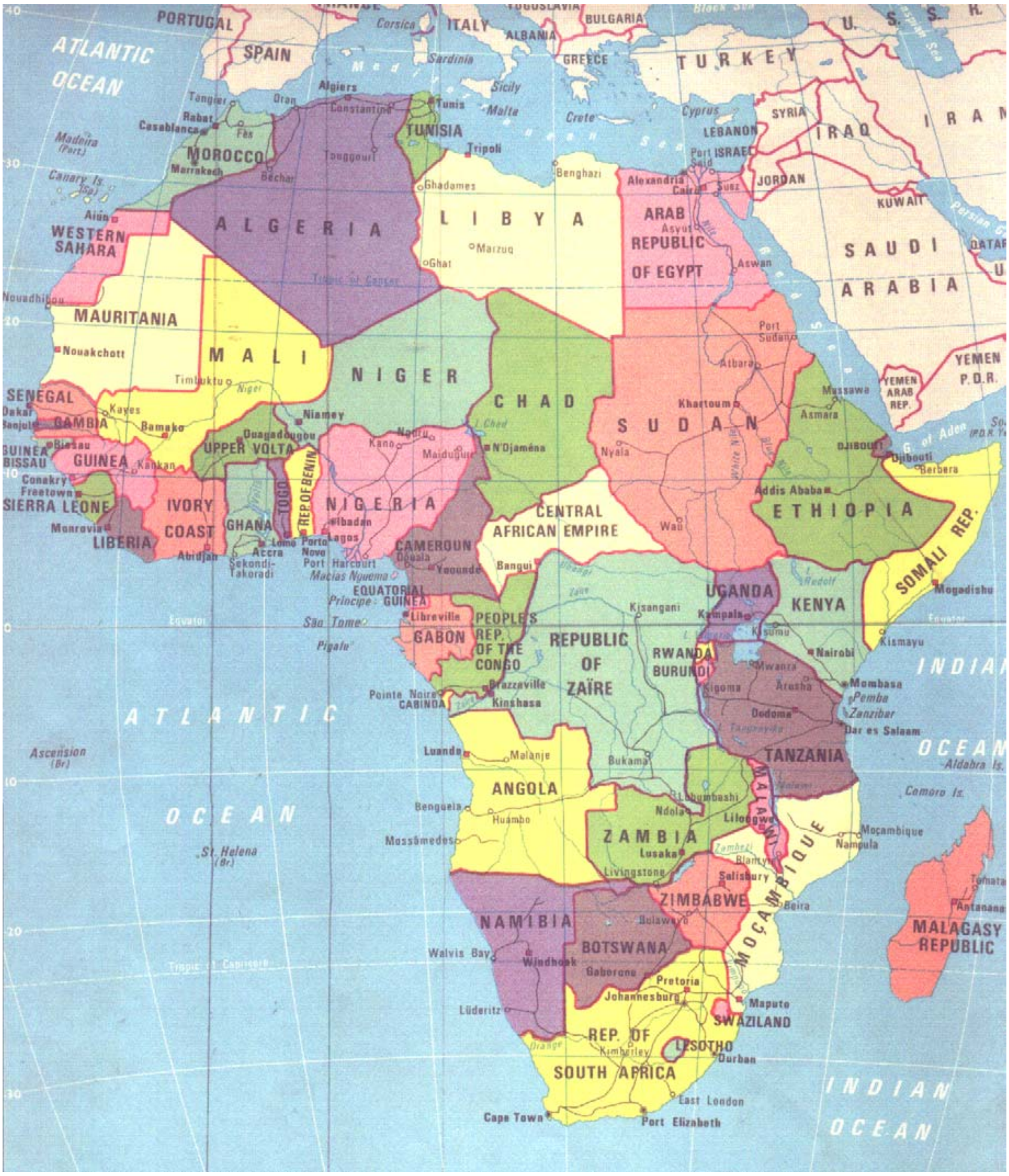

Fig 1.1: Map showing countries of Sub-Sahara Africa, Region V; excluding Algeria, Egypt, Libya and Morocco, which belong to the Mediterranean Region.

Straddling the equator, Sub-Sahara Africa stretches about 6500 km from its northern most part in Mauritania, to its southernmost tip, Cape Agulhas in South Africa. The maximum width of the continent measured from the tip of the Cape Vert in Senegal, in the west, to Cape Xaafuun (Ras Hafun) in Somalia, in the east, is about 7,560 km. The highest point on the continent is the perpetually snow-capped Mount Kilimanjaro (5,895 m) in Tanzania; the lowest is Lake 'Asal (153 m below sea level) in Djibouti.

The coastal and marine environment of sub-Saharan Africa embodies 32 countries including the small island states. The coastline is characterised by few indentations with total length of about 25,000 km, which in proportion to its area is less than that of any other continent. Population density is about 30 persons per sq km. However, the coastal areas are the most densely populated and industrialised parts of almost every sub-Saharan country, with about 50% of the population residing within 100 km of coastline. The coastal areas are also the location of the main import and export centres and provide food supplies for the landlocked countries of the region. PTS pesticide imports enter the countries through the ports mainly while land borders are important with respect to transboundary movements of PTS within the sub-regions.

The main islands associated with a combined area of some 621,600 sq km, are Madagascar, Zanzibar, Pemba, Mauritius, Reunion, the Seychelles, and the Comoro Islands in the Indian Ocean; São Tomé, Principe, and Bioko in the Gulf of Guinea; St Helena, Ascension, and the Bijagós Archipelago in the Atlantic; and the Cape Verde Islands, the Canary Islands, and the Madeira Islands in the North Atlantic. Although considered geographically part of Africa, St Helena, Ascension, the Bijagós Archipelago, the Canary Islands, and the Madeira Islands have few, if any, economic, political, or cultural links with the continent. Their ties are rather with western Europe: St Helena and Ascension are dependencies of the United Kingdom; the Canary and Madeira islands are an integral part of metropolitan Spain and Portugal, respectively.

1.5 PHYSICAL SETTING

Since the initiative taken on POPs (the Stockholm Convention) was part of the driving force behind this PTS project, and part of the concern regarding POPs deals with long distance transport, other geological, geographical issues and exposure of humans and biota, knowledge regarding these aspects is required for a better understanding of PTS in Africa. In the following sections, relevant geographical, topographical, biological and social aspects of the region will be discussed.

1.5.1 Physical/Geographical Description of the Region

Africa may be divided into three major regions: the Northern Plateau, the Central and Southern Plateau, and the Eastern Highlands. In general, elevations increase across the continent from northwest to southeast, the average being about 560 m. The coastal plains, with the exception of the Mediterranean and the Guinea coasts, are generally narrow.

The Eastern Highlands, the highest part of the continent, lie near the eastern coast, extending from the Red Sea south to the Zambezi along the fault line of the Rift Valley. The region has an average elevation of more than 1,500 m, and in the Ethiopian Plateau it rises in stages to about 3,000 m. Ras Dashan (4,620 m in northern Ethiopia) is the highest point of the plateau. South of the Ethiopian Plateau are a number of towering volcanic peaks, including Mount Kilimanjaro, Mount Kenya, and Mount Elgon. The most distinctive feature of the Eastern Highlands is the Rift Valley, the vast geologic fault system that begins in Anatolia, in eastern Turkey, stretches through the Jordan Valley and the Dead Sea, and then follows down the length of the Red Sea to Lake Turkana (formerly Lake Rudolph). At the southern end of Lake Turkana, the rift divides around Lake Victoria, but joins again at the head of Lake Malawi (Lake Nyasa), from where it runs down the Shire and Zambezi rivers, and finally out to sea. Altogether, the Rift Valley extends around almost one-fifth of the Earth, and contains some of its deepest lakes. West of the Rift Valley is the Ruwenzori Range, which rises up to 5,119 m above sea level. The topography of the island of Madagascar features a rugged central highland extending in a generally north-south direction near the eastern coast.

1.5.1.1 Soils

Africa has been a land area since Precambrian times, except for a few incursions from the sea. Its soils have, therefore, developed locally, chiefly by weathering. A few areas have alluvial soils laid down by rivers or ocean currents. African soils, for the most part, have irregular drainage and no definite water tables. Being typical tropical soils, most are relatively infertile, lacking humus and subject to mineral leaching from heavy rainfall and high temperatures. These factors could contribute to higher leaching and volatilisation with shorter persistence of certain chemicals including PTS. Desert soils (arid sols and entisols), which have the least organic content, cover large areas. The most fertile soils include the mollisols, also known as chernozems and black soils, of eastern Africa, and the alfisols, or podzolic soils, of parts of western and southern Africa.

1.5.1.2 Climate

Since climatic conditions affect the fate and behaviour of PTS, this aspect needs further expansion, for a better understanding thereof. Eight main African climatic zones can be distinguished:

- The central portion of the continent and, the eastern coast of Madagascar, has a tropical rainforest climate. Here the average annual temperature is about 26.7° C, and the average annual rainfall is about 1,780 mm.
- The climate of the Guinea coast resembles the equatorial climate, except that rainfall is concentrated in one season; no months, however, are rainless.
- To the north and south of the rainforest a tropical savannah climate zone encompasses about one-fifth of Africa's climate. Here the climate is characterised by a wet season during the summer months, and a dry season during the winter months. Total annual rainfall varies from 550 mm to more than 1,550 mm.
- Away from the equator, to the north and south, the savannah climate zone grades into the drier steppe climate zone. Average annual rainfall varies between 250 and 500 mm, and is concentrated in one season.
- Africa has a proportionately larger area in arid, or desert, climate zones than any continent, except Australia. Each of these areas - the Sahara in the north, the Horn of Africa in the east, and the Kalahari and Namibia deserts in the southwest - has less than 250 mm of rainfall annually. In the Sahara, daily and seasonal extremes of temperatures are great; the average July temperature is more than 32.2° C; during the cold season the night-time temperature often drops below freezing.
- Mediterranean climate zones are found in the extreme northwest of Africa and in the extreme southwest. These regions are characterised by mild, wet winters and warm, dry summers.
- In the highlands of eastern Africa, particularly in Kenya and Uganda, rainfall is well distributed throughout the year, and temperatures are equable.
- The climate on the high plateau of southern Africa is temperate.

The climate of Africa is the most generally uniform of any of the continents. This results from the position of the continent in the Tropical Zone, the impact of cool ocean currents, and the general absence, within the continental plateau, of mountain chains serving as climatic barriers. The equatorial belt generally has rainfall, whereas northern and southern Africa countries, and those in the Horn of Africa, are typically arid or semi-arid (Figs1.2a and 1. 2b).

This variability in climatic zones in different parts of the region has implications for the transport and fate of PTS. It implies that the various sub-regions will experience differences in PTS contamination, exposure and transport in and out of that specific region.

1.5.2 Water Resources

Water can be regarded as the most precious resource in Africa. Since most of all development occurs close to water bodies (fresh, estuarine and coastal), water resources require serious consideration in terms of PTS contamination, exposure and long distance transport.

1.5.2.1 Drainage and Water Resources

Africa contains some of the world's greatest rivers, which has implications for the transboundary transport of PTS. In all, six major networks drain Africa. With the exception of those draining into the Lake Chad basin, and those surrounding the Kalahari, all have outlets to the sea.

- **The River Nile** drains northeastern Africa, and, at 6,650 km, is the longest river in the world. It is formed from the Blue Nile, which originates at Lake Tana in Ethiopia, and the White Nile, which originates at Lake Victoria. The two converge at Khartoum in Sudan, from where the Nile flows west and north before emptying into the Mediterranean Sea in Egypt.
- **The River Congo**, some 4,670 km long, drains much of central Africa. It originates in Zambia, in southern Africa, and flows north, west, and south to empty into the Atlantic Ocean in the Democratic Republic of Congo.
- The third longest African river, **the Niger** in West Africa, is about 4,180 km long; its upper portions are navigable only during rainy seasons. The Niger rises in the highlands of the Fouta Djallon and flows north and east before turning south to empty into the Gulf of Guinea.
- **The River Zambezi**, about 3,540 km long, originates from tributaries that begin in Zambia and Angola, and converge in Zambia; it then flows south and east to empty into the Indian Ocean in Mozambique. Numerous rapids cut the Zambezi, the most spectacular being the Victoria Falls.
- Draining southern Africa are the **Limpopo and Orange rivers**. The Orange River, with its tributary, the River Vaal, has a length of about 2,100 km. It rises in the Drakensberg and flows west to the Atlantic.
- **Lake Chad**, a shallow freshwater lake with an average depth of only about 1.2 m, drains nearby rivers and constitutes the largest inland drainage system on the continent.

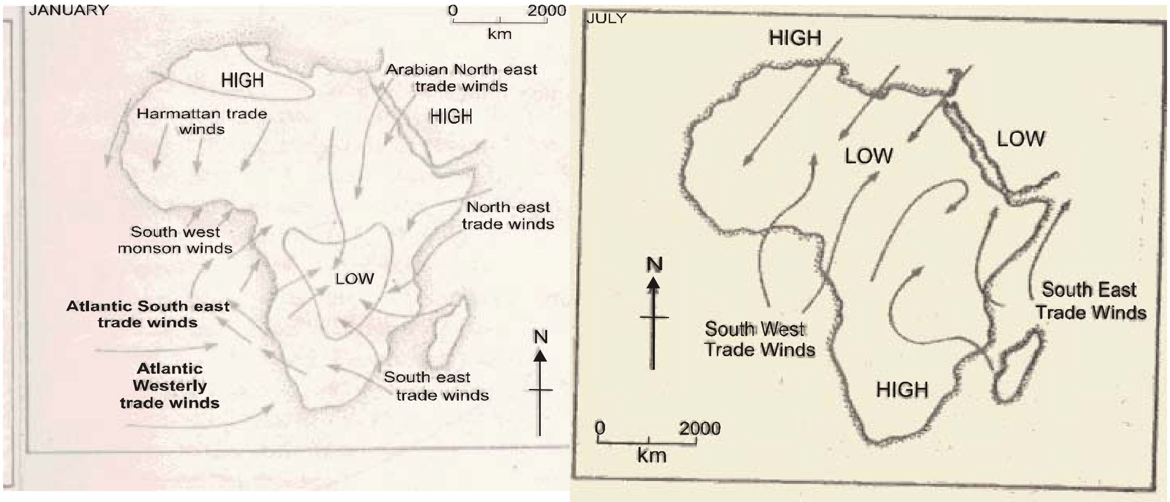

Fig. 1.2a: Map of Sub-Sahara Africa Showing Winds

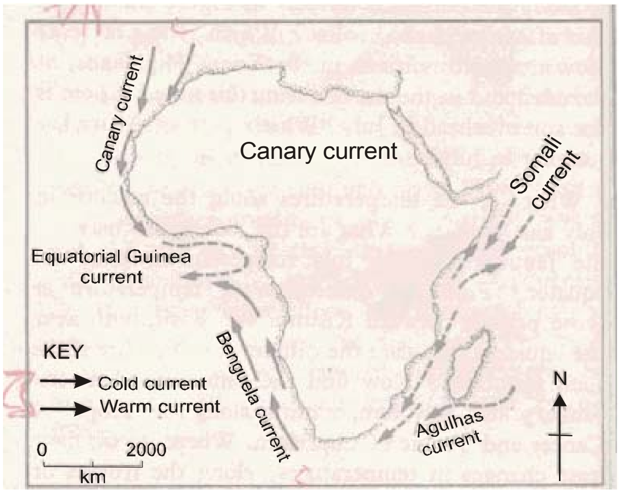

Fig. 1.2b: Map of Sub-Sahara Africa Showing Ocean Currents

The Rift Valley contains a series of great lakes. This equatorial lake system includes lakes Turkana, Albert, Tanganyika, and Malawi. Lake Victoria, the largest lake in Africa and the third largest in the world, is, however, not part of this system; it occupies a shallow depression in the Eastern Highlands. The River Limpopo originates in South Africa and runs 1,610 km, east and south to drain into the Indian Ocean in southern Mozambique. Achieving effective control of water supplies is a major problem in Africa. Vast areas suffer low rainfall; still larger areas receive only irregular rainfall and must store water as insurance against drought or poor rains. Other areas have an over-abundance of water: there are great swamps, like the Sudd of southern Sudan, and large areas suffer from periodic flooding.

The above discussion on water systems in Africa highlights that the limited fresh water resources are shared between a number of nations. Therefore, any pollution will in most cases have a cross-boundary implication, especially where persistent toxic substances are concerned. The large rivers aforementioned also constitute major pathway of PTS from land-based sources to the coastal and marine environment.

1.5.3 Vegetation

African vegetation can be classified according to rainfall and climate zones.

- **The tropical rainforest zone**, where the average annual rainfall is more than 1,270 mm, has a dense surface covering of shrubs, ferns, and mosses, above which tower evergreens, oil palms, and numerous species of tropical hardwood trees.
- **A mountain forest zone**, with average annual rainfall only slightly less than in the tropical rainforest, is found in the high mountains of Cameroon, Angola, eastern Africa, and parts of Ethiopia. Here a ground covering of shrubs gives way to oil palms, hardwood trees, and primitive conifers.
- **A savannah woodland zone**, with annual rainfall of 890 to 1,400 mm, covers vast areas with a layer of grass and fire-resistant shrubs, above which are found deciduous and leguminous fire-resistant trees.
- **A savannah grassland zone**, with annual rainfall of about 500 to 890 mm, is covered by low grasses and shrubs, and scattered, small deciduous trees. The thorn bush zone, steppe vegetation, with an annual rainfall of about 300 to 510 mm, has a thinner grass covering and a scattering of succulent or semi- succulent trees.
- **The sub desert scrub zone**, with an annual rainfall of 130 to 300 mm, has a covering of grasses and scattered low shrubs.
- **The zone of desert vegetation**, found in areas with an annual rainfall of less than 130 mm, has sparse vegetation or none at all.

The rich diversity of vegetation has implication for PTS levels in the atmosphere as they have been proven to be bio-indicators of PTS with ability to absorb them from air. Utilisation of plants for medicinal, food and other purposes, constitute pathways of exposure to PTS in this regard.

1.5.4 Wildlife

Sub-Sahara Africa is famous for its great variety of distinctive animals and birds, although many of these are now under threat of extinction from loss of habitat and poaching. The woodland and grassland areas are the traditional habitats of numerous species of antelope and deer, of zebra, giraffe, buffalo, the African elephant, rhinoceros, and the baboon and various monkeys. Carnivores, or meat-eating animals, include the lion, leopard, cheetah, hyena, jackal, and mongoose. The hippopotamus is found in the rivers, emerging at night to graze. The gorilla, the largest ape in the world, inhabits the rainforests of equatorial Africa, as do monkeys, flying squirrels, bats, and lemurs. However, many of these species, notably the elephant, rhinoceros, leopard, lion, and gorilla, are now found only in specially delineated game reserves.

Most bird life belongs to Old World groups. The guinea fowl is a leading game bird. Water birds, notably pelicans, goliath herons, flamingos, storks, and egrets, congregate in great numbers. The ibis is common in the Nile region, and the ostrich is found in eastern and southern Africa. Reptiles are also mainly having Old World origin and include lizards, crocodiles, and tortoises. A variety of venomous snakes, including the mamba, are encountered throughout the Ethiopian zone. Among the constricting snakes, pythons are found throughout Africa. Freshwater fish abound, with more than 2,000 known species. The continent has a variety of highly destructive insects, notably mosquitoes, driver ants, termites, locusts, and tsetse flies. The tsetse flies transmit sleeping sickness to humans and animals.

The consumption of wildlife meat as food and their use in traditional medicine also constitute this as a pathway of human exposure to PTS due to ingestion of PTS contaminated wildlife. By itself, wildlife can also be threatened by exposure, as will be seen in Chapter 3.

1.5.5 Demography

Human health and welfare are specifically considered under the various international agreements on chemicals. Therefore, good knowledge about the characteristics of demography, culture and geography of the region is needed to understand PTS exposure and pathways.

Although the region is about one-fifth the total world land surface, it has only about 10 % of its population. When the population living on arable or productive land is calculated, the average density could be 139 people per sq km. The most densely settled areas of the continent are those along the northern and western coasts; in the Nile, Niger, Congo, and Senegal River basins; and in the eastern African plateau. Nigeria, with a population of approximately 126 million, is the most populous nation in Africa.

Sub-Sahara Africa's rate of population growth averages about 3 per cent a year; in contrast the growth rate in Europe is about 0.4, and in Latin America is 2 per cent. The spread of medical services since World War II has been responsible for a sharp decrease in the death rate, which averages about 15 per 1,000, but varies considerably between countries. The age distribution is weighted heavily towards the young. In most African countries, about half the population is 15 years of age or younger.

Africa's population remains predominantly rural, with only about one-fifth of the population living in towns of more than 20,000 inhabitants. But there are individual countries with high levels of urbanization, such as Zambia (50 per cent urbanized), and major cities are located in every part of the continent. Cities in the region with populations of more than 1 million include Lagos, Nigeria; Addis Ababa, Ethiopia; Abidjan, Côte d'Ivoire; Kinshasa, Democratic Republic of the Congo; Johannesburg, Cape Town, and Soweto in South Africa, Khartoum in Sudan. The urban centres act as magnets, attracting large numbers of rural migrants who come either as permanent settlers or as short-term workers. Urban growth has been particularly rapid since the 1950s. A substantial international labour migration has also developed, particularly of Africans from central Africa to the mines and factories of Zambia, Zimbabwe, and South Africa, and of North and West Africans to France and Italy, and, more recently, to the European Union as a whole. Civil wars in a number of countries in recent years—notably Angola, Mozambique, Ethiopia, Sudan, Liberia, and most recently Rwanda—have led to a massive displacement of population, as have droughts and famines. Africa has the world's largest concentration of refugees, including people displaced within their own countries, as well as people who have fled across borders in search of safety. An increasing population implies greater demand for food with concomitant demand in use of PTS pesticides to boost food production and vector disease control.

1.6 PATTERNS OF ECONOMIC DEVELOPMENT

Traditionally, the vast majority of Africans have been farmers and herders who raised crops and livestock for subsistence. Manufacturing and crafts were generally carried on as part-time activities. Modern processing industries developed, as did new ports and administrative centres. A variety of consumer industries sprang up to fill newly created local consumer needs. A feature of the African economy is the side-by-side existence of both subsistence and modern exchange economies. Future growth depends on the availability of investment funds, the world demand for local raw materials, fair world prices for these raw materials, the availability of energy sources, the size of local markets, a solution to the foreign debt problem, which is crippling so many African economies, and the willingness of the industrialized economies to reduce trade barriers to processed and manufactured African goods.

1.6.1 Agriculture

Despite the expansion of commerce and industry, most Africans remain farmers and herders. PTS pesticides therefore remain an important parameter in agricultural production for food security in the region. The majority of these farmers are producing for the local market, at least in a small way, but some are highly commercialised. Although some 60 per cent of all cultivated land is in subsistence or semi subsistence agriculture, commercial or cash-crop farming is common in all parts of the continent. Foodstuffs are grown for local urban markets, but cloves, coffee, pineapples, cotton, cacao, sugar, tea, maize, rubber, sisal, groundnuts (peanuts), palm oil, vegetables, pulses, cereals, citruses, mangoes, bananas, gum Arabic and tobacco are among the long-established crops grown by Africans for export. In the past 15 years, there has been significant development of new export crops, aimed at the high-value end of the Western, primarily European market, including green beans, roses and other flowers, and kiwi fruit. For certain traditional African agricultural exports, such as cacao, groundnuts, cloves, and sisal, the continent produces the majority of the world supply. Large-scale plantations and farms, often owned by foreign companies or farmers of European descent, and found mainly in eastern and southern Africa, concentrate on citrus, tobacco, tea, and other export crops. The high residue levels of PTS, for example Lindane in cocoa and other cash crops has caused severe economic losses to African countries, which are dependent on agricultural produce.

1.6.2 Forestry and Fishing

Although about one-quarter of Africa is covered by forest, much of the timber has little value, except as local fuel. Gabon is a major producer of okoume, a wood used in making plywood; Côte d'Ivoire, Liberia (before the civil war), Ghana, and Nigeria are major exporters of hardwoods. The Sudan is a major producer of gum Arabic, a product of *Acacia* trees. Inland fishing is concentrated in the Rift Valley lakes and rivers (*viz*. the Nile and its tributaries) and in the increasing numbers of fish farms. Ocean fishing is widespread for local consumption; it is commercially important off Morocco, Mauritania, Namibia, Mozambique, and South Africa. The Red Sea is a major source of fish for the Sudan, Eritrea, Somalia and Djibouti.

1.6.3 Industry

Stemming from mineral and oil extraction are processing industries, such as refining and smelting, which are located in most mineral-rich countries with adequate energy. South Africa is the most industrialized of Africa's countries, but virtually all other countries have developed a manufacturing base of some sort; Zimbabwe and Nigeria have very sizeable industrial sectors. Heavy industry, such as metal producing, machine making, and transport equipment, is concentrated in South Africa and Nigeria. Significant industrial centres have also developed in Kenya, Sudan, and Ghana amongst others. Mineral-related industries are well developed in the Democratic Republic of the Congo and Zambia; Kenya, and Côte d'Ivoire have developed primarily in textiles, light industry, and building materials. The manufacturing industry sector is a potential source of environmental release of PTS (e.g. dioxins and furans) and PAHs into the environment.

1.6.4 Energy

Nigeria, Libya, Algeria, and Angola are major world producers of oil, and several other African countries are also oil exporters, including Gabon, Sudan and Chad. Africa's natural-gas exports are centred in Algeria and Nigeria.

Coal production is concentrated mainly in Zimbabwe and South Africa, although many other countries have sizeable reserves (such as Botswana), which await development because of a lack of markets. The bulk of African coal production is used internally. Most African countries must import fuels, especially petroleum and oil. The oil price rises of the 1970s were disastrous for many of them, precipitating many of the balance of payments and debt problems, which have undermined their economies in the 1980s and early 1990s. Although Africa has some 40 per cent of the world's hydroelectric power potential, only a relatively small portion has been developed owing to high construction costs, inaccessibility of sites, and their distance from markets. The energy sector may be considered a major source of PTS (PCBs, dioxins and furans and PAHs) release into the environment.

1.7 SOCIAL ASPECTS

Recently, expectations in African nations for a better living standard have increased. However, while the prices of imported consumer and other manufactured goods have risen steadily, the world prices of most African primary products have lagged behind. A worldwide recession in the early 1980s multiplied difficulties that were initiated by the oil-price increases of the 1970s. Serious foreign-exchange problems and the burden of foreign debt have aggravated public discontent. Famine and drought plagued the northern and central regions of the continent in the 1980s, and millions of refugees left their homes in search of food, increasing the problems of the countries to which they fled. Medical resources, already inadequate, were overwhelmed by epidemics of acquired immune deficiency syndrome (AIDS), cholera, and other diseases. In the late 1980s and the first half of the 1990s protracted local conflicts in Chad, Somalia, Sudan, the Saharan area, southern Africa, and elsewhere on the continent destabilized governments, halted economic progress, and cost the lives of thousands of Africans.

Another major problem has been Africa's inability to project an effective voice in international affairs. Most African states regard themselves as part of the developing world and the non-aligned nations. Because of their lack of financial, technological and political power, however, the views of African nations rarely appear to be taken into account.

Nevertheless, as the 21st century dawned, Africa remained a continent of sharp contrasts and paradoxes. Low levels of education, poverty and malnutrition, augmented by natural disasters continue to be major issues for Africa. In addition, the search continues to find an appropriate response to the AIDS epidemic, which continues to devastate the population, and is likely to be the most important issue for Africa for the foreseeable future. Approximately 10 per cent of adults on the continent have HIV/AIDS, and the disease will increasingly strain the economic and labour resources of African nations. Medical services are already struggling to cope and vast numbers of people removed from the work force owing to illness or looking after sick relatives, and this will have a devastating impact on productivity. According to the United Nations Environment Programme (UNEP), Africa is the only region in the world where poverty is expected to increase in the 21st century. Other problems include a further loss of agricultural land because of desertification and other factors; deforestation; and the increasing scarcity of freshwater supplies.

In line with the above-mentioned problems, the lack awareness of PTS and the consequences of their uses may confound these issues, as many are inter-related. DDT and malaria, as well as the use of other pesticides, the release of PCDD/Fs and PCBs, and the exposure profiles that the human population and biota are experiencing due to these compounds, are some of the examples that need to be urgently addressed in Africa. The New Partnership for Africa’s Development (NEPAD) with active support from GEF/UNEP and other international donor agencies provide hope for improved health and poverty alleviation among the people in the region, including PTS issues.

1.8 SUMMARY

The region has a wide diversity of bio-geographical, cultural, language, demographic and natural resource features. It comprises several mainland African countries as well as small island states in the West Indian Ocean and the Gulf of Guinea. It has some of the longest rivers and largest lakes in the world. Indian Ocean surrounds the continent on the eastern side and the Atlantic Ocean on the western side. Rivers and oceans, including migratory fish and birds, as well as winds ocean currents, therefore constitute pathways of PTS in and out of the region. Because the soils of the region have low organic matter content, and the region experiences temperature extremes, these variable conditions will *inter alia* affect the persistence and behaviour of PTS.

The African economy is fragile and largely agricultural with huge debt burdens crippling the national economies and impoverishing the population, which has limited access to health care. The new NEPAD initiative is expected to promote economic development in the region, with improvement in health care and alleviation of poverty among the people.

1.9 REFERENCES

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2 SOURCE CHARACTERISATION

2.1 INTRODUCTION

As can be seen from Chapter 1, the conditions and circumstances of the countries involved in Sub-Saharan Africa Region V of the RBA project are varied and complex in nature. Even though some, or perhaps even most, of the individual country's PTS releases into the environment may be little, the problem may however become significant after aggregating the releases for the region. This bio-geographical aspect combined with the social and economic developing nature of the continent, therefore results in a wide variety of sources of PTS.

In this chapter, a general categorization and brief description of anthropogenic and natural sources of PTS will be presented, highlighting those that differ from developed regions. The RBA project brief lists the following as information to be collected on sources during the country contribution phase, particularly from the questionnaires for source identification:

- Production and use of PTS pesticides, as well as the identification of major agricultural areas;
- Sources of industrial chemicals and identification of major industrial centres or specific production sites;
- Sources of unintentional PTS by-products (including identification of point sources and diffuse sources and information on industries potentially releasing PTS);
- Import and export statistics of PTS and PTS containing wastes;
- Identification of stocks and reservoirs of PTS;
- Data gaps;
- Summary of most significant regional sources.

The identifiable main sources of PTS in the region are production, agriculture, vector control, stocks of obsolete and expired pesticides, and not the least as by-products of combustion. These sources are discussed individually and/or in groups while an attempt is also made of the relative ranking of the source categories based on knowledge of the region.

2.2 PRODUCTION OF PTS PESTICIDES

Generally PTS pesticides are not produced in Africa. Only atrazine seems to be currently produced (only in South Africa), but previous production of compounds such as DDT (at least in South Africa) is known. The current production of the other PTS pesticides (no. 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14, 15, 19, and carbaryl, chlorpyrifos and herbicides in general under number 28 of the "Common names of PTS" in the Listing of Questions) is not done in Africa, but are imported from elsewhere. However, pesticide formulation plants exist in many countries (Table 2.1). Where PTS are being produced or formulated in this region, there is likely to be little data available on production, as well as on current and past releases to the environment. Production waste is also likely to be not well quantified, and there are unconfirmed reports of major polluted areas of past production waste associated with such production and formulation activities.

Table 2.1 Known formulation plants in Region V (RBA Workshop information).

Country	PTS Pesticide Produced	PTS Pesticide formulated	Estimated annual amount	Specific Sites	Estimated Production Waste
South Africa	Atrazine	Atrazine DDT	2000 tons	Berlin Plant East London	Data Gap
South Africa		Endosulfan	129 tons	Canelands Chloorkop	Data Gap
		Lindane (gamma BHC)	55 tons		Data Gap
		Chlordane	45 tons		Data Gap
Zimbabwe1		Chlordane Lindane Atrazine Endosulfan	12 tons 2,5 tons 160 tons 33 tons	Bulawayo Harare	Data Gap
Nigeria		Lindane	Data Gap	Ibadan	Data Gap
Ethiopia		Endosulfan	40 tons		Data Gap
Kenya2		No PTS	Data Gap	Data Gap	Data Gap
Sudan3		Non currently	Data Gap	Data Gap	Data Gap
Madagascar		Data Gap	Data Gap	Antananarivo	Data Gap
Senegal		Data Gap	Data Gap	Data Gap	Data Gap
Ghana		Lindane	900 000l	Tema	Data Gap

- It is unsure which compounds are formulated at the Zimbabwe plants.
- The plant in Kenya does not formulate PTS pesticides.
- The formulation plants referred to in Sudan are currently in the process of being licensed.

Production and formulation sites, due to the water requirements of this industry, are likely to be closely associated with freshwater sites such as rivers, lakes or lagoons and estuaries in coastal areas, which increases the potential for pollution and long-distance transport via water.

2.3 THE IMPORT OF PTS PESTICIDES

Due to the bio-geographical and the social and economic developing nature of the continent in general, Africa (RBA Region V) uses very little on a global basis in terms of pesticide use. In 1994 it was estimated that Africa used only 5% of the world total of pesticides produced (Wiktelius & Edwards1997). The data from the FAO supports this (Table 2.2) and indicates that in the past eight years, imports never rose above the 5% levels on a global comparison. Industry data however, indicates the percentage to be between 2-3%. The difference is likely accounted for by foreign aid contributions, which might not be taken into account by the industry.

Table 2.2: Imports of pesticides into Africa compared with world trade figures ($1000). Export figures are not included. (FAO data)

Year	1992	1993	1994	1995	1996	1997	1998	1999
Africa	378907	392850	429797	465450	499387	526667	571647	504344
World	8135455	8070441	8639721	10232080	11125033	11103189	11634888	11730915
%	4.66	4.87	4.97	4.55	4.49	4.74	4.91	4.30

Due to the lack of data on PTS use in Africa, an approximation of PTS use could be obtained from information on pesticide importation figures (Table 2.3). Most of these pesticides will not be PTS. The RBA Technical workshop that included representatives from industry derived a figure of 18% of the total pesticides to be PTS for Region V, from various calculations and estimates. This represents $211 million in value terms. In general it should also be taken into account that low value pesticides (including most of the PTS pesticides) could be applied at higher rates than higher value products.

Table 2.3 does indicate however, which countries have major agricultural activities using pesticides. Table 2.3 shows that 22 RBA Region V countries each imported more than $5 million worth of pesticides. Although these figures do not include local production and export, it can be safely assumed that these countries use the majority of pesticides (80.8% in value terms) in this region. Table 2.3 also shows that only four countries imported more than $20 million worth of pesticides during 2001. These four countries (Ghana, Kenya, South Africa and Zimbabwe) together imported 54% (in value terms) of all the pesticides imported into Africa. This table therefore gives a rough estimate (excluding exports and local production) of where most pesticides (including PTS) might be applied. South Africa is the largest exporter ($89 million in 2001), but the balance between import and local production, as well as between import and export for all countries is not known. Also, when comparing these figures with that from Table 2.1, it seems probable that the production figures for South Africa might be an under-estimate, and therefore a data gap to be investigated further.

The RBA technical workshop listed the most widely used PTS pesticides for Region V as shown below, in no particular order, although this does not mean that others are or have not been used:

- Atrazine
- Endosulfan
- Chlordane
- Lindane
- DDT
- Heptachlor
- Toxaphene
- HCB
- Aldrin

The RBA Technical Workshops and the Priority Setting Meeting both indicated the possibility and likelihood of illegal use of PTS pesticides (likely to include DDT as well) in the region. However, it is not possible to estimate the amounts involved, but this would most probably be low, when compared with the overall amounts used legally. Awareness of the problems associated with PTS was also judged to be low.

Table 2.3 Yearly data for countries importing more than $5 million of pesticides during 1999 ($1000). Countries importing more than $20 million worth of pesticides during 1999 are highlighted. Export figures are not included. (FAO data, adjusted by RBA workshop)

Year Country	1992	1993	1994	1995	1996	1997	1998	1999
Cameroon	10000	15548	14837	19587	12865	15020	16000	16000
DRC	6000	6000	6000	6000	6000	6000	6000	6000
Côte d'Ivoire	16000	18000	20000	25677	20086	20000	19500	19500
Ethiopia		5813	11449	6325	6300	6300	6300	6300
Ghana	15910	16000	17000	18000	19031	31793	30000	32000
Kenya	30199	27954	23734	39712	31640	41643	62802	40497
Malawi	7383	5682	5029	5697	8000	14470	10035	10000
Mali	14000	14000	14000	14000	14000	14000	14000	14000
Mauritius	9545	7898	8783	9577	10543	9939	9327	8347
Mozambique	15000	20000	20811	9393	11626	11700	11800	11800
Nigeria	8495	11000	13000	16065	19000	25000	37149	16000
Senegal	6000	7057	7367	8019	8000	6749	10424	11511
South Africa	66442	77418	85102	94941	115473	111218	108862	101498
Sudan	13000	14000	15000	16300	9712	10000	11000	16000
Swaziland	5000	7000	8000	8258	8500	9434	7639	7500
Tanzania	16000	15000	14000	12500	11000	10151	10100	10100
Togo	5066	4937	4304	5631	5782	7219	7980	8000
Uganda	3000	3000	4000	6000	8000	11000	13838	9511
Zimbabwe	29442	21330	27765	29443	44492	37033	38654	32487
TOTALS	276482	297637	320181	351125	370050	398669	431410	377051

The RBA technical workshop found that the data in general reflected the real situation, although some small adjustments were made.

When assessing sources of PTS, it is also important to identify the major ports of entry of PTS into countries. These ports, including major railheads, are areas where pollution, due to years of spillages and accidents might have occurred, and therefore represent potential secondary sources of contamination. A provisional list of major ports and railheads identified by the RBA workshop includes the following: Cape Town, Durban, East London, Port Elisabeth, Maputo, Port Djibouti, Obock, Tadjoura, Rail link to Djibouti via Addis Ababa, Port Sudan, Sawakin, Port Louis, Mogadishu, Barbara, Mombasa, Free Town, Guinea, Accra, Beit Bridge, Abidjan, Dakar, Lagos, Douala, Mombassa, Tamatave, Port Harcourt, Cotonou.

Harbours and railway heads are not the only routes of entry, as many land-locked countries have no railway links and these are served by roads. Additional risk exists from spillages that may occur along any of the roads, thereby creating local contaminated hotspots. From experience from South Africa, road spillages are not an uncommon event, yet it is unlikely that many countries do not have the means to attend to these spills in a timely fashion, if such spills do get reported.

2.4 THE USE OF PESTICIDES AND MAJOR AGRICULTURAL AREAS

Table 2.4 presents the agricultural areas (including pasture) and irrigation of the countries of RBA Region V. Not all these lands will experience pesticide treatment, but it is likely that the larger irrigated areas will be treated regularly. The large areas in Sudan and South Africa are notable. Possibly the largest single irrigation scheme in this region is the Gezira in the Sudan, with 800 000 ha.

Table 2.4: Areas used for agriculture (including pasture), as well as areas under irrigation, in the various countries of the RBA Region V. Countries with more than 100 000 ha under irrigation are highlighted in bold (FAO data for 1999, and adjusted by RBA workshop)

Country	Agricultural lands (1000 ha)	Irrigated lands (1000 ha)	Major agricultural areas
Angola	57500	75	
Benin	2400	12	North and centre
Botswana	25946	1	
Burkina Faso	9450	25	South west, South and West
Burundi	2200	74	
Cameroon	9160	33	
Central African Republic	5145		South, Centre, West, Lake Chad, Chari-Logone region
Chad	48550	20	
DRC	22880	13.5	Kinshasa region, Kasai, Lower Congo, Equator
Republic of Congo	10220	1	Niari Valley, Songha
Côte d'Ivoire	20350	73	
Djibouti	1300	1	
Eritrea	7467	22	
Ethiopia	30728	190	
Gabon	5160	15	
Gambia	659	2	
Ghana	13628	11	Volta Basin, Middle Belt, Savannah Region
Guinea	12185	95	
Guinea-Bissau	1430	17	
Kenya	25820	67	
Lesotho	2325	1	
Liberia	2327	2	
Madagascar	27108	1090	Centre, West, South West

Malawi	3850	28	North Western Region, Central Region South Eastern Region
Mali	34650	138	
Mauritania	39750	49	
Mauritius	113	20	
Mozambique	47350	107	
Namibia	38820	7	
Niger	17000	66	
Nigeria	69938	233	North-East, North-West, Middle Belt, East and Western Areas
Rwanda	1661	5	
Reunion	49	12	
Sao Tome and Principe	42	10	
Senegal	7916	71	
Seychelles	7		
Sierra Leone	2740	29	
Somalia	44065	200	
South Africa	99640	1354	Western cape, Free State, Kwazulu-Natal, Mpumulanga, Mhkahatini flats Toyhandou - Levhubu
Sudan	126900	1950	Gezira, El-Rahad, New Halfa, Suki, Blue Nile, White Nile, Khartoum, Kenana, Asalya, Sinnar, Elgunaid
Swaziland	1330	69	
Tanzania	39650	155	
Togo	3300	7	
Uganda	8610	9	
Zambia	35279	46	
Zimbabwe	20550	117	Highveld, Middleveld, Lowveld, Eastern Highlands.
Totals	987148	6522.5	

Table 2.5: Agricultural production data for the various countries of the RBA Region V (CIA Factbook 2001 data, and amended by RBA workshop). Countries with more than $10 b worth of agricultural production are highlighted. Crops with likely use of PTS use are included.

Country	GDP ($b)	Agric % GDP	Agriculture ($b)	Agricultural products using PTS
Angola	10.1	60	6.1	Sugarcane, cotton,
Benin	6.6	37.9	2.5	Cotton,
Botswana	10.4	4	0.4	groundnuts (peanuts)
Burkina Faso	12	26	3.1	peanuts, cotton, sorghum
Burundi	4.4	50	2.2	Cotton
Cameroon	26	43.4	11.3	Cotton
Central African Republic	6.1	53	3.2	Cotton
Chad	8.1	40	3.2	Cotton
Comoros	0.419	40	0.2	
Congo (Brazzaville)	3.1	10	0.3	sugarcane
Cote d'Ivoire	26.2	32	8.4	sugarcane, cotton, rubber; timber
Democratic Republic of Congo	31	58	18.0	sugarcane, cotton, tobacco
Djibouti	0.574	3	0.1	hides
Equatorial Guinea	0.96	20	0.2	
Eritrea	2.9	16	0.5	Cotton, tobacco
Ethiopia	39.2	45	17.6	sugarcane, hides
Gabon	7.7	10	0.8	sugarcane
Ghana	37.4	36	13.5	Cocoa, peanuts
Guinea-Bissau	1.1	54	0.6	peanuts, cotton, timber
Guinea	10	22.3	2.2	
Kenya	45.6	25	11.4	sugarcane, floriculture, tobacco
Lesotho	5.1	18	0.9	
Liberia	3.35	60	2.0	Cocoa, sugarcane, timber
Madagascar	12.3	30	3.7	sugarcane, cocoa, peanuts;
Malawi	9.4	37	3.5	tobacco, sugarcane, cotton,
Mali	9.1	46	4.2	Cotton, peanuts;

Mauritania	5.4	25	1.4	
Mauritius	12.3	10	1.2	sugarcane, tobacco
Mozambique	19.1	44	8.4	Cotton, sugarcane,
Namibia	7.6	12	0.9	peanuts;
Niger	10	40	4.0	Cotton, peanuts
Nigeria	117	42	36.0	Cocoa, peanuts, cotton, root crops
Rwanda	6.4	40	2.6	
Sao Tome and Principe	0.178	23	0.1	Cocoa,
Senegal	16	19	3.0	peanuts, cotton,
Seychelles	0.61	3.1	0.1	sugarcane
Sierra Leone	2.7	43	1.161	Cocoa, peanuts
Somalia	4.3	60	2.6	sugarcane
South Africa	369	5	18.5	corn, sugarcane, vegetables, cotton
Sudan	35.7	39	13.9	cotton, groundnuts (peanuts), sugarcane,
Swaziland	4.4	10	0.4	Sugarcane, cotton, corn, tobacco peanuts
Tanzania	25.1	50	12.5	Coffee, cotton, maize, fruit
Togo	7.3	42	3.1	Coffee, cocoa, cotton, sugarcane
Uganda	26.2	43	11.3	Coffee, cotton, tobacco,
Zambia	8.5	18	1.5	flowers, tobacco, cotton, sugarcane, hides
Zimbabwe	28.2	28	8.0	corn, cotton, tobacco, coffee, sugarcane, peanuts

From Table 2.5, more than 25 countries produce crops that are likely to involve the application of significant amounts of pesticides. During the RBA workshop, experts from various countries indicated additional uses of pesticides such as DDT for domestic use and malaria control at ports and airports. The Priority Setting Meeting delegates also voiced their concerns about other potential uses. Such uses include the regular or incidental control of malaria, tsetse fly, Quelea (South Africa and Sudan), locust (many countries), blackfly, bilharzias and problem animals (such as jackal and hyena, the latter in Djibouti, and caracal). Other (legal/illegal) uses are for food collection (e.g. fish and birds), harvesting for traditional medicine (e.g. vultures), exotic vegetation control, and infrastructure protection (railways, electricity pylons, etc). These applications rarely happen on agricultural lands, but often in natural areas. Although the overall amounts used might be low when compared to agricultural application, they can be used at high rates and therefore contribute towards local impacts and the creation of polluted areas, from where water, biota and humans can be affected.

2.5 IDENTIFICATION OF STOCKS AND RESERVOIRS OF PTS PESTICIDES

According to the FAO, obsolete unwanted and banned pesticides and persistent organic pollutants (POPs) are serious environmental hazards, especially where they are stocked and mostly neglected. Stocks of leaking and corroding metal drums filled with obsolete and dangerous pesticides and industrial waste, the source of which is often from outside Africa, is fortunately not increasing as rapidly as before in African countries, but they can still often be found. The FAO estimates that there might be more than 40 000 tons, perhaps even much more, of these chemicals stocked or discarded over many parts of Africa. These chemical leftovers affect not only the country's agriculture and its environment, but also fundamentally the health of its people and consequently both rural and urban development. Where research has been done, it was clear that these pesticides enter the soil and eventually contaminated ground and surface water, with consequent further contamination of humans, livestock and biota. These residues will therefore also become available for long-range transport.

It is particularly worthy of note that some of the obsolete pesticides were imported as part of foreign aid. In some cases, developed countries donated these pesticides that had been banned in their home countries, or were no longer wanted, or had expired or were nearing expiry dates to unsuspecting African countries. This practice should be discouraged, as the chemicals will eventually return to developed countries for ultimate disposal.

According to the FAO (1999), obsolete pesticides take into consideration the following criteria:

- Pesticides that are in the form of liquids, powder or dust, granules, emulsions, etc.
- Empty and contaminated pesticide containers of all forms and kinds (i.e. metal drums, plastic containers, paper cartoons, jute and other bags, etc.)
- Heavily contaminated soil,
- Buried pesticides, etc. (FAO 1999)

Obsolete pesticides are therefore pesticides that can no longer be used for their intended purpose or any other purpose. Thus it requires disposal. Common causes of this situation include the following:

- Use of the product has been prohibited or severely restricted for health or environmental reasons (e.g. through banning, withdrawal of registration, or policy decisions).
- The product has deteriorated as a result of improper or prolonged storage and can no longer be used according to its label specifications and instructions for use, nor can it easily be reformulated to become usable again.
- The product is not suitable for its intended use and cannot be used for other purposes, nor can it easily be modified to become usable. (FAO 1999)

Although the location, condition and identities of many of these stocks have been identified, the situation is not static. Changes in conditions (such as floods, and neglect) can alter the status of the existing stocks or dumps, or the stocks might be transferred elsewhere, sent for incineration, or misappropriated. There is therefore a need to regularly update the existing databases. The latest available data are from the FAO (2002), and are presented in Table 2.6.

Table 2.6 Available data from inventories conducted in Region V countries, of obsolete stocks that require disposal (FAO 2002). Countries with more than a 1000 tons are highlighted.

Country	Number of Affected Sites	Number of Different Pesticides	Stocks in Country (tons)
Angola			
Benin	23	50	421

Botswana	6	60	18248
Burkina Faso	21	?	275
Burundi	2	6	169
Cameroon	97		283
Cape Verde	13	30	43
Central African Republic	3	15	238
Chad			
Congo, Democratic Republic of the	6	7	591
Congo, Republic of the	7	1	2
Côte d'Ivoire	5	10	828
Djibouti			
Equatorial Guinea	5	25	146
Eritrea	45	>30	223
Ethiopia	764	>400	3402
Gabon			
Gambia			
Ghana	19	45	72
Guinea-Bissau			
Guinea-Conakry	12	9	47
Kenya	33	49	56
Lesotho			
Liberia			
Madagascar	48	106	1
Malawi	20	70	111
Mali	24	>25	14001
Mauritania	15	>11	97

Mauritius			
Mozambique	>148	>143	198
Namibia	1	1	43
Niger	28	>29	151
Nigeria	55	40	22
Rwanda	3	15	451
Sao Tome and Principe	1	3	3
Senegal	12	20	265
Seychelles			
Sierra Leone	5	15	7
Somalia			
South Africa	>4	>10	70000
Sudan	44	145	666
Swaziland			
Tanzania	>325	>250	1136
Tchad	5	5	0
Togo	12	45	86
Uganda	>28	>19	214
Zambia	6	51	0
Zimbabwe	15	166	27
TOTAL			112522

Table 2.6 shows that for Region V, 112522 tons of obsolete stocks have been inventoried. In some areas such as Malawi, South Africa, Zambia, Tanzania, programmes have been completed or are current in addressing accumulated stocks. The RBA workshop commented on the probable inaccuracies of the information, as well as a number of countries not included, and has also adjusted some of the numbers. Note was taken of the intended World Bank project to rid the whole continent of this problem in one concerted action.

There are indications from the Sudan and South Africa of PTS contaminated soil (Technical Workshops). These are just known examples and this category should therefore be indicated as a data gap.

2.5.1 Country Ranking According To Agricultural PTS

The data presented in many of these tables could be used to rank countries according to the perceived sources of agricultural PTS. This must not be confused with a risk assessment. The RBA workshop considered this approach and was in favour of including the resultant table (Table 2.7). The following score- and ranking criteria were used:

- A score of 1 was given for each \$5 million of pesticide imports for each country (Table 2.3)
- A score of 1 was given for each \$5 billion of agricultural production (Table 2.5)
- Obsolete stocks of pesticides were scored according to the criteria presented below Table 2.7

Table 2.7 Relative and indicative ranking of countries according to PTS pesticide data

Country	Pesticide imports	Agricultural production	Obsolete stocks	TOTAL	RANK
	@ \$5 m	@ \$5 b	Score*		
South Africa	20	4	6	30	1
Nigeria	3	9	1	13	2
Cote d'Ivoire	4	2	5	11	3
Kenya	8	2	1	11	3
Ethiopia	1	4	6	11	3
Ghana	6	3	1	10	4
Sudan	2	3	5	10	4
Tanzania	2	2	6	10	4
Mali	3	1	6	10	4
Zimbabwe	6	2	1	9	5
Democratic Republic of the Congo	1	4	4	9	5
Botswana	1	1	6	8	6
Cameroon	3	2	2	7	7
Mozambique	2	2	2	6	8
Uganda	2	2	2	6	8
Rwanda	1	1	4	6	8
Benin	1	1	3	5	9
Senegal	2	1	2	5	9
Guinea	1	2	1	4	10
Mauritius	2	1	1	4	10
Malawi	2	1	1	4	10
Eritrea	1	1	2	4	10

Namibia	1	1	2	4	10
Niger	1	1	2	4	10
Togo	2	1	1	4	10
Burkina Faso	1	1	2	4	10
Central African Republic	1	1	2	4	10
Burundi	1	1	2	4	10
Swaziland	2	1	1	4	10
Gabon	1	1	1	3	11
Mauritania	1	1	1	3	11
Madagascar	1	1	1	3	11
Zambia	1	1	1	3	11
Lesotho	1	1	1	3	11
Congo (Brazzaville)	1	1	1	3	11
Angola	1	1	1	3	11
Chad	1	1	1	3	11
Guinea-Bissau	1	1	1	3	11
Sierra Leone	1	1	1	3	11
Somalia	1	1	1	3	11
Liberia	1	1	1	3	11
Equatorial Guinea	1	1	1	3	11
Djibouti	1	1	1	3	11
Sao Tome and Principe	1	1	1	3	11
Seychelles	1	1	1	3	11
Comoros	1	1	1	3	11
Gambia	1	1	1	3	11

*Score: 1= 0 - 150; 2=151-300; 3=301-450; 4=451-600; 5=601-750; 6=751-

2.6 SOURCES OF INDUSTRIAL

Essentially, very little is known about the pollution caused by various industries in Africa, but it is possible to identify and describe the major industrial complexes in this region. In most cases they are located mainly on the coast, but there are highly industrialized inland areas, such as the Vaal Triangle region in South Africa and the Ikeja and Kaduna Industrial Estates in Nigeria. In all cases these are located close to water, with possible concomitant water pollution potential from PTS. Available studies indicate localized environmental media pollution with deleterious human health effects in the vicinity of industrial plants. The major industrial complexes in the region will be identified and described as a means of rapid assessment, if only in qualitative terms of potential PTS releases into the environment.

Industrial PTS chemicals of concern are PCBs, HCB which is also a PTS pesticide, pentachlorophenol (PCP) and phthalates. The electricity generating industry is the major source of PCB release into the environment. PCBs are contained in transformer oils and PCB containing equipment such as transformers and capacitors.

PCBs however, can also be formed during combustion processes. HCB is used as industrial solvent, PCP as wood preservative, while phthalates are used as plasticisers in industry. Data is lacking on the use and import of PTS industrial chemicals in the region. This data gap may be addressed when most of the countries have carried out "Country Chemical Profile" study being driven by the Intergovernmental Forum on Chemical Safety (IFCS).

To obtain an overview of possible indicators or surrogates of PTS production from industry of countries in Region V, comparative country data was gathered on GDP ($), percentage of industry contribution to GDP, the size of the industrial activity ($), major industrial products, and electricity production. The size of the electricity production might provide a comparative surrogate of the possible PCB problems facing each country. These data are presented in Table 2.8. The industries that are potential sources of PTS releases into the environment are:

- Petroleum refining (catalyst regeneration)
- Textiles and tanneries
- Cement kilning
- Wood products preservation
- Truck and bus assembly
- Chemicals
- Paper milling
- Solid minerals mining
- Iron and steel industry
- Pharmaceuticals
- Bleached chemical pulp and paper mills
- Crematoria
- Drum & barrel reclamation facilities
- Ferrous Foundries
- Hazardous waste incinerators
- Industrial boilers burning hazardous waste
- Kraft black liquor recovery boilers
- Motor vehicles (leaded, unleaded and diesel)
- Municipal solid waste incinerators
- Medical waste incinerators
- Power generating facilities (coal and oil)
- Primary ferrous metal smelting (sinter and coke)
- Primary non-ferrous metal smelting
- Residential oil combustion
- Secondary non-ferrous metal smelting (aluminium, copper, lead)
- Sewage sludge incineration
- Scrap electric wire recovery
- Tyre combustion
- Wood combustion

Table 2.8: GDP data for the Region V countries. (CIA Factbook 2001 amended by RBA workshop). Countries with a GDP of more than $20 b, and countries with an electricity production of more than 4 b kWh are highlighted in bold. Industrial products, whose production is likely associated with PTS, are indicated in italics.

Country	GDP ($b)	Industry % GDP	Industry ($b)	Industrial products	Electricity production, (billion kWh)
Angola	10.1	7	0.707	Petroleum, iron ore, basic metal products; textiles.	1.475
Benin	6.6	13.5	0.891	Textiles, petroleum	0.51
Botswana	10.4	46	4.784	Mining	0.61
Burkina Faso	12	27	3.24	Textiles, mining	0.285
Burundi	4.4	18	0.792		0.141
Cameroon	26	20.1	5.226	Petroleum production and refining, textiles, lumber	3.47
Central African Republic	6.1	20	1.22	mining, sawmills, textiles, footwear, assembly of bicycles and motorcycles	0.102
Chad	8.1	14	1.134	cotton textiles,	0.09
Comoros	0.419	4	0.017	textiles,	0.017
Congo (Brazzaville)	3.1	48	1.488	petroleum extraction, cement kilning, lumbering	0.302
Cote d'Ivoire	26.2	18	4.716	wood products, oil refining, truck and bus assembly, textiles, fertilizer	4.06
Democratic Republic of the Congo	31	17	5.27	mining (diamonds, copper, zinc), mineral processing, textiles, cement	5.268
Djibouti	0.574	22	0.126	brick clay firing	0.18
Equatorial Guinea	0.96	60	0.576	petroleum, saw milling	0.021
Eritrea	2.9	27	0.783	Textiles	0.165
Ethiopia	39.2	12	4.704	textiles, chemicals, metals processing, cement, hides, pharmaceuticals	1.625
Gabon	7.7	60	4.62	textile; lumbering and plywood; cement; petroleum extraction and refining; mining; chemicals; ship repair	1.02

Ghana	37.4	25	9.35	mining, lumbering, light manufacturing, aluminium smelting,	5.466
Guinea-Bissau	1.1	15	0.165		0.055
Guinea	10	35.3	3.53	mining, light manufacturing	0.75
Kenya	45.6	13	5.928	plastic, batteries, textiles oil refining, cement, paper, chemicals	4.225
Lesotho	5.1	38	1.938	textiles,	0 from the RSA
Liberia	3.35	10	0.335	rubber processing, mining	0.432
Madagascar	12.3	14	1.722	tanneries, textiles, cement, automobile assembly plant, paper, petroleum, mining	0.81
Malawi	9.4	29	2.726	sawmill products, cement	1.025
Mali	9.1	21	1.911	Mining	0.445
Mauritania	5.4	31	1.674	mining	0.151
Mauritius	12.3	29	3.567	textiles, chemicals, metal products, transport equipment	1.26
Mozambique	19.1	19	3.629	chemicals (fertilizer, paints), petroleum products, textiles, cement,	2.3
Namibia	7.6	25	1.9	mining (diamond, lead, zinc, tin, silver, tungsten, uranium, copper)	1.198
Niger	10	18	1.8	mining, cement, brick, textiles, chemicals,	0.2
Nigeria	117	40	46.8	crude oil, mining, rubber, wood, hides and skins, textiles, cement, chemicals, plastics, fertilizer, printing, ceramics, steel	18.7
Rwanda	6.4	20	1.28	cement, plastic goods, textiles	0.132
Sao Tome and Principe	0.178	19	0.034	textiles, timber	0.017
Senegal	16	20	3.2	fertilizer production, petroleum refining	1.27
Seychelles	0.61	26.3	0.16	boat building, printing	0.16
Sierra Leone	2.7	26	0.702	mining, textiles, petroleum refining	0.24

Somalia	4.3	10	0.43	textiles, petroleum refining	0.26
South Africa	369	30	110.7	mining, automobile assembly, metalworking, machinery, textile, iron and steel, chemicals, fertilizer, foodstuffs, plastics, cement, paper	186.903
Sudan	35.7	17	6.069	textiles, cement, petroleum refining, pharmaceuticals	1.76
Swaziland	4.4	46	2.024	mining, wood pulp	0.375
Tanzania	25.1	17	4.267	mining, oil refining, shoes, cement, textiles, wood products, fertilizer, salt	2.248
Togo	7.3	21	1.533	mining, cement; textiles	0.092
Uganda	26.2	17	4.454	cement	1.326
Zambia	8.5	27	2.295	mining and processing, chemicals, textiles, fertilizer	7.642
Zimbabwe	28.2	32	9.024	mining, steel, wood products, cement, chemicals, fertilizer	5.78

Table 2.8 shows that certain countries are more likely to have sites and activities for unintentional PTS production, including the combustion of waste and discarded products. In addition, the electricity production data can be associated with the use of PCBs in transformers and other equipment.

From the Priority Setting Meeting, the following data on PCB stock were obtained: Senegal inventoried 36043 tons of PCB polluted oils, and Congo Brazzaville reported 119 tons, although this inventory was not complete (74 transformers, out of a total of 495, were not yet tested).

2.6.1 Country Ranking According to Industrial PTS Production

The data presented in Table 2.8 could be used to rank countries according to the perceived sources of PTS, using economic data as surrogates for PCDD/Fs production, and electricity data for PCBs. This approach must not be confused with a risk assessment, but only as an approximation, due to the lack of other data. The RBA Technical Workshop and the Priority Setting Meeting considered this approach, and was in favour of including the resultant table (Table 2.9). The following criteria were used:

- A score of 1 was given for each \$1 billion of industrial production, as surrogate for unintentional PCDD/F production (Table 2.8)
- A score of 1 was given for each 1 billion kWh produced as surrogate for PCB use (Table 2.8)
- The countries were then ranked according to total scores.

The results are presented in Table 2.9.

Table 2.9 Relative and indicative ranking of countries according to derived unintentional PTS production surrogates (PCDD/Fs and PCBs)

Country	Industry	Electricity production	TOTALS	RANK
	@ $1 b	@ 1 b kWh		
South Africa	111	187	298	1
Nigeria	47	19	66	2
Zimbabwe	9	6	15	3
Ghana	9	5	14	4
Kenya	6	4	10	5
Democratic Republic of the Congo	5	5	10	5
Zambia	2	8	10	5
Cote d'Ivoire	5	4	9	6
Sudan	6	2	8	7
Cameroon	5	3	8	7
Ethiopia	5	2	7	8
Tanzania	4	2	6	9
Mozambique	4	2	6	9
Gabon	5	1	6	9
Botswana	5	1	6	9
Botswana	5	1	6	9
Uganda	4	1	5	10
Guinea	4	1	5	10
Mauritius	4	1	5	10
Senegal	3	1	4	11
Burkina Faso	3	1	4	11
Malawi	3	1	4	11
Mali	2	1	3	12
Lesotho	2	1	3	12
Mauritania	2	1	3	12
Madagascar	2	1	3	12
Namibia	2	1	3	12
Niger	2	1	3	12
Togo	2	1	3	12
Benin	1	1	2	13

Central African Republic	1	1	2	13
Burundi	1	1	2	13
Rwanda	1	1	2	13
Eritrea	1	1	2	13
Congo (Brazzaville)	1	1	2	13
Angola	1	1	2	13
Chad	1	1	2	13
Swaziland	2	1	3	13
Guinea-Bissau	1	1	2	13
Sierra Leone	1	1	2	13
Somalia	1	1	2	13
Liberia	1	1	2	13
Equatorial Guinea	1	1	2	13
Djibouti	1	1	2	13
Sao Tome and Principe	1	1	2	13
Seychelles	1	1	2	13
Comoros	1	1	2	13
Gambia	1	1	2	13

This table should be interpreted with caution. It should be seen as a relative ranking of countries, rather than an estimation of the absolute condition regarding PCDD/F production, and the possible condition regarding PCBs. Factors that can affect the rank includes current PCB elimination programmes, as well as implementation of pollution control technologies to reduce PCDD/F production. Another serious consideration is the surface area where these activities take place. Small countries and islands might have a higher risk profile than suggested by this approach. Again this highlights the serious limitation placed by the lack of data.

2.7 OTHER SOURCES OF PTS

PTS of concern in this category are PAHs and PCDD/Fs. Although not quantified, the main source categories are:

- PAHs – exhaust emission from combustion of fossil fuels in vehicles and electrical generating sets. The latter provide the main source of energy for most industries in the region due to epileptic power supply from the national grid in many countries.

- Dioxins and furans - Waste burning is possibly the least known factor in the production of PCDD/Fs in Africa. A large amount of accidental and deliberate combustion is taking place, including the burning of rubber tyres as well as stripping insulation of copper wires and cable. Waste combustion could potentially be the largest source of PTS in Africa. Moreover, in countries producing sugar, burning of sugar cane fields, to cut costs, just before harvest is of common practice. This could also contribute to the formation of dioxins.

Uncontrolled waste incineration, especially incineration of hospital/clinical wastes, municipal and industrial wastes is probably the major source of PCDD/F production. In an effort to arrive at some measure of quantification of PCDD/Fs releases from the uncontrolled burning of domestic waste, the RBA technical workshop went through an exercise to derive country level release estimation. The following assumptions were discussed and agreed upon:

- Although the per capita waste production differs significantly between rural and urban people, and based on some data available from South Africa and the Africa Environment Outlook: Past, Present and Future (UNEP 2002), a mean of 0.4 kg of domestic waste (10-15% plastics, rubber and oils) per person was assumed per country.
- Not all waste will be burned. The workshop assumed that only 25% would be burned in open landfill or dumps.
- The conversion factor for uncontrolled domestic waste burning emission to air is 300 μg / ton waste (UNEP 2001).
- The conversion factor for uncontrolled domestic waste burning emission as burned residue is 600 μg / ton waste (UNEP 2001).
- We did not attempt a TEQ estimation for leaching from landfills and waste dumps, due to the lack of data regarding leachate production, which is used in the conversion factor. Since the conversion factor is low (30 pg / l leachate; UNEP 2001), this source is for now deemed negligible.

These assumptions were applied to population levels during the workshop. Accurate population levels were not available, but subsequent correlation with external data showed a remarkable correlation. To derive estimations for all countries in the region, the latest population estimates (2001) from the CIA Factbook were used as basis. The results are presented in Table 2.10. This data was then ranked according to country.

Table 2.10 Countries ranked according to estimated daily TEQ releases from uncontrolled domestic waste combustion, based on population data1

Country	Population (2001 estimates)	Waste production (tons/day)	Air releases (mg TEQ)	Burned Residue (mg TEQ)	TOTAL TEQ from domestic waste (mg TEQ / day)	200µg divisions	County Rank
Nigeria	126635626	50654	3799	7598	11397	57	1
Ethiopia	65891874	26357	1977	3954	5930	30	2
DRC	53624718	21450	1609	3217	4826	24	3
South Africa	43586097	17434	1308	2615	3923	20	4
Tanzania	36232074	14493	1087	2174	3261	16	5
Sudan	36080373	14432	1082	2165	3247	16	5
Kenya	30765916	12306	923	1846	2769	14	6
Uganda	23985712	9594	720	1439	2159	11	7
Ghana	19894014	7958	597	1194	1790	9	8
Mozambique	19371057	7748	581	1162	1743	9	8
Cote d'Ivoire	16393221	6557	492	984	1475	7	9
Madagascar	15982563	6393	479	959	1438	7	9
Cameroon	15803220	6321	474	948	1422	7	9
Burkina Faso	12272289	4909	368	736	1105	6	10
Zimbabwe	11365366	4546	341	682	1023	5	11
Mali	11008518	4403	330	661	991	5	11
Malawi	10548250	4219	316	633	949	5	11
Angola	10366031	4146	311	622	933	5	11
Niger	10355156	4142	311	621	932	5	11
Senegal	10284929	4114	309	617	926	5	11
Zambia	9770199	3908	293	586	879	4	12
Chad	8707078	3483	261	522	784	4	12
Guinea	7613870	3046	228	457	685	3	13
Somalia	7488773	2996	225	449	674	3	13

Rwanda	7312756	2925	219	439	658	3	13
Benin	6590782	2636	198	395	593	3	13
Burundi	6223897	2490	187	373	560	3	13
Sierra Leone	5426618	2171	163	326	488	2	14
Togo	5153088	2061	155	309	464	2	14
Eritrea	4298269	1719	129	258	387	2	14
Central African Republic	3576884	1431	107	215	322	2	14
Liberia	3225837	1290	97	194	290	1	15
Congo (Brazzaville)	2894336	1158	87	174	260	1	15
Mauritania	2747312	1099	82	165	247	1	15
Lesotho	2177062	871	65	131	196	1	15
Namibia	1797677	719	54	108	162	1	15
Botswana	1586119	634	48	95	143	1	15
Guinea-Bissau	1315822	526	39	79	118	1	15
Gabon	1221175	488	37	73	110	1	15
Mauritius	1189825	476	36	71	107	1	15
Swaziland	1104343	442	33	66	99	1	15
Comoros	596202	238	18	36	54	1	15
Equatorial Guinea	486060	194	15	29	44	1	15
Djibouti	460700	184	14	28	41	1	15
Sao Tome and Principe	165034	66	5	10	15	1	15
Seychelles	79715	32	2	5	7	1	15
TOTALS	673656437	269463	20210	40419	60629		

1 Data derived from CIA Factbook (2001) estimates

Table 2.10 shows a daily TEQ production of around 60g (21360 g TEQ/year) for dioxins and furans for Region V, from uncontrolled domestic waste combustion. Care should be taken with this estimate, as some of the assumptions will not be valid under certain conditions, such as very poor communities with less waste production, or countries with less than normal use of plastics, as well as better landfill practices (in some countries) where combustion is not carried out. The obverse is also true, as some combustion practices might have higher conversion factors than indicated. The Table also shows that 15 countries produce more than 1000 mg TEQ per day (arbitrary criterion only). These countries also have populations of more than 11 million. Results given in this table suggest that even non-industrialised countries with large populations (such as Ethiopia, Madagascar and Burkina Faso) might have to address the TEQ (PCDD/Fs) production derived from waste combustion in their countries.

It must also be kept in mind that natural formation of some PTS probably occurs, notably the PCDD/Fs, during combustion of natural vegetation (forest, savannah), and crops such as sugar cane. In some countries, the burning of sugarcane is common practice, to mature the cane, but also to reduce the volume for extraction of sugar. Some components of Africa's natural vegetation contain relatively high levels of chlorine and, although not yet measured, could contribute towards environmental levels of PCDD/Fs.

The data gap on PCDD/Fs releases will only be partially addressed in the near future, since only a few countries are currently carrying out the inventory of dioxins under the aegis of UNEP Chemicals. There are only a few active research studies in Africa to cover some of these data gaps.

2.8 IMPORT AND EXPORT STATISTICS OF PTS CONTAINING WASTES

The Basel convention, Bamako Convention and many national environmental laws in the region prohibit export of hazardous wastes including those containing PTS from OECD countries into African countries, not even under the guise of wastes recycling. Since engineered landfill sites are generally lacking in the region, coupled with non-availability of efficient high temperature incinerators with air pollution control devices, the countries in the region have at present no option but to export their hazardous wastes containing PCBs and obsolete pesticides for incineration to approved facilities in the developed countries. Illegal traffic in PTS wastes in the region has been minimized through the Toxic Waste Dump Watch Alert system put in place by the Organization of African Unity (OAU), and active cooperation with the Secretariat of the Basel Convention. Otherwise, no data on imports or exports were available in the public domain, which constitutes a major data gap.

2.9 COUNTRY RANKING ACCORDING TO PTS SCORES

The various rankings attempted in this Chapter, can be combined to provide an overview of the possible relative sizes of PTS issues in each country. These ranks are provided for each country, alphabetically, in Table 2.11 below. Because the ranks were derived independently using different criteria, they cannot be combined or totalled. The countries are therefore given in alphabetical order.

Table 2.11 Ranking scores for the countries, according to agricultural PTS, unintended industrial PTS production, and TEQ production through uncontrolled open waste burning

Country	Agricultural PTS Rank	Industry PTS Rank	Domestic waste combustion Rank
Angola	11	13	11
Benin	9	13	13
Botswana	6	9	15
Burkina Faso	10	11	10
Burundi	10	13	13
Cameroon	7	7	9
Central African Republic	10	13	14
Chad	11	13	12
Comoros	11	13	15
Congo (Brazzaville)	11	13	15
Cote d’Ivoire	3	6	9

Democratic Republic of Congo	5	5	3
Djibouti	11	13	15
Equatorial Guinea	11	13	15
Eritrea	10	13	14
Ethiopia	3	8	2
Gabon	11	9	15
Gambia	11	13	
Ghana	4	4	8
Guinea	10	10	13
Guinea-Bissau	11	13	15
Kenya	3	5	6
Lesotho	11	12	15
Liberia	11	13	15
Madagascar	11	12	9
Malawi	10	11	11
Mali	4	12	11
Mauritania	11	12	15
Mauritius	10	10	15
Mozambique	8	9	8
Namibia	10	12	15
Niger	10	12	11
Nigeria	2	2	1
Rwanda	8	13	13
Sao Tome and Principe	11	13	15
Senegal	5	11	11
Seychelles	11	13	15
Sierra Leone	11	13	14
Somalia	11	13	13
South Africa	1	1	4
Sudan	4	7	5
Swaziland	10	13	15
Tanzania	4	9	5
Togo	10	12	14
Uganda	8	10	7

Zambia	11	5	12
Zimbabwe	5	3	11

Table 2.11 shows that the magnitude of the various PTS problems might derive from different sources from different countries. Comparing for instance Nigeria with South Africa shows that Nigeria's biggest problem might be open burning, while that of South Africa might be industry and agriculture.

Once again it must be cautioned that the scores were in many cases derived from surrogate data, or based on incomplete information. This indicates yet again the importance of the existing data gaps that makes it very difficult to derive a better justified overview and priority setting. Ranking of sources and the associated data gaps is the subject of the next section.

2.10 RANKING OF PTS CHEMICALS FROM SOURCES BY COUNTRIES

At the Technical Workshop, experts from the countries present were asked to score the PTS as released from sources according to levels of concern, as well as the data gaps for that specific country. The experts were asked to rank from 0 for no concern, to 3 for major concern. The results are presented in Table 2.12 and 2.13. Some country experts did indicate however, that their scoring was indicative only, but the combined scores from the countries will give a good indication of the overall level of relative concern.

> Note: The scoring system used by this region differed slightly from that of the other regions. A system of 0-3 was used, while the other regions used 0-2. Converting the scores from this region to a 0-2 system was attempted, but did not convey the concerns of the participants. The overall ranking by totals from the various countries should therefore rather be used.

Table 2.12 Levels of concern for different PTS sources as scored by various countries present at the Technical and Priority Setting Workshops. Shading indicates indicative categories

	Ben	Bkf	Chd	Com	Con	C.Iv	Dji	DRC	Eth	Gan	Ken	Mrts	Nig	SLe	Sey	RSA	Sud	Tan	Tog	Zam	Zim	Tot
PCBs	2	2	1	0	3	1	1	3	2	3	1	0	3	2	1	2	1	2	2	3	2	37
Dioxins	1	2	0	0	2	0	3	2	1	3	2	1	3	2	2	3	0	3	2	3	2	37
Furans	1	2	0	0	2	0	3	2	1	3	2	1	3	2	2	3	0	3	2	3	2	37
DDT	2	2	0	1	1	1	3	0	3	2	1	1	1	2	0	2	2	2	2	3	1	32
Atrazine	1	1	1	1	2	0	0	1	3	2	2	1	2	1	0	3	1	2	1	3	3	31
Endosulf.	3	2	1	1	0	1	0	1	3	3	2	0	2	0	0	3	2	2	1	0	3	30
HCH	1	1	1	0	2	1	1	0	2	2	1	0	3	2	0	2	1	1	2	1	2	26
Org. Pb	1	2	0	0	2	0	2	1	1	2	1	1	3	2	0	1	0	1	1	3	1	25
Chlordane	0	1	0	0	0	1	2	0	2	1	0	0	0	1	0	2	1	1	2	3	2	19
Chlor.Paraf	0	2	1	0	0	0	2	0	1	1	-*	0	2	2	0	2	0	-	1	1	2	17
Dieldrin	1	1	0	0	0	1	0	0	2	1	1	0	0	1	2	0	2	1	2	1	0	16
Org. Hg	1	1	0	0	0	0	0	1	1	1	0	0	0	2	0	2	1	1	1	1	3	16
PAHs	2	1	0	0	0	0	1	0	0	1	-	0	3	2	0	2	0	0	1	0	2	15
Aldrin	1	1	0	0	1	1	0	0	2	1	1	0	0	1	0	0	2	1	1	1	0	14

Endrin	1	1	0	0	0	1	0	0	2	1	0	0	0	1	2	0	1	1	1	1	0	13
Heptachlor	1	1	0	1	1	1	0	0	2	1	1	0	0	0	0	0	1	1	1	1	0	13
HCB	1	2	1	0	0	1	0	0	1	1	0	0	0	3	0	0	0	1	1	1	0	13
Nonphenol	0	2	0	1	0	0	0	0	0	1	1	0	0	0	0	3	0	-	1	1	3	13
Octphenol	0	2	0	0	0	0	0	0	0	1	1	0	0	0	0	3	0	0	1	1	3	12
Phthalate	1	2	0	0	0	0	0	0	1	1	-	0	1	0	0	2	0	0	1	0	2	11
Toxaph.	1	1	0	1	0	1	1	1	0	1	0	0	0	0	0	0	1	1	1	0	0	10
Org. tin	0	2	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	0	1	8
PBDE	0	1	0	0	0	0	0	0	0	1	-	0	0	2	0	2	0	0	1	0	0	7
PCP	0	1	0	0	0	0	0	0	0	2	1	0	0	0	0	0	1	0	1	0	0	6
Chlordeco	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	-	1	1	0	5
Mirex	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	4

* - indicates no score presented.

From Table 2.13 it is clear that the country experts and representatives rated the unintentional production of PCDD/Fs, as well as the problem of PCBs, as the highest concern for most countries, including the associated data gaps. DDT, atrazine and endosulfan were ranked as the most important PTS pesticides. Organic lead and mercury, as well as most of the other PTS pesticides were categorized in the next section. The lack of knowledge by the participants about compounds such as PBDE and octyl and nonyl phenols might have resulted in the low ranking of these compounds.

Table 2.13 Data gaps for different PTS sources as scored by various countries present at the Technical Workshop and the Priority Setting Workshop. Shading indicates indicative categories.

	Ben	Bk f	Chd	Co m	Con	C.I v	Dj i	DR C	Et h	Ke n	Mrt s	Ni g	SLe	Sey	S. A	Sud	Tan	To g	Za m	Zi m	Total
Dioxins	3	3	3	3	3	3	3	3	3	3	2	3	2	3	3	3	3	3	2	3	57
Furans	1	3	3	3	3	3	3	3	3	3	2	3	2	3	3	3	3	3	2	3	55
Org. Pb	1	3	3	3	3	3	3	3	1	3	1	3	1	1	3	3	1	3	2	3	47
Endosulf.	3	3	2	3	3	3	3	3	3	1	0	2	3	1	3	2	3	3	1	1	46
PCBs	3	3	2	1	3	2	3	3	3	3	0	3	1	2	3	2	2	3	2	1	45
HCH	2	3	2	3	3	3	3	3	3	1	0	3	3	1	2	2	1	3	1	2	44
PCP	1	3	3	3	3	3	3	3	1	3	0	0	3	1	3	3	1	3	1	3	44
PAHs	2	3	3	3	3	3	3	3	1	-	0	3	2	1	3	3	1	3	1	3	44
Aldrin	2	3	3	3	3	2	3	3	3	2	0	0	3	2	1	2	2	3	3	0	43
DDT	3	3	3	1	3	2	3	3	3	2	1	1	2	1	2	2	2	3	2	1	43
Atrazine	1	3	3	1	3	3	3	3	2	1	1	2	2	1	3	3	2	3	1	1	42
Octphenol	1	3	3	3	3	3	3	3	1	3	0	0	3	1	3	3	0	3	1	2	42
Dieldrin	2	3	3	3	3	2	3	3	3	2	0	0	3	2	1	2	2	3	1	0	41
Org. Hg	1	3	3	2	3	3	3	3	3	2	0	0	1	1	3	3	1	3	1	2	41
Phthala	1	3	3	3	3	3	3	3	1	-	0	1	3	1	3	3	0	3	1	3	41
Chlor.Paraf	1	3	3	3	3	3	3	3	1	-	0	2	2	1	3	3	0	3	1	3	41
Endrin	2	3	3	3	3	2	3	3	3	1	0	0	3	2	1	2	2	3	1	0	40

Nonphenol	1	3	3	1	3	3	3	3	1	3	0	0	3	1	3	3	0	3	1	2	40
Chlordane	1	3	3	3	3	2	3	3	3	-	0	0	2	1	1	2	1	3	1	3	38
Heptachlor	2	3	3	1	3	2	3	3	3	2	0	0	3	1	1	2	2	3	1	0	38
PBDE	1	3	3	3	3	3	3	3	1	-	0	0	1	1	3	3	0	3	1	3	38
HCB	2	3	2	3	3	2	3	3	1	2	0	0	2	1	1	3	2	3	1	0	37
Mirex	1	3	3	3	3	3	3	3	2	1	0	0	3	1	1	3	0	3	1	0	37
Toxaph.	2	3	3	1	3	2	3	3	2	2	0	0	3	2	1	2	2	3	0	0	37
Org. tin	1	3	3	2	3	3	3	3	1	1	0	0	3	1	0	3	1	3	1	1	36
Chlordeco.	1	3	3	1	3	3	3	3	1	1	0	0	3	1	0	3	0	3	1	0	33

* - indicates no score presented.

When comparing this table with the previous, it becomes obvious that the participants gave much higher scores for data gaps, than for levels of concern. PCDD/Fs were classified together as the compounds with the greatest data gaps. PCBs were ranked lower, probably because more work has been done, or is ongoing, on PCB inventories. For example, a complete inventory of PCBs has been achieved for Senegal. The industrial compounds, such as organic lead, PCP, PAHs, and octyl and nonyl phenols were ranked higher than in the previous table. Closer scrutiny also shows that certain participants might have inadequate knowledge about the various compounds, and therefore the preponderance of zeros from certain countries. On the other hand, PBDE for instance, was only scored as 0, 1 or 3, not 2. Only mirex and organic tin scored more than 3 zeros. This table therefore clearly shows the high level of the data gaps for almost all compounds

2.11 SUMMARY: SOURCE CHARACTERISATION

Source characterization is probably the most important aspect required from the management of PTS in any region. The main categories of sources identified in the region were production and imports, use of PTS pesticides, obsolete stocks of PTS pesticides, industrial sources (manufacture, mining and electricity), and open burning of waste.

2.11.1 Production And Imports

The manufacture of PTS pesticides is, as far as could be ascertained, only done in one country; Atrazine in South Africa (Table 2.1). A number of other countries do import active ingredients and formulate and package for local or regional use. The FAO data on import (in monetary terms) will therefore be a good indicator, as only very little is produced inside the region. These data (Tables 2.2 and 2.3) show that the countries of the region only import about 5% of the world imports. Not all these imports will be PTS pesticides, and from calculations done at the Technical Workshops, it was estimated at 18% of the total imported into Region V (equals $211 million). It also shows a preponderance of certain countries in terms of import; Ghana, Kenya, South Africa and Zimbabwe imported more than half (54%) in value terms, of the pesticides, for the whole of Region V.

Imports are channelled through harbours and railway heads, where spillages and accidents may occur, and the majority of these have also been identified, but more information on road transport and routes need to be added.

2.11.2 Use Of PTS Pesticides

Pesticides are mainly used in agriculture. The total area in Region V that might experience application is estimated at almost one million ha (Table 2.4). The major agricultural areas for many countries have also been identified, and reported. Ethiopia, Madagascar, Mozambique, Somalia, South Africa, Sudan, Tanzania and Zimbabwe have especially large areas under cultivation and pasture, but smaller countries (such as islands) might have a much higher percentage allocated. An analysis was also made of the major crops, probably requiring the application of PTS pesticides, in each country. For the region only 25 such countries were identified (Table 2.5).

It was also recognised that pesticides, including PTS, will also be used outside agricultural areas, for purposes of disease vector control, vegetation control, food collection and others.

2.11.3 Stocks Of Obsolete Pesticides

Stocks of obsolete pesticides are a particular insidious problem in Africa. With more than 112 000 tons estimated to be on the continent, this is a problem requiring urgent attention. Data however, is incomplete, but the problem will be addressed by the African Stockpiles Programme (ASP). From the availablr data, countries with particular problems appear to be Botswana, Ethiopia, Mali and Mozambique (Table 2.6).

When scores were applied to the data on pesticides for the various countries, the countries could be ranked, although the rankings should be treated with caution. It seems that especially South Africa, Nigeria, Cote d'Ivoire, Kenya, Ethiopia and Ghana might have more serious PTS issues to deal with, compared with others (Table 2.7).

2.11.4 Industrial Chemicals, Including PCBS

Since almost no data was available on this issue (also see Chapter 3), surrogates were needed as an approximation. The percentage of industry as a component of the national GDP for each country was calculated. Information on the major types of industries (as related to PTS) was also collected and tabled (Table 2.8). As a surrogate for PCBs, electricity production was used, and tabled.

This information was then scored and the countries ranked accordingly (Table 2.9). Again South Africa and Nigeria were highlighted as countries with an apparent large industrial PTS problem, namely for HCB, PCDD/F and PCBs, followed by Zimbabwe, Ghana, Kenya, DRC and Zambia.

2.11.5 PTS Production From Open Burning

Once again the complete lack of data on this topic for Africa, forced the use of a surrogate. Estimations were made on amounts of domestic waste generated by each person, as well as the percentage of this waste that will eventually be burned in an uncontrolled manner. Conversion factors were applied and the daily TEQ calculated (Table 2.10). For Region V, the daily TEQ production calculated from this source was about 60 g/day. Since the only fixed and accurate information are population figures, only countries with a population of more than 11 million produced more than 1 g/day (an arbitrary criterion only) via this source. When ranked, countries that seem to have a particular problem are: Nigeria, Ethiopia, DRC and South Africa, followed by Tanzania, Sudan, Kenya and Uganda.

Again this approach must be treated with caution. The conversion factors might not be applicable, and the waste production and waste burning profiles might differ significantly between countries. Open burning is likely to be a major source of PTS production, and the data gap indicated is therefore a serious issue, when attempting to characterise the PTS profile for Region V.

Scoring of PTS by source and data gaps: The country experts scored PCBs and PCDD/Fs highly for both level of concern and data gaps (Tables 2.11 and 2.13). PTS pesticides of concern were DDT, atrazine and endosulfan. A lack of knowledge probably hampered scoring on PTS chemicals such as the nonyl and octyl phenols. The scoring was much closer on data gaps than on levels of concern, once again indicating the constraints facing Africa regarding PTS sources and its management.

2.11.6 REFERENCES

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3 ENVIRONMENTAL LEVELS, TOXICOLOGICAL AND ECOTOXICOLOGICAL CHARACTERISATION

3.1 INTRODUCTION

On the basis of about 3,000 questionnaires filled by experts in the region, this chapter presents data on the levels and trends of PTS in environmental media and clinical samples. Toxicological data are generally lacking in the region. Nonetheless, toxic effects are discussed in relation to the trends and levels based on the regional survey.

Out of the 47 countries of Sub-Sahara Africa, only 16 countries have data related to levels of PTS in the environment. These data have been classified according to the biological or non-biological matrix in which the different PTS have been detected (Table 3.1).

Attempts have been made to undertake analysis of trends either on temporal and/or spatial basis where feasible in spite of THE paucity of data for such an exercise. Almost all data have been "one-off" analyses and there are no sites that have been regularly monitored over a long period of time for PTS. Nonetheless special trends have been noted as high agricultural and highly industrialised countries in the region with higher PTS sources (Chapter 2) tend to have higher levels of PTS in environmental media.

Table 3.1 Sub-Sahara Africa Countries that have provided PTS data

	AIR	WATER	SOILS	SEDIMENTS	VEGETATION	ANIMALS	HUMANS
BENIN	_	Endosulfan, Dieldrin, DDT, Heptachlor,	endosulfan, dieldrin, DDT, heptachlor	endosulfan, dieldrin, DDT, PAHs	endosulfan, dieldrin,DDT, PAHs	Endosulfan, DDT, PAHs	_
COTE d'IVOIRE	_	Lindane, Heptachlor, Aldrin, HCH, DDT, dieldrin	Lindane, heptachlor, aldrin, HCH, DDT, dieldrin	Lindane, hepta- chlor, aldrin, HCH, DDT, dieldrin	Lindane, heptachlor, aldrin, HCH, DDT, dieldrin	Lindane, Heptachlor, Aldrin, dieldrin, Endosulfan	lindane, heptachlor, aldrin, HCH, DDT, dieldrin
CONGO (DRC)	_	_	_	_	_	_	HCH,DDT, heptachlor, dieldrin, HCB PCBs
MADA- GASCAR	DDT	Pyrene	_	_	DDT,dieldrin endosulfan Lindane, aldrin heptachlor	DDT,lindane, Endosulfan	endosulfan HCH

MALAWI	mirex, HCB, Heptachlor, HCH, endrin, dieldrin, DDT, Chlordane Aldrin	Mirex, aldrin, Dieldrin, DDT, Heptachlor, HCH, endosulfan, Chlordane, HCB,endrin, Atrazine	_	_	DDT	DDT	_
MAURITIUS	_	_	atrazine	_	_	Organic Hg	Organic lead
NAMIBIA	_	_	_	_	_	PCBs, chlordane Toxaphene, Dieldrin, DDT	_
NIGERIA	_	Lindane, Aldrin, DDT Heptachlor, Endrin, Endosulfan Dieldrin,HCB PCBs, HCH	Lindane, aldrin,DDT, heptachlor, endosulfan endrin, PCBs dieldrin	DDT, PCBs, dieldrin,HCH aldrin,lindane HCB, hepta-chlor, endo-sulfan	HCB,DDT, aldrin,lindane dieldrin, PCBs heptachlor, endosulfan, HCH, endrin	OrgHg, Lindane Aldrin, dieldrin DDT, HCB, HCH, PCBs, Heptachlor, Endosulfan	endrin, heptachlor dieldrin, endosul-fan,PCBs DDT, aldrin Lindane
SEYCHELLES	_	_	_	_	HCH, DDT	_	_
SOUTH AFRICA	_	Endosulfan Atrazine, endrin PCBs, DDT, HCB Dieldrin, aldrin Heptachlor, Chlordane	_	dieldrin, DDT PCB	Dieldrin, DDT PCB	PCBs, DDT, Heptachlor, HCB, endrin, Toxaphen, Endosulfan Chlordane Aldrin,atrazin	DDT,* dioxins, furans, HCB, dieldrin
SUDAN	-	-	DDT, BHC, Endosulfan	_	DDT	DDT	DDT,BHC, dieldrin
ZIMBABWE	_	Aldrin, dieldrin	HCB, dieldrin	HCB,aldrin,	DDT	HCB,aldrin, Dieldrin,DD	DDT,HCH,

		DDT	DDT, aldrin	dieldrin,DDT		T, PCBs,HCH	dieldrin
GHANA	-	HCB,endosulfan, DDT, heptachlor, Lindane	Aldrin, dieldrin, DDT, HCB	DDT,HCB, lindan, heptachlor, endosul-fan	Lindan, DDT, heptachlor, HCB, endosulfan	-	Lindane, heptachlor-or, HCB, endosul-fan
KENYA	-	Dieldrin, Lindane			Dieldrin, Lindane, DDT, PCB	Dieldrin, endosulfan, DDT, PCB, Lindane	-
UGANDA	-	Lindane	-	-	-	-	-
ZAMBIA	-		Dieldrin, DDT, endosulfan, aldrin		Aldrin,dieldrin, Heptachlor, DDT, Lindane, Endosulfan	Dieldrin, Aldrin, DDT, Lindane	

* Clinical samples from humans taken from South Africa.

3.2 CONCENTRATIONS OF PTS IN ABIOTIC COMPARTMENTS

Sub-Sahara Africa is a region with fairly active agricultural pests and disease vector control activities that necessitated the use of PTS pesticides for a long period of time, *viz*. DDT, BHC, aldrin, dieldrin, heptachlor, chlordane and endosulfan. Organochlorines (OCs) levels detected in various abiotic compartments (*viz*. air, water, soil and sediments, Table 3.1) since the 1970's to date indicate that African countries are under the threat of these PTS pesticides. Moreover, most of the 16 countries have reported data concerning many of the PTS, excluding dioxins and furans. Table 3.1 indicates that only South Africa had reported data for these two PTS and only in human tissues (1990). Moreover, PCBs were detectable in sediments, vegetation and animals of South Africa. Data from Nigeria shows that all compartments, and some human samples are contaminated with PCBs. Sediments, vegetation and animals also showed some levels of HCB. Although certain countries like Sudan, Nigeria, Democratic Republic of Congo (DRC) and South Africa amongst others, do have qualified scientists to analyse dioxins or furans. Most, if not all of the countries of Region V, are however not properly equipped to undertake these analyses.

The data gathered *via* the questionnaires have been re-grouped according to their year of study. Data for the period 1970 to 1979, 1980 to 1989 and 1990 to date (2002) are shown in tables 3.2, 3.3 and 3.4, respectively. As these data come from different studies and from different areas (country or sub-region), therefore for each biological or non-biological matrix, only the lowest and highest mean values of the PTS are reported in the three tables.

Table 3.2**:** PTS levels detected in the environment in Sub-Sahara Africa for the period 1970-1979

PTS	**Country**	**Water (ng/l)**	**Vegetation (ng/g)**	**Animals* (ng/g)**
DDT	S. Africa	<200- 300	97-540	1 – 25900
Dieldrin	S. Africa Zimbabwe	<100 - 852	20-420	109 – 1144
Endosulfan	S. Africa	684 – 4843	-	5 - 2 467
Lindane	Zimbabwe	-	-	6305
Toxaphene	Zimbabwe	-	-	671 – 3119
PCBs	Zimbabwe S. Africa	2-2000	1300-2500	87 – 18000
HCB	Zimbabwe	-	-	0.7 – 915

*Terrestrial and aquatic animals

Table 3.3: PTS levels detected in the environment in Sub-Sahara Africa for the period 1980-1989

PTS	**Country**	**Water (ng/l)**	**Vegetation (ng/g)**	**Animals* (ng/g)**
DDT	S.Africa Zimbabwe Nigeria	ND – 400	ND – 233	0.5 – 221797
Dieldrin	S.Africa Zimbabwe Nigeria	0.2 – 200	17.8 – 657	78 – 275
Aldrin	S.Africa Zimbabwe	ND – 100	ND - 143	ND

	Nigeria			
Endosulfan	S. Africa Zimbabwe Nigeria	ND – 260	17 – 111	ND – 904
Lindane	Nigeria	ND - 41.9	2.2 - 23.4	0.2 – 598
Heptachlor	Nigeria	ND – 11.4	1.8 – 20	ND – 300
Atrazine	S. Africa	6900 – 44000	-	-
PCBs	Nigeria, S. Africa	ND – 5.3	ND – 2700	74 – 8847
HCB	Zimbabwe	ND – 100	ND - 5.0	0 – 6788

* Terrestrial and aquatic animals

Table 3.4: PTS levels detected in the environment in Sub-Sahara Africa for the period 1990 - to date

PTS	**Country**	**Water (ng/l)**	**Vegetation (ng/g)**	**Animals (ng/g)**
DDT	S. Africa Malawi Nigeria Madagascar	Rivers: ND - 1266 Lakes: 0 - 700 Rain water: 0.097	3.2 – 88.2	19 – 11065
Dieldrin	S. Africa Malawi Nigeria, Kenya	Rivers: ND - 657 Rain water: 0.205*** Lakes: 10- 5	15 - 44.5	0.3 – 70
Aldrin	S. Africa Malawi Nigeria	Rivers: ND - 40 Lakes: 0 - 120 Rain water : 0.525	ND - 7.5	ND – 30
Endrin		Rivers: ND - 4200 Lakes : 0 Rain water: 0.004	1.3	-
Chlordane	S. Africa Malawi Sudan	Rivers : 0.02 Lakes: 0.018 - 1.9 Rainwater : 0.051	-	44
Heptachlor	S. Africa Nigeria Malawi Sudan, Ghana	Rivers: ND - 202 Lakes: ND - 0.07 Rainwater: 0.07	-	-
HCH (Lindane)	Ghana, Nigeria	Rivers : ND - 297 Lakes : 0.028 Rain water : 0.309	2.5 – 82.7	1 – 527

HCB	S. Africa Malawi Nigeria Ghana	Rivers: ND - 92 Lakes: ND - 12.7 Estuarine: ND Rain water: 0.031	0.2 - 1.2	913
PCBs	S. Africa, Nigeria	Rivers: ND - 0.3	-	ND – 8847
Atrazine	S. Africa Malawi, Zimbabwe	River: 0.38 - 2500 Lakes: 0.38 - 97705 Ground water: 2482		
Pyrene (PAH)	Madagascar	300	-	-
Nonyphenols	S. Africa	Rivers: 4	-	-
Mirex	Malawi	Lake: ND – 0.003		
Endosulfan	S. Africa Malawi Nigeria Sudan, Ghana	Rivers: ND - 430 Lakes: 0.004 - 11.4	2.7 – 15	ND – 21

The wide range (in some cases high) of environmental concentrations observed in most of the areas of each country indicates that Sub-Sahara Africa is grossly contaminated by PTS. The levels will tend to increase in countries still using PTS in relatively large quantities (*e.g.* Nigeria, South Africa and Zimbabwe) and in countries that have not enforced a ban or restriction, or countries without regulatory control on the use of PTS chemicals.

During the period 1970 - 1979, data on only seven out of the twenty-eight PTS have been reported for Region V (Table 3.2), which increased to nine for the period 1980-1989 (Table 3.3). This second period corresponds to the period during which people became aware about the hazardous effects of most of the PTS. In this period, most developed countries and some developing countries, including countries of Region V, banned and/or restricted the use of most POPs pesticides. While DDT, Lindane, endosulfan, dieldrin PCBs and HCB were the PTS that were detected in both periods, heptachlor, aldrin and atrazine were of concern only for the 2nd period (1980’s) and was not reported in the first period (1970’s). In the third period, 1990 - to date, several new chemicals used in the agricultural, constructional and industrial sector that are toxic and persistent in the environment, *e.g.* endrin, chlordane, PAH compound (pyrene) and nonylphenols were detected in the different environmental compartments of the region (Table 3.4). Surprisingly, PCBs and HCB have been detected and reported, as early as the 1970's, in the region (S. Africa and Zimbabwe). Significant levels of PCBs in water, vegetation and animals were detected, and very high levels (up to 18000 ng/g) in animals were reported (Table 3.2). For that specific period (1970’s), HCB was only detected in animals in Zimbabwe (0.7- 915 ng/g, Table 3.2). During the 1980’s, the HCB levels in animals in Zimbabwe ranged from zero to 6788 ng/g. The maximum level in the latter is high enough to be of health concern.

Tables 3.2, 3.3 and 3.4 reveal that DDT levels showed a decreasing trend in the water medium; the levels observed decreased from 705 ng/L for the 1970’s, to 400 ng/L in the 1980’s and, finally to 350 ng/L for the last period (1990 - to date). The levels of DDT in vegetation exhibited a different trend, *i.e.* 97 ng/g, 233 ng/g and 88.2 ng/g for the same three periods respectively. This trend is an indication that DDT was most intensively used (agriculture & vectors control) during the 1980’s and is reflected in the high levels of DDT reported for other biota (vegetation and animals) during that period (Table 3.3). For example, an extremely high concentration (221797 ng/g) of DDT was reported in animals in Zimbabwe (Douthwaite *et.al.*,1995; Table 3.3).

Regarding dieldrin, the 1970’s period showed the highest levels in all the environmental compartments. The highest levels (109 - 1144 ng/g) were reported in animals for studies done in South Africa and Zimbabwe

(Table 3.2). In the 1980’s and the 1990’s, dieldrin was still detectable in the environment but at much lower concentrations (78 - 275 ng/g). The levels of dieldrin in animals, from the previously mentioned countries, in addition to Malawi, Nigeria and Kenya did not exceed 70 ng/g for the 1990's corresponding to the period during which the use of POP pesticides use was restricted / limited.

The trend for the 1990’s (Table3.4) is that for all PTS, except for atrazine, the levels found in rivers are generally higher than levels detected in lakes. For atrazine, exceptionally high concentrations in both rivers and lakes have been detected with the lakes exhibiting higher levels: 2500 ng/L & 97705 ng/L for rivers & lakes, respectively, as reported in studies done in S. Africa & Zimbabwe (Table 3.4). High levels of atrazine in water correlates with its relatively high water solubility.

3.2.1 Environmental Media: AIR

For Region V, very little data have been collected concerning PTS levels in air (Table 3.5). This is consistent with general lack of air quality data for the region. Only two recent studies from Madagascar and Malawi reported levels of PTS in ambient air. Table 3.5 indicates that an excessively high level of DDT (699000 pg/m^3) was detected in Madagascar (Bigouret, 1998), suggesting this study must have been carried out immediately following DDT application. Karlsson *et al.* (2000) in a recent study reported variable trace levels in pg/m^3 of 9 PTS in ambient air samples collected in air at Senga Bay, Malawi, from the period 27^{th} February 1997 to 2^{nd} May 1998Malawi (Table3.5). Amongst the different PTS detected that of mirex is worth noting as this chemical is not officially used or imported in Malawi. Therefore, its detection, although at a very low level (1 pg/m^3) must be due to either recycling of historical contamination, transboundary movement, or from illegal trade and use. Generally the PTS pesticides in the study area were not extensively weathered, implying recent use. Elevated levels of heptachlor, aldrin and dieldrin were detected periodically, which indicated use on a regular basis. The study also suggested that tropical regions may act as both a global source and sink for PTS since removal processes may be faster compared to temperate and arctic regions. It was concluded that regional sources are dominating in the lake Malawi area. Nonetheless, ambient air levels reported thus far except in the Madagascar study, are much lower than maximum air levels of 100 - 1000 ng/m^3 for POPs under Occupational and safety laws in several developed countries.

Table 3.5: Mean Levels of PTS (pg/m^3) detected in air in Sub-Sahara Africa

Country	Location	Sampling date	DDT	Mirex	HCB	Hepta-chlor	Lindane (HCH)	Endrin	Dieldrin	C r
Madagas-car	Ambient	11/97 to 12/97	699000							
Malawi	Ambient	02/97 to 05/98	26	0.51	11	44	25	1	80	5

3.2.2 Environmental Media: Water

Data gathered for this project indicate that Sub-Sahara African fresh waters (rivers, lakes, ground, estuaries and rainwater) are contaminated by a broad spectrum of 14 measured PTS. From these data, the following range of concentrations in rivers (ng/l) was found: endosulfan (ND - 4843), atrazine (0.38 - 44000), PCBs (ND - 0.3), dieldrin (ND - 921), DDT (ND - 350), HCB (ND - 9.4), heptachlor (ND - 5.3), chlordane (0.02) and HCH (ND - 0.1) (Tables 3.2, 3.3 and 3.4). Nonylphenols were reported for a river in South Africa at 4 ng/l while PAHs were detected in Madagascar at 300 ng/l. Mirex, PAHs and endrin were not detected in rivers in S. Africa and Nigeria. These results come from individual studies done in some countries and do not reflect the general situation of the region.

The reported range of concentrations (ng/l) for the PTS detected in lakes (Malawi, Nakuru, etc.) was as follows: endosulfan (ND - 18.5), atrazine (0.004 - 97705), PCBs (ND - 2.0) , dieldrin (0.01 - 11.4), DDT (0.06 - 8.1), heptachlor (ND -100), chlordane (0.9 - 30.9) and HCH (ND - 0.1). PAHs were reported for only a lake in Madagascar at a concentration of 300 ng/l. In South Africa, PCBs were detectable in the lakes as early as 1974 (2 ng/l). However, more recent data about the levels of PCBs in lakes rivers, dams and streams (ND - 2000 ng/l), have been reported from Nigeria, South Africa, Zimbabwe, Kenya and Cote d’Ivoire (1990/1992). The levels reported were much higher than 1970-1989 figures.

Except for dieldrin, PCBs and DDT with concentrations above 100 ng/l in some rivers (Table 3.2, Van Dyke *et al.*, 1978), most of the Sub-Sahara African waters have PTS concentrations below (10 ng/l) according to the data that have been gathered so far for the region. However, this may not be the case generally in Africa, as a huge data gap exists concerning levels of PTS in the environment in most African countries. Nonetheless, the high values of PTS in water reported for some countries (Table 3.2) are of concern when compared to standards for POPs in water in Australia (4 ng/l) and New Zealand (1 ng/L).

The only reported study done on PTS in rainwater was conducted in Malawi (Table 3.4). The following PTS concentrations (ng /l) were obtained: endosulfan (0.10 ng/l), endrin (0.004), PCBs (ND - 0.3), dieldrin (0.21), HCB (0.03), aldrin (0.52), chlordane (0.05), DDT (0.09), heptachlor (0.10), chlordane (0.02) and HCH (0.31 ng/l). Mirex was not detected in rainwater, but detected at a very low level (0.003 ng/L) in Lake Malawi by Karlsson *et al*. (2000; Table 3.4). However, it was not reported in any African country that mirex was in their list of imported pesticides. Kepone (isomer of mirex) was donated to Sierra Leone as mentioned by its representative during the technical workshop.

The problem of ground water contamination by OC pesticides has also been identified in certain parts of Nigeria (dieldrin, alpha-HCH, gamma-HCH, HCB, heptachlor, aldrin, endosulfan, DDT metabolites and PCBs) (Osibanjo and Aiyejuyo 1994). Mean concentrations of total DDT and heptachlor exceed the WHO limits for these chemicals in drinking water. This is expected to have health implications, as most urban and peri-urban dwellers rely on ground water as the major source for drinking, washing and cooking.

3.2.3 Environmental Media: Marine Water

No data on PTS concentrations in marine waters have been reported in the questionnaires submitted for Region V. It is probable that none of the coastal countries have conducted research in marine water, whether for academic purposes or for safety/environmental purposes. Lack of facilities, funds and awareness are expected to be responsible for the lack of information. However, it is expected, because of the poor working conditions in almost all the African Ports, including potential spills of pesticides, oils and damaged containers, that contamination by PTS in the marine environment especially near shore areas could be high (Chapters 2 & 4).

3.2.4 Environmental Media: River And Lake Sediments

Very little data have been gathered from the questionnaire survey as far as the levels of PTS in sediments are concerned. Only data from Zimbabwe, Nigeria, South Africa and Madagascar have been reported (Table 3.6). These levels indicate relatively high levels of PTS in certain local hot spots. For example, in Madagascar (1999), levels of 1100 ng/g and 76 ng/g have been reported for pyrene (a PAH) and DDT, respectively. In Nigeria (1991), dieldrin and DDT at concentrations of 4560 ng/g and 263 ng/g have been detected. Other cases of relatively high contamination levels of PTS include South Africa (1974), PCBs in a lake (320 ng/g), and Zimbabwe (1983), DDT (223 ng/g).

In summary PTS contamination levels in lake sediments (in ng/g dry weight) were as follows: Lindane (89 - 423), HCB (16), aldrin (1), dieldrin (2 - 5), DDT (13 - 223), PCBs (70 - 320) and Pyrene (1100). Heptachlor, mirex, endosulfan and endrin were not detected (Tables 3. 6 & 3.7).

In the case of river sediments, the following concentrations (ng/g dry weight) of PTS have been reported: HCB (0.4), aldrin (ND-56), dieldrin (1 - 4560), DDT (1 - 263), HCH (0.2 - 1.1), heptachlor (ND - 64), endosulfan (ND - 30), and pyrene (1100). PCBs, mirex, and endrin were not detected. However, due to the big data gap that exists in this compartment of the environment, this trend, again, cannot be generalised for the whole of Region V (Table 3.6).

Table 3.6: Concentrations of PTS (ng/g dry weight) in Fresh Water Sediments in Sub-Sahara Africa

Country	Location	Sampling date	HCB	Aldrin	Dieldrin	DDT	Pyrene (PAH)	PCBs	Heptachlor	Endosulfan	Lindane (HCH)	Endrin	Reference
Zimbabwe	Lake (Mcllwaine)	03/87 to 03/78	16	1	4	57		120					Greichus *et. al*. 1978a
	N. I. (Kariba)	12/82 to 04/83		1.0 (ND - 12)									Matthiessen 1983
	Lake (Mcllwaine)	N.I.			5.0 (ND-16)	76 (32-146)					16 (2-42)	1.0 (ND-12)	Mhlanga & Madziva, 1990
Mada-gascar	Lake (Hartbeesport)	06/99 to 06/99					1100						Pijilot, B. *et. al*. 1999
South Africa	Dam (Hartbeesport)	July 1974			2	45		70					Greichus *et. al*. 1977
	Dam (Voelvlei)	N.I.			<1	13		320					Greichus *et. al*. 1977
Nigeria	N. I.	06/90 to 12/90		ND 56	1.1 4560	10.8 263		ND	ND 64	ND 30	0.2		Osibanjo *et. al*. 1994
		05/91 to 11/91	0.4								1.1		Osibanjo *et. al*. 1994
	River (Ogunpa, Ibadan)	NI		ND	0.9 (ND-1.8)	13.1 (ND-37.3)		ND	ND	ND	1.2 (ND-4)		Sunday, 1990
Kenya	Lake (Nakuru)	NI			<1.0	30		20					Greichus *et. al*. 1978b
Tanzania	Lake (Nyumbaya Mungu)				131 (ND-251) 4 (3-6)	5 (ND-11)					1 (ND-4)		Passiverta *et. al*. 1988
Uganda	Lakes				10								Sserunjoji, 1974, 1976

					(2-39)								

* Wet weight
N.B: Mean Concentrations and range in parantethis

3.2.5 Environmental Media: Marine Sediments

Marine sediments can be considered to be the ultimate destination for certain PTS, as transport by rivers is one of the main routes by which these PTS migrate (Chapter 4). However, no data has been gathered on the levels in marine sediments for Sub-Sahara Africa. This constitutes a major data gap that must be filled before any conclusions can be drawn.

Coastal water sediments of the region also received little attention with respect to PTS. The only two studies known were done on Ebrie lagoon, Cote d'Ivoire. The 1985 study by Marchand & Martin (1985) revealed sediments with high concentrations of Lindane (0.5-19 ng/g), DDT (1-997 ng/g) and PCB (2-213ng/g). However, by the early 1990's, the levels DDT had drastically decreased to 2-243ng/g while PCBs increased to 8-1014ng/g (Kaba 1992, unpublished data).

3.2.6 Environmental Media: Soil

As for the soil compartment, the questionnaire survey for Region V and other published data revealed that PTS have been investigated in only a few countries, namely Mauritius (2001), Nigeria (1985) and Sudan (1994) (Table 3.8). It is also noteworthy that all the PTS mentioned in Table 3.8 mostly concern pesticides; no data have been reported for the other chemicals, except PCBs in Nigeria. The data showed that most PTS levels reported were not alarmingly high, except in a few cases (e.g. the Sudan) where DDT and HCH at a level of 17400 ng/g and 880 ng/g, respectively, have been reported. The relatively high levels of PCBs (538 ng/g) in Nigeria are worth noting. However, the major concern here is not the relatively high levels of some PTS, but the major data gap that exists for the region.

Table 3.7: Concentrations of PTS (ng/g dry weight) in coastal water sediments in Sub-Sahara Africa

Country	Location	Lindane (HCH)	DDT	PCBs	Dieldrin	Heptachlor	Aldrin	Reference
Coted'Ivoire	**Lagoon (Ebrie)**	2.3 (0.5-18)	17.1 (1.1-997)	46.7 (2.213)				Marchand & Matin 1985
Coted'Ivoire	**Lagoon (Ebrie)**	6.2 (0.08-33.2)	46.2 (2.5 – 242.8)	356 (8.5-1014)	17.8 (ND-126)	0.9 (ND-6.8)	157(0.07-62.1)	Kaba (Unpublished) data)

N.D. = Not Detected

Table 3.8: Mean PTS concentrations (ng/g dry weight) in the soils of Sub-Sahara Africa

Country	Site	Sampling Period	Atrazine	Lindane (HCH)	Aldrin	Heptachlor	Endosulfan	Endrin	Dieldrin	DDT	PCB	Reference
Mauritius	Agricultural	06/97 to 08/97	22									Msiri report July 2001
	Agric. Land											MSIRI, Mauritius 2001
Nigeria	Agricultural land	05/85 to 11/85		18	58	3	ND	ND	31.9	155	538	Babatunde 1985
Sudan	Agric. Scheme & Stores	1974 to 1993		880						17400		Elzorgani *et. al.* 1994
		1998					160					Ahmed 1999
Zambia	Agric. Land	01/1992 to 06/1992		64								Anonymous 2002a

3.3 CONCENTRATIONS OF PTS IN BIOTIC MEDIA

From the few data gathered so far (1970 - 2002) for Sub-Sahara Africa, the following PTS have been detected in the different biotic media: aldrin, dieldrin, DDT, heptachlor, endosulfan, Lindane, toxaphene, PCBs, HCB and endrin. Among the PTS that had the highest values, the trend observed is DDT> PCBs> toxaphene. (see Tables 3.2, 3.3 & 3.4,).

3.3.1 PTS in Vegetation

PTS data in vegetation for Region V are presented in Tables 3.2, 3.3 and 3.4 & 3.9. Most samples showed residue levels below the FAO's MRL. Nonetheless, in certain cases, high concentrations of PTS have been reported. Some examples are 882 ng/g of DDT (lettuce in Madagascar,) 1900 ng/g of PCBs (aquatic micro algae in South Africa), 233 ng/g of DDT (pine needles) and 2700 ng/g PCBs (plants from refuse dumps in Nigeria). In the Sudan, fairly high levels of OC insecticides (e.g. 200 ng/g of DDT in cottonseeds,) have been reported and, as result, these OCs were banned and /or restricted in the Sudan, except endosulfan.

Aquatic plants, *viz*. Water hyacinth in South Africa (1300 ng/g dry weight) and Nigeria (2700 ng/g dry weight) proved to contain high levels of PCBs. Algae also showed high concentration of this industrial PTS (2500 ng/g dry weight). Dieldrin, in Nigeria, was detected at a much lower concentration in water hyacinth (43 ng/g dry weight). Plants from Lake Nymba Ya Mungu, in Tanzania, *viz*. *Pistia stratiotes,* showed the following levels of PTS: dieldrin 27 ng/g, Lindane 4.5 ng/g and aldrin 25 ng/g dry weight. Higher plants of Kenyan lakes proved to contain from traces to 107 ng/g dry weight of total DDT. A study done in Hartbeespoort Dam Lake in South Africa (Greichus *et al.* 1977) revealed that algae (2500 ng/g dry weight) contained higher levels of PCBs than water hyacinth (1300 ng/g dry weight). Following the same order, concentrations of 230 and 540 ng/g dry weight were detected for DDT respectively. The same trend was also found for dieldrin (20 and 50 ng/g; Table 3.9).

Table 3.9: Mean concentrations of PTS (ng/g dry weight) in aquatic plants in Sub-Sahara Africa

Country	Location	Dieldrin	Lindane (HCH)	Aldrin	DDT	Heptachlor	Endosulfan	PCB	Reference
Uganda	Lake (Higher Plants)	90							Sserunjoji 1974, 1976
Tanzania	Lake (Nyumba Ya Mangu; Pista Stratiotes)	27	4.5	25	33				Paasivirta *et. al*. 1988
Kenya	Lake (Naivasha, Algae)				7				Lincer *et al*. 1981
	Lake (Naivasha, Higher plants)				30				
	Lake (Naivasha, Ferns, Salvinia auriculata)				107				
	Lake (Naivasha, Total vegetation)				31				
	Lake (Naivasha, Oscillatoria platensis)				ND				
	Lake (Baringo; plant parts with algae and Spirogyra)				ND				
Nigeria	Coastal water (Lagoon Badagry; Water Hyacinth)	43	49			52	17	2700	Ogunseitan 1987

South Africa	Dam (Hartbeespoort; Algae)	50 20			540 230			2500 1300	Greichus *et al*. 1977

3.3.2 PTS in Animals

Animals in this text refer to aquatic and terrestrial animals. Data reported in Tables 3.2, 3.3, 3.4 and 3.10 concern animals, their organs and tissues, milk, etc.

3.3.3 PTS in Aquatic Animals

Table 3.10 provides available data on PTS levels in aquatic animals in the region. It is worth noting that most of the reported data in Table 3.10 are below the FAO's MRL. El-Zorgani and Ali (1981) found that all fish tissue samples collected from different areas of the Sudan contained DDT residues. The concentration in the muscles and liver ranged between 0.04 and 0.2 μg/g. Fat samples contained higher levels, ranging from 0.3 - 3.3 μg/g.

In the 1970's the levels of DDT, dieldrin and PCBs in the finfish of Lake Nakuru of Kenya were found to be < 11 - 13, 1.5 - 7, and < 140 ng/g, respectively. During the same period, Lake Tanganyika (Tanzania) finfish was found to have levels of DDT ranging from 50 to 330 ng/g. The finfish of Lake Nubia, between Egypt and the Sudan, in 1979 showed DDT levels ranging from 6 to 184 ng/g, whereas in 1976 the River Nile finfish showed levels ranging from 270 to 116000 ng/g. The finfish of Lake Victoria (Kenya) was studied in the years 1990 and 1992. The levels obtained were 7 - 70 ng/g for dieldrin, 1 - 47 ng/g for Lindane, 20 ng/g for aldrin, 3 - 460 ng/g for DDT and 20 - 332 ng/g for PCBs (Table 3.10). It should be noted that Lake Victoria feeds the river Nile that in turn feeds Lake Nubia. Data gap due to lack of systematic study makes PTS trend analysis difficult. Moreover, high levels of DDT detected in the different lakes during that period, (when DDT was not banned or restricted), can be correlated to its intensity of use for vector control in the region.

Generally fish from Kenyan rivers have high PTS contamination as follows: Lindane (4-295ng/g), Endosulfan (nd-110ng/g), DDT (85 –1185ng/g). Nigerian rivers also have high PTS contamination in fish as indicated by the following levels (Osibanjo et.al 1994) : dieldrin (nd-173ng/g) , Lindane (0.2- 598ng/g), endosulfan (3-904ng/g),DDT(3-161ng/g) and PCB (8-130 ng/g) respectively.

There are large data gaps on PTS levels in marine fish as data are available only for 6 countries (Benin, Gambia, Sierra Leone, Cameroon, Nigeria and Cote D'Ivoire) in the region. In general , marine fish are less contaminated than freshwater species (Table 3.10). Data from marine fish from Cameroon however show high levels for DDT and PCBs. A study done in Cameroon (1992) revealed that shrimps contained several PTS: DDT (244 ng/g), PCBs (342 ng/g) and Lindane (0.98 ng/g). Oysters showed a different picture: DDT (113 ng/g), PCBs (209 ng/g), and Lindane (144 ng/g) respectively. On the other hand, Nigerian shellfish (shrimps, crab and oysters) proved to contain almost all the commonly encountered PTS. DDT was found at 37 ng/g, PCBs at 94.5 ng/g, Lindane at 0.8 ng/g and HCB at 0.22 ng/g(Osibanjo & Bamgbose 1990). Lower levels were found in Gambia and Cote d'Ivoire shellfish (Table 3.10). Although the data available are limited, Table 3.10 indicates that the aquatic environment of Region V is contaminated by a number of PTS chemicals including PCBs and pesticides with shellfish having higher values than finfish in general.

Mean methyl mercury concentrations of about 300 ng/g were reported for fish in Nigeria, the only country reporting this PTS. Furthermore, no levels of PAHs and dioxins/furans in animals were reported in the region.

Table 3.10: Concentrations of PTS (ng/g fresh weight) in fish and shellfish from Inland, Coastal and marine waters in Sub-Sahara Africa

Country	Location	Dieldrin	Endosulfan	DDT	PCBs	Lindane (HCH)	Aldrin	HCB	Heptachlor	Reference
Kenya	Lake (Nakuru)	1.5-7		13	150					Greichus, 1978b Koeman et. al. 1972
	River (Tana, Masinga Dam)		20(ND-110)							Munga, 1985
	Lake (Victoria)	7-70		3.0-460	90 (20-332)	1-47	20			Mitema and Gitau 1990 Calamari *et. al.* 1992
Sudan	Lake (Nubia)			58 (6-184)						El-Zorgani, 1979
	River Nile			2950 (270-16000)						El-Zorgani, 1976
Uganda	Lakes	5(2-27)								Sserunjoji, 1974 and 1976
Tanzania	Lake (Nyumbaya Mungu)	3		8		1				Paasivirta et al, 1988
	Lake (Tanganyika)			165 (50-330)						Deelstra et al; 1976
Nigeria	River (Ogun and Oyo)		173 (3-904)	21 (3.161)	29 (8-130)	20.5 (7-106)		13 (9-130)	50 (1-300)	Amakwe, 1984
Nigeria	River (Cross River and Akwa Ibom)		14 (ND-89.6)	2.5	3.8 (0.7-14)	62 (0.87-20.4)	55 (ND-14.9)		0.3 (ND-1.0)	Fayomi, 1987
	Coastal & Marine (finfish)		0.16	4.37 (0.15-	40.9 (11.0 –	0.83	2.85	0.92 (0.04-	1.29 (ND-21.40)	Osibanjo & Bamgbose 1990

			(ND-4.95)	18.60)	225)	(ND-5.30)	(ND-54.60)	9.48)		
	Coastal & Marine Shellfish (Shrimp, Crab, Oyster, Snail		2.41 (ND-21.0)	37.0 (4.73-152)	94.5 (37.287)	0.80 (ND-1.69)	0.52 (ND-194)	0.22 (ND-0.80)	1.35 (ND-4.16)	Osibanjo & Bamgbose 1990

3.3.4 PTS in Terrestrial Animals

High concentrations of DDT were measured in Zebu (1917 ng/g) and chicken (777 ng/g) in Madagascar (1996); in crocodile (34420 ng/g) and wildlife (25900 ng/g) in Zimbabwe were reported. Similarly high concentrations of PCBs (8847 ng/g), Lindane (6305 ng/g) and toxaphene (3119 ng/g) were found in wildlife of South Africa .

Another study done in Nigeria (Osibanjo & Adeyeye, 1997) on the residue levels of OCs in cow, pig and goat indicated high Lindane levels (μg/kg) in pigs (226), followed by goat meat (54), and cow meat (35). The same trend was observed for aldrin and dieldrin, and the former showed higher levels than the latter. The ranking of total DDT level (μg/kg) in meat was as follows: pig (510)> cow (164)>goat (141). HCB and heptachlor were not found in any of the three animals. Thus, dietary intakes of meat, milk, milk products, and other animals probably form the greatest sources of human exposure to PTS. The MRL for total HCH is set at 2000 μg/kg, for aldrin at 200 μg/kg, for total DDT at 5000 μg/kg, and for heptachlor 200 μg/kg.

Eltom (1997) analysed 50 samples of cow's milk from a village (Fadasi) in the central Sudan and found 0.12 μg/g of Lindane, 0.01 μg/g of aldrin, 1.28 μg/g of heptachlor epoxide and 1.75 μg/g of DDE.

These results and many more contained in the PTS database for Region V on the GEF/UNEP website indicate that animals contamination by PTS could be a major problem in Sub-Sahara Africa.

3.3.5 PTS in Humans

The concentrations of PTS contaminants in human tissues, blood and breast milk provide a reliable indicator to PTS exposure of different population groups. Although data are abundant for developed countries, studies on PTS contaminants in human samples including breast milk are very limited in Africa. Table 3.8 indicates that PTS, especially OC pesticides and PCBs grossly contaminate human tissues in the region, although the values vary widely from country to country. The OC pesticides concentrations are relatively higher than values reported in literature for European countries, but much lower than values for Hong Kong, except for HCB.

The occurrence of relatively high levels of DDT, HCB, lindane and endosulfan in human breast milk for the region is of concern in view of WHO's vigorous campaign that mothers breast milk is best for children. It has been established by studies in South Africa that OCs can be transferred to infants *via* breast milk. Thus infants are being exposed to these xenobiotics while the toxicological hazards and risks have not been studied in many African countries.

In DRC, adipose DDT level proved to be extremely high (15000 μg/g) compared to the other PTS (range 10-49 μg/g). The adipose tissue in South Africa showed high levels of HCB (4650 μg/kg) and DDT (6375 μg/kg). Breast milk in South Africa contained the following levels of dioxins (318 μg/kg) and furans (21 μg/kg). In Madagascar (1997) mothers' milk contained 49 μg/kg of HCH and 12 μg/kg of endosulfan. In Nigeria, occupational exposure effected levels in blood as high as 11565 μg/kg of DDT, 3778 μg/kg of PCBs, 958 μg/kg for aldrin, and 92 μg/kg for dieldrin. Levels of mothers' breast milk in Zimbabwe's urban and rural population showed that 6000 μg/kg of DDT was detectable, and 910 μg/kg lindane was also detectable

Table 3.11: Mean concentration of PTS (ng/g wet weight) in Humans in Sub-Sahara Africa

Country	Sample	Exposure	Sampling date	Lindane (HCH)	DDT	Hepta-chlor	Dieldrin	HCB	PCBs	Reference
Congo (DRC)	Adipose	Urban	09/1982 to 01/1983	41	15000	10	30	30	37	Okond'Ahoka *et. al* 1984
Madagascar	Milk	Urban and Rural	04/1996 to 06/1996	49						Cyril Nogier *et. al*. 1997
South Africa	Serum	Urban	11/1987		202					Bouwman *et al.* 1990
	Adipose	-	06/1968 to 06/1975		6375		40	4650		Van Dyk *et al* 1982
Zimbabwe	Milk	Urban & Rural		910	6000	50				Chikunio *et al* 1989
Nigeria	Blood	Occupational	05/11987 to 11/1987		11565	10	92	3778		Osasumwen 1987
	Blood	Urban			21.97	0.88		198.73		Ikem 1988
Sudan	Blood	Rural	October 1977	0.40	10.00		1.00			Liedholm & Amisi 1978
Kenya	Milk, Serum Fat	-	1986				0.08			Kimani V. 1997
	Umbilical cord, serum, milk	-			2.75-4.86					Kimani V. 1997
Madagascar	Milk	Urban & Rural	04/1996 to 06/1996	12						Cyril Nogier
South Africa	Milk	Urban & Rural	1988 to 1990			318	21			Schecter et *al.* 1990
Nigeria	Blood	Occupational	05/1987 to	59	958			ND		Osasumwen 1987

			11/1987							
		Urban	05/1987 to 12/1988	1.75	3.15					Ikem 1988
Mauritius	Blood	Rural & Urban	07/2001 to 01/2002						4.2µg/dl	Univ. M. 2002
Kenya	Milk	-	1986		0.4					Kimani V. 1997
	Serum	-	1986					4.83		Kimani V. 1997

3.4 EVIDENCE OF HARMFUL EFFECTS

For Region V, the few reported cases of poisoning due to PTS are given in Table 3.12. Many cases of accidental or intentional release of large amounts of PTS (for fishing or hunting) causing severe stress to the environment have been reported in the region. For example, according to Osibanjo *et al.* (1994) the accidental release of OCs in large quantities had caused massive fish kills in many countries, such as Senegal, Nigeria and Kenya.

3.4.1 Comparison Of Measured Data With Health And Environmental Quality Criteria

In the Sudan, a study was conducted in 1976 on Desert Locust Control Organisation-East Africa (DLCO-EA) Staff, and the Plant Protection staff; 90 blood samples were taken. Samples were analysed for OCs, namely DDT, dieldrin & HCH on persons who were 22 - 63 year olds. For HCH (Lindane) the minimum detectable concentration (ng/ml whole blood) was nil; the acceptable concentration for unexposed populations was not available at that time. The upper acceptable limits used in the study were 20 ng/ml whole blood. For dieldrin the respective values were 1.0, 3.5 and 100 ng/ml whole blood. Following the same order, DDT figures were 10.0, 10.0 and 500 ng/ml whole blood. Some workers had very high OC levels in their blood, E.g. a few, worker N° 11: 12.4, 54.4, and zero, for HCH, DDT, and dieldrin; N° 13: 322.8 DDT only; N° 15: 33.6 HCH, 2101.2 DDT and 384 dieldrin (Liedholm & Amisi, 1978).

People working in plant protection department, Wad Medani, Sudan were occupationally exposed to insecticides, either by selling, mixing or spraying. OCs were shown to affect the biochemistry of mammalian systems in various ways. The problem is mainly their chronic effects. The results obtained from the blood serum of occupationally exposed people were as follows: DDE was found in all samples with a range of 0.02 to 0.72 ng/ml whole blood; p,p-DDT was detected in seven samples out of 24 (0.01-0.18); o,p'-DDT & TDE were also detected(0.01-0.4& 0.02-0.2 µg/ml, respectively. HCH was detected in 11 samples (0.07-0.15 ng/ml whole blood). The occurrence of aldrin & dieldrin was less frequent; their concentrations were lower than 0.03 µg/ml. There is correlation between DDE level in the whole blood & adipose tissue. DDT in the blood indicated very recent exposure, whereas DDE reflected the chronic level of DDT exposure. One year was required for the metabolism of DDT into DDE, when volunteers were fed high DDT dosages (5-35 mg/day). The results of this work showed that there was no correlation between year of exposure & the concentration in blood serum. The values obtained were higher than those from Tunisia & Brazil and lower than those from India. DDT use was stopped in the Sudan 1981.

El-Zorgani and Musa (1976) studied the residues of OCs in the blood of 22 exposed personnel of the Gezira Research Farm (Wad Medani, Sudan). The authors found DDE, and p,p'-DDT in all samples (0.01 - 0.12 ppm for DDE and 0.02 - 1.01 ppm for p,p'-DDT). The occurrence of dieldrin was less frequent and at concentrations not exceeding 0.01 ppm. Eltom (1997) studied 50 blood samples from one village in central Sudan. HCH, aldrin, heptachlor epoxide and DDE were detected at the levels of 0.12 ppm, 0.01 ppm, 1.28 ppm and 1.75 ppm, respectively.

Common Name of PTS incriminated	Country	Species used	Pathway of exposure	Exposure occurrences	Type of effect	Period of Assessment	Reference
Endosulfan	South Africa	Various	Environment	Single/Accident 370 incidents of wildlife poisonings	Acute toxicity	1980 to 1995	Fourie 1996
Toxaphene	South Africa	*Crocodylus niloticus*	Environment	Single/ accident	Behavioural	08/1978 to 03/1979	Brooks 1980
Toxaphene	South Africa	*Tilapia sparmanii*	Environment	Single/ accident	Acute toxicity	08/1978 to 08/1978	Brooks 1980
Toxaphene	South Africa	*Oreochromis mossambicus*	Environment	Single/ accident	Acute toxicity	08/1978 to 08/1978	Brooks 1980
Toxaphene	South Africa	*Pseudocreni-labrus philander*	Environment	Single/accident	Acute toxicity	08/1978 to 08/1978	Brooks 1980
Toxaphene	South Africa	*Clarias garie pinus*	Environment	Single/accident	Acute toxicity	08/1978 to 08/1978	Brooks 1980
Toxaphene	South Africa	*Barbus spp* (fish)	Environment	Single/accident	Acute toxicity	08/1978 to 08/1978	Brooks 1980
Toxaphene	South Africa	*Anguilla spp*	Environment	Single/accident	Acute toxicity	08/1978 to 08/1978	Brooks 1980
Toxaphene	South Africa	*Podocica senegalensis* (bird)	Environment	Single/ accident	Acute toxicity	08/1978 to 08/1978	Brooks 1980
Endosulfan	Botswana	*Ceryle rudis*	Environment	Single/ accident	Behavioural	07/1978 to 10/1978	Douth-waite 1982
DDT	Zimbabwe	*Nematode, Acari, collembola, insecta*	Environment	Single/ accident	behavioural	16/1989 to1 2/1998	Tingle, CCD
DDT	Zimbabwe	*Haliaeetus vocifer*	Environment	Multiple/ Chronic	Reproductive	1980 to1990	Douth-waite 1992

3.5 ECOTOXICOLOGICAL DATA AND APPROPRIATE TEST SPECIES

Several studies were conducted in the Sudan aiming at studying the fate of these compounds in fish, birds, rats and plants (cotton & vegetables). One of these studies was conducted by Elhabieb et al (1995): Uptake, distribution and metabolism of C-14 DDT in the fish *Oreochromis niloticus*. The results showed that rapid uptake of the insecticide was observed, and the labeled material was distributed in the different organs.

Concentration of DDT in fish increased with the increase in the exposure period. The highest concentration (31.1 mg/kg) was found in the liver. The lowest mean concentration from organ samples was observed in muscles. The means ranged from 0.191 to 0.836 mg/kg. In the alimentary canal the amount of radioactivity was high, but fluctuated within the different sampling date. The means ranged from 2.1 to 8.5 mg/kg. In the brain, there was a clear build-up in the concentration of the labelled material with the increase in the exposure time. It ranged from 1.1 to 21.5 mg/kg after an exposure period of 3 weeks to 0.05 mg/l DDT in water. The fish was able to metabolise p,p'-DDT into p,p'-DDE, and p,p'-TDE. About 80% of insecticide was found as p,p'-DDT. The highest TDE percentage was found in the alimentary canal. The highest DDE percentage was found in the muscles. DDT, TDE and DDE were also found in the aquarium water.

3.6 RANKING OF PTS CHEMICALS

At the technical workshops, the experts from the countries present were also asked to indicate by scoring the priority attached to data gaps for different PTS on environmental levels and human effects according to levels of concern for that specific country. The experts were asked to rank from 0 for no concern, to 3 for major concern. The results are presented in Tables 3.13, 3.14, 3.15 and 3.16 respectively. Some country experts did indicate however, that their scoring was indicative only, but the combined scores from the countries will give a good indication of the overall level of relative concern. From Table 3.13 it is clear that the country experts rated the levels of dioxins and PCBS in environmental media as highest concern. DDT was of the highest concern among pesticides followed by endosulfan, atrazine, Lindane, aldrin, dieldrin, chlordane and heptachlor. Organic lead was the organometalic of most concern. These concerns are in good agreement with concerns on sources indicated earlier in Table 2.12. Similar pattern of response was obtained for data gaps on human effects.

Table 3.13: Ranking of concern on environmental levels by countries in Sub-Sahara Africa

	Ben	Bkf	Chd	com	Con	CIv	Dji	Drc	Eth	Ken	Mts	Nig	SLe	Sey	SA	Sud	Tan	Tog	Zam	zim	Total
DDT	2	3	0	1	0	1	2	0	0	1	0	3	1	0	3	1	2	2	3	2	27
Dioxins	1	3	0	0	0	0	1	0	0	2	1	3	1	2	3	0	0	3	2	1	23
Furans	1	3	0	0	0	0	1	0	0	2	1	3	1	2	3	0	0	3	2	1	23
PCBs	2	2	1	1	0	1	1	0	0	1	0	3	1	1	1	0	0	2	3	1	21
Org. Pb	1	1	0	0	0	0	1	0	0	1	2	3	2	0	2	0	1	1	3	1	19
Endosulf.	3	2	1	1	0	1	0	0	0	0	0	2	0	0	2	1	3	1	0	1	18
Atrazine	1	1	1	2	0	0	0	0	0	1	1	1	1	0	2	0	2	1	2	0	16
HCH	1	1	0	0	0	1	1	0	0	1	0	3	0	0	0	1	1	2	1	2	15
Aldrin	1	1	0	0	0	1	0	0	0	1	0	1	0	1	1	1	0	2	1	1	12
Chlordane	0	1	0	0	0	1	1	0	0	0	0	0	1	0	2	1	0	2	2	1	12
Dieldrin	1	1	0	0	0	1	0	0	0	1	0	1	0	1	1	1	1	2	1	1	12
Endrin	1	1	0	0	0	1	0	0	0	1	0	1	0	1	1	0	0	2	1	1	11
Hepta	1	1	0	1	0	1	0	0	0	0	0	1	0	0	1	1	0	2	1	1	11
Chlor.Paraf	0	2	1	0	0	0	1	0	0	-	0	1	1	0	2	0	0	1	1	0	10
HCB	1	2	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	2	1	1	10
Nonphenol	0	2	0	1	0	0	0	0	0	1	0	0	0	0	2	0	0	1	1	1	9
Org. Hg	1	1	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	1	1	1	9
PAHs	2	1	0	0	0	0	0	0	0	-	0	3	0	0	2	0	0	1	0	0	9
Octphenol	0	2	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	1	1	1	8
Toxaph.	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	2	0	0	7
PBDE	0	1	0	0	0	0	0	0	0	-	0	0	2	0	2	0	0	1	0	0	6
Phthalate	1	1	0	0	0	0	0	0	0	-	0	1	0	0	2	0	0	1	0	0	6
Mirex	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	5

Org. tin	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	5
Chlordeco.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
PCP	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2

Table 3.14 : Ranking of concern on data gaps on environmental levels by countries in Sub-Sahara Africa

	Ben	Bkf	Chd	Com	Con	CIv	Dji	Drc	Eth	gha	gam	Ken	Mts	Nig	Sle	Sey	SA	Sud	Tan	Tog	Zam	zim	Total
Furans	0	3	3	0	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	1	57
Dioxins	0	3	3	0	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	0	56
HCH	2	3	3	0	3	3	3	3	3	3	3	1	3	3	3	1	3	2	2	3	2	1	53
Endosulfan	3	3	2	0	3	2	3	3	3	2	1	3	3	2	3	1	3	2	3	3	2	1	51
DDT	2	3	3	1	3	2	3	3	3	2	1	1	3	3	2	1	3	2	3	3	2	1	50
Endrin	2	3	3	0	3	2	3	3	3	1	1	3	3	1	3	2	3	3	1	3	2	1	49
PCBs	2	3	2	0	3	2	3	3	3	3	3	-	3	3	1	2	3	3	0	3	2	1	48
Atrazine	-	3	3	1	3	3	3	3	3	2	1	3	2	1	2	1	3	3	2	3	2	1	48
Aldrin	2	3	3	0	3	2	3	3	3	1	1	2	3	1	3	2	3	2	1	3	2	1	47
PCP	0	3	3	0	3	3	3	3	1	2	2	3	3	0	3	1	3	3	3	3	2	0	47
PAHs	2	3	3	0	3	3	3	3	3	2	2	-	3	3	2	1	3	3	1	3	1	0	47
HCB	2	3	3	0	3	2	3	3	2	2	2	3	3	0	2	1	3	3	0	3	2	2	47
Dieldrin	2	3	3	0	3	2	3	3	3	1	1	1	3	1	3	2	3	2	2	3	2	1	47
Org. Pb	-	3	3	0	3	3	3	3	2	1	1	3	2	3	1	1	3	3	3	3	2	0	46
Hepta	2	3	3	0	3	2	3	3	3	1	1	2	3	1	3	1	3	2	1	3	1	1	45
Chlordeco.	0	3	3	0	3	3	3	3	1	1	1	3	3	0	3	1	3	3	3	3	2	0	45
Toxaph.	2	3	3	0	3	2	3	3	1	1	1	3	3	0	3	2	3	3	0	3	1	1	44
Org. tin	0	3	3	0	3	3	3	3	2	1	1	3	3	0	3	1	3	3	2	3	1	0	44
Org. Hg	0	3	3	0	3	3	3	3	2	1	1	3	3	0	1	1	3	3	3	3	1	1	44
Octphenol	0	3	3	0	3	3	3	3	1	1	1	3	3	0	3	1	3	3	3	3	1	0	44
Nonphenol	0	3	3	0	3	3	3	3	1	1	1	3	3	0	3	1	3	3	3	3	1	0	44
Phthala	-	3	3	0	3	3	3	3	1	1	1	-	3	1	3	1	3	3	3	3	2	0	43

Chlordane	0	3	3	0	3	2	3	3	3	1	1	2	3	0	2	1	3	2	1	3	2	2	43
Chlor.Paraf	0	3	3	0	3	3	3	3	2	1	1	-	3	1	2	1	3	3	3	3	1	1	43
PBDE	0	3	3	0	3	3	3	3	1	1	2	-	3	0	1	1	3	3	3	3	1	0	40
Mirex	0	3	3	0	3	2	3	3	1	1	1	3	3	0	3	1	3	3	0	3	0	0	39

Table 3.15 : Ranking of concern on data gaps on eco-toxicological effects by countries in Sub-Sahara Africa

	Ben	Bkf	Chd	com	Con	CIv	Dji	Drc	Eth	Ken	Mts	Nig	SLe	Sey	SA	Sud	Tan	Tog	zam	zim	Total
DDT	2	3	3	1	3	2	3	3	3	2	3	3	2	1	3	3	3	3	2	1	49
Dieldrin	0	3	3	0	3	2	3	3	3	3	3	1	3	2	3	3	3	3	2	1	47
Dioxins	0	3	3	0	3	3	3	3	3	-	3	3	2	3	3	3	3	3	3	0	47
Furans	0	3	3	0	3	3	3	3	3	-	3	3	2	3	3	3	3	3	3	0	47
HCH	0	3	3	0	3	3	3	3	3	2	3	3	3	1	3	3	2	3	2	1	47
Aldrin	0	3	3	0	3	2	3	3	3	2	3	1	3	2	3	3	3	3	2	1	46
Endrin	0	3	3	0	3	2	3	3	3	3	3	0	3	2	3	3	3	3	2	1	46
PCBs	0	3	2	0	3	2	3	3	3	3	3	3	1	2	3	3	3	3	2	1	46
Chlordane	0	3	3	0	3	2	3	3	3	3	3	0	2	1	3	3	3	3	2	1	44
Endosulf.	2	3	2	0	3	2	3	3	3	3	3	2	3	1	3	3	0	3	2	-	44
Atrazine	0	3	3	1	3	3	3	3	3	2	3	1	2	1	3	3	2	3	2	0	44
Hepta	0	3	3	0	3	2	3	3	3	3	3	1	3	1	3	3	1	3	1	1	43
Toxaph.	0	3	3	0	3	2	3	3	1	3	3	0	3	2	3	3	3	3	1	1	43
PCP	0	3	3	0	3	3	3	3	1	3	3	0	3	1	3	3	3	3	2	0	43
Chlordeco	0	3	3	0	3	3	3	3	1	3	3	0	3	1	3	3	3	3	2	0	43
HCB	0	3	3	0	3	2	3	3	2	3	3	0	2	1	3	3	3	3	2	0	42
Org. Hg	0	3	3	0	3	3	3	3	2	3	3	0	1	1	3	3	3	3	1	1	42
Org. Pb	0	3	3	0	3	3	3	3	2	-	3	3	1	1	3	3	3	3	2	0	42
Octphenol	0	3	3	0	3	3	3	3	1	3	3	0	3	1	3	3	3	3	1	0	42
Nonphenol	0	3	3	0	3	3	3	3	1	3	3	0	3	1	3	3	3	3	1	0	42
PAHs	0	3	3	0	3	3	3	3	3	-	3	3	2	1	3	3	1	3	1	0	41
Org. tin	0	3	3	0	3	3	3	3	2	3	3	0	3	1	3	3	1	3	1	0	41
Phthalate	0	3	3	0	3	3	3	3	1	-	3	1	3	1	3	3	3	3	2	0	41

Mirex	0	3	3	0	3	2	3	3	1	3	3	0	3	1	3	3	3	3	0	0	40
Chlor.Paraf	0	3	3	0	3	3	3	3	2	-	3	1	2	1	3	3	3	3	1	0	40
PBDE	0	3	3	0	3	3	3	3	1	-	3	0	1	1	3	3	3	3	1	0	37

Table 3.16: Ranking of concern on data gaps on human effects by countries in Sub-Sahara Africa

	Ben	Bkf	Chd	Com	Con	CIv	Dji	DRC	Eth	Gha	Ken	Mts	Nig	SLe	Sey	SA	Sud	Tan	Tog	Zam	Zim	Total
DDT	2	3	3	1	3	2	3	3	3	3	3	3	2	2	1	3	2	3	3	2	0	52
Dioxins	0	3	3	3	3	3	3	3	3	3	-	3	3	2	3	3	3	3	3	3	0	50
Furans	0	3	3	3	3	3	3	3	3	3	-	3	3	2	3	3	3	3	3	3	0	50
Endosulf.	2	3	3	1	3	2	3	3	3	3	3	3	2	3	1	3	3	3	3	2	0	50
Dieldrin	0	3	3	3	3	2	3	3	3	2	3	3	1	3	2	3	2	3	3	2	0	49
PCBs	0	3	3	1	3	3	3	3	3	3	3	3	3	1	2	3	3	3	3	2	0	49
HCH	0	3	3	3	3	3	3	3	3	3	3	3	3	3	1	3	2	2	3	2	0	49
Endrin	0	3	3	3	3	3	3	3	3	2	3	3	0	3	2	3	3	3	3	2	0	48
Atrazine	0	3	3	1	3	3	3	3	3	3	3	2	1	2	1	3	3	3	3	2	0	47
Aldrin	0	3	3	3	3	3	3	3	3	2	3	3	0	3	2	3	2	3	3	2	0	46
Chlordane	0	3	3	3	3	3	3	3	3	2	3	3	0	2	1	3	3	3	3	2	0	46
Toxaph.	0	3	3	1	3	3	3	3	1	2	2	3	0	3	2	3	3	3	3	1	0	45
PCP	0	3	3	3	3	3	3	3	1	2	3	3	0	3	1	3	3	3	3	2	0	45
HCB	0	3	3	3	3	3	3	3	2	2	3	3	0	2	1	3	3	3	3	2	0	44
Org. Hg	0	3	3	2	3	3	3	3	2	2	3	3	0	1	1	3	3	3	3	1	1	44
Nonphenol	0	3	3	1	3	3	3	3	1	2	3	3	0	3	1	3	3	3	3	1	0	44
Hepta	0	3	3	1	3	3	3	3	3	2	3	3	1	3	1	3	2	2	3	1	0	43
PAHs	0	3	3	3	3	3	3	3	3	2	-	3	3	2	1	3	3	2	3	1	0	42
Org. tin	0	3	3	2	3	3	3	3	2	2	3	3	0	3	1	3	3	2	3	1	0	42
Org. Pb	0	3	3	3	3	3	3	3	2	2	-	3	3	1	1	3	3	3	3	2	0	42
Phthala	0	3	3	3	3	3	3	3	1	2	-	3	1	3	1	3	3	3	3	2	0	42
Chlor. Paraf	0	3	3	3	3	3	3	3	2	2	-	3	1	2	1	3	3	3	3	1	0	42

Mirex	0	3	3	3	3	3	3	3	1	2	3	3	0	3	1	3	3	3	3	0	0	40
PBDE	0	3	3	3	3	3	3	3	1	2	-	3	0	1	1	3	3	3	3	1	0	39
Chlordeco.	0	3	3	1	3	3	3	3	1	2	3	3	0	3	1	3	3	3	3	2	0	32
Octphenol	0	3	3	3	3	3	3	3	1	2	3	3	0	3	1	3	3	3	3	1	0	31

3.7 DATA GAPS

Sub-Sahara African countries lack the analytical facilities in terms of high technology equipment, such as Mass-Spectrometry (MS), High Resolution Gas Chromatograph (HRGC) and High Pressure Liquid Chromatograph (HPLC), in addition to recently developed efficient extraction and clean up apparatus/equipment. Highly trained experts in trace organic analysis, access to current periodicals and other literature, as well as funds for solvents and other pertinent chemicals are the main limiting factors for conducting research and/or monitoring on PTS residues and pollutants in general.

Expertise is presumed to be available in at least 30% of Region V countries. PTS data gaps are in the following areas:

- PTS atmospheric concentrations in more than 90% of the countries in the region..
- Levels in water and sediments of the major rivers e.g. Nile, Niger, Limpopo etc and lakes, *e.g.* Tana, Victoria, Chad, Nubia, Nakuru, etc.
- Dioxins & furans, in environmental compartments and humans
- Systematic studies on the food-web contamination & biomagnification,
- Transboundary movement of PTS residues,
- The effect of burning crop residues, *e.g.* cotton, sugarcane, etc.
- Effect of improper burning garbage.
- The long-term effect of the accumulated stocks of obsolete PTS on the health of the human and animal populations near them,
- The effect of the emissions from the chimneys of the sugar and cement factories on the human and animal populations in their areas and the vicinity, at least within 50 km from the site, where some settles.
- Concentrations of PAHs and dioxins/furans in environmental media and biota.

3.8 SUMMARY

Sub-Sahara is mainly an agricultural continent and it has been using pesticides for pest and disease control for more than 30 years. Except for South Africa and Zimbabwe, no systematic pesticide monitoring/analysis exists in all the countries of the region. These two countries account for more than two thirds of the filled questionnaires gathered for the region. A big data gap therefore exists in the region as far as levels of PTS in the environment is concerned.

Concentrations of PTS in abiotic and biotic media: From the data gathered through filled questionnaires, the trend of concentration observed in Sub-Sahara Africa for PTS is DDT> PCBs> toxaphene for both the biotic and abiotic media. However no systematic monitoring has been undertaken so far.

For the abiotic environments, most of the data reported are for soil and water compartments and these indicate fairly high levels of PTS. Very few studies have been reported for air and coastal marine sediment compartments. However, it should be pointed out that although mirex is not used in Sub-Sahara Africa, it has been detected in one study in Malawi.

The data for biotic media apparently indicate that humans were less directly exposed than animals and vegetation to PTS during the period 1970 - 2002. However the main risk remains the food-web contamination. The occurrence of relatively high levels of DDT, PCB and dioxins in adipose tissues and blood of occupationally exposed persons is of immense concern. Equally disturbing is the high levels of HCB, lindane and endosulfan in human breast milk for the region in view of WHO's vigorous campaign that mothers breast milk is best for children. It has been established by studies in South Africa that OCs can be transferred to infants via breast milk. Thus infants are being exposed to these xenobiotics while the toxicological hazards and risks have not been studied in many African countries.

Evidence of harmful effects: Many cases of accidental or intentional release of large amounts of PTS (for fishing or hunting) causing severe stress to the environment have been reported in the region. For example, the accidental release of organochlorine pesticides (OCs) in large quantities had caused massive fish kills in many countries, such as Senegal, Nigeria and Kenya. Cases of people suffering from diseases as a result of exposure to organochlorine insecticides while selling, mixing or spraying these were reported in Wad Medani, Sudan.

Ranking of PTS chemicals on environmental levels, toxicological and ecotoxicological characterisation by countries: At the technical workshops, the country experts rated dioxins and PCBs of highest concern in regard to their levels in the environment. Among the PTS pesticides, it was DDT that was of highest concern followed by endosulfan, atrazine, lindane, aldrin, dieldrin, chlordane and heptachlor respectively. A similar pattern of response was obtained for data gaps: dioxins, PCBs and DDT were the chemicals that the experts considered of highest priority.

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4 ASSESSMENT OF MAJOR PATHWAYS OF CONTAMINANTS TRANSPORT

4.1 INTRODUCTION

Pathways are routes by which a substance released from a given source are translated or transported among several compartments of the environment from one place, country or region to another. Information in Chapter 2 indicates that anthropogenic activities are the primary sources of PTS input into environmental media in the region. The latter has a diversity of ecosystems, e.g. coastal and marine, tropical rain forest, wetlands, Sahelean, semiarid and deserts with different climatic conditions. These will therefore greatly influence the migration and/or movement and fate of PTS once released into the environment. Specific or systematic studies of the pathways and fate of PTS in the region are generally lacking. Nonetheless some theories may be developed regarding transboundary movement of PTS in and out of the region. In particular, the potential impact on the island states in the West Indian Ocean in East Africa and the Gulf of Guinea in West Africa needs attention.

Below are the major pathways that would determine the fate of PTS in the environment:

- Atmospheric transport dry or wet deposition
- Food web transfers
- Terrestrial aspects
- Aquatic transport (oceanic currents, rivers, lakes, etc.)

Regional weather patterns have the potential to impact transport of PTS. Cyclones with their strong winds and heavy rains can transport contaminants across the region into the ocean or other landmasses within a relatively short amount of time. Cyclone conditions also affect oceans, increasing erosion and causing some deposition on land. Contaminated particulate matter may be carried by winds and moved in colloidal suspension. Temperature and salinity have an effect on the solubility of many of the PTS. The low organic content of soils may also have an effect on concentrations and breakdown of PTS.

Near surface groundwater in the West Indian Ocean Islands may be brackish and have a hydrological connection to the ocean. Therefore, contaminants may be mobilized swiftly from land to the surrounding ocean. In other cases, fresh water lenses may impede movement of contaminants into the saline environment. Many point source water discharges occur directly into the ocean and air sources are often dispersed above the ocean especially in the islands, the coastal areas of East Africa, the Horn Of Africa and southern Africa respectively.

4.2 OVERVIEW OF EXISTING MODELLING PROGRAMMES

Modelling of environmental pollutants is still in its infancy and little to no data is available on the success of the modelling approach to the region. Application of compartmental mass balance models will certainly be an essential tool for establishing and predicting the fate and distribution of PTS in the region. The application of this technology will aid greatly in identifying areas within the region where a given PTS compound may be more problematic than others, thus aiding in identifying 'Hot Spots' of contamination. The models could also aid in the evaluation of the design of remediation strategies for the region. They could also be applied to newer generation compounds and potential PTS, providing information on potential fate and distribution, and in this way help in managing compounds that are potential PTS.

Research conducted in South Africa on pesticide leaching models indicate that the existing pesticide leaching models developed primarily in USA and Europe do not accurately predict the leaching patterns in soils of the southern region (Meinhardt, pers comm). This trend is likely to also be relevant to other models, such as for prediction of chemical movement in air and carry-over into ground and surface water resources. It will be necessary to either 'fine-tune' existing models for Africa or develop new models as necessary to ensure accuracy. Very limited capacity is available in Region V to conduct this type of exercise, but it is also financially constrained. Model development and evaluation is an expensive exercise, as data has to be generated locally from which such models can be calibrated.

There is an urgent need for capacity building and institutional strengthening in the application of this invaluable predictive, monitoring and assessment tool for Region V. The development and evaluation of modelling capability should be done in parallel to PTS monitoring and other assessments for this area.

4.3 ATMOSPHERIC TRANSPORT

Atmospheric deposition/fallout of chemicals can be divided into two categories: substances with short atmospheric residence times and those with long ones. PTS belong to the class of substances with long residence time and are widely distributed on national, regional or global scales. These semi-volatile substances can occur either in the vapour phase or adsorbed on atmospheric particles/dust, or in solution in atmospheric water thereby facilitating their long-range transport through the atmosphere. They reach the atmosphere in many ways including spray drift, volatilisation from soil and water and dust erosion. PTS undergo the iterative process of deposition, remobilisation into the atmosphere and re-deposition. This "global distillation" (Mackay and Wania, 1995) and their long-range transport have been given as a reason for their prevalence in Polar Regions.

The uniqueness of the African continent in terms of secondary drift and temperature inversions is significant in determining the environmental fate of PTS. For example air- monitoring data in Zimbabwe and Malawi (Karlsson H et. al. 2000) has showed that elevated ambient temperatures volatilise sprayed DDT into pockets of warm air that could drift down stream far from the spray site. The distillation and condensation of PTS on top of cold mountains, like Kilimanjaro, could also take place, although no data from Africa exists to confirm this.

Air has therefore been recognized as an important medium of long-range transport of PTS (GESAMP 1989). While there have been many studies of the atmospheric input of chemicals including PTS into coastal waters in Europe and North America, there is paucity of such data in Sub-Sahara Africa. Several studies have established the fact that atmospheric input of PTS is much more important for the open ocean than riverine input or land-based sources which are more dominant in near shore environment. This could also be true for Africa but data is lacking to support this. Deposition of sand and particulate matters coming from Africa in Southern Europe and the Americas are well known. This is indicative of the potential long-range atmospheric transport of PTS released in Sub-Sahara Africa to other continents. The contamination of Region V through this pathway from other parts of the world should therefore be seriously considered. It is not known whether Africa is a net source or sink of global PTS. Current thinking is that the presence of the Inter-Tropical Convergence Zone will prevent atmospheric transport of PTS to the north and vice versa. However, whether Africa acts as a source of PTS to the Antarctic is unknown. Indications are that levels of PTS in the Antarctic are lower when compared with the Arctic (see RBA Reports for the Antarctic and Arctic regions). Nonetheless some studies on the occurrence of PTS in the atmosphere over the Atlantic Ocean indicated an influence of air masses from the African continent (Nagabe et al., 1992).

In this context, the island states are particularly vulnerable to this atmospheric mode of contamination by PTS. For the region there is recognised large big data gap concerning atmospheric transport of PTS and this underscores the importance of modelling efforts.

From data collected in Malawi, mirex has been detected in air at a level of 1pg/m3, although there has been no history of the use of this PTS in the country. Although the level is very low, this could be a tenuous indication of long-range atmospheric transport. However, besides the RBA project no other data suggesting long-range transport exist. This lack of information therefore constitutes a major data gap.

4.4 COASTAL AND MARINE ENVIRONMENT

On entry into the aquatic environment through various routes, PTS being non-polar, semi-volatile and fairly persistent may remain in the water body unchanged for a long period of time, may undergo transformation (e.g. DDE from DDT), may be adsorbed on solid surfaces (sediments and biota), or may get reversibly transferred into the atmosphere by volatilisation.

The ultimate fate of these chemicals will depend on a certain number of factors including: concentration, dilution, water solubility, biogeochemical processes taking place, adsorption to soils, suspended particulate and sediments, lipophilicity, and bioaccumulation in living organisms (Khan, 1977).

The hydrophobic nature of PTS results in their presence in water to be at low-level concentrations. The adsorption of these compounds to particulate matter and sediment is an important mechanism for their removal from the water column. Consequently, the sediment component of aquatic ecosystems can be a significant sink of PTS. Suspended particulates entering slow moving waters, such as large water bodies and estuaries, settle out, and their associated PTS are added to the existing sediment load.

Being hydrophobic, PTS have a high potential for bioaccumulation in aquatic plants, fish and shellfish and undergo bio-magnification along trophic levels. The accumulation of these recalcitrant PTS in birds and mammals, feeding on contaminated aquatic biota, may occur which can then result in water transport of PTS over great distances (migratory birds, fish and mammals) from estuaries to the oceans. This has been demonstrated in Chapter 3. Organotin compounds from the anti-fouling paints of ships and PAHs in sediments will be major exposure sources for aquatic biota and top predators such as fish-eating birds and humans, as the Atlantic Ocean is the major route of large crude oil and cargo carriers/tankers which transport oil and cargo from the Middle East to Europe, Asia and North America via the Cape.

PTS have been recognised as one of the high priority issues in the region based on the regional priority rankings of the GPA/LBA contaminant classes (GESAMP, 2001). Land-based sources, especially riverine inputs, are the major sources of PTS into the coastal and marine environment, especially for the near shore environment. Agricultural run-off from agricultural fields, effluents from PTS formulation plants and other industries, which release PTS in the course of their operations, are also important. Past regional monitoring programmes under the aegis of the UNEP Regional Seas have established contamination of coastal and marine fishes and shellfish with some PTS, especially PTS pesticides and PCBs (FAO, 1994). While data on levels of PTS in coastal/marine waters is lacking for most of the region, some data exist on PTS concentrations in rivers, lakes and dams (FAO, 1994 and Chapter 3). Riverine and oceanic transport of OCs, PAHs, organotins, organomercurials, as well as PCDD/Fs are yet to be studied in a systematic manner.

The oceanic environment is the least studied in terms of contaminant levels in the region (see Chapter 3). While copious data exists in Europe and North America on PTS levels and behaviour in the oceans, there is a paucity of such data and understanding in the region. Africa has a number of large rivers that cross many countries (see Chapter 1) and since most of the socio-economic activities are associated with these rivers and other water bodies, it is expected that significant amount of PTS are transported across boundaries and released into lakes, seas and oceans. The magnitude of this input is unknown for the region, but it is recognised as another major data gap.

In addition, Africa is not isolated from the rest of the world and thus may contribute and/or receive the effects of PTS, because of the transport via oceanic currents. Oceanic PTS transport is significant as a large portion of food production is derived from the seas/oceans. PTS contamination of Africa's marine systems from either the region itself, or from other regions such as the Americas or Oceania, could further cause health, environmental and socio-economic problems.

4.5 TERRESTRIAL ASPECTS

The emphasis of this section will mainly concern the behaviour and fate of PTS in soils. The various soil types of the region are mentioned in Chapter 1. The persistence and fate of PTS in soils is influenced by its half-life, t1/2, amongst many other factors. There is however a paucity of data on the factors that affect the half-lives of PTS in soils in the region. Transposing PTS degradation data from developed countries with temperate weather will not be realistic in the tropical weather conditions of this region. Literature reviews of the pathways of PTS in the atmosphere suggest volatilisation as a major pathway. Volatilisation and degradation of PTS are assumed to be more rapid in the tropics than in the temperate regions. Comparison of soil half-lives of PTS based on the limited data in the region (Chapter 3) indicate that PTS generally have shorter t1/2 of a few weeks in African soils, compared to several weeks or years in the cold temperate soils. The data available is not comprehensive and is only available for a few substances. For example, the trend of persistence of a few PTS in Nigeria is: Lindane < aldrin < DDT (Lalah et al. 2001; Osibanjo, 2002). The potential mobility of these chemicals in the soil is also found to have the trend: Lindane> aldrin > DDT, similar to the water solubility trend of these chemicals. This suggests a higher potential for Lindane and aldrin to leach into ground water. The contamination levels of PTS in soils are: agricultural lands < industrial sites < municipal refuse dumps (Osibanjo, 2002). Major data gaps exist on levels of PAHs, dioxins and PCBs in soils in Region V (see also Chapter 3).

Recent data produced from South African field leaching and laboratory studies have shown that under environmental and soil conditions pertaining to South Africa, pesticides may persist for longer periods of time than in countries outside the region. This data is in contrast with what has been found in other regions in Africa. An example of this effect is that of the organophosphate insecticide fenthion which has a published half-life of one day. Laboratory leaching trials conducted in South Africa have shown a half-life of up to 7 days could be expected for this compound. This seven-fold increase in half-life is significant (Meinhardt pers comm). The implications are that some PTS may remain in these soils for extended periods, even longer than what is expected in temperate countries.

The persistence of a compound is but one of the important aspects that should be considered in assessment of the risks associated with PTS. Another aspect that should be considered is that of the mobility of a compound in soil.

Persistence is an important issue as varying results have been attained from various areas in the region even though indications are that compounds may have shorter half-lives. In the same studies conducted, field leaching of pesticides were evaluated. Results of field leaching studies for fenthion shows that this compound may be highly mobile in soils relevant to South Africa, contrary to the its assumed immobility from international literature (Meinhardt pers comm).

It is generally accepted that South African soils may be deemed as having developed from aged geomorphic structures. The presence of organic topsoil horizons on South African soils is limited, leading to the soils being characteristically low in organic carbon, and often having low microbial activity. These factors could contribute to higher leaching characteristics and prolonged persistence of certain chemicals, including PTS in soil. This aspect of soil composition, structure and development is expected to hold true for other southern African countries and possibly Region V (Meinhardt pers comm). Temperature differences across the region should also be taken into account, as major variations are experienced (Chapter 1).

This aspect of the behaviour of PTS in Region V again constitutes a major data gap. In depth studies on these aspects in the region are essential to obtain a clearer picture of PTS behaviour in soil, and on the environmental and human health risks associated with these compounds.

Leaching of chemical compounds in soil is not limited to downward movement of a compound to groundwater (Meinhardt pers comm). An aspect, which must be highlighted, is that of the upward movement of a compound, primarily together with the soil waterfront to the surface of the soil. This is especially relevant to Region V, because of general high evaporation rates experienced combined with intermittent and cyclical rainfall events. An additional aspect is that of preferential flow of a compound in fissures, cracks earthworm holes etc. Preferential flow does not only occur in heavy cracking clay soils, but also in more sandy soil, even though chromatographic flow will tend to be prevalent in sandy soils. Preferential flow leads to rapid movement of a compound in soil, and is independent of the compounds adsorption ability. This means that even if a compound is generally easily bound to soil particles, it could move freely in the soil. Also, preferential flow occurs at the interfaces of heterogeneous soil layers. In a heterogeneous soil, a compound will leach into soil, reach the interface with a different soil type, and this allows the compound to move vertically in the soil and possibly enter surface water sources in this way (Meinhardt pers comm).

4.6 DATA GAPS

There is a recognised need to fill the following data gaps:

- Application and validation of mult-media fate models at a range of spatial scales (local, Regional and Global).
- Ambient air monitoring data throughout the Region
- Quantification of riverine inputs into the coastal/marine environment
- Significance of upward migration of contaminants in soils
- Impact of ccean currents as a transport medium
- Validation of soil contaminat fate models for a range of African soil types
- Significance of migrating animals and birds in terms of the potential for PTS bio-transport

4.7 SUMMARY

Modelling of environmental pollutants is still in its infancy and very limited data is available on the use or success of chemical fate and behaviour modelling efforts in the region. The uniqueness of the African continent in terms of climate and temperature inversions is significant in determining the environmental fate of PTS.

It is not known whether Africa is a net source or sink of global PTS compounds. Current thinking is that the presence of the Inter-Tropical Convergence Zone will prevent atmospheric transport of PTS to the north and vice versa. However, whether Africa acts as a source of PTS to the Antarctic is not known. Island states are particularly vulnerable to atmospheric transport of contamination by PTS. Almost no data on the potential for PTS transport within the Region exists via monitoring data, a factor that is recognised as a large data gap.

Since most of the socio-economic activities of Region V are associated with rivers and other water bodies, it is expected that significant amounts of PTS be transported across boundaries and released into lakes, seas and oceans via this route. The magnitude of this input is unknown for the region, but it is likely to be significant and therefore recognised as another major data gap.

Movement of PTS via soils is recognised as an important route of transfer within the Region. Models of contaminant movement developed in Europe and the US may not be valid for Region V as the soil type and climatic conditions are very different and require validation prior to use.

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5 ASSESSEMENT OF THE REGIONAL CAPACITY AND NEEDS TO MANAGE PTS

5.1 INTRODUCTION

The economies of Sub-Sahara Africa countries largely depend on agriculture. Inadequate exploitation of the vast available natural resources and the existence of political instabilities have contributed greatly to the ongoing poverty experienced in most of the countries and constrains their ability to meet national, regional and global obligations (see Chapter 1).

The small and medium-scale farmers in rural areas, of many countries, produce the required national food and livestock. To adequately feed the populations, the farmers have to produce more food and livestock. To facilitate this demand, farmers have turned to improved agricultural packages, which include the use of conventional pesticides and PTS to control pests that destroy food and vectors of diseases. Additional conventional pesticides and PTS are now due to the proliferation of industries without cleaner technologies amongst the Sub-Saharan countries. The burning of charcoal (forests), solid waste, animal carcasses and various crop residues are common in Sub-Saharan Africa and are significantly increasing the PTS burden to the environment, particularly for compounds such as PAHs and PCDD/Fs (see Chapter 2).

African governments are not passive concerning the problems and associated issues (disease, illiteracy, malnutrition, poverty, etc.) regarding hazardous compounds, (including PTS), but are joining the rest of the world to contribute towards protection and conservation of the environment through involvement in fora such as NEPAD, WSSD and different international agreements (Basel, Rotterdam, Stockholm, Bamako, see Table 5.1). These demand new or strengthened initiatives and policy thrusts from African Governments towards the environmentally sound management of PTS and other hazardous substances, that threaten the environment and the health of the people.

Table 5.1 The status of countries that have signed and / or ratified the Stockholm and Basel Conventions.

Country	Conventions	
	Stockholm	**Basel**
Angola	-	-
Benin	yes	yes
Botswana	yes	yes
Burkina Faso	yes	yes
Burundi	yes	yes
Cameroon	yes	yes
Central African Republic	yes	-
Chad	yes	-
Comoros	yes	yes
Congo (Brazzaville)	yes	-
Cote d'Ivoire	yes	yes
Democratic Republic of Congo	-	yes
Djibouti	yes	yes

Equatorial Guinea	-	-
Eritrea	-	-
Ethiopia	yes	yes
Gabon	yes	-
Gambia	yes	yes
Ghana	yes	-
Guinea	yes	yes
Guinea-Bissau	-	-
Kenya	yes	yes
Lesotho	yes	yes
Liberia	-	-
Madagascar	-	yes
Malawi	-	yes
Mali	yes	yes
Mauritania	yes	yes
Mauritius	yes	yes
Mozambique	-	yes
Namibia	-	yes
Niger	yes	yes
Nigeria	yes	yes
Rwanda	-	-
Sao Tome and Principe	-	-
Senegal	yes	yes
Seychelles	yes	yes
Sierra Leone	-	-
Somalia	-	-
South Africa Sudan	yes -	yes -
Swaziland	-	-
Tanzania	yes	yes
Togo	yes	-
Uganda	-	yes
Zambia	-	yes
Zimbabwe	-	-

5.2 MONITORING CAPACITY

Capabilities to monitor the levels of PTS are seriously lacking in most parts of the region. The monitoring of PTS in the environment varies from country to country depending on the level of development and financial resources available. Sub-Sahara African countries lack the analytical facilities in terms of high technology equipment, such as Mass-Spectrometry (MS), High Resolution Gas Chromatograph (HRGC) and High Pressure Liquid Chromotograph (HPLC), in addition to recently developed efficient extraction and clean up equipment. Highly trained experts in trace organic analysis, access to current periodicals and other literature, as well as funds for solvents and other pertinent chemicals are the main limiting factors for conducting research and/or monitoring on PTS residues and pollutants in general. They also present limitations with respect to upgrading the capacities in the region

Necessary expertise is presumed to be available in at least 30% of Region V countries. Certain countries like Sudan, Nigeria, Democratic Republic of Congo (DRC) and South Africa amongst others have the necessary qualified scientists to carry out analysis of dioxins and furans

5.3 EXISTING POLICIES, REGULATIONS AND MANAGEMENT OF PTS

It is evident from available data that most of the countries of the region have developed, and others are in the process of developing, policies and regulations in the management of chemicals including PTS. It is possible that the low level of awareness among the stakeholders and the poor dissemination of available information of the adverse effects of PTS on humans and the environment, are responsible for the slow pace in developing regulations and policies on PTS (Table 5.2). Even then some of the existing national policies need to be reviewed in response to new challenges and international obligations within existing Conventions (e.g. Stockholm Convention on POPs).

Table 5.2 Summary of countries with regulations/policies and institutional framework to manage chemicals/PTS

Country	**Regulations/Policies**		**Institutional Framework**
	Other chemicals	**PTS**	
Angola	-	-	-
Benin	Yes	no	yes
Botswana	yes	no	yes
Burkina Faso	yes	no	yes
Burundi	yes	no	yes
Cameroon	yes	no	yes
Central African Republic	yes	no	yes
Chad	yes	no	yes
Comoros	yes	no	yes
Congo (Brazzaville)	yes	no	yes
Cote d'Ivoire	yes	no	yes
Democratic Republic of Congo	yes	no	yes
Djibouti	no	no	no
Equatorial Guinea	no	no	no

Eritrea	no	no	no
Ethiopia	yes	no	yes
Gabon	yes	no	yes
Gambia	yes	no	yes
Ghana	yes	no	yes
Guinea	yes	no	yes
Guinea-Bissau	no	no	no
Kenya	yes	no	yes
Lesotho	yes	no	yes
Liberia	yes	no	yes
Madagascar	yes	no	yes
Malawi	yes	no	yes
Mali	Yes	no	yes
Mauritania	Yes	no	yes
Mauritius	Yes	no	yes
Mozambique	-	-	-
Namibia	-	-	-
Niger	Yes	no	yes
Nigeria	Yes	no	yes
Rwanda	--	-	-
Sao Tome and Principe	Yes	no	yes
Senegal	Yes	no	yes
Seychelles	Yes	no	yes
Sierra Leone	Yes	no	yes
Somalia	No	no	no
South Africa	Yes	no	yes
Sudan	Yes	no	yes
Swaziland	--	-	-
Tanzania	Yes	no	yes
Togo	Yes	no	yes
Uganda	Yes	no	yes
Zambia	Yes	no	yes
Zimbabwe	Yes	no	yes

Note: Most of the Region V countries have policies/Regulations on PTS-Pesticides.

It is regrettable that whereas most of the national legislations are either too general or too fragmentary in nature and non-specific to PTS, some countries do not have any laws regarding hazardous chemicals. It will be important that national legislations are enacted and/or harmonised to deal with hazardous chemicals in general and PTS in particular.

It is also evident that most countries have established or are developing institutions to manage the environment but lack management strategies regarding hazardous chemicals. There is further evidence that these institutions also lack adequate capacity and resources for the environmentally sound management of hazardous chemicals and PTS. A major constraint towards sustainable chemical management is the lack of and / or weak enforcement of regulations. For the region to contribute effectively in the global effort to reduce PTS, there is need to establish and/or strengthen existing institutions and legal frameworks through capacity building and putting in place necessary mechanisms for compliance monitoring and enforcement.

The monitoring of PTS and other chemical levels in the environment vary from country to country depending on the level of development and financial resources available. The few established organizations and research institutions lack adequate trained scientists and proper equipment to monitor and assess PTS in various media. Data that might have been generated by research is rarely published and disseminated to relevant authorities that might use such data to establish control measures or perform enforcement. It must also be noted that most generated data, if not all, are from individual studies, and not ongoing. This has resulted in fragmentary data and numerous data gaps (Chapter 3). Despite these limitations, the increasing awareness about PTS is stimulating cooperation amongst the various research institutions and other stakeholders. This may be a good indication of proper future PTS management in Sub-Saharan Africa. It is also encouraging that international agencies are joining hands with countries of the Sub-Saharan Africa region in addressing the potential effects of PTS.

5.4 ALTERNATIVES AND/OR MEASURES FOR REDUCTION OF PTS

Some of the existing national legislations, rules and regulations in the region have placed a ban and/or restriction on the importation, formulation and use of some PTS pesticides. This situation leads to the search for alternatives for use in both agriculture and vector control. Due to lack of adequate knowledge about the newly developed alternatives, some farmers are still using PTS pesticides 'undercover'. This calls for aggressive awareness raising amongst farmers of the alternatives on the one hand and the effects of PTS on the other in order to convince them of the need to turn to these alternatives.

Another common perception is that alternatives to PTS pesticides are ineffective and expensive. Countries that cannot afford the alternatives can still use PTS pesticides within the period allowed under the Stockholm Convention. The development of alternative chemicals to replace PTS has however continued in the Sub-Saharan region. In East Africa for example, most of the banned PTS pesticides (organochlorines) have been replaced by pyrethrums (some of which are locally manufactured and formulated).

It is noteworthy that there are some successful stories by well-established International Institutions (such as IITA, IRRI, SAARC), which are implementing alternatives to PTS pesticides in agriculture and vector control. For example, Integrated Pest Management (IPM) and Integrated Vector Management (IVM) have been developed and are currently being implemented in various parts of the world including Region V. Another example is the potential use of the extract of the Neem tree to control agricultural pests and some fungal diseases instead of conventional pesticides. Furthermore the ecological approach entails the technology of using chemicals, such as pheromones, to control the behaviour, sexual maturation, and swarming behaviour of pests, so as to reduce the need for PTS.

It is encouraging to note that FAO has assisted some countries of the region to prepare inventories of obsolete pesticides. Finding funds to dispose of these obsolete stocks safely will reduce PTS in the region. There is hope that international funding agencies will provide assistance to African Governments for the disposal of obsolete chemicals and chemical wastes.

Other options being explored are the employment of cleaner production technologies to reduce PTS. For example, in the paper manufacturing industry the use of the thermo-mechanical paper process will certainly reduce the release of dioxins and furans into the environment. High temperature incineration technology is proven for effective treatment and disposal of hazardous chemicals. Nonetheless the prohibitive cost of this technology makes it less attractive to the Governments of the region but provides a unique opportunity for foreign investment. This will minimise the trans-boundary movement of hazardous wastes from the region to other continents.

5.5 SOCIO-ECONOMIC INTERVENTIONS

In the foreseeable future, agriculture will remain one of the pillars of economic activities for Sub-Sahara Africa and inevitably chemicals will still be used for better yields. In the light of the current health, nutritional and educational status of the population of the region, a cleaner and safer environment is a necessity for a sustainable socio-economic growth.

Data available for the region show that little or no socio-economic interventions have taken place to date. To change the habits of its populations who are still using PTS containing and/or releasing chemicals, in addition to what have been mentioned earlier, Governments of the region should give various incentives (reduce cost of alternatives, tax rebates, compensations for loss of property, etc.) to the respective stakeholders. Moreover, the developed nations should be encouraged to co-operate with the countries of the region to promote low cost PTS free technologies and products.

5.6 THE REGIONAL NEEDS

Arising from the foregoing problems and related issues in the region the following needs have been identified:

a) The development of basic capacities in each country for identifying and addressing PTS management issues:

   I. Awareness amongst the populations
   II. Specific mandates/policies/regulations and the harmonisation of laws
   III. Human resource development
   IV. Information resources (such as data bases)
   V. Communication and dissemination
   VI. Coordination amongst stakeholders
   VII. Responsible care

b) Development of institutions and legal infrastructure relative to PTS:

   I. Evaluation of existing national / regional institutional and legal infrastructures
   II. Strengthening of institutions where needed
   III. Development of legal instruments where needed

c) Development of action plan for management including monitoring, research and development for PTS:

   I. Inventories
   II. Infrastructures (laboratories, equipment, etc.)
   III. National / regional data base
   IV. Partnership (Industry to industry and state)
   V. Research and monitoring capacities
   VI. Development of quality management systems and capacity

VII. Development of capacity for modelling and prediction

VIII. Alternative measures, strategies and cleaner production technologies

d) Development of links between all stakeholders and establishment of national/regional co-ordinating mechanisms that will relate to:

I. Academia and research

II. Private sectors

III. Educational institutions

IV. Bilateral agencies

V. Multilateral agencies

VI. NGOs

VII. Professional associations

VIII. Governments, African Union, and NEPAD

e) Initiatives on trans-boundary issues:

I. Regional protocols, procedures, enforcement and compliance monitoring programmes

II. Development of joint co-operation programmes (research and monitoring facilities etc.)

III. Involvement of the Regional Trade and development blocks such as SADC and ECOWAS.

IV. Joint management of common water bodies such as Lakes Chad, Zambia, Tanganyika, Victoria and the rivers Nile and Niger

V. High priority for the establishment of national / regional laboratories for PTS and in particular for dioxins and furans

f) Financial resource requirements for PTS management:

a) Internal

- National/Regional personnel costs
- Communication
- Secretariat
- Information collection and dissemination
- Exchange of expertise

b) External

- Facilities and equipment
- Training
- Human resource development
- Development, use and assessment of the technical assistance
- Formulation and development of programmes and their implementation
- Technical assistance in disposal and elimination of wastes
- Technical support in IT
- Costs of Capacity Building

- Technical assistance in enforcement facilities.

5.7 SUMMARY

The information and data in Chapters 1, 2, 3,and 4 confirm that countries of Sub-Sahara Africa region are developing and that most of their economies rely mainly on agriculture. It has also been shown that pesticides are used to control pests in agriculture and insect vectors in public health. Rapid industrialisation in most of the countries of the region and waste combustion, amongst others, are also significantly increasing the PTS load to the environment, especially PCDD/Fs.

Nevertheless, many countries of the region have made significant developments on chemical issues, including policies / regulations, as well as appointing authorities to manage and monitor hazardous chemicals, including PTS. The available information shows that the replacement of PTS by alternatives is currently under investigation, but much has to be done, including awareness raising on this issue. The disposal of stockpiles of pesticides and other hazardous chemicals is ongoing, but many countries of the region require more technical and financial support.

It is important, in addition to the harmonization of the policies / regulations, to harness finances and develop human capacities to aid environmentally sound management of PTS. Linkages and co-operation between all the countries stakeholders and the international agencies have been identified to be a very necessary tool in support of the sound management of the environment. Introduction of various incentives, including tax rebates to industries with cleaner technology that are willing to support the sound management of the environment, was identified as another positive way to incorporate stakeholders.

5.8 REFERENCES

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6 CONCLUSIONS AND RECOMMENDATIONS

Although many of the countries of Region V have signed the different conventions (Stockholm, Basel, Rotterdam and Bamako), it is clear, as seen in the previous Chapters, that most of them do not have adequate legal framework and resources to soundly manage PTS (Chapter 5). Moreover, the existence of data gaps at all levels (sources, concentrations in the environment, inventory of obsolete stocks, trans-boundary movement of PTS, import & export data, etc.) renders the management of these PTS even more difficult (Chapters 2, 3 and 4). A very big task therefore lies ahead for Sub-Saharan African Governments, with the financial and technical assistance of international agencies to reduce or eliminate PTS in Region V.

6.1 KEY FINDINGS

PTS are not manufactured in the region but imported largely from developed countries and Asia. Anthropogenic activities in agriculture, industrial manufacturing, waste burning, energy production and use, and vehicular transport emissions are identifiable sources of PTS release into the environment. About 112,000 tons of obsolete stocks of PTS pesticides exist in the region, awaiting environmentally sound disposal.

Research studies done in the African continent show ubiquitous PTS contamination of environmental media and associated resources as well as humans. High concentrations of some PTS especially DDT, PCBs, Lindane, Dieldrin and Toxaphene were reported for livestock, fish, wildlife, human blood and mothers breast milk in countries with high usage of these chemicals, in particular South Africa, Zimbabwe, Madagascar, Sudan and Nigeria. For example the estimated Allowable Daily Intake (ADI) of aldrin and dieldrin in some foodstuffs from Nigeria was greater than the FAO ADI, which calls for caution and intervention.

The foregoing underscores the fact that PTS contamination of the environment and humans is a problem shared by both developed and developing countries. Data gaps in most countries need to be addressed to enable a realistic assessment of PTS issues and concerns in Region V.

The need to strengthen institutional and regulatory framework is compelling to ensure effective compliance with national and international laws. Capacity building for regulators and the private sector is required towards forging a partnership that will facilitate effectiveness of national and regional strategies for PTS reduction. Awareness raising at all levels about the effects of PTS and its management is vital for the region.

Based on the foregoing chapters, the regional team felt that the general issues listed below require urgent attention:

- Existing environmental data gaps should be filled as a matter of priority, as meaningful policy interventions to protect humans and the environment from risk of exposure to PTS cannot be achieved in a data vacuum. Environmental monitoring of PTS levels at national / regional level in water, sediments, biota, air, livestock and human blood / breast milk is essential for identifying all the hot spots for remedial action. The available number of reports in the RBA PTS database on PCDD/Fs for Region V is less than 10, while for Germany it is about 10 000.
- The pathways and fate of PTS in the region should be studied, so that the critical pathways and routes of exposure can be identified, followed by the evaluation of the relative impact of processes, estimation of transport fluxes, and assessment of remedial measures. Information is lacking in this critical area.
- Capacity building needs in the region deserve priority action to ensure global success of the recent Stockholm Convention and other international agreements for the environmentally sustainable management of PTS and other hazardous chemicals. Regionally based research including development of ecotoxicological data based on the African environment is important. Training African experts in the use of models and risk assessment for sound chemicals management and environmental protection is also advantageous to the region and the international community.

6.2 SETTING OF PRIORITIES

- The following procedure was used to derive the list of priorities contained in this document:
- The draft document, following the Technical Workshops in Mombasa Kenya in late July 2002, was submitted to all countries of the region, together with an invitation to send a ministerial delegation to the Priority Setting Meeting, to be held in Nairobi, Kenya, during 30 October to 01 November 2002.
- Delegations from the following countries attended the technical workshops: Benin, Burkina Faso, Chad, Comoros, Cote d' Ivoire, Democratic Republic of Congo, Cote d' Ivoire, Djibouti, Ethiopia, Kenya, Madagascar, Mauritius, Malawi, Nigeria, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Zambia and Zimbabwe.
- At the Priority Setting Meeting, the participants from the following countries attended: Senegal, Tanzania, Ghana, Ethiopia, Democratic Republic of Congo (DRC), Swaziland, Sierra Leone, Burkina Faso, Togo, Mauritius, Niger, Cote d'ïvoire, Sao Tome & Principe, Namibia, Congo Brazzaville, Benin, Gambia, Djibouti, Zambia, Sudan, Kenya, Nigeria and South Africa.
- The participants were introduced to the aim and scope of the project, with lectures, based on the various chapters of the draft report. French - English translation was provided.
- The participants were then briefed to do the following in two groups; a Francophone and an Anglophone group:
- Review the report and provide general comments
- Add, improve (or remove) information in the report, where deemed necessary
- Evaluate the scores on sources, levels and data gaps, and amend where deemed appropriate.
- Evaluate the indicative list of issues supplied (these were drawn up by the team, and proposed as short headings to indicate possible priorities to be considered).
- Amend, add or remove issues in the list where needed
- Where possible, expand on each issue with justifications. Make recommendations as realistic and specific as possible (e.g. indicate where a regional approach would be preferred).
- Also add the barriers that need to be overcome to implement these priorities.
- Prioritise the list of issues according to the following criteria:
    1) Immediate attention (short term: 1-2 years implemented or completed*)
    2) Urgent attention (medium term: 2-5 years implemented or completed)
    3) Attention required (long term: 4-10 Years implemented or completed)
- The reports from the two groups were then presented together in plenary, and, through consensus and discussion, chaired by the Regional Coordinator, and supported by the chairpersons of the Francophone and Anglophone groups, a single document was drawn up, while a simultaneous text translation in French was provided on a separate screen.
- The results of the priorities are reflected in the next section.

* By this is meant that the priority should be addressed or have been implemented within this timeframe. In certain cases it also means that the activity is to be continued after implementation.

6.3 PRIORITIES AS AGREED UPON BY THE PRIORITY SETTING MEETING

The priorities have been evaluated specifically within the context of strengthening the capacity of Sub-Sahara Africa to deal with the current and future social, technological, economic and environmental development requirements.

The priorities below are presented in no particular order.

6.3.1 Short Term Priorities (1-2 years)

(1) Survey of the current PTS contamination status of fresh, coastal and marine waters by PTS.

Justification:

- Impact of pollution on export markets if PTS pollution is not managed from knowledge (Chapter 5)
- These ecosystems are already incorporated in NEPAD as an important priority (Chapter 5)
- Address the data gap indicated by this report, regarding lack of data (Chapters 2, 3 and 4)
- Pollution is closely linked to human health (chapters 1, 3 and 4)
- Pollution affects the integrity of affected ecosystems (Chapter 3)
- Polluted environments affect livelihood support of affected communities (Chapter 1)
- Fresh and coastal water important to life and maintenance of ecosystems (Chapter 1)

Barriers:

- Lack of resources (technical and financial)
- Lack of awareness
- Lack of existing data
- *Weak legislation and enforcement*

(2) Identification, quantification and mapping of sources of PTS contaminants that release PTS to the environment.

Justification:

- Address the data gap indicated by this report, regarding lack of data (Chapters 2 and 3)
- Data gathered will facilitate appropriate intervention measures (Chapters 2, 3, 4 and 5)
- Improved knowledge of pollution to support sustainable development and address poverty (Chapter 5)
- To build trust and partnerships between all stakeholders (Chapter 5)

Barriers:

- Lack of laboratory equipment
- Insufficient legal framework to deal with pollution
- Inadequate personnel to deal with analytical and ecotoxicological issues
- Poor management of PTS
- Poor (or even reluctance) collaboration of all stakeholders to achieve aims of PTS management
- Lack of knowledge of distribution of sources (see Priority 1)

(3) Collection of import and export data for PTS through existing and strengthened databases, with clear categorisation.

Justification:

- Need to facilitate planning and development of strategies regarding PTS (Chapter 5)

- Need for awareness on the part of the relevant government officers and all other stakeholders (Chapter 5)
- Strengthening knowledge regarding PTS in trade, with a specific need to obtain knowledge on illicit trade and illegal use and trade (Chapters 2 and 5)

Barriers:

- No proper records currently being kept
- No existing infrastructure for data management
- Insufficient technical infrastructure and / or legal capacity to deal or obtain the required data

(4) Develop and / or strengthen appropriate national and (harmonised) regional regulations (in line with relevant international agreements) for environmentally sound PTS management.

Justification:

- Need to ensure an environmentally sound management of chemicals including PTS at all levels (Chapter 5)
- Need to regulate trans-boundary movement (Chapter 5)

Barriers:

- *Low priority for funding*
- Inadequate institutional capacity
- Lack of specific national focal points
- Lack of centre of excellence for PTS management
- Insufficient political will

(5) Intensify awareness regarding PTS issues, amongst stakeholders, relevant government regulatory officers and civil society.

Justification:

- Existing levels of ignorance of hazardous effects of PTS in most African countries needs to be urgently addressed (Chapter 5)

Barriers:

- Low level of education of the population
- Lack of financial resources
- Lack of means of communication

(6) Disposal of obsolete PTS stocks and remediation of sites contaminated by such (African Stockpiles Programme).

Justification:

- Source of contamination of soil and associated ecosystems (Chapters 2 and 3)
- Prevalence of huge stockpiles in Africa (Chapter 2)
- Adverse health and environmental effects of communities and biota (Chapters 1 and 4)
- Access to existing liability and redress articles in the various Conventions possible

Barriers:

- Lack of funds,

- Lack of clean disposal technology,
- Continued use and imports of obsolete chemicals,
- Lack of regulatory framework to prevent accumulation,
- Lack of comprehensive inventories,
- Lack of knowledge about PTS other than obsolete pesticides stockpiles

(7) Inventory of PTS sources, contaminated sites, affected communities and others (other than PTS pesticides).

Justification:

- Intensive use of PTS in Africa (Chapter 2)
- Data gap on impacts of PTS use (Chapter 3)
- Facilitate intervention measures such as remediation (Chapter 5)
- Improved knowledge of pollution (Chapter 3)
- To build trust and partnerships amongst all stakeholders (Chapter 5)
- Protecting human health and environment (Chapter 1)

Barriers:

- Lack of laboratory equipment
- No legal framework
- Insufficient personnel
- Poor management of PTS
- Poor (or even reluctance of) collaboration of all stakeholders to achieve aims
- Lack of knowledge of distribution of sources
- Vast areas involved (including aquatic)
- The number of areas involved
- Accessibility of sites
- Lack of applicable assessment techniques and technologies

(8) Specific attention to address open burning (combustion without Air Pollution Control measures) (e.g. sugarcane, vegetation, forests, domestic waste, etc.), to reduce TEQ releases and thereby reduce the risk to affected communities and ecosystems.

Justification:

- Common practice in Africa (Chapter 2)
- Probably a major source of release and exposure of humans and biota to PTS (Chapter 2)
- Source of PTS for long-distance transport (Chapters 2, 3 and 4)
- Domestic waste contains chlorine
- Waste can also contain PTS (hazardous waste) (Chapter 2)

Barriers:

- Poverty

- Ignorance of consequences
- Lack of alternative practices
- Entrenched burning practices
- Lack of trained human resources
- Lack of suitable sites for disposal of urban waste
- Lack of technical alternatives
- Lack of finance
- Lack of public awareness of health consequences of open burning

(9) Support the maintenance of the existing RBA database, and thereby monitoring the reduction of the identified data gaps.

Justification:

- Supports future monitoring and modelling of PTS residues in the environment, as well as fate and pathways (Chapters 2, 3 and 4)
- Absence and/or insufficient reliable data will be addressed, adding substance and information to environmental and health management at all levels (Chapters 2, 3 and 5)

Barriers:

- Lack of funding
- Lack of technical infrastructure
- Insufficient Information Technology
- Incompatibility of existing data
- Inaccessible information (proprietary)

(10) Initiate and/or support implementation of regionally applicable (including research) IPM and IVM, including the use of alternatives, to reduce the use of PTS pesticides.

Justification:

- Need to minimise the use of PTS pesticides and to establish ecologically sound approaches to pest and vector control (Chapter 5)
- Efficiency of the IPM / IVM programmes (Chapter 5)
- Collaboration with other initiatives, such as Roll Back Malaria

Barriers:

- Cost of alternatives
- Resistance to implementation of IPM / IVM
- Time and funding required for research and implementation

(11) Support an assessment of alternative industrial (cleaner) technologies as being relevant to African conditions.

Justification:

- Environmentally sound production for economic development (Chapters 1 and 5)
- Improved export opportunities of products produced by cleaner technologies (Chapter 5)

- Need to minimise the production and release of PTS containing wastes to reduce accumulation of hazardous waste (Chapter 5)
- Potential for poverty reduction by improved health and a cleaner environment (Chapter 5)
- Reduced exposure and pollution (Chapters 4 and 5)
- Support from, and synergy with, various international conventions (Chapters 1 and 5)

Barriers:

- High initial investment required
- Possible resistance to adoption by some stakeholders

(12) Support human resource development relevant to PTS programmes

Justification:

- Capacity building/improvement needed to deal with various requirements (Chapter 5)
- Implementing relevant international agreements (e.g. Stockholm, Basel and Rotterdam) (Chapter 5)

Barriers:

- Funding
- Inadequate training centres

(13) To establish capacity to address disasters and emergencies relative to PTS (fires, explosions, contaminated products etc.)

Justification:

- Protect the integrity of the environment as well as human lives and property

Barriers:

- Lack of funding
- Lack of technology
- Lack of training

(14) To improve solid waste management

Justification:

- No existing or implemented sound management (Chapter 5)
- Preventing contamination of environment by PTS containing waste (Chapters 2, 4 and 5)
- Prevent off-site pollution by leachate
- Protection of public health through better waste management

Barriers:

- Lack of funding,
- Lack of appropriate technology
- Rapid urbanization increases waste and overburdens existing waste handling infrastructure

(15) Inventory and strengthening of existing laboratories for PTS analysis

Justification:

- Enable monitoring and research into residues, exposure, risk assessment and effectiveness of cleaner technologies and PTS management (Chapters 2, 3, 4 and 5)

- Satisfy environmental and health standards (Chapter 5)
- Compliance with international agreements (Chapter 5)

Barriers:

- Lack of funding
- Inadequate existing facilities
- Lack of trained personnel

(16) Integrate PTS studies with health and environment initiatives

Justification:

- Awareness raising of impacts of PTS (Chapter 5)
- Support poverty reduction through establishing knowledge of linkages between exposure, risk and health outcomes (Chapters 3 and 5)
- Improve effectiveness of existing and strengthened laboratories and human resources (Chapters 3 and 5)

Barriers:

- Lack of analytical tools
- Lack of funding
- Lack of existing collaborative research and risk assessment networks

6.3.2 Medium Term Priorities (2-5 years)

(17) Protection of the environment from contamination by PTS through the adoption of improved technologies, enforcement, monitoring and information from 1 and 2.

Justification:

- This issue has been incorporated in NEPAD programmes where applicable (Chapter 5)
- Linkage to human health that will be improved through better management (Chapter 5)
- Improved integrity, quality and maintenance of ecosystems through reduced exposure to PTS (Chapters 3 and 4)
- Improved livelihood support through a cleaner environment, and thereby addressing poverty reduction (Chapters 1 and 5)
- Need for assessment and follow-up through research and monitoring (Chapter 5)
- Need for protection of export markets though production of more acceptable production methods (relevant international standards such as WHO and FAO Maximum Residue Limits) (Chapters 1 and 5)

Barriers:

- Lack of funding
- Lack of skilled personnel
- Lack of access to existing technology
- Lack of knowledge of technologies relevant to Africa

(18) Identify, strengthen and improve capacity (laboratory infrastructure) in the region to deal with PTS issues (scientific, analytical, modelling, accreditation, risk assessment), and support intra-

African (collaboration specifically Anglophone and Francophone) on PTS projects and research, to support associated Conventions (Stockholm, Basel, Rotterdam, Bamako, etc).

Justification:

- To deal with PTS analysis and related scientific issues as identified (Chapters 2, 3, 4 and 5)
- To deal with the complex characteristics of PTS (Chapters 1 and 5)
- To deal with the transboundary aspects of PTS pollution (Chapters 4 and 5)

Barriers:

- Lack of funding
- Lack of skilled personnel
- Lack of access to facilities
- Lack of knowledge of technologies relevant to Africa
- Existing linguistic barriers
- Insufficient supporting policies

(19) Establish an African PTS Advisory/Research Group

Justification:

- Stimulating, strengthening and coordinating African research work on PTS and alternatives (Chapter 5)
- Strengthening communication between linguistic groups (Chapter 5)

Barriers:

- Lack of financial and technical resources
- Lack of IT infrastructure, especially communication and data management
- Long distances between centres hamper travel
- Lack of established links and protocols regarding research

(20) Develop tools and indicators to assess the impact of PTS on socio-economic activities, as well as the success of the implementation of the various conventions, relevant to Africa.

Justification:

- Support sound identification of the socio-economic issues involved *vis à vis* the international agreements (Chapters 1 and 5)
- Facilitate technical and management solutions for PTS (Chapter 5)
- Produce end-points to measure achievement goals (Chapters1 and 5)

Barriers:

- Lack of funding and technical resources

(21) Support and expand existing expert network to deal with research and monitoring

Justification:

- To foster collaboration and share experiences (Chapters 1 and 5)
- Improve regional co-operation (Chapters 1 and 5)
- Increase efficiency of research and monitoring (Chapter 5)

Barriers:

- Lack of funding
- Weak communication network

(22) Support a specific project to analyse existing and new data to model the fate, transport and effects of PTS in Region V.

Justification:

- Different climatic and biotic conditions prevail in Africa, requiring the application of models to generate research questions (Chapters 1, 3 and 4)
- The lack of existing data could to some degree be addressed by modelling (Chapters 1, 3 and 4)
- Models currently not shown to have been calibrated to African conditions, requiring extensive research before application of results (Chapter 4)

Barriers:

- Lack of funding
- Lack of skilled personnel
- Lack of data
- Lack of infrastructure to deal with models

(23) Conduct a risk assessment using existing and new data, specifically aimed at determining the risk to the human population and biota.

Justification:

- Provide information for decision making (Chapter 5)
- Identification of specific areas and magnitude / scope of risk (Chapters 2, 3, 4 and 5)
- Identify risk due to exposure profiles specific to Africa (Whole report)
- Need to harmonise Risk Assessment methodologies (Chapter 5)
- Need to develop Risk Assessment models applicable to African conditions (Chapter 5)

Barriers:

- Lack of funding
- Lack of skilled personnel
- Insufficiency of data

6.3.3 Long Term Priorities (5 to 10 years)

(24) Assessment of need for regional incinerators.

Justification:

- Need to deal with obsolete stockpiles in an environmentally sound manner (Chapters 3 and 5)
- Reduce health hazards due to PTS wastes (Chapters 2 and 5)
- Determine the cost effectiveness of regional incineration (Chapter 5)

Barriers:

- Lack of funding

- Unknown cost structure
- Resistance to incineration
- Possible pollution from such plants
- Lack of established availability of regionally applicable technology
- Location of plant to be established

6.4 AREAS OF PRIORITY FOCUS

The delegates to the Priority Setting Meeting identified the following issues as the areas of priority focus, against which actions and outcomes should be measured.

1. Protection of international waters
2. Reduction or monitoring of transboundary movements of PTS
3. Monitoring of sediments, biota (biodiversity protection), air, soil
4. Policy and legal harmonization
5. Reduction of open burning
6. Judicious use of DDT / Lindane
7. Inventory / elimination of PCBs
8. Technology transfer and development
9. Laboratories (upgrading, strengthening and capacity improvement)
10. Increase knowledge base in particular on PCDD/Fs
11. Involvement of NGOs / civil society at all levels

6.5 FINAL WORD

Throughout this project, the RBA team for this region was impressed with the willingness of the experts, academics, NGO representatives, members of the industry, members of IGOs and governments to contribute meaningfully towards addressing the issues and problems posed by PTS in Africa. While communication and transport were frequent problems encountered during this project, the energy and willingness to participate, contribute and overcome all the obstacles, was an indication of what can be done on this scale.

The communication that was brought about by this project has, in our opinion, significantly raised the awareness of PTS in the region. This report will hopefully contribute in meaningful ways, but, as such, cannot be the end. It set out to make an assessment upon which further action can be based. Further action is therefore, as has been expressed by the participants at both the Technical Workshops, as well as the Priority Setting Meeting, crucial. The impression the team members received from the various international organizations was that of a genuine commitment to this cause, in a region facing so many problems. The lesson from this project is that with the right people and committed support from all sources, Africans will be able to solve these issues. With this report go the hopes of 760 million people.

ANNEX: ABBREVIATIONS AND ACRONYMS

ADI	Acceptable Daily Intake
AIDS	Acquired Immune Deficiency Syndrome
AU	African Union
BHC	Benzenehexachloride
ºC	Celsius (Centigrade)
CHCs	Chlorinated Hydrocarbons
CIA	Central Intelligence Agency (USA)
DDT	Dichlorodiphenyltrichloroethane
DRC	Democratic Republic of Congo
E	East
EAF	East Africa
ECOWAS	Economic Commission of West African States
FAO	Food and Agriculture Organisation
GEF	Global Environment Facility
GESAMP	Group of Experts on the Scientific Aspects of Marine Environmental Protection
GDP	Gross Domestic Product
HCB	Hexachloroclobenzene
HCH	Hexachlorocyclohexane (Lindane)
Hg	Mercury
IARC	International Agency for Research on cancer
IFCS	Intergovernmental Forum on Chemical safety
IGOs	Intergovernmental Organisations
IITA	international Institute for Tropical Agriculture
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
IVM	Integrated Vector Management
Kg	Kilogram
KOW	Octanol / Water Partition Coefficient
KWh Kilowatt hour	
LC_{50} Median	Lethal Concentration
LD_{50} Median	lethal Dose
LOEL	Lowest Observed Effect Level
L	Litre
MRL	Maximum Residue Limit

mg	Milligram
µg	Microgram
ml	Millilitre
N	North
ng	Nanogram
NEPAD	New Partnership for African Development
NOEL	No Observed Effect Level
OCs	Organochlorines
OCPs	Organochlorine Pesticides
OECD	Organisation for Economic Co-operation and Development
OPs	Organophosphates
Org.Hg	Organic mercury
Org.Pb	Organic Lead
OAU	Organisation of African Unity
PAHs	Polycyclic Aromatic Hydrocarbons
PBDEs	Polybrominated Diphenyl Ethers
PCBs	Polychlorinated biphenyls
PCDD	Polychlorinated Dibenzo-*p*-Dioxins
PCDD/Fs	Polychlorinated Dibenzo-p- Dioxins and Furans
PCDF	Polychlorinated DibenzoFurans
PCP	Pentachlorophenol
pg	Picogram
Pb	Lead
POPs	Persistent Organic Pollutants (group of twelve as defined in the Stockholm Convention 2001)
ppm	Part Per Million
ppb	Part Per Billion
ppt	Part Per Trillion
PTS	Persistent Toxic Substances (as defined in the GEF project)
RBA	Regionally Based Assessment
RC	Regional Co-ordinator
RT	Regional Team
RSA	Republic of South Africa
S	South
SAARC	South Africa Agricultural Research Council
SADC	Southern Africa Development Cooperation

$	U.S. Dollar
TCDD	TetrachloroDibenzo-p-Dioxins
TEQ	Toxicity Equivalent
UNEP	United Nations Environment Programme
UNECE	United Nations Economic Commission for Europe
W	West
WACAF	West and Central Africa
WG	Working Group
WHO	World Health Organisation

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