GLOBAL MONITORING PLAN

FOR PERSISTENT ORGANIC POLLUTANTS

UNDER THE STOCKHOLM CONVENTION ARTICLE 16 ON EFFECTIVENESS EVALUATION

SECOND REGIONAL MONITORING REPORT

AFRICA REGION

MARCH 2015

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PREFACE

Persistent organic pollutants (POPs) are a group of chemicals that have toxic properties, resist degradation in the environment, bioaccumulate through food chains and are transported long distances through moving air masses, water currents and migratory species, within and across international boundaries. POPs belong to three main groups, however some of the chemicals fit into more than one of these three general categories:

- pesticides used in agricultural applications[1]
- industrial chemicals used in various applications[2]
- chemicals generated unintentionally as a result of incomplete combustion and/or chemical reactions[3].

Twelve POPs were initially listed in the Stockholm Convention (shown in bold font in footnotes 1-3). In general, these 'legacy' POPs were first produced and/or used several decades ago, their persistence, bioaccumulative properties and potential for long-range transport are well studied, and they have been globally banned or restricted since 2004. In 2009, nine more substances were added to the Convention (chemicals with an asterisk in footnotes 1-3). Two additional chemicals were listed in 2011 and in 2013 (two and three asterisks in footnotes 1-3 respectively).

Article 16 of the Stockholm Convention requires the Conference of the Parties to evaluate periodically whether the Convention is an effective tool in achieving the objective of protecting human health and the environment from persistent organic pollutants. This evaluation is based on comparable and consistent monitoring data on the presence of POPs in

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[1] **aldrin, chlordane**, chlordecone*, **dichlorodiphenyltrichloroethane (DDT), dieldrin,** endosulfan**, **endrin, heptachlor, hexachlorobenzene (HCB),** gamma-hexachlorocyclohexane (γ-HCH, lindane)* and by-products of lindane [alpha-hexachlorocyclohexane (α -HCH)* and beta-hexachlorocyclohexane (β -HCH)*], **mirex, toxaphene**.

[2] tetra- and pentabromodiphenyl ethers (PBDEs)*, hexa- and heptabromodiphenyl ethers (PBDEs)*, hexabromocyclododecane*** (HBCD), hexabromobiphenyl*, perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOS-F)*, pentachlorobenzene (PeCB)*, **polychlorinated biphenyls (PCBs).**

[3] hexachlorobenzene (HCB), pentachlorobenzene (PeCB)*, polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-*p*-dioxins (PCDDs) and dibenzofurans (PCDFs).

the environment and in humans, as well as information from the national reports under Article 15 and non-compliance information under Article 17. The global monitoring plan for POPs, which has been put in place under the Convention, is a key component of the effectiveness evaluation and provides a harmonized framework to identify changes in concentrations of POPs over time, as well as information on their regional and global environmental transport.

The present monitoring report is synthesizing information from the first and second phase of the global monitoring plan and presents the current findings on POPs concentrations in the Africa Region. While the first monitoring report, presented at the fourth meeting of the Conference of the Parties, provided information on the baseline concentrations of the 12 legacy POPs, this second monitoring report, to be submitted to the seventh meeting of the Conference of the Parties in 2015, provides first indications as to the changes in concentrations of the chemicals initially listed in the Convention, as well as baseline information on the newly listed POPs.

ABBREVIATIONS AND ACRONYMS

ACP	Arctic Contamination Potential
ADI	Acceptable Daily Intake
ALRT	Atmospheric Long Range Transport
AMAP	Arctic Monitoring and Assessment Programme
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
APEs	Alkylphenol Ethoxylates
AU	African Union
BCF	Bioconcentration Factor
BHC	Benzenehexachloride
BPH	Benzo(a)pyrene oxidation
CEE	Central and Eastern Europe
CEN-SAD	Community of Sahelo-Saharan States
CEP	Caspian Environment Programme
CIEN	Chemical Information Exchange Network
CIS	Commonwealth of Independent States
COMESA	Common Market for Eastern and Southern Africa
COP	Conference of the Parties
CRM	Certified Reference Material
CTD	Characteristic Travel Distance
CV	Coefficient of Variation
CVUA	Chemical and Veterinary Analysis of Food
DDD /DDE	Metabolites of DDT
DDT	Dichlorodiphenyltrichloroethane
DLPCBs	Dioxin-like PCBs
DTIE	Division of Technology, Industry and Economy
EAC	East African Community
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States

EDCs	Endocrine Disrupting Chemicals
EMAN	Ecological Monitoring and Assessment Network
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long-Range
ENRTP Energy	Environment and Sustainable Management of Natural Resources including
ENSO	El Niño-Southern Oscillation
EPER	European Pollutant Emission Register
ERL	Effects Range Low
ERM	Effects Range Median
EROD	7-ethoxyresorufin-O-deethylase
EU	European Union
EUSES	European Union System for the Evaluation of Substances
FAO	Food and Agriculture Organisation of the United Nations
FERTIMEX	Fertilizantes Mexicianos, S.A.
GAPS	Global Atmospheric Passive Sampling Survey
GCG	Global Coordination Group
GEF	Global Environment Facility
GEMS	Global Environment Monitoring System
GLBTS	Great Lakes Bi-national Toxics Strategy
GMP	Global Monitoring Plan
HCB	Hexachlorobenzene
HCHs	Hexachlorocyclohexanes
HELCOM	Helsinki Commission/The Baltic Marine Environment Protection Commission
HIPS	High Impact Polystyrene
HPLC	High Performance Liquid Chromatography
HRGC	High Resolution Gas Chromatography (capillary column)
HRMS	High Resolution Mass Spectrometer
HxBB	Hexabromobiphenyl
IADN	Integrated Atmospheric Deposition Network
IARC	International Agency for Research on Cancer
ICES	International Council for the Exploration of the Sea

IFCS Intergovernmental Forum on Chemical Safety

IMO International Maritime Organisation

INFOCAP Information Exchange Network on Capacity Building for the Sound Management of Chemicals

INSPQ Centre de Toxicologie du Québec

IPPC Integrated Pollution Prevention and Control

ITCZ Intertropical Convergence Zone

I-TEQ International Toxicity Equivalence

ITF Intertropical Front

K_{AW} Air/Water Partition Coefficient

KEMI Swedish Chemical Agency

K_{oA} Octanol/Air Partition Coefficient

K_{ow} Octanol/Water Partition Coefficient

LC_{50} Median Lethal Concentration

LD_{50} Median Lethal Dose

LOAEL Lowest Observable Adverse Effect Level

LOD Limit of Detection

LOQ Limit of Quantification

LRT Long Range Transport

LRTAP Long Range Transport Air Pollutants

LRTP Long Range Transport Potential

MDL Minimum Detectable Level

MEA Multi Lateral Environmental Agreements

MEDPOL Mediterranean Pollution Monitoring and Research Programme

MONET Monitoring network

MRL Maximum Residue Limit

MSCE-East Meteorological Synthesizing Centre-East

NAFTA North American Free Trade Agreement

NARAPs North American Regional Action Plans

ND Not detected

NGOs Non-Governmental Organisations

NHATS	National Human Adipose Tissue Survey
NIP	National Implementation Plan
NIS	Newly Independent States
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observable Adverse Effect Level
NOEL	No Observable Effect Level
NWT	Northwest Territories
OCPs	Organochlorine Pesticides
OCs	Organochlorines
OECD	Organisation for Economic Co-operation and Development
OPs	Organophosphates
OSPAR	Commission for the Protection of the Marine Environment of the North-East Atlantic
PAHs	Polycyclic aromatic hydrocarbons
PBDEs	Polybrominated diphenyl ethers
PCBs	Polychlorinated biphenyls
PCDDs	Polychlorinated dibenzo- p-dioxins
PCDFs	Polychlorinated dibenzofurans
PCP	Pentachlorophenol
PFOS	Perfluorooctane sulfonate
PFOSA	Perfluorooctanesulfonic acid
PIC	Prior Informed Consent
POPs	Persistent Organic Pollutants
PRTRs	Pollutant Release and Transfer Registers
PTS	Persistent Toxic Substances
PUF	Polyurethane Foam
PVC	Polyvinylchloride
QA/QC	Quality Assurance and Quality Control Regimes
REACH	Registration, Evaluation and Authorisation of Chemicals
RECETOX	Research Centre for Environmental Chemistry and Ecotoxicology
RENPAP	Regional Network on Pesticide Production in Asia and Pacific

ROGs	Regional Organization Groups for the Global Monitoring Plan
ROPME	Regional Organisation for the Protection of the Marine Environment
ROWA	Regional Organisation of West Asia
SADC	South African Development Cooperation
SAICM	Strategic Approach to International Chemicals Management
SCCPs	Short-chain chlorinated paraffins
SOP	Standard Operating Procedure
SPM	Suspended particulate matter
SPREP	South Pacific Regional Environment Programme
SSA	Sub-Saharan Africa
SSTs	Sea Surface Temperatures
TBBPA	Tetrabromobisphenol A
TCDD	Tetrachlorodibenzo-*p*-dioxin
TEL	Tetraethyllead
TEQ	Toxicity Equivalents
TOMPS	Toxic Organic Micropollutants Survey
TPT	Triphenyltin
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation
WEEE	Waste Electrical and Electronic Equipment
WFD	Water Framework Directive
WHO	World Heath Organisation
WMO	World Meteorological Organization
XAD	Styrene/divinylbenzene-co-polymer Resin

GLOSSARY OF TERMS

Activity Any programme or other activity or project that generates data or information on the levels of POPs in the environment or in humans that can contribute to the effectiveness evaluation under Article 16 of the Stockholm Convention Core matrices These are the matrices identified by the Conference of the Parties to the Stockholm Convention at its second meeting as core for the first evaluation: A = ambient air; M = (human) mother's milk and / or B = human blood

CTD The characteristic travel distance– defined as the "half-distance" for a substance

present in a mobile phase

I L-1 Instrumentation level 1 capable to analyze PCDD/PCDF and dioxin-like PCB at ultra-trace concentrations: must be a high-resolution mass spectrometer in combination with a capillary column

I L-2 Instrumentation level capable to analyze all POPs: (capillary column and a mass-selective detector)

I L-3 Instrumentation level capable to analyze all POPs without PCDD/PCDF and dioxin like PCB (capillary column and an electron capture detector)

I L-4 Instrumentation level not capable to do congener-specific PCB analysis (no capillary column, no electron capture detector or mass selective detector)

Intercomparisons -Participation in national and international intercalibration activities such as ring-tests, laboratory performance testing schemes, etc LOD Limit of detection. Definition: The lowest concentration at which a compound can be detected; it is defined as that corresponding to a signal three times the noise.

<LOD Result below the of limit detection

LOQ Limit of quantification. Definition: The lowest concentration that can quantitatively be determined is three times higher than LOD.

<LOQ Result below limit of quantification. Compounds found at levels between LOD and LOQ can be reported as present, or possibly as being present at an estimated concentration, but in the latter case the result has to be clearly marked as being below LOQ.

MDL Method detection limit. The MDL considers the whole method including sampling, sample treatment and instrumental analysis. It is determined by the background amounts on field blanks.

Phase I-Activities to support the Article 16 effectiveness evaluation that will be conducted by the Conference of the Parties at its fourth meeting, information collected between 2000 and 2008.

Phase II- Activities to support the Article 16 effectiveness evaluation that will be conducted by the Conference of the Parties at its seventh meeting, information collected between 2009 and 2013.

EXECUTIVE SUMMARY

This second monitoring report synthesizes information from the first and second phase of the global monitoring plan and presents the current findings on POPs concentrations in the Africa Region. The second phase of the global monitoring plan focused on the inclusion of the newly listed POPs in ongoing monitoring activities, addressed the need for harmonized data handling and ensured support to the collection, processing, storing and presentation of monitoring data in regions with limited capacity through a global monitoring plan data warehouse. Enhancing the comparability within and across monitoring programmes to evaluate changes in concentrations of POPs over time and their regional and global transport was also an important milestone in the second phase.

0.1 Contributing programmes

Strategic programmes that contributed data to the first and second evaluation period included MONET-Africa programme coordinated by RECETOX (Czech Republic) for provision of ambient air and water data; Global Atmospheric Passive Sampling (GAPS) programme coordinated by Environment Canada for provision of ambient air data; 3) The World Health Organization (WHO) for provision of mothers' milk data, and 4) UNEP/GEF 1 project coordinated by UNEP Chemicals DTIE for provision of additional data for ambient air, mothers' milk, water and other media.

0.2 Key message on baseline concentrations

POPs levels in air: Pesticides were the most dominant POPs in ambient air sampling sites. DDTs, HCHs and endosulfans were the most dominant POPs pesticides detected in air. The presence of pesticides such as DDTs could be attributed to the widespread agricultural and public health uses in the past throughout the region. Moreover, there is high probability that contamination might originate from obsolete stockpiles or contaminated sites/soils.

PCBs were the most predominant industrial POPs. The major sources of PCBs could include power generation activities such as leakages from old transformers, releases from contaminated soils and transport sector. Their proper management lies at different scales depending on the country by country situation. The concentrations of indicators PCBs were generally higher than the levels of dioxin like PCBs in air.

High prevalence of unintentionally produced POPs such as PCDDs and PCDFs was registered in all sites, although the concentrations were generally lower compared to other POPs chemicals like pesticides, PCBs and PBDEs. The levels of PCDDs were generally higher than PCDDFs. High incidences of UPOPs emissions in the region could be attributed to releases from uncontrolled combustion of wastes including municipal wastes, medical wastes incineration, biomass burning of agricultural fields, industrial power generation activities and related thermal processes.

PBDEs were generally low compared to other industrial POPs. The most important PBDEs were PBDE 47 and PBDE 99. Their probable origin is the crude recycling practices of e-wastes and end-of-life vehicles. The presence of PBDEs in GMP sites signify the potential contamination of the region with the new POPs in gradient and hotspot sites that need to be monitored in countries under the implementation of NIP activities.

PFOS, FOSA, N-methyl and N-ethyl-perfluoroalkane sulfonamides (MeFOSA & EtFOSA) and N-methyl and N-ethyl perfluoroalkane sufonamidoethanols (MeFOSE & EtFOSE) were measured in ambient air in two samples submitted in 2013, but the levels were generally low.

POPs in mothers' milk: The pesticides of concern in mothers' milk were mainly DDTs which registered the highest concentrations in most of the samples. Dieldrin, heptachlors, HCHs, toxaphene and endosulfans were also detected in mothers' milk samples but at much lower frequencies and generally lower concentrations <20 ng/gfat. Aldrin, chlordanes, endrin, mirex were below the limit of quantification in all mothers' milk samples collected in the first UNEP/WHO survey from 2009-2010 and UNEP/GEF Project in 2011/2012. Chlordecone was not measured in all the samples.

Industrial POPs of concern in mothers' milk were PCBs which registered a total of six indicator PCBs concentrations between bdl to 70 ng/gfat. Dioxin like PCBs were generally lower than indicator PCBs with sum of *dl*PCBs ranging from bdl to 5 ng/gfat.
The concentrations of PBDEs in mothers' milk were generally lower than PCBs and most of the POPs pesticides. The levels ranged from bdl to 1.6 ng/gfat. The highest PBDEs in mothers' milk were PBDE 47, 153 and 99.

The levels of PCDDs and PCDDF were generally lower than all the other POPs in mothers' milk samples, with concentrations spanning from 15.30-465.2 pg/gfat for 6 PCDDs and from bdl to 11.54 pg/gfat for PCDFs.

Quantifiable levels of PFOS were detected in mothers' milk from all the eleven regional countries that submitted samples during UNEP/WHO mothers' milk survey and the UNEP/GEF project, with levels ranging from 1.00 ng/L to 34.00 ng/L. Assuming that there is no industrial production of PFOS in the region, exposure of humans to PFOS and related chemicals might probably come from different kinds of waste, releases from industrial applications in fire fighting and the various consumer products.

POPs in Water: PFOS and salts were the only POPs monitored in the water samples during the second evaluation period. Only PFOS had quantifiable levels in water, whereas FOSA, NMeFOSA, NEtFOSA, NMeFOSE & NEtFOSE were all below the limit of quantification. The concentration of PFOS measured under GMP was much lower than the levels reported from impacted sites in the region such as industrials areas and wastewater effluent discharges.

POPs in other media: the other media analysed included: soil, sediment, fish and foodstuff. The most common pesticides detected in other media were DDTs, HCB, dieldrin, HCHs and The concentrations were generally low in sediments, fish and soil from background sites. The

concentration of PCBs were also relatively low in sediments ranging from bdl to 1.2 ng/g. Similar trend was observed in fish samples with concentrations ranging from bdl to 0.15 ng/g. Fly ash sample analysed was dominantly contaminated with PCDDs, PCDFs and dioxin like PCBs. Dioxins were also detected in some fish samples with concentrations ranging from bdl to 59 pg/g. However, the levels of dioxin like PCBs in fish were higher than PCDDs and PCDFs.

POP pesticides constituted the most dominant POPs in other media followed by PCBs and lastly the PCDDs and PCDFs. PBDEs and PFOS were not analysed in samples collected for assessment of POPs in other media under the UNEP/GEF project. Despite the fact that some data on these POPs exist from some national activities, they could not be compared regionally due to differences in sampling schedule and analytical protocols applied.

0.3 Key message on evidence of temporal trends

The POPs concentrations in ambient air were found to vary from one year to another over the sampling period. However, the absence of sufficiently long-term regional monitoring programmes and sufficient data did not allow a comprehensive investigation and evaluation of temporal trends of POPs in the region to conducted POPs levels in ambient air have been monitored from 2008 to 2013. Breaks were experienced between the first and the second evaluation creating data gaps. On the other hand, the available data for mothers' milk have been generated through a single WHO mothers' milk survey per country, therefore, the data are not adequate for assessment of temporal changes in POPs levels. For water, the existing data were collected through the initial pilot projects within the 2013/2014 period hence they are not adequate for assessment of temporal trends of POPs concentrations in water.

0.4 Key message on evidence of long-range transport

The presence of POPs in remote areas possibly indicates long range transport of POPs in the region. Nevertheless, more information on local climatology and meteorology is needed to correctly analyse the relationship between the variability of the atmospheric POPs and transport pathways. The initial analysis of back trajectories conducted in the first evaluation revealed that the transport of POPs in the region is highly dynamic and influenced by meteorological and climatic conditions.

0.5 Key message on gaps in data coverage and needs

Air data coverage: The ambient air sampling sites under MONET Africa, GAPS and UNEP/GEF project have established are wider coverage of sites within the region. However, the region lacks continuity in POPs monitoring activities due to lack of adequate financial resources to ensure continuous monitoring at all sites. The MONET Africa programme has produced data from 2008 to 2013 but experienced a break in 2009, whereas UNEP GEF data collection only covered one year period between 2011 and 2012. The discontinuity in some years and inconsistencies at some sites creating data gaps which cause difficulties in analysis and interpretation of both temporal trends and spatial distribution of POPs within the region. The coverage of the active samplers in the region is limited to two; the most deal is to have at least one active sampler per subregion.

PFOS levels in ambient air have been analysed in samples from only two countries in the region representing the Eastern Africa and Western Africa in 2013. Data gaps exist in the sub-regions of Northern, Central and Southern Africa and Small Island states with respect to PFOS data in ambient air.

Mothers' milk data coverage: There gaps in the baseline data for POPs in mothers' milk from the Southern Africa Sub-region. Additional data gaps were experienced in analysis of temporal trends of POPs in mothers' milk since only one sampling has been conducted per country through the UNEP/WHO milk survey and the UNEP/GEF project between 2009-2012. Therefore, the available data for mothers' milk are not adequate for evaluation of changes in concentration over time. Furthermore, some POPs such as chlordecon have not been analysed in mothers' milk, whereas PFOS and its salts were analysed in mothers' milk from Northern and Southern Africa Sub-regions, creating additional data gaps in POPs parameters.

Water data coverage: The first comparable data set for PFOS in water were produced through the UNEP/GEF project and the MONET Africa pilot projects in 2013/2014. There is no continuous monitoring programme for PFOS and its salts and HCHs in water media. The existing data provide indicative levels of PFOS in water, but they are not adequate for assessment of temporal changes in PFOS and salts in water.

Other media: Comparable analytical data from UNEP/GEF project of POPs in other media have revealed different levels of contamination of soil, sediments, fish and foodstuff by POPs pesticides, PCBs and PCDDs and PCDFs. However, there is no established regional/national programme for routine monitoring of POPs in other media. Therefore, the available data show indicative levels of POPs in other media, but no temporal trends could be evaluated.

0.6 Key message on existing capacity for POPs analysis

Capacity building remains of high priority to the region to effectively participle in the Global Monitoring Plan and effectiveness evaluation of the Stockholm Convention.

Human capacity: There exist capacities in the regional institutions such as universities, research institutions and analytical laboratories to support POPs monitoring activities. These have been demonstrated through research and training activities, publications on POPs and participation in supporting GMP activities in the region. However, the existing capacities are limited to basic POPs such as pesticides and PCBs, hence further regional capacity building is required for advanced POPs such as PCDDs, PCDFs, PBDEs and PFOS compounds.

Analytical capacity: Majority of the regional institutions have basic instrumentations such as GC/ECD and Low Resolution GC/MS capable of analysing basic POPs such as pesticides and PCBs. However, the high resolution equipment necessary for analysis of complex POPs such as PCDDs, PCDFs, PBDEs and PFOS are lacking.

The regional countries participated in two inter-calibration/proficiency studies under the UNEP/GEF project 2011/2012 to evaluate their competencies in analysis of POPs in core media (ambient air and mothers' milk) and other media such as soil and sediments. The

results showed the need for further capacity building for most of the laboratories in region to analyse POPs.

0.7 Key message on ongoing activities

MONET Africa: The programme span stretches from 2008 to the present and has long-term goal to conduct assessment of the long-term trends for POPs levels in the region. Long-term passive air POPs monitoring at multiple sites, establishment of two active air monitoring sites (Kenya and Ghana), active-passive inter-calibration exercise and screening of the POP levels in surface waters. All data from the programme are made available in www.genasis.cz gradually – as the samples are analyzed in laboratories and also in GMP Data warehouse in line with reporting periods.

Active air sampling and calibration of passive samplers: Active air sampling stations were established in Ghana and Kenya through RECETOX donation in 2013. Three months active-passive inter-calibration exercise was carried out in 2014 followed by regular weekly active air sampling. These sites should serve as part of the African supersites providing the most precise information on the atmospheric levels of POPs and points of inter-calibration of passive and active air samplers. Inter-calibration exercise under the tropical conditions is crucial to determine site-specific performance of the passive samplers.

For the third passive air monitoring (2014-2017), MONET Africa programme proposed keeping minimal set of the organochlorines except for polychlorinated *p,p'*-dioxins and furans based on the cost of their analyses and their generally low levels at many sites. For the purpose of establishment of the long-term trends, such could only be measured in active samples. Similarly, keeping PBDEs in the PAS analyses would be appropriate, whereas HBCDs and PFOS could be dropped from the list of POPs monitored in PAS due to the generally very low levels.

GAPS Programme: The GAPS programme has maintained limited number of sites in the region to support assessment of data comparability with MONET Africa programme. The sites also play vital role in establishment of long-range transport of POPs in the region.

UNEP/GEF project 1 &2 : The GMP1 project contributed to human capacity enhancement among the participating counties in Africa region to monitor POPs in ambient air using PUF-PAS technique. Regional mothers' milk sampling capacity and contacts were established and maintained in the participating countries, which will provide the framework for future WHO mothers' milk survey in the region. In addition, the regional countries participated in two international inter-laboratory calibration exercises to evaluate their performance in POPs analysis. Future participation in inter-laboratory calibration exercises will enhance analytical performance of the laboratories in POPs analysis.

The second UNEP/GEF regional has already been endorsed by the regional countries. The project will support further capacity enhancement in the analysis of new POPs in the ambient air, mothers' milk and water.

World Health Organization (WHO) mothers' milk survey: Under the WHO Program, mothers' milk samples were collected from the regional countries and submitted to the WHO reference laboratory for analysis. All mothers' milk sampling activities follow WHO approved protocol.

Regional institutions: Some academic and research institutions within the region have ongoing research activities mainly covering other media, but also address the core media to a limited extent. However, since there is no established regional programme for POPs monitoring in other media, most of the national activities are conducted following different sampling schedules, QA&QC protocols and analytical methodologies which hamper comparability of the data at regional level.

0.8 Key message on the adequacy of monitoring for effectiveness evaluation

Monitoring POPs in ambient air: Several efforts have been establish for monitoring of POPs in ambient air through MONET Africa, GAPS and UNEP/GEF project. Continuity of these initiatives is vital to ensure continuity in data collection to allow evaluation of temporal trends in POPs concentrations in ambient air and assessment of long-range transport.

Monitoring POPs in mothers' milk: Mothers' milk monitoring has been conducted through UNEP/WHO and UNEP/GEF projects. Baselines have been achieved in most of the subregions, except the Southern Africa subregion, however, the existing data are not sufficient for determination of temporal trends since only a single survey per country has been effected from 2009-2012. Additional and periodic mothers' milk surveys are needed to allow assessment of temporal trends.

Monitoring POPs in water: The existing data for PFOS in water were produced using active and passive samplers through the pilot studies conducted in 2013/2014. However, currently there is no established routine monitoring programme for POPs such as PFOS and HCHs in water. There is need to establish a programme for routine monitoring of PFOS and polar POPs in water to provide sufficient data for analysis of temporal trends.

Monitoring POPs in other media: There are national and regional efforts towards assessment of POPs in core media and other media. There are comparable baseline data for POPs in other media obtained from the UNEP/GEF project in 2011/2012. In addition, some POPs data in other media also exist from national research activities conducted in individual academic and research institutions within the region, however the protocols applied and QA/QC framework may not satisfy the GMP criteria for comparability, consistency and continuity due to financial constrains that hamper routine monitoring activities.

0.9 Recommendations for the future evaluations

The presence of POPs in regional environment signals a threat to human health and environment due to deleterious effects associated with POPs chemicals that negatively impacts on reproductive health, immunity and general wellbeing. Therefore, the regional countries should streamline POPs management into regional development agenda to support

reduction and elimination of POPs in the environment. POPs activities could also be included under the national/regional activities to implement the 2008 Libreville Declaration on Health and environment strategic Alliance (HESA).

0.9.1 Recommendations on POPs baseline levels

POPs levels in air-The high prevalence of POPs pesticides such as DDTs, HCHs and endosulfans among others in ambient air reinforces the need to strengthen POPs management to control releases of these chemicals into environment. Although these chemicals have been banned or restricted in most countries, the management of contaminated soils and treatment of obsolete stocks remain a top priority in the region. In addition, the countries are encouraged to promote adoption of alternatives to POPs pesticides to minimise new releases of POPs in environment. Further, targeted research activities in alternatives to POPs pesticides should be encouraged to reduce overreliance on pesticide POPs and minimise their releases.

The presence of PCBs in ambient air long after their ban could suggest releases from old transformers; evaporation from contaminated soils and combustions processes including incineration and open burning of wastes that need to be controlled. Since the extent of source contributions vary from country to country, regional countries are encouraged to conduct further assessments and research to establish the priority sources of PCBs to allow development of target specific control measures. Further, countries are encouraged to continue the promotion of using PCB alternatives in their power generation and industrial applications.

High prevalence of UPOPs in ambient air and mothers' milk poses a health risk to the regional population and environment, hence there is need to strengthen the regional capacity for adoption/ integration of BAT and BEP in environmental management as well as management of municipal and industrial wastes, medical wastes and elimination of open burning of wastes and agricultural fields to reduce releases of UPOPs.

The presence of new industrial POPs such as PBDEs and PFOS in ambient air samples suggests active releases from the industrials activities, products and wastes. Countries should develop integrated waste management schemes in order to properly address the widespread sources of new industrial POPs such as PBDEs and PFOS, and develop and implement national/regional plans for the ESM of wastes containing and/or consisting PBDEs and PFOS.

There is need to integrate adoption of the alternatives to PBDEs and PFOS and related compounds in national and regional development agenda to control further releases of PBDEs and PFOS from household goods and industrial materials and products.

POPs in mothers' milk: Several POPs including Pesticides, PCBs, PBDEs and PFOS were detected in mothers' milk from background sites in the region suggesting multiple

contamination pathways such as including foodstuff, indoor and outdoor air and drinking water that need to be controlled. There is need to delineate and prioritise key exposure pathways to POPs in the region and implement mitigation measures to reduce POPs and eliminate POPs exposure to human and environment.

POPs in water: The results of pilot studies on PFOS and salts in water from background sites have revealed measurable levels of PFOS underpinning potential threat of exposure to human. Stringent regulations for water and wastewater should be developed to control releases of industrial POPs into water systems. There is need for continuous monitoring of PFOS and industrials POPs in water resources to establish the source pathways and reduce exposure levels. Countries should support application of PFOS alternatives to reduce/or eliminate new releases into water system.

POPs in other media: Other media such as soil, sediment, fish and foodstuff revealed low levels of POPs such as pesticides, PCBs and PCDDs and PCDFs suggesting potential contaminations that need to be managed through the National Implementation Plans activities at national and regional levels. Although the levels were relatively low, the findings raise environmental and health concerns as these chemicals have long persistence, bioaccumulate in the body and cause toxicity to human.

0.9.2 Recommendations on evidence of temporal trends

Baseline data have been established for ambient air, but the amount of existing data is not adequate for evaluation of temporal changes in POPs levels in the region, hence there is need to ensure continuation of the established monitoring activities in the region.

Substantial amount of mothers' milk data have been generated through the UNEP/WHO and UNEP/GEF project and have revealed contamination of POPs in human tissues, but the existing data are inadequate for assessment of temporal changes in POPs levels over time. Therefore, there is need for countries to participate in additional mothers' milk surveys to provide additional data for evaluation of time trends in POPs concentrations.

Comparable data for PFOS and salts in water from background sites have only been established for first time in the region. Further monitoring activities are needed to provide sufficient data for analysis of temporal trends in concentrations. Further, this should include data for other polar POPs such as HCHs and endosulfans.

There are no adequate data for analysis of temporal tends of POPs in other media since the existing data from most of the national research activities lack comparability. There is need for collection of additional POPs data for other media to allow evaluation of temporal trends.

0.9.3 Recommendations on long-range transport

Monitoring data have revealed POPs contamination of ambient air from remote sites on top of mountains and desert such as Mt. Kenya and Timbuktu, respectively, suggesting potentials contribution of long-range transport to POPs contamination at these sites. However, additional metrological data, information on climatological conditions and modelling tools

are required to establish the contribution of long-range transport on distribution POPs in the region.

In general, POPs monitoring data have been collected over a short period of time hence additional monitoring data are required to verify the modelling predictions with the monitoring results. There is need for building regional capacity for application and interpretation of long-range transport models and results to support policy makers to incorporate the modelling predictions in national and regional POPs management interventions.

0.9.4 Recommendations on data coverage and gaps

Air data coverage: Representatives ambient air monitoring sites have been established in the region to support collection of comparable POPs data through MONET Africa, UNEP/GEF and GAPS programmes. However, there is need for ensure continuity of sampling activities and consistence at every site in order to provide adequate data for evaluation of trends, spatial distribution and long range transport of POPs in the region.

Mothers milk data: The first survey of mothers' milk sampling received considerable support and participation of the regional countries that provided samples for analysis of POPs. However, data gaps exist in the Southern Africa sub region that needs to be filled to establish a more representative overview of POPs levels in the entire region. The Northern Africa subregion also lack data for PFOS and PBDEs in mothers' milk. There is need to fill the existing data gaps and to continue mothers' milk survey in order to establish temporal trends in POPs levels.

Water data: Water has been collected once under the UNEP/GEF project and MONET Africa pilot study, but data gaps were experienced in some sub regions. The existing data represent indicative baseline for PFOS in water. However, participation of more countries is needed to allow establishment of a representative baseline that will be used to establish temporal trends in PFOS concentrations.

Coverage for other media: Data for other media was obtained from 12 countries that participated in the UNEP/GEF project, and the key matrices included sediments, fish and soil. Participation of more countries is required to increase the data coverage and achieve regional representation. Future efforts to provide data for other media should include detailed protocols and repeat of similar matrices to allow comparison of temporal trends in POPs levels in other media.

0.9.5 Recommendations on existing capacity for POPs analysis

Human capacity: The Stockholm Convention is highly dynamic and new chemicals are regularly added to the annexes that require inclusion in monitoring activities. This necessitates continuous human and analytical capacity building to be able to collect and analyse a large number of samples for the listed chemicals.

Therefore, capacity building for POPs monitoring remains of a high priority for all the countries and the region at large. These include:

- training in sample collection and preservation procedures for all POPs including new POPs in the core media and other media;
- training is sample preparation and analysis for all POPs including new POPs in the core media and other media;
- training in data interpretation and reporting following the established GMP standards;
- quality assurance and quality control protocols for POPs analysis for GMP;
- training in overall maintenance and troubleshooting of analytical instrumentation for POPs analysis.

Analytical capacity: The number of POPs chemicals is substantially large and additional chemicals are regularly listed which increases the burden and cost of analysis. There is need to build the regional capacities to provide comparable quality analytical data and to ensure long-term sustainability. Currently most of the laboratories possess basic instrumentation for analysis of POPs pesticides and PCBs but no capacities for PCDDs, PCDFs, PBDEs and PFOS. There is need for capacity building to:

- establish dedicated regional laboratories with necessary high resolution equipment for analysis of all POPs compounds;
- support for regional approach to POPs monitoring by establishing regional programmes with standardized protocols for determination of POPs in core media and non-core media;
- involve national laboratories in regional programmes (eg. proficiency testing and upgrading of laboratories);
- support capacity building for data storage and retrieval facilities for both the core media data and other media data to facilitate regional data dissemination and information exchange.
- support sample/specimen banking for retrospective analyses of new POPs and future verification of the data;
- strengthen communication among the regional organization groups and focal points through Chemical Information Exchange Network (ESTIS/CIEN) and similar efforts.

0.9.6 Recommendations on ongoing programs/activities

To achieve the goals of effectiveness evaluation, data on temporal trends and long-range transport are vital. Therefore, continuity of established monitoring activities is necessary to produce adequate data and information on POPs in core media and supportive data from other media to aid in interpretation of the POPs levels in the regional. Accordingly, there is need to:

- support continuation of established air monitoring programmes such as MONET Africa, GAPS and UNEP/GEF established sites in the region.
- facilitate the parties to participate in subsequent rounds of WHO mother's milk surveys.
- establish water monitoring programme to provide data for PFOS and other polar POPs in water according to GMP guidance.

- provide resources for POPs monitoring activities in other media in the region as foreseen in GMP guidance and the NIPs.
- include new POPs in ongoing monitoring programmes to ensure continuity in data production.
- continue to strengthen data comparability within and across monitoring programmes for the core media and other media in the region through inter-calibration and validation of the methodologies.

1 INTRODUCTION

The present monitoring report synthesizes information from the first and second phase of the global monitoring plan and presents the current findings on Persistent Organic Pollutants (POPs) concentrations in the Africa Region. While the first monitoring report, presented at the fourth meeting of the Conference of the Parties in May 2009, provided information on the baseline concentrations of the 12 legacy POPs, this second monitoring report, to be submitted to the seventh meeting of the Conference of the Parties in May 2015, provides first indications as to the changes in concentrations of the chemicals initially listed in the Convention, as well as baseline information on the newly listed POPs.

At its sixth meeting in May 2013, the Conference of the Parties, by decision SC-6/23 on the global monitoring plan for effectiveness evaluation, adopted the amended global monitoring plan for persistent organic pollutants (UNEP/POPS/COP.6/INF/31/Add.1) and the amended implementation plan for the global monitoring plan (GMP) (UNEP/POPS/COP.6/INF/31/Add.2). It also adopted the Guidance on the Global Monitoring Plan for POPs (UNEP/POPS/COP.6/INF/31), which has been updated to address the sampling and analysis of the newly listed POPs, providing a useful basis for monitoring of these chemicals in the second phase of the GMP, as well as for harmonized data collection, storage and handling.

The global coordination group met four times over the period 2011-2014 in order to oversee and guide implementation of the second phase of the global monitoring plan, with particular emphasis on addressing the sampling and analysis of the newly listed POPs, harmonizing data collection, storage and handling, addressing the needs for ensuring sustainability of on-going monitoring activities and for further capacity strengthening to fill the existing data gaps, as well as improving data comparability within and across monitoring programmes.

Long term viability of existing monitoring programmes (air and human bio-monitoring) is essential to ensure that changes in concentrations over time can be investigated. National air monitoring activities having contributed data to the first monitoring reports continued during the second phase, and new programmes have been identified to support the development of the second reports. Likewise, the continued operation of global and regional air monitoring programmes was a major pillar in the second phase. For the new monitoring activities, collaboration with strategic partners has ensured cost-effective generation of data and use of harmonized protocols for POPs monitoring. The implementation of the second phase of the UNEP/WHO human milk survey is another important pillar of the global monitoring plan, providing useful long-term results showing how human exposure to POPs changed over time as measures are implemented to enforce the Convention.

Enhanced comparability within and across monitoring programmes to evaluate changes in levels over time and the regional and global transport of POPs was an equally important

milestone in the second phase. Quality Assurance and Quality Control Regimes (QA/QC) practices have been and continue to be essential for ensuring comparability, along with inter-laboratory exercises and intercalibration studies. Efforts continue to be directed at ensuring comparability within and across programmes, providing for evaluation of changes in concentrations of POPs over time and enabling regional comparisons.

Considering the global dimension of the monitoring plan under the Stockholm Convention, air, and human milk and/or blood have been established as core matrices as they provide information on the sources of POPs, environmental transport and the levels of exposure in human populations. The listing of new POPs in the Convention brought additional challenges in the implementation of the global monitoring plan. Perfluorooctane sulfonic acid (PFOS) and its salts do not follow the "classical" pattern of partitioning into fatty tissues, but instead bind preferentially to proteins in the plasma and are hydrophilic. Water has thus been added to the list of core matrices for these particular substances. This report also provides the first set of results as to the concentrations of such chemicals in water.

During the second phase of the global monitoring plan, harmonized data handling was enabled and appropriate support was given to the collection, processing, storing and presentation of monitoring data in regions with limited capacity. A global monitoring plan data warehouse (http://www.pops-gmp.org/visualization-2014/login) supports data collection and assists the regional organization groups and the global coordination group in producing the regional and global monitoring reports and the effectiveness evaluation. The global monitoring plan data warehouse also constitutes a publicly available repository of valuable information that can serve as a useful resource for policy makers and researchers worldwide.

2. DESCRIPTION OF THE REGION

2.1 Overview of General and Socio-Economic Features

Africa is one of the largest continents in the world. The total area of the continent of Africa including the Indian Ocean and Atlantic Ocean Island States is 11,677,239 square miles, and the total population in 2013 of this area was about one billion people living in 54 sovereign states. It is projected that this population will increase up to 1.9 billion in 2050 making Africa the second most populous continent on earth (World population statistics, 2014). Africa is divided into the following sub-regions: Northern Africa, Southern Africa, Eastern Africa, Western Africa, Central Africa and the Island States (AU, 2008).

Agriculture forms the backbone of most African economies. The continent is also rich in natural resources including minerals and fossil deposits.

Five official AU languages are spoken in Africa namely, English, French, Arabic, Portuguese and Spanish. It should be noted however, that each African country is constituted of many ethnic groups or subgroups that speak languages other than the five official ones. Africa is the most multilingual continent in the entire world. It is estimated that around 2000 languages are spoken throughout the many countries. The major religions are Christianity and Islam, in addition to traditional religions.

Africa has a preponderance of high poverty index value (Elvidge *et al.,* 2009) and characterized by deepening environmental degradation globally, it has the largest percentage of people living on less than USD1 per day, and two thirds of the 48 countries included in the list of least developed countries (LDCs) are in Africa. In this regard, all efforts are geared towards the achievement of food security and poverty reduction. It is, therefore, not surprising that within the context of environmental issues more emphasis is placed on desertification and climate change issues which are prone to lead to problems of diminishing food resources and the capacity to enhance food security. The overuse and misuse of chemicals, including POP pesticides, to control pests and boost agricultural productivity could also be attributable to this desire to enhance food security.

2.2. Political Structures

Independence and self-rule was introduced in most African countries in the late 1950s, allowing Africa to start taking its destiny into its own hands. Soon after, the process of uniting Africa started and one of these processes led to the birth of the Organization of African Unity (OAU) in 1963. The objective of establishing the OAU was to achieve greater unity and solidarity and to promote political and socio economic development in Africa.

Following the dissolution of the OAU in July 2002, the African Union (AU) was established the same year to capture the Organization's goal of establishing a common economic market and political union across the continent, thereby ensuring Africa's ability to play a more meaningful role in the global economy. The AU is a Pan-African body responsible for spearheading Africa's rapid integration and sustainable development by promoting unity, cohesion, peace and cooperation within African states as well as developing new partnerships worldwide. The AU has a mandate to promote regional cooperation on environmental management and conservation. Regional groupings, particularly economic communities such as the South African Development Cooperation (SADC), the Economic Community of Central African States (ECCAS), the Economic Community of West African States (ECOWAS), Common Market for Eastern and Southern Africa (COMESA), East African Community (EAC), Community of Sahel-Saharan States (CEN-SAD) and the Union du Maghreb Arab (UMA) now form part of the AU.

2.3. Climatic and Geographical Characteristics

2.3.1. Climatic characteristics

Climate variability is a normal part of Africa's climate). Periods of drought and flood, warmth and cold have occurred interchangeably in the past (Ropelewski and Halpert, 1987; Ogallo, 1988; Nicholson and Kim, 1997; Tyson et al., 2002). Most countries in Africa are already vulnerable to extreme climate events such as tropical cyclones, droughts and floods. Daily variability in climate over Africa occurs through diurnal effects such as land-sea breezes, local topographic and coastal effects on airflow into lower latitudes (Tyson and Preston-Whyte, 2001). Sea surface temperatures (SSTs) in Atlantic and Indian Oceans are the primary influence of African inter-annual rainfall fluctuations and are linked to the El Niño-Southern Oscillation (ENSO) phase shifts (Rocha and Simmonds, 1997; Nicholson and Selato, 2000; Reasons *et al.,* 2000). There exist association between the wet (dry) conditions on the African continent and cold (warm) sea surface temperature conditions in the Atlantic and Indian Oceans (Nicholson and Kim, 1997; Reason et al., 2000). At irregular intervals the North Atlantic Oscillation (NOA) and ENSO events have major impacts on inter-annual climate fluctuations on the continent (Tyson, 1986; Ward, 1998; Reason *et al.,* 2000).

Africa has a highly variable and unpredictable climate and is acutely vulnerable to floods and droughts for example. There have been predictions forecast with a probability of >90% higher temperatures during the growing season in the tropics and subtropics that will exceed the most extreme seasonal temperatures recorded in the last century (Battisti and Naylor 2009). National Communications on climate change from African countries Parties to the UNFCCC have been reporting that populations are facing significant variations and disturbances in climatic regimes and that there is an increasing need for adaptation strategies in order to enhance resilience.

The intertropical convergence zone (ITCZ) or monsoon trough dominates Africa's climate (Lewis and Berry, 1988; Waliser and Gautier, 1993). This ITCZ shifts over the land from one hemisphere to another in sympathy with the shift in areas of maximum solar heating. Significant latitudinal differences in climate exist across the continent in response to differences in land sea distribution, topography and geographical location in relation to subsidence associated with the subtropical high pressure cells. Rainfall across the continent varies from about 1,500 mm yr^{-1} in the equatorial regions to <50 mm yr^{-1} over Northern Africa (Sahara desert region) and to <300 mm yr^{-1} in Southern Africa. In Southern Africa, there is also an east-west gradient with rainfall varying from about 900 mm yr^{-1} to <50 yr^{-1} in the western regions (Kalahari Desert region).

Easterly and westerly wave disturbances form a major component of the continent's climate system. About 10% of the wave disturbances later intensify into tropical storms or cyclones (Tyson and Preston-Whyte, 2001). The tropical cyclone formation follows preferred zones in the Atlantic and Indian Oceans during summer. Pre-requisites for tropical cyclone formation include: warm sea surface (26-28^{0}C to a depth of about 60 m), low-level convergence to maintain sensible and latent heat supply and upper level divergence to maintain ascent (Mason, 1995). Major moisture sources for rainfall over the continent are the gulf of Guinea and Congo basin, and the Atlantic and Indian oceans (Rocha and Simmonds, 1997).

Onset of summer monsoon in West Africa is linked to an abrupt latitudinal shift of the ITCZ from a quasi-stationary location of 50^{o}N in May-June to another quasi-stationary location at 10^{o}N in July-August. The mean date of summer monsoon onset is 24 June with a standard deviation of 8 days. The pre-onset stage is characterized by the arrival in the Sudano-Sahelian zone of intertropical front (ITF), a confluence line between moist southwesterly monsoon winds and dry northeasterly – the Harmattan – at 15^{0}N (Taljaard, 1986; Shinoda and Kawamura, 1994).

2.3.2. Vegetation characteristics

The vegetation of Africa comprises tropical forests, savannas, steppes and deserts.

The sub-tropical and temperate seasonal climates are characterized by vegetation that is fire prone, comprising unique fire-dependent ecosystems that have evolved with fire as integral to biodiversity persistence and ecosystem functions. Fire is also widely used by people to manage such systems for human benefits, especially for improving grazing potential. In most of these ecosystems grazing by livestock is itself an important influence on vegetation structure and may limit fuel accumulation, leading to the potential for quite rapid human-induced changes in fire regime, and resulting switches in vegetation structure such as bush encroachment. The impact of disturbances by fire is therefore a key component of consideration in monitoring the emissions of un-intentional POPs on the continent.

2.3.3. Geographical characteristics

The continent has several features that constitute its geographical characteristics. The most prominent features are: The longest river in Africa is the Nile with a length of 6,695 km and a large catchment or basin area of 3, 720, 000 sq km covering Egypt, both Sudan and South Soudan, Uganda, Tanzania, DRC Congo, Burundi, Rwanda, Kenya, Eretria and Ethiopia**.**

The largest lake is Lake Victoria, which is about 69,000 sq km and 1,130 meters above sea level, bordered by Uganda, Kenya and Tanzania.

The highest mountain is the Kilimanjaro in north eastern Tanzania with a height of 5,895 meters high while the largest desert in Africa, the Sahara, is around 9 million sq. km and covers part of northern and western Africa

Because of heavy rains and large water bodies, POPs on land and water environments may be carried away in run-offs. Low lying countries and cities will easily receive these run-offs. Some cities for example in Western Africa (e.g. Cotonou, Benin) are flat and low-lying (below sea level) while others in Eastern Africa (e.g. Addis Ababa) lie 4,500 m above sea level.

2.3.4. Biodiversity characteristics

Africa is home to a significant portion of global biodiversity, both faunal and floristic. Africa as a whole contains about one-fifth of all known species of plants, mammals and birds, and about one-sixth of the amphibians and reptiles. Such riches in biodiversity is perhaps not surprising given that SSA covers a remarkable climatic and topographic range, from equatorial rainforest through to temperate regions of Southern Africa, with limited representation of alpine climates at mountain tops, and with rainfall seasonality ranging from all-season, summer-season and winter-season, incorporating some of the driest regions of the world in form of the Namib Desert.

The region contains four biodiversity hotspots that together host 3.5% of the world's endemic plant species and 1.8% of endemic vertebrate species in areas that are reduced from their original extent by between 73.2% and 93.3% (Myers *et al.,* 2001), statistics that indicate a potentially high level of threat to Africa's endemic biodiversity. There appears to be an increasing exposure of natural ecosystems to human impacts in SSA, despite the generally low population densities outside of the major urban centres.

African biodiversity is, as in other parts of the world, positively correlated with human population densities (Balmford *et al.,* 2001), with significant implications for human impacts on species persistence into the future. Human pressures on biodiversity is increasing strongly in many parts of the sub-continent, with direct use through, for example, bush meat harvesting threatening to extirpate many species of a variety of types (Bowen-Jones and Pendry, 1999; Thibault and Blaney, 2003). Development and timber harvesting are threats in

some areas, and land conversion to agriculture is transforming landscape, causing spatial fragmentation of ecosystems in many areas (Laurence, 1999; Kemper, Cowling and Richardson, 1999; Mentens and Lambin, 2000; Zhang, Justice and Desanker, 2002). The problem of allein invasive species is also increasingly seen as a threat to biodiversity on the continent (Morrison *et al.,* 2004; Le Maitre, Richardson and Chapman, 2004).

Despite the varied threats, many sub-Saharan ecosystems retain substantial proportions of the biodiversity that occurred prior to the expansion of human and during the late Pleistocene. The region has retained almost a full suite of its mega-herbivores and large carnivores, in sharp contrast to all other continents of the world, although they have suffered significant reduction in areas over which they potentially range in the wild. The Congo Basin has retained a substantial proportion of its primary tropical forest and thus represents a globally important carbon store and much of the tropical and sub-tropical savannah and woodland ecosystems are relatively intact. In South Africa, Scholes and Biggs (2005) found that biodiversity can be classified as more than 80% intact, according to an index which assesses the persistence of species richness across all land-use types.

The uniqueness of the African continent, in terms of geographical location, climate variability and diverse socio-economic activities, is significant in determining the environmental fate of PTS (and POPs). These conditions can influence the behaviour of POPs, 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. In addition, studies on the assessment of PTS also indicate that DDT and PCBs are the most encountered POPs in fish and marine environment since 1970s. The same studies also indicate widespread PTS contamination of foodstuffs of both plant and animal origin, including fish and fish products, breast milk and dairy products. Fish constitutes the major source of animal protein for coastal, lacustrine and riparian populations of some African countries, and is thus an indirect source of exposure to POPs for these populations. POPs also occur in sediments of the major lakes such as Lake Victoria, and need to be addressed (UNEP, 2002a).

2. 4. Agricultural Activities

Most of the African countries' economies are based on agriculture, which contributes largely to the GDP and to the countries' exports. The 19th AU Heads of State and Governments Summit held from 15-16th July 2012 in Ethiopia Addis Ababa declared 2014 the year of Agriculture and food security in Africa. Agricultural sector accounts for 24 % of world outputs and constitutes the lifeline to 80% of the population in SSA. However, its performance is projected to drop as a result of negative effects of the ongoing global climatic changes. Projected reductions in yield in some countries in SSA could be as much as 50 % by 2020, and crop net revenues could fall by as much as 90 % by 2100, with small-scale farmers

being the most affected. This would adversely affect food security and income generation in SSA. Several seasonal crops as well as cash crops are grown.

The agriculture is sometimes plagued by periodic drought, and more persistently by land degradation caused by inappropriate agricultural practices and overgrazing, deforestation, population pressure, undeveloped water resources, and poor transport infrastructure. However, irrigation as well as other methods such as agricultural diversification strategies are being increasingly used to boost agricultural productivity.

The maritime fisheries sector as well as livestock production also occupy prominent places in the national economies of some African countries. Horticulture has expanded rapidly in the last two decades to become one of the largest contributors to GDP. As a result, fruit and vegetable conservation and transformation form an important part of the agro-food industry.

In response to the need to boost agricultural productivity and to attain food sufficiency, there is a tendency towards the use of chemicals such as fertilizers, veterinary chemicals and plant protection substances. Pesticides constitute one of the major sources of PTS and POPs in sub-Saharan Africa. Pesticides are generally imported and not produced. However, pesticide formulation plants exist in many countries of the region. Sub-Saharan Africa imports less than 5% in terms of value of the total pesticides import of the world. Most eS pesticides including organochlorines are DDT, endosulfan, chlordane, lindane (HCH), heptachlor, toxaphene, HCB and aldrin (UNEP, 2002a). Countries like Kenya, Uganda and Ethiopia to name but a few are known as important growers of flowers and other horticultural productions involving pesticide-intensive practices.

In general, the following are the key features regarding agricultural sector in the region:

i) Agriculture contributes 20-40% to GDPs of most countries in Africa;

ii) Agriculture contributes to food security and sovereignty and is the main source of foreign exchange earnings in most African countries;

iii) Fisheries occupy an important place in several countries;

iv) Agroindustry contributes 4-32% to the national GDPs.

Main constraints include inappropriate agricultural practices, lack of modern technology and techniques, disastrous climatic conditions, lack of awareness on the use of harmful products, lack of adequate laws, weak enforcement capacity and lack of adequate monitoring schemes on chemicals used in agriculture and industry. Very often African countries are faced with: sites/lands contaminated with chemicals including POP pesticides, stock piling of obsolete chemicals including POP pesticides and unsound management of empty containers (burial, burning in the open, domestic uses, etc.).

2.5 Industry and energy services:

The industrial sector, despite its small contribution to GDP, supplies important consumer goods both to the domestic and international markets. The main manufacturing products are textiles, foodstuffs, beverages, leather and non-metallic products. The industrial sector is progressively gaining ground in many African countries. It now represents 4% to 32% of national GDPs in most African countries. Having been dominated by food industries for a long time, the industrial sector has rapidly diversified due to the rise of certain strategic chemical sectors such as petroleum, pesticide and pharmaceuticals, among others. Other sectors that contribute significantly to the GDP are the services sector and tourism (which includes the hotel industry). Mining is a growing important activity in many countries and this sector is likely to be using some POP chemicals (PCBs, PFOS and related chemicals: Annex B chemicals).

To meet its developmental needs, Africa imports increasing amounts of various types of chemicals for industrial, domestic and agricultural purposes, and even for cosmetics, food, plastics, laboratory, petroleum, and a host of other uses. On the other hand, some countries have successfully diversified their economic activities by carving out special niches in textiles, financial services, and information & communication technologies.

Power generation, storage, transport and distribution sector which is a key to social and economic development involves fuels and equipment that may lead to the release of POPs like PCBs (Annex A chemicals) and unintentionally produced POPs (Annex C).

2.6. Environmental Health Scenario Links to POPs

Africa region offers significant potential for human, social and economic development. However, it is facing enormous challenges such as rapid population growth, rising levels of poverty, diseases and inappropriate development practices which are also the main factors that affect the regional state of the environment. Exacerbated by rapid population growth, poverty remains the primary cause of most of the sub-Saharan Africa's environmental health problems. Half of Africa's population has no access to health services and two thirds lack safe drinking water (Mintz *et al.,* 2001).

Persistent organic pollutants (POPs) are toxic chemicals that adversely affect human health and the environment around the world. Because they can be transported by wind and water, most POPs generated in one country can and do affect people and wildlife far from where they are used and released. Contamination of the environment can occur through industrial processes (e.g. polychlorinated biphenyls (PCBs) and heavy metals), agriculture (pesticides), or accidental industrial by–products (e.g. polychlorinated dibenzo-p-dioxins and furans-PCDD/Fs).

With regard to diseases, in many sub-Saharan African countries, malaria remains a national health priority and a big concern to the Governments. A review conducted in The Gambia reported that 40% of all deaths in children between the ages of 1-4 years are due to malaria (references), a figure higher than the continental average of 10-30%. This trend seems to persist to date in many African countries. One of the greatest challenges facing malaria control worldwide is the spread and intensification of parasite resistance to antimalarial drugs. The limited number of such drugs has led to increasing difficulties in the development of antimalarial drug policies and adequate disease management. The Roll-back Malaria Programs championed and implemented by several African Governments has still not registered significant impacts.

Although the use of pesticides such as DDT in agriculture has been banned in almost all countries some countries have extended this ban to public health applications. However, in some countries (e.g. Uganda, Swaziland), DDT is still used for indoor residual spraying to control malaria vector. The use of DDT was addressed at the 1995 meeting of the WHO Study Group on Vector Control for Malaria and Other Mosquito-Borne Diseases. The Study Group stated that DDT may be used for vector control, provided that it is only used for indoor spraying, it is effective, the WHO product specifications are met, and the necessary safety precautions are applied for its use and disposal. Under the POPs Convention, several countries are considering or have decided to phase out DDT use in their public health services over periods of between 3 and 8 years.

Considering the fact that DDT might play a role in combating malaria in future, particularly in the poorest endemic countries, it was suggested that restrictions on DDT for public health use be accompanied by technical and financial mechanisms to ensure that effective malaria control is maintained through vector control methods that depend less on pesticides generally, and on DDT in particular.

Due to lack of knowledge on environmentally sustainable alternatives and proper quality control of agricultural products, African farmers have greatly increased their use of chemical based insecticides, herbicides and fungicides. Persistent Organic Pollutants are still being stocked (Photo 2.1.) in make shift stores where the dangers and risks due to exposure are enormous**.** The stock is sometimes comprised of packages of substandard, deteriorated pesticides including POPs. At least 20,000 tons of obsolete pesticides and tens of thousands of tons of contaminated soils have accumulated in most African countries over long periods (FAO, 1998). More recent FAO estimates are that there might be more than 40 000 tons, perhaps even much more, of these chemicals stocked or discarded over many parts of Africa (UNEP, 2002a). These pesticides pose a serious threat to the health of both rural and urban populations and contribute to land and water degradation. The main causes of accumulation of obsolete pesticides in Africa are:

i) pesticides for locust and malaria control;

ii) prolonged storage of products under non optimal storage conditions;

iii) unnecessary donations, particularly under the KR2 scheme;

iv) banned, unlabelled or illegally imported products.

Photo 2.1: Stock of hazardous chemicals and contaminated wastes in an African country (Source: NIP update Project Implementation Report-Togo 16/09/2014).

Many cases of acute pesticide poisoning, including those with only minor effects, occur annually in Africa, making them a major public health problem. The source of poisoning can stem from inappropriate storage and disposal facilities. Chemicals such as fertilizers and persistent organic pollutants previously widely used in agriculture and for disease vector control, continue to contaminate water bodies. POPs are also used in industry or are generated as by-products in industrial processes.

The major industrial PTS (including POPs) 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 (UNEP, 2002a). Since the early 1930s PCBs have been widely used as dielectric fluids in electrical transformers and capacitors. The minor applications of PCBs in equipment have been as heat transfer fluids and hydraulic fluids in industry, and as cooling fluids in switches, voltage regulators and motors. Open applications of PCBs have been as plasticizer in paint, plastics and sealants and in carbonless copy paper.

PCBs themselves or PCB contaminated equipment stored as waste and/or more commonly PCB containing equipment still in service exist in many countries. They may be found in closed electrical systems, in partially closed applications or as heat transfer and hydraulic fluids, vacuum pumps, switches, etc. Draining of old transformers containing mineral oil and PCB-contaminated mineral oil, as well as their inconsiderate disposal can lead to leakage and contamination of the soil (Photo 2.2). Therefore, suitable storage facilities that comply with the obligations of the safe storage management plan of the Basel and Stockholm Conventions should be put in place. In some African countries, metal scrap from transformers have been known to be transformed into cooking pots by local smiths, such pots are used domestically, mainly by women.

Photo 2.2: Photo 2.2. Power transformers *in Swaziland (*Inventory report on POP-PBDEs, PFOS and PCBs (Industrial Chemicals) and contaminated sites in Swaziland – 2014)

Mining can also have a variety of detrimental environmental effects, including contamination of groundwater with heavy metals, siltation and sedimentation of riparian ecosystems.

Medical waste incineration, lack of shredding plants, burning of scraps, steel fabrication with welders having limited protective gears and domestic waste burning all contribute to dioxin and furan contamination.

A large amount of accidental and deliberate combustion is taking place, including the burning of rubber tyres as well as the 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 (e.g. Togo, Uganda, Swaziland, Congo, DRC, Cote d'Ivoire, Burkina, etc.) could also contribute to the

formation of dioxins. A daily TEQ production of around 60g (21,360 g TEQ/year) for dioxins and furans for Sub Saharan Africa has been estimated based only on uncontrolled domestic waste combustion (UNEP Chemicals, 2002). This would equate to $2x10^{-5}$ g TEQ/year per capita, but does not include industrial or any other anthropogenic or natural sources as these were not taken into consideration in the assessment (UNEP Chemicals, 2002). Uncontrolled and widespread combustions of materials at household levels, and in industrial processes present a serious threat to human health due to release of POPs and particularly dioxins and furans.

Waste electrical and electronic equipment (WEEE), end-of-life vehicles (cars, buses, mini-buses, trucks) and other articles (carpets, fire fighting foams, aviation hydraulic fluids, shoes, textiles, etc.) generate hazardous wastes. Due to ignorance and lack of appropriate technical infrastructures such wastes are being currently managed through crude and unsound practices that expose workers and the environment (air, soil, water) to the releases of newly listed industrial POPs (PBDEs, PFOS and related chemicals) and dioxins and furans.

The long term inappropriate use of POPs in agriculture and vector control, as well as in industries, and exposure from uncontrolled burning, may result in the presence of these toxic chemicals in human blood and breast milk.

The trend of concentration observed in Africa for PTS is DDT> PCBs> toxaphene. The report indicated 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 (UNEP Chemicals, 2002).

The following can be given as a summary of the scenario in the region:

i) Most African countries neither manufacture nor export chemicals but are importers;

ii) Food security being a priority, the potentials to use more pesticides is high;

iii) Malaria is still a leading killer disease and the urge to use an effective insecticide such as DDT is high;

i) Stocks of obsolete pesticides are still present in some African countries;

ii) POP contamination in environmental media is present but not fully inventorised;

iii) Both Agriculture and Industry can be responsible for hazardous chemicals pollution;

iv) Principal sources of PCBs in Africa are transformers and capacitors;

v) The WHO, RECETOX, GAPS, IVM and other international Programs on the monitoring of POPs in breast milk and environmental media presently do not cover all African countries.

vi) In response to the need to address the above problems, African countries have taken individual and collective control measures and steps to halt the negative impact of toxic chemicals. These measures include:

vii) Development of action plans, monitoring scheme and programs on hazardous chemicals

viii) Most countries have developed National chemical Profiles to assess their countries' capacities for chemicals management;

ix) Regulatory actions are being taken by many countries on hazardous chemicals including POPs, particularly through the Rotterdam Convention requirements;

x) Most countries have banned DDT in agriculture but some allow its use in vector control, especially in malaria cases;

xi) Most African countries are signatories to chemical conventions; Bamako/Basel, Rotterdam, Stockholm, Vienna/Montreal, Kyoto Protocol;

xii) Most African countries participate in regional and international programs on chemicals regulation; IFCS, SAICM, GHS, Risk Management of UNITAR; ASP, CILSS Common Regulations on Pesticide and other similar ones in other RECs;

xiii) WHO Monitoring Program on POP in breast milk and human tissues, the RECETOX programs on POPs in environmental media, GAPS, UNEP/DGEF Capacity building Programs are on-going.

Given that human and environmental health in Africa is strongly linked to socio-economic factors such population growth, economic growth and poverty, the proposed measures must be implemented in the framework of sustainable development.

Thus, in order to ensure the success of the proposed measures, the following issues need to be addressed: awareness creation, technology transfer, stricter control of porous borders, domestication of Conventions, access to data, infrastructure development analytical capacity building and strengthening. The region also suffers from POPs contamination in human tissues and environmental media.

3 ORGANIZATION OF REGIONAL IMPLEMENTATION

3.1 Regional strategy

The Africa Regional Organization Group (ROG) for the second evaluation consisted of six experts from each of the following countries: Ethiopia, Kenya, Mali, Morocco, the Republic of Congo and Tanzania. ROG members were responsible for development of the regional strategy for the preparation of the second regional monitoring report. The major activities included workshops, coordination of monitoring and capacity building, collection of comparable POPs monitoring data and compilation of the regional report. The detailed activities are discussed below.

3.2 Establishment and responsibilities of the regional organisation groups

Regional organization groups were established in the five United Nations regions by decision SC-3/19. The main objective of the regional organization groups is to define and implement the strategy for regional information gathering, including facilitating capacity enhancement activities and to produce the regional monitoring reports.

The main tasks of the ROGs include:

i) Identifying where existing suitable monitoring data are and are not available;

ii) Promoting and updating as necessary the regional strategy for implementation of the global monitoring plan;

iii) Promoting and helping to maintain regional, sub-regional and interregional monitoring networks and extending them as necessary to improve geographic coverage;

iv) Coordinating with Parties involved in sampling and analytical arrangements;

v) Ensuring compliance with protocols for quality assurance and quality control, noting the examples described in the guidance on the global monitoring plan for persistent organic pollutants for sample collection and analytical methodologies, for data archiving and accessibility and for trend analysis methodologies to ensure quality and allow comparability of data;

vi) Ensuring and improving internal consistency of the methods and comparability of the data within a particular programme over time;

vii) Maintaining the interaction with other regional organization groups and the Secretariat, as appropriate;

viii) Identifying further capacity enhancement needs in its region;

ix) Assisting, for the purpose of filling gaps, in the preparation of project proposals, including through strategic partnerships;

x) Preparing a summary of experiences in implementing the duties assigned in subparagraphs (h) and (j) above for transmission to the coordination group via the Secretariat;

xi) Preparing regional reports;

xii) Encouraging transparency of communication and information dissemination within and between regions, noting the need for stakeholder involvement;

xiii) Nominating for each evaluation cycle three of its members to serve in the global coordination group.

3.3 Regional Organization and coordination of activities

The ROG members adopted a communication strategy similar to the one used in the preparation of the 1st POPs regional monitoring report. The six sub-regions established in phase one were maintained in the implementation of phase two of the GMP. The respective ROG member was tasked to oversee communication with the SC focal points and the national contacts. In addition, the ROG members agreed to use electronic communication as much as possible in the implementation of phase two of the GMP. Communication with the countries was copied to the SC focal points and the national contacts. The Table 3.1 below summarises the agreed sub-regional divisions and responsible ROG members.

Table 3.1 Sub-regional divisions and responsible ROG member country

Rep. of Congo	Ethiopia	Kenya	Mali	Morocco	Tanzania
Cameroon Democratic Republic of Congo Central African Republic Gabon Angola SaoTome and Principe Equatorial	Egypt Sudan Djibouti Somalia South Sudan Ethiopia	Burundi Uganda Mauritius Madagascar Rwanda Seychelles Eritrea Kenya	Niger Chad Senegal Guinea Guinea-Bissau The Gambia Cape Verde SierraLeone Liberia Côte d'Ivoire Burkina Faso	Algeria Libyan Republic Tunisia Morocco Mauritania	Zambia Zimbabwe Mozambique Namibia Botswana Swaziland South Africa Lesotho Malawi Comoros Tanzania

Guinea Republic of Congo			Ghana Benin Nigeria Togo Mali		

3.4 Workshops and preparatory meetings

The ROG members participated in four workshops and meetings during the second evaluation phase to facilitate preparation of the regional report.

i) First meeting

The first meeting was the meeting of the Coordination Group of the Global Monitoring Plan for POPs under the Stockholm Convention held at the International Environment House in Geneva, Switzerland, from 8 to 10 March 2011. The meeting discussed finalizing the revisions of the guidance document on the global monitoring plan (GMP), including revisions to the strategy, the process and the draft structure for future regional monitoring reports. The meeting also discussed the status of regional monitoring activities to implementation of the second phase of the GMP and to facilitate the preparation of the second monitoring reports. During the meeting, the ROG members developed the regional strategy for development of the second POPs regional monitoring report.

- The key conclusions and recommendations from the meeting included:
- Monitoring activities, coverage and gaps
- Comparable POPs monitoring data in core media in Africa region are generated by three main programmes: MONET Africa, Global Atmospheric Passive Sampling (GAPS) for ambient air and UNEP/WHO mothers' milk programme.
- The African region is collaborating with the following programmes and strategic partners to obtain data on ambient air: MONET-Africa coordinated by the Research Centre for Environmental Chemistry and Ecotoxicology, (RECETOX) Brno, Czech Republic, and the Global Atmospheric Passive Sampling (GAPS) programme coordinated by Environment Canada. MONET Africa has sampling sites in 15 countries namely: Kenya, Mali, South Africa, Mauritius, Zambia, Ethiopia, Sudan, Egypt, Togo, Ghana, Nigeria, Congo Republic, Democratic Republic of Congo, Senegal and Tunisia, whereas GAPS has four sampling sites in Kenya, Uganda, and in South Africa (two sites).
- Eight countries (Mali, Kenya, Uganda, Senegal, Nigeria, Ghana, Mauritius, DR Congo, Togo) submitted human milk samples to WHO reference laboratory between

2008-2009 period through the support of UNEP Stockholm Convention Secretariat/WHO project. Togo and Ethiopia submitted additional samples between 2010-2012, whereas Zambia was expected to submit mothers' milk samples under the UNEP/GEF medium size projects.

- Data gaps were identified for new POPs such as PFOS, PBDE in all core media. It was agreed that existing air and mothers' milk monitoring programmes be expanded to cover new POPs. For more hydrophilic POPs such as PFOS and HCHs, additional suitable matrices such as human blood and water ought to be considered. The ROG members noted that there are no established programmes covering PFOS in water and therefore efforts should be geared towards ensuring their long-term monitoring. Further, there is need to ensure continuation of the MONET Africa programme to support regional ambient air monitoring and establish trends in POPs levels.

- Continuity of established monitoring activities is a regional priority and therefore financial resources are required to support the established air monitoring programmes and mothers' milk sample collection for analysis of both old and new POPs. Concurrently, effort should be made to build regional capacity for sustainable long-term POPs monitoring activities and laboratory analyses.

- Capacity enhancement

- The Africa Region implemented the first UNEP/GEF project on capacity enhancement in 2011/2012. The main objective of the project was to strengthen the monitoring capacity of the participating countries to contribute with national data to the Global Monitoring Plan for Persistent Organic Pollutants (POPs) through:

- Development of detailed guidelines, protocols and manuals for POPs sampling;

- Training of staff in the participating laboratories; and

- Participation of laboratories in proficiency tests.

- Long-term capacity building projects are required to enable continuity of established activities to ensure that the laboratories are capable of providing comparable data. The following are the regional priorities:

- Continuation of Ambient air Monitoring including new POPs

- Supporting participation in the 5th round of UNEP/WHO mothers' milk sampling for analysis of all POPs.

- Establishment of a longer follow up capacity building project for POPs monitoring laboratories through human capacity enhancement and provision of specialised laboratory equipment and consumables.

- UNEP and development partners should prioritise technical assistance to build infrastructural analytical capacity for the region to measure more POPs analytes including the new POPs.

- Strengthening chemical information exchange capacity in the region including supporting infrastructural capacity development through expansion of CIEN activities.

- Establishing network for monitoring new POPs in additional suitable media such as water and blood.

- Strengthening capacity for long-range transport, climate change parameters and interpretation of POPs monitoring and modelling data in the region.

- Strengthening capacity for high volume sampling and validation of PAS data bearing in mind the regional diversities.

- Promotion of POPs research based activities in the region to enhance awareness creation and validation of sampling and analytical protocols.

ii) Second meeting

The second meeting was the meeting of the Coordination Group and Regional Organization Groups under the Global Monitoring Plan (GMP) held in Brno, Czech Republic, from 17 to 20 September 2013. The meeting objectives and expected outcomes were to finalize the GMP data warehouse and training ROG members on its use and ensuring that necessary arrangements and tools are in place for the preparation of the second monitoring reports. ROG members discussed the status of regional monitoring activities and the progress towards the development of regional monitoring reports.

The ROG members updated the comparable programmes that would contribute to the second phase to include: MONET-Africa, UNEP/GEF project and GAPS for air data. The UNEP/WHO milk survey and UNEP/GEF projects were identified as the key sources of mother's milk data. The data for water would be generated through UNEP/GEF active sampling projects and MONET Africa passive water sampling for PFOS.

The ROG members agreed on the need to fill data gaps identified in the first regional report especially the gaps in mothers' milk data in the Southern Africa sub-region. For the second phase, MONET-Africa, UNEP GEF project and GAPS air data were made available, along with human milk data generated through UNEP/WHO milk survey. Water data were

generated via active sampling within the framework of UNEP/GEF projects and via passive sampling within MONET Africa programme.

To ensure sustainability of monitoring activities in the region, effort should be made towards aligning sampling sites and further developing regional laboratories for POPs analysis.

Low internet connectivity was identified as a key impediment towards the work of the ROG in developing the second monitoring report.

iii) Third meeting

The third meeting was the regional drafting workshop held from 30th to 31st October 2014 in Nairobi Kenya, to review the draft regional report. The workshop was attended by ROG members, the drafting consultant from Togo and invited local experts in POPs. The ROG members agreed on the general layout and content of the regional report based on the GMP template. The workshop also agreed on the revised timeframe to for the finalization of the regional report, circulation to countries and translation in French.

iv) Fourth meeting

The fourth a meeting was the Meeting of the Coordination Group for the Global Monitoring Plan (GMP) for Persistent Organic Pollutants (POPs) held at the International Environment House in Geneva, Switzerland, from 10th to 12th November 2014. The meeting objectives were to agree on the final steps and timetable towards finalizing the five regional monitoring reports, developing conclusions and recommendations to be considered at COP-7, defining the approach, steps and timelines towards the development of the global monitoring report and identifying the GMP coordination group representative to the effectiveness evaluation committee.

The ROG members agreed on the following conclusions during the meeting:

i) Initial findings from the regional report show that pesticides were the most dominant POPs in ambient air and human milk. DDT was the highest in mothers' milk and ambient air compared all other POPs chemicals. HCHs and endosulfan were also widely detected in air samples. PCDD/PCDF were widely detected in both ambient air and mothers' milk. Industrial POPs (PCB, PBDEs and PFOS) were detected in quantifiable levels in the core media underpinning the fact that the regional population is exposed to these contaminants.

ii) The absence of sufficiently long-term regional monitoring programmes and underpinning data could not allow for a comprehensive investigation and evaluation of temporal trends of POPs in the region that would address influence of climatological and metrological factors as well as human activities. The presence of POPs in remote areas might indicate long range transport of POPs in the region, however, more

climatological and meteorological information is needed to analyse the relationship between the variability of the atmospheric concentrations of POPs and of the releases, along with collaboration with climatologists and modelers to assess long range transport.

iii) The existing POPs monitoring data have been produced over a short period of time (<6 years). Therefore, the data are not sufficient for assessment of spatial and temporal trends in the region, hence, there is need to support continuation of established monitoring activities to provide adequate data for the evaluation of temporal and spatial trends.

iv) Capacity building for POPs monitoring and analysis remains of high priority in the region at large. This includes human capacity building to analyse all POPs listed in the Convention, supporting laboratories with necessary high resolution analytical equipment for analysis of different POPs compounds; supporting regional POPs monitoring activities with standardized protocols for determination of POPs in core media and other media.

v) Most African countries have limited capacity to initiate analyses of dioxins/furans and new POPs such as PFOS, PBDEs etc. in core media, since these required advanced instrumentation for analysis; therefore the need to support capacity building for the regional laboratories to produce high quality POPs data.

e) E-Forums

Apart from the face to face meetings, the ROG members have maintained the Africa Regional Organization group CIEN platform to support information sharing within the region and beyond. The platform is continuously updated to provide additional information on the implementation of GMP activities in the region. The platform can be accessed at http://www.ESTIS.net/sites/rog/.

3.5 Linkages with strategic programmes and institutions.

Several strategic partners have established in the first evaluation have been maintained to support continuity of the regional monitoring activities through the second evaluation. These include UNEP Chemicals, BSR secretariat, GEF RECETOX, GAPs and WHO. The main strategic programmes that provided POPs data for the second evaluation included: MONET Africa, GAPS, UNEP/GEF project 2010/2011for air data; UNEP/WHO and UNEP/GEF project 2010/2011 for mothers' milk data; and UNEP/GEF project 2014 and MONET Africa 2014 for PFOS levels in water.

1) **The Secretariat**: The secretariat supported strategic arrangements with key partners in the implantation of the first and second GMP activities.

2) **GEF:** Within the second evaluation period GEF supported **t**wo medium size projects in the Africa region that were coordinated by UNEP Chemicals in 2011/2012.

3) **UNEP Chemicals:** UNEP Chemicals coordinated the implementation of two GEF funded projects in the region to support capacity enhancement to analyse POPs. The West Africa project covered DR Congo, Ghana, Mali, Nigeria, Senegal and Togo, whereas the Eastern and Southern Africa Project included Egypt, Ethiopia, Kenya, Mauritius, Uganda and Zambia. The projects focused on Gap Analysis on the initial 12 POPs and development of detailed guidelines, protocols and manuals, training of participating national and regional laboratories and provision of technical, backstopping by established international laboratories, as well as strengthening analytical performance in participating countries by provision of consumables and spare parts for sampling and analysis of POPs in key matrices and participation in international inter-laboratory calibration exercise and information dissemination through national, regional workshops and global workshops.

   The two UNEP/GEF projects contributed to capacity enhancement in terms of personnel and laboratory methodology to produce POPs data for national reporting of POPs. Analysis of mothers' samples revealed the presence of POPs in human tissues. This was attributed to environmental contamination contributing to the buildup of POPs in the food chain. The findings show the need to establish continuous monitoring of POPs in mothers' milk, air and foodstuff to track environmental levels. In addition, the UNEP-GEF project contributed to enhancing the capacity of participating countries to analyse POPs in the ambient air and mothers' milk in the region. The established capacity should be extended to support implementation of the NIPs activities in the region such as national monitoring of POPs and development of comprehensive inventories.

4) RECETOX[4] monitoring activities in Africa – MONET Africa

During the second phase, MONET Africa ambient air monitoring covered 15 countries: Congo, Democratic Republic of Congo, Egypt, Ethiopia, Ghana, Kenya, Mali, Mauritius, Nigeria, Senegal, South Africa, Sudan, Togo, Tunisia and Zambia. The main matrices monitored include: ambient air, soil (once during the pilot phase/upon establishment of a site), water (added in 2013). The monitoring programme uses passive samples in all the countries, and in addition, active sampling was initiated in Ghana and Kenya in 2013.

Screening of POPs in surface water

In 2013/2014 MONET Africa conducted pilot study on screening of POPs in water using a combination of active and passive approaches. Silicon rubber passive samplers were deployed at the same sites. Selected analytes (especially PFCs) were measured with a goal of providing background information and a guidance for future monitoring efforts.

[4] Research Centre for Toxic Compounds in the Environment, Masaryk University, Brno, Czech Republic

Summer schools

As part of regional capacity building, the Regional organization group members have continued collaboration with the Stockholm Convention Secretariat and RECETOX to provide POPs training during the annual summer school to train the regional staff on various aspects of POPs sampling and analysis. The participants were from several regional countries including Ethiopia, Egypt, Ghana, Algeria, Kenya, Democratic Republic of Congo, Mali, Mauritius, Morocco, Nigeria, Senegal, South Africa, Sudan, Togo, Tunisia, Uganda and Zambia among others.

5) Global Atmospheric Passive Sampling (GAPS)

GAPS program supports production of comparable global-scale data for POPs and consists of more than 60 sites in seven continents. Its objectives are to i) demonstrate the feasibility of passive air samplers (PAS) for POPs; ii) determine spatial and temporal trends for POPs in air; and iii) contribute useful data for assessing regional and global long-range atmospheric transport of POPs. GAPS provided POPs monitoring data for Africa for the sites located in Ghana, Kenya, South Africa, Malawi and Egypt.

6) World Health Organization (WHO)

Under the WHO Program, breast milk samples were collected from the participating countries and sent to the WHO reference laboratory for analysis. The mothers' milk sampling activities follow WHO protocol.

4. METHODS FOR SAMPLING, ANALYSIS AND HANDLING OF DATA

4.1 Strategy for gathering new information

To ensure the effective participation in the second effectiveness evaluation in 2015, the African region established a strategic partnership with Research Centre for Environmental Chemistry and Ecotoxicology (RECETOX), GAPs, UNEP/GEF project 1 and WHO to help the region collect comparable POPs data for ambient air, human milk and water through their respective monitoring programs. This chapter summarizes the background information on these international programs along with their relevant technical procedures to sample, analyze and process POPs data.

4.1.1 Programs/activities related to air monitoring

The first Africa report was based on two programmes that provided data for ambient air monitoring: the Global Atmospheric Passive Sampling Programme (GAPs) and MONET Africa. The second evaluation also benefited from additional data MONET Africa, GAPS and UNEP/GEF project 1.

4.1.1.1 MONET Africa

MONET Africa was launched in January 2008, as a six month pilot project supported by the Stockholm Convention Secretariat and the Czech Republic, and covered 15 countries with a total of 26 sampling sites. Both programs use passive sampling, which is a well-known cost-effective ambient air sampling technique. Figure 4.1 shows MONET Africa sampling sites.

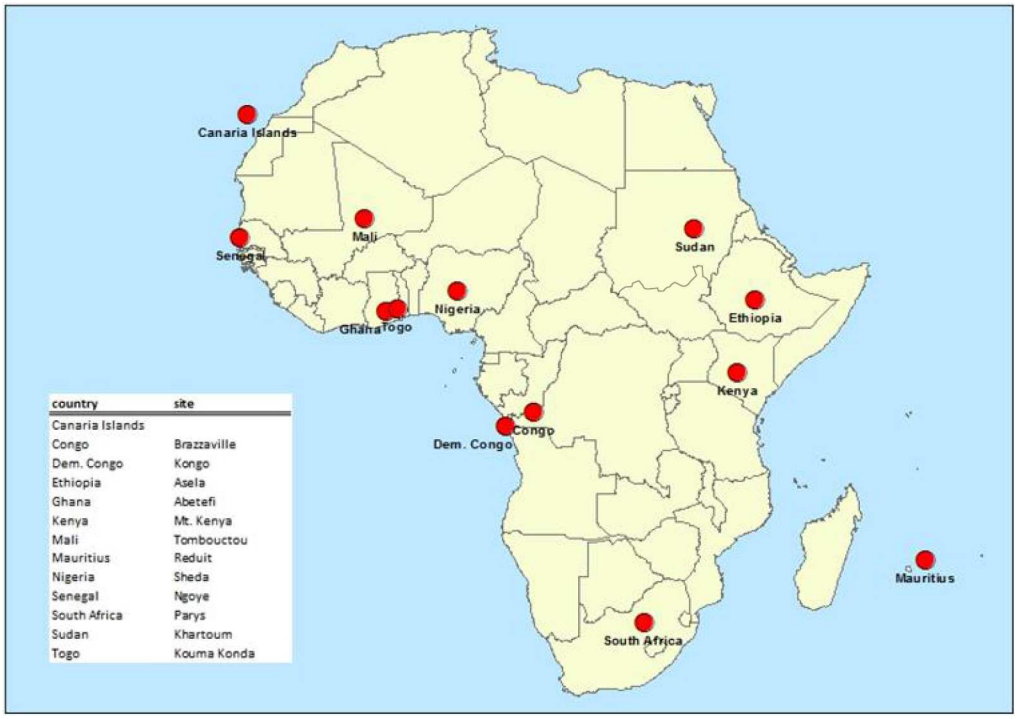

Figure 4.1: Map of the sampling sites in Africa (MONET 2010-2012)

To prepare the second effectiveness evaluation report, RECETOX to provided addition data for over the period 2010-2012. Twenty one sampling sites were initially selected but finally data came from only 19 sites (Table 4.1)

Table 4.1: List of the sampling sites in Africa (MONET 2010-2012)

Sampling site	Classification	Country	latitude	Longitude	Altitude
Orstom de Brazzaville	Impacted urban	Congo	-4.281	15.244	298
Muanda	Background urban	DR Congo	-5.919	12.336	34
Kongo		DR Congo	-5.817	12.246	4
Cogelos	background	DR Congo	-4.443	15.305	476
Kinkenge		DR Congo	-5.949	12.483	130
Kinshasa Ereift	Background urban	RD Congo	-4.410	15.307	408
Kinshasa Ereift Garden	Background urban	RD Congo	-4.418	15.309	447
NA	N.A	Egypt	No samples sent to RECETOX	No samples sent to RECETOX	No samples sent to RECETOX
Asela	Background urban	Ethiopia	7.957	39.143	2372
Abetefi	Background urban	Ghana	6.683	-0.750	595
Mt. Kneya	Background	Kenya	-0.030	37.220	3678

	remote, mountain				
Dandora	Impacted suburban	Kenya	-1.248	36.906	1625
Tombouctou	Background remote	Mali	16.948	-3.007	264
Réduit	Background urban	Mauritius	-20.233	59.498	310
Sheda	Background suburban, agricultural	Nigeria	8.881	7.062	229
Dakar Ngoye	Background urban	Senegal	14.650	-16.430	40
Nooitgedacht (Parys)	Background rural	South Africa	-26.400	29.933	No information
Khartoum	Background urban, industrial	Sudan	15.563	32.514	390
Koumakonda	Background rural, agricultural	Togo	6.951	0.617	576
NA	N.A	Zambia	No samples sent to RECETOX	No samples sent to RECETOX	No samples sent to RECETOX
Izana Canary Islands	Background remote		28.309	-16.499	2400

4.1.1.1. Key message

The first effectiveness evaluation report helped provide Africa with some data and information on the levels of POPs in ambient air. As air pollution remains an issue of great public health concern, and with new regulations introduced, there is a pressing need to obtain more POPs data in a cost-effective manner. Thus, the Global Monitoring Network established in 2008 between the Africa region and RECETOX (University of Brno, Czech Republic) to support the purpose of the Stockholm Convention, with the objective of establishing baseline trends at global background sites pursued its activities during the period 2010-2012. Passive air samplers (PAS) offer a cheap and versatile alternative to the conventional high volume air sampling and they have been currently recommended as one of the methods suitable for the purpose of new long-term monitoring projects.

4.1.1.1.2. Background

MONET-Africa project was based on the Memorandum between UNEP (represented by the Secretariat of the Stockholm Convention) and Masaryk University, Brno, Czech Republic (represented by the Research Centre for Environmental Chemistry and Ecotoxicology RECETOX). This Memorandum was signed for the purpose of implementation of the

Agreement between the Swedish Chemical Agency (KEMI) and the Secretariat of the Stockholm Convention on support of the global monitoring of POPs for evaluation of effectiveness of the Stockholm Convention. The project activities were further supported by: the Ministry of Education of the Czech Republic, Project MSM 0021622412, and the Ministry of Environment of the Czech Republic, Project SP/1b1/30/07.

Project goals and related activities:

Application of the polyurethane foam based passive air sampler (PAS) as a tool for determination of the effectiveness of measures of the international POPs conventions (POPs under the Stockholm Convention and POPs Protocol of CRLTAP). Establishment of the long-term monitoring of background sites as well as evaluation of an impact of the local primary point sources, secondary and diffusive sources, and a long-range transport is necessary. The design of the project is based on the experience from the pilot studies performed by RECETOX in the Czech Republic and Western Balkan since 2003 (Klanova *et al.*, 2006; Klanova *et al.,* 2007; Cupr *et al.,* 2006).

Filling the information gap concerning POP levels in ambient air in the African continent where the regular monitoring programs are missing. Representative set of the sampling sites (Table 4.1) ranged from industrial (Sudan), background rural agriculture (Togo, Nigeria, South Africa), background remote mountain (Mali, Kenya, Canary Islands), background urban and suburban (DRC, Ethiopia. Ghana, Mauritius and Senegal) to impacted urban and suburban (Congo and Kenya).

Evaluation of temporal and spatial trends in the POP concentrations in ambient air in the countries of the African continent. Variability of the POP levels between the sampling sites as well as the seasonal variability on each site was assessed.

Establishment of the long-term PAS monitoring program in this region. A monitoring network in the Czech Republic serves as a model for development of other networks. After completing both stages of the African screening study in August, 2008, the set of the sampling sites suitable for the long term monitoring will be selected and steps will be taken (in cooperation with the local institutions) towards the establishment of the regional monitoring program.

Transfer of know-how, dissemination of information about new techniques for sampling, chemical analysis, toxicological screening, and risk assessment. Educational and training activities, workshops and conferences initiated in the last five years under umbrella of the Research Centre for Environmental Chemistry and Ecotoxicology RECETOX, EU DG Research Centre of Excellence, will be promoted by Central and Eastern European POPs Centre to strengthen the scientific cooperation within and outside this region.

Presentation of activities of the Regional POPs Centre, National POPs Centre of the Czech Republic and Research Centre for Environmental Chemistry and Ecotoxicology RECETOX, Masaryk University, Brno, Czech Republic.

4.1.1.1.3. Sampling

Passive air sampling device consists of two stainless steel bowls attached to the common axes to form a protective chamber for the polyurethane foam filter (Figure 4.2). The filter is attached to the same rod and it is sheltered against the wet and dry atmospheric deposition, wind and UV light. Exposure times between four and twelve weeks enable determination of many compounds from the POP group. Average sampling rate was estimated to be 3.5 m^3/day which roughly corresponds to 100 m^3 of the air sampled during four weeks of deployment.

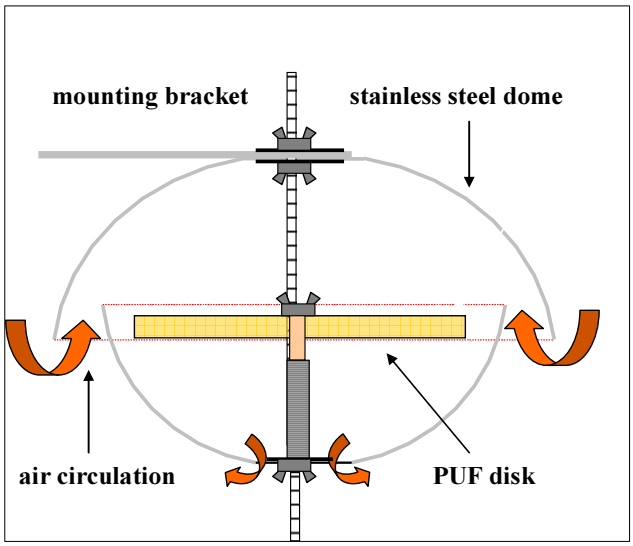

Figure 4.2: Schematic diagram of the passive air sampler

Previous RECETOX studies (Klanova *et al.,* 2006; Klanova *et al.,* 2007; Cupr *et al.,* 2006) confirmed that PAS are sensitive enough to mirror even small-scale differences, which makes them capable of monitoring spatial, seasonal and temporal variations. Passive samplers can be used for point sources evaluation on the scale of several square kilometres or less - from the local plants to diffusive emissions from transportation vehicles or household incinerators - as well as for evaluation of diffusive emissions from secondary sources. While insensitive to temporally short accidental releases, passive air samplers are suitable for measurements of long-term average concentrations at various spatial and time scales.

Passive air samplers consisting of the polyurethane foam disks (15 cm diameter, 1.5 cm thick, density 0.030 g cm^{-3}, type N 3038; Gumotex Breclav, Czech Republic) housed in the protective chambers are employed. Sampling chambers were pre-washed and solvent-rinsed with acetone prior to installation. All filters were pre-washed, cleaned (8 hours extraction

in acetone and 8 hours in dichloromethane), wrapped in two layers of aluminum foil, placed into zip-lock polyethylene bags and kept in the freezer prior to deployment. Exposed filters were wrapped in two layers of aluminum foil, labeled, placed into zip-lock polyethylene bags and transported in coolers at 5 °C to the laboratory where they were kept in the freezer at –18 °C until the analysis. Field blanks were obtained by installing and removing the PUF disks at all sampling sites.

4.1.1.1.4. Sample analytical procedures

All samples were extracted with dichloromethane in a Büchi System B-811 automatic extractor. One laboratory blank and one reference material were analyzed with each set of ten samples. Surrogate recovery standards (*d8*-naphthalene, *d10*-phenanthrene, *d12*-perylene for PAHs analysis, PCB 30 and PCB 185 for PCBs analysis) were spiked on each filter prior to extraction. Terfenyl and PCB 121 were used as internal standards for polyaromatic hydrocarbon (PAH) and polychlorinated biphenyl (PCB)/organochlorine pesticide (OCP) analyses, respectively. Volume was reduced after extraction under a gentle nitrogen stream at ambient temperature, and fractionation achieved on a silica gel column; a sulphuric acid modified silica gel column was used for PCB/OCP samples. Samples were analyzed using GC-ECD (HP 5890) supplied with a Quadrex fused silica column 5% Ph for PCBs: PCB 28, PCB 52, PCB 101, PCB 118, PCB 153, PCB 138, PCB 180, and OCPs: α-hexachlorocyclohexane (HCH), β-HCH, γ-HCH, δ-HCH, 1,1-dichloro-2,2-bis (p-chlorophenyl)ethylene (*p,p´*-DDE), 1,1-dichloro-2,2-bis (p-chlorophenyl) ethan (*p,p´*-DDD), 1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethan (*p,p´*-DDT), *o,p´*-DDE, *o,p´*-DDD, *o,p´*-DDE, hexachlorobenzene (HCB), and pentachlorobenzene (PeCB). 16 US EPA polycyclic aromatic hydrocarbons were determined in all samples using GC-MS instrument (HP 6890 - HP 5972) supplied with a J&W Scientific fused silica column DB-5MS.

4.1.1.5. Quality Assurance and Quality Control

Recoveries were determined for all samples by spiking with the surrogate standards prior to extraction. Amounts were similar to detected quantities of analytes in the samples. Recoveries were higher than 76 % and 71 % for all samples for PCBs and PAHs, respectively. Recovery factors were not applied to any of the data. Recovery of native analytes measured for the reference material varied from 88 to 103 % for PCBs, from 75 to 98 % for OCPs, and from 72 to 102 % for PAHs. Laboratory blanks were under the detection limits for selected compounds. Field blanks consisted of pre-extracted PUF disks and they were taken on each sampling site. They were extracted and analyzed in the same way as the samples, and the levels in field blanks never exceeded 3% of quantities detected in samples for PCBs, 1% for OCPs, and 3% for PAHs, indicating minimal contamination during the transport, storage and analysis.

4.1.1.1.6 Generation of back trajectories

Trajectories were generated using the HYSPLIT model of the American National Oceanic and Atmospheric Administration, NOAA (NOAA, 2003). Three-dimensional four day back trajectories were generated for individual sampling intervals. The trajectories were generated every four hours of the sampling interval. The main output of the HYSPLIT model are geographical coordinates indicating the location of hourly trajectory segment endpoints. As the trajectories are calculated 96 hours back in time, each one in the map is usually defined by 96 segment endpoints.

The trajectories were generated at a starting height of 200 m above ground level. This level ensures that the trajectory starts in the mixing layer of the atmosphere. Additional control on this condition was conducted, and only sporadic trajectories were found to have their starting height above the mixing layer height during night. During previous days, the starting heights of all trajectories were well within the mixing layer, and no trajectory was excluded from the data set. However, since pollutant sources are mainly in the mixing layer, the trajectory changes its height and can reach heights above it when going back in time. In such cases, trajectory segments above this layer were excluded.

4.1.1.1.7. Data comparability

All samples collected from the MONET Africa pilot study were analysed in the same laboratory at RECETOX, in the Czech Republic to ensure that the data can be compared spatially and temporally. Data comparability between the air monitoring programmes in the region was evaluated using data from parallel samplers located at an existing station in Kostice, Czech Republic.

4.1.1.1.8. Sample and data storage

Sample extracts were capped tightly in Gas Chromatography vials and stored in a freezer at a temperature of about -20 °C. Air concentration results and relevant sample information (such as Sample ID, site ID, location name, sample duration, meteorological conditions etc.) are recorded in excel spreadsheets.

4.1.1.2 Global Atmospheric Passive Sampling (GAPS) Network

4.1.1.2.1 Key message

GAPs was launched in January 2005 in four countries (Egypt, Ghana, Malawi, and South Africa). In 2008 an additional GAPS site was established at Mt. Kenya alongside the MONET Africa samplers to support assessment of data comparability between the two programmes.

The first results from the Global Atmospheric Passive Sampling (GAPS) Network (January–December 2005) provided baselines of air concentrations for persistent organic pollutants (POPs) at four sampling sites in the Africa region (Figure 4.3). These data represent the first comparable ambient air measurements of POPs in this region and will be useful for assessing temporal and spatial trends and regional and global transport of POPs in air.

4.1.1.2.2. Background

GAPS program was initiated in December 2004 as a two-year pilot study before evolving into a network, and consists of more than 60 sites on seven continents. Its objectives are to i) demonstrate the feasibility of passive air samplers (PAS) for POPs; ii) determine spatial and temporal trends for POPs in air; and iii) contribute useful data for assessing regional and global long-range atmospheric transport of POPs. PAS are advantageous because of their low cost, simple construction and electricity-free operation. Deployment of PAS worldwide over several years will allow for temporal trends to be established and thus, the effectiveness of POPs control measures to be evaluated. Figure 4.3 shows the GAPS Network sites in the Africa region since 2005.

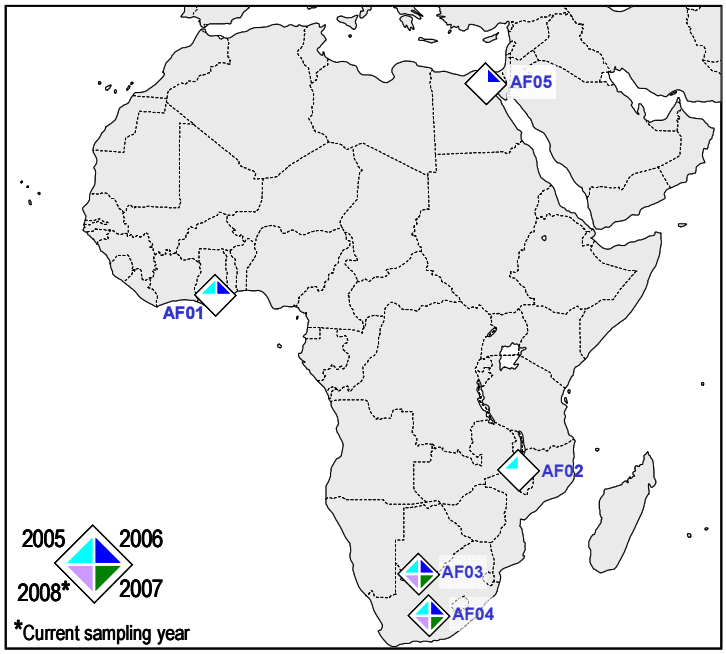

Figure 4.3: Sampling sites and sampling years in Africa

The GPS locations and background information on site classification are summarised in Table 4.2.

Table 4.2: Information on sampling locations in Africa

Site ID	Location	Country	Site Type [1]	Latitude	Longitude	Elevation (m a.s.l.)[2]
AF01	Accra	Ghana	RU	8º 00' N	2º 00' W	NA
AF02	Lilongwe	Malawi	AG	14º 11' S	33º 47' E	1148 m
AF03	Kalahari	South Africa	BA	25º 52' S	22º 54' E	NA
AF04	De Aar	South Africa	BA	30º 40' S	24º 00' E	1287 m
AF05	Cairo	Egypt	RU	30º 08' 25.18" N	31º 37' 08.94" E	193 m
AF07	Mt. Kenya	Kenya	BA	0º 03'752"	037º17'841" E	3,669 m

[1] m a.s.l. = Meter above sea level

[2] BA = background; RU = rural; AG = agricultural and UR = urban

4.1.1.2.3. Sampling

Types of PAS used: two types of PAS are used (Figure 4.4).The PUF-disk sampler (left) is deployed for three-month periods to capture seasonal differences and the XAD (right) sampler is exposed for a full year.

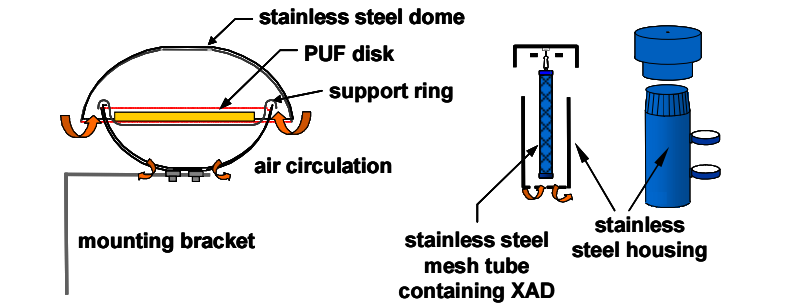

Figure 4.4. Schematic diagrams of passive air samplers

The PUF-disk sampler is described in Shoeib and Harner (2002) and Pozo et al. (2006) and the XAD sampler is described in Wania et al. (2003). Both types of PAS are installed outdoors far away from potential sources of contamination to the site (e.g., exhaust vents, electronics, sources of combustion or human activity). They are mounted approximately two meters above the ground in an open area with unobstructed airflow.

Sampling conditions

PUF-disk PAS

PUF-disk PAS were deployed at four African sites in 2005.Table 4.2 shows the exposure times (days), average temperatures (°C) and effective sampling rates (m^3/day) for each of the four sampling periods at each site. Generally, the PUF-disk sampling was as follows: January–March (Period 1); April–June (Period 2); July–September (Period 3); and October–December (Period 4).

XAD-based PAS

XAD-based PAS were deployed at three African sites in 2005 and four sites in 2006. By sampling air for one year, XAD resin-based PAS provides annually averaged concentrations of organic pollutants. The sampling lengths and the sequestered amounts of selected OCPs in ng/PAS were assessed. Analyses were performed for the pesticides that are classified under the Stockholm Convention: CC, TC, TN, DDT, DDE, dieldrin, HEPT,and HEPX, and also for the pesticides that are not classified under Stockholm Convention, including *a*- and *g*-HCH, Endo I and II, $EndoSO_4$, chlorothalonil (CT), dacthal (DT), and trifluralin (TF).

4.1.1.2.4. Sample analytical procedures

Procedure for PUF- Disk PAS

Details for the extraction and analysis of the PUF-disk samples and field blanks are given in Pozo et al. (2006).The following QA/QC procedures were employed for the PUF-disk sampler:

Field blanks – A PUF disk field blank was collected once a year from each site to assess possible contamination caused by shipping, handling and storage.

Method blanks – A solvent blank was extracted with every set of eight samples to assess possible contamination during laboratory analysis (i.e., from sample preparation to instrumental analysis). Also, during preparation of PUF disks for deployment, one sample from each batch was extracted and checked for purity.

Instrument blanks – A solvent blank was analyzed with every set of twelve field samples to assess for any instrument contamination.

Surrogate spikes – Prior to extraction, PUF-disk samples were spiked with a method recovery standard consisting of ^{13}C-PCB-105, d_6-*α*-HCH, and d_8-*p, p'*-DDT to confirm analytical integrity.

Matrix spikes – Analytical (method) recoveries were determined by spiking clean PUF disks with known quantities of the target chemicals and treating them as samples to assess matrix effects on extraction efficiencies.

Field co-located samples – Duplicate samples were collected at several sites in the GAPS Network to assess overall precision of both sampling and laboratory methods.

Mirex was added as an internal standard to correct for volume differences in sample extracts. All samples and field blanks were quantified for target compounds including organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs). OCPs, PCBs, and PBDEs were analyzed on a Hewlett-Packard 6890 gas chromatograph-5973 mass spectrometer (GC-MS) using electron impact (EI) for PCBs and negative chemical ionization (NCI) for OCPs and PBDEs in the selected ion monitoring mode.

Procedure for XAD PAS

Cleaning of XAD-2 resin, and packing of XAD PAS samples were carried out as described by Wania et al. (2003). Cleaning, preparation and extraction of PAS were done in a clean lab. The XAD-2 resin was Soxhlet extracted with dichloromethane for 20 hours. Prior to extraction, the resin was spiked with standards consisting d_6- -HCH, $^{13}C_{10}$-HEPX, $^{13}C_{10}$-TN, $^{13}C_{12}$-dieldrin, d_8-*p,p'*-DDT and $^{13}C_{12}$-PCB-32, $^{13}C_{12}$-PCB-77, $^{13}C_{12}$-PCB-118 and $^{13}C_{12}$-PCB-126 to test for the loss of the compounds during the extraction and clean-up procedures. The extracts were volume reduced using a rotary evaporator and concentrated to around 1 ml using a gentle stream of nitrogen. The extracts from first year samples were cleaned using alumina columns, but not those from the second year. After reducing samples to 3 ml using a rotary evaporator, the extracts from second year samples were passed through sodium sulfate (baked at 450 °C overnight) columns to remove any water present in sample. The extracts from the first year air samples were cleaned on a column with 1 g of 6% deactivated alumina (baked at 450 °C overnight) and 0.5 cm of sodium sulfate. The samples were eluted with 20 ml of DCM: PE (5:95; v/v). The extracts were concentrated to 1 ml using a stream of nitrogen and then were solvent-exchanged to isooctane. The final volume of the extracts was 1 ml, and 100 ng of mirex was added to the sample as an internal standard for correcting volume differences in the sample.

The sample and blank (field and laboratory) extracts were analyzed for Stockholm Convention POPs as well as pesticides not classified under Stockholm Convention POPs

using an Agilent 6890 gas chromatograph (GC) coupled to a 5973 mass selective detector (MSD) with a negative chemical ionization source for organchlorine pesticides (OCPs) in selected ion mode. The analyzed non-Stockholm Convention pesticides in air samples are: α-HCH, γ-HCH, α-endosulfan, β-endosulfan, endosulfan sulfate, dacthal, chlorothalonil, pendimethalin and trifluralin.

Quality assurance and control measures were used to monitor all analytical procedures. Field blanks were collected to determine the levels of contaminants introduced by handling, shipping and storage and one laboratory blank was analyzed for every set of sample extractions to determine the levels of contaminants introduced during extraction and clean-up. The laboratory blanks and field blanks were processed in the same way as the samples. Air samples were not spiked with surrogates for the pesticides that are not classified under the Stockholm Convention POPs, such as chlorothalonil, dacthal, metribuzin, pendimethalin, and trifluralin. To test for the loss of these compounds during the extraction and clean-up procedure, six samples of 20 g of XAD-2 were spiked with the pesticides, then extracted and cleaned in the same way as the samples.

4.1.1.2.5. Data comparability

All PUF-disk samples were prepared and analyzed in the same laboratory [Hazardous Air Pollutants (HAPs), Environment Canada in Toronto] to ensure that the data could be compared spatially and temporally. The HAPs laboratory participates in international intercalibration studies for POPs and performs well in these exercises.

4.1.1.2.6. Sample and data storage

Sample extracts were capped tightly in GC vials and stored in a freezer at a temperature of about -20°C. Air concentration results and relevant sample information (e.g. sample ID, site ID, location name, sample duration, meteorological conditions etc.) were recorded in Excel spreadsheets. For the second evaluation, the GAPS data was transmitted to the GMP data warehouse and combined with the datasets from MONET Africa for in the regional node for visualization.

4.1.2 Programs/activities related to human tissues (milk)

Concentrations of POPs in human milk are considered good indicators of the actual body burden. In addition, human milk is considered as one of the best sampling matrices for biomonitoring due to its availability and non-invasive approach when collecting individual samples. Its high lipid content makes the extraction method for POPs easier and the precision of the measurements higher. Over the last decades, human milk has generally been used as a medium to measure contamination in humans, and analytical techniques have been well established for most POPs included in the Stockholm Convention.

Furthermore, the uptake of these chemicals by the infant via human milk is of high toxicological relevance. The risk-benefit assessment of breastfed infants represents one of the most challenging aspects of human toxicology, as possible adverse health effects associated with exposure to POPs concur with significant health benefits of breastfeeding. In this perspective, the results of the human milk survey are not meant to derive a "ranking" of countries with respect to risks for the breastfed infant. The surveys are primarily aimed at identifying worldwide quantitative differences of human milk contamination with these POPs, and provide a baseline for those countries for which such information was previously not available. This will allow in the future evaluating the effectiveness of measures taken to reduce POPs exposure. The quantitative differences observed in these surveys may provide a suitable basis for possible source-directed measures to further reduce levels of specific POPs on a country-by-country basis. Therefore it is useful to interpret the results in a national/regional context, and introduce targeted measures to further decrease human exposure.

4.1.2.1 Key message

Human milk and maternal blood are both equally good sample media for assessing POPs exposure in humans. Furthermore, both these media can be used to demonstrate possible temporal trends in levels and thus show effectiveness of regulations of the use of POPs. It should be encouraged to sample both milk and blood of the same mother.

4.1.2.2 Background

In 2005, at the second meeting of the Conference of the Parties to the Stockholm Convention, it was recognized that human biomonitoring is essential to evaluate whether human exposure to POPs is indeed decreasing over time. Monitoring of human milk allows thus countries and regions to identify contamination problems and formulate measures to reduce and prevent human and environmental exposure to these chemicals.

Building on the previous WHO human milk monitoring studies, the United Nations Environment Programme (UNEP) and the World Health Organisation (WHO) jointly implement a global study to monitor changes in human exposure over time. The survey measures POPs concentrations in human milk and is implemented in a wide range of countries with large differences in food consumption patterns and environmental levels of POPs.

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Early WHO surveys performed mainly in Europe and North America in 1987-1989 and 1992-1993 exclusively focused on PCB, PCDD and PCDF. In 2001-2003, a larger global survey was implemented, covering the twelve POP compounds initially listed in the Stockholm Convention. Following the ratification of the Stockholm Convention, WHO and UNEP started their collaboration, and two additional global surveys were completed in 2005-2007 and 2008-2012. These significantly enlarged the geographical scope of the study to provide representative results for all regions of the globe. The results of these surveys have been compiled in document UNEP/POPS/COP.6/INF/33.

The second phase of the human milk survey (2013-2014) aimed at detecting changes in the levels of legacy POPs measured in human populations and building a consistent baseline for human exposure to the newly listed POPs.

4.1.2.3 Sampling

In order to promote reliability and comparability, participating countries are encouraged to adhere as closely to WHO protocol as much as possible. However, it is also recognized that the situations in countries vary considerably so that some flexibility is required. Guidance is provided to assist countries in developing their national protocols, including:

Number of donors: A minimum of 50 individual donors should each provide 50 ml of human milk for preparing the pooled sample. Note that one additional participant per million population over 50 million is recommended for large countries and in some cases, more than one pooled sample may need to be prepared. On the other hand, a lower number samples may be necessary for small countries.

Strategies for selecting donors: The following criteria for selection of donating mothers shall be applied: a) they should be primiparae, b) healthy, c) exclusively breastfeeding one child (i.e. no twins), and d) residing in the area for about five years. Interviewing of potential donors can take place pre- or post-natal or in well-baby clinics. The stratification of donors should represent the presumed national exposure profile of each country. This would include consideration of diet, occupational exposure, rural and urban residence and proximity to potential POPs releasing sources such as industries and waste sites.

Biosafety: In general, the handling of any milk sample should comply with biosafety rules to protect workers who will handle samples. The National Coordinators should decide whether HIV-positive donors can participate in the survey.

Consequently, the sampling protocol will vary among countries and therefore, comparison of results between countries should be approached with caution. However, once the national protocol is established, it should be applied in subsequent rounds so that changes/trends can be followed. In these cases, observation of temporal trends should be scientifically valid provided information on the distribution of levels in individual samples is available.

4.1.2.4 Analytical procedures

Procedure for PCDDs, PCDFs and PCBs

After freeze-drying of the whole sample, fat and contaminants of interest are extracted in a hot extraction device (”Twisselmann extractor”) with cyclohexane/toluene (50/50) for 8 hrs. After evaporation of the solvent, an aliquot of fat is spiked with 13C-labeled internal standards (17 PCDD/Fs, 5 non-ortho PCBs [37, 77, 81, 126, 169], 6 mono-ortho PCBs [28, 60, 105, 118, 156,189] and 7 di-ortho PCBs [52, 101, 153, 138, 180, 194 and 209]). Gel permeation chromatography on Bio Beads S-X3 removes fat. A silica column impregnated with sulfuric acid removes remaining oxidizable substances. A florisil column separates PCDD/F from PCBs. The PCDD/F-fraction is purified on a Carbopack C-column. After addition of 1,2,3,4-13C12-TCDD, determination is performed by HRGC/HRMS (Fisons Autospec; resolution 10,000; DB5-MS). The PCBs are separated on a Carbopack B-column into three fractions of first di-ortho PCBs (elution with hexane), then mono-ortho PCBs (elution with hexane/toluene; 92.5/7.5) and finally non-ortho PCBs (reversed elution with toluene). After addition of 13C12-PCB 80, the different PCB groups are determined by HRGC/HRMS (Fisons Autospec; resolution 10,000; DB5-MS) in three separate runs. Marker PCBs are PCB 28, 52, 101, 138, 153 and 180.

Procedure for analytically simple POPs

The milk samples were analysed for POP pesticides. Fats and POPs of interest were extracted from freeze-dried human milk as described above for PCDDs, PCDFs and PCBs. Up to 0.5 g of the fat extract was re-dissolved in cyclohexane/ethyl acetate and the internal standards

(2,4,5-Trichlorobiphenly and Mirex), dissolved in cyclohexane, were added. The applied clean up-parts of the analytical method followed the principles of the European standardized methods for pesticide residue analysis for fatty food - Determination of pesticides and PCBs", EN 1528 part 1-4, 1996-10 (confirmed 2001). To remove fat, gel permeation chromatography was performed on a chromatography column using Bio-Beads S-X3 with cyclohexane/ethyl acetate as eluting solvent. After concentration and transfer into iso-octane, chromatography on a small column of partially deactivated silica gel was used as final clean up steps with toluene as eluent. Determination was performed with GC/ECD using a GC (Fisons Mega 2) with two parallel columns of different polarity (fused silica no. 1:30 m PS-088 [97.5% Dimethyl -2.5% diphenyl siloxane copolymer] 0.32 mm id., 0.32 µm film thickness, fused silica no. 2:30 m OV-1701-OH, 0.32 mm id., 0.25 µm film thickness, both columns customs column made). Results were confirmed by GC-LRMS (GC: HP 6890 / MS: HP 5973; 30 m HP5-MS, 0.25 mm id., 0.25 µm film thickness + 2.5 m pre-column; detection mode: MSD – EI). The limit of quantification (LOQ) was 0.5 ngg^{-1} fat.

Procedure for PFOS and related chemicals

Milk samples were extracted using weak anion exchange, solid-phase extraction (Waters Oasis® WAX, Waters Corporation, Milford, USA) using a previously reported method (Kärrman *et al.,* 2007). Internal standard ($^{13}C_4$-PFOS) and 2 mL formic acid/water (1:1) were added to 1 mL milk. The solution was sonicated for 15 min and centrifuged at 9000 x g for 30 minutes. The supernatant was extracted on Oasis WAX and PFOS was eluted with 1 mL 2% ammonium hydroxide in methanol, after washing the column with 2 mL sodium acetate buffer solution (pH 4) and 2 mL 40% methanol in water. After evaporation the final extract volume was 20 µL, then 30 µL 2mM ammonium acetate in water and performance standard ($^{13}C_8$-PFOS) were added. Milk extracts were injected (10 µL) on an Acquity UPLC Xevo TQ-S tandem mass spectrometer (Waters Corporation, Milford, USA) with an atmospheric electrospray interface operating in negative ion mode. The analytes were separated on an Acquity BEH C18 column (2.1 x 100 mm, 1.7 µm) and analyzed on a MS/MS system run in electrospray ionization mode (ESI). Multiple reaction monitoring (MRM) was used and three product ions were monitored for PFOS. Milk samples were quantified using external standards in solvent and the internal standard method. The performance standard was used to assess the recovery of the internal standard.

4.1.2.5 Data comparability

To ensure reliability of exposure data and to improve comparability of analytical results from different laboratories, WHO has coordinated a number of inter-laboratory quality assessment studies. The State Institute for Chemical and Veterinary Analysis of Food Freiburg met all the pre-set criteria for analyses of PCDDs, PCDFs, dioxin-like PCBs, marker PCBs and fat in human milk and was thus selected as the WHO Reference Laboratory for the WHO human milk studies. Perfluorinated chemicals are likewise analyzed in a single laboratory at the MTM Research Centre, Örebro University, Sweden.

It should also be noted that the sampling concept for the mothers' milk exposure studies changed between 2000 and 2012. Whereas in 2000-2003 countries were encouraged to prepare two or more pooled samples to address differences within a country, the guidance document for the Global Monitoring Plan under the Stockholm Convention asks for one representative sample for up to 50 million citizens. In order to obtain comparable results, the median concentration from all national pools that were submitted is commonly used.

Among the newly listed POPs, PFOS and its salts do not follow the "classical" pattern of partitioning into fatty tissues, but instead bind preferentially to proteins in the plasma, such as albumin and gamma-lipoproteins, and in the liver, such as liver fatty acid binding protein. Due to higher albumin content, blood is considered the preferable and recommended medium to determine fluorinated compounds, but analyzing PFOS in milk samples is also a viable option with today's technology. The levels in human milk are generally much lower than those in blood, but a strong association between serum and milk concentrations of PFOS has been reported.

Kärrman and Davies (2013) collected milk and serum samples from primiparae women in Uppsala, Sweden in the period from 2004 to 2011. 48 serum samples and 48 milk samples were collected and analyzed on a MS/MS system run in electrospray ionization mode. PFOS (linear isomer) was quantified in all samples and concentrations ranged from 1.3 to 20 ng/mL in serum and 0.028 to 0.354 ng/mL in milk. The limit of detection was 0.05 ng/mL for serum and 0.012 ng/mL for milk. Serum levels of PFOS were compared with levels of PFOS in human milk from the same mother. The regression analysis showed that levels of PFOS measured in milk and serum were highly correlated, with a Pearson's correlation coefficient of 0.9171. Milk levels in this study are on average 1.55% of the corresponding serum levels. This value is in agreement with previous studies on similar serum to milk relationships, that have reported 1.09% (Kim et al. 2011), 1% (Kärrman et al. 2007), and 1.4% (Thomsen et al. 2010).

4.1.2.6 Data storage

Data are stored at the GEMS/Food database located at WHO in Geneva, Switzerland and is password-accessible through the WHO Summary Information and Global Health Trends (http://SIGHT) portal. Data are stored at the GMP data warehouse, available at www.pops-gmp.org.

4.1.3 Programs/activities related to human tissues (blood)

There is no established human blood monitoring programme in the region to provide comparable data on POPs listed in annex A, B and C. The existing POPs data for human blood are mainly from individual research activities. Due to diversity of research objectives among different studies, analytical methodologies and sampling periods are highly variable. In addition the QA and QC procedures are also different among the individual studies and the

samples are normally stored by the individual researchers. The region, therefore, strongly relies on mothers' milk matrix to provide POPs data for human tissue.

4.1.4 Programs/activities related to water

Preliminary work has been initiated to provide comparable POPs data in water media under the UNEP/GEF project 2014 and MONET Africa programme. The UNEP/GEF project objective was to develop methodologies for analysis of new POPs in water matrix. Water samples were collected from Kenya and Mali in 2014 by active sampling method.

The MONET Africa water sampling was conducted in 2014 to test potential application of passive samplers in monitoring PFOS in water.

4.1.4.1 Key message

The existing PFOS data for water was obtained from preliminary water sampling activities conducted under UNEP/GEF pilot project and MONET Africa pilot water monitoring study applying active and passive sampling, respectively.

4.1.4.2. Background

Perfluorinated chemicals (PFCs) have been in use for over 5 decades (OECD, 2002). However, there has been increased concern about their presence in environmental media due their high persistence, biomagnification in food webs and potential toxicity. The major groups of PFCs are the perfluoralkyl acids and their salts: perfluoroalkyl sulfonates, perfluoralkyl carboxylates, and including polyfluorinated telomer alcohols and their derivatives.

According to Lau et al. (2007) the two most widely known PFAAs have an eight-carbon backbone with either a sulfonate (PFOS) or carboxylate (PFOA- perfluorooctanoic acid) attached. The major applications of PFOS-related chemicals are include: surface treatments for soil/stain resistance, coating of paper as a part of a sizing agent formulation and in specialized applications such as fire fighting foams. The strong C-F bonds accounts for the extreme stability towards metabolism and non-biodegradability in the environment. In addition, PFOS is soluble in fresh water, but the solubility tends to decrease with increasing salinity. Further studies have reported the surface-active properties of PFOS, it forms three layers in octanol/water making an n-octanol/water (Kow) partition co-efficient unable to be determined. Although the direct data on human toxicity of these compounds are very rare, laboratory experiments have shown that these compounds could have adverse effects to human and environment.

By decision SC-4/17 the Conference of the Parties listed perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride in the annex B of the Convention.

PFOS and PFOA are characterized by high water solubility, despite their lipophilic tail, and water solubility ranges between 570 mg/L for PFOS and 3,400 mg/L for PFOA (UNEP 2015, Draft guidelines for PFOS analysis). Consequently, the open oceans water column has been suggested to be a final sink of PFASs, such as PFOA (Lohmann *et al.,* 2013).

4.1.4.3. Sampling techniques

Water sampling methodologies for hydrophilic POPs are under development. At the moment, both active and passive sampling techniques are being tested. Direct sampling of 0.2-1.0 L of water is the most commonly used approach for PFAS analysis in water. In addition, passive sampling have been investigated for polar compounds and the results have been satisfactory (Kaserzon *et al.* 2012). Passive samplers have an advantage of collecting representative samples over a long time period. The major disadvantage is the complexity to determine the kinetics of the passive sampler material and design. Therefore calibration of the samplers is key to development of the passive sampling techniques.

In the UNEP/GEF pilot project active sampling method was deployed. Water was collected grab method in 500 ml high density polyethylene (HDPE) bottle to avoid sorption of PFOS and salts onto the container walls. Figure 4.5 shows the water samples in HDPE bottles used.

Figure 4.5 Passive sampling devices installed during the pilot water sampling for PFOS

MONET Africa pilot water sampling exercise was conducted in 2013/2014 and deployed two passive water sampling devices: XAD and semi permeable membrane device (SPMD). For XAD resin, water sample was collected in 1 L bottle and stored for 3 days to allow organic contaminants to sorb on the resin, after which the water was drained. The residue consisting of the resin was stored at -18 °C until analysis.

The SPMD used was silicon rubber. The SPMD was anchored on the metallic strainers and exposed in the field for a period of 28 days. After the exposure period, the samples were collected and stored at -18 °C until analysis. Figure 4.6 shows the passive sampling devices deployed.

Figure 4.6 Passive sampling devices installed during the pilot water sampling for PFOS

4.1.4.4. Sample analysis procedure

The recommended method of analysis of PFOS and salts is the LC-MS/MS instrumentation with the capacity to determine qualifying and quantifying ions. Instruments such as a LC with quadrupole Time-of-Flight (Q-TOF) or quadrupole ion trap (Q-Trap) detectors are also suitable. According to the draft guidelines for PFOS analysis, the quantifier and qualifier are the same for the linear and the branched PFOS isomers. To quantify the branched PFOS it is recommended to use both m/z 80 and 99 as quantifiers take the average concentration for the two values, as one is commonly over and the other under estimate the concentration due to lack of accurate IS for the branched isomers (UNEP 2015, Draft guidelines for PFOS analysis).

The samples collected in the two pilot projects were analysed in the backup laboratories. The active water samples were analysed at the Institute of Environmental Studies (IVM), University of Amsterdam. The Passive water samples were centrally analysed at RECETOX, Masaryk University, Czech Republic using established protocols.

4.1.4.5. Data comparability

Analysis of two water samples from active monitoring was conducted centrally by two backup laboratories, the IVM at the University of Amsterdam, and MTM at the Orebro University. Analysis of the passive water samples collected under the MONET Africa was conducted at RECTOX using established programme QA&QC protocols. The results were processed and presented in the same units to allow comparability.

4.1.4.7. Sample and data storage

There is no established specimen banking for water samples. The POPs data sets generated from the pilot water sampling activities have been transmitted to the GMP global database for archiving. The data can be accessed for visualization at http://www.pops-gmp.org/dwh.

4.1.5 Programs/activities related to other media

4.1.5.1. Key message

A survey of literature reports showed that research work is being done within the African region on the contamination of water, soil, sediments, and food by pesticides with a focus on organochlorine POP pesticides. The interest in POPs seems to have been enhanced in a certain extent due to sensitization brought up by the Stockholm Convention. In this report, the Region decided to incorporate some monitoring data dealing with the contamination of water, soil, sediments and food (other media) by POP pesticides in order to show that the African region does have some relevant technical infrastructure and effective expertise that need to be strengthened to enable the region participate fully in future Effectiveness Evaluations.

4.1.5.2. Background

In the African region, the issue of POPs is undoubtedly a recent one as revealed by many countries that have elaborated their National Implementation Plans (NIPs) under the Stockholm Convention. Certain knowledge does exist in the region on hazardous pesticides including POPs. Hence, researchers from different institutions either individually or as teams have conducted assessment of POP pesticides. However, very little was known in Africa about PCBs, dioxins and furans before the issues of the adverse effects of such compounds on humans and the environment was raised by the Stockholm Convention. Thus, there are few available data dealing with PCBs contamination and no monitoring data seemed to be recorded in the region on PCDDs/PCDFs. The ROG decided to include in this regional report only monitoring data on POP pesticides retrieved from the relevant literature, based on scientific papers published in international high level journals covering the time period recommended within the framework of this evaluation. Some data could be found on human milk, but they were recorded using procedures that were not similar to the WHO methodology.

4.1.5.3. Sampling

A variety of matrices have been analyzed with different sampling methodologies. In most cases sampling methodologies described in the papers do not clearly refer to international standard methodologies but employed internally validated methodologies.

4.1.5.4. Sample analytical procedures

The other media covered include soil, sediments, fish and foodstuff. Most of the publications reviewed do not mention QA/QC requirements, but all the papers selected for inclusion in this report used state-of the art equipment, especially GC and GC/MS with the conventional electron capture detector. Matrix samples were extracted using common organic solvents

often as mixtures thereof, the solvent evaporated, the residue properly cleaned and handled as appropriate and finally analyzed. The analytes were identified using authentic standards.

4.1.5.5. Data comparability

The monitoring data on soil, sediments, water, and food presented in this report cannot be compared across sites as they were not obtained from harmonized protocols/programs, and in addition have been recorded for different time periods.

4.1.5.6. Data storage

The only way the data selected can be considered as being stored to a certain extent, is that they were published in scientific journals and as such are available and could be consulted based on the references of the individual journals. It is not evident that the original laboratories that produced the results do have data bases for convenient analytical data storage. Indeed, it should be noted that there was no information on whether those laboratories were accredited or not.

4.2 Strategy concerning analytical procedures

Air sampling was conducted using established protocols provided by MONET Africa and GAPS. Sample analysis was conducted at centralised facilities following validated methods for RECETOX for MONET network, GAPS and backup laboratories at IVM University of Amsterdam and MTM at Örebro University for the data from UNEP/GEF project. Data from local regional laboratories were manly produced under the UNEP GEF capacity enhancement project and were compared with the results of backup laboratories. Further, data collected from passive ambient air sampling technique using PUF have been calibrated under regional conditions using two the two active sampling sites located in Kenya and Ghana. The samples were analysed at RECETOX.

Mother's milk samples were collected following the WHO protocol and analysed from the WHO reference laboratory.

For active water sampling, water was collected following the agreed upon protocol from UNEP/GEF project backup laboratories, whereas for passive samplers MONET Africa protocol was followed. Sample analysis for PFOS in water was conducted at centralised facilities at RECETOX and IVM and MTM for UNEP/GEF project. At the moment, the regional laboratories do not have sufficient capacities to participate in analysis of PFOS in water.

Data for other media were produced by MONET Africa (for soil collected in first evaluation) and through UNEP/GEF capacity enhancement project which covered soil, sediments, fish and food stuff for samples collected between 2010-2012. The data produced from the backup

laboratories were compared with those obtained from the regional laboratories that participated in the project.

4.3 Strategy concerning participating laboratories

POPs laboratories databank has been developed since 2005 through a global UNEP/GEF project "Assessment of Existing Capacity and Capacity Building Needs to Analyse POPs in Developing Countries". The databank is maintained and continuously updated by UNEP Chemicals to support the effectiveness evaluation of the Stockholm Convention Global POPs Monitoring Plan.

It is accessed through the URL: http://www.chem.unep.ch/Pops/laboratory/default.htm.

From the databank, most of the regional laboratories have GC-ECD and low resolution GC-MS. Very few laboratories are in possession of sophisticated instrumentation required for analysis of complex POPs such as dioxins and furans, PFOS and PBDEs. Both backup laboratories and regional laboratories participate in international inter-laboratory comparison studies to assess their performance in POPs analysis.

The laboratories are classified according to Tiers based on analytical instrumentation, accreditation, number of samples analyzed per year and qualification and experience in POPs analysis (UNEP Chemicals, 2007). The Tier categories include:

i) Tier 1 = High resolution gas chromatograph + High resolution mass spectrometer;
ii) Tier 2 = High resolution gas chromatograph + Low resolution mass spectrometer;
iii) Tier 3 = High resolution gas chromatograph + Electron capture detector;
iv) Tier 9 = No high resolution gas chromatograph (HRGC) or
-no high resolution mass spectrometer (HRMS),
- no low resolution mass spectrometer (LRMS),
- no electron capture detector (ECD).

Most of the regional laboratories listed in the POPs laboratory databank fall within the tier 3 hence not capable to analyse complex POPs such as dioxins/furans and PBDEs among others. This shows the need to invest heavily in building regional laboratory capacities to support activities under the NIPs and GMP. There is also need to continue updating the information in the databank as the capacities of laboratories are enhanced to provide updated information to their clients. New registrations and updating of laboratory information can be down by filling POPs laboratory questionnaire. Table 4.3 shows the summary of the regional POPs laboratories in the databank (UNEP, 2015).

Table 4.3 Summary of the regional POPs laboratories in the databank.

Name	Country	Region	Tier Value	Tier Percent
Environmental Chemistry Laboratory of CERES-LOCUSTOX Foundation	Senegal	Africa	3	30
Food and Drugs Control	Zambia	Africa	3	30
Department of Chemistry, University of Nairobi	Kenya	Africa	3	30
Central Laboratory of Residue Analysis of Pesticides and Heavy Metals in Food	Egypt	Africa	3	20
CITET - Centre International des Technologies de l'Environnement de Tunis	Tunisia	Africa	3	20
Multidisciplinary Central Research Laboratory/Basel Convention Regional Coordinating Centre for Africa	Nigeria	Africa	3	0
National Chemical Laboratories	Sudan	Africa	3	0
Department of Chemistry, Ghana Atomic Energy Commission	Ghana	Africa	3	0
Food and Drugs Board Laboratory Services Department	Ghana	Africa	3	0
Pesticide Residue Laboratory, Ghana Standards Board	Ghana	Africa	3	0
Environmental Chemistry Laboratory, CSIR Water Research Institute	Ghana	Africa	3	0
Environmental Toxicology and Quality Control Laboratory of Central Veterinary Laboratory	Mali	Africa	3	0

4.4 Data handling and preparation for the regional monitoring report

Each ROG member was tasked to collect readily available data from their respective sub-regions. Consideration was given to the contaminants identified under the Stockholm Convention and listed in GMP guidance document. Data on the core media namely; air, mothers' milk and water for perfluorinated compounds were considered. Supportive POPs data for other media were collected from regional international programmes/projects with verified QA/QC routine were also considered. Attention was given to reporting of individual compounds and congeners or isomers.

Data selection and evaluation followed the GMP guidelines with objective to provide sufficient supplementary data and information to allow valid interpretation of the datasets.

The data parameters required for each data set included:

i) The sampling location including site description;
ii) The time of sampling or the time period represented by the dataset;
iii) Data on other factors that may be relevant to interpretation of temporal trends for example, age/size of mothers sampled, volumes of air sampled, information on dietary habits of the sampled populations, methods employed, etc.;
iv) Data on parameters to allow conversion between reporting basis *e.g.* % lipid and methods used for lipid determination;
v) Information on methodologies employed for sampling, analysis and QA/QC routines;
vi) Information on results of laboratory performance in international inter-calibration exercises and laboratory performance testing schemes.

International programmes with comparable POPs monitoring data on core media such as MONET, GAPS and WHO with verified QA/QC protocols were invited to transmit their data to the GMP data warehouse. The uploaded data were verified and transmitted to the regional node for review; discussion and approval by ROG members before transmittal to the GMP regional data visualization tool and download to the regional report.

Effort was made to collect comparable human milk data in the sub-regions where data gaps were experienced during the first evaluation period, such as the southern Africa sub-region. New participating countries were invited to provide mothers' milk samples in order to fill identified gaps.

Data from other sources within the region that meet GMP criteria were collected by the ROG members using harmonized templates from GMP database for specific matrices. Collected data and/or original report were circulated for review by ROG members through the ROG coordinator. The identified originators of comparable data were invited to submit the data to the GMP data warehouse.

Format for data submission

The ROG members agreed to use the GMP templates for data collection from established programmes such as MONET, GAPS and WHO. Data from UNEP/GEF projects was uploaded to the GMP data capture tool and incorporated into the regional report.

Evaluation of readily available data sets

Evaluation of the regional data was conducted by the ROG members. Evaluation was based on the quality criteria established in the GMP guidance document. Data were evaluated and approved by the ROG members electronically under the GMP data warehouse.

Data storage

Data from regional GMP1 and GMP2 activities are stored in the regional node setup in the GMP data warehouse accessed at http://www.pops-gmp.org/dwh. In addition, the ROG platform established during GMP phase 1 contains the condensed summaries of the regional Monitoring activities.

Further, training will be required for all ROG members and key stakeholders to be able to use the platform and the regional node for data storage and information sharing to support their participation in implementing GMP activities in the region.

Accessibility to the Global database

The ROG members laid down the access permits to the regional node to facilitate wider stakeholder access to the regional data and enhance regional information dissemination. The access permits include:

i) All ROG members access the platform to evaluate the regional data.

ii) Identified originators of the approved POPs data access the platform to upload and/or verify the data entries.

iii) The identified consultants for drafting the regional report access the platform to review the data.

iv) Upon completion of evaluation and agreement by the ROG members, the ROG coordinator performs the final approval of the data to the GMP data warehouse and usage in the regional report.

v) Participants in ambient air sample collection, mothers' milk collection and water collection access the platform data visualization to review their site data.

vi) Regional focal points and national contacts access the platform data visualization tool to use their national data in POPs management strategies.

Statistical considerations

The correct definition of data is a prerequisite for the subsequent statistical analysis. Only reliably reported concentration values can be accepted for any spatial or temporal comparison. Therefore, a multilevel evaluation procedure based on the annually aggregated concentration values is implemented in order to maintain a high predictive value of the GMP records while avoiding bias in the concentration values.

The data evaluation procedure in place in the second phase GMP guarantees comparability of the different samples, especially from the point of view of the type of site, matrix, sampling

method, time span and sampling frequency. Heterogeneity in these factors might dramatically increase the uncertainty in the final outcomes. The processing procedures in place also limit the impact of uncontrolled covariates and thus reduce the risk of false trend detection or neglecting truly significant changes.

Details on statistical considerations and their implementation in the second phase GMP are available in the guidance document (UNEP/POPS/COP.6/INF/31).

The information warehouse

Harmonized data handling and appropriate support given to the collection, processing, storing and presentation of monitoring data in regions with limited capacity was a major focus of the work in the second phase GMP. A global monitoring plan data warehouse supports data collection and assists the regional organization groups and the global coordination group in producing the regional and global monitoring reports, and the effectiveness evaluation. It includes an interactive on-line data capture system, handling, and presentation module.

The global monitoring plan data warehouse also constitutes a publicly available repository of valuable information that can serve as a useful resource for policy makers and researchers worldwide. The tool is available at www.pops-gmp.org.

Data from existing programmes

Data from existing programmes as described in 4.1.1-4.1.4 have been incorporated in the GMP data warehouse and made available to the regional organization groups for validation and analysis. Access to information from ongoing existing monitoring progarmmes and activities is provided to the regional organization groups in an efficient and user friendly manner for the development of monitoring reports, and ensures harmonized data analysis and presentation across the regions.

4.5 Preparation of the monitoring report

The Regional report was drafted by ROG members with the assistance of the consultant: Prof. Komla Sanda: Professor of Chemistry at the University of Lomé, Togo.

Responsibilities of the drafting team

To review the first Africa GMP report and subsequent chapters according to the guideline and template from the Stockholm Convention Secretariat and develop the Second GMP regional report.

To receive all the readily available data collected by the ROGs and the supplementary generated from the Africa region, analyse and present it in a manner recommended for Global

monitoring report (following GMP Template and Chapter 7 of the revised Global Monitoring Plan guidance document).

To draft the second Global monitoring report for the Africa region in the manner recommended by the TWG and the secretariat: Specifically the report should include the following components:

i) Introduction covering the objectives of Article 16 of the Stockholm Convention and of the GMP drafted by the Secretariat.

ii) Description of the Africa region covering overall composition of the region, political, geographical, links to POPs, industrial activities, agriculture and regional boundaries.

iii) Description of the organization arrangements made in the Africa region to facilitate the implementation of GMP.

iv) Description of the methodology for sampling, analysis and handling of data used in the implementation of GMP in Africa region.

v) Description of the arrangements made to oversee the preparation of the monitoring report in Africa region.

vi) Description of the results of the substances in Annexes A, B and C of the Stockholm Convention including all new POPs and description of the historical, and current sources, regional considerations, trends in environmental levels reported elsewhere; identification of data gaps and capacity development needs to fill the gaps; review of levels and trends to support subsequent effectiveness evaluations.

vii) Summary of findings of the GMP in Africa Region providing a clear and concise synopsis of the results of the Global POPs Monitoring Programme to be used by the Conference of the Parties for effectiveness evaluation of the Stockholm convention.

viii) References to the literature covered in the preparation of the report.

The consultant was allowed to conduct further research to obtain additional appropriate information. The draft report was discussed during and improved during the ROG drafting workshop in Nairobi Kenya, in October 2014.

The draft report was circulated and endorsed regionally before the final copy was submission to the Secretariat of the Stockholm Convention.

5. RESULTS

5.1 The results in context

This second monitoring report synthesizes information from the first and second phase of the global monitoring plan and presents the current findings on POPs concentrations in the Africa Region. While a comparison of the levels was of effective relevancy, temporal trends analysis could not be undertaken due to the short sampling time frame and discontinuity throughout the sampling year either in participating countries or individual sampling sites. Moreover, some chemicals were only analysed only on very few sites, and some were not even analysed.

Therefore, future network has to be carefully considered from the sustainability point of view taking into account local capacities (trained personnel, travel funds, analytical infrastructures, etc.). Considering the geographic coverage, sampling sites from the North Africa represent the weakest point of the current network.

The overview of the POPs in ambient air over the period 2008-2013 in the region is as follow:

In Congo, the most important POPs detected were PCDDs/PCDFs, PCBs, endosulfan and gamma-HCH with variable concentrations over time.

The most prevailing contaminants in DR Congo were Annex A industrial chemicals (HCB, PCBs and POP-PBDEs) and PCDDs/Fs and HCHs

In Ethiopia, sampling at the Addis Ababa and Asela sites in 2010 and 2011 showed that HCB, *gamma*-HCH, *alpha*-endosulfan, PCBs, DDTs as well as dioxins and furans were the main POPs of concern.

Ambient air sampling in Ghana in 2010 and 2011 showed that almost all POPs were present at the sites of Abetefi and Accra. The most prevailing were endosulfans, HCH, DDTs (pesticides), PCBs and dioxins and furans.

Sampling campaigns at the Mt. Kenya site were made annually from 2008 to 2012. All POPs were detected over the sampling period with the exception of toxaphene, mirex and dl-PCBs.

Ambient air in Mali from 2008 and 2013 at the sites of Bamako and Tombouctou had measurable levels of almost all POPs with the most important ones being PCBs, DDTs, HCB, *alpha*-endosulfan, dioxins and furans.

In Mauritius, the prevailing POPs found in ambient air were DDTs, endrin, endosulfan, HCB, PCBs, dioxins and furans.

In Nigeria, ambient air was predominantly contaminated by *alpha*-endosulfan, gamma-HCH, DDTs, PCBs and dioxins and furans.

In Senegal, sampling of ambient air in 2008, 2010 and 2011 revealed that the prevailing POPs were HCHs, *alpha*-endosulfan, dieldrin, DDTs, PCBs, dioxins and furans, all of them in decreasing concentration over the sampling period.

Pesticides including *alpha*-endosulfan, HCB, gamma-HCH and oxychlordane were the most prevailing POPs in South Africa during the sampling period.

In Sudan, most of the POPs with variable contamination levels were detected in ambient air except dl-PCB and mirex over the period 2008-2012.

All POPs of interest were found in Togo at the site of Koumakonda. The most important POPs detected in ambient air over the period 2008-2011 were DDTs, HCB, HCHs and *alpha*-endosulfan, PCBs including dl-PCBs, dioxins and furans.

In Uganda, most important pollutants were DDTs, dieldrin, HCB and indicator PCBs.

Almost all POPs were found at Lusaka site except POP-PBDEs over the period 2008-2011. The most important contaminants were DDTs, chlordanes, dieldrin, HCB, HCH, indicator PCBs and dioxins and furans.

5.2 Review of concentrations and their changes over time in Africa

5.2.1 Ambient air

5.2.1.1. Aldrin

Fourteen countries participated in the sampling campaigns from 2008-2012 with a total of 27 sampling sites. Figure 5.2.1.1) shows the spatial distribution of aldrin in MONET Africa sampling sites from 2010-2012. High levels of aldrin were observed at Abetefi, Kongo and Brazaville.

Figure 5.2.1.1 Aldrin levels in ambient air (PAS, ng sample-1) in Africa, 2010-2012

The concentrations of aldrin in 2008 ranged from 1.36 pg.m^{-3} in Tombouctou (Mali) to 21.06 pg.m^{-3} at Khartoum (Sudan). In 2009, data on ambient air contamination by aldrin was available only for South Africa, where contamination level at the sites of De Aar and Vanderbijil Park was 0.49 pg.m^{-3} (Figure 5.2.1.2).

In 2010, all participating countries provided data except South Africa; aldrin levels in ambient air ranged from 1.66 to 5.39 pg.m^{-3}; the higher contaminations was found at Abetefi in Ghana (5.39 pg.m^{-3}), Bamako in Mali (4.26 pg.m^{-3}), Ngoye Bambey in Senegal (4.05 pg.m^{-3}) and Addis Ababa in Ethiopia (4.01 pg.m^{-3}).

In 2011, the lowest level of aldrin (0.28 pg.m^{-3}) was measured at Addis Ababa site in Ethiopia and the highest (43.01 pg.m^{-3}) at Kinshasa site in DR Congo. In 2012, the levels of aldrin ranged from 0.84 pg.m^{-3} at Nooitgedacht site in South Africa to 2.81 pg.m^{-3} at Cogelos site in DR Congo.

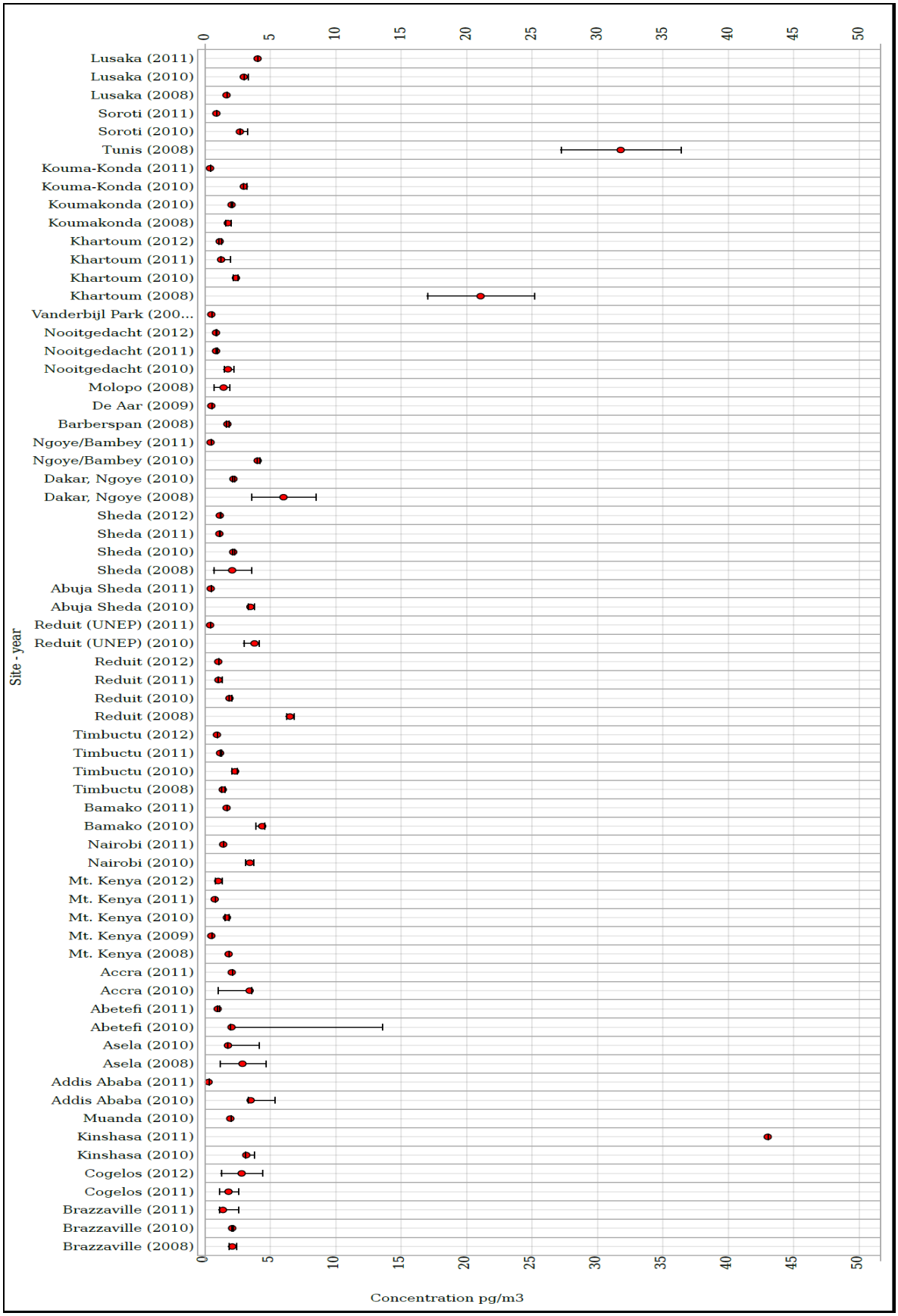

Figure 5.2.1.2 Concentration of aldrin in ambient air

5.2.1.2 Chlordanes

The general distribution of chlordanes over the period 2010-2012 is summarised in Figure 5.2.1.3. High levels were observed at Kouma Konda, Khartoum, Sheda, Payrs and Canary Island.

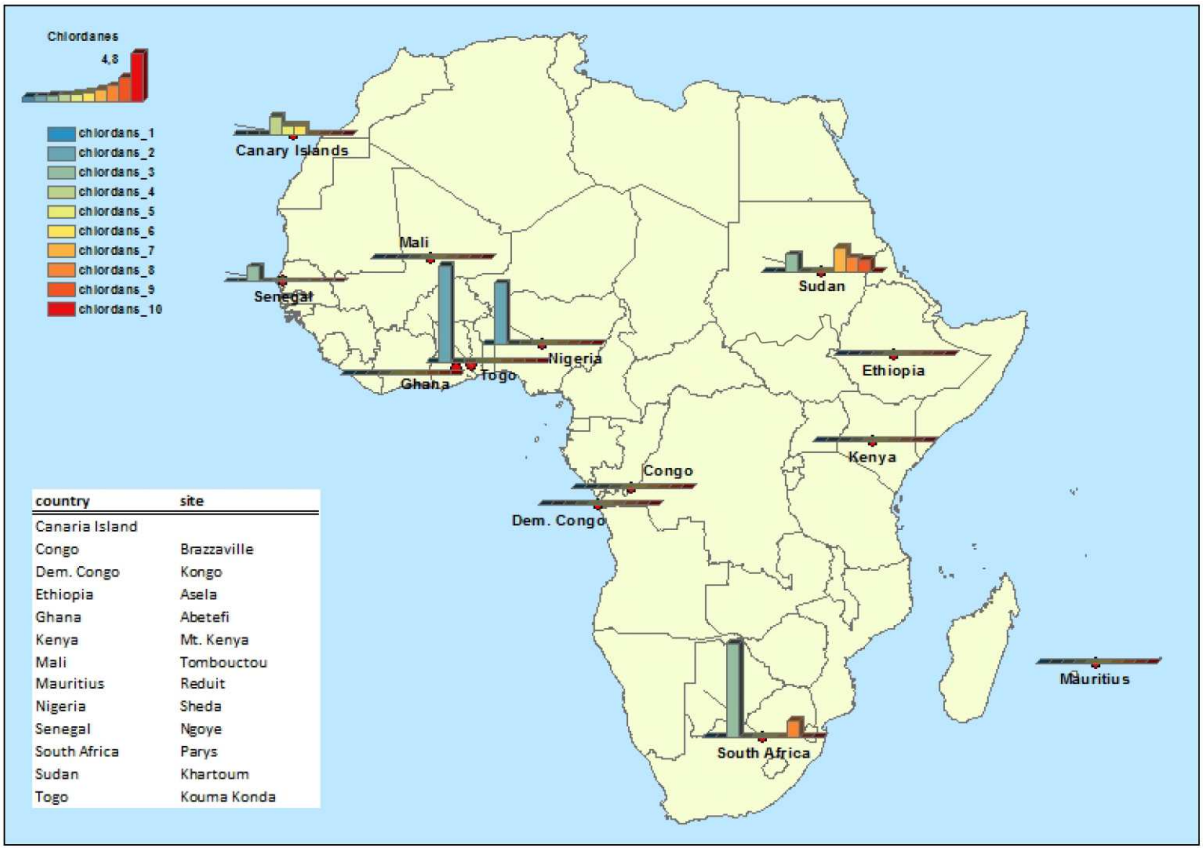

Figure 5.2.1.3 Chlordane (2 isomers) levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

Sixteen countries participated in the sampling campaigns from 2008-2012 at 27 sampling sites to determine ambient air contamination by chlordanes. Data collected included *cis*-chlordane (Annex), *trans*-chlordane and oxychlordane.

cis-chlordane

In 2008, the concentration levels of *cis*-chlordane ranged from 10.36 pg.m^{-3} at Mt. Kenya to 31.83 pg.m^{-3} at the site of Dakar Ngoye (Senegal). Data on *cis*-chlordane were collected only from Kenya and South Africa in 2009. The levels ranged from 0.25 pg.m^{-3} at Mt. Kenya site to 2.03 pg.m^{-3} at Vanderbijil Park site in South Africa. In 2010, the lowest level of *cis*-chlordane (1.60 pg.m^{-3}) was measured at the Soroti site in Uganda, while the highest values were recorded at Addis Ababa, Ethiopia (14.43 pg.m^{-3}) and Lusaka in Zambia (14.06 pg.m^{-3}). In 2011, the lowest and the highest contamination levels were recorded in Mali at the

Tombouctou site (0.54 pg.m^{-3}) and the Bamako site (3.74 pg.m^{-3}). Sheda site in Abuja Nigeria also showed high levels of *cis*-chlordane (2.81pg.m^{-3}). In 2012, the levels of *cis*-chlordane ranged from 0.61pg.m^{-3} (Tombouctou, Mali) to 1.38 pg.m^{-3} (Khartoum, Sudan).

trans-chlordane

During the 2008 sampling period, Asela site recorded the highest levels of *trans*-chlordane with a mean concentration of 3.96 pg.m^{-3}, while the lowest levels were measured at Mt. Kenya with a mean concentration of 0.28 pg.m^{-3}. In 2009, only Kenya and South Africa provided data for *trans*-chlordane. Contamination levels were 0.14 pg.m^{-3} at Mt. Kenya and 1.20 pg.m^{-3} at Vanderbijil Park (Figure 5.2.1.4).

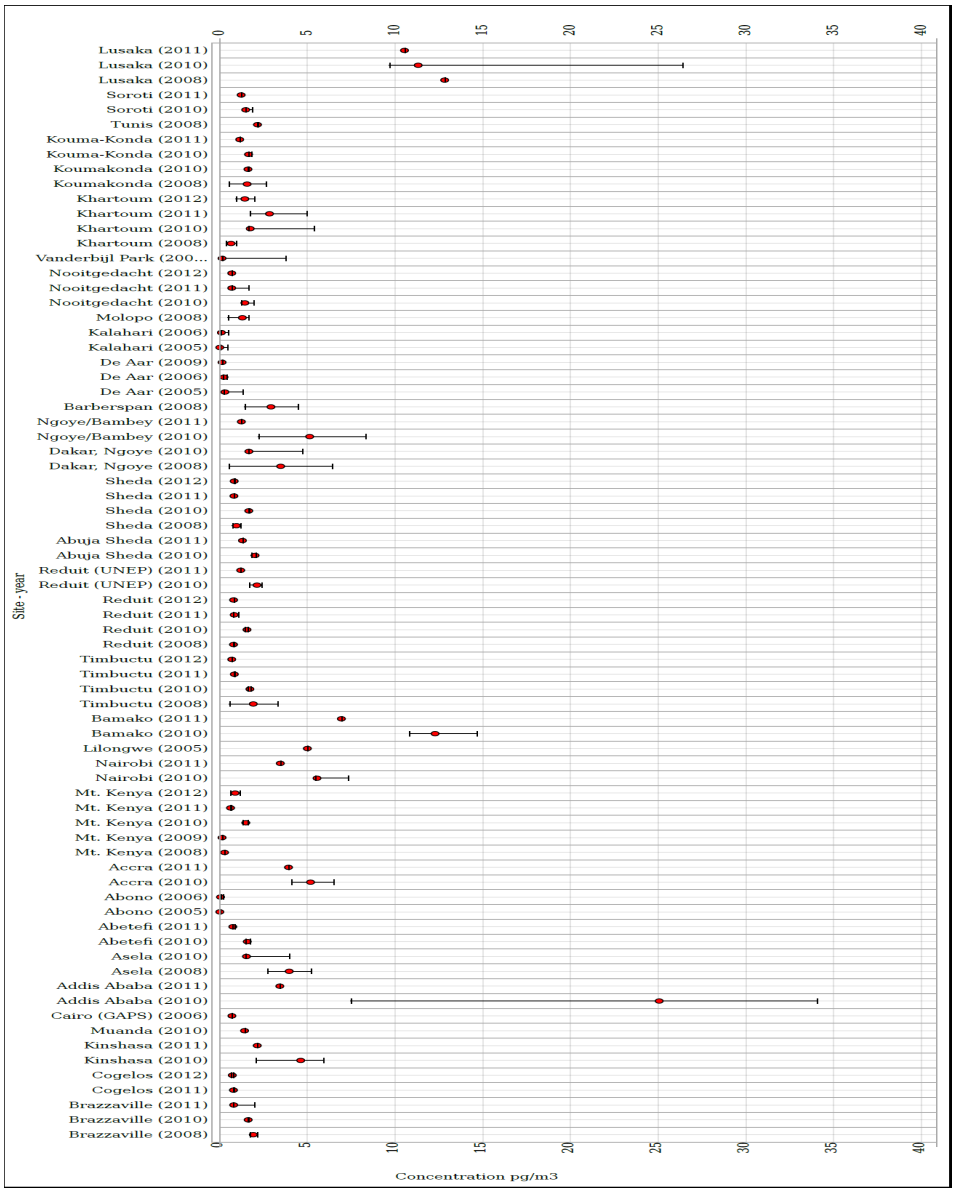

Figure 5.2.1.4 Concentration of trans-chlordane in ambient air

In 2010, the contamination range was 1.42 pg.m^{-3} (Muanda, DRC) to 25.19 pg.m^{-3} (Addis Ababa, Ethiopia). Other sites with high contamination level were Lusaka, Zambia (15.78 pg.m^{-3}), Bamako Mali (12.00 pg.m^{-3}) and Ngoye Bambey in Senegal (5.21 pg.m^{-3}). Sampling in 2011 showed the lowest levels at Mt. Kenya (0.62 pg.m^{-3}) and the highest concentrations at Lusaka in Zambia (10.53 pg.m^{-3}). Other samples with significant contamination were Bamako Mali (6.94 pg.m^{-3}), Kabete in Nairobi Kenya (3.46 pg.m^{-3}) and Khartoum Sudan (3.21 pg.m^{-3}). In 2012, the levels of chlordane ranged from 0.69 pg.m^{-3} at Nooitgedacht, South Africa to 1.44 pg.m^{-3} at Khartoum Sudan.

5.2.1.3. Trans-nonachlor

Twelve countries provided air samples that were analysed for *trans*-nonachlor in 2008. The result showed the highest *trans*-nonachlor concentration at Dakar Ngoye site (9.99 pg.m^{-3}) and the lowest at Mt. Kenya. In 2009, contamination of ambient air by *trans*-nonachlor was only measured in Kenya and South Africa (Figure 5.2.1.5). The levels were 0.058 pg.m^{-3} at Mt. Kenya and 0.77 pg.m^{-3} at Vanderbijil Park.

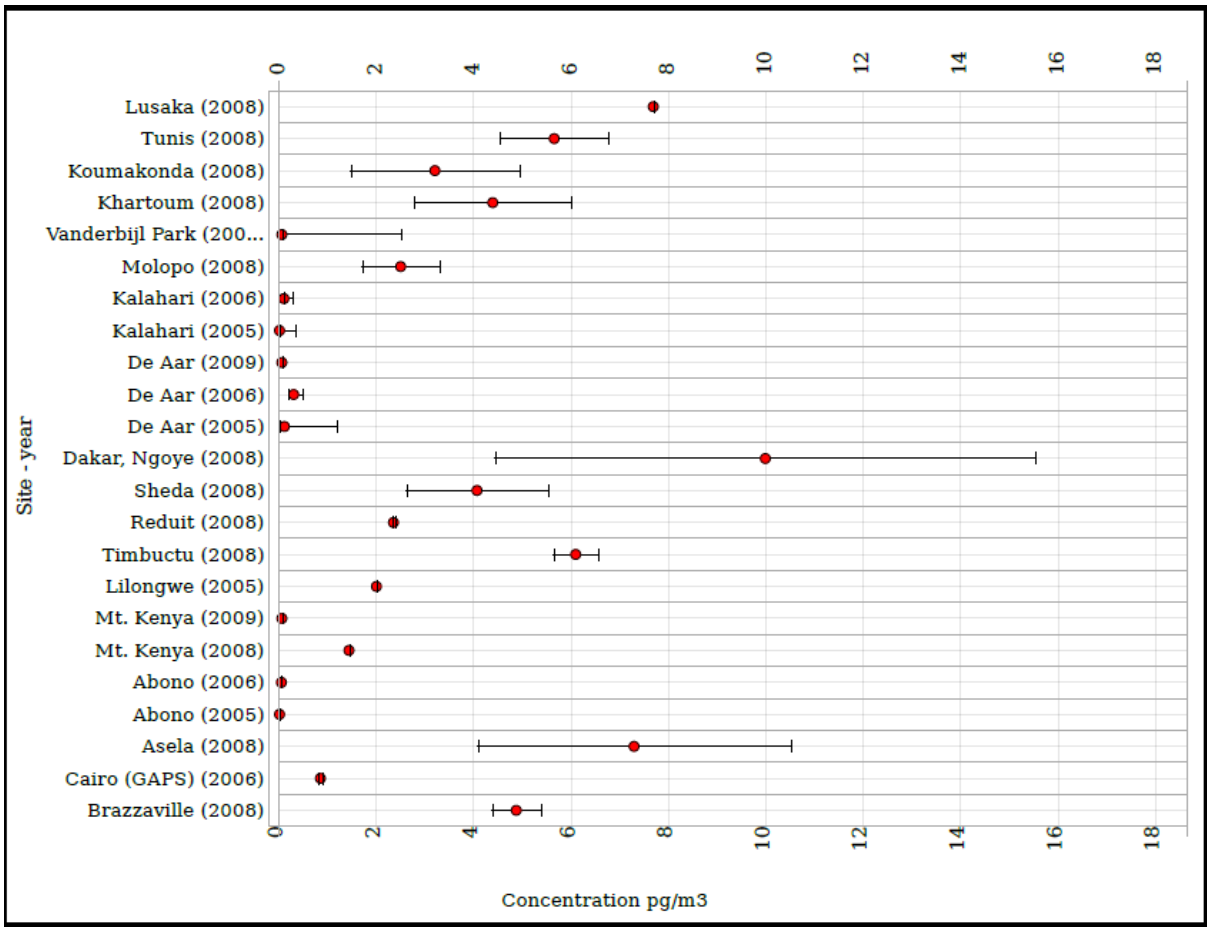

Figure 5.2.1.5 Concentration of trans-nanochlor in ambient air

Oxychlordane

In 2008 oxychlordane was reported only in two sites from South Africa with almost constant concentration of about 20 pg.m^{-3}. In the period running from 2010 to 2012, measurable concentrations of oxychlordane were were reported from 12 countries. Values ranged from 9.92 pg.m^{-3} (Mt. Kenya) to 17.85 pg.m^{-3} (Koumakonda Togo in 2010). In 2011, the highest air concentration of oxychlordane was measured at Khartoum Sudan (8.15 pg.m^{-3}) while the lowest was detected at Mt. Kenya (4.35 pg.m^{-3}). In 2012, oxychlordane levels ranged from 4.88 pg.m^{-3} at Nooitgedacht in South Africa to 6.24 pg.m^{-3} at Sheda in Nigeria.

5.2.1.4. Dieldrin

From MONET Africa sites, the highest levels of dieldrin in the second evaluation were measured in Khartoum Sudan, Ghana and Congo Brazaville (Figure 5.2.1.6).

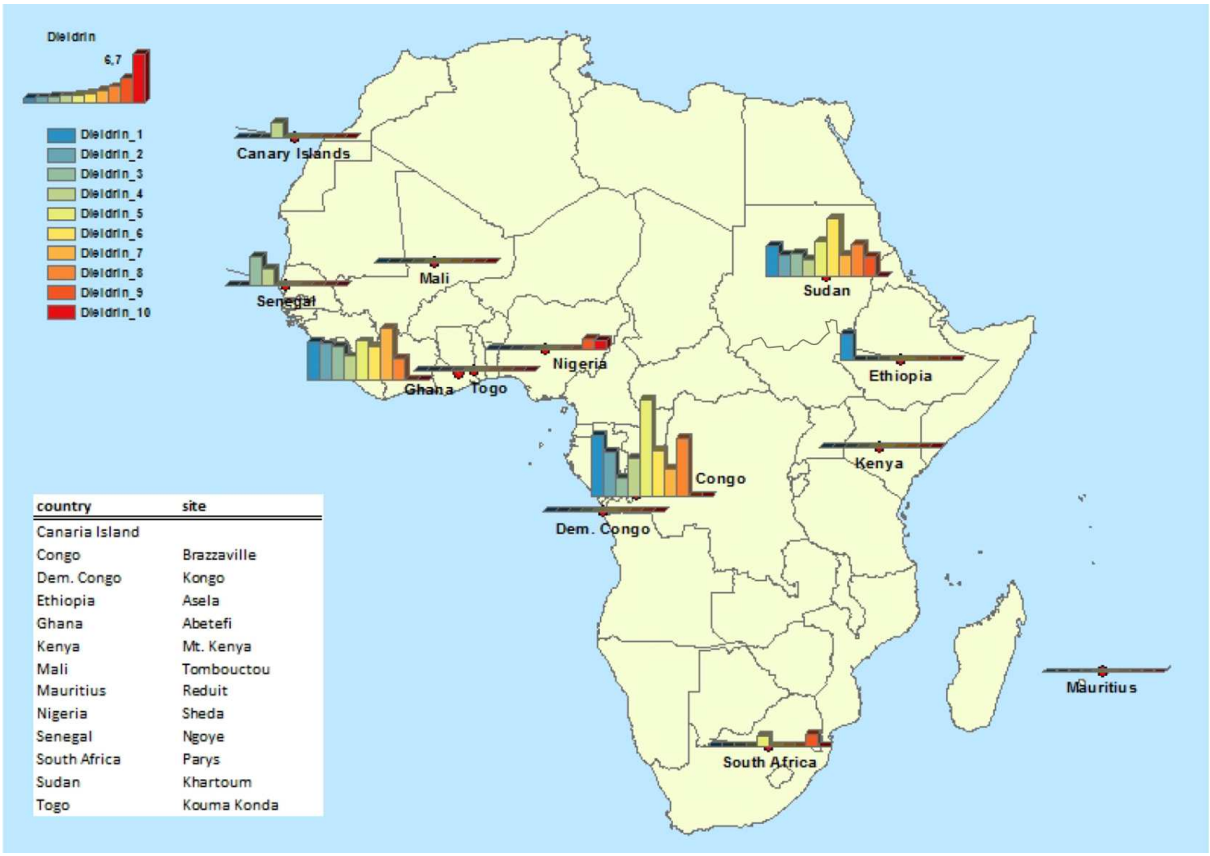

Figure 5.2.1.6 Dieldrin levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

Over the period 2008-2012, the mean concentration of dieldrin in 2008 varied from 0.46 pg.m^{-3} (Mt. Kenya) to 158.18 pg.m^{-3} (Dakar Ngoye). The second highest dieldrin level (46.06 pg.m^{-3}) was detected at Brazzaville. In 2009, only Kenya and South Africa provided data. The

highest concentration (15.72 pg.m^{-3}) was detected at Vanderbijil Park site and the lowest one (3.62 pg.m^{-3}) at De Aar in South Africa (Figure 5.2.1.7).

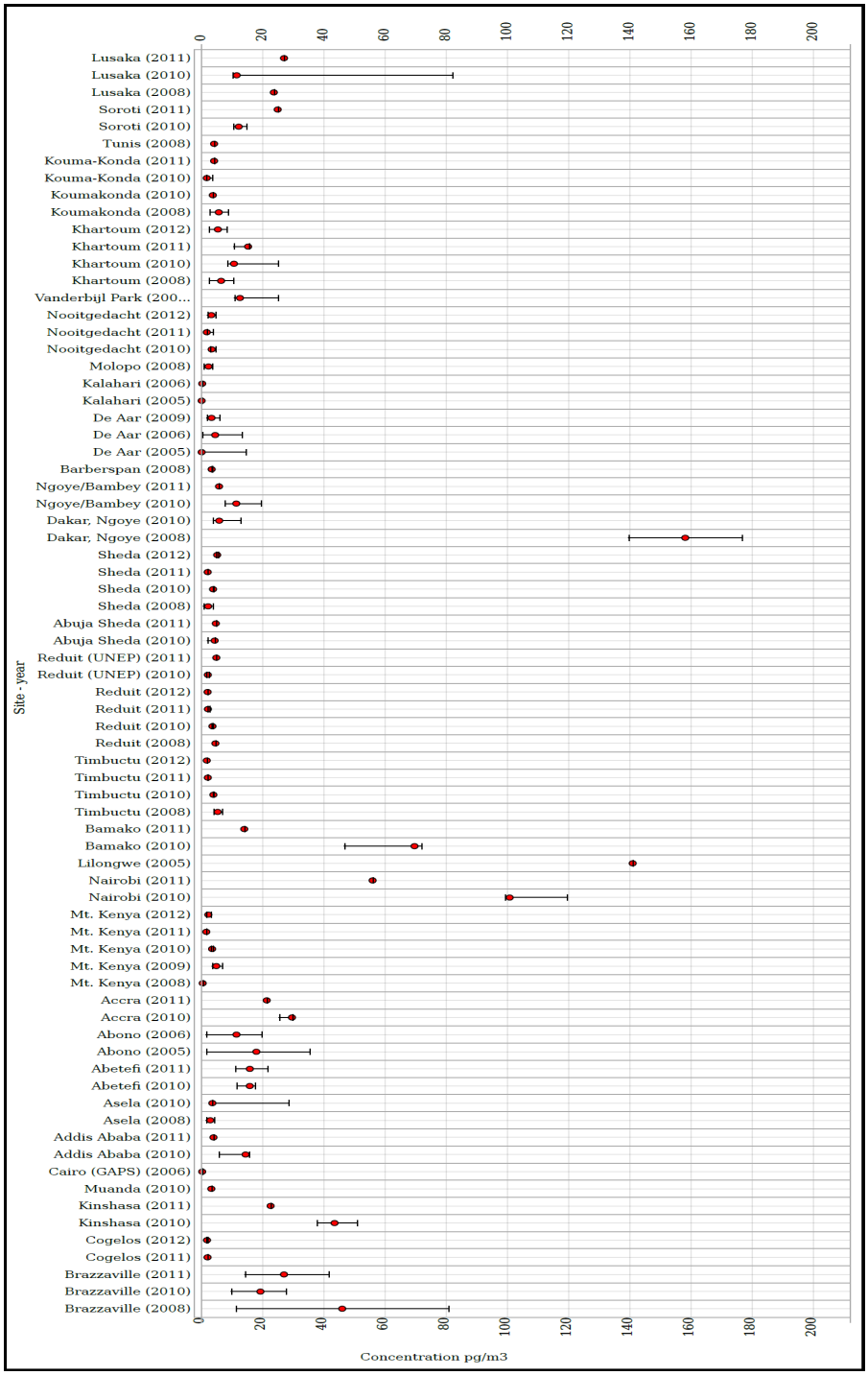

Figure 5.2.1.7 Concentration of dieldrin in ambient air

In 2010 high levels of dieldrin were found in Kabete, Nairobi Kenya (105.75 pg.m^{-3}), Bamako in Mali (62.81 pg.m^{-3}) and Kinshasa in DRC (44.11 pg.m^{-3}). Intermediate contaminated sites were Lusaka in Zambia (34.63 pg.m^{-3}) and Accra in Ghana (28.29 pg.m^{-3}).

The lower levels of dieldrin were detected at the following sites: Tombouctou in Mali, Reduit in The Seychelles, Sheda in Nigeria, Koumakonda in Togo, Muanda in DRC, Mt. Kenya and Nooitgedacht in South Africa.

In 2011, the sites with high levels of dieldrin were Accra in Ghana (21.39 pg.m^{-3}), Brazzaville in the Republic of the Congo (28.70 pg.m^{-3}), Kinshasa in DRC (22.66 pg.m^{-3}), Kabete in Nairobi Kenya (55.99 pg.m^{-3}), Lusaka in Zambia (27.04 pg.m^{-3}) and Soroti in Uganda (24.97 pg.m^{-3}). The sites with lowest contamination sites were Cogelos in DRC (2.04 pg.m^{-3}), Sheda in Nigeria (2.08 pg.m^{-3}), Tombouctou in Mali (2.13 pg.m^{-3}) and Nooitgedacht in South Africa (2.40 pg.m^{-3}). In 2012, low levels of dieldrin ranging from 1.79 (Tombouctou in Mali) to 5.492 pg.m^{-3} (Khartoum in Sudan) were detected.

5.2.1.5. Endrin

An overview of the distribution of endrin measured in ambient air from MONET Africa sites is shown in Figure 5.2.1.8. The highest levels of endrin were detected at sites in Khartoum, Sheda, Brazaville and Abetefi within the period 2010-2012. The concentrations were variable within different sampling intervals but no clear trend was established.

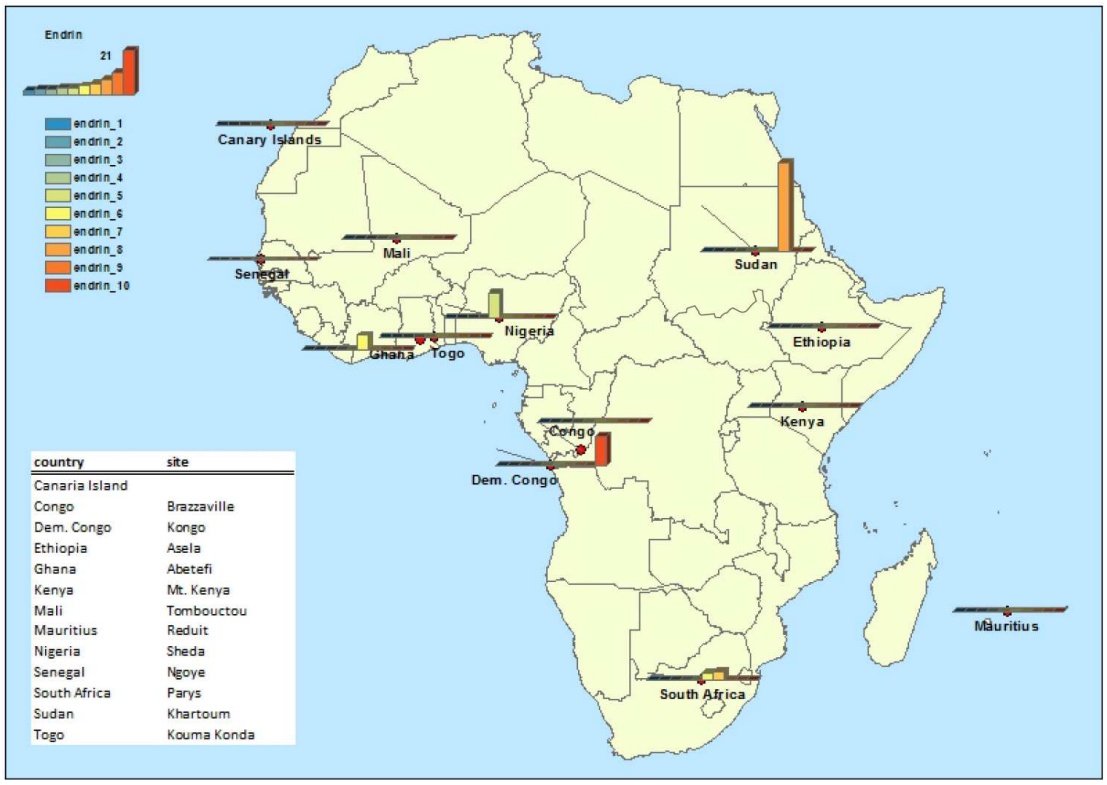

Figure 5.2.1.8 Endrin levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

In 2008, the highest and lowest concentrations of endrin were 18.21 pg.m^{-3} at Barbespan site and 0.90 pg.m^{-3} at Mt. Kenya, respectively (Figure 5.2.1.9). There was no monitoring of endrin evaluation during 2009 in the participating countries. Sampling campaign of 2010,

high levels of endrin were recorded at the sites in Khartoum in Sudan (40.24 pg.m^{-3}), Dakar Ngoye in Senegal (39.50 pg.m^{-3}), Reduit in Mauritius (31.61pg.m^{-3}), Abetefi in Ghana (32.94 pg.m^{-3}), Asela in Ethiopia (41.13 pg.m^{-3}), Tombouctou in Mali (38.82 pg.m^{-3}), Sheda in Nigeria (36.65 pg.m^{-3}), Brazzaville in Congo (34.82 pg.m^{-3}), Muanda in DRC (32.73 pg.m^{-3}), Mt. Kenya (27.78 pg.m^{-3}) and Nooitgedacht in South Africa (29.84 pg.m^{-3}).

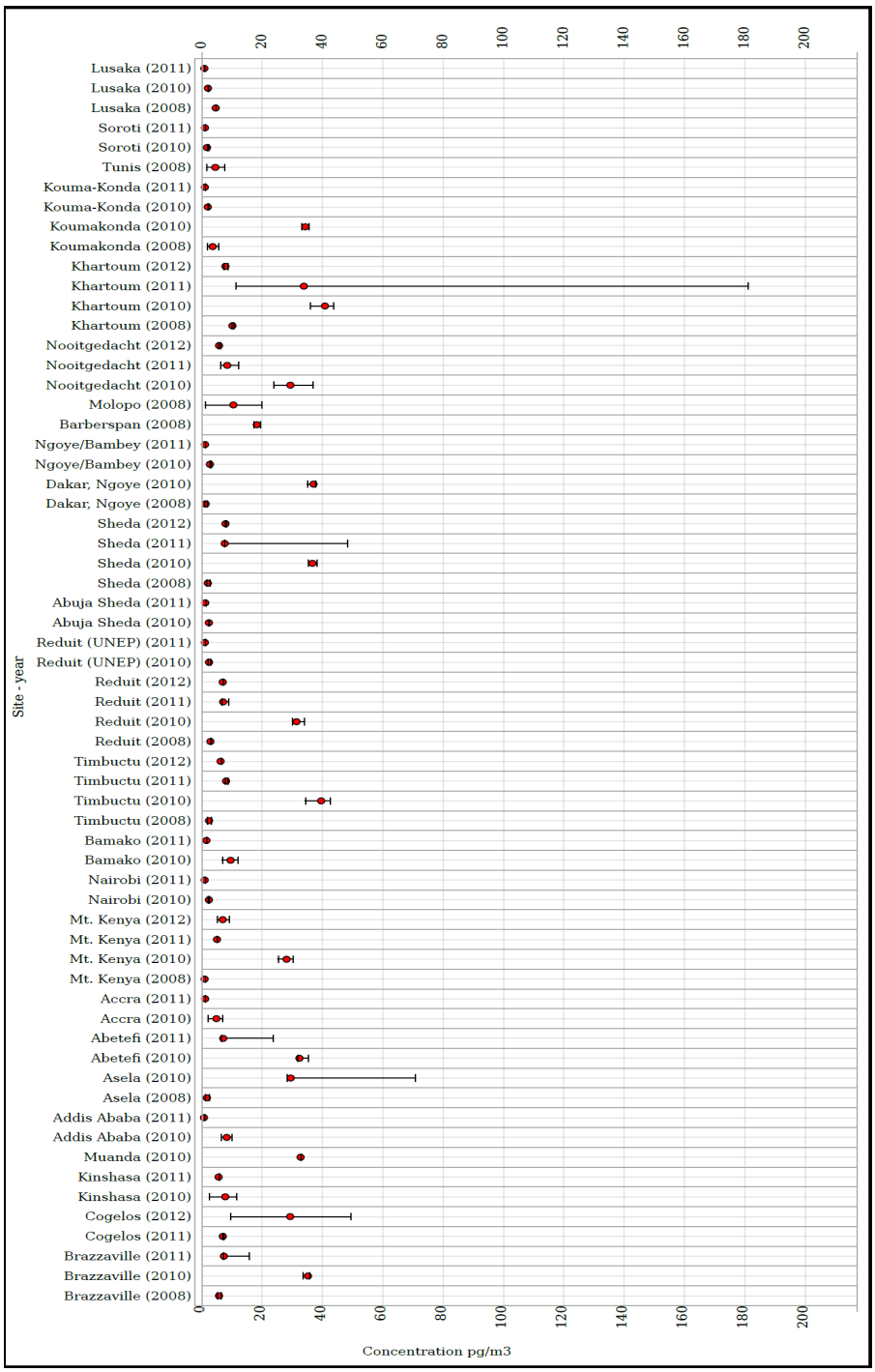

Figure 5.2.1.9. Concentration of endrin in ambient air

The sites that recorded low concentrations of endrin included Ngoye Bambey in Senegal, Reduit UNEP in Mauritius, Accra in Ghana, Abuja Sheda in Nigeria, Koumakonda in Togo, Kabete in Nairobi Kenya, Lusaka in Zambia and Soroti in Uganda, with levels ranging from 1.83 pg.m^{-3} (Soroti, Uganda) to 4.44 pg.m^{-3} (Accra, Ghana).

In 2012, the levels of endrins throughout the participating countries were rather low (ranging between 5.69 and 7.83 pg.m^{-3}), with the exception of the Cogelos site in DRC which registered levels reaching 29.27 pg.m^{-3}. Contaminations at remotes sites such as Mt. Kenya could be attributed to atmospheric transport of endrin.

5.2.1.6. Heptachlors

Figure 5.2.1.10 shows the spatial distribution of heptachlor in MONET Africa sites within the period 2010-2012. Abetefi and Khartoum sites recorded the highest concentration within this period whereas majority of the sites exhibited relatively low concentrations.

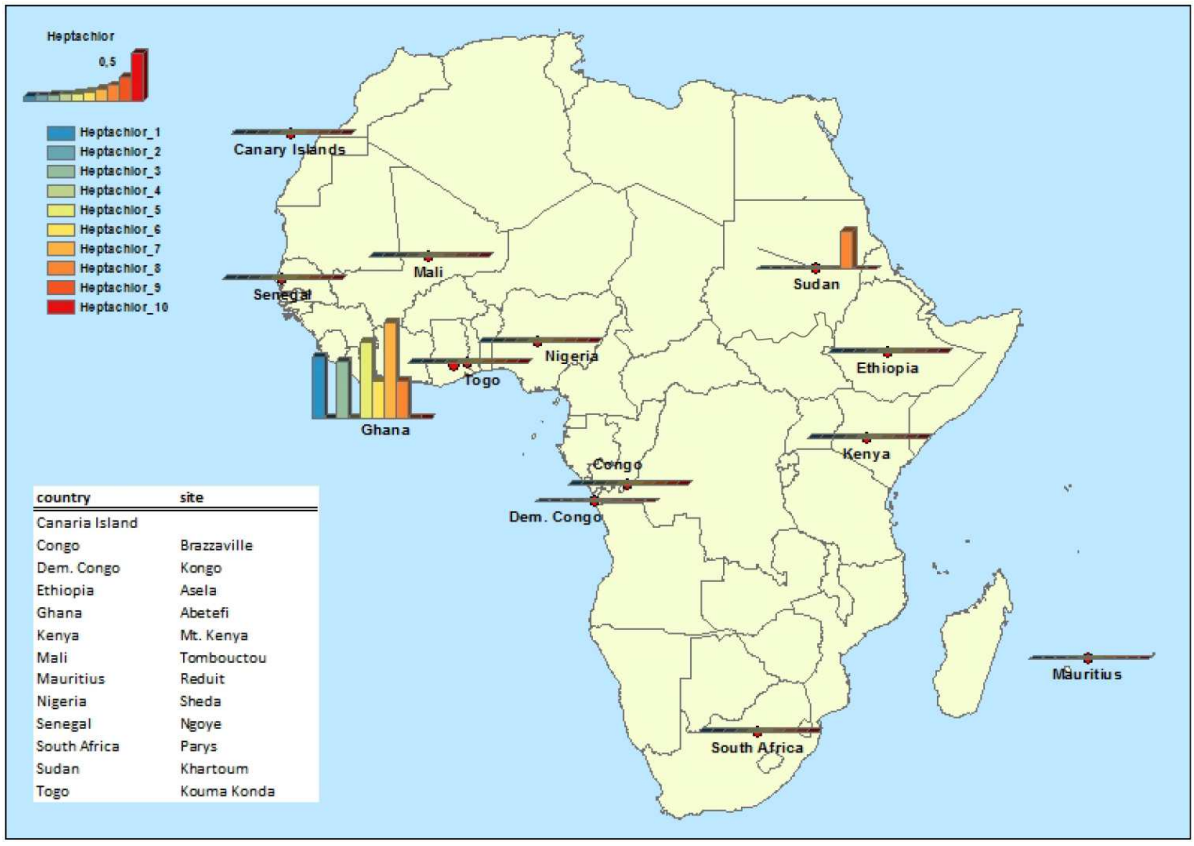

Figure 5.2.1.10: Heptachlor levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

Levels of heptachlors as *trans*-heptachlor and *cis*-heptachlor in ambient air in African region over the period 2008-2012 are shown in Figure 5.2.1.11. Thirteen sites were sampled in 2008, and Dakar Ngoye recorded the highest concentration while Barbespan had the lowest level of heptachlor.

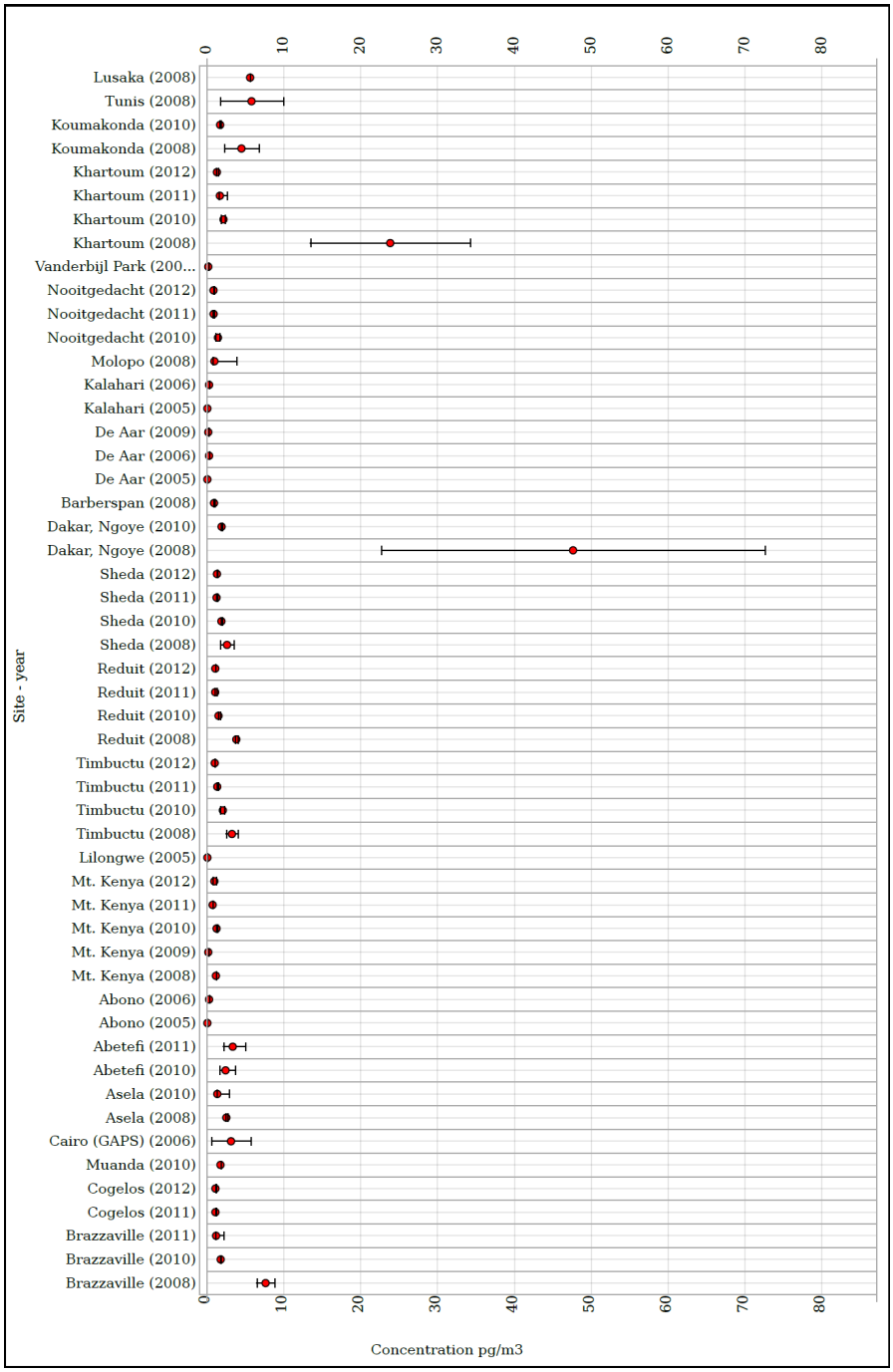

Figure 5.2.1.11 Concentration of heptachlor in ambient air

During 2009 ambient air sampling heptachlor levels were only measured in Kenya and South Africa giving comparable concentrations of 0.19 pg.m^{-3} in both countries. In 2010, heptachlor levels were almost uniform in all participating countries and ranged from 1.26 pg.m^{-3} (Reduit in Mauritius) to 2.57 pg.m^{-3} (Abetefi in Ghana).

In 2011, the levels of heptachlor ranged from 0.76 pg.m^{-3} (at Mt. Kenya) to 3.48 pg.m^{-3} (at Abetefi, Ghana). Throughout participating countries, heptachlor air pollution in 2012 was rather uniform ranging from 0.87 pg.m^{-3} (Nooitgedacht, SA) to 1.32 pg.m^{-3} (Sheda, Nigeria).

cis-Heptachlorepoxide

In 2008, there was no data on *cis*-heptachlorepoxide in the Africa region. However, in the following year in 2009, comparable levels of *cis*-heptachlorepoxide were recorded in Kenya and South Africa. In 2010 ambient air sampling campaign, the highest values were measured at Bamako, Mali (7.14 $pg.m^{-3}$), Accra, Ghana (3.56 $pg.m^{-3}$), Addis Ababa, Ethiopia (6.18 $pg.m^{-3}$) and Lusaka, Zambia (3.08 $pg.m^{-3}$). The same trend was observed in 2011 with highest levels recorded in the same sites (Figure 5.2.1.12).

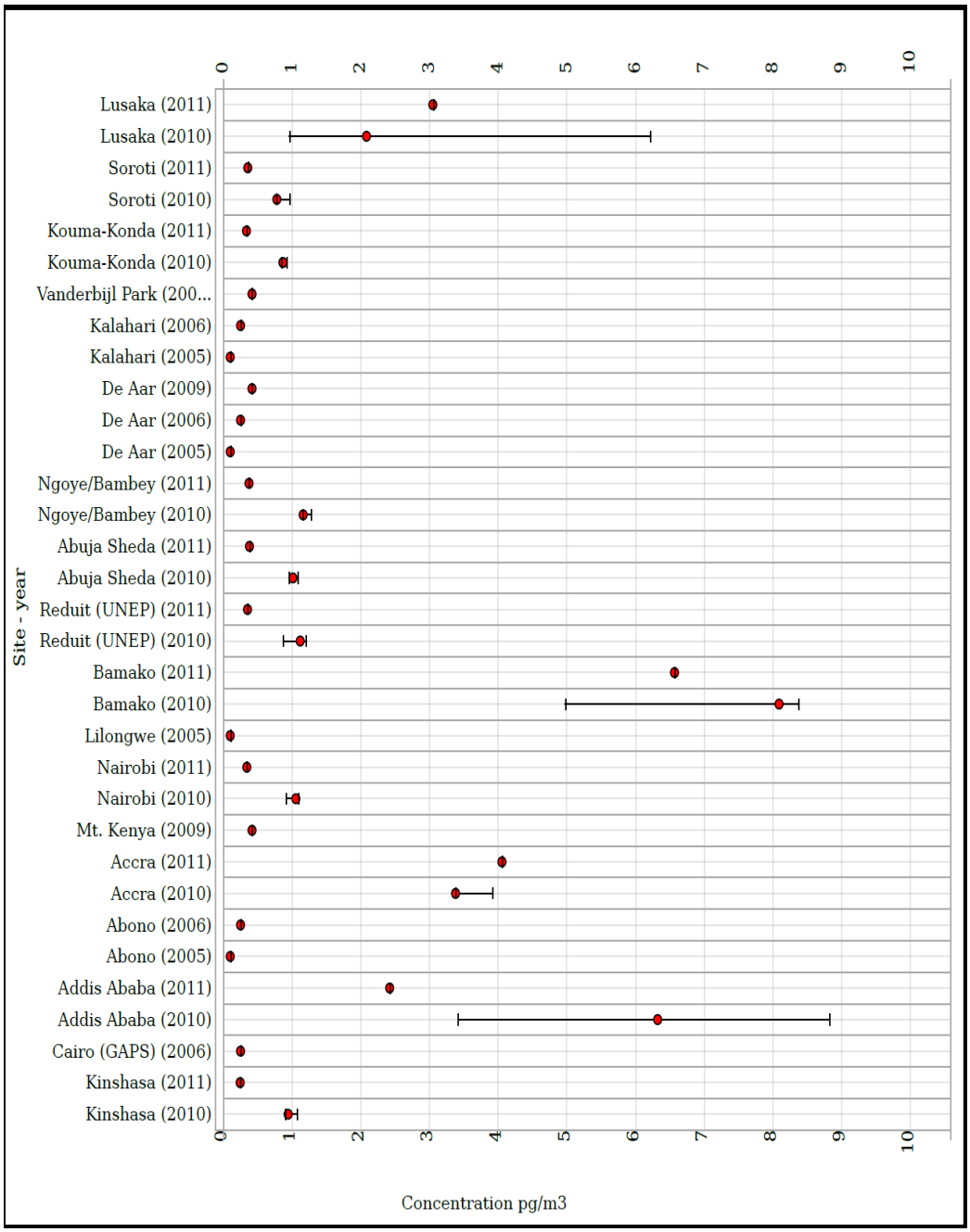

Figure 5.2.1.12 Concentration of cis-heptachlor epoxide in ambient air

5.2.1.7. Mirex

The general distribution of mirex in MONET Africa over the period 2010-2012 is shown in Figure 5.2.1.13. High levels were measured at Khartoum and Canary Island compared to the rest of the sites.

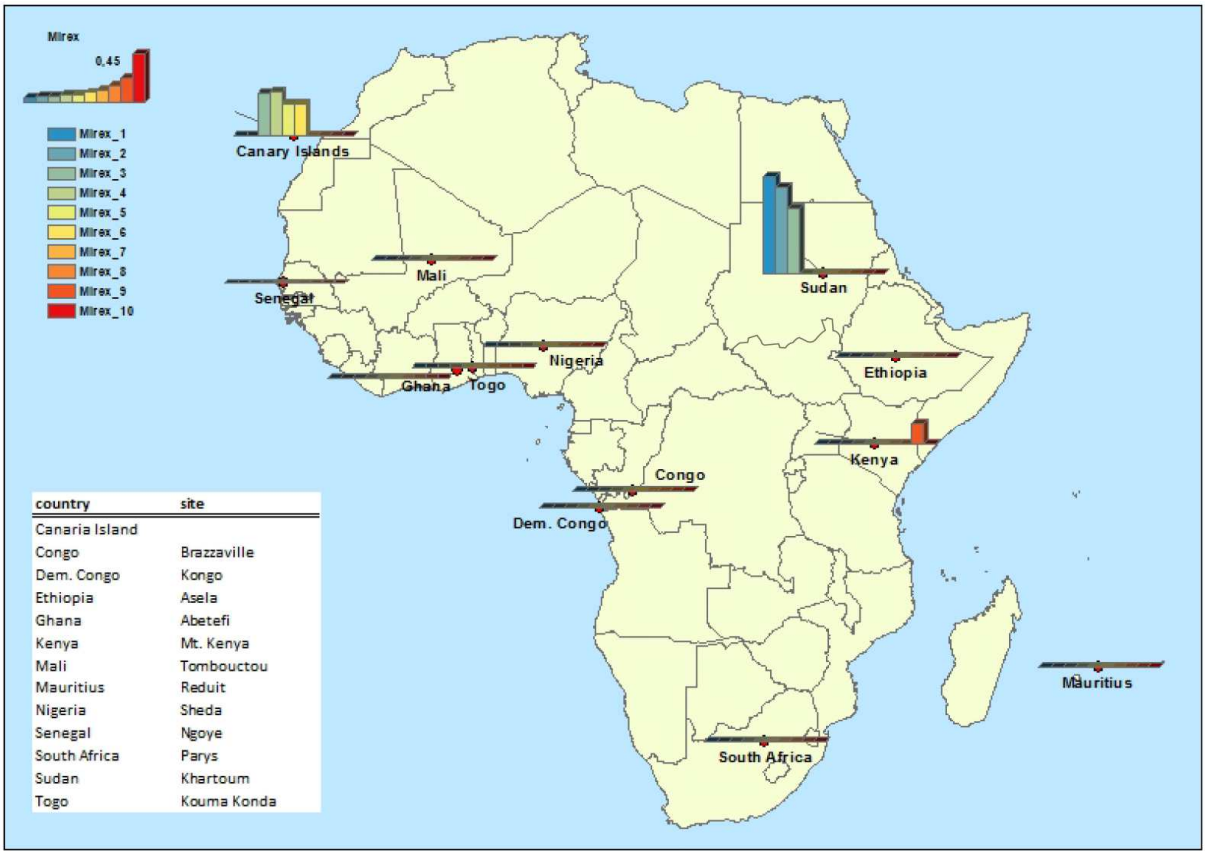

Figure 5.2.1.13 Mirex levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

Figure 5.2.1.14 shows mirex levels in ambient air for all reported sites over the period 2010-2011 in the Africa region. The results show that the levels of mirex in 2010 were quite uniform in most of the participating countries and ranged from 1.02 pg.m^{-3} (Accra, Ghana) to 1.77 pg.m^{-3} (Ngoye Bambey, Senegal).

In addition, there was a general decrease in the concentrations of mirex in participating countries in 2011, with the average concentrations ranging from 0.52 pg.m^{-3} (Lusaka, Zambia) to 0.86 pg.m^{-3} (Bamako).

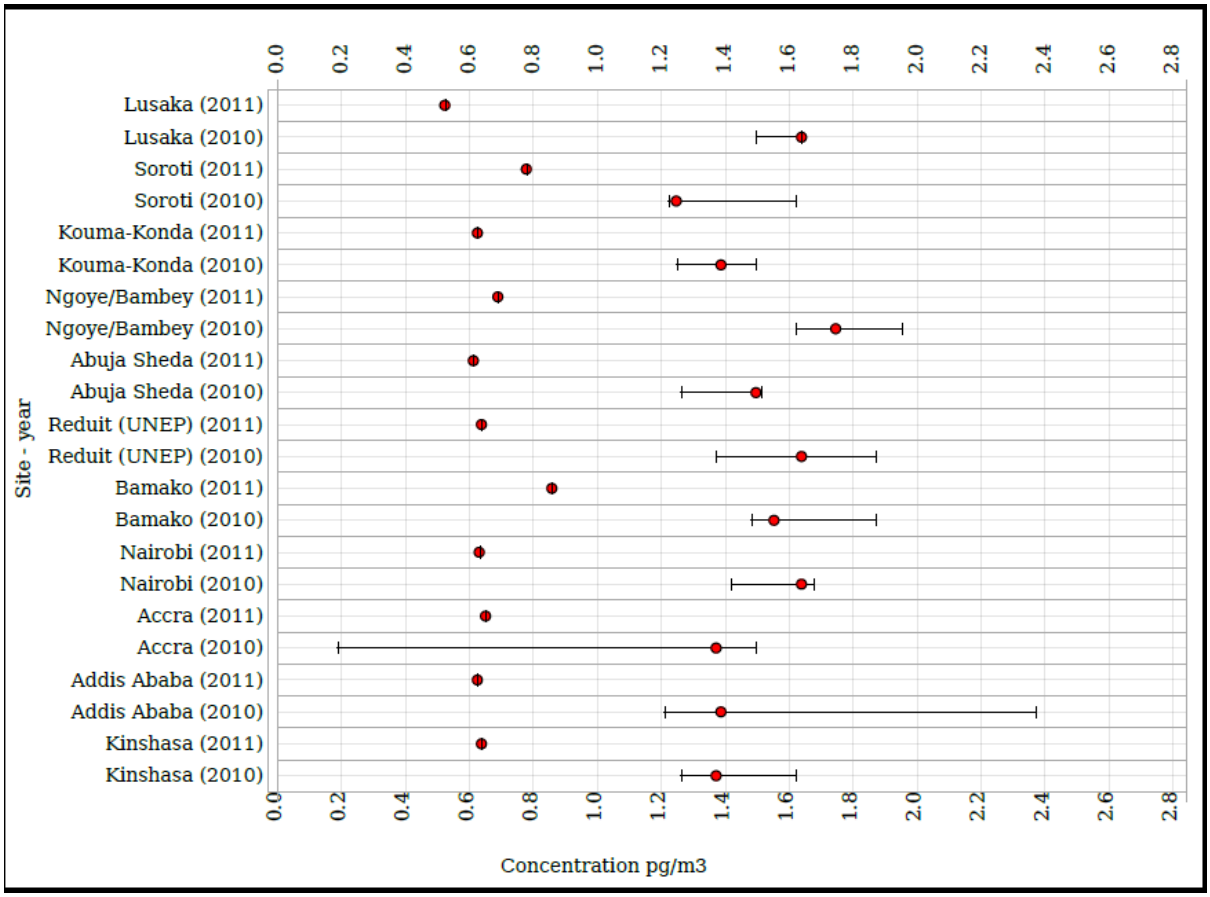

Figure 5.2.1.14 Concentration of mirex in ambient air

5.2.1.8. Dichlorodiphenyltrichlorethane (DDTs)

o,p'-DDT

The concentrations of *o,p'*-DDT were variable over 2008-2012 (Figure 5.2.1.15). In 2008, the levels of *o,p'*-DDT varied from 0.44 pg.m^{-3} at Tombouctou site to 504.87 pg.m^{-3} in Dakar Ngoye. In 2009 only Kenya and South Africa provided data for *o,p'*-DDT. The mean concentration was 2.51 pg.m^{-3} at Mt. Kenya and Vaderbijil Park and 9.04 pg.m^{-3} in De Aar (South Africa).

In 2010, the highest mean concentration (208.19 pg.m^{-3}) was measured at Lusaka site and the lowest (0.35 pg.m^{-3}) in Tunis. The contamination levels of *o,p'*-DDT in 2011 ranged from 0.31 pg.m^{-3} at Koumakonda site to 109.79 pg.m^{-3} at Lusaka site. In 2012, the mean concentrations of *o,p'*-DDT decreased, and varied from 0.13 pg.m^{-3} (Tombouctou) to 10.29 pg.m^{-3} in Khartoum.

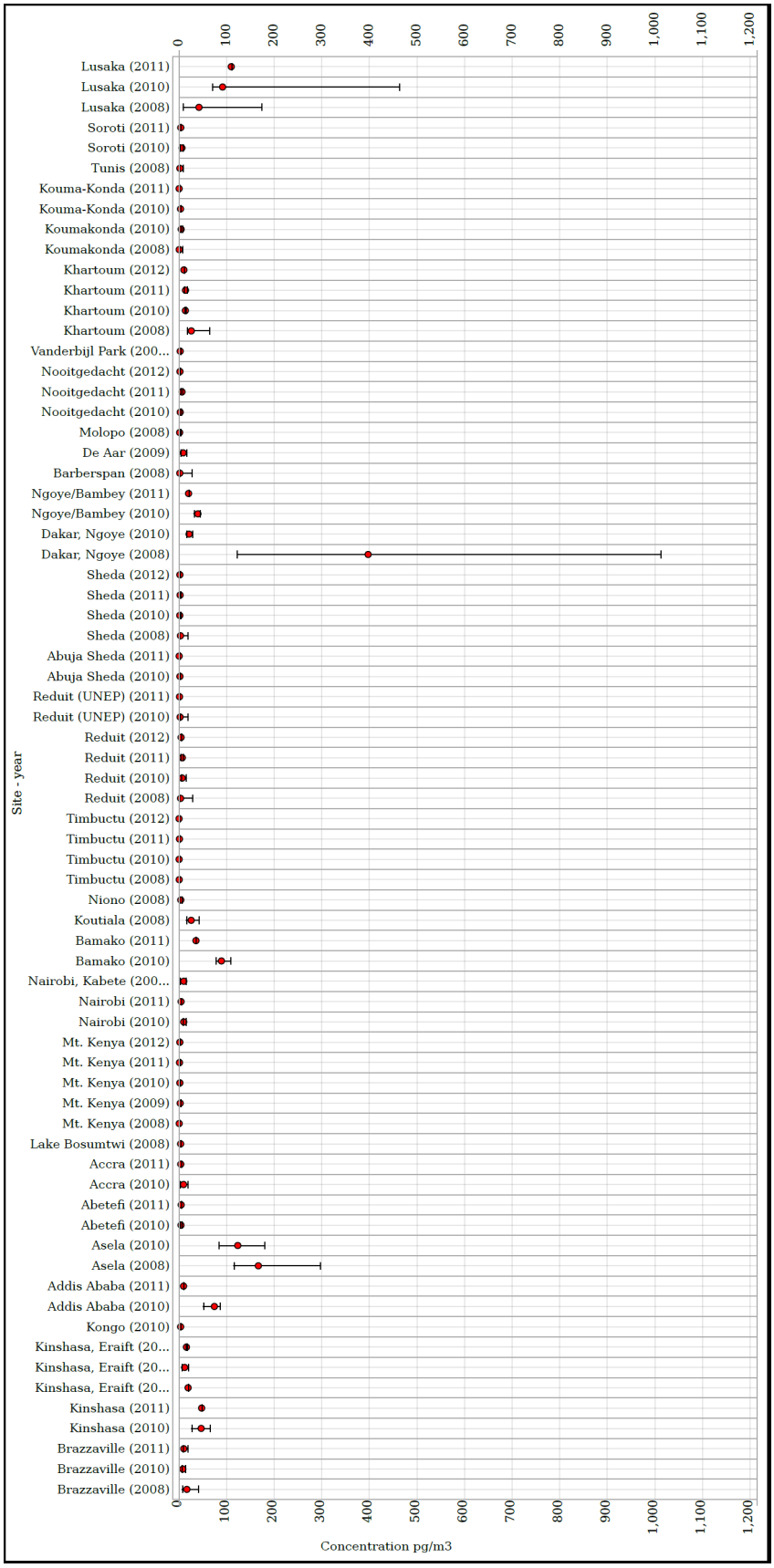

Figure 5.2.1.15 Concentration of o,p'-DDT in ambient air

p,p'-DDT

In 2008, Dakar Ngoye recorded the highest mean concentration of *p,p'*-DDT (1,481.96 pg.m^{-3}), while the lowest concentration level was found in Tombouctou (Figure 5.2.1.16). In 2009, the concentration of *p,p'*-DDT was 14.57 pg.m^{-3} at De Aar and 41.247 pg.m^{-3} at Vanderbijil Park in South Africa.

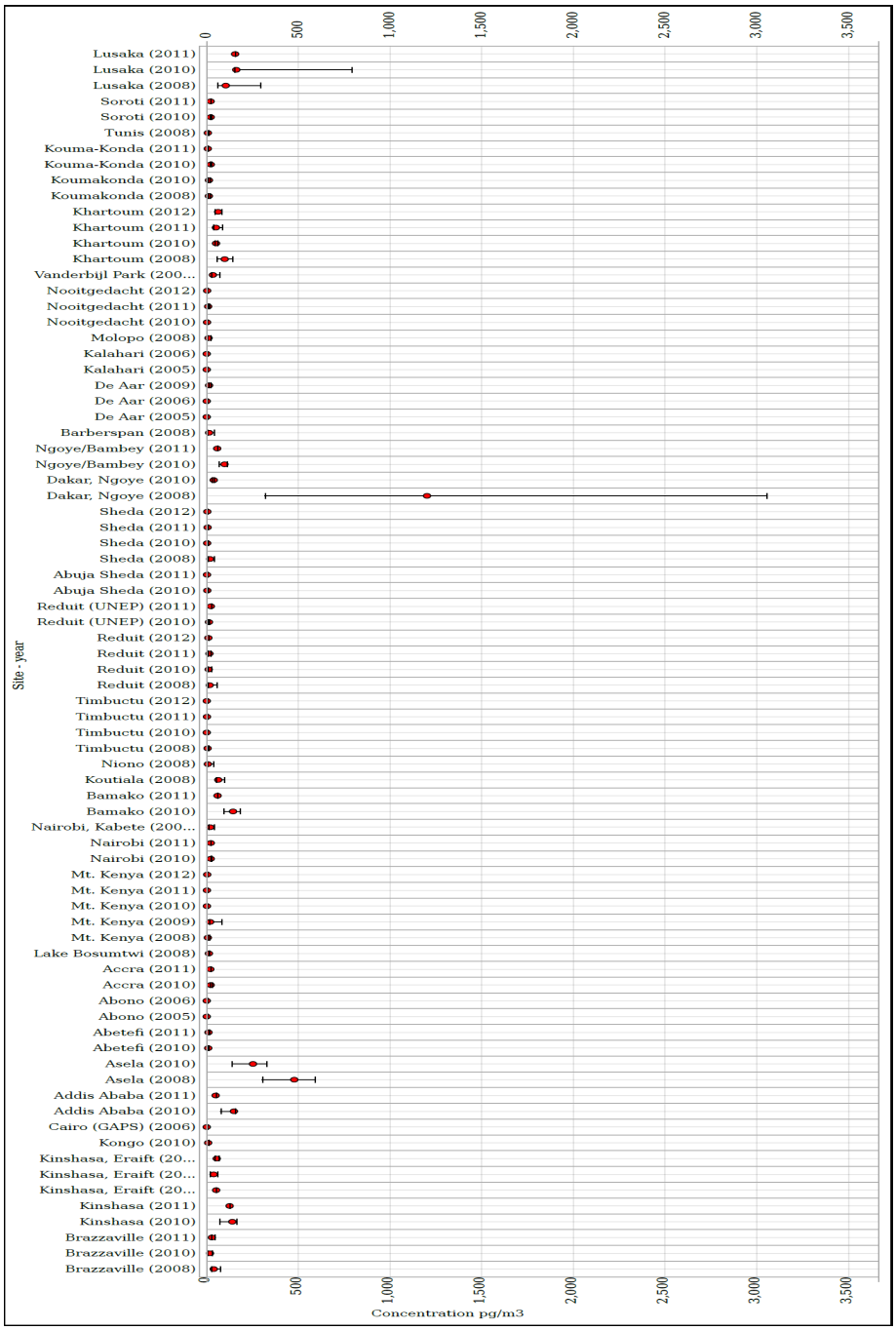

Figure 5.2.1.16 Concentration of p,p'-DDT in ambient air

Between 2010 and 2011, the highest levels of *p,p'*-DDT were found at Lusaka site with mean concentrations of 366.98 pg.m^{-3} and 155.21 pg.m^{-3}, respectively, while the lowest concentrations were measured at Tombouctou in both years. In 2012, the levels of *p,p'*-DDT varied from 2.50 pg.m^{-3} at Nooitgedacht (South Africa) to 62.50 pg.m^{-3} in Khartoum.

Sum DDTs

The sum concentrations of 6 DDTs contamination during the period 2009-2011 are shown in Figure 5.2.1. 17. In 2009, Vanderbijil Park (South Africa) recorded the highest concentrations with the mean concentration of 79.00 pg.m^{-3} followed by Mt. Kenya (45.32 pg.m^{-3}). In 2010, the highest levels of sum DDTs were recorded at Bamako Mali (1442.95 pg.m^{-3}), Lusaka Zambia, Ngoye Bambey, Kinshasa and Addis Ababa.

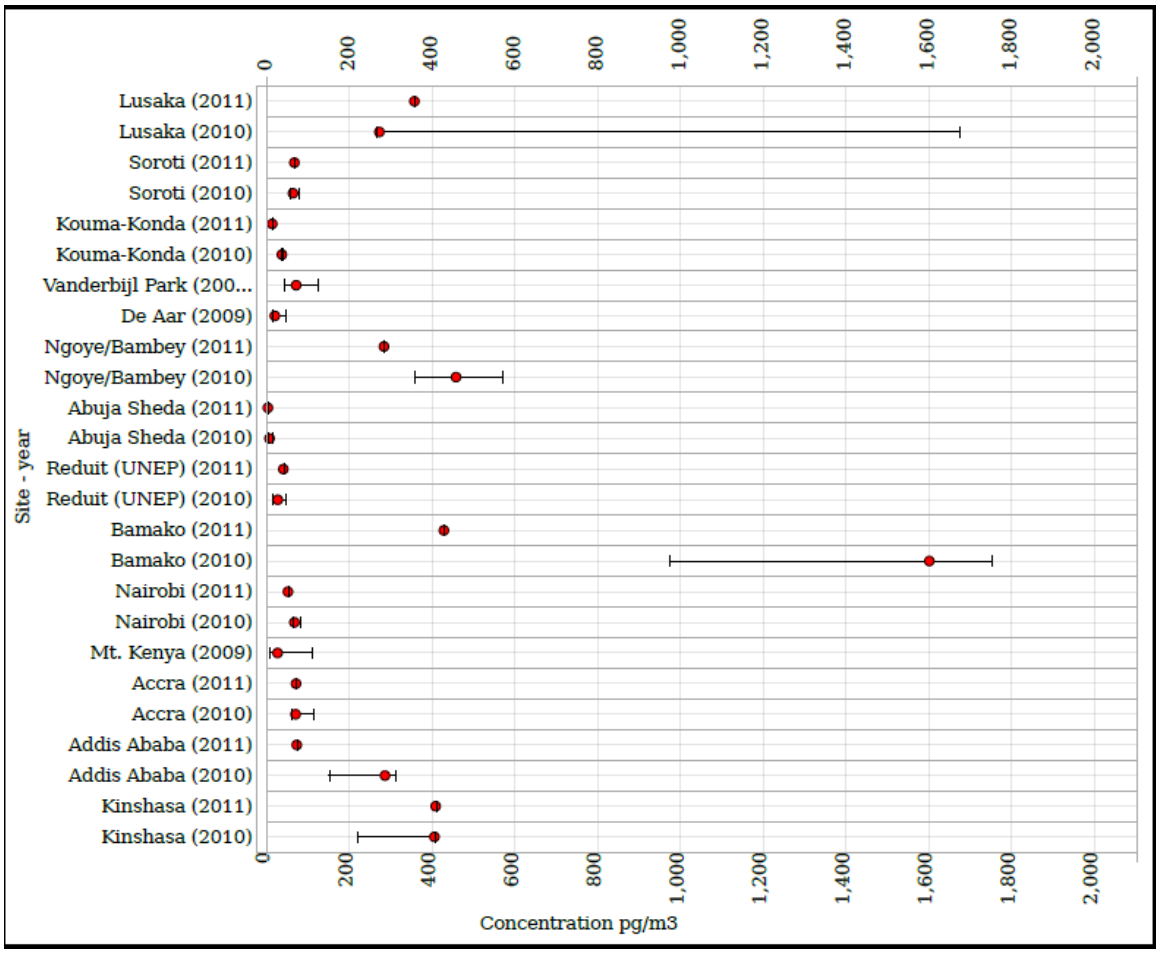

Figure 5.2.1.17 Sum of 6 DDTs in ambient air

Figure 5.2.1.18 shows the spatial distribution of 6 DDTs. The highest levels were recorded at the sites in Senegal, Sudan, DR Congo and Ethiopia. DDT has been used in the past to control public health disease vectors such as mosquitoes. The lowest level was recorded at Sheda site in Abuja, Nigeria. In 2011, there was a considerable decrease in DDT contamination in ambient air compared to the previous year mostly at the sites like Bamako,

Lusaka, Ngoye Bambey and Addis Ababa. The detection of DDT in significant concentration (45.32 pg.m^{-3}) at the Mt. Kenya site, which is a remote site, was most probably a result of atmospheric transport of this chemical, contributing to its overall long-range transport.

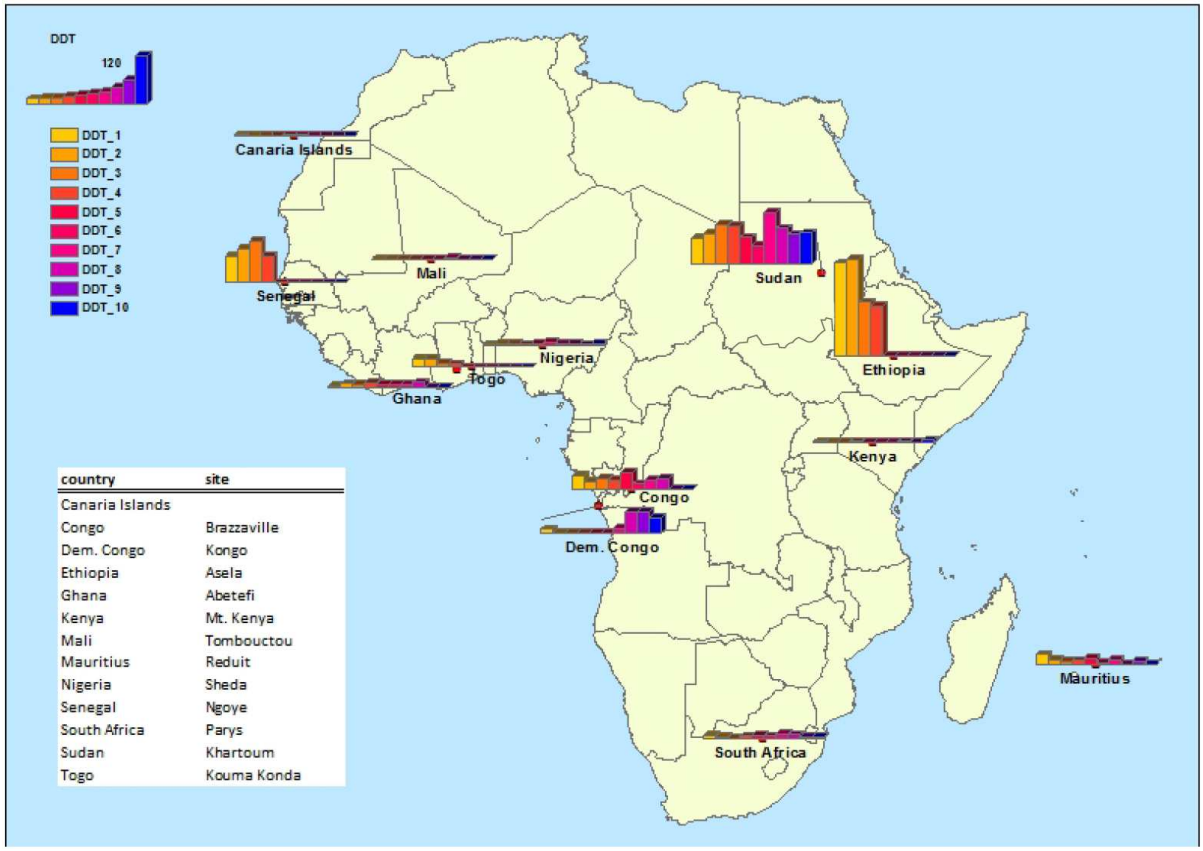

Figure 5.2.1.18 DDT (6 compounds) levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

5.2.1.9. Toxaphenes

Toxaphenes (as Parlar 26 and Parlar 50) were measured in ambient air in Bamako (Mali) and Kabete Nairobi (Kenya) for the sampling year of 2013. Kabete registered the highest levels of both Parlar 26 (45.01 pg.m^{-3}) and Parlar 50 (74.33 pg.m^{-3}).

5.2.1.10. Hexachlorobenzene (HCB)

Spatial distribution of HCB in Africa region from 2010-2012 is illustrated in Figure 5.2.1.19. below. The highest levels within this sampling period were observed at Canary Island, Mt. Kenya and Khartoum. There was no clear trend in concentrations of HCB in the region due to erratic changes observed in concentrations measured at different sites over the period.

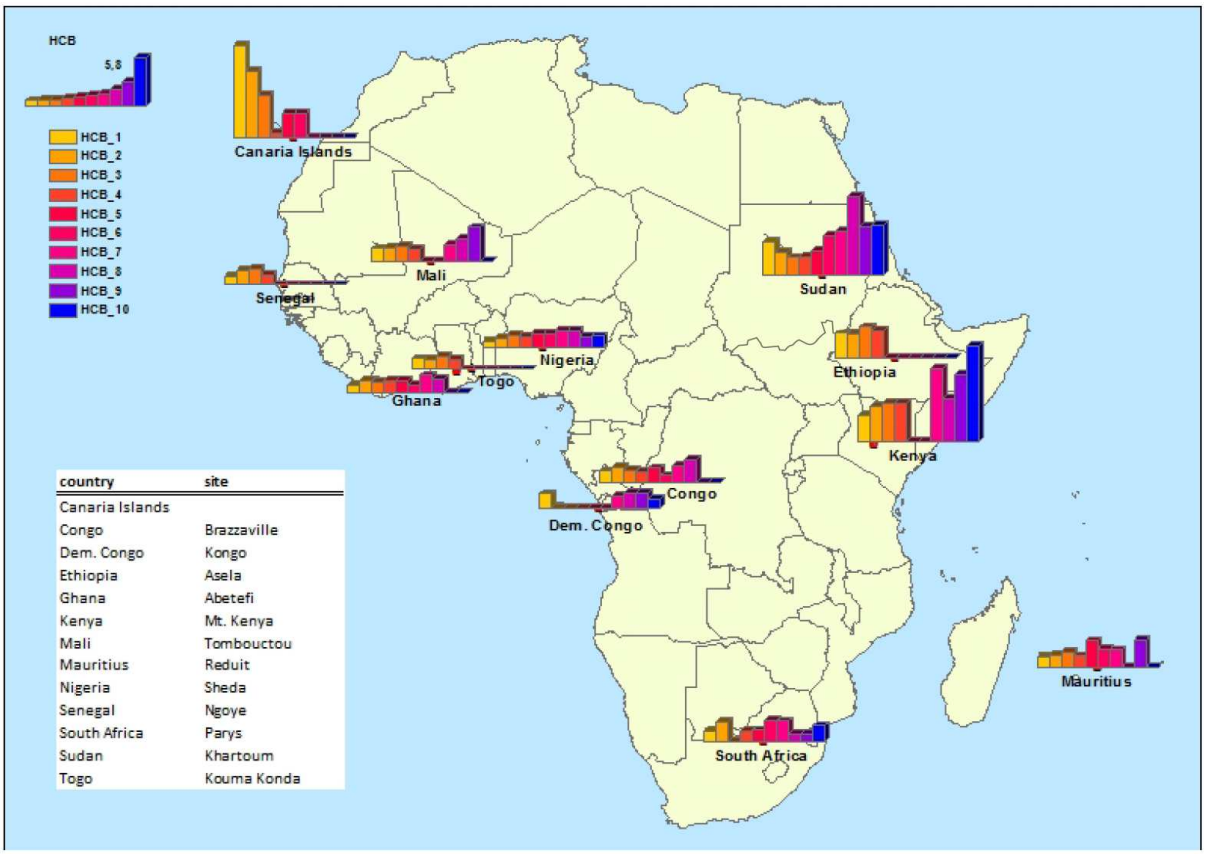

Figure 5.2.1.19: HCB levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

Hexachlorobenzene variations in ambient air over the period 2008-2012 in the Africa region are shown in Figure 5.2.1.20 below. In 2008, samples were collected from eighteen sites distributed in 14 countries in the Africa region. During the same period, sample analysis indicated HCH contamination levels ranging from 16.77 pg.m^{-3} at Molopo site to 46.24 pg.m^{-3} at Khartoum, Sudan. Throughout the period from 2010-2012, the highest HCB contamination levels were recorded at Khartoum in Sudan, Tombouctou in Mali, and Mt. Kenya.

In 2010, HCB levels varied from 6.91 pg.m^{-3} measured at Soroti, Uganda to 23.88 pg.m^{-3} measured in samples from Khartoum, Sudan. In 2011, the highest HCB levels were found in Khartoum (48.44 pg.m^{-3}) and Mt. Kenya (39.57 pg.m^{-3}) while Abuja Sheda showed the lowest air contamination with HCB. In 2012, HCB levels in ambient air remained the highest in Khartoum and Mt. Kenya along with Tombouctou site. Lowest contamination level (1.13 pg.m^{-3}) was found in Kinshasa Ereift. The general trend was that the site of Khartoum in Sudan emerged as the most polluted one by HCB throughout the sampling campaigns.

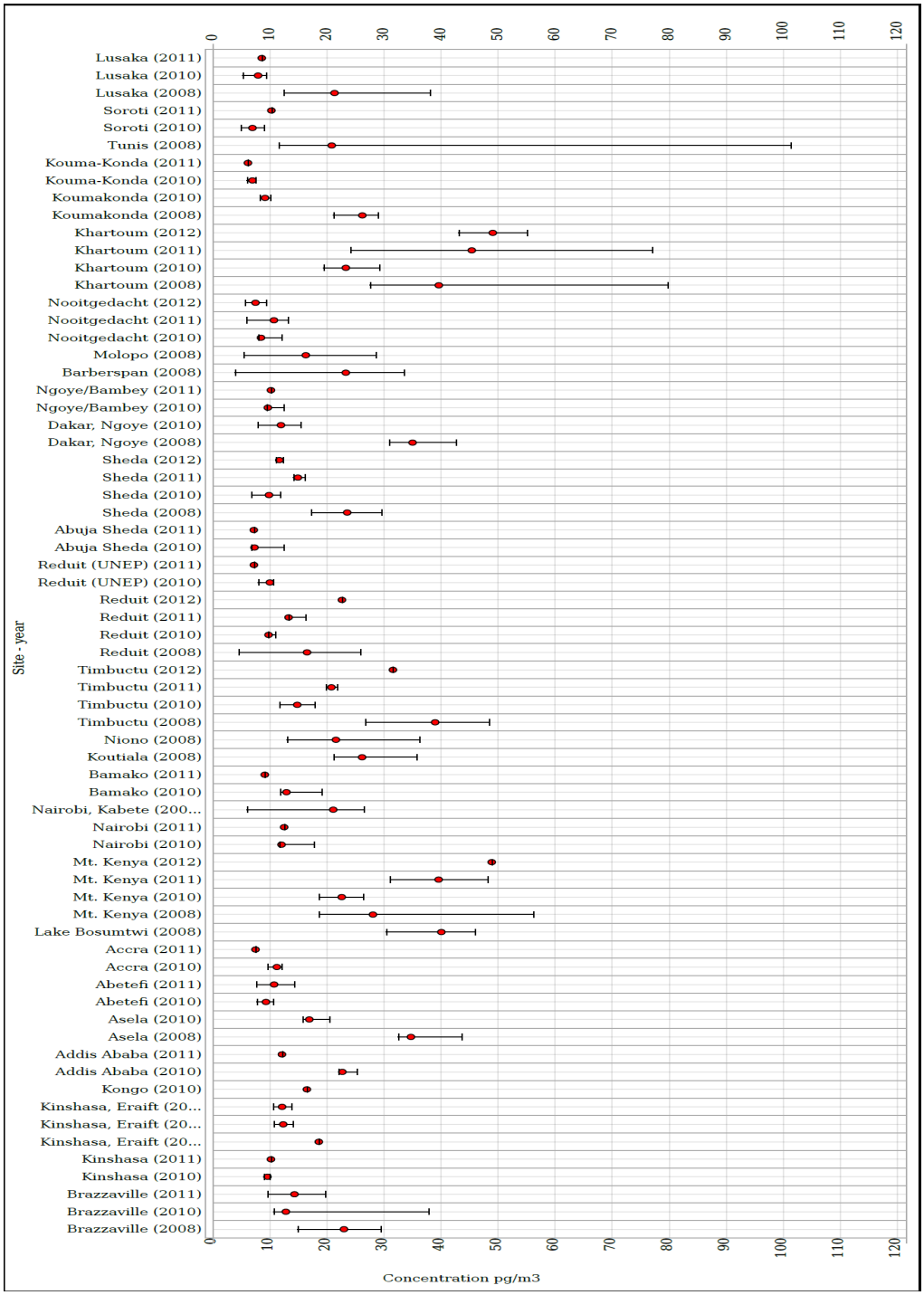

Figure 5.2.1.20 Concentration of HCB in ambient air

The Khartoum site is an urban site and contamination may originate from various sources including open burning of waste. However, the high contamination detected at the Mt. Kenya site which is located in a remote environment could be attributed to transportation by atmospheric currents.

5.2.1.11. Polychlorinated biphenyls (PCBs)

The spatial distribution of 7 PCBs in the region for the period between 2010-2012 is shown in Figure 5.2.1.21 below. Khartoum, Kongo and Brzaville registered the highest levels of PCBs compared to other sites.

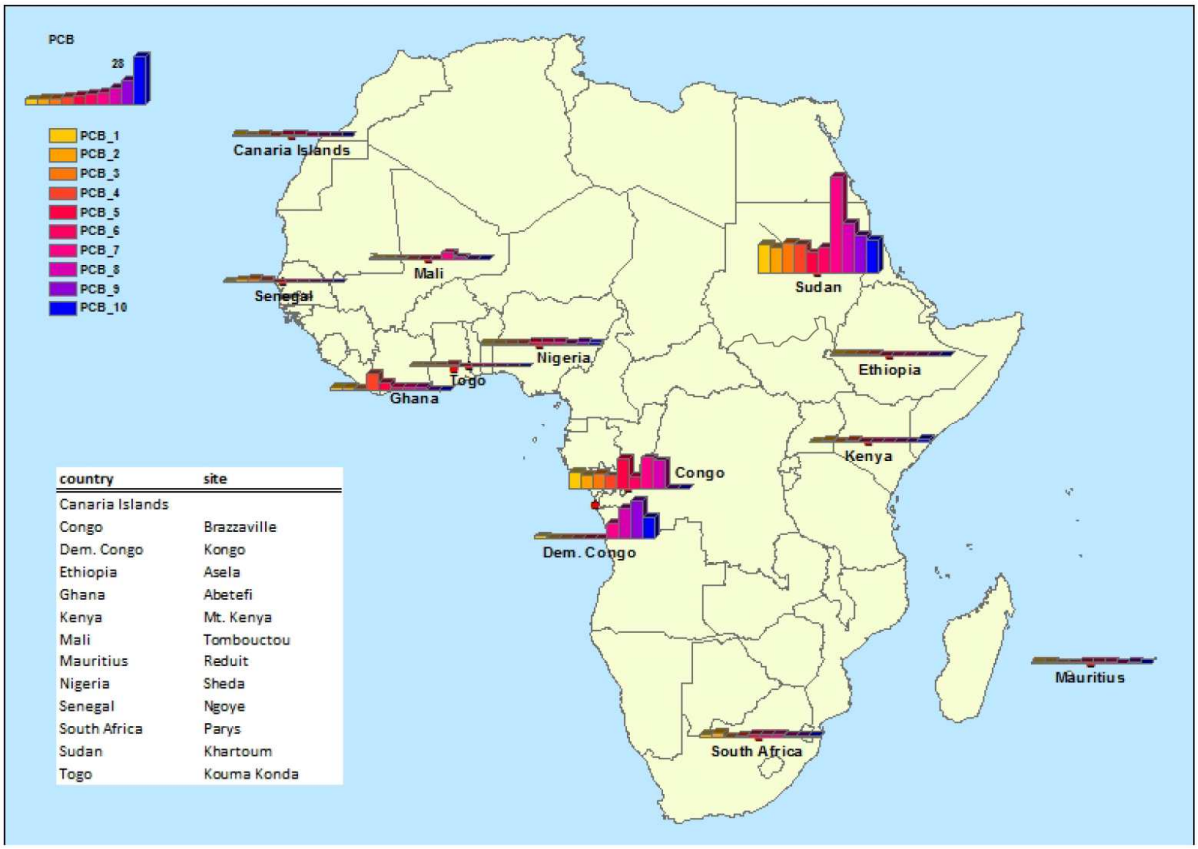

Figure 5.2.1.21 PCB (7indicator congeners) levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

The changes in concentration of the sum of 7 PCBs in ambient air over the period 2008-2012 in the region are shown in Figure 5.2.1.22. In 2008, Dakar Ngoye has the highest PCBs concentration (786.09 pg.m^{-3}) followed by Khartoum (199.13 pg.m^{-3}) and Tunis (106.02 pg.m^{-3}). The contamination levels were the lowest at Tombouctou in Mali (4.98 pg.m^{-3}) and Mt. Kenya (8.84 pg.m^{-3}). The sum of 7 PCBs were highest at Dakar Ngoye (863.58 pg.m^{-3}), Khartoum (223.51 pg.m^{-3}), Kinshasa Ereift (240.13 pg.m^{-3}) and Tunis (109.92 pg.m^{-3}) and lowest at Toumbouctou, Mali (6.92 pg.m^{-3}).

In 2009, only Kenya and South Africa provided data, with the highest mean value of 25.72 pg.m^{-3} at Vanderbijil Park (South Africa). In 2010, the Brazzaville site in Congo recorded the sum concentration of 7 PCBs as 67.58 pg.m^{-3}, whereas in 2011 the sum of 7 PCBs ranged from 1.47 pg.m^{-3} at Mt. Kenya to 147.34 pg.m^{-3} measured at Khartoum in Sudan. In 2012, the

highest concentration was measured in Khartoum with a mean concentration of 68.38 pg.m^{-3}, whereas the lowest levels were recorded at Tombouctou in Mali.

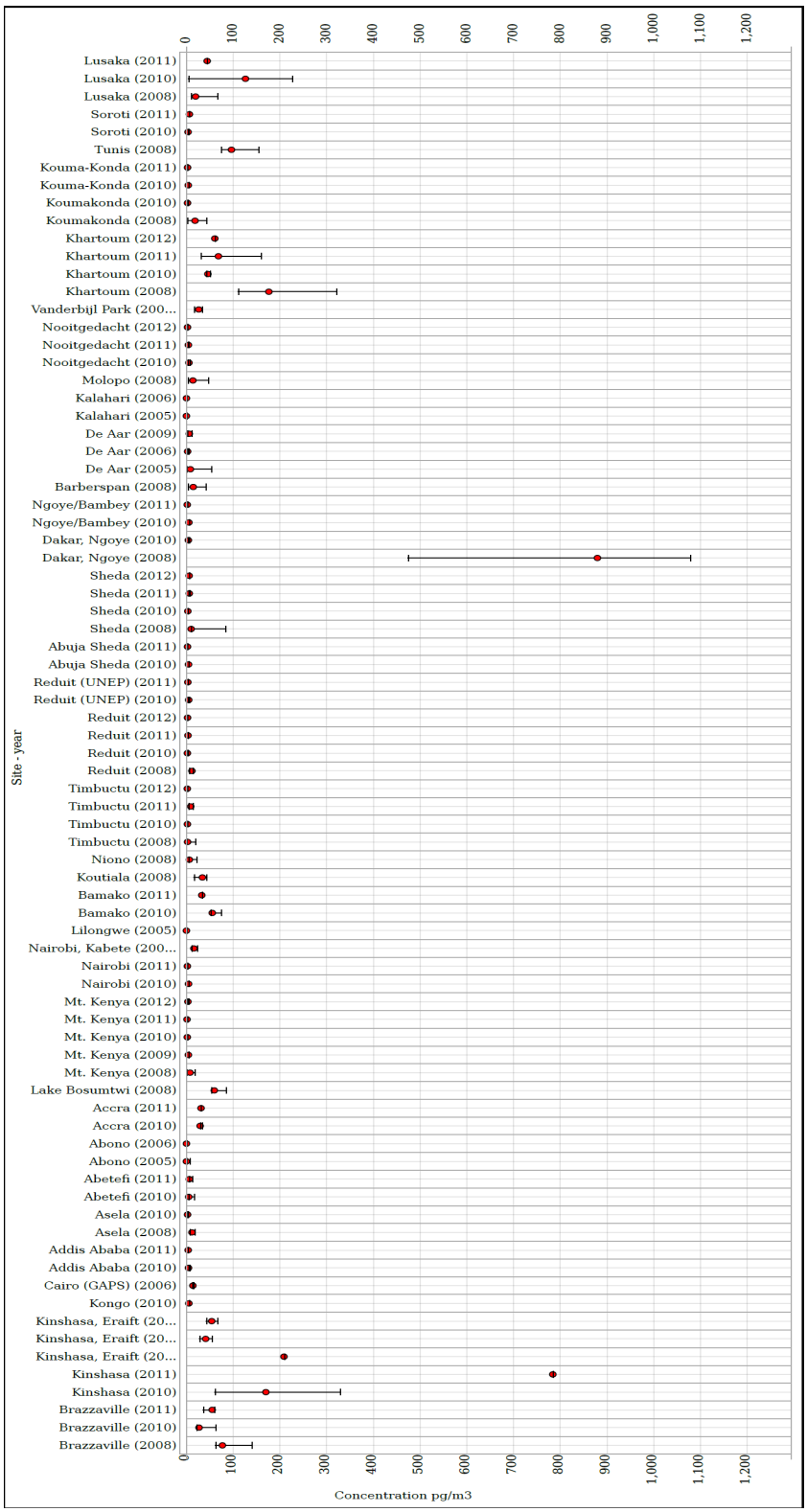

Figure 5.2.1.22 Sum of 6 PCBs in ambient air

The mean concentrations of 6 indicator PCBs varied in the concentration range from 1.83 $pg.m^{-3}$ to 186.59 $pg.m^{-3}$ in 2010. High concentrations were measured at Khartoum site in Sudan, Kinshasa in DR Congo, Lusaka in Zambia and Bamako in Mali (Figure 5.2.1.23). The lowest concentration site was Mt. Kenya. In 2011, again Kinshasa remained the most polluted site with highest concentration level of 783.96 $pg.m^{-3}$. In 2012, highest contamination levels were found in Khartoum (60.92 $pg.m^{-3}$) and at Kinshasa Ereift (54.30 $pg.m^{-3}$) while the lowest level was recorded at Tombouctou (Mali).

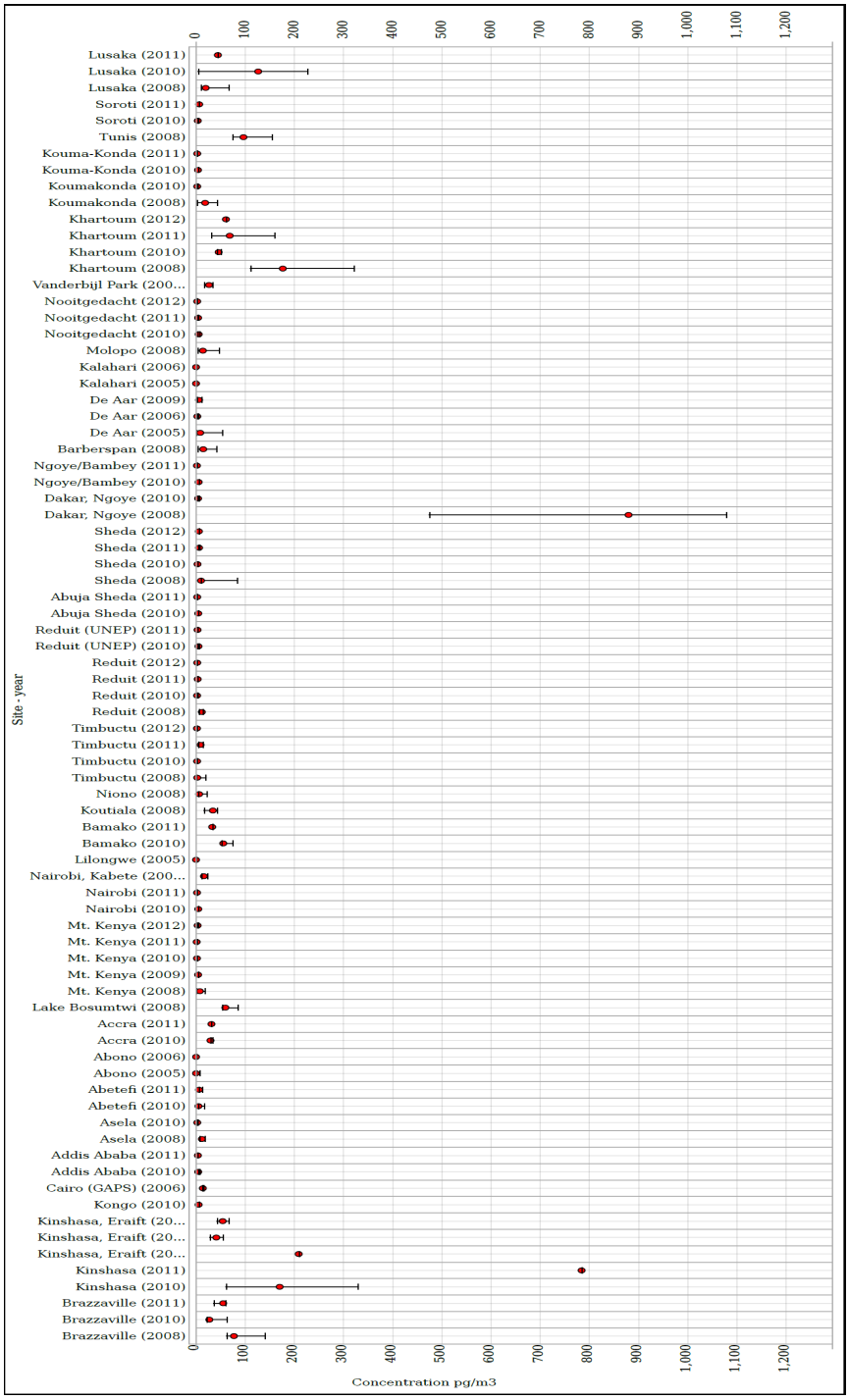

Figure 5.2.1.23 Sum of 6 PCBs in ambient air

5.2.1.12. Dioxin-like Polychlorinated Biphenyl (dl-PCBs)

Concentrations of dioxin-like Polychlorinated biphenyl (*dl*-PCBs) detected in ten participating countries in the Africa region during the year 2010 are indicated in Annex. The most contaminated sites in order of magnitude were Kinshasa (DR Congo), Lusaka (Zambia), Bamako (Mali) and Accra (Ghana).

The lowest mean concentrations were found at Réduit UNEP, Mauritius (143.60 $fg.m^{-3}$) and Koumakonda, Togo (164.07 $fg.m^{-3}$). In 2010 TEQ levels ranged from 0.33 $fg.m^{-3}$ in Addis Ababa to 14 $fg.m^{-3}$ in Kinshasa (Figure 5.2.1.24).

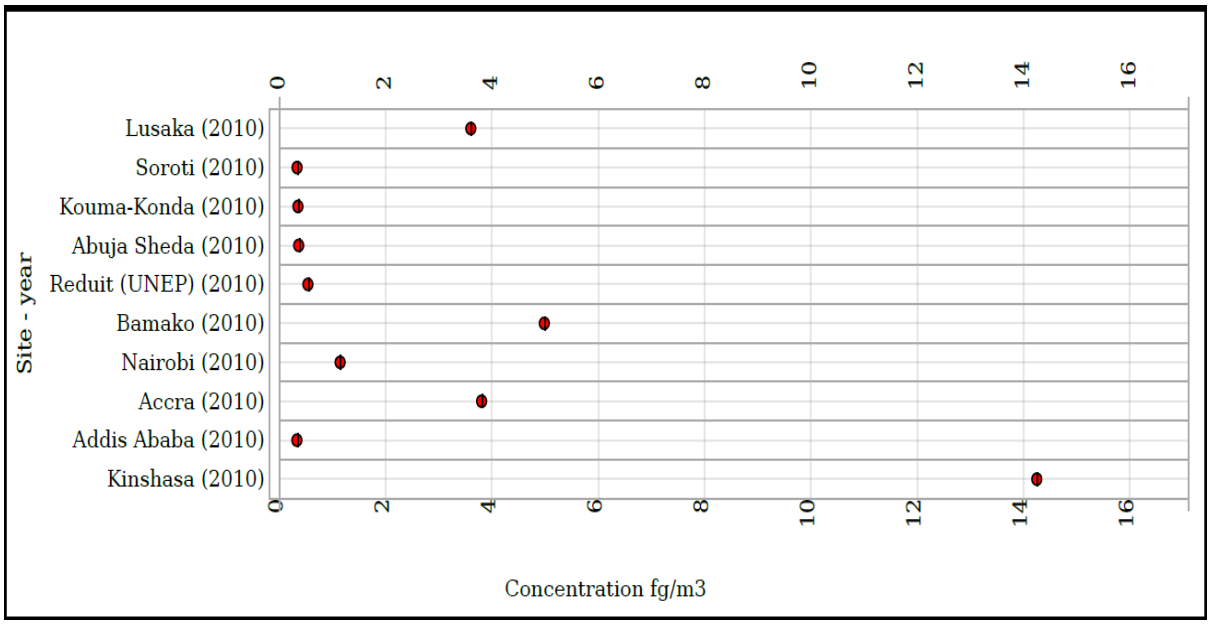

Figure 5.2.1.24 WHO 1998 TEQ LB of dl-PCBs in ambient air

Figure 5.2.1.25 shows the overall WHO 1995 TEQ of dioxin like PCBs in ambient air between 2010-2012. The highest values of WHO 1995 TEQ for *dl*-PCBs were recorded at Khartoum, Kongo and Brazaville.

A wide presence of dioxin like PCBs was observed in the region, suggesting potential active sources of these compounds. The trend could also be attributed to contaminated soils and possibility of stockpiles still existing in the region that need to be delineated and proper mitigation measures put in place.

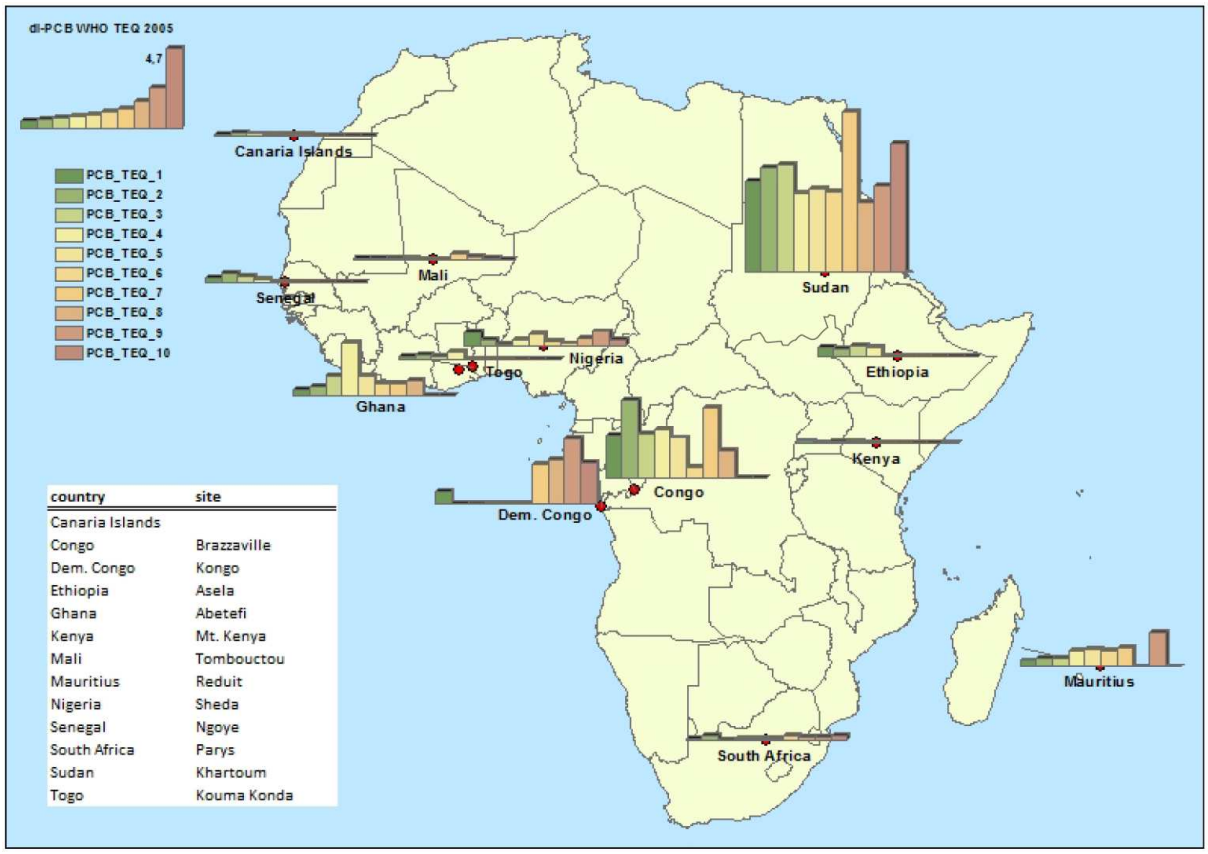

Figure 5.2.1.25: dl-PCBs WHO TEQ 2005 in ambient air (PAS, pg sample^{-1}) in Africa, 2010-2012

5.2.1.13. Polychlorinated dibenzo-dioxins and Polychlorinated dibenzo-furans (PCDDS/PCDFS)

The levels of PCDDs/PCDFs in ambient air in the region over the period 2008-2012 are shown in Figure 5.2.26. In 2010, Addis Ababa, Mt. Kenya and Soroti (Uganda) had lowest levels of PCDDs compared to the other sites, whereas Brazzaville (Congo), Dakar Ngoye, Khartoum (Sudan), Kongo (DRC) and Tombouctou had significantly higher levels compared to other sites.

The WHO 1998 TEQ varied from 0.022 fg.m^{-3} at Mt. Kenya to 28.99 fg.m^{-3} at Brazzaville.

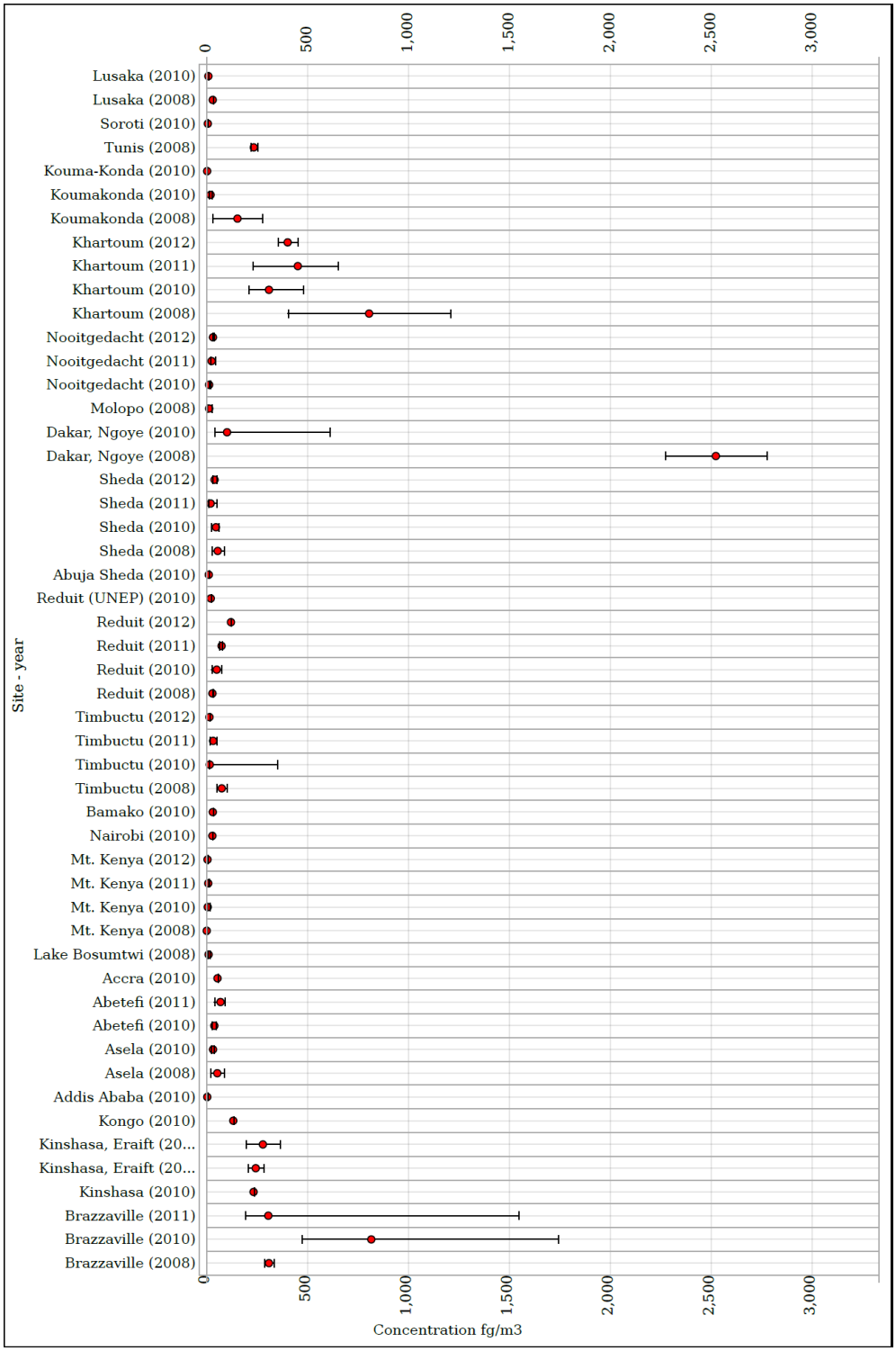

Figure 5.2.1.26 Sum of 7 PCDDs in ambient air

In 2011, although there was a decrease in PCDDs levels at Brazzaville site, it still recorded the highest levels followed by Khartoum and Kinshasa Ereift (Figure 5.2.1.27). WHO 1998 TEQ values were lowest at Mt. Kenya, Sheda and Tombouctou and highest at Khartoum.

Analysis of data in 2012 revealed that Khartoum, Kinshasa and Reduit Mauritius registered the highest levels of PCDDs.

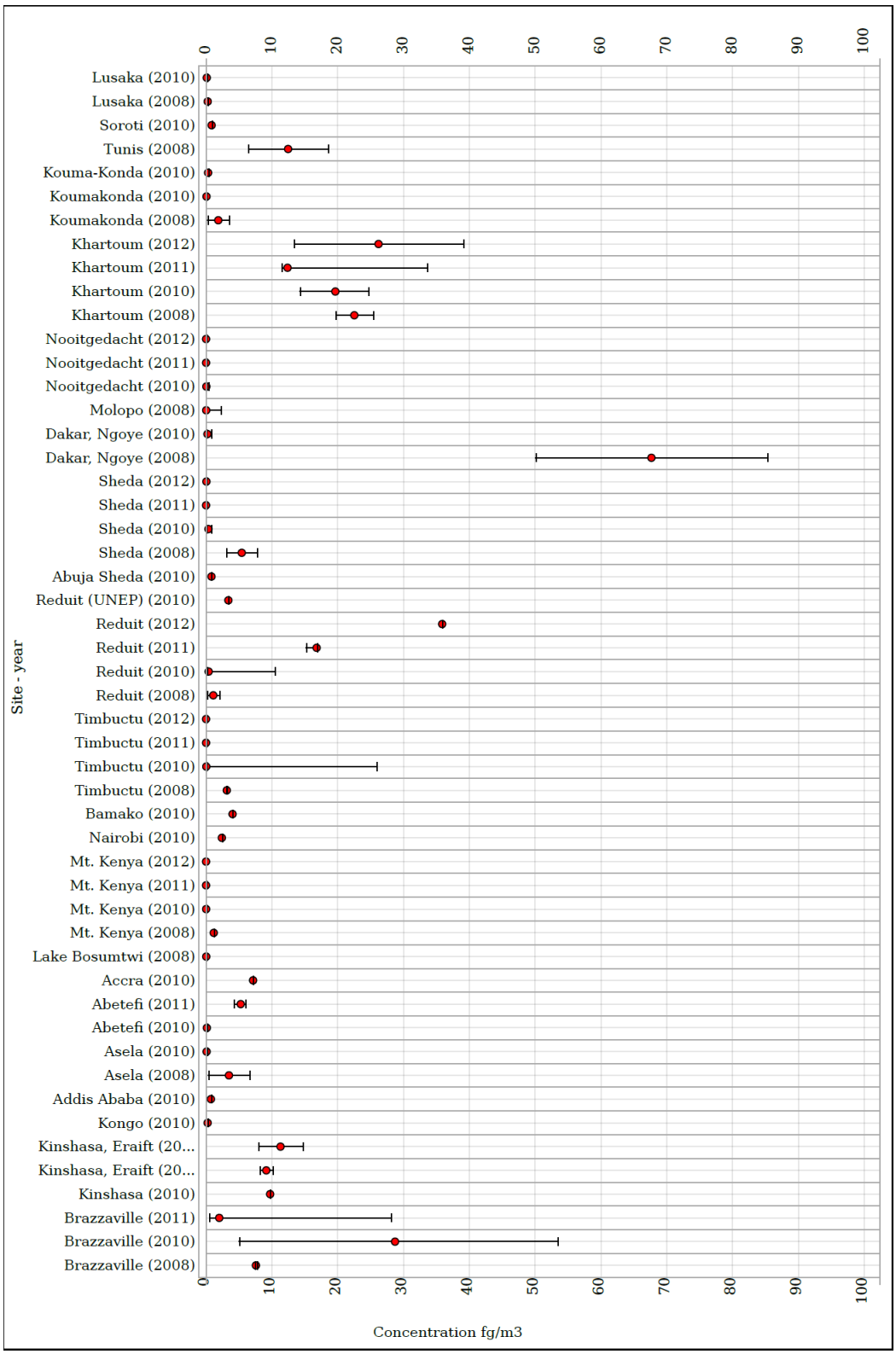

Figure 5.2.1.27. WHO 1998 TEQ LB for PCDDs in ambient air

The highest level of sum PCDFs was recorded in Dakar Ngoye in 2008. Over the period 2010-2012, the sites with highest levels of PCDFs were Khartoum, Reduit, Brazzaville and Kinshasa Ereift as illustrated in Figure 5.2.1.28.

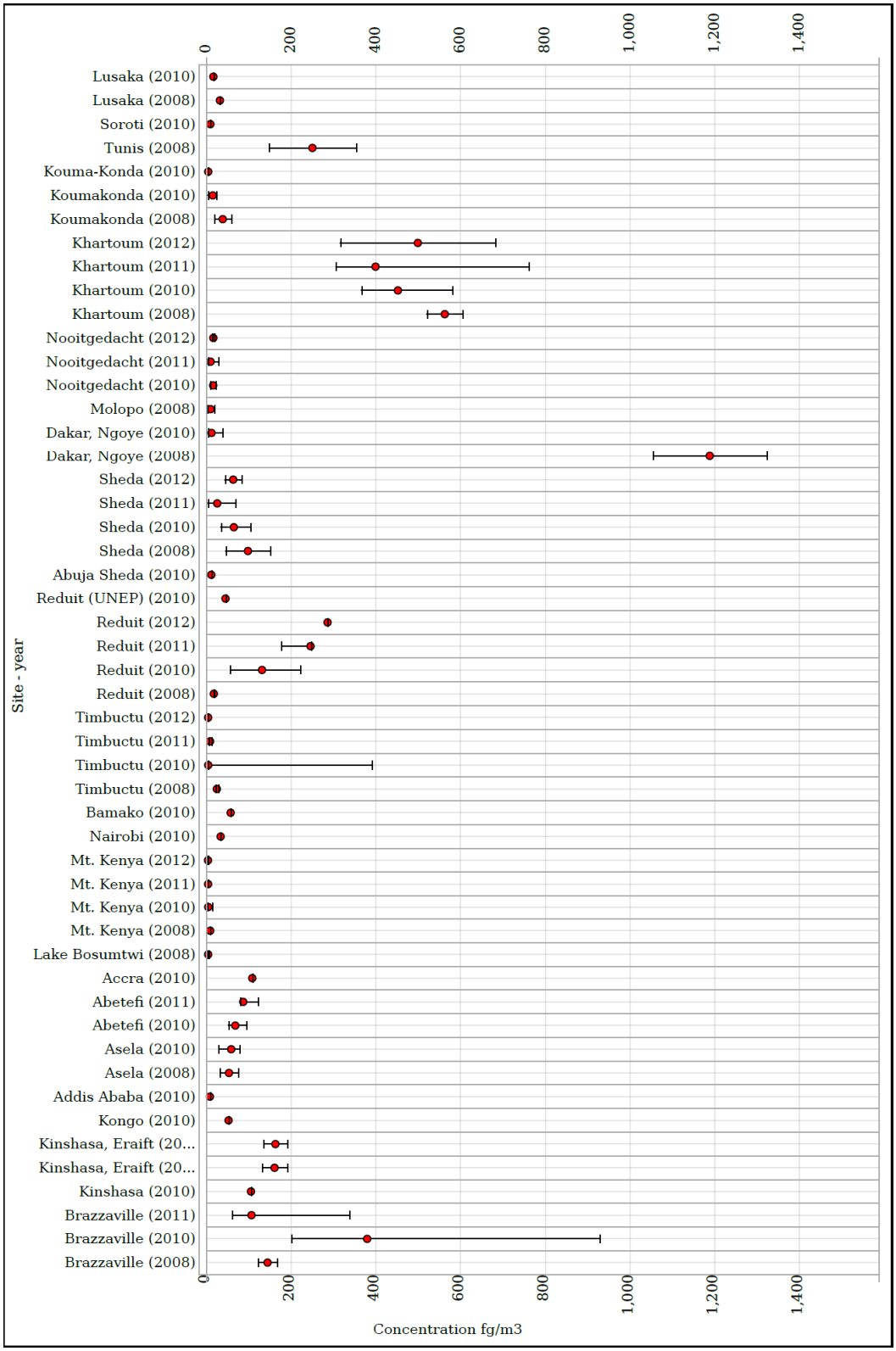

Figure 5.2.1.28. Sum of 10 PCDFs in ambient air

Mt. Kenya and Tombouctou had the lowest WHO 1998 TEQ levels (Figure 5.2.1.29), whereas Dakar Ngoye had the highest values. Highest levels of PCDFs were found at urban sampling sites, suggesting open burning, transportation, industry and residential sources of PCDD/PCDFs to be the predominant ones.

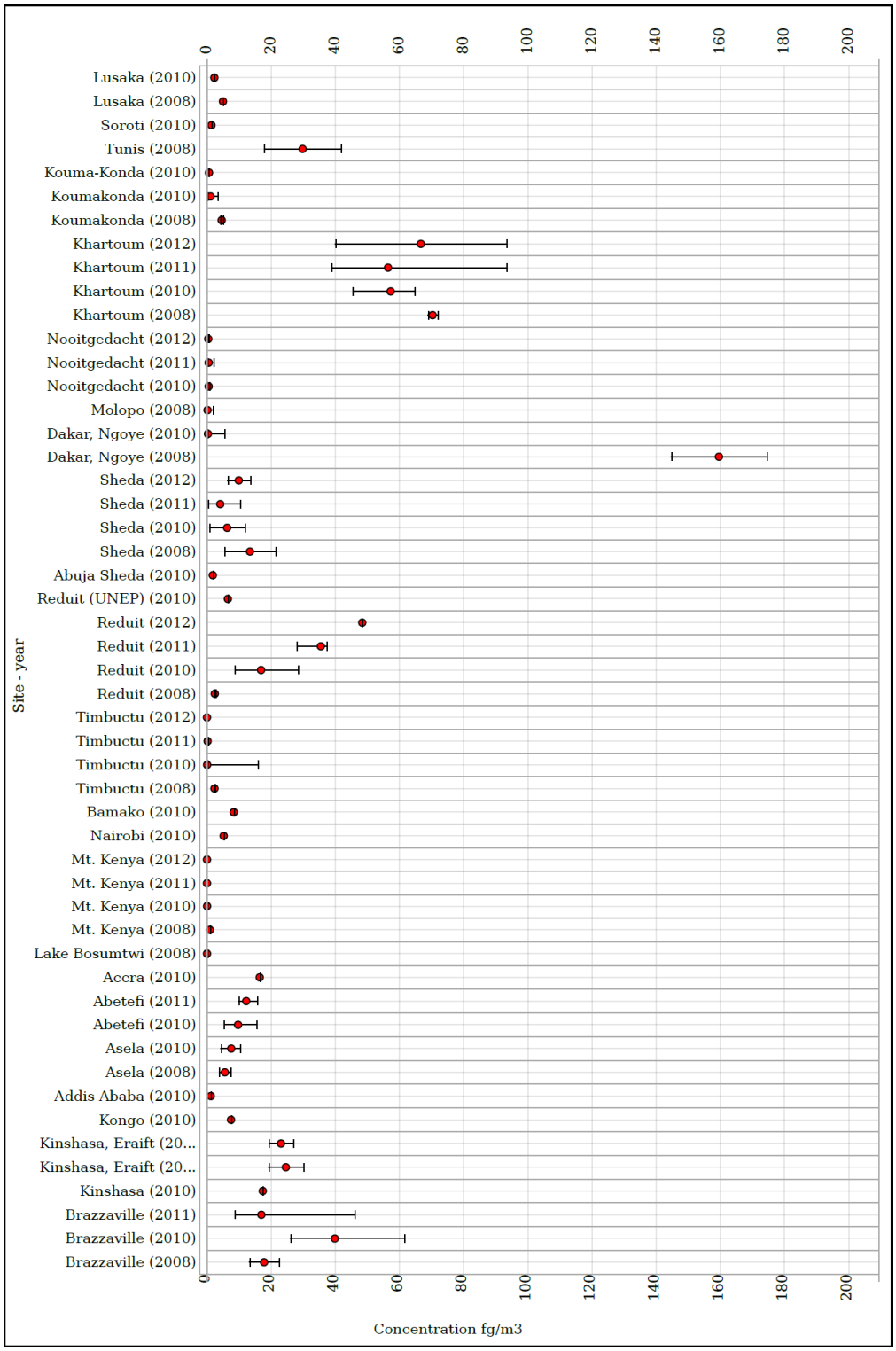

Figure 5.2.1.29 WHO 1998 TEQ LB for PCDFs in ambient air

The overview of PCDDs/Fs WHO TEQ 2005 in ambient air in the region over the period 2010-2012 is shown in Figure 5.2.1.30. The highest levels were obtained in Khartoum, Brazzaville and Reduit. PCDDs/Fs releases are highly associated with uncontrolled combustion activities. The major sources are incineration facilities that do not high temperature and open burning of wastes. The wide presence of PCDDs/Fs in the region could be strongly attributed to these sources, in addition to long range transport. However, additional studies are required to delineate the local contributions to the PCDDs/Fs releases to allow the countries to prioritize mitigation measures that will curb the emissions.

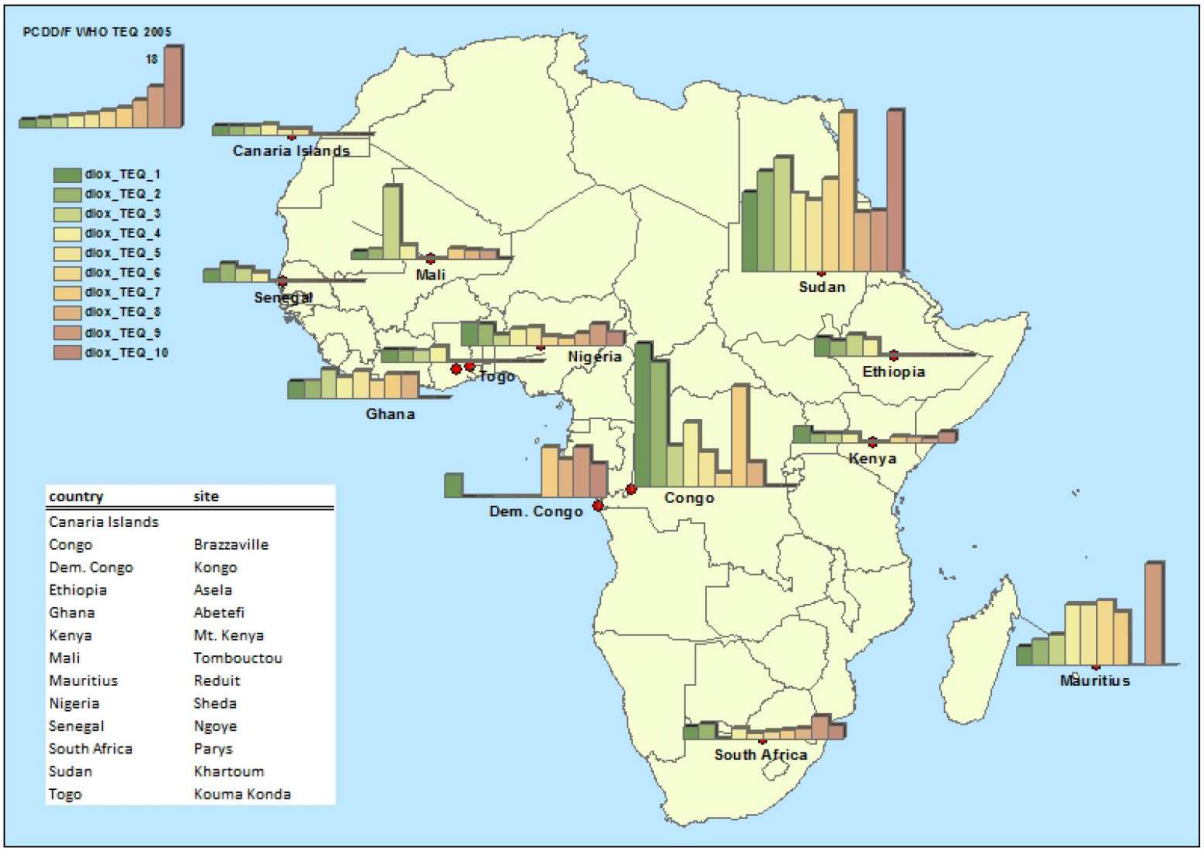

Figure 5.2.1.30 PCDDs/Fs WHO TEQ 2005 in ambient air (PAS, pg sample^{-1}) in Africa, 2010-2012

5.2.1.14. Chlordecone

The levels of chlordecone were below the detection limit at all sampling sites. This could be attributed to the limited use of this pesticide in the Africa region.

5.2.1.15. Endosulfans

Ambient air sample analysis in the Region showed variable contamination levels of endosulfan and its isomers over the second evaluation period (Figures 5.2.1.31). Asela, Khartoum, Abetefi, and Sheda registered the highest levels of endosulfans compared to other sites with the 2010-2012 period. However, it is noteworthy that endosulfans were widely detected at all the sites monitored in the region.

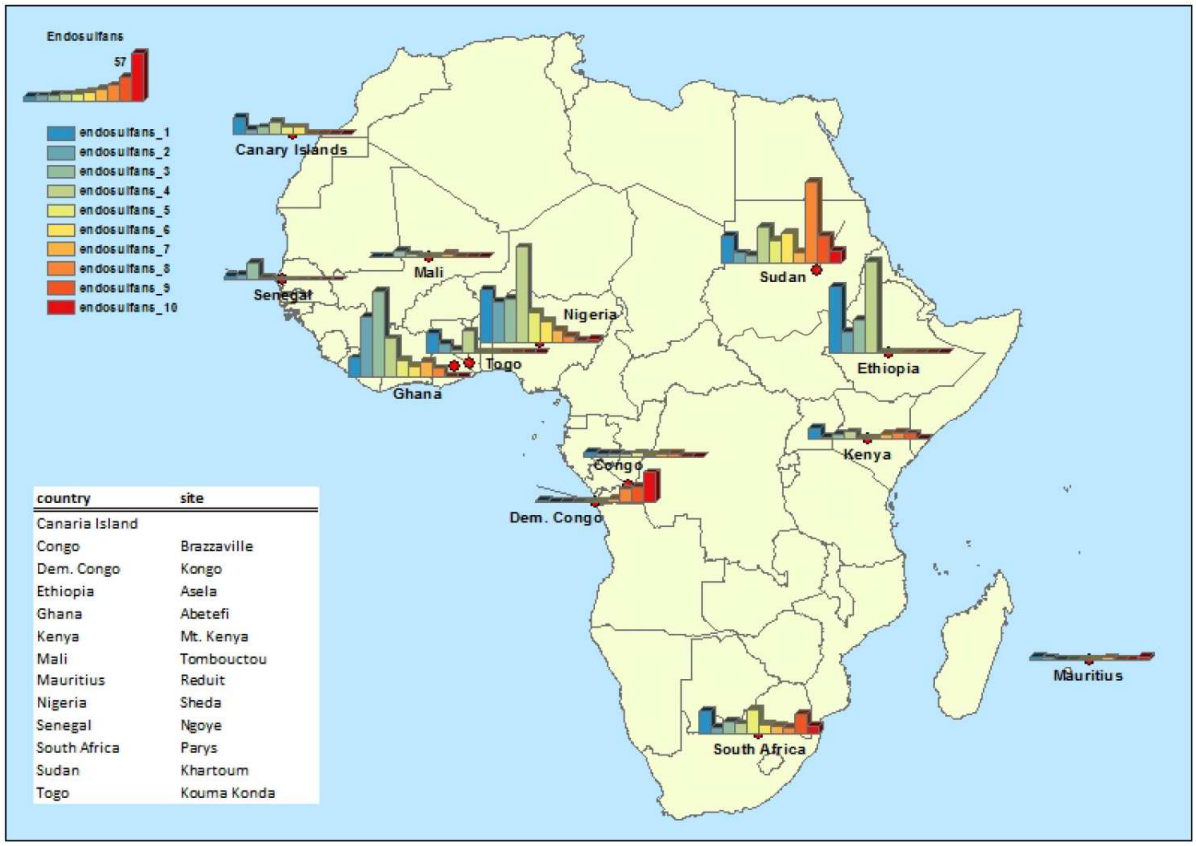

Figure 5.2.1.31 Endosulfans (2 isomers) levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

Alpha-endosulfan

The highest levels of *alpha*-endosulfan were recorded in 2005 and 2006 at Abono site. In 2009, only two countries (Kenya and South Africa) participated in the sampling campaign. Data recorded on *alpha*-endosulfan contamination in ambient air were high with the highest at Mt. Kenya (146.44 pg.m^{-3}).

In 2010, the highest levels were measured at Asela site in Ethiopia (243.09 pg.m^{-3}), Sheda in Nigeria (179.25 pg.m^{-3}) and Abetefi in Ghana (141.95 pg.m^{-3}). Khartoum, Dakar Ngoye, Koumakonda, Mt. Kenya and Nooitgedacht sites had moderate levels of *alpha*-endosulfan

while the lower contamination levels were found at the sampling sites Reduit, Tombouctou, Brazzaville and Muanda (Figure 5.2.1.32).

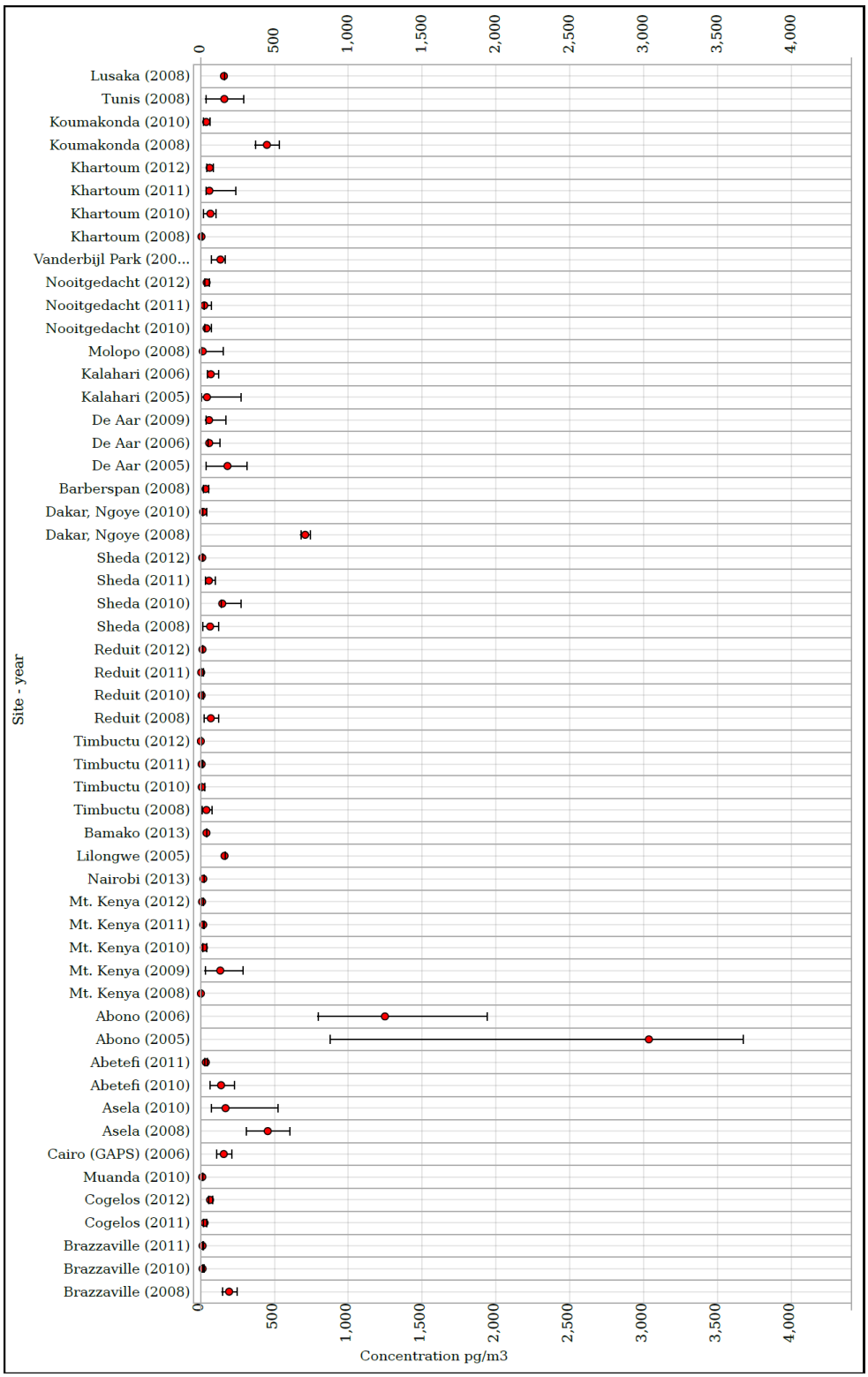

Figure 5.2.1.32 Concentration of alpha-endosulfan in ambient air

Ambient air sampling in 2011 indicated the highest level (114.76 pg.m^{-3}) at the Khartoum site in Sudan. Other sites like Abetefi in Ghana, Sheda in Nigeria, Cogelos in DRC, Nooitgedacht in South Africa and Mt Kenya showed relatively high *alpha*-endosulfan concentrations ranging from 18.02 pg.m^{-3} to 58.82 pg.m^{-3}. The lowest value (7.11 pg.m^{-3}) was recorded at Réduit (Mauritius).

In 2012, the highest levels in ambient air were detected at the Cogelos site in DR Congo (64.07 pg.m^{-3}), Khartoum in Sudan (61.16 pg.m^{-3}) and the Nooitgedacht site in South Africa (40.77 pg.m^{-3}). The Tombouctou site in Mali had the lowest contamination level with a value of 1.68 pg.m^{-3}

Of the two countries that participated in the sampling campaign in 2013, the site of Bamako in Mali showed the highest *alpha*-endosulfan contamination level (39.62 pg.m^{-3}) while the Nairobi site in Kenya had less than half of the concentration found in Mali.

Beta-endosulfan

Data for 2005 and 2006 were obtained from GAPs programmes and revealed high concentrations of *beta*-endosulfan at Abono site. In 2009, data were provided by Kenya and South Africa showed higher *beta*-endosulfan contamination level (18.35 pg.m^{-3}) at Vanderbijil Park in South Africa as compared to the 0.2 pg.m^{-3} at the Mt. Kenya site. In 2013 only Mali and Kenya provided data on *beta*-endosulfan; the most polluted site was that of in Bamako in Mali (Figure 5.2.1.33).

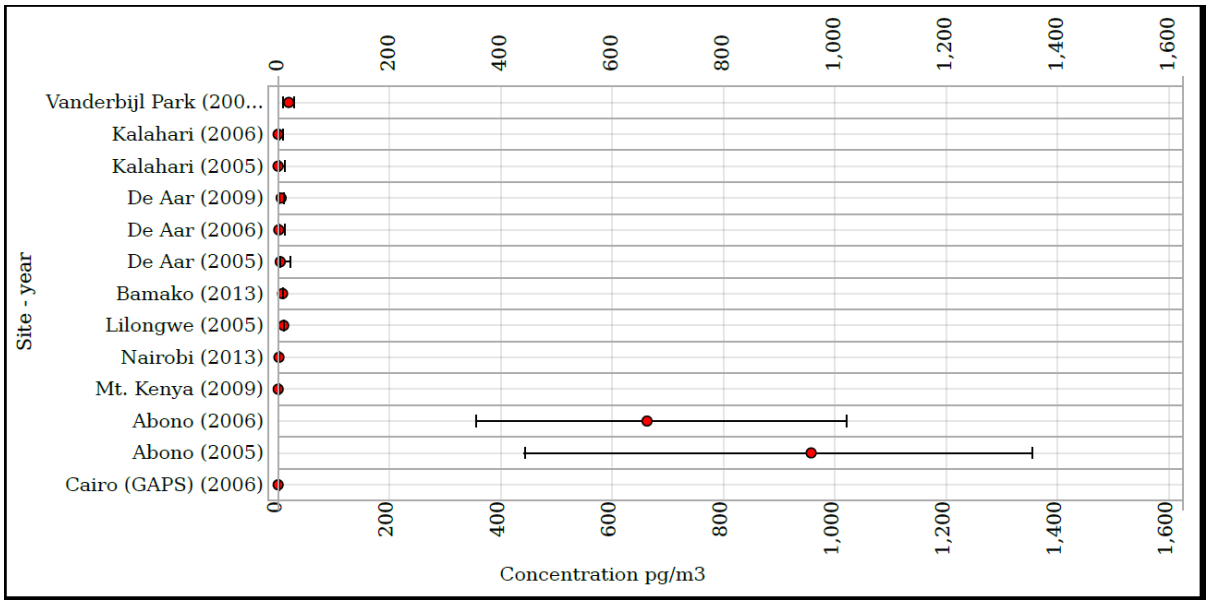

Figure 5.2.1.33 Concentration of beta-endosulfan in ambient air

Endosulfan sulphate

In 2005 and 2006, the concentration of endosulfan sulphate was highest at Abono with concentrations of 69.5 and 93.0 ng.m^{-3}. Cairo, De Aar, Kalahari and Lilongwe recorded levels not exceeding 3.0 ng.m^{-3}. In 2009, contamination of ambient air was only measured in Kenya and South Africa where the levels were 0.11 pg.m^{-3} at Mt. Kenya and 1.55 pg.m^{-3} at Vanderbijil Park. In 2013, endosulfan sulphate levels in ambient air were 7.46 pg.m^{-3} at the Kabete, Nairobi site and only 0.73 pg.m^{-3} at the Bamako site (Figure 5.2.1.34).

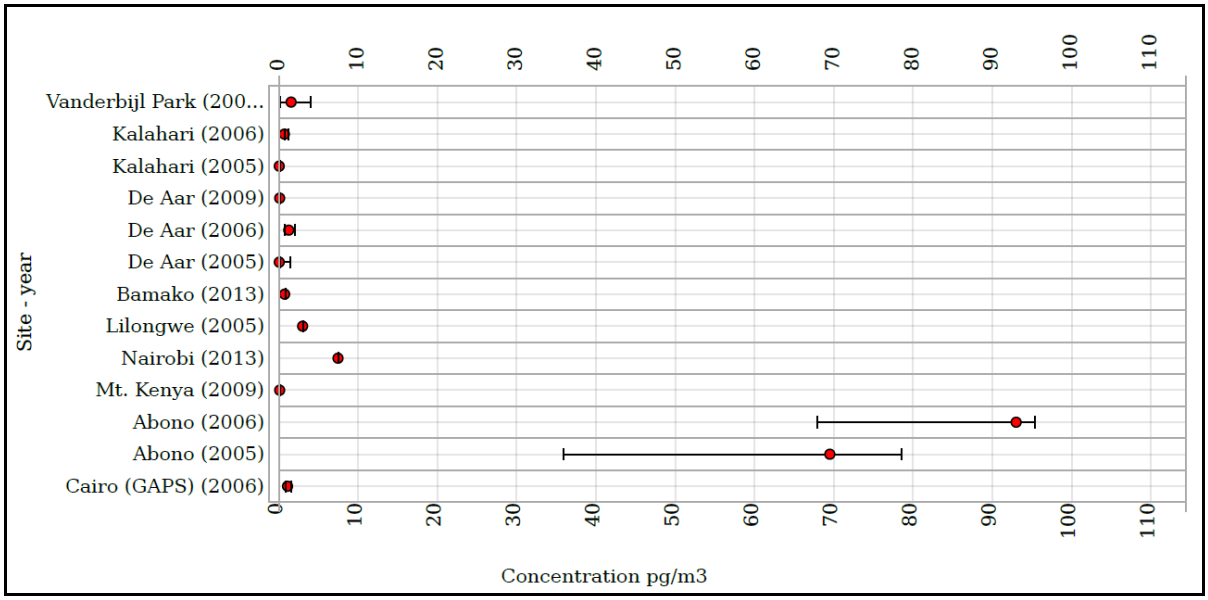

Figure 5.2.1.34 Concentration of endosulfan sulphate in ambient air

5.2.1.16. Hexabromobiphenyl (HBB = PBB 153)

Within the 2010-2012 sampling period, the highest levels of HBB/PBB 153 were measured at Khartoum, Bamako and Brazaville sites (Figure 5.2.1.35). The low levels of HBB recorded at remotes sites such as Mt. Kenya could be attributed to long range transport processes. The data shows that in spite of being considered a “dead chemical”, HBB still continues to contaminate ambient air, showing that environmentally sound management of waste that might contain this chemical will be of relevancy among the mitigation measure to be adopted by countries including the African country Parties to the Stockholm Convention.

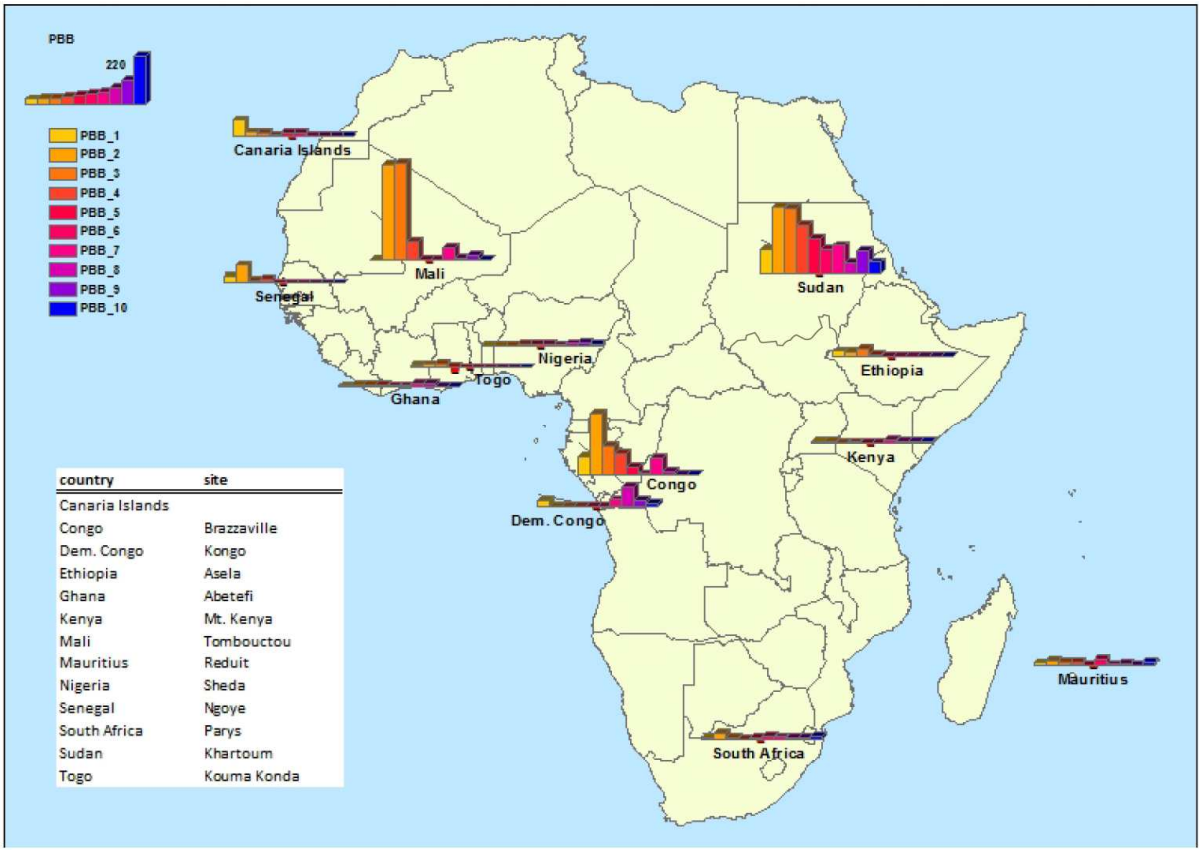

Figure 5.2.1.35 PBB levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

5.2.1.17. Hexabromocyclododecanes (HBCD)

The highest levels of HCBD in the period 2010-2012 were recorded at Asela, Khartoum and Canary Island sites. Moderate levels were measured at Brazaville, Bamako, Abefetfi, Reduit, Sheda, Mt. Kenya and Kouma Konda sites (Figure 5.2.1.36).

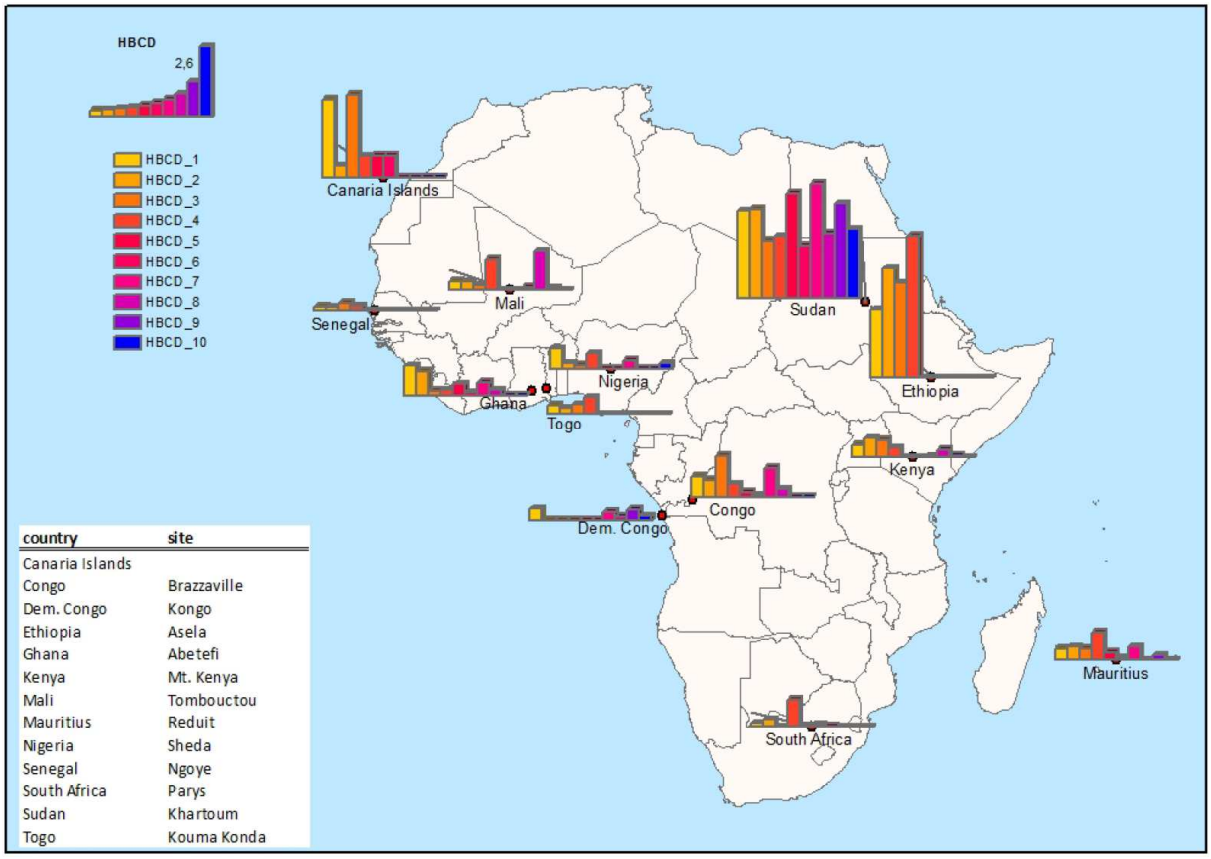

Figure 5.2.1.36 HBCD levels (4 isomers) in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

In 2013, HBCDs (as *alpha*-HBCD, *beta*-HBCD and *gamma*-HBCD) concentration levels measured only at Bamako (Mali) and Nairobi (Kenya) sites in 2013 although rather low, were higher in Nairobi than in Bamako. It is important to note that HCBDs are not yet taken on board in most of the national implementation plans of most of the Africa countries despite the presence of this chemical in ambient air.

5.2.1.18. Hexachlorocyclohexanes (HCHs)

The distribution of HCHs is in the region for the period 2010-2012 is illustrated in Figure 5.2.1.37 below. HCHs were widely detected at all the sites in the region. The highest levels of the 4 HCH isomers were measured at Darkar Ngoye, Kkartoum, Abetefi, Sheda, Brazaville, Reduit and Asela.

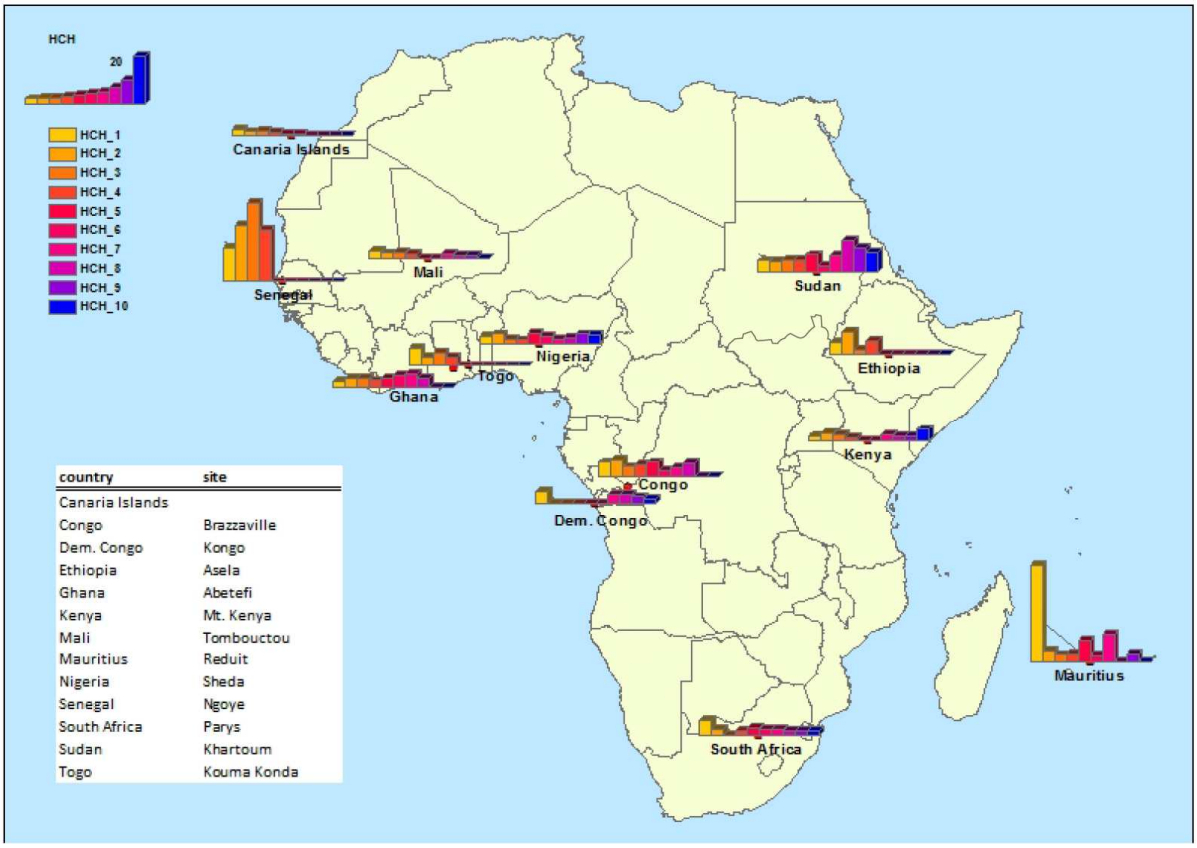

Figure 5.2.1.37 HCH (4 isomers) levels in ambient air (PAS, ng sample^{-1}) in Africa, 2010-2012

alpha-HCH

In 2009, the data provided by Kenya and South Africa indicated air contamination levels of 14.25 pg.m^{-3} at De Aar (SA) site and 2.63 pg.m^{-3} at Mt. Kenya. In 2010, all countries showed quantifiable levels of *alpha*-HCH. The highest levels were measured at two sites from Senegal namely Dakar Ngoye (45.82 pg.m^{-3}) and Ngoye Bambey (106.84 pg.m^{-3}) while the lowest levels were measured at Reduit site with 2.81 pg.m^{-3}.

Ngoye Bambey remained the leading site with *alpha*-HCH concentration of 49.65 pg.m^{-3} during 2011 air sampling. In 2012, *alpha*-HCH levels decreased in almost all participating countries and ranged from 2.37 pg.m^{-3} (Nooitgedacht) to 5.86 pg.m^{-3} (Khartoum). In 2013 alpha-contaminated levels were 2.64 pg.m^{-3} in Bamako and 2.15 pg.m^{-3} in Nairobi. The high concentrations were found in Senegal in 2010 and 2011. However, not easy to understand based on consideration of anthropogenic activities associated with the urban background sites. Likewise, the shifting from high contamination in 2010 and 2011 to lower contamination in 2012 and 2013 could suggest a declining trend, but due to the short duration of sampling, conclusive deduction could not be reached.

beta-HCH

In 2009, Vanderbijil Park (South Africa) recorded the higher levels of *beta*-HCH compared to Mt. Kenya site. With regard to *beta*-HCH concentrations in 2010, Dakar Ngoye and Ngoye Bambey recorded the highest values of 44.94 $pg.m^{-3}$ and 27.97 $pg.m^{-3}$, respectively, while Reduit site recorded the lowest concentration with *beta*-HCH level of 0.28 $pg.m^{-3}$. In 2011, Khartoum had the highest *beta*-HCH concentration (8.85 $pg.m^{-3}$). Other sites that recorded moderate levels of *beta*-HCH were Ngoye Bambey, Reduit UNEP, Accra, Bamako, Abuja Sheda and Nairobi. In 2012, Khartoum recorded the highest concentration with 9.11 $pg.m^{-3}$, while Mt. Kenya had the lowest concentration. In 2013, only Kenya and Mali provided data for *beta*-HCH. The concentration of *beta*-HCH was 6.75 $pg.m^{-3}$ in Bamako and 1.37 $pg.m^{-3}$ in Nairobi.

gamma-HCH

In 2009, *gamma*-HCH ambient air levels ranged from 33.04 $pg.m^{-3}$ at Mt. Kenya to 165.07 $pg.m^{-3}$ at Nooitgedacht (South Africa) (Figure 5.2.1.38). The data for samples collected in 2010, showed highest levels at Reduit (58.88 $pg.m^{-3}$) and Abuja Sheda (44.76 $pg.m^{-3}$), and the lowest concentrations at Mt. Kenya with 33.04 $pg.m^{-3}$. In 2011, *gamma*-HCH levels varied from 1.48 $pg.m^{-3}$ (Addis Ababa) to 26.66 $pg.m^{-3}$ (Reduit).

In 2012, the highest contamination levels were recorded at Khartoum (26.98 $pg.m^{-3}$) and the lowest at Tombouctou (1.92 $pg.m^{-3}$). In 2013 data provided by only two countries were 22.87 $pg.m^{-3}$ at Nairobi and 8.36 $pg.m^{-3}$ at Bamako site. *Gamma*-HCH is the active ingredient of the pesticide Lindane, which is and agricultural pesticide, and *gamma*-HCH is also used as active ingredient in pharmaceuticals against head lice and scabies.

Irregular changes in concentrations were observed from one sampling period to the other making it difficult to establish any trends over the completed evaluation period. It will be important to maintain regular sampling at all the sites to provide adequate data that can be used to establish temporal trends. In addition more effort should be geared toward maintaining comparability among the monitoring activities.

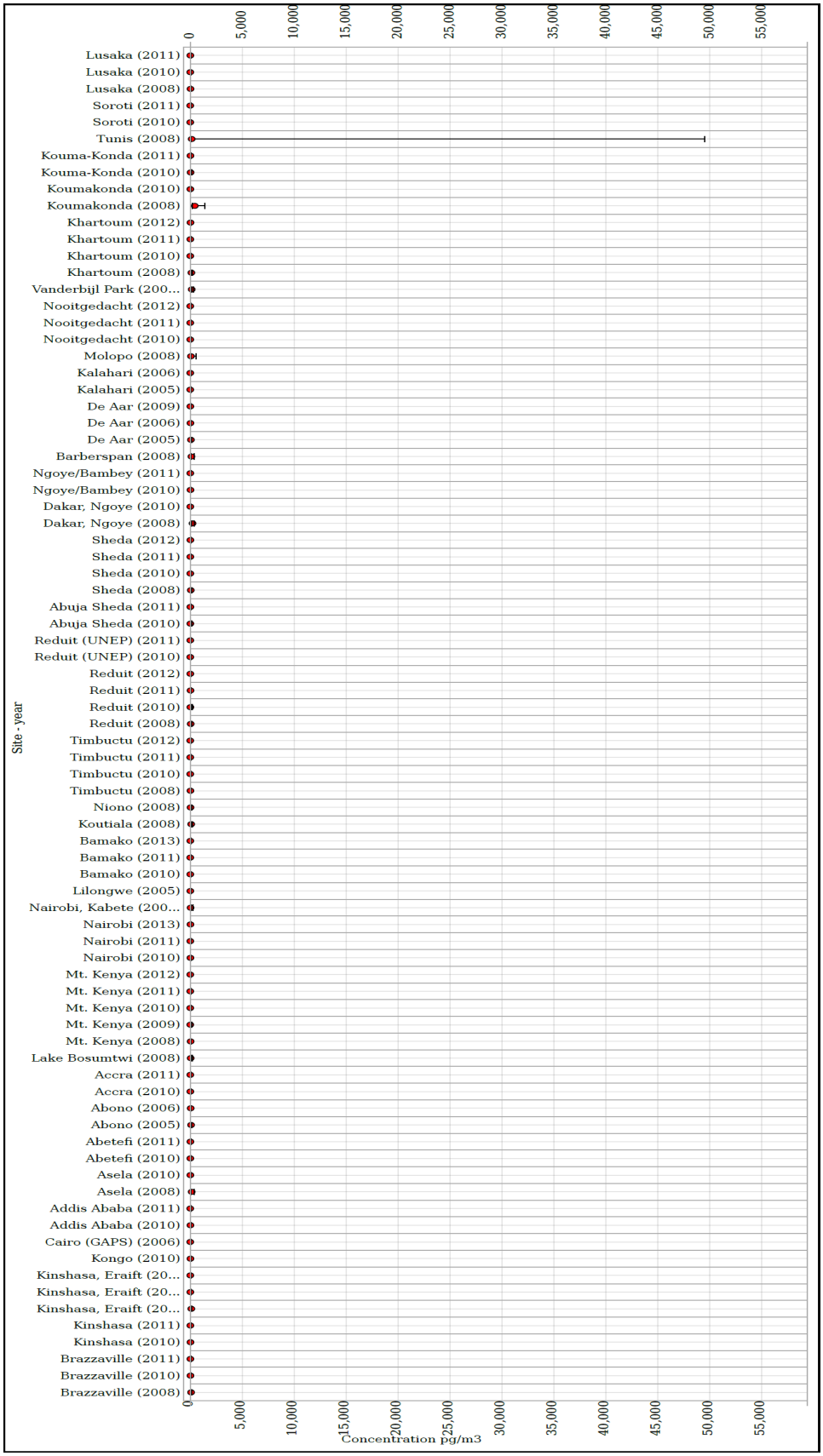

Figure 5.2.1.38 Concentration of gamma-HCH in ambient air

5.2.1.19. Pentachlorobenzene (PeCB)

The overall concentration of PeCB in ambient air over the period 2010-2012 is summarised in Figure 5.2.1.39. The highest levels were measured at the site in Khartoum. Other sites with high concentrations were Mt. Kenya, Asela, Canary Island, Kouma Konda, Sheda, Brazaville and Reduit. A wide distribution of PeCB was recorded in the region at all the sites. There was no established trend of the compound due to sporadic changes in concentrations observed from time to time.

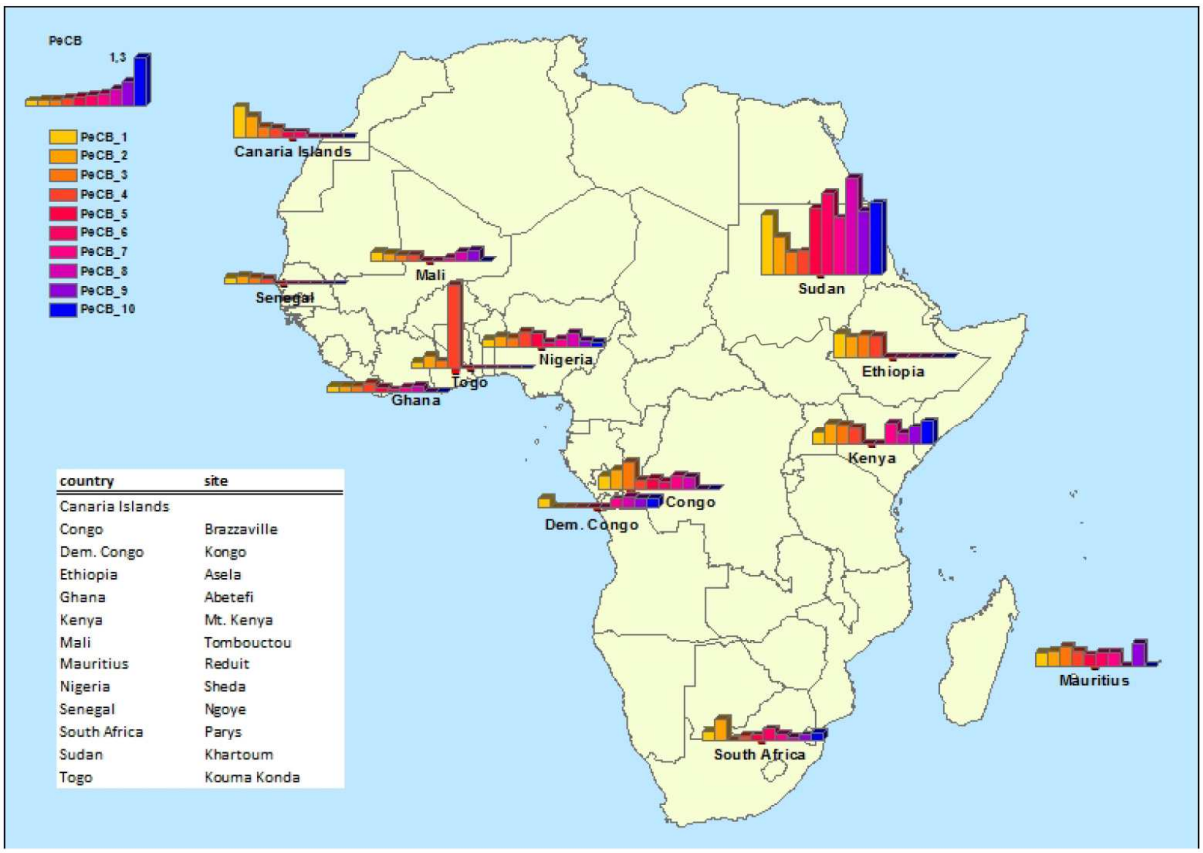

Figure 5.2.1.39 PeCB levels in ambient air (PAS, ng sample-1) in Africa, 2010-2012

In 2013, only Kenya and Mali provided data for PeCB. Bamako site in Mali recorded concentration of 22.48 pg.m^{-3}, whereas the site at Kabete, Nairobi had 9.30 pg.m^{-3}.

5.2.1.20. Polybrominated Diphenyl Ethers (PBDEs)

The distribution of PBDEs in MONET sites in the region from 2010-2012 is summarised in Figure 5.2.1.40 below. High levels of PBDEs were recorded at the sites in Khartoum and Brazzaville, with moderate levels at Sheda, Canary Island, Reduit and Kongo.

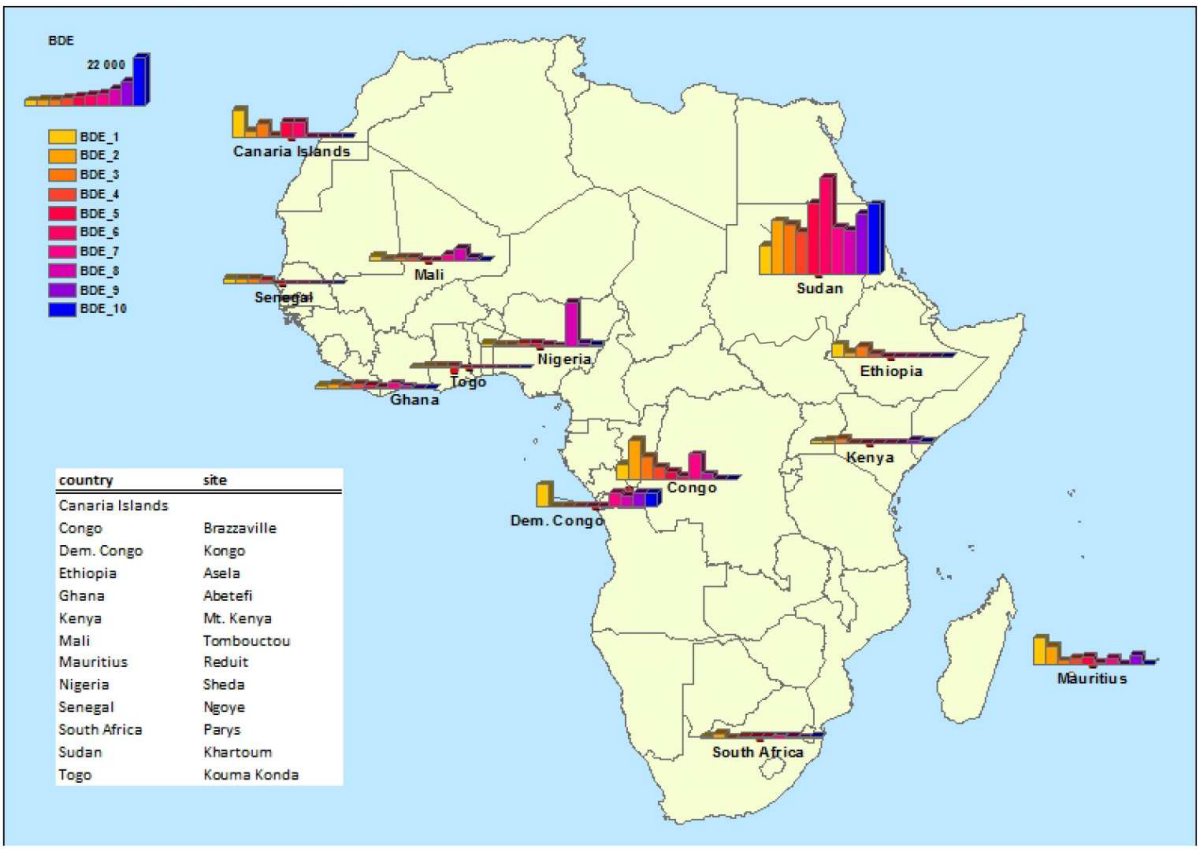

Figure 5.2.1.40 PBDE levels in ambient air (PAS, pg sample^{-1}) in Africa, 2010-2012

PBDE 153

Over the period 2008-2012 the highest levels of PBDE 153 were reported at Khartoum in Sudan with the mean concentration of 0.80 pg.m^{-3}. For the period between 2011 and 2012, the lowest concentrations were measured at Mt. Kenya site with levels of 0.013 and 0.017 pg.m^{-3}, respectively (Figure 5.2.1.41).

In 2013 the highest value was recorded at Bamako Mali (1.52 pg.m^{-3}). On the other hand, the lowest concentration of 0.010pg.m^{-3} was found at Nooitgedacht South Africa in 2010.

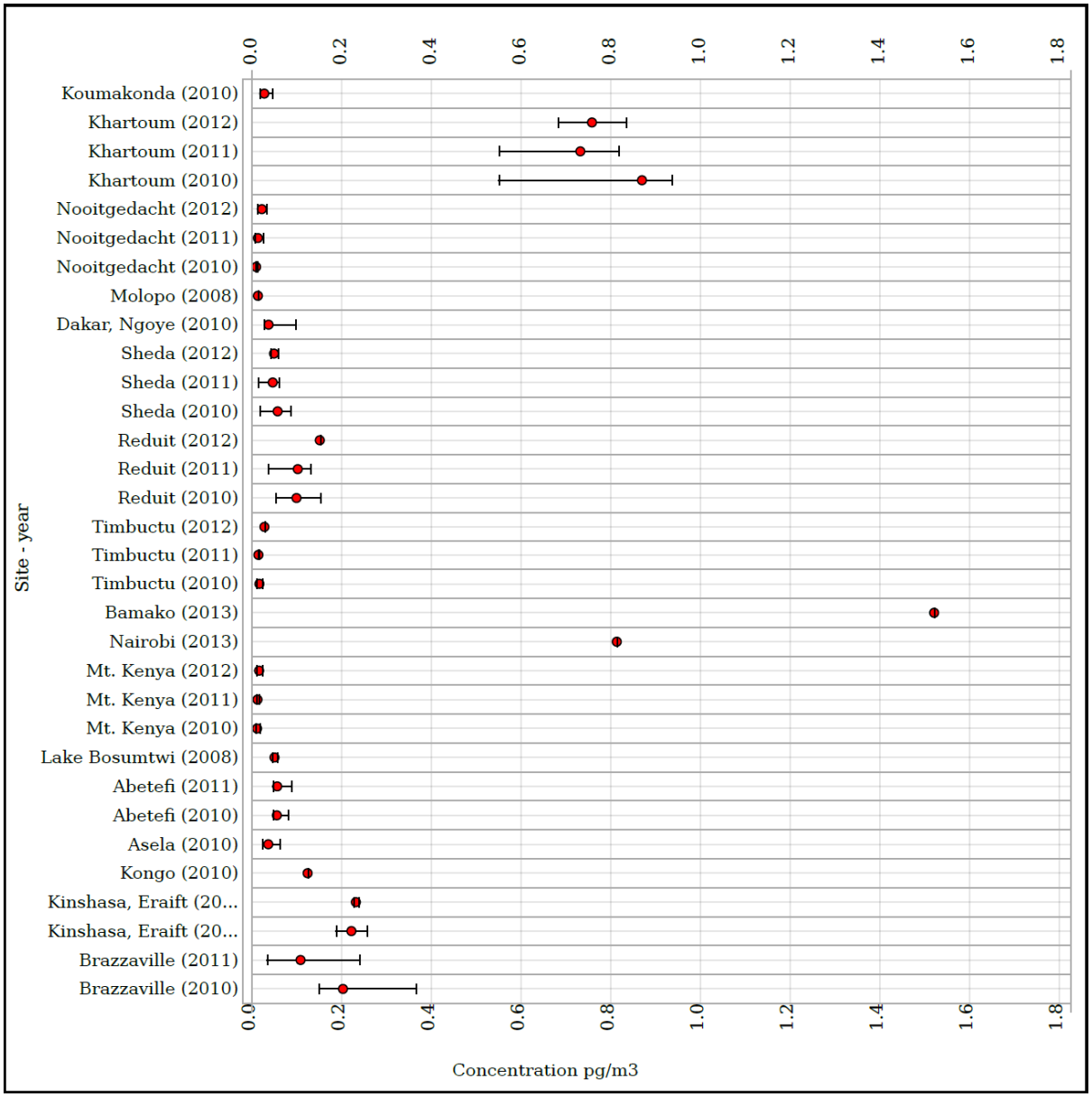

Figure 5.2.1.41 Concentration of PBDE 153 in ambient air

PBDE 154

Over the period 2010-2012 the highest concentration of PBDE 154 was measured at Khartoum (> 0.44 pg.m^{-3}) whereas the lowest levels were recorded at Mt. Kenya (<0.01 pg.m^{-3}). In 2013, samples from Mali and Kenya had uniform concentration of 0.88 pg.m^{-3} each (Figure 5.2.1.42).

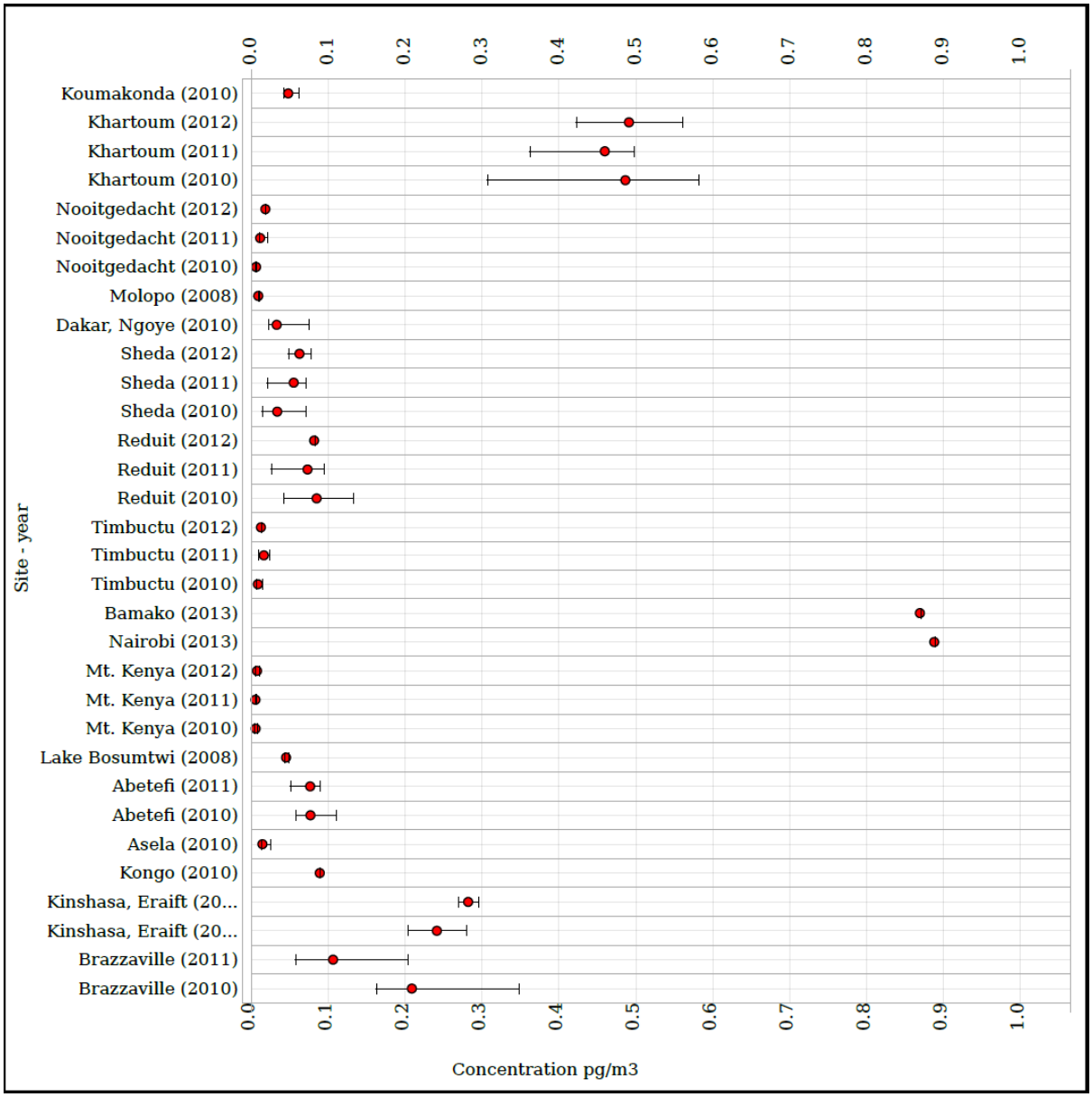

Figure 5.2.1.42 Concentration of PBDE 154 in ambient air

PBDE 175/183 and PBDE 17

Ambient air contaminations by both PBDE 175/183 and BDE 17 were measured in Kenya and Mali in 2013. The concentration of PBDE 175/183 were between 0.9 and 1.3 pg. m^{-3}, whereas the PBDE 17 were between 1.5 and 6.5 $pg.m^{-3}$. Higher concentration was measured at Bamako Mali.

PBDE 28

Over the period 2010-2012, the Mt. Kenya was the least contaminated site with PBDE 28. In 2010, the highest polluted sites were Brazzaville, Congo (1.25 $pg.m^{-3}$) and Khartoum (0.70

pg.m^{-3}). In 2011, Abetefi (Ghana), Kinshasa Ereift (DR Congo) and Khartoum (Sudan) were the most contaminated sites (Figure 5.2.1.43). The two later sites remained highly contaminated in 2012. In 2013 higher mean values of PBDE 28 were recorded in Bamako (3.16 pg.m^{-3}) and Nairobi (2.25 pg.m^{-3}).

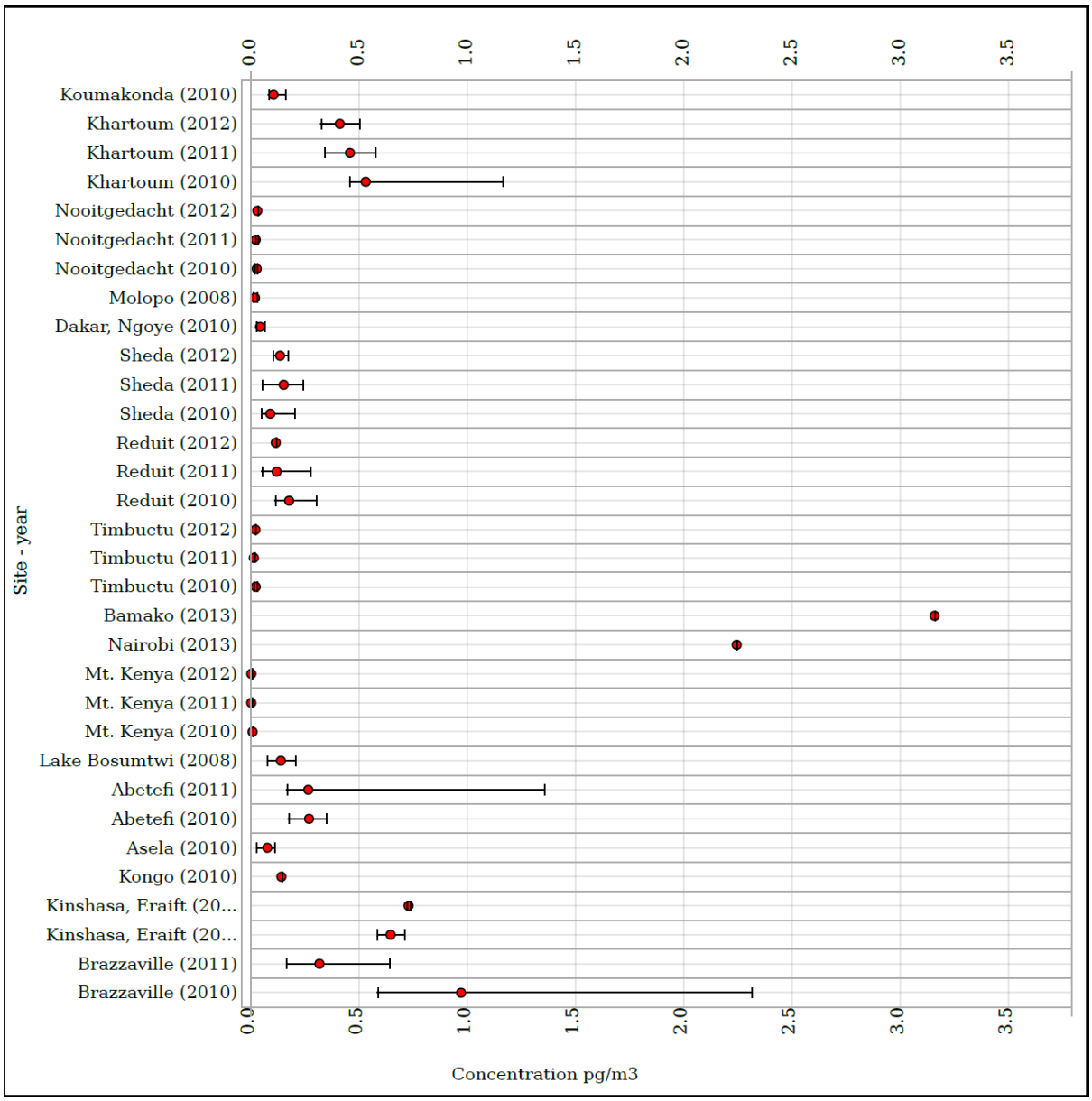

Figure 5.2.1.43 Concentration of PBDE 28 in ambient air

PBDE 47

The sites at Khartoum, Reduit, Abetefi, Brazzaville and Kinshasa Ereift recorded the highest concentrations of PBDE 47 over the period 2010-2012. In 2013, only samples from Kenya and Mali were reported. Bamako, Mali recorded higher mean concentration of PBDE 47 (10.17 pg.m^{-3}) compared to Kabete, Kenya which recorded 2.97 pg.m^{-3} (Figure 5.2.1.44).

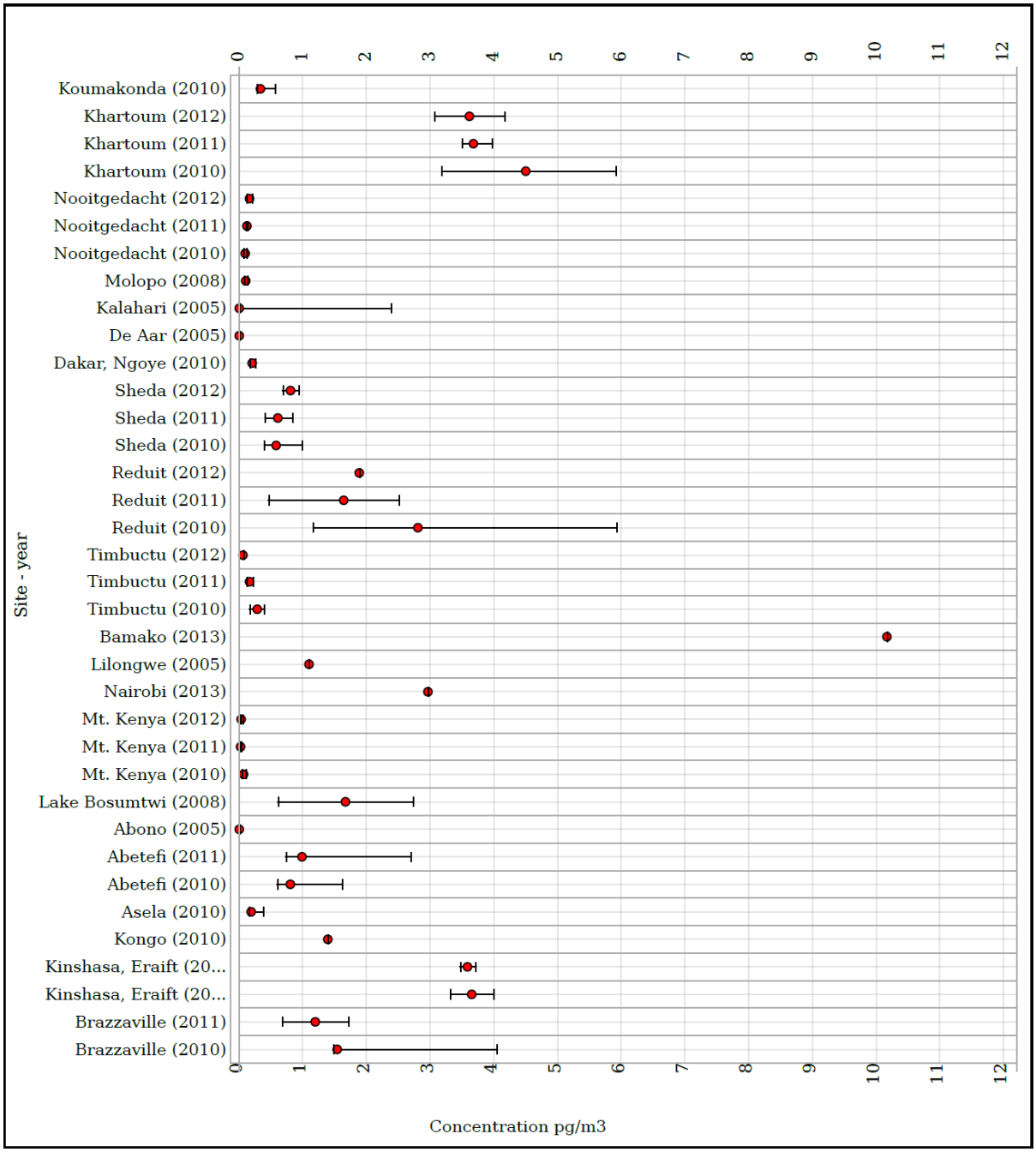

Figure 5.2.1.44 Concentration of PBDE 47 in ambient air

PBDE 99

The levels of PBDE 99 varied over the period 2010-2012, but showed the same trend as PBDE 47. Khartoum recorded the highest concentrations with mean levels of 4.31 $pg.m^{-3}$ (2010), 3.33 $pg.m^{-3}$ (2011) and 3.98 $pg.m^{-3}$ (2012), while Mt. Kenya was the least contaminated site with concentrations below 0.05 $pg.m^{-3}$ from 2010 to 2012. In 2013 Bamako recorded the highest concentration of PBDE 99 (Figure 5.2.1. 45).

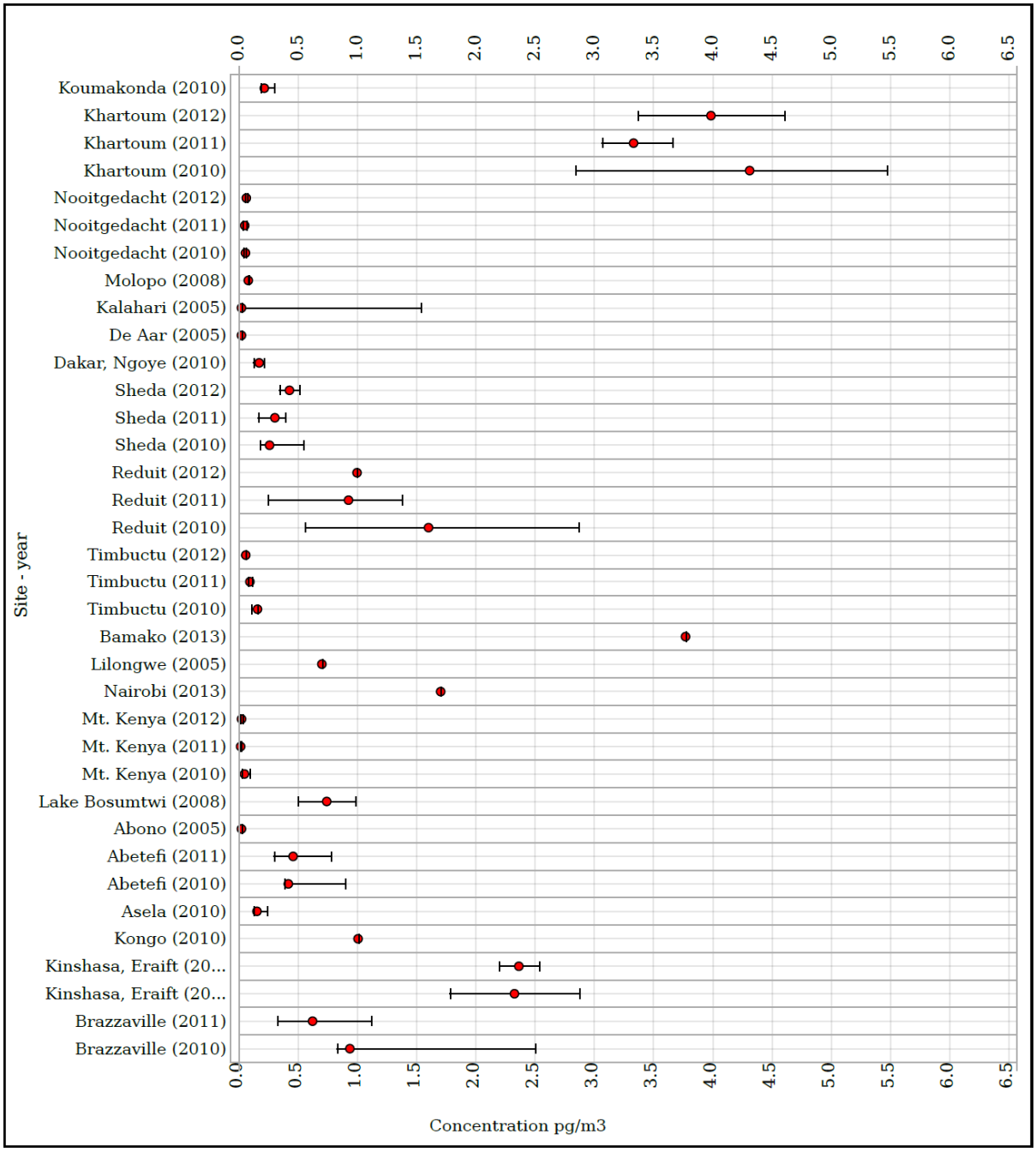

Figure 5.2.1.45 Concentration of PBDE 99 in ambient air

PBDE 100

Over the period 2010-2012 low PBDE levels ranging from 0.01-0.98 pg.m^{-3} were recorded in the Africa region except in 2011 where high contamination level of 10.97 pg.m^{-3} was found at Sheda, Nigeria (Figure 5.2.1.46). In comparison with the POP pesticides (listed in Annex A and Annex B) POP-PBDEs had significantly lower contamination levels. Contamination

occurred predominantly at urban sites (Khartoum, Bamako, Nairobi Brazzaville, Kinshasa etc.) and might originate from crudes recycling articles that used to contain these chemicals as flame-retardants. The site of Khartoum in Sudan is affected by almost all PBDEs congeners.

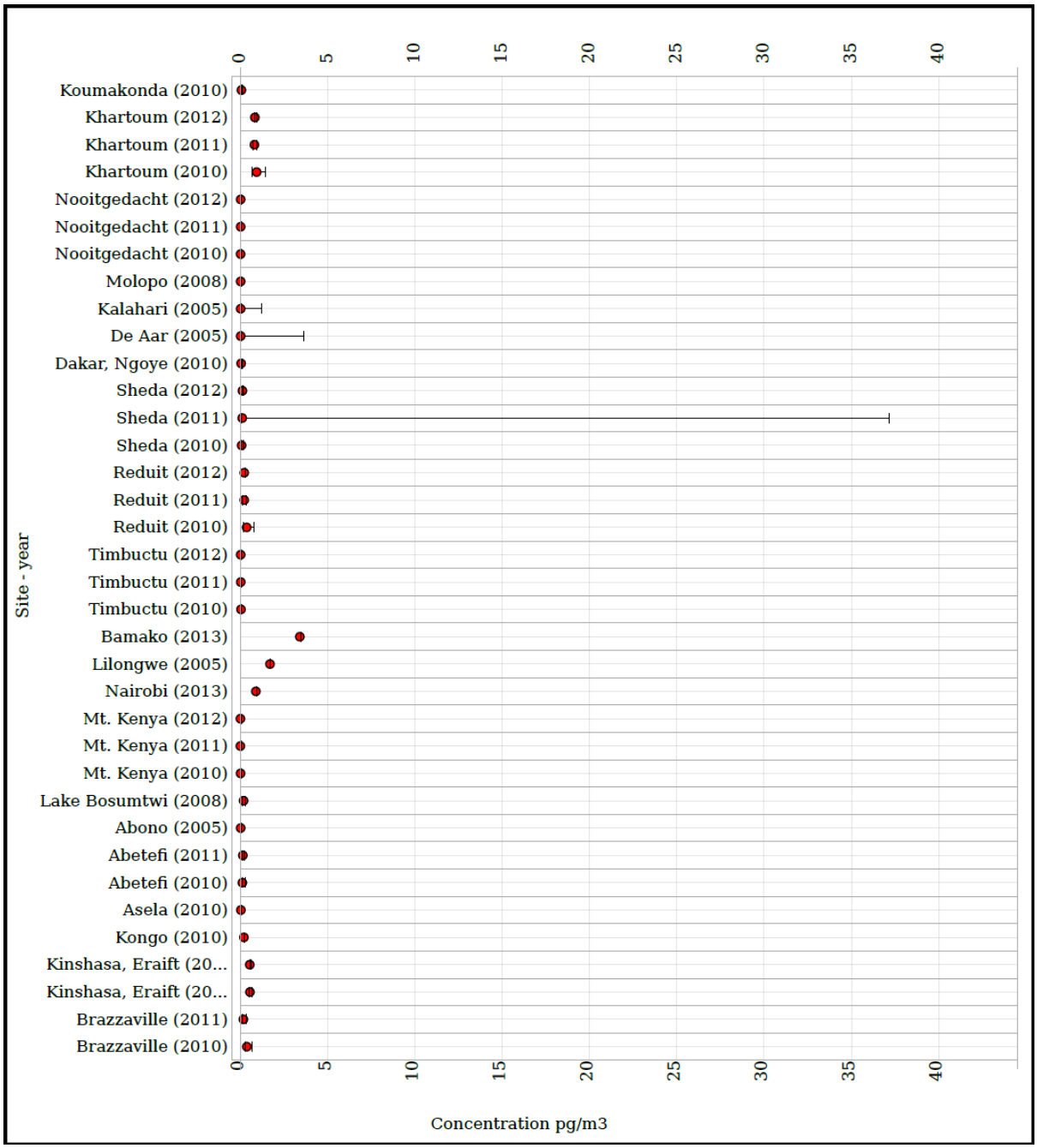

Figure 5.2.1.46 Concentration of PBDE 100 in ambient air

5.2.1.21. Perfluorooctane Sulfonates (PFOS)

Perfluorooctane sulfonates were analysed in 2013 at only Bamako (Mali) and Nairobi (Kenya) sites. The concentrations of PFOS, FOSA, N-methyl and N-ethyl-perfluoroalkane sulfonamides (MeFOSA & EtFOSA), and N-methyl and N-ethyl perfluoroalkane sufonamidoethanols (MeFOSE & EtFOSE) PFOS and salts in ambient air from two sites in the region are shown in Figure 5.2.1.47 below. The levels of PFOS were between 10.57 pg.m^{-3}and 14.98 pg.m^{-3}, PFOSA (21.58-24.04 pg.m^{-3}), NMeFOSA (2.76-3.07 pg.m^{-3}), NEtFOSA (2.65-2.71 pg.m^{-3}), NMeFOSE (21.49-81.67 pg.m^{-3}) and NEtFOSE (0.22-33.94). Kabete site recorded higher levels of NMeFOSE and NEtFOSE, whereas Bamako registered higher levels of PFOS, PFOSA, NMeFOSA and NEtFOSA.

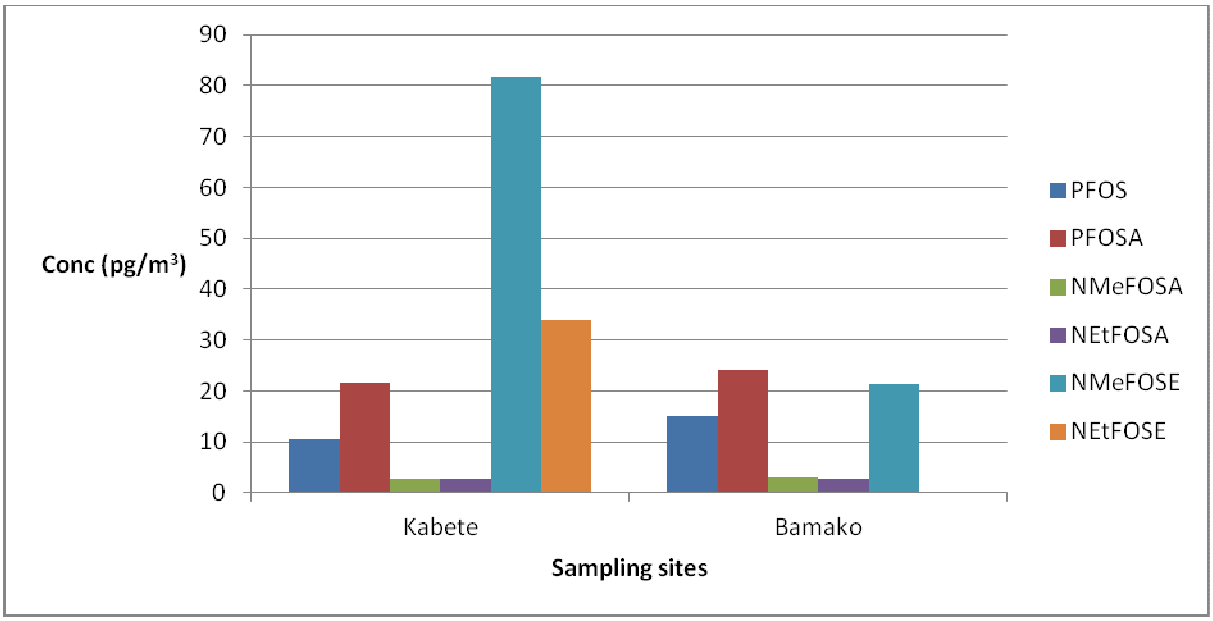

Figure 5.2.1.47 Concentration of PFOS and salts in ambient air

5.2.1.22. Discussion of POPs levels in ambient air in individual countries

The next section provides a brief discussion of the POPs levels measured in ambient air per given participating country.

i) POPs Levels in Ambient Air in Republic of Congo

In the Republic of the Congo, Brazzaville site participated in the sampling in 2008, 2010 and 2011. The site was contaminated with chemicals from Annex A (pesticides and industrial chemicals) and Annex C chemicals (PCDDs/PCDFs). The most important POPs detected were PCDDs/PCDFs, PCBs, endosulfan and *gamma*-HCH. From 2008 to 2011 there was a general decreasing trend in POP pesticides while, an increasing trend was observed for PCDDs/Fs in Congo.

The simultaneous presence of annex A pesticides, Annex A industrial chemicals as well as dioxins and furans in the Republic of the Congo corroborated the fact that the site Brazzaville site an urban site, it was impacted by agricultural, industrial and unsound wastes disposal activities.

ii) POPs levels in ambient air in The Democratic Republic of Congo (DRC)

In DRC, the sites of Cogelos, Kinshasa, Kinshasa Ereift and Muanda participated in the sampling campaigns in 2008, 2010, 2011 and 2012. At the site of Muanda, data were collected only for 2010. Annex A pesticides only were detected as contaminants, endrin and oxychlordane being the most important. The same contaminants were found at the site of Cogelos in 2011 and 2012. Aldrin, endrin and *alpha*-endosulfan were the predominating POPs pesticide with an increasing trend from 2011 to 2012. At the site in Kinshasa in 2010 and 2011, the prevailing contaminants were *trans*-chlordane, dieldrin, endrin, heptachlorepoxide, HCHs, aldrin, sum of 6 DDTs and the 6 PCBs indicators. Compared to the contamination levels in 2010, those from 2011 showed a decrease for *trans*-chlordane, dieldrin, endrin, heptachlorepoxide and HCHs while an increase was observed for aldrin, sum of 6 DDTs and 6 PCBs indicators. At the site of Kinshasa Ereift, the most prevailing contaminants were Annex A industrial chemicals (HCB, PCBs and POP-PBDEs), PCDDs/Fs and HCHs. From 2008-2012, a decrease was observed in the levels of HCB, 6 PCBs indicator, 7 PCBs, *alpha*- and *gamma*-HCH, while the levels of 7 PCDDs increased and those of PCDFs and POP-PBDEs remained almost constant.

Since all the sites in DRC were urban background sites, the presence of POPs as contaminants of ambient air is most probably linked to anthropogenic activities including industry, agriculture and municipal solid wastes disposal. The presence of agricultural type pesticide like endosulfan, aldrin, endrin, heptachlor might originate from urban agriculture which is widespread in African cities. Illegal agricultural uses or the application of the control of malaria vector were certainly the domestic causes of the presence of DDTs in ambient air.

iii) POPs levels in ambient air in Ethiopia

Addis Ababa and Asela were the two sampling site in Ethiopia in 2008, 2010 and 2011. At the Addis Ababa site, the contaminants detected included Annex A pesticides, Annex B pesticides, PCBs and dioxins and furans. In 2008 only furans as the sum of 10 PCDFs were analysed. In 2010 and 2011 the predominant contaminants were DDTs (sum of 6 DDTs) and PCBs (12 *dl*-PCBs). From 2010 to 2011, the general trend was a decrease in all detected POPs level. As an example the concentration of DDTs decreased from 250 $pg.m^{-3}$ to 73.44 $pg.m^{-3}$.

Annex A pesticides, Annex A industrial chemicals (PCBs and POP-PBDEs) and dioxins and furans were detected at the Asela site in 2008 and 2010. As compared to their levels in 2008,

the levels of dieldrin, endrin, PCDFs (sum of 10), *alpha*- and *beta*- HCH were in an increasing trend in 2010. Conversely, the levels of chlordanes (*cis*- and *trans*-), HCH, PCBs (sum of 6), PCDDs (sum of 7), *gamma*-HCH and *alpha*-endosulfan decreased in 2010 in comparison to their levels in 2008.

In Ethiopia, sampling at the Addis Ababa and Asela sites in 2010 and 2011 showed that HCB, *gamma*-HCH, *alpha*-endosulfan, PCBs, DDTs as well as dioxins and furans were the main POPs of concern.

iv) POPs levels in ambient air in Ghana

In Ghana two sites, Abetefi and Accra, were sampled from 2010 to 2011. At Abetefi site of the detected POPs were inclusive of Annex A pesticides, Annex A industrial chemicals and dioxins and furans. Dieldrin, *alpha*-endosulfan, PCDDs, PCDFs, *gamma*-HCH, HCB, endrin and oxychlordane were the most important contaminants analysed. At the Abetefi site, the temporal trend indicated that aldrin, chlordanes, endrin and *alpha*-endosulfan decreased over the period 2010-2011, while there was an increase in the contamination levels of PCDDs (sum of 7) and PCDFs (sum of 10) and *gamma*-HCH. The concentration levels of POP-PBDEs remained almost constant over the sampling period.

At the Accra site, the most important POPs detected were dioxin-like PCB with a concentration level as high as 2,641.12 $pg.m^{-3}$ in 2010. Other POPs with significant concentration were followed by PCDFs (sum of 10), PCDDs (sum of 7), DDTs (sum of 6), PCBs (sum of 6) and dieldrin.

Ambient air sampling in Ghana in 2010 and 2011 showed that almost all POPs were present at the sites of Abetefi and Accra. The most prevailing were endosulfans, HCH, DDTs (pesticides), PCBs (industrial chemicals) and dioxins and furans (unintentional by-products).

v) POPs levels in ambient air in Kenya

Sampling campaigns at the Mt. Kenya site were made annually from 2008 to 2012. All POPs were detected over the sampling period at the exception of toxaphene, mirex and *dl*-PCBs. Over the five year sampling period, the concentration of the various POPs ranged from 0.0036 $pg.m^{-3}$ (POP-PBDE 28 in 2012) to 146.44 $pg.m^{-3}$ (*alpha*-endosulfan in 2009). The concentration of POP pesticides (Annex A and Annex B chemicals) was in the range of 0.058 $pg.m^{-3}$ (*trans*-nonachlor in 2009) and 146.44 $pg.m^{-3}$ (*alpha*-endosulfan in 2009). Industrial chemicals included PCBs (sum of 7 and 6 indicator PCBs) in the range of 1.42 $pg.m^{-3}$ (6 indicator PCBs in 2011) to 8.84 $pg.m^{-3}$ (all PCBs in 2008). The other group of analysed Annex A industrial chemicals were POP-PBDEs; their levels varied from 0.0036 $pg.m^{-3}$ (PBDE 28 in 2012) to 0.075 $pg.m^{-3}$ (PBDE 47 in 2010). The dioxins level increased from 1.17 $fg.m^{-3}$ in 2008 to 8.65 $fg.m^{-3}$ in 2011. The concentration of furans decreased from 9.03 $fg.m^{-3}$ in 2008 to 3.85 $fg.m^{-3}$ in 2012. DDTs were only quantified once in 2009 during the

sampling period. The level of *alpha*-endosulfan increased from 1.97 pg.m^{-3} to 146.44 pg.m^{-3}in 2009 and then decreased to 9.88 pg.m^{-3} at the end of the sampling campaign in 2012. Likewise, *gamma*-HCH increased from 4.80 pg.m^{-3} in 2008 to 33.04 pg.m^{-3} in 2009 and then decreased to 5.83 pg.m^{-3} at the end of the sampling campaign in 2012. Another pesticide with similar trend was endrin the level of which increased from 0.90 pg.m^{-3} in 2008 to 27.78 pg.m^{-3} in 2010 and then decreased to 6.91 pg.m^{-3} in 2012.

At the Nairobi site, the levels of POP-PBDEs, Endosulfans, PFOS and related chemicals, HBB, HBCD and toxaphenes were determined only in 2013 preventing any attempt to undertake time trend analysis from 2008-2013. Likewise, PCBs were analysed only in 2008 (sum of 7 PCBs). HCH (alpha- and beta) decreased from 2010 to 2013 while the gamma isomer showed an irregular trend over the period, with decreasing in 2011 and increasing in 2013. Levels of many pesticides (Annex A and Annex B) tended to decrease from 2010 to 2011.

In general, the contamination of ambient air at Mt. Kenya site used to be the lowest making this site the least polluted of all sampling sites in the Africa region. Almost all types of POPs were found at this site although at low levels indicating a pollution that probably originated from atmospheric current as a component of the long range transport of POPs to this remote site.

vi) POPs levels in ambient air in Mali

At the Bamako site the levels of most pesticides decreased from 2010 to 2011. As an example DDTs (sum of 6) decreased from 1,442.95 pg.m^{-3} in 2010 to 428.95 pg.m^{-3} in 2011. The concentration of HCHs was irregular from 2010-2013.

PCBs (sum of 6 PCBs indicators) decreased from 64 pg.m^{-3} to 32.99 pg.m^{-3} from 2010 to 2011. Dioxin-like PCBs were only analysed in 2010 and showed a high level reaching 3195.06 pg.m^{-3}. Dioxins and furans were only analysed in 2010.

Many chemicals (PeCB, POP-PBDEs, endosulfans, PFOS and related chemicals, HBCDs, toxaphene and HBB) were determined only in 2013.

Sampling of ambient air at the Tombouctou site was almost continuous from 2008 to 2012 at the exception of 2009. Various Annex A pesticides were found (HCB, HCH, *alpha*-endosulfan, oxychlordane, endrin, dieldrin) registered decreasing levels between 2008-2012.

The levels of PCBs (sum of 7 and sum of 6) decreased over the sampling period as well as the concentration of PBDEs, which were slightly decreasing.

Dioxins and furans had the highest concentrations. The levels of dioxins increased from 75.43 pg.m^{-3} in 2008 to 112.87 pg.m^{-3} in 2010 and then decreased to 14.58 pg.m^{-3} in 2012.

Furans increased from 24.67 pg.m^{-3} in 2008 to 117.41 pg.m^{-3} and decreased to 4.20 pg.m^{-3} in 2012.

Sampling of Ambient air in Mali from 2008 and 2013 at Bamako and Tombouctou sites showed that almost all POPs were present but the most important ones were PCBs, DDTs, HCB, *alpha*-endosulfan, dioxins and furans. The temporal trend could be summarised as a decrease in levels of the detected POPs.

vii) POPs levels in ambient air in Mauritius

Over the sampling period 2008-2012 with the exception of 2009, almost all Annex A pesticide were detected at Reduit site in Mauritius. The level of endrin increased from 2.82 pg.m^{-3} in 2008 to 31.61 pg.m^{-3} in 2010 and then decreased to 6.91 pg.m^{-3} in 2012. A decrease was observed in the level of HCB from 16.49 pg.m^{-3} in 2008 to 10.07 pg.m^{-3} in 2010 followed with a significant increase to 22.61 in 2012. Contamination with HCH (*alpha* and *beta*-) and *alpha*-endosulfan decreased over the sampling period. The concentration of industrial chemicals (*dl*-PCBs) and unintentional POPs (dioxins and furans) increased significantly over the sampling period.

For the sampling conducted under the UNEP/GEF project in 2010 and 2011, various Annex A pesticides were found including mirex, HCHs, dieldrin, endrin, chlordanes, heptachlor, as well as DDTs. The industrial chemicals detected included *dl*-PCBs. Dioxins (sum of 7 PCDDs) and furans (sum of 10) were among the major contaminants. At the exception of an increase in the levels of DDTs, the amount of data available does not allowed analysis of temporal trends in the levels of other POPs.

In Mauritius, the prevailing POPs found in ambient air were DDTs, endrin, endosulfan, HCB, PCBs, dioxins and furans. There was an increase in the levels of DDTs, dioxins and furans over the sampling periods.

viii) POPs levels in ambient air in Nigeria

The Sheda site was almost continuously sample from 2008 to 2012 except in 2009. Annex A pesticides detected were the following: aldrin, chlordanes, dieldrin, endrin, HCB, HCH, and *alpha*-endosulfan; the latter was the most important of the detected pesticides. The most important industrial chemicals were PCBs, along with small amount of PBDEs. PFOS and related chemicals were not detected, whereas dioxins and furans were found in significant amount.

Amongst the POPs detected dioxins, furans and *alpha*-endosulfan were the most prevailing ones. Over the time, levels of POPs tended to decrease, although the period over which the monitoring was conducted was too short to provide conclusive trend.

Sampling at Abuja Sheda site took place in 2010 and 2011. Major POPs detected were: dieldrin, HCB, HCHs (Annex A pesticides), DDTs (Annex B), 6 PCBs indicators, 12 *dl*-PCBs (Annex A industrial chemicals), dioxins and furans (Annex C) chemicals. The most important POPs over the sampling period were *dl*-PCBs (182.36 $pg.m^{-3}$ in 2010) and *gamma*-HCH (44.76 $pg.m^{-3}$ in 2010) with a decrease to 14.71 $pg.m^{-3}$ in 2011. Various POPs were not detected or detected at lower concentrations were: aldrin, endrin, heptachlor, *alpha-e*ndosulfan and PBDEs.

In Nigeria, ambient air was predominantly contaminated by *alpha*-endosulfan, *gamma*-HCH, DDTs, PCBs and dioxins and furans. There was a decreasing trend in the levels of these POPs.

ix) POPs levels in ambient air in Senegal

The site of Dakar Ngoye was sampled in 2008 and 2010. The following Annex A pesticides were detected: aldrin, chlordanes, dieldrin, endrin, HCB, HCHs and *alpha*-endosulfan. All pesticides had decreasing levels over the sampling period at the exception of endrin and *alpha-* and *beta*-HCH. The most predominant pesticides were dieldrin, *gamma*-HCH and *alpha*-endosulfan. The most industrial POPs were PCBs (sum of 6 indicator PCBs). The concentration of the indicator PCBs markedly decreased from 786.09 $pg.m^{-3}$ in 2018 to 4.28 $pg.m^{-3}$ in 2010. The POP-PBDEs, analysed only in 2010, were found in very low concentrations (0.042 $pg.m^{-3}$ - 0.21 $pg.m^{-3}$). Dioxins (sum of 7 PCDDs) decreased from 2,523.27 $fg.m^{-3}$ in 2008 to 232.29 $fg.m^{-3}$ in 2010. Likewise, the levels of furans (sum of 10 PCDFs) decreased from 1,188.06 $fg.m^{-3}$ in 2008 to 17.44 $fg.m^{-3}$ in 2010.

At the site of Ngoye Bambey, sampling took place in 2010 and 2011. The pesticides detected were aldrin, chlordanes, dieldrin, endrin, mirex, HCB, HCHs (Annex pesticides), DDTs (Annex B) and PCBs, the most important being DDTs and HCHs, all with decreasing levels over the sampling period.

In Senegal, sampling of ambient air in 2008, 2010 and 2011 revealed that the prevailing POPs were HCHs, *alpha*-endosulfan, dieldrin, DDTs, PCBs, dioxins and furans, all of them in decreasing concentration over the sampling period.

x) POPs levels in ambient air in South Africa

Sampling in South Africa took place at 3 sites: Nooitgedacht (2010-2012), De Aar (2009) and Vanderbijil Park (2009). At the site of Nooitgedacht, the pesticides detected were aldrin, chlordanes, dieldrin, endrin, HCB, heptachlor, HCH and *alpha*-endosulfan. The prevailing ones were *alpha*-endosulfan, HCB, *gamma*-HCH and oxychlordane, the latter two ones with a decreasing trend. PCBs were mainly represented by PCBs indicators (sum of 6). PBDEs were also detected in low concentrations. Dioxins and furans were among the most important POPs. Dioxins increased while furans remained almost stable over the sampling period.

Sampling at the sites of De Aar and Vanderbijil Park in 2009 showed that aldrin, dieldrin, HCHs, endosulfans, DDTs and PCBs were the most important POPs. Of these, the prevailing ones were DDTs, HCH and *alpha*-endosulfan.

xi) POPs levels in ambient air in Sudan

In Sudan, sampling took place in Khartoum which is an urban industrial background. Most of the POPs with variable contamination levels were detected in ambient air except DDTs, dl-PCB and Mirex over the period 2008-2012. Aldrin, chlordane, dieldrin, endrin, HCB, HCHs, heptachlor and *alpha*-endosulfan were the most important pesticides detected.

Contamination level of aldrin, HCHs and heptachlor decreased, while *alpha*-endosulfan increased over the four year sampling period. HCB decreased from 2008 to 2010 and increased slightly in 2012. Among the African participating countries, Sudan has emerged as the most polluted site by HCB and *gamma*-HCH throughout the sampling campaigns. Industrial chemicals like PCBs and non-intentional pollutants (dioxins and furans) were the most pollutants with high concentration levels, but gradually showed a decline over the sampling period. Although POP-PBDEs had lower concentration levels compared to the levels of other POPs detected in Sudan, the Khartoum site remained the most contaminated site with PBDEs in the African region over the period 2010-2012.

xii) POPs levels in ambient air in Togo

All POPs of interest were found in Togo at the site of Koumakonda. The most important POPs detected in ambient air over the period 2008-2011 were DDTs, HCB, HCHs and *alpha*-endosulfan (pesticides), PCBs including dl-PCBs, dioxins and furans. POP-PBDEs were only detected in 2010. *Gamma*-HCH, *alpha*-endosulfan and sum of 7 PCDDs with high concentrations of 614.51pg.m^{-3}, 448.90 pg.m^{-3} and 153.38 pg.m^{-3}, respectively in 2008, and decreased considerably in 2010. Similar decreasing trends were observed in the concentrations of DDTs, HCB, PCBs (sum of 6), furans and *alpha*-and *beta*-HCH.

xiii) POPs levels in ambient air in Uganda

POPs detected in Uganda over the two year sampling period 2010-2011 were aldrin, chlordanes, DDTs, dieldrin, endrin, HCB, heptachlor, mirex, HCHs (pesticides), PCBs, dioxins and furans. Endosulfan and POP-PBDEs were not found at the Soroti site. Most important pollutants were DDTs, dieldrin, HCB and indicators PCBs (sum of 6), all with an increasing trend over the period 2010-2011. High concentration of *dl*-PCBs (sum of 12) was only quantified in 2010.

xiv) POPs levels in ambient air in Zambia

Almost all POPs were found at Lusaka site except POP-PBDEs over the period 2008-2011. The most important contaminants were DDTs, chlordanes, dieldrin, HCB, HCH (pesticides), PCBs indicators (sum of 6) and dioxins (sum of 7 PCDDs) and furans (sum of 10 PCDFs). DDTs, chlordanes, HCB, HCHs and dioxin/furans decreased over the sampling period. The pollutants *alpha*-endosulfan was only detected in 2008 with a high level reaching 158 $pg.m^{-3}$ and *dl*-PCB (sum of 12) in 2010 with the highest concentration level (7,797.84 $pg.m^{-3}$).

5.2.2 Human tissues (mothers' milk)

The results from milk were obtained from the UNEP/WHO mothers' milk survey and the UNEP/GEF project implemented between 2008 to 2012. Mothers' milk data from Sudan was obtained in 2006.

5.2.2.1. Aldrin

Levels of aldrin were below LOQ in all participating countries (Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Ethiopia, Ghana, Kenya, Mali, Mauritius, Nigeria, Niger, Senegal, Togo, and Uganda).

5.2.2.2 Chlordane

Only oxychlordane was found in quantifiable levels between LOQ and 12.05 ng/g fat (Figure 5.2.2.1) in all participating countries except Kenya and Uganda, while *cis*-chlordane (= *alpha*) and *trans*-chlordane (= *gamma*) had levels below LOQ (0.5 $ng.g\ fat^{-1}$) in the participating countries. The highest levels were found in Sudan, Senegal, Niger, Mali, Côte d'Ivoire and Togo. Medium concentrations were measured in samples from Mauritius, Djibouti, Ghana, Ethiopia, Nigeria, Egypt and DR Congo, while Uganda and Kenya were in the lower range.

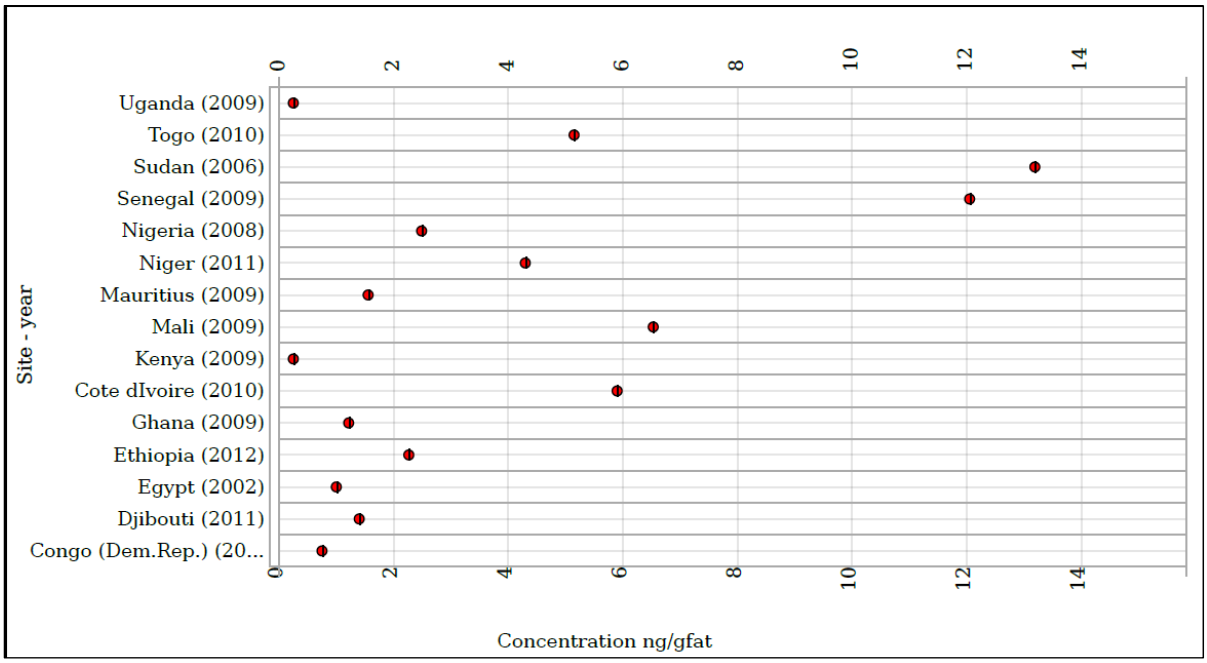

Figure 5.2.2.1 Concentration of oxychlordane in mothers' milk

5.2.2.3 Dieldrin

Dieldrin was detected in considerably high levels in human milk from all countries (Figure 5.2.2.2). The sample collected from Mali in 2009 had the highest concentration of dieldrin (11.21 ng.g fat^{-1}). The concentration was comparable with the levels reported in mothers' milk sample from New Zealand in 2011 (9.00 ng.g fat^{-1}). Nevertheless the contamination of human milk from Mali was far less than the one of the sample from Tajikistan in 2009 (more than 35 ng.g fat^{-1}).

Higher concentrations of dieldrin in human milk were also detected in mothers' milk samples from Kenya, Nigeria Côte d'Ivoire and Senegal. On the other hand, the mothers' milk samples from Ghana, DR Congo and Djibouti had the moderate contamination levels, while the samples from Ethiopia and Egypt recorded the lowest concentration of dieldrin in mothers' milk.

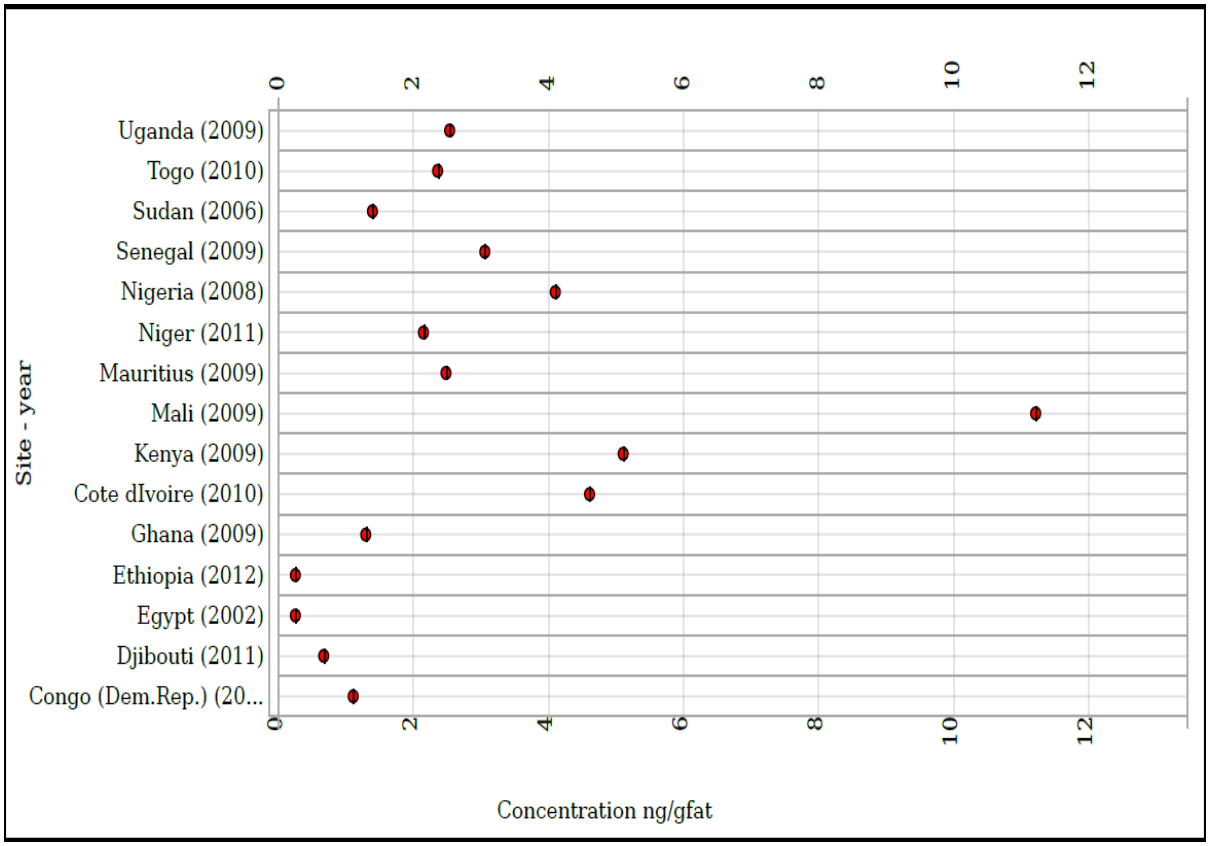

Figure 5.2.2.2 Concentration of dieldrin in mothers' milk

5.2.2.4 Endrins

The levels of endrin in mothers' milk were below LOQ (0.5 ng.g fat^{-1}) in all participating countries (Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Ethiopia, Ghana, Kenya, Mali, Mauritius, Nigeria, Niger, Senegal, Togo and Uganda).

5.2.2.5 Heptachlors

Figure 5.2.2.3 shows the levels of heptachlor in mothers' milk from the participating countries. High concentrations of heptachlor in human milk were found in samples from Ethiopia, Sudan, Togo and DR Congo. The highest heptachlor level was found in mothers' milk samples from Ethiopia (13.76 ng.g fat^{-1}). Low concentrations were reported in samples from Senegal, whereas the rest of the countries had levels below LOQ.

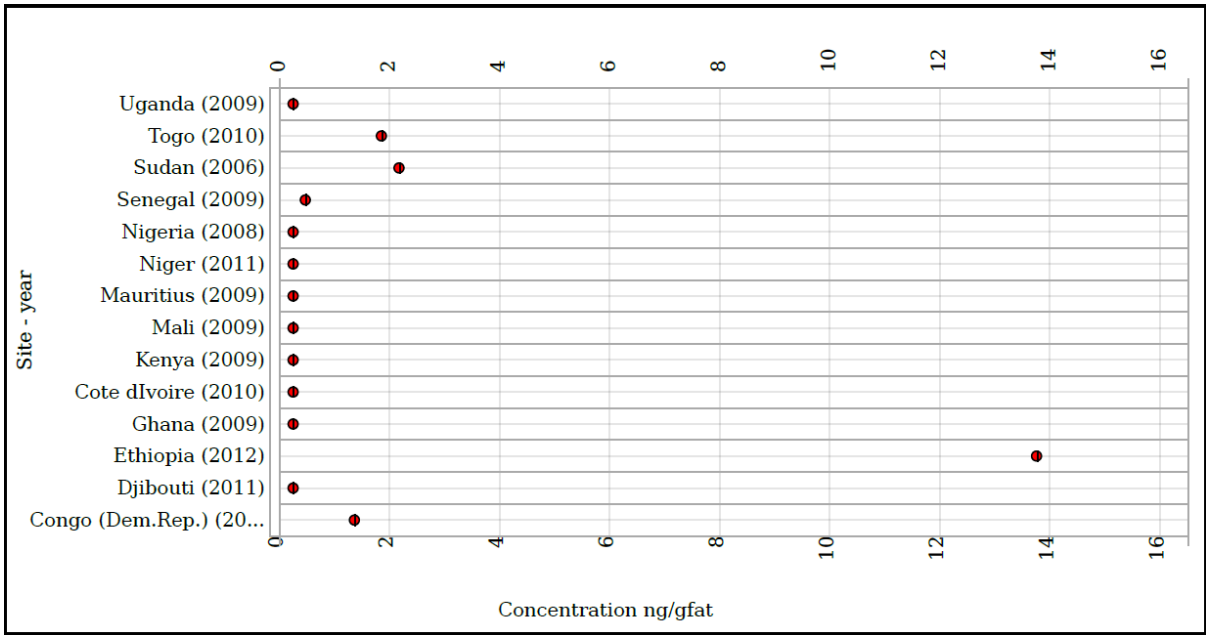

Figure 5.2.2.3 Concentration of heptachlor in mothers' milk

Highest concentrations of heptachlorepoxides were recorded in mothers' milk samples from Côte d'Ivoire, Mali, Togo, Senegal and Niger (Figure 5.2.2.4). The high concentration from human milk sample from Côte d'Ivoire in 2010 was comparable to the one from Belgium in 2010 (around 4.50 ng.g fat^{-1}). Levels of heptachlorepoxides were below LOQ in the following countries: Djibouti, DRC, Kenya, Mauritius and Uganda.

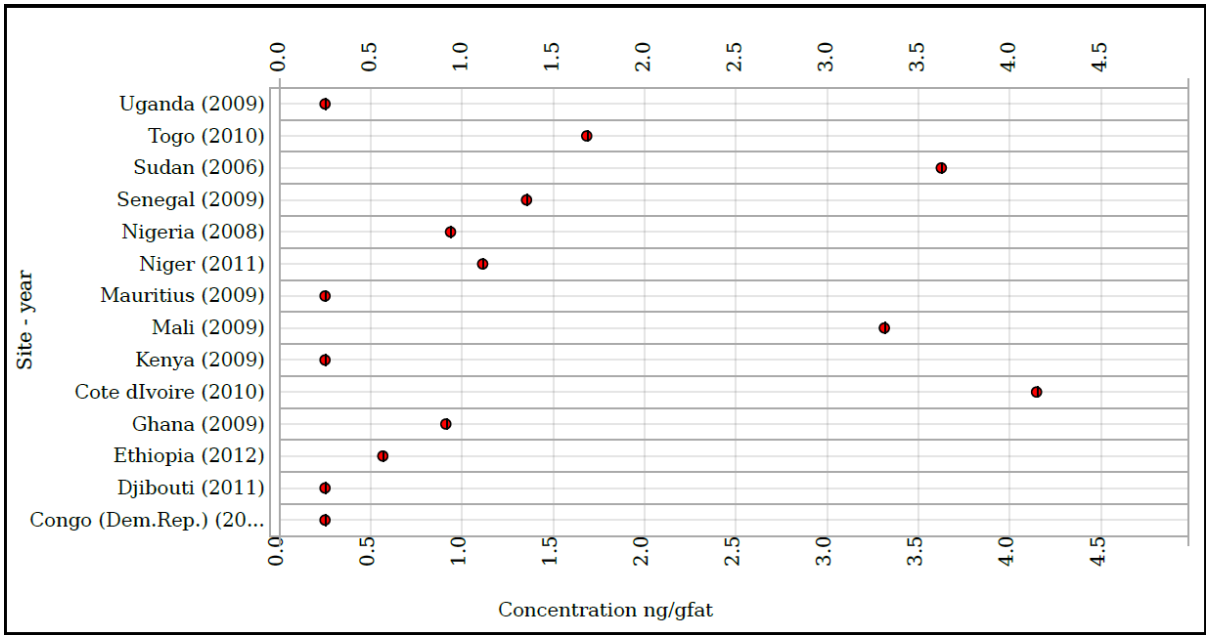

Figure 5.2.2.4 Sum heptachlorepoxides in mothers' milk

5.2.2.6 Mirex

Mirex levels in human milk were below LOQ (0.5 ng.g fat^{-1}) in all participating countries (Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Ethiopia, Ghana, Kenya, Mali, Mauritius, Nigeria, Niger, Senegal, Togo and Uganda.

5.2.2.7 Dichlorodiphenyltrichlorethane (DDTs)

Human milk from all participating countries had quantifiable levels with DDTs (Figure 5.2.2.5). The highest concentrations were detected in mothers' milk from Ethiopia (10,734 ng.g fat^{-1}). During the period 2011-2013, that sample from Ethiopia showed the highest contamination ever detected. The level of contamination was about 8,000 ng.g fat^{-1} in the sample from Tajikistan, which had the second highest contamination in the world during the same period. Other milk samples had concentration below 500 ng.g fat^{-1} for instance in Djibouti, Mauritius, Togo, Cote dIvoure, Mali and Nigeria.

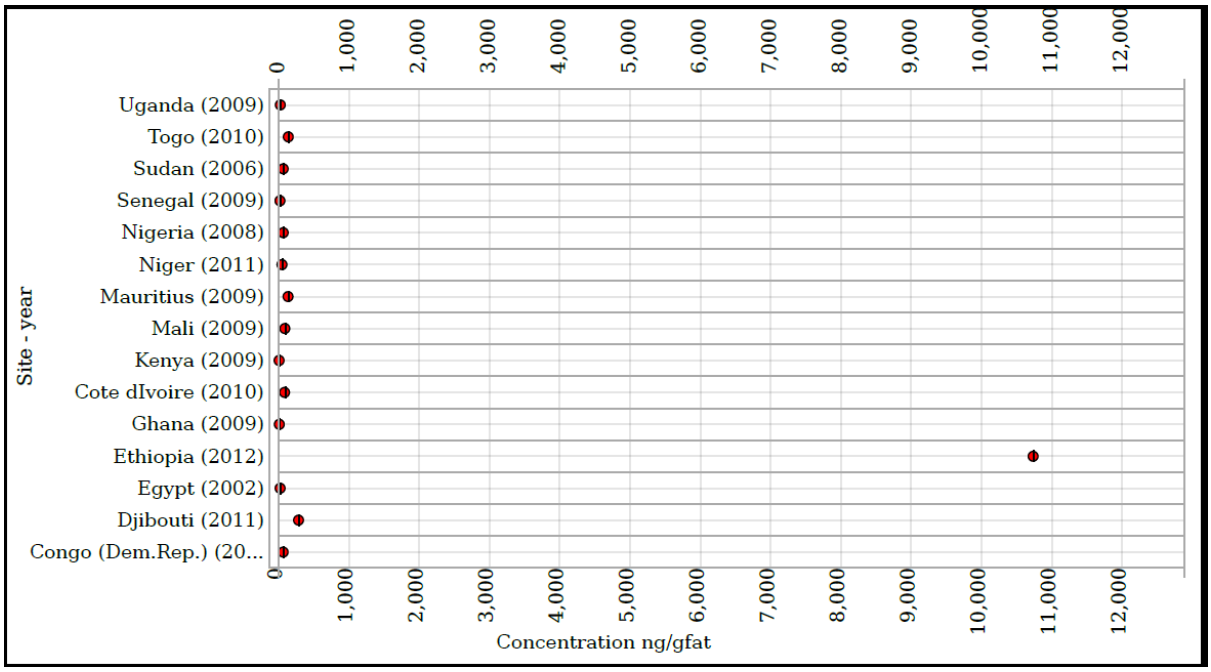

Figure 5.2.2.5 Concentration of p,p'-DDT in mothers' milk

The sum of 6 DDTs in mothers' milk registered elevated levels of DDTs signifying the contribution of other DDT congeners. Although Ethiopia remained with the highest concentration of sum DDTs (Σ6DDTs = 22,285.9 ng.g fat^{-1}), all other countries recorded sum DDTs above the limit of quantification. For instance in a number of countries such as Mali, Mauritius, Sudan, Togo, Uganda, Djibouti and Cote dIvoire that had registered <500 ng.g fat^{-1} of *p,p'*-DDT recorded sum DDTS > 1000 ng.g fat^{-1}, whereas Kenya, DR Congo, Egypt, Niger, Nigeria, Senegal and Ghana all recorded levels above the LOQ (Figure 5.2.2.6). This shows the significance of environmental contamination of DDT in the region.

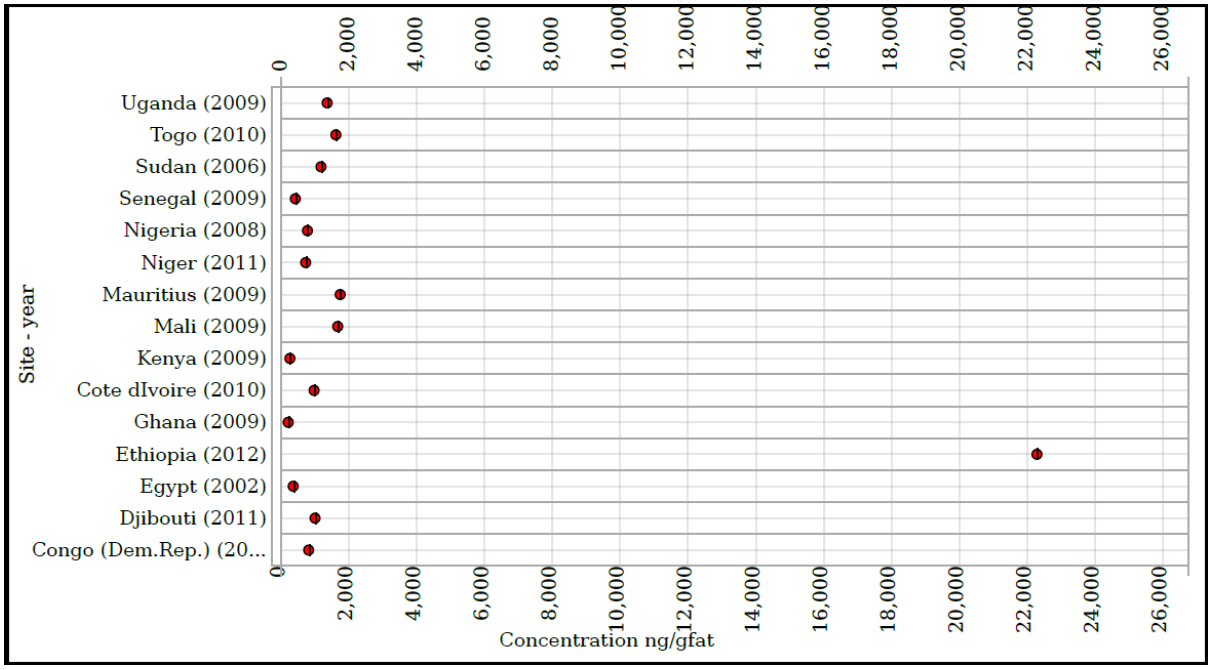

Figure 5.2.2.6 Sum of 6 DDTs in mothers' milk

5.2.2.8 Toxaphenes

Quantifiable levels (0.5 ng.g fat-1) of toxaphene as parlar 26 (Figure 5.2.2.7) were detected only in three countries (Nigeria: 1.09 ng.g fat^{-1}, Côte d'Ivoire: 0.82 ng.g fat^{-1} and DRC: 0.51 ng.g fat^{-1}). The values below LOQ were recorded in other participating countries: Senegal, Uganda, Ethiopia, Ghana, Djibouti, Kenya, Mauritius, Togo, Mali and Niger.

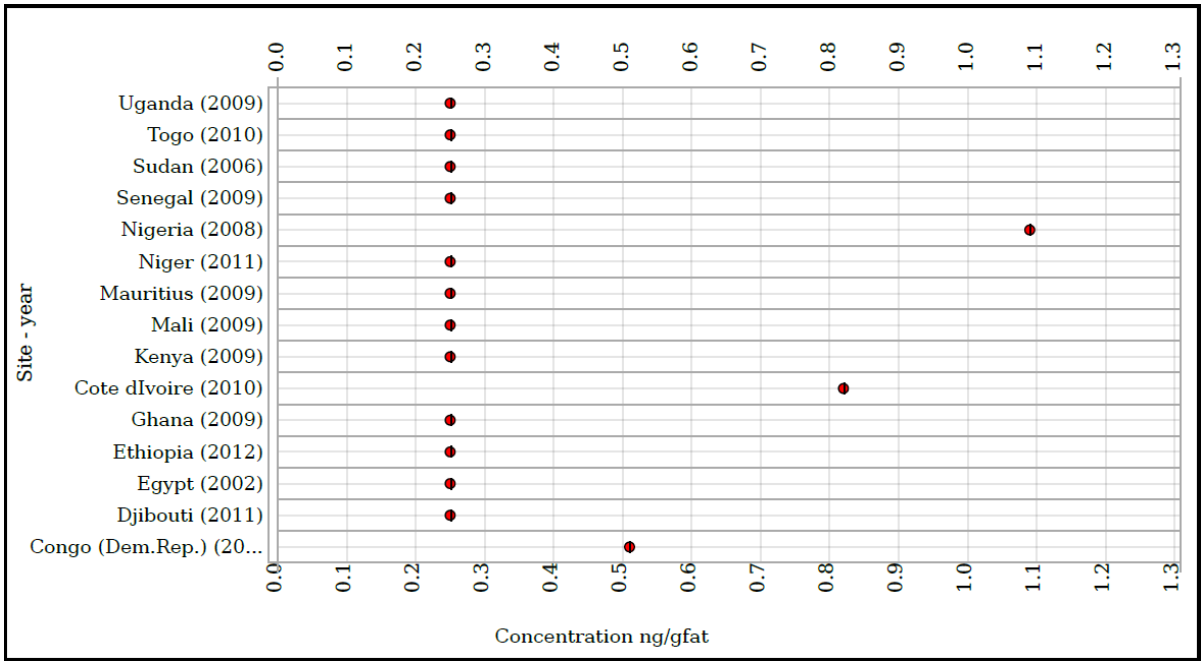

Figure 5.2.2.7 Concentration of toxaphene (parlar 26) in mothers' milk

Likewise, quantifiable levels of toxaphene as parlar 50 (5.2.2.8) were measured in three countries: Nigeria, 2.97 ng.g fat^{-1}; Côte d'Ivoire, 2.01 ng.g fat^{-1} and DRC, 0.89 ng.g fat^{-1}. All other participating countries had levels below LOQ. Levels of toxaphene as parlar 62 were below LOQ in all participating countries.

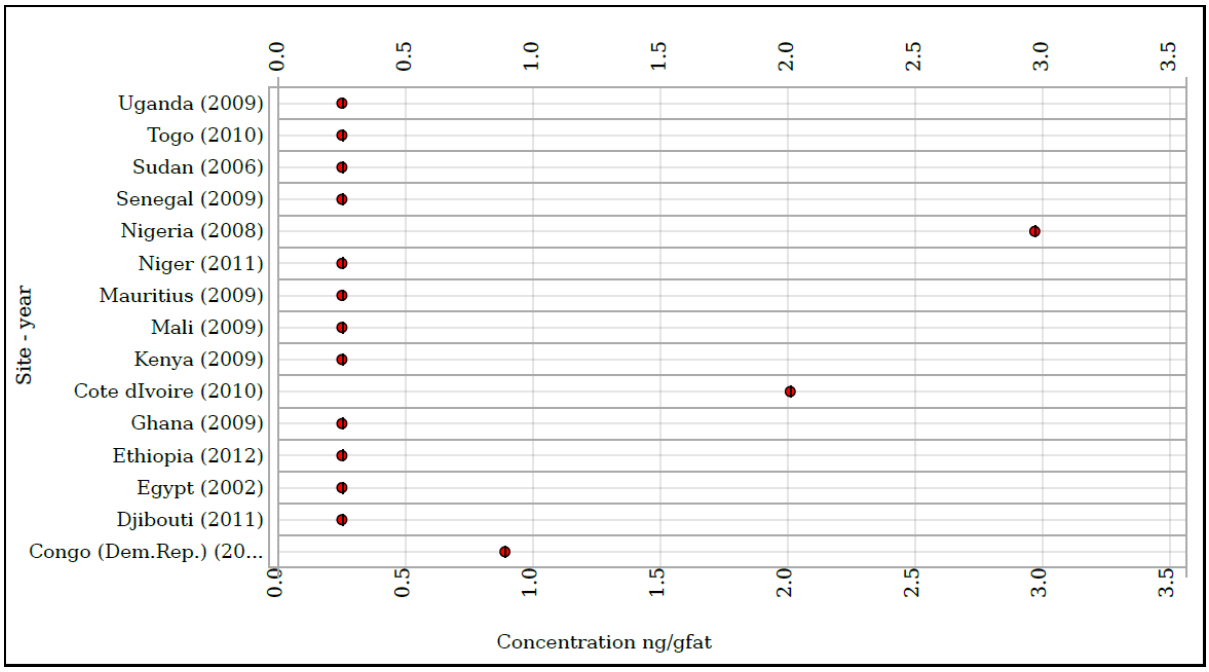

Figure 5.2.2.8 Concentration of toxaphene (parlar 50) in mothers' milk

5.2.2.9 Hexachlorobenzene (HCB)

Figure 5.2.2.9 shows the levels of HCB in mothers' milk samples collected from different countries in the region. The concentration ranged from 1.64 ng.gfat^{-1} in Togo to 5.03 ng.g fat^{-1} in Nigeria. Medium concentrations were recorded in mothers' milk samples from Mauritius, Egypt, Senegal, Sudan and Kenya.

In general, the contamination levels of HCB reported here were lower than those reported in other countries outside the region, for instance when compared to other countries such as Hong Kong (Asia) with about 25 ng.g fat^{-1} and Moldova (140 ng.g fat^{-1}) in Europe (milk UNEP-POPS-COP 6-INF-33, 2013). Nevertheless, the fact that these compounds are detectable in mothers' milk samples and have potential to cause deleterious effects to human health obliges the regional countries to put in place measures to eliminate these compounds in environment and foodstuff with are the key pathways leading to human contamination.

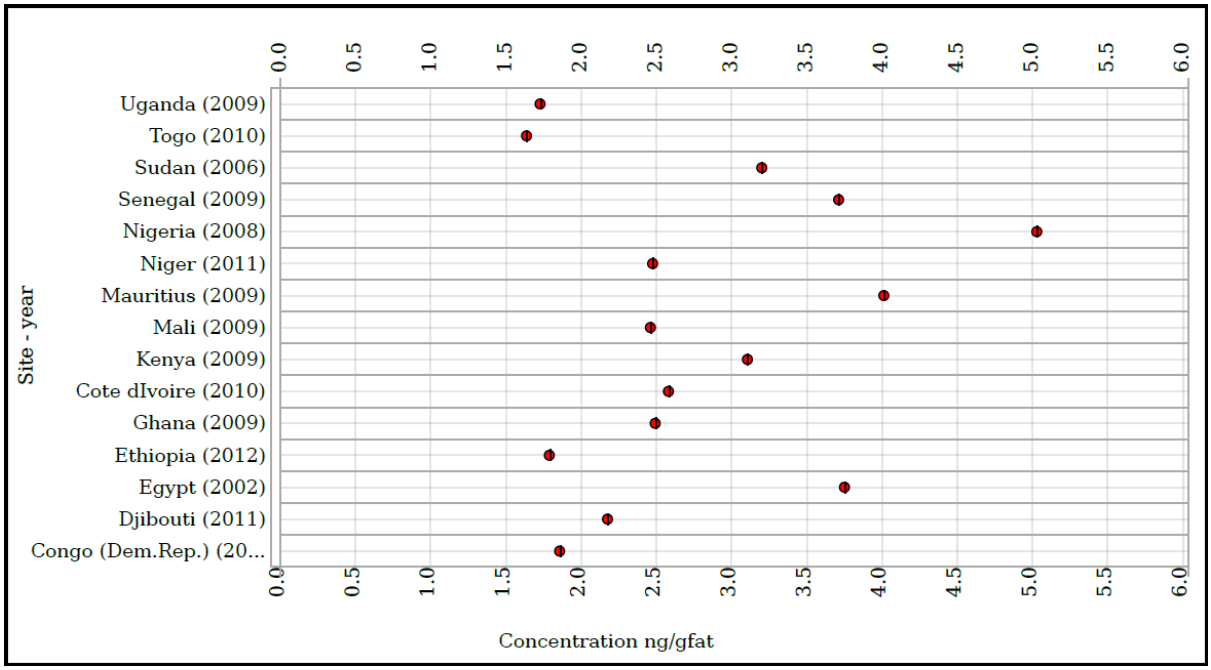

Figure 5.2.2.9 Concentration of HCB in mothers' milk

5.2.2.10 Polychlorinated Biphenyls (PCBs)

All human milk samples were contaminated with quantifiable levels of indicator PCBs (sum of 6 PCBs i.e. CB28, CB52, CB101, CB138, CB153 and CB180) are shown in Figure 5.2.2.10 below. The highest concentrations were recorded in Senegal, Côte d'Ivoire, Sudan and Nigeria. The concentrations found were among the highest during the 2008 to 2012 UNEP/WHO Human milk survey that involved 46 countries worldwide.

Low concentrations of indicator PCBs were measured in mothers' milk samples from Ethiopia, Kenya Mauritius and Uganda, whereas medium levels were recorded in samples from Djibouti, Egypt, Mali, DRC, Ghana, Niger and Togo. Contamination of mothers' milk with PCBs is of concern due to the toxic effects associated with these compounds. For instance, PCBs have been linked to cancer, endocrine disruption and reproductive disorders.

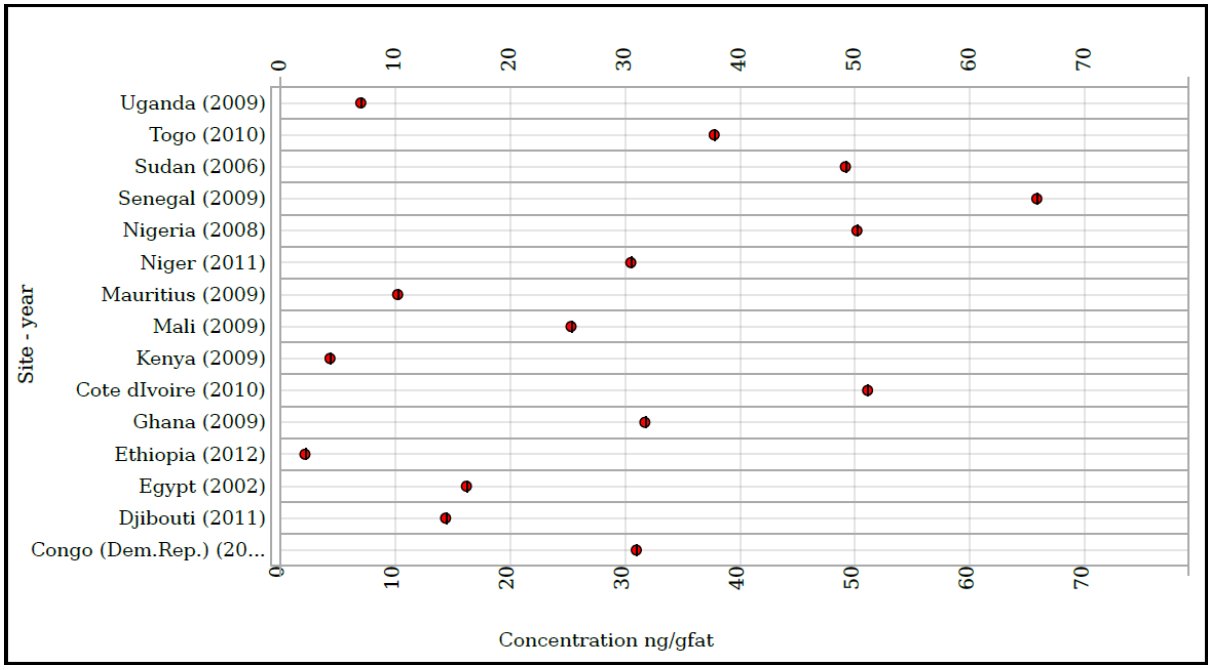

Figure 5.2.2.10 Sum of 6 PCBs in mothers' milk

5.2.2.11 Dioxin-like PCBs (dl-PCBs)

Dioxin-like PCBs (sum of 12 dl-PCBs) were quantifiable in all samples (Figure 5.2.2.11). Nigeria and Senegal showed the highest contamination levels while Ethiopia and Kenya had the lowest contamination values.

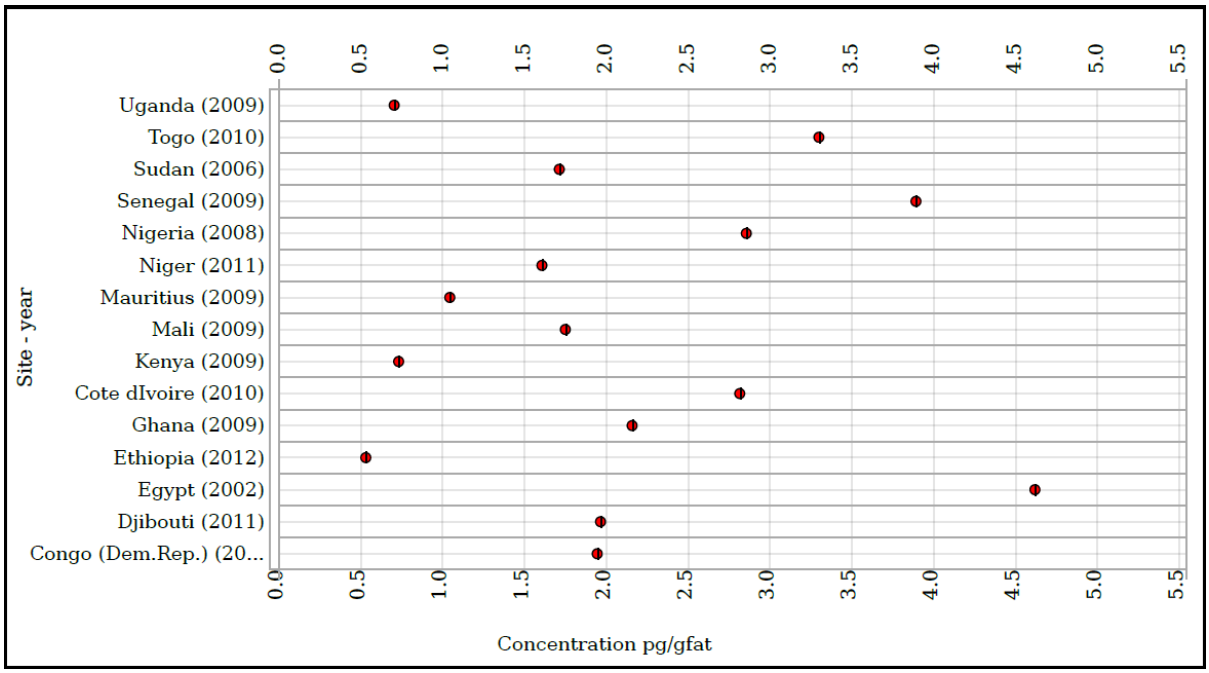

Figure 5.2.2.11 WHO 2005 TEQ LB of dl-PCBs in mothers' milk

The 12 dl-PCB comprise of eight mono-*ortho* PCB congeners (CB105, CB114, CB118, CB123, CB156, CB157, CB167 and CB189) and four non-*ortho* PCB congeners (CB77, CB81, CB126 and CB169). Their toxicological properties are associated with their strong binding to Ah receptor similar to the PCDDs and PCDFs, a factor which led to adoption of toxic equivalence factors (TEQ) for each congener to allow estimation of toxicities on the basis of 2,3,7,8 tetrachlorodibenzo-dioxin.

5.2.2.12 Polychlorinated Dibenzo-Dioxins (PCDDs) and Polychlorinated Dibenzo-Furans (PCDFs)

All participating countries had quantifiable levels (15.30 pg.g fat^{-1} to 465.16 pg.g fat^{-1}) of contamination by PCDDs (sum of 7 Isomers) as shown in Figure 5.2.2.12.

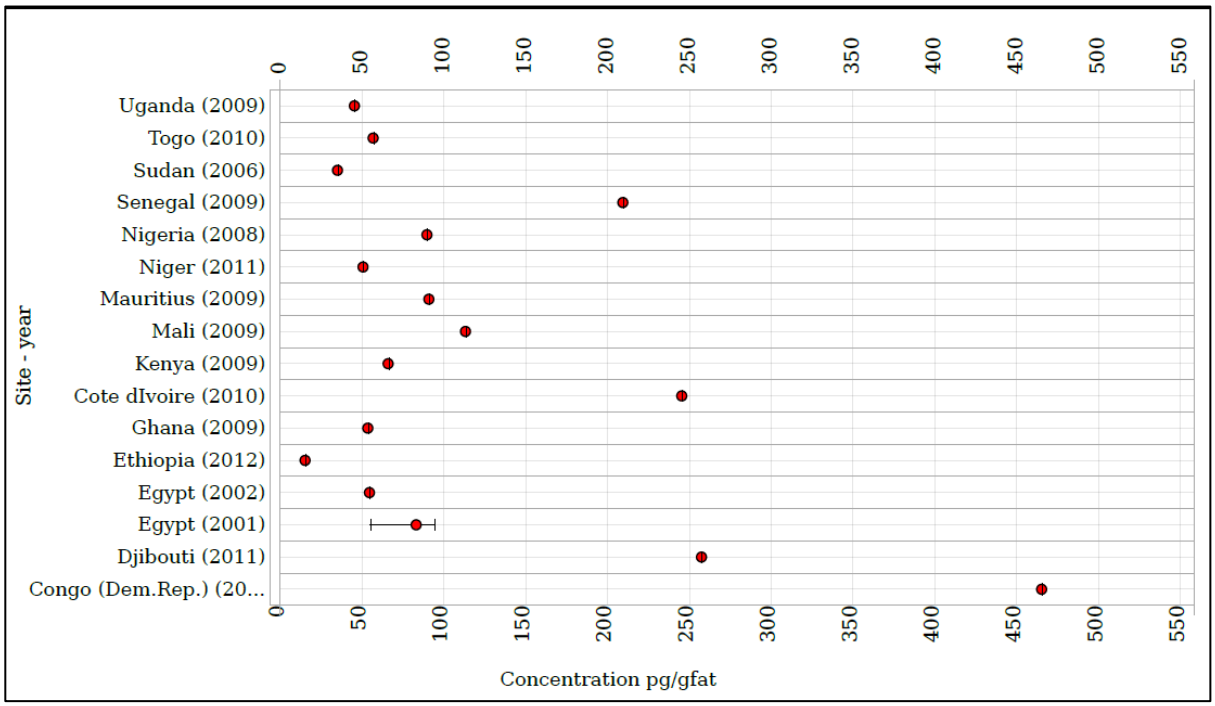

Figure 5.2.2.12 Sum of 7 PCDDs in mothers' milk

The highest concentration was recorded in the sample from The Democratic Republic of the Congo (465.16 pg.g fat^{-1}) followed by Djibouti, Cote dIvoire and Senegal which recored above 200 ng.g fat^{-1}. The lowest level was recorded in mothers' milk sample from Ethiopia, whereas Egypt, Ghana, Kenya, Mali, Mauritius, Niger, Nigeria, Sudan, Togo and Uganda recorded concentrations between 30 ng.g fat^{-1} and 200 ng.g fat^{-1}.

The WHO 2005 TEQ LB for mothers' milk varied between 0.5 ng.g fat^{-1} and 12 ng.g fat^{-1}. The Highest WHO 2005 TEQ LB was recorded for mothers' milk from the Democratic Republic of Congo, followed by Cote dIvoire and Egypt, whereas Ethiopia recorded the lowest (Figure 5.2.2.13).

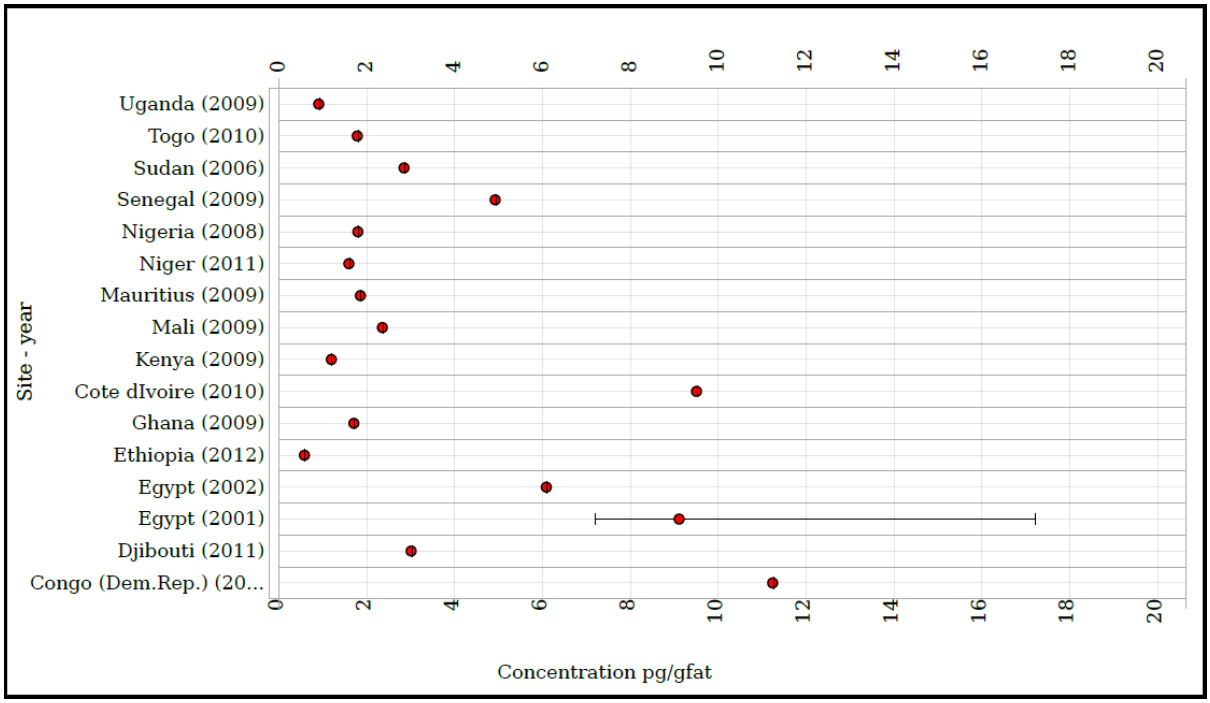

Figure 5.2.2.13 WHO 2005 TEQ LB for PCDDs in mothers' milk

Human milk contamination with PCDFs was in general ten times less than that of PCDDs (Figure: 5.2.2.14). Samples from Djibouti (11.54 pg.g fat^{-1}) and Senegal (11.15 pg.g fat^{-1}) were the most contaminated while the one from Ethiopia remained the least contaminated.

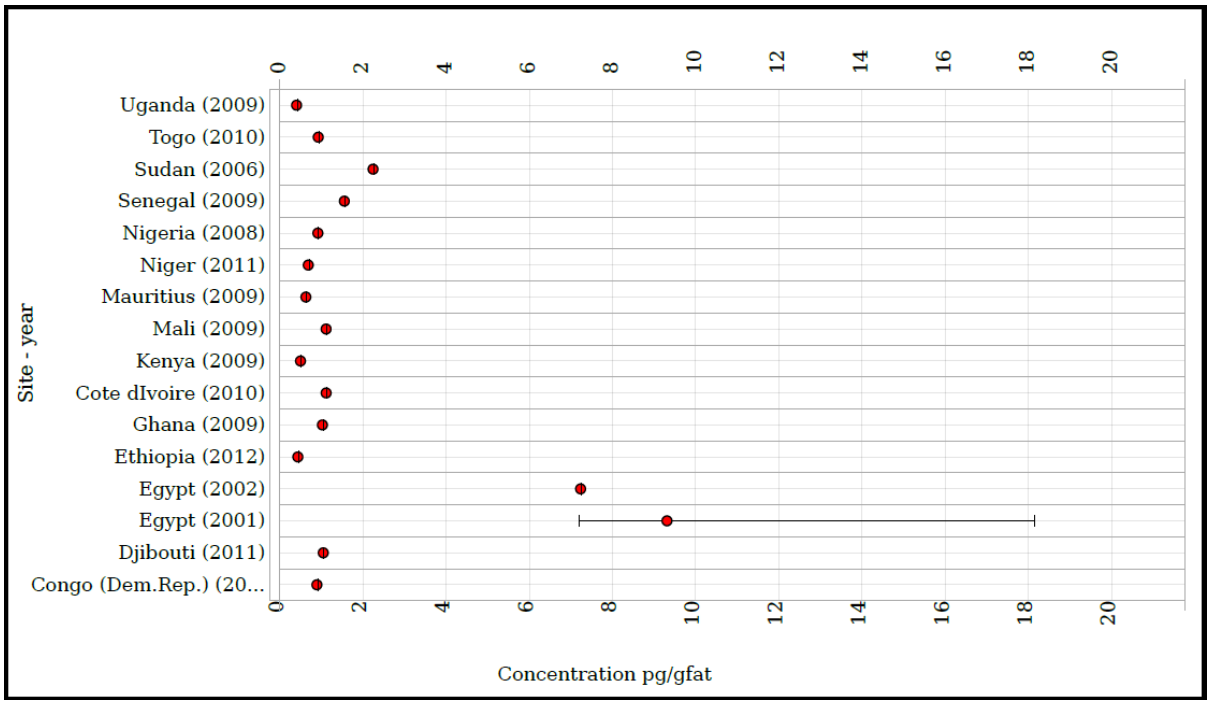

Figure 5.2.2.14 WHO 2005 TEQ LB for PCDFs in mothers' milk

5.2.2.13 Chlordecon

No data was provided by the WHO/UNEP program on chlordecone.

5.2.2.14 Endosulfans

The only country with quantifiable level of *alpha*-endosulfans in human milk was Nigeria with a concentration of 2.004 n.g fat^{-1}. Concentrations of *beta*-endosulfan were below LOQ in all countries. Quantifiable levels of endosulfan sulphate were measured only in Sudan and Nigeria (Figure 5.2.2.15).

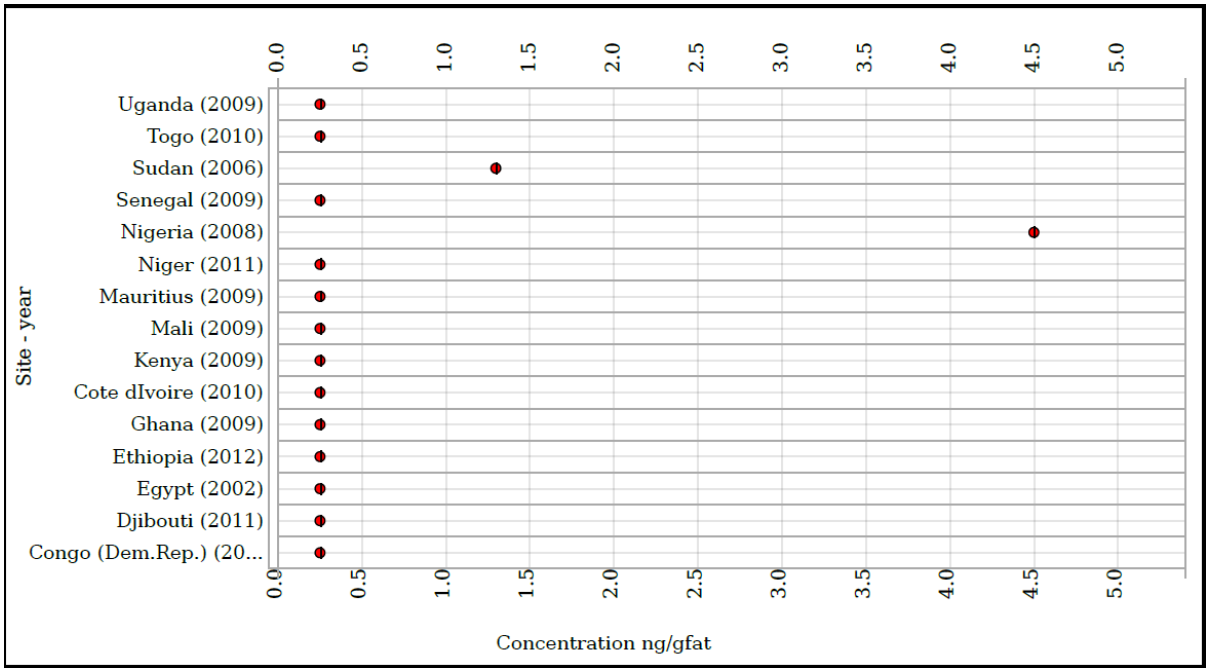

Figure 5.2.2.15 Concentration of endosulfan sulphate in mothers' milk

5.2.2.15 Hexabromobiphenyl (HBB)

The only country with quantifiable levels of HBB was the Democratic Republic of the Congo (0.95 ng.g fat^{-1}). All other participating countries had levels below LOQ (0.5 ng.g fat^{-1}).

5.2.2.16 Hexabromocyclododecanes (HBCDs)

The *gamma*-HBCD was measurable only in the samples from Mauritius at concentration of 0.10 ng.g fat^{-1} and the Democratic Republic of the Congo at 0.11 ng.g fat^{-1}. The beta isomer was not quantifiable in all samples (LOQ =0.05 ng.g fat^{-1}). Except Uganda, all participating countries showed quantifiable levels of *alpha*-HBCD in human milk as illustrated in Figure 5.2.2.16 below.

Ghana, Mauritius and Nigeria recorded the highest levels of *alpha*-HBCD contamination while Djibouti, Uganda and Kenya the lowest levels compared to the other participating countries in the Africa region.

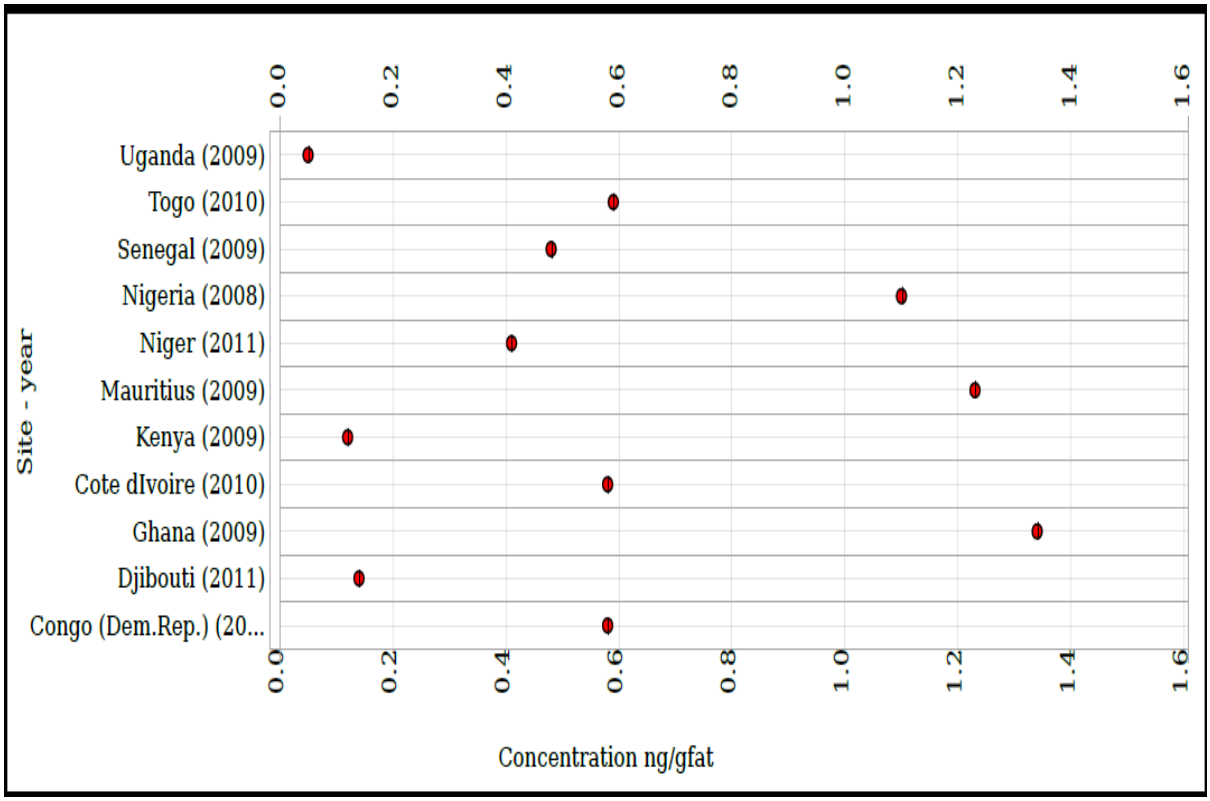

Figure 5.2.2.16 Concentration of alpha-hexabromocyclododecane in mothers' milk

5.2.2.17 Hexachlorocyclohexans (alpha-HCH, beta-HCH, gamma-HCH)

All participating countries had human milk contamination in *alpha*-HCH below the limit of quantification (Annex). Human milk from Senegal, Mali, Mauritius and Nigeria had the highest concentration of *beta*-HCH in the region. However, the contamination levels were by far lower than the one found in India in 2009 (about 850 ng.g fat^{-1}).

From 2001 to 2012, the highest contamination of human milk by *gamma*-HCH (lindane) was found in the sample from Senegal (16.02 ng.g fat^{-1}) amongst the countries that undertook the survey throughout the world. Senegal, Togo, Kenya, Côte d'Ivoire and Mauritius were among the countries worldwide with the highest contamination by lindane (Figure 5.2.2.17).

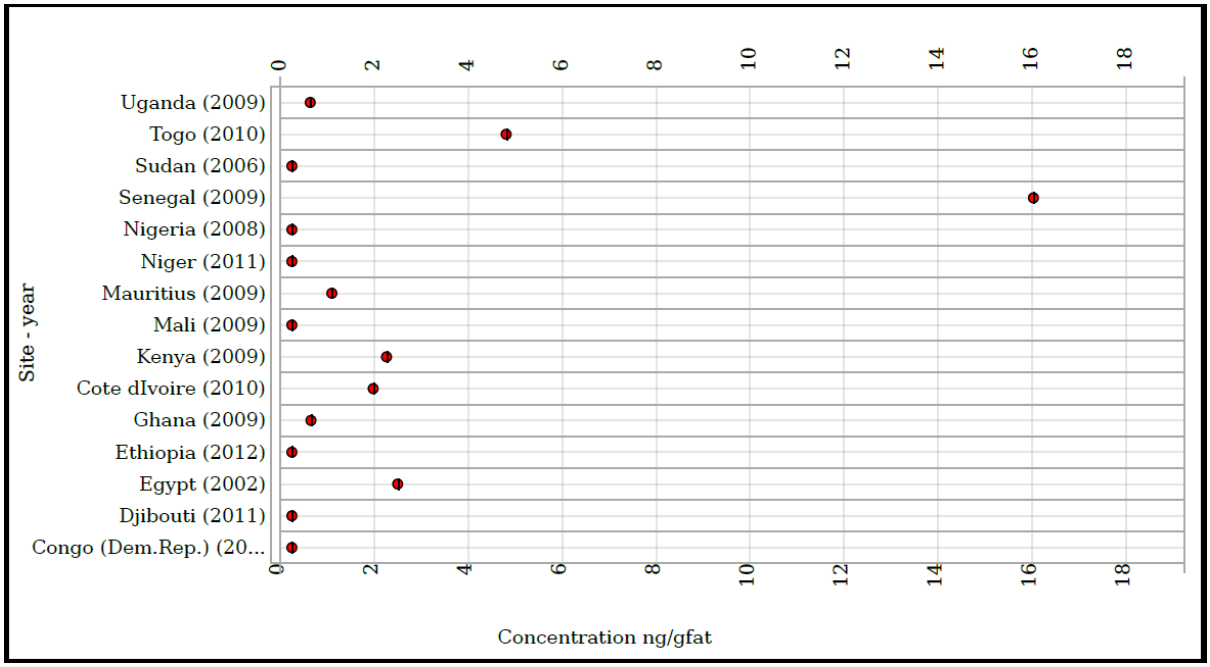

Figure 5.2.2.17 Concentration of gamma-HCH in mothers' milk

5.2.2.18 Pentachlorobenzene (PeCB)

Togo was the only country that had milk sample with quantifiable level of PeCB (0.68 ng.g fat^{-1}). All other participating countries had levels below LOQ (0.5 ng.g fat^{-1}): Côte d'Ivoire, DRC, Uganda, Nigeria, Ethiopia, Ghana, Djibouti, Kenya, Mauritius, Mali and Niger.

5.2.2.19 Polybrominated Diphenyl Ethers (PBDEs)

Concentrations of PBDEs in human milk were variable over the period 2008-2012 in the Africa region. Generally, the levels of PBDEs are low ranging from bdl - 1.60 ng.gfat$^{-1.}$

PBDE 17

The concentration of PBDE 99 in mothers' milk ranged from 0.01-0.08 ng.g fat^{-1}. The highest levels were measured in samples from Niger and Togo, whereas the lowest levels were recorded in samples from Cote dIvoire, Kenya, Mauritius and Senegal. Medium concentrations were recorded in Ghana, DR Congo, Djibouti, Nigeria and Uganda (Figure 5.2.2.18).

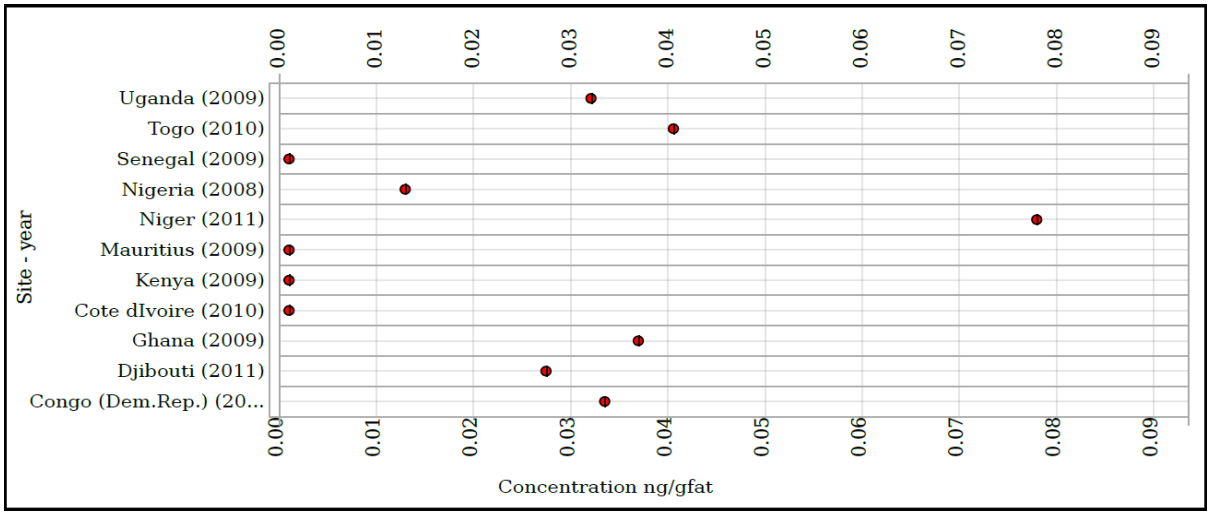

Figure 5.2.2.18 Concentration of PBDE 17 in mothers' milk

PBDE 28

The levels of PBDE 28 ranged from 0.03-0.12 ng.g fat^{-1}. The highest concentrations were recorded in DR Congo and Uganda. The lowest concentrations were recorded in Mauritius and Senegal, whereas medium concentrations were recorded in Djibouti, Cote dIvoire, Ghana, Kenya, Niger, Nigeria and Togo (Figure 5.2.2.19).

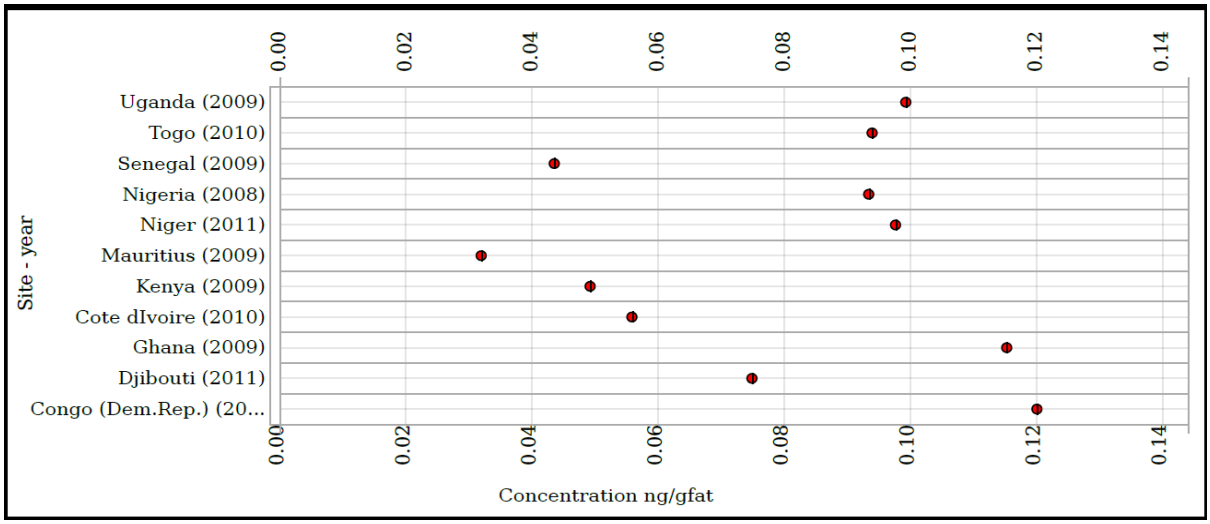

Figure 5.2.2.19 Concentration of PBDE 28 in mothers' milk

PBDE 47

Polybrominated diphenyl ether as PBDE 47 was the most abundant in the Africa region ranging from 0.34 ng.g fat^{-1} (Mauritius) to 1.60 ng.g fat^{-1} (DR Congo). The concentrations varied from one country to the other, with the highest levels were measured in sample from DR Congo, Uganda and Nigeria. The lowest concentrations were detected in samples from

Mauritius and Senegal, whereas medium levels were found in Cote dIvoire, Kenya, Niger, Djibouti and Togo (Figure 5.2.2.20).

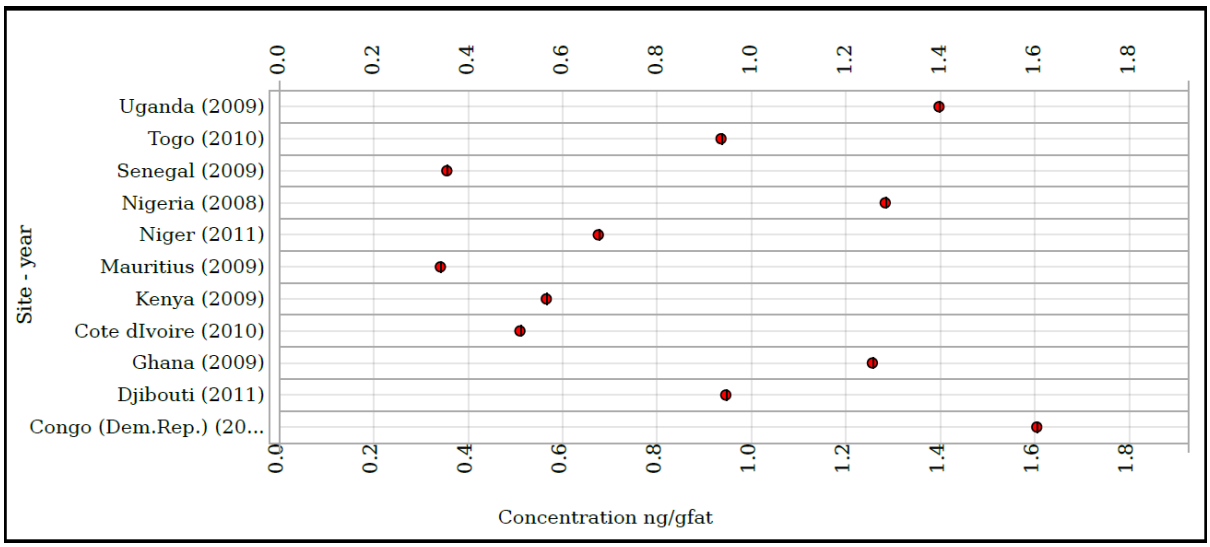

Figure 5.2.2.20 Concentration of PBDE 47 in mothers' milk

PBDE 99

The concentration of PBDE 99 in mothers' milk ranged from 0.10-0.44 ng.g fat^{-1}. The highest levels were measured in samples from DR Congo and Uganda, whereas the lowest levels were recorded in samples from Senegal and Mauritius. Countries that recorded medium levels were recorded in Kenya, Cote dIlvoire, Niger, Nigeria, Togo, Ghana and Djibouti (Figure 5.2.2.21).

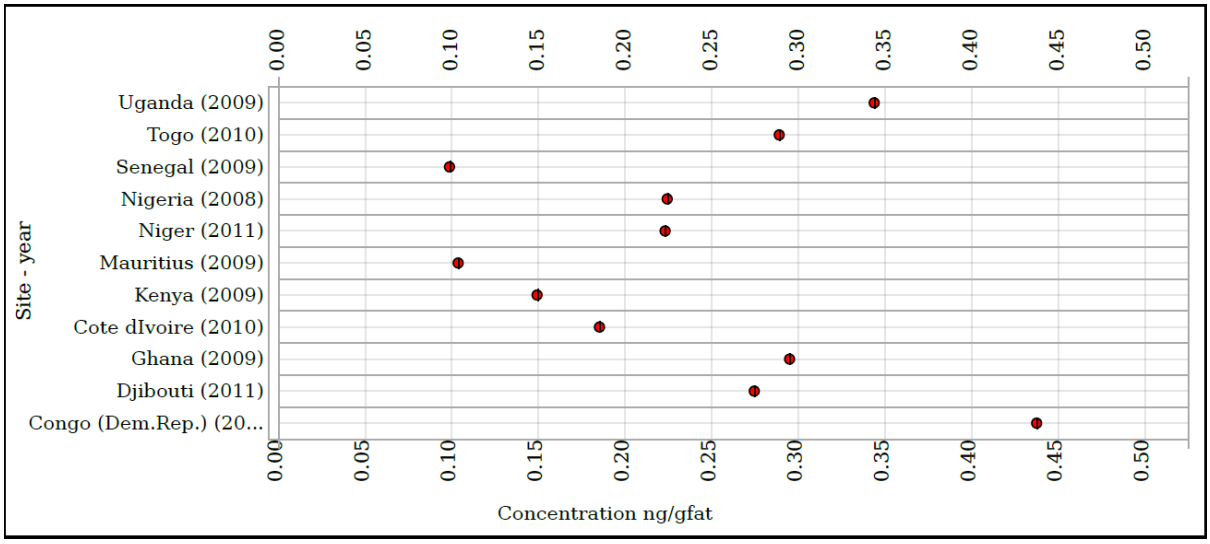

Figure 5.2.2.21 Concentration of PBDE 99 in mothers' milk

PBDE 100

The levels of PBDE 100 varied from 0.08-0.29 ng.g fat^{-1}, with the highest levels measured in samples from Djibouti, Ghana and Nigeria, whereas the lowest were measured in samples from Kenya, Mauritius, Cote dIvoire and Niger. The countries that recorded medium concentrations were Djibouti, Senegal, Uganda and Togo (Figure 5.2.2.22).

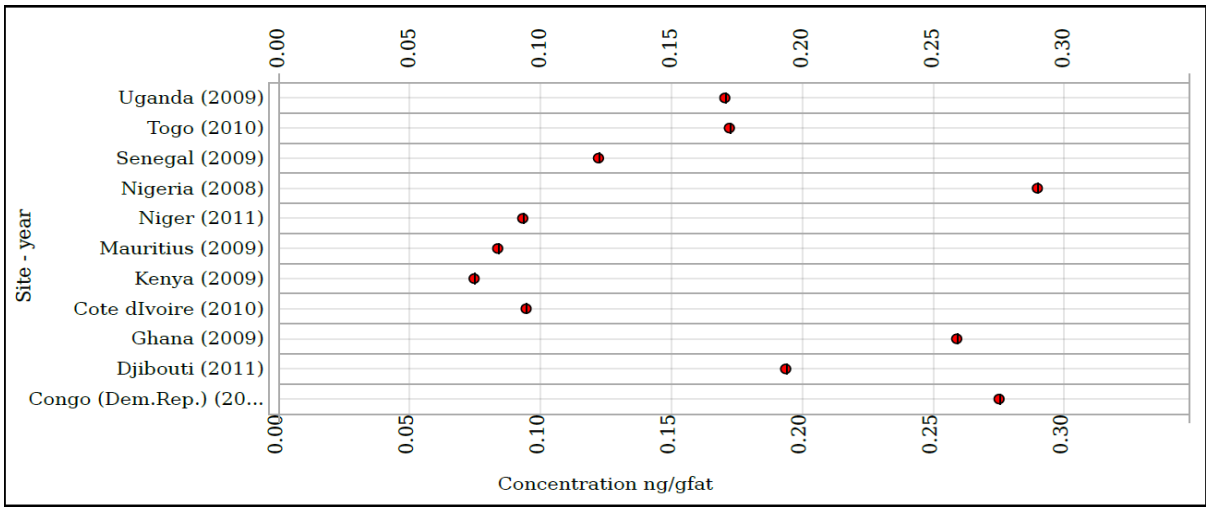

Figure 5.2.2.22 Concentration of PBDE 100 in mothers' milk

PBDE 153

PBDE 153 levels in mothers' milk from the region ranged from 0.14-0.50 ng.g fat^{-1}. The levels were highest in DR Congo and Nigeria and lowest in Mauritius and Kenya. Medium concentrations of PBDE153 were recorded in Djibouti, Ghana, Niger, Cote dIvoire, Senegal, Togo and Uganda (Figure 5.2.2.23).

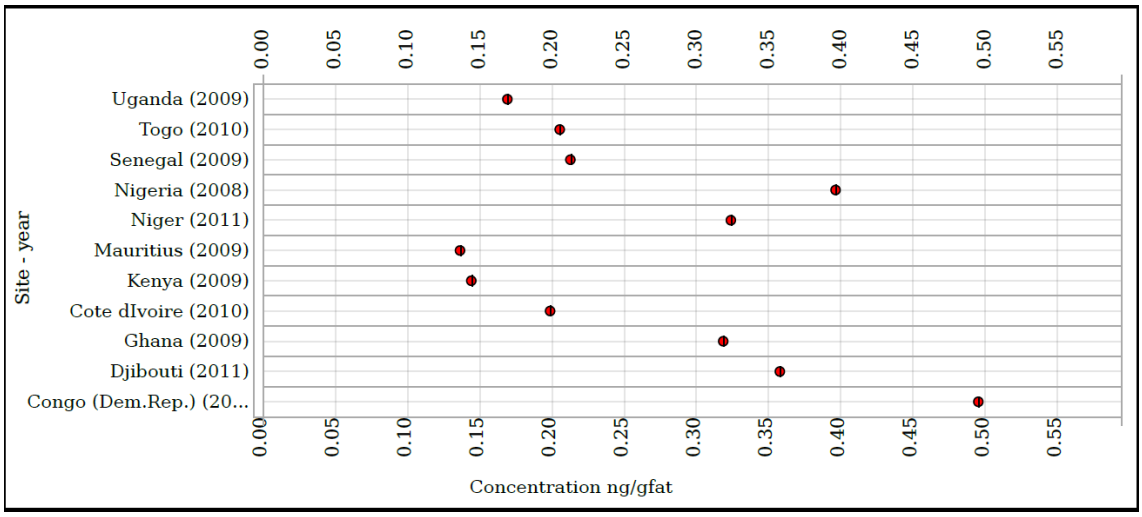

Figure 5.2.2.23 Concentration of PBDE 153 in mothers' milk

PBDE 154

Among all the PBDEs, the concentrations of PBDE 154 were the lowest in mothers' milk and ranged from 0.01-0.05 ng.g fat^{-1}. The highest levels were recorded in Djibouti and Ghana, whereas the lowest levels were recorded in Kenya, Senegal and Togo. Medium levels were measured in samples from Mauritius, Uganda, Nigeria, Niger, Cote dIvoire and DR Congo (Figure 5.2.2.24).

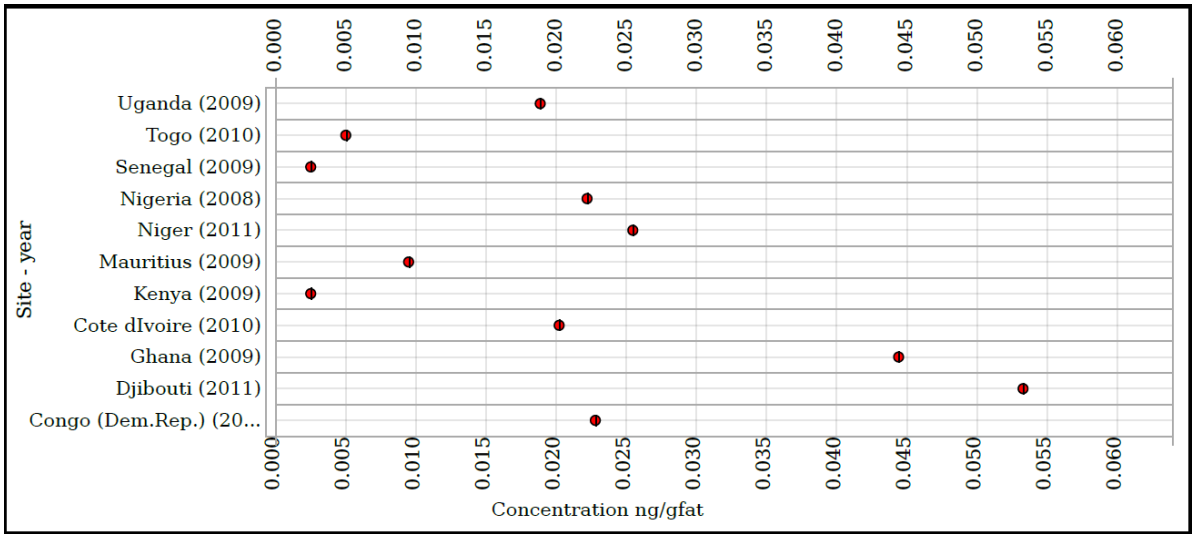

Figure 5.2.2.24 Concentration of PBDE 154 in mothers' milk

5.2.2.20 Perfluorooctane Sulfonates (PFOS)

PFOS was found in quantifiable levels in human milk from all participating countries (Figure 5.2.2.25). The concentrations of PFOS in human milk were highest in Nigeria, Togo and Côte d'Ivoire, while Niger and Uganda had the lowest levels. Since it is assumed that in Africa there is no industrial production and use of PFOS (UNEP-POPS-GUIDE-NIP-2012-PFOS-INVENTORY, July 2012), the exposure of human to PFOS and related chemicals might probably come from different kinds of waste and the various articles from the consumer market that contain these contaminants.

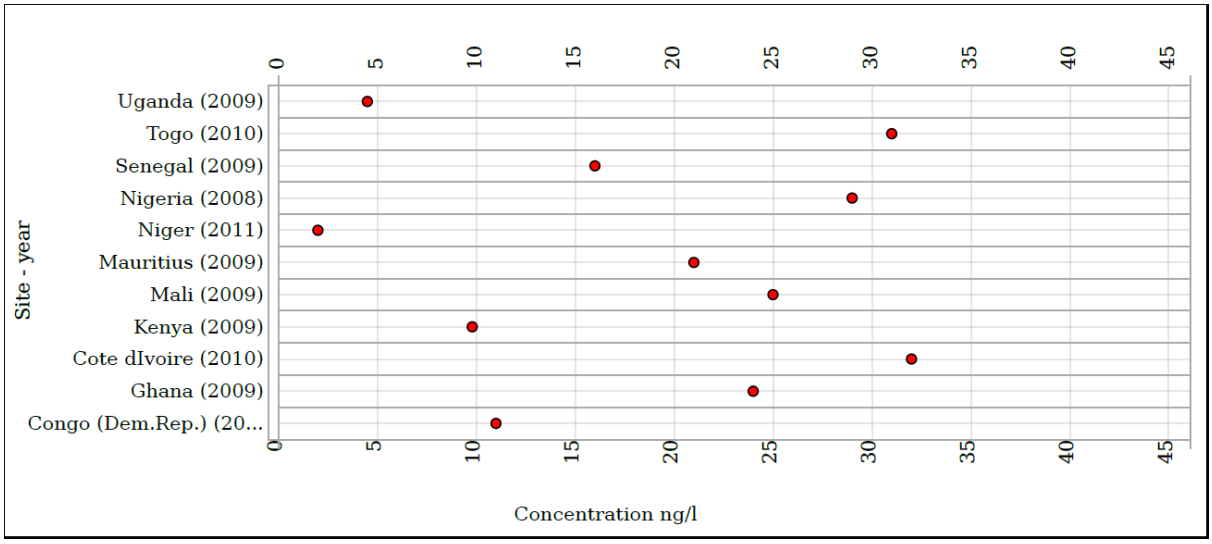

Figure 5.2.2.25 Concentration of PFOS in mothers' milk

5.2.3. Concentrations of POPs in water

Perfluorooctane Sulfonate (PFOS) and salts were the only POPs monitored in water during the MONET Africa and UNEP/GEF pilot studies.

PFOS in water

The UNEP-GEF project only provided data on PFOS in water in Mali and Kenya. Concentrations of PFOS were 4.70 ng/L in Mali and 4.6 ng/L in Kenya.

The data from passive samplers deployed during the MONET Africa pilot study covered Congo, Egypt, Kenya, Mauritius, Morocco and Nigeria. Variations in levels of PFOS were observed displaying the diversities of socioeconomic and industrial activities and local environmental conditions at the sampling sites in different countries.

The concentration of PFOS in water from the site in Nigeria was 1,390 pg/L. while the lowest was measured in Congo and Morocco both having concentration of 35 pg/L (Figure 5.2.3.1). Medium concentrations were recorded in water from sites in Kenya, Mauritius and Egypt. The concentrations measured cannot be directly compared due to differences in site characteristics. The concentration of PFOS in water samples was comparable with some levels measured in river water samples from Spain at concentration ranging from <0.24 ng/L – 5.88 ng/L (Erickson *et al.,* 2008). However, the highest concentration established in Spain was 4 times higher than the levels determined in water from the region.

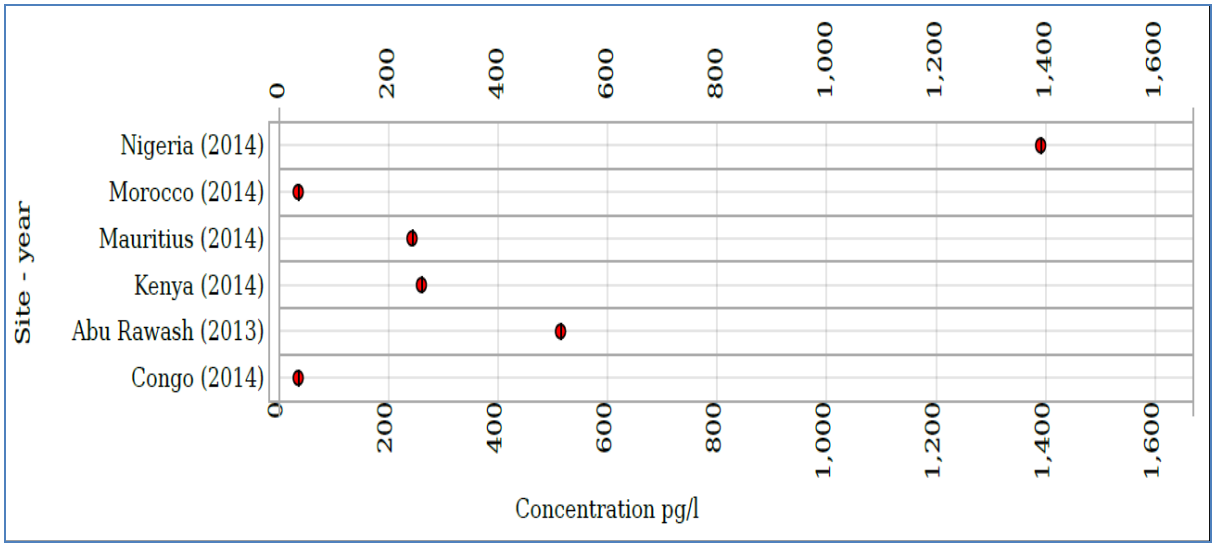

Figure 5.2.3.1 Concentration of PFOS in water

PFOSA in water

The concentration of PFOSA below the LOQ (2.00 pg/L) in all the countries that submitted samples for analysis in 2014 (Figure 5.2.3.2)

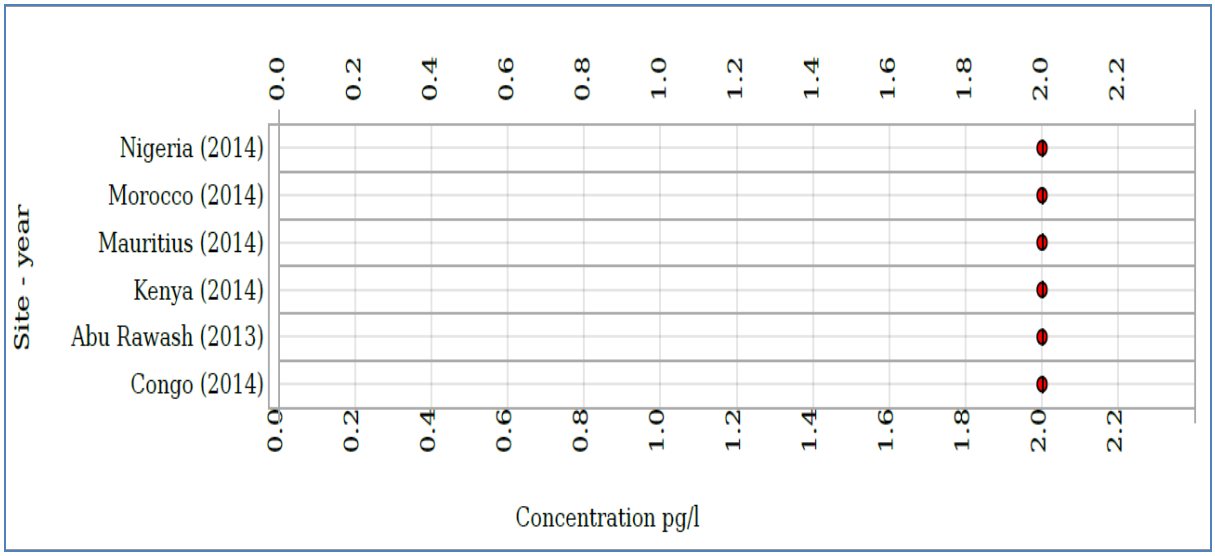

Figure 5.2.3.2 Concentration of PFOSA in water

NMePFOSE in water

Water samples from all the six countries that participated in the MONET Africa pilot sampling had NMePFOSE concentrations below the LOQ (100.00 pg/L) (Figure 5.2.3.3).

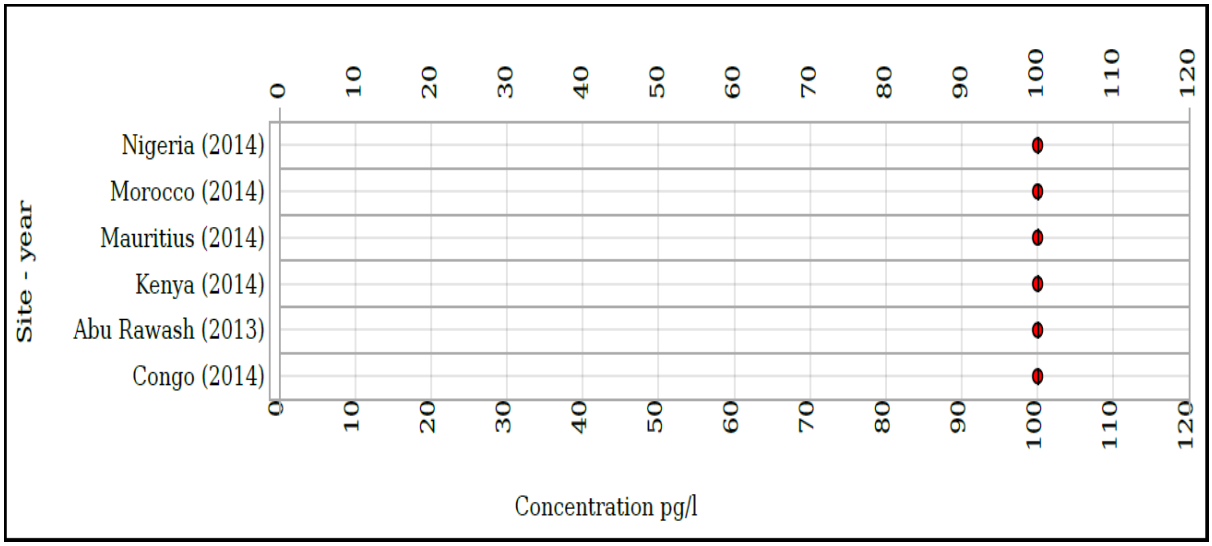

Figure 5.2.3.3 Concentration of NMePFOSE in water

NEtPFOSE in water

Water samples from all countries had the levels of NEtPFOSE below the LOQ of 50 pg/L (Figure 5.2.3.4).

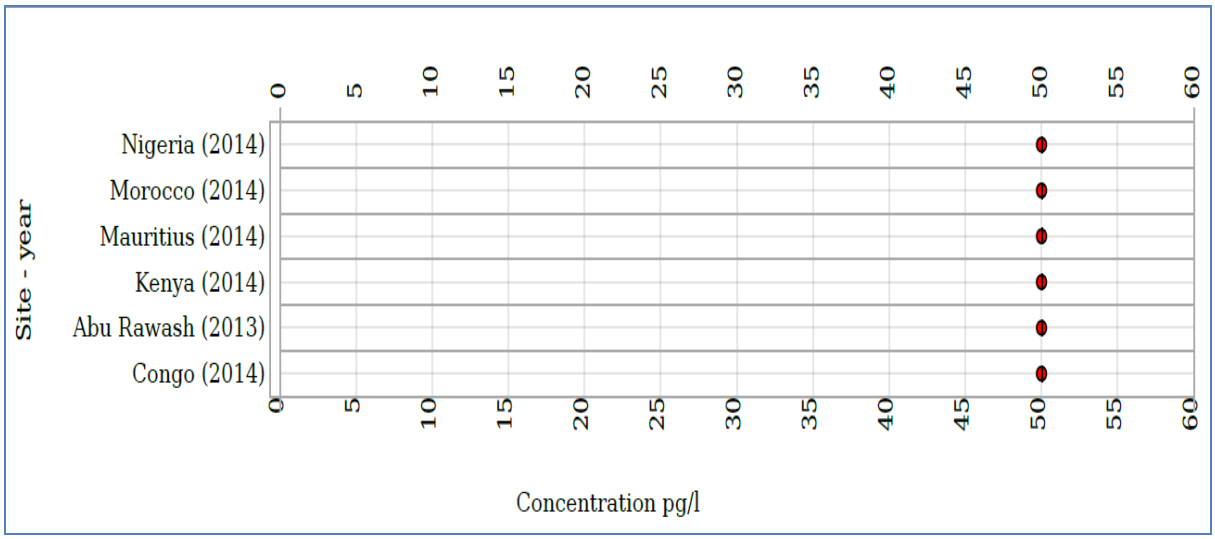

Figure 5.2.3.4 Concentration of NEtPFOSE in water

5.2.4 Other media

5.2.4.1 Concentrations in other media

In general, the concentrations of PCDD/PCDF in sediments were much lower compared to dioxin like PCBs.

Fish was submitted by 5 out of the six participating countries in the East and Southern Africa sub region. The concentration of PCDD/PCDF in fish were highly variable across the countries and across the individual PCDD/PCDF and dioxin like PCBs. PCDD/PCDF concentrations in fish varied from below detection limit to as high as 59 pg. g fat^{-1}. The observed trend in the concentration of dioxins in fish was similar to that observed in sediments where dioxin like PCBs in the in fish were in orders up to 100 times higher that dioxin/furans in fish lipid. Ideally, this could be attributed to widespread use of PCBs in industrial activities prior to their ban under the Stockholm Convention.

Soil, baby meal and fly ash were also selected for analysis as priority matrices in some countries. The concentration of PCDD/PCDF was slightly lower compared to concentrations of similar compounds in sediments. However, significant concentrations of dioxin like PCBs were noted in the soil samples. On the other hand, baby meal had characteristically low concentrations of dioxins, although slightly elevated concentrations of dioxin like PCBs were noted.

On the contrary, fly ash had significantly high concentrations of PCDD/PCDF compared to all other samples analysed. The concentrations of individual dioxin like PCBs were also observed to be lower than most dioxins/ furans in this matrix.

i) Basic POPs in national samples from Egypt

The national samples from Egypt included baby milk, fish meal and dry soil. The result shows that the concentrations of POPs in baby milk were considerably low with most of the analytes registering concentrations below detection limit.

The concentrations of POPs in fish meal ranged from bdl to 9.9 $ng.g^{-1}$, whereas the POPs concentrations in agricultural soils were between bdl and 1.60 $ng.g^{-1}$.

ii) Basic POPs in national samples from Ethiopia

The national samples from Ethiopia were mainly sediments. The concentrations of basic POPs in the samples varied from bdl and 47 $ng.g^{-1}$ for OCPs and bdl to 0.1 $ng.g^{-1}$ for PCBs. It was noted that the major pesticides detected were *p,p′*-DDT, *p,p′*-DDE and HCB.

iii) Basic POPs in national samples from Kenya

The national samples from Kenya included fish, sediments and soil. The data shows significant concentrations of dieldrin, *p,p′*-DDE and *p,p′*-DDT in the samples especially soil and sediments. The concentration of POP pesticides and PCBs in fish ranged from bdl to 0.03 ng/g. Evaluation of individual basic POPs analysed in fish revealed that more than 75% of the analytes had concentrations below the method detection limit.

The results of POPs in sediments showed comparatively higher concentrations compared to the fish sample. OCP concentrations ranged from bdl to 1.5 $ng.g^{-1}$, whereas PCBs concentrations were between bdl and 0.15 $ng.g^{-1}$.

The soil sample had much higher concentrations of OCPs compared to the concentrations observed in sediments and fish. However, it should be noted that some of the soil sample might have collected from impacted sites such as former obsolete pesticide storage site. This could also signify the need for decontamination of the pesticide contaminated sites that are scattered all over the region.

iv) Basic POPs in national samples from Mauritius

The national samples from Mauritius included sediments and fish fillet. The concentrations of POP pesticides in sediments ranged between bdl and 14 $ng.g^{-1}$, whereas PCBs varied from bdl to 0.08 $ng.g^{-1}$ in the same matrix. The concentration of OCPs in fish fillet varied from bdl to 0.33 $ng.g^{-1}$, whereas PCB concentrations ranged from bdl to 0.10 $ng.g^{-1}$.

The main pesticides detected in the national samples were *p,p′*-DDT, *p,p′*-DDE, *p,p′*-DDD and HCB. The same pesticides also dominated in the PUF samples indicating their present in ambient air.

v) Basic POPs in national samples from Uganda

The national samples from Uganda included fish and sediments. The POP OCPs in fish samples ranged from bdl to 0.19 $ng.g^{-1}$, whereas PCBs ranged from bdl to 0.08 $ng.g^{-1}$. For sediments, the concentrations varied from bdl to 0.35 $ng.g^{-1}$ for OCPs and from bdl to 0.05 $ng.g^{-1}$ for PCBs. The dominant OCPs included *p,p′*-DDT, *p,p′*-DDE, dieldrin, γ-HCH and BHC.

vi) Basic POPs in national samples from Zambia

Fish and sediments constituted the two national samples from Zambia. The concentration of basic POPs varied from bdl to 0.1 $ng.g^{-1}$ for OCPs and from bdl to 0.10 $ng.g^{-1}$ in the case of PCBs. The concentration of POPs in sediments ranged from bdl to 1.2 $ng.g^{-1}$ for OCPs and from bdl to 0.06 $ng.g^{-1}$ for indicator PCBs.

5.3 Long-range transport

Data were not available for the period 2008-2012. Results from long range transport from the baseline data in the first GMP report are included in this section.

Trajectories were generated for all countries using one sampling site per country. In countries with multiple sites, two backgrounds were selected for trajectory analysis wherever possible.

It has to be noted however, that although back trajectories can indicate the source areas for background sites, they cannot serve the purpose of source identification in the industrial or residential areas with strong local emission sources (like Egypt or Senegal, in this study).

While in some countries (such as Ghana and Kenya) the trajectories seemed to be quite consistent over the whole sampling period, their patterns varied greatly between the individual sampling months in other countries (Ethiopia, Mali, Sudan).

However, it is important to note that further information on local climatology and meteorology is needed to analyse correctly the relationship between the variability of the atmospheric POPs and the back trajectories. Temperature, sunshine, wind speed or wet deposition are some of the factors affecting the fate and life time of the compounds in the atmosphere (together with local and distant sources).

5.2.5 Challenges in implementing GMP in the Region

1) Increasing number of new POPs chemicals. New chemicals are continually added to the initial list of 12 chemicals/groups. The current 23 chemicals/groups has increased pressure on monitoring activities since some of the new POPs like PFOS are more hydrophilic and are more suitable to be monitored in water than air and mothers' milk, hence new methodologies are required for the new matrices and compounds.

2) Capacity building needs for the regional personnel to participate in the sample collection and analysis of POPs as well as interpretation of the POPs monitoring data and long-range transport of POPs. POPs monitoring and production of comparable data demand continuous training and capacity building for the personnel involved. Addition of the new matrices and new POPs compounds need to be included in the training.

3) Analytical capacities to analyse POPs at regional level. Most of the regional laboratories are in possession of HRGC/ECD and LRGC/MS which cannot analyse sophisticated POPs such as PCDDs/PCDFs, PBDEs and PFOS. At the moment the region depends on the strategic partners to analyse all POPs in the monitoring samples. However, for long-term sustainability, there is need to build regional capacity for analysis of POPs in core media and other media.

4) Lack of monitoring programme for POPs in water and other media. The listing of PFOS which is more hydrophilic has seen the addition of water as a core-media. This requires establishment of a harmonized water monitoring programme and protocol to ensure production of comparable data for analysis of temporal trends. Some new POPs have significant influence from emissions from the wastes, such as waste water treatment plants and landfills, to water, air, and contaminated soil that need to be clearly delineated through targeted research to help in the interpretation of the monitoring data.

5) Communication and information exchange. ROGs experienced impediments due to weak internet network connection at regional level. The application of Skype and participation in teleconferences and webinars could not be exploited to the maximum due to weak signal encountered most of the time. In addition, significant success reduction of UPOPs will depend on creating awareness among the general population to desist from biomass burning and open burning of wastes.

6) The region faces challenges with comparability of POPs levels in other media such as soil, sediments, fish and biota due to lack of uniform protocol for sampling, analysis and data presentation. As a consequence, the ROG mainly relied on the data for other media from the UNEP-GEF project implemented between 2010-2012 since the samples were collected within the same timeframe and analysed centrally.

7) Data gaps in some subregions. Data gaps were experienced for mothers' milk in some regions due to long bureaucratic procedures in approving the mothers' milk sampling protocol that delayed collection of the mothers' milk. The data gaps created will subsequently affect analysis of temporal trends in POPs levels over time.

8) Sample specimen banking and storage of the POPs data. Whereas huge amount of POPs data have been produced, the addition of new compounds to the POPs list or the need for data verification may require retrospective analysis of the samples to determine the temporal trends. Although WHO provides specimen banking for mothers' milk samples, there is no capacity for centralised specimen banking for air, water and other media. In addition data storage for other media is required in order to establish temporal trends.

9) Sustainability of existing programmes. Existing comparable data for air, mothers' milk and water have been collected over a short duration and could not allow analysis of temporal trends and long-range transport of POPs. Resources are required to ensure continuity of the monitoring activities including sampling, analysis and data storage in order to establish trends in POPs levels.

10) Political and security challenges at some sites inhibited continuous sampling of air. In some instances sites experienced temporal discontinuation from data collections which created data gaps.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Findings and conclusions

This section provides a brief synopsis of the major findings and the key messages for the Conference of the Parties. It also provides the gaps in the sampling programs and areas that need improvement.

6.1.1 Summary of the baseline concentrations

a) POPs levels in air

1) Analysis of core media revealed presence of various POPs in the Africa region. This provides evidence of environmental contamination contributing to the build-up of POPs in the food chain. These findings raise environmental and health concerns as these chemicals are persistent in environment, bioaccumulative, toxic and have the propensity to undergo long-range atmospheric transport from their points of release.

2) Pesticides were found in most of the sites in ambient air sampling sites. Of these, DDTs, HCHs and endosulfans were the most prevailing in ambient air. Chlordecone was not detected probably indicating that most countries did not have extensive applications of this pesticide. The presence of pesticides such as DDTs in core media could be attributed to the widespread agricultural and public health uses in the past throughout the region. Moreover, there is high probability that contamination might originate from obsolete stockpiles or contaminated sites/soils. This raises the concern and also the need to ensure that obsolete stockpiles and contaminated sites are managed in an environmentally sound manner.
   - The detection of DDTs in ambient air raises the need to promote research and application of alternatives to DDT. This will enable countries to protect their population and the environment from the adverse effects of these compounds.

   - Endosulfans levels were highest in 2005/2006 period with levels up to 3000 $pg.m^{-3}$, but the subsequent years saw significant reductions in concentrations, up to <250 $pg.m^{-3}$ in the samples collected in 2010 and <100 between 2011-2013, at the GMP background sites.

   - HCHs concentrations were also significantly higher compared to most of the other POPs pesticides, with the highest levels recorded in 2009 and 2010, but showed a gradual decline in 2011, 2012 and 2013.

3) Among the industrial POPs, PCBs were the most predominant. The concentrations of indicators PCBs were higher than the levels of dioxin like PCBs in air. The data provided depict the fact that countries in the region could be at risk of exposure to PCBs. The major sources of PCBs could include power generation activities such as leakages from old transformers, releases from contaminated soils and transport sector. Their proper management lies at different scales depending on the country by country situation. The risk posed to human health is clearly shown by the quantifiable contamination of PCBs in human milk samples in all countries in the region.

4) High prevalence of unintentionally produced POPs such as PCDDs and PCDFs was registered in all sites, although the concentrations were generally lower compared to other POPs chemicals like pesticides, PCBs and PBDEs. The levels of PCDDs were generally higher than PCDDFs. High incidences of UPOPs emissions in the region could be attributed to releases from uncontrolled combustion of wastes including municipal wastes, medical wastes incineration and biomass burning of agricultural fields. In addition, the contributions of industrial power generation activities and related thermal process could also be a significant source of UPOPs that need to be delineated and appropriate control measures put in place.

5) The concentrations of PBDEs were generally lower compared to other industrial POPs groups. The most important PBDEs were PBDE 47 and PBDE 99. Their probable origin is the crude recycling practices of e-wastes and end-of-life vehicles. The presence of PBDEs in GMP sites signify the potential contamination of the region with the new POPs in gradient and hotspot sites that need to be monitored in countries under the implementation of NIP activities.

6) PFOS, FOSA, N-methyl and N-ethyl-perfluoroalkane sulfonamides (MeFOSA & EtFOSA), and N-methyl and N-ethyl perfluoroalkane sufonamidoethanols (MeFOSE & EtFOSE) were measured in ambient air in two samples submitted from Kenya and Mali in 2013. The levels these compounds were generally low. The concentrations of NMeFOSE, PFOSA and PFOS were higher than NMeFOSA and NEtFOSA.

b) POPs in mothers' milk

1) The pesticides of concern in mothers' milk were DDTs which registered the highest concentrations in most of the samples with individual congeners concentrations ranging from bdl to 10,478 ng/gfat and sum DDTs from bdl to 22,668 ng/gfat. Dieldrin, heptachlors, HCHs, toxaphene and endosulfans were also detected in mothers' milk samples but at much lower frequencies and generally lower concentrations <20 ng/gfat.

2) Aldrin, chlordanes, endrin, mirex were below the limit of quantification in all mothers' milk samples collected in the first UNEP/WHO survey from 2009-2010 and UNEP/GEF Project in 2011/2012. Chlordecone was not measured in all the samples.

3) Industrial POPs of concern in mothers' milk were PCBs which registered total of six indicator PCBs levels in the range between bdl to 70 ng/gfat. Dioxin like PCBs were generally lower than indicator PCBs with sum (6) levels ranging from bdl to 5 ng/gfat.

4) The concentrations of PBDEs in mothers' milk were generally lower than PCBs and most of the POPs pesticides. The levels ranged from bdl to 1.6 ng/gfat. The highest PBDEs in mothers' milk were PBDE 47, 153 and 99.

5) The levels of PCDDs and PCDDF were generally lower than all the other POPs in mothers' milk samples, with concentrations spanning from 15.30-465.20 pg/gfat for 6 PCDDs and from bdl to 11.54 pg/gfat for PCDFs. However, PCDDs and PCDFs registered high prevalence in all the mothers' milk samples suggesting wider level of contamination. The critical concern raised here is that these compounds are extremely toxic even at low concentrations and therefore they have high potential to cause deleterious effects in the human population.

6) Quantifiable levels of PFOS were detected in mothers' milk from all the eleven regional countries that submitted samples during UNEP/WHO mothers' milk survey and the UNEP/GEF project, with levels ranging from 1.00 ng/L to 34.00 ng/L. Assuming that there is no industrial production of PFOS in the region, exposure of humans to PFOS and related chemicals might probably come from different kinds of waste, releases from industrial applications in fire fighting and the various consumer products.

c) POPs in Water

PFOS and salts were the only POPs monitored in the water samples during the second evaluation period. Only PFOS had quantifiable levels in water whereas FOSA, NMeFOSA and NEtFOSA, NMeFOSE & NEtFOSE were all below the limit of quantification. The concentration of PFOS measured under GMP was much lower than the levels reported from impacted sites in the region such as industrials areas and wastewater effluent discharges.

Table 6.1 gives the summary of availability of POPs baseline data for different core media in the Region. The analysis shows that although significant amounts of data have been generated in the region through the GMP1 and GMP2 activities and the baselines for POPs data in ambient air and mothers' milk have been achieved, however the existing data have been produced for a short period of time and therefore they are not adequate for determination of temporal changes and long-range transport of POPs in the region.

Table 6.1 Available comparable baseline data on POPs in different core media in Africa Region.

POP Chemical	Air	Mothers' milk	Water
Aldrin			

chlordane			
chlordecone			
DDT			
toxaphene			
dieldrin			
endosulfan			
endrin			
HBB			
HBCD			
HCB			
α HCH			
β HCH			
γ HCH			
Heptachlor			
PeCB			
mirex			
PBDEs			
Σ PCBs			
PCDD/Fs			
PFOS			

	Adequate data available for baseline
	Moderate data available for baseline
	No information on baseline

d) POPs in other media

1) Other media that are frequently analysed in the region include: soil, sediment, fish and foodstuff. The widely analysed POPs are pesticides and PCBs, although PCDD and PCDF have been analysed recently through the UNEP/GEF project. The data presented in this report were mainly produced under UNEP/GEF project, since the samples were collected within the same time period and analysed centrally using the same methodologies.

2) The most common pesticides detected in other media were DDTs, HCB, dieldrin, HCHs and BHC. The concentrations were generally low in sediments, fish and soil. However, it is noteworthy that most of the samples were collected from background sites to meet the GMP criteria. It is possible that contaminated soils, especially pesticide contaminated soils, would show much higher concentrations than the levels reported here.

3) The concentration of PCBs were also relatively low in sediments ranging from bdl to 1.2 ng/g. Similar trend was observed in fish samples with concentrations ranging from bdl to 0.15 ng/g.

4) Fly ash sample analysed was dominantly contaminated with PCDDs, PCDFs and dioxin like PCBs. Dioxins were also detected in some fish samples with concentrations ranging from bdl to 59 pg/g. However, the levels of dioxin like PCBs in fish were higher than PCDDs and PCDFs.

5) In general POP pesticides constituted the most important contaminants in other media followed by PCBs and lastly the PCDDs and PCDFs. PBDEs and PFOS were not analysed in samples collected for assessment of POPs in other media under the UNEP/GEF project. Despite the fact that some data on these POPs exist from some national activities, they could not be compared regionally based on variations in sampling schedule and analytical protocols applied.

6) Industrial POPs such as PFOs have also been analysed under individual research activities. The concentrations reported in these studies were higher than the levels found under the GMP monitoring activities. The difference could be attributed to the fact that under most of the national research activities, samples are collected from impacted areas such as industrial effluents, urban centres and areas with intensive agricultural activities.

6.1.2 Summary of evidence of temporal trends

Although POPs concentration levels were found to vary from one year to another over the sampling period, the absence of sufficiently long-term regional monitoring programmes and sufficient data did not allow for a comprehensive investigation and evaluation of temporal trends of POPs in the region that would address influence of climatological and metrological factors as well as human activities.

POPs levels in ambient air have been monitored from 2008 to 2013. However, breaks have been experienced between the first and the second evaluation creating a data gap. On the other hand, the available data for mothers' milk have been generated through single WHO mothers' milk survey in 2009-2010 and UNEP/GEF project in 2011/2012 therefore not sufficient for establishment of temporal trends. Water data have been collected through the initial pilot projects in within the 2013/2014 period and do not qualify for establishment of regional trends.

Table 6.2 below summarizes the status of existing data with respect to establishment of temporal trends.

Table 6.2 Summary of available temporal trend data on POPs in core media in Africa region.

POP Chemical	Air	Mothers' milk	Water
Aldrin			
chlordane			
chlordecone			
DDT			
toxaphene			
dieldrin			

endosulfan			
endrin			
HBB			
HBCD			
HCB			
α HCH			
β HCH			
γ HCH			
Heptachlor			
PeCB			
mirex			
PBDEs			
Σ PCBs			
PCDD/Fs			
PFOS			

	Adequate information on temporal trends
	Limited information on temporal trends
	No information on temporal trends

6.1.3 Summary of evidence of long-range transport

The presence of POPs in remote areas might probably indicate long range transport of POPs in the region. Nevertheless, more information on local climatology and meteorology is needed to correctly analyse the relationship between the variability of the atmospheric POPs and the back trajectories.

The initial analysis of back trajectories conducted in the first evaluation revealed that the transport of POPs in the region is highly dynamic and influenced by climatological factors (UNEP, 2009).

6.1.4 Summary of gaps in data coverage and the resources needed to overcome the gaps or establish/strengthen the capacity within the region

i) Air data coverage

The region lacks continuity in POPs monitoring activities due to lack of adequate financial resources to ensure continuous monitoring at all sites. The region has 13 ambient air monitoring sites under the MONET Africa programme and 12 sites under UNEP/GEF project. The MONET Africa programme has produced data from 2008 to 2013 but a break was experienced in 2009, whereas UNEP GEF data is for only one year 2011/2012.

Air data coverage is moderately distributed across the subregions, however, there has been lack of consistence some discontinuity in some years and inconsistencies at some sites

creating data gaps. Data gaps create difficulties in trend analysis, for both interpretation of temporal changes and spatial resolution.

The anthropogenic activities that might release POPs in the surroundings of the sampling sites were not sufficiently described nor continuously updated in order to enable making a link between the levels of POPs and such activities.

PFOS levels in ambient air have been analysed in samples from only two countries in the region representing the Eastern Africa and Western Africa. Data gaps exist in the sub-regions of Northern, Central and Southern Africa and Small Island states with respect to PFOS in air. Table 6.3 gives the overall status of baseline data on POPs in different subregions.

Table 6.3 Summary of available comparable baseline data on POPs in air in different Subregions

	Central Africa	East Africa	North Africa	West Africa	Southern Africa	Island states
aldrin						
chlordane						
chlordecone						
DDT						
toxaphene						
dieldrin						
endosulfan						
endrin						
HBB						
HBCD						
HCB						
α HCH						
β HCH						
γ HCH						
heptachlor						
PeCB						
mirex						
PBDEs						
Σ PCBs						
PCDD/Fs						
PFOS						

	Adequate information on baselines
	Moderate information on baselines
	No information on baselines

ii) Mothers' milk data coverage

There exist data gaps exist in the baseline for POPs in mothers' milk from the Southern Africa Sub-region.

Data gaps were also experienced in POPs temporal trends in Mothers' milk since sampling per country has only been conducted once during the UNEP/WHO milk survey and the UNEP/GEF project between 2009-2012. Therefore, the available POPs data for mothers' milk are insufficient for evaluation of changes in concentration over time.

Furthermore, some POPs such as chlordecon have not been analysed in mothers' milk, whereas PFOS and its salts have not been analysed in both the Northern and Southern Africa Sub-regions, creating additional data gaps in POPs parameters.

Table 6.4 Summary of available comparable baseline data on POPs in Mothers' milk in different Subregions in Africa.

	Central Africa	East Africa	North Africa	West Africa	Southern Africa	Island states
aldrin						
chlordane						
chlordecone						
DDT						
toxaphene						
dieldrin						
endosulfan						
endrin						
HBB						
HBCD						
HCB						
α HCH						
β HCH						
γ HCH						
heptachlor						
PeCB						
mirex						
PBDEs						
Σ PCBs						
PCDD/Fs						
PFOS						

	Adequate information on baselines
	Moderate information on baselines
	No information on baselines

iv) Water data coverage

The first comparable data set for PFOS in water were produced through the UNEP/GEF project (two regional countries) and the MONET Africa pilot projects in 2013/2014 (six countries: Kenya, Congo, Mauritius, Nigeria, Morocco and Egypt). There is no continuous

programme and monitoring protocol for PFOS and its salts and HCHs for water media. The existing data are not adequate for assessment of temporal changes in PFOS and salts in water media. Table 6.5 summarizes the available baseline data on POPs in water from different subregions.

Table 6.5 Summary of available comparable baseline data on POPs in water in different Subregions in Africa.

	Central Africa	East Africa	North Africa	West Africa	Southern Africa	Island states
α-HCH						
β-HCH						
γ-HCH						
PFOS						

	Adequate information on baselines
	Limited information on baselines
	No information on baselines

v) Other media

Comparable analytical data from UNEP/GEF project of POPs in other media have revealed different levels of contamination of soil, sediments, fish and foodstuff by POPs pesticides, PCBs and PCDDs and PCDFs. However, there is no established regional/national program for POPs monitoring for continuous production of comparable data in other media. The available data show indicative levels of POPs in other media, but no temporal trends could be evaluated.

6.1.5 Summary of existing capacity for POPs analysis

i) Human capacity

There exist capacities in the regional institutions such as universities, research institutions and analytical laboratories to support POPs monitoring activities. These have been demonstrated through research and training activities, publications on POPs and participation in supporting GMP activities in the region. However, the existing capacities are limited to basic POPs such as pesticides and PCBs, hence further capacity building is required for advanced POPs such as PCDDs, PCDFs, PBDEs and PFOS compounds.

ii) Analytical capacity

Majority of the regional institutions have basic instrumentations such as GC/ECD and Low Resolution GC/MS capable of analysing basic POPs such as pesticides and PCBs. However, the high resolution equipment necessary for analysis of complex POPs such as PCDDs, PCDFs, PBDEs and PFOS are lacking.

The countries have participated in two inter-calibration/proficiency studies under the UNEP/GEF project 2011/2012 to evaluate the competencies in analysis of POPs in two core

media (ambient air and mothers' milk) and other media such as soil and sediments, which established the need for further capacity building.

6.1.6 Summary of ongoing programs/activities

The Africa ROGs collaborated with several strategic partners in the implementation of the second evaluation. These included: 1) RECETOX (Czech Republic) coordinating MONET-Africa programme; 2) Global Atmospheric Passive Sampling (GAPS) programme coordinated by Environment Canada for ambient air data; 3) The World Health Organization (WHO) for provision of mothers' milk data, and 4) UNEP Chemicals and the GEF supporting implementation of the GMP 1 project on capacity enhancement.

i) MONET Africa

The programme span stretches from 2008 to the present and has long-term goal to conduct assessment of the long-term trends for POPs levels in Africa:

Long-term passive air POPs monitoring for at multiple sites, establishment of two active air monitoring sites (Kenya and Ghana), active-passive inter-calibration exercise and screening of the POP levels in surface waters. All data from the programme are made available in www.genasis.cz gradually – as the samples are analyzed in laboratories and also in GMP Data Warehouse in line with reporting periods.

Active air sampling and calibration of passive samplers

Active air sampling stations were established in Ghana and Kenya through RECETOX donation in 2013. Three months active-passive inter-calibration exercise was carried out in 2014 followed by regular weekly active air sampling. These sites should serve as part of the African supersites providing the most precise information on the atmospheric levels of POPs, and points of inter-calibration of passive and active air samplers. This is because in the past, all the calibration studies were only performed in the mild climate, but it is crucial to perform the inter-calibration exercise in the tropical conditions to determine site-specific performance (sampling rates) of passive samplers.

Active air samples were used to screen the atmospheric concentrations of POPs including perfluorinated compounds as well as some candidate compounds. However, remaining pesticides (aldrin, dieldrin, endrin, isodrin, heptachlor, methoxychlor, mirex, and chlordanes) were monitored in PAS as a contribution of RECETOX together with currently used (polar) pesticides and polyaromatic hydrocarbons. Brominated flame retardants were also added to the list. Polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecanes (HBCDs) were part of the contract while novel brominated flame retardants were again screened in PAS as a contribution of RECETOX. Similarly, perfluorinated substances (PFCs) were also screened in passive air samples.

For the third passive air monitoring assessment (2014-2017), MONET Africa recommend keeping the same minimal set of the organochlorines (as 2010-2013) except for polychlorinated *p,p'*-dioxins and furans. Based on the cost of their analyses and their generally low levels at many sites, MONET Africa would limit their analyses to several sites where they were either proved to be a problem or where they were never measured and need more information. For the purpose of establishment of the long-term trends, such could only be measured in active samples.

From the set of brominated flame retardants, keeping PBDEs in the PAS analyses would be appropriate. HBCDs as well as PFOS could be dropped from the list of POPs monitored in PAS due to the generally very low levels.

All POPs recommended above for monitoring in PAS should be measured during the calibration exercise and in all the active air samples. The active air samples should also be used for monitoring of PCDDs/Fs, HBCDs and PFCs in the future.

In the pilot active sampling study, active air samples were used to screen for the levels of some candidate compounds as chlorinated naphthalenes, hexachlorobutadien and short chain chlorinated paraffins. The active water samples were used to screen especially for the levels of perfluorinated compounds. The passive samples screened for POPs provide first background information.

Summer schools & trainings

As part of capacity building in the region, the Stockholm Convention Secretariat and RECETOX have collaborated to support training of regional staff through annual summer schools. The trainings have covered diverse areas of POPs management including general theory and practicals on installation of passive air samplers (PUF), installation of passive water samplers (XAD and Silicon rubber), extraction, cleanup, analysis of POPs using GC and GC-MS/MS, Operation of active air samplers for POPs monitoring, application of GIS in POPs data handling and presentation and onsite field visits to fully fledged operational POPs air monitoring station.

ii) GAPS Programme

The GAPS programme has maintained limited number of sites in the region to support assessment of data comparability with MONET Africa programme. The sites also play vital role in establishment of long-range and transport of POPs in the region.

iii) UNEP/GEF project

The GMP1 project contributed to human capacity enhancement among the participating counties in Africa region to monitor POPs in ambient air using polyurethane foam passive sampling technique.

Regional mothers' milk sampling capacity and contacts were established and maintained in the participating countries. These will provide framework for future WHO human milk survey for POPs in the region.

The project revealed that majority of the regional laboratories have different analytical capacities ranging from GC-ECD, LRGC-MS to analyse basic POPs. The countries in the region enhanced their capacities to analyse basic POPs such as organochlorine pesticides and polychlorinated biphenyls in the core media.

The project provided the opportunity to establish links among the technical personnel in the participating countries' laboratories. It supported networking of the technical staff in the region and therefore provided the platform for collaboration among the regional countries.

The provision of laboratory consumables and spare parts to the regional laboratories in the participating countries supported development of new methods and improvement of analytical resolution of the equipment.

Further, countries participated in two international inter-laboratory calibration exercises to evaluate their performance in POPs analysis. Future exercises will continue to improve the analytical performance of the laboratories. Table 6.6 shows the regional laboratories that participated in UNEP/GEF project inter-laboratory calibration for analysis of POPs.

Table 6.6 Regional Laboratories that participated in the global inter-laboratory calibration for POPs analysis in 2011/2012

Country	Laboratory	City	1st	2nd
Egypt	Central Laboratory for analysis of pesticides residues and heavy metals in food	Doki , Giza	X	
Ghana	Pesticide residue Laboratory, Ghana Atomic Energy Commission	Accra	X	X
Kenya	KEPHIS analytical Chemistry Laboratory	Nairobi	X	X
Kenya	Department of Chemistry, University of Nairobi	Nairobi	X	X
Mali	Central Veterinary Laboratory	Bamako	X	X
Mauritius	Government Analyst Laboratory	Reduit		X
Nigeria	Analytical and Environmental Lab, Chemistry Department, University of Lagos	Lagos		X
Senegal	Ceres Locustox	Dakar	X	X
Tunisia	CITET	Tunis		X
Uganda	Directorate of Government Analytical Laboratory	Kampala	X	X
Zambia	University of Zambia, Department of Chemistry Analytical Services Laboratory	Lusaka	X	X

UNEP/GEF Project 2

The second UNEP/GEF regional has already been endorsed by the regional countries. The project will support further capacity enhancement in the analysis of new POPs in the ambient air, mothers' milk and water. The project has been endorsed by the GEF.

iv) World Health Organization (WHO) mothers' milk survey

Under the WHO Program, breast milk samples were collected from the participating countries and sent to the WHO reference laboratory for analysis. The mothers' milk sampling activities follow WHO protocol.

v) Regional institutions

Some academic and research institutions within the region, have ongoing research activities mainly covering other media, and also address the core media to a limited extent. Since there is no established regional programme for POPs monitoring in other media, most of the activities are conducted following different QA&QC protocols and analytical methodologies.

6.1.7 Comment on the adequacy of monitoring for effectiveness evaluation

i) Monitoring POPs in ambient air

Several efforts have been establish for monitoring of POPs in ambient air through MONET Africa, GAPS and UNEP/GEF project. Continuity of these initiatives is vital to ensure continuity in data collection to support long-term monitoring of POPs to allow evaluation of temporal trends in POPs concentrations in ambient air and assessment of long-range transport.

ii) Monitoring POPs in mothers' milk

Mothers' milk monitoring has been conducted through UNEP/WHO and UNEP/GEF projects. Although baselines have been achieved in most of the subregions, except the Southern Africa subregion, the existing data is inadequate for determination of temporal trends since only a single survey has been effected from 2009-2012. Additional and periodic mothers' milk surveys are needed to allow comparison of POPs levels over time.

iii) Monitoring POPs in water

Water monitoring data for PFOS have been produced through the pilot projects using active and passive samplers through the pilot studies in 2013/2014. However, currently there is no established POPs monitoring programme with established protocols to ensure periodic sampling analysis of hydrophilic POPs such as PFOS and HCHs in water.

iv) Monitoring POPs in other media

There are national and regional efforts towards assessment of POPs in core media and other media. There are baseline comparable data for POPs in other media obtained from the UNEP/GEF project in 2011/2012. In addition, some POPs data in other media also exist from national research activities conducted in academic and research institutions within the region, however the protocols applied and QA/QC framework may not satisfy the GMP criteria for comparability, consistency and continuity due to financial constrains.

6.2 Recommendations for the future evaluations

The presence of POPs in regional environment signals a threat to human health and environment due to deleterious effects associated with POPs chemicals that negatively impacts on reproductive health, immunity and general wellbeing, hence the regional countries should streamline POPs management into regional development agenda to support reduction and elimination of POPs in the environment. POPs activities could be included under the national/regional activities to implement the 2008 Libreville Declaration on Health and environment strategic Alliance (HESA).

6.2.1 Recommendations from POPs baseline levels

6.2.1.1 POPs levels in air

i) The high prevalence of POPs pesticides such as DDTs, HCHs and endosulfans among others in ambient air reinforces the need to strengthen POPs management and control activities to reduce releases of these chemicals in environment. Although these chemicals have been banned or restricted in most countries, the management of contaminated sites and soils and treatment of obsolete stocks remain a top priority activity in the region. In addition, the countries are encouraged to promote adoption of alternatives to POPs pesticides to minimise new releases of POPs in environment. Further, targeted research activities on POPs pesticides alternatives should be encouraged to reduce overreliance on POPs and adequately contribute to minimising their releases.

ii) The presence of PCBs in ambient air long after their ban could suggest releases from old transformers; evaporation from contaminated soils and combustions processes including incineration and open burning of wastes that need to be controlled. Since the source contributions vary from country to country, regional countries are encouraged to conduct further assessments and research to establish the priority sources of PCBs to allow development of target specific control measures. Further, countries are encouraged to continue the promotion of using PCB alternatives in their power generation and industrial applications.

iii) High prevalence of UPOPs in ambient air and mothers' milk poses a health risk to the regional population and environment, hence there is need to strengthen the regional capacity for adoption/ integration of BAT and BEP in environmental management as well

as management of municipal and industrial wastes, medical wastes and elimination of open burning of wastes and agricultural fields to reduce releases of UPOPs.

iv) The presence of new industrial POPs such as PBDEs and PFOS in ambient air samples suggests active releases from the industrials activities, products and wastes. Countries should develop integrated waste management schemes in order to properly address the widespread sources of new industrial POPs such as PBDEs and PFOS, and develop and implement national/regional plans for the ESM of wastes containing and/or consisting PBDEs and PFOS.

v) There is need to integrate adoption of the alternatives to PBDEs and PFOS and related compounds in national and regional development agenda to control further releases from household goods and industrial materials and products.

6.2.1.2 POPs in mothers' milk

Several POPs including Pesticides, PCBs, PBDEs and PFOS were detected in mothers' milk from background sites in the region suggesting multiple potential contamination pathways including foodstuff, indoor and outdoor air and drinking water that need to be controlled. There is need to delineate and prioritise key exposure pathways for POPs in the region and implement mitigation measures to reduce and eliminate POPs exposure to human and environment.

6.2.1.3 POPs in water

The results of pilot studies on PFOS and salts in water from background sites have revealed measurable levels of PFOS underpinning potential threat of exposure to human. Stringent regulations for water and wastewater should be developed to control releases of industrial POPs into water systems.

There is need for continuous monitoring of PFOS and industrials POPs in water resources to establish the source pathways and reduce exposure levels.

Countries should support application of PFOS alternatives to reduce/or eliminate new releases into the water systems.

6.2.1.4 POPs in other media

Other media such as soil, sediment, fish and foodstuff revealed low levels of POPs such as pesticides, PCBs and PCDDs and PCDFs suggesting potential contaminations that need to be managed through the National Implementation Plans activities at national and regional levels. Although the levels were relatively low, the findings raise environmental and health concerns as these chemicals have long persistence, bioaccumulate in the body and cause toxicity to human.

6.2.2 Recommendations from evidence of temporal trends

Baseline data have been established for ambient air, but the amount of existing data is insufficient for evaluation of temporal changes in POPs levels in the region, hence there is need to ensure continuation of the established monitoring activities in the region.

Substantial amount of mothers' milk data have been generated through the UNEP/WHO and UNEP/GEF project and have revealed contamination of POPs in human tissues, but the existing data are inadequate for assessment of temporal changes in POPs levels over time. Therefore, there is need for countries to participate in additional mothers' milk surveys to provide additional data for evaluation of time trends in POPs concentrations.

Comparable data for PFOS and salts in water from background sites have only been established for first time in the region. Further monitoring activities are needed to provide sufficient data for analysis of temporal trends in concentrations. Further, this should include data for other polar POPs such as HCHs and endosulfans.

There are no adequate data for analysis of temporal tends of POPs in other media since the existing data from most of the national research activities lack comparability. There is need for collection of additional POPs data for other media to allow evaluation of temporal trends.

6.2.3 Summary of evidence of long-range transport

Monitoring data have revealed POPs contamination of ambient air from remote sites on top of mountains and desert such as Mt. Kenya and Timbuktu, respectively, suggesting potentials contribution of long-range transport to POPs contamination at these sites. However, additional metrological data, information on climatological conditions and modelling tools are required to establish the contribution of long-range transport on distribution POPs in the region.

Further, the data have been collected over a short period of time hence additional monitoring data are required to verify the modelling predictions with the monitoring results. Lastly, there is need for building regional capacity for application and interpretation of long-range transport models and results to support policy makers to incorporate the modelling predictions in national and regional POPs management interventions.

6.2.4 Recommendations on data coverage and gaps

i) Air data coverage

Representatives ambient air monitoring sites have been established in the region to support collection of comparable POPs data through MONET Africa, UNEP/GEF and GAPS programmes. However, there is need for ensure continuity of sampling activities and consistence at every site in order to provide adequate data for evaluation of trends, spatial distribution and long range transport of POPs in the region.

ii) Mothers milk data

The first survey of mothers' milk sampling received considerable support and participation of the regional countries that provided samples for analysis of POPs. However, data gaps exist in the Southern Africa sub region that needs to be filled to establish a more representative overview of POPs levels in the entire region. The Northern Africa subregion also lack data for PFOS and PBDEs in mothers' milk.

iii) ***Water data***

Water has been collected once under the UNEP/GEF project (two countries) and MONET Africa pilot study (six countries), but data gaps were experienced in some sub regions. The existing data represent indicative baseline for PFOS in water. However, participation of more countries is needed to allow establishment of a representative baseline. There is need for development of water monitoring programme to provide comparable data that will be used to establish temporal trends in PFOS concentrations.

iv) ***Coverage for other media***

Data for other media was obtained from 12 countries that participated in the UNEP/GEF project, and the key matrices included sediments, fish and soil. Participation of more countries is required to increase the data coverage and achieve regional representation. Future efforts to provide data for other media should include detailed protocols and repeat of similar matrices to allow comparison of temporal trends in POPs levels in other media.

6.2.5 Recommendations on existing capacity for POPs analysis

i) Human capacity

The Stockholm Convention is highly dynamic and new chemicals are regularly added to the annexes that require inclusion in monitoring activities. This necessitates continuous human and analytical capacity building to be able to collect and analyse a large number of samples for the listed chemicals.

Therefore, capacity building for POPs monitoring remains of high priority for all the countries and the region at large. These include:

- training in sample collection and preservation procedures for all POPs including new POPs in the core media and other media;
- training in sample preparation and analysis for all POPs including new POPs in the core media and other media;
- training in data interpretation and reporting following the established GMP standards;
- quality assurance and quality control protocols for POPs analysis in according to GMP guidelines; and
- training in overall maintenance and troubleshooting of analytical instrumentation for POPs analysis.

ii) ***Analytical capacity***

The number of POPs chemicals is substantially large and additional chemicals are regularly listed which increases the burden and cost of analysis. There is need to build the regional capacities to provide comparable quality analytical data and to ensure long-term sustainability. Currently, most of the laboratories possess basic instrumentation for analysis of POPs pesticides and PCBs but no capacities for PCDDs, PCDFs, PBDEs and PFOS. There is need for capacity building:

- to establish dedicated regional laboratories with necessary high resolution equipment for analysis of all POPs compounds;
- to support for regional approach to POPs monitoring by establishing regional programmes with standardized protocols for determination of POPs in core media and non-core media;
- to involve national laboratories in regional programmes (e.g. proficiency testing and upgrading of laboratories);
- to promote regional data sharing and storage capacities;
- to support sample banking for future evaluations;
- to strengthen communication among the regional organization groups and focal points through Chemical Information Exchange Network (ESTIS/CIEN) and similar efforts.

6.2.6 Recommendations on ongoing programs/activities

To achieve the goal of effectiveness evaluation, data on temporal trends and long-range transport are vital. Therefore, continuity of established monitoring activities is necessary to produce adequate data and information on POPs in core media and supportive data from other media to aid in interpretation of the POPs levels in the regional. Accordingly, there is need to:

- support continuation of established air monitoring programmes such as MONET Africa, GAPS and UNEP/GEF established sites in the region.
- facilitate the parties to participate in the subsequent rounds of WHO mother's milk surveys.
- establish water monitoring programme to provide data for PFOS and other polar POPs in water according to GMP guidance.
- provide resources for POPs monitoring activities in other media in the region as foreseen in GMP guidance and the NIPs.
- include new POPs in ongoing monitoring programmes to ensure continuity in data production.
- support data storage and sample banking for retrospective analyses of new POPs and future verification of the data.

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