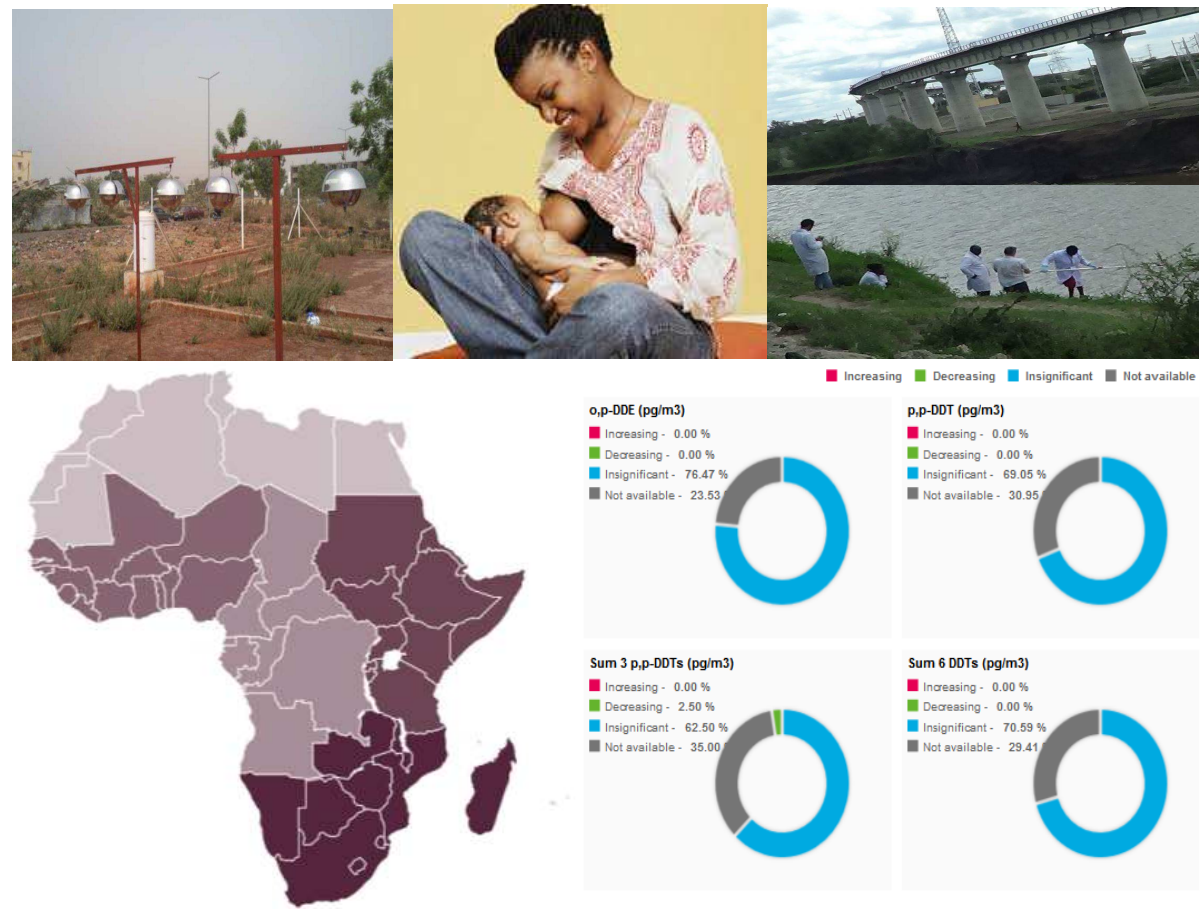
GLOBAL MONITORING PLAN
FOR PERSISTENT ORGANIC POLLUTANTS

UNDER THE STOCKHOLM CONVENTION ARTICLE 16 ON EFFECTIVENESS EVALUATION

THIRD REGIONAL MONITORING REPORT

AFRICA REGION



MAY 2021

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ACKNOWLEDGEMENTS

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Air monitoring activities are implemented in the five UN regions in cooperation with strategic partners: the Arctic Monitoring and Assessment Programme (AMAP), the Global Atmospheric Passive Sampling (GAPS) Network, the East Asia Air Monitoring Program, the European Monitoring and Evaluation Programme (EMEP), the Integrated Atmospheric Deposition Network (IADN) and the MONET Programme of the Research Centre for Toxic Compounds in the Environment (RECETOX).

The human milk survey draws on the collaboration between the Secretariat of the Stockholm Convention, the United Nations Environment Programme (UNEP) Division of Technology, Industry and Economics (DTIE) Chemicals Branch and the World Health Organization (WHO). The State Institute for Chemical and Veterinary Analysis of Food (CVUA), Freiburg, Germany, is acknowledged for the analytical work related to human milk samples. The MTM Research Centre, Örebro University, Sweden, is acknowledged for the analysis and provision of data on perfluorinated chemicals in human milk. Thanks are also expressed to the national coordinators of the joint WHO/UNEP exposure study for the work to collect and process the human milk samples.

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The ROG members for Africa Region are listed below:
1) Ms. Halimatou KoneTraore, Mali
2) Mr. Jean de Dieu Nzila, Republic of Congo
3) Mr. Martin Benoit Ngassoum, Cameroun
4) Mr. Otmani Anas, Morocco
5) Mr. Taelo Letsela, Lesotho
6) Mr. Vincent Odongo Madadi, Kenya

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. Eighteen additional chemicals have been listed in the Annexes of the Convention since, bringing the total number of POPs to thirty as of January 2020 (the meetings of the Conference of the Parties at which the listing of the chemicals took place are indicated in parenthesis in footnotes 1-3).

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 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.

While monitoring activities are ongoing in the frame of the GMP, every six year the information generated is collected, compiled and analyzed in monitoring reports (regional and global). The

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[1] **aldrin, chlordane**, chlordecone (COP-4, 2009), **dichlorodiphenyltrichloroethane (DDT),** dicofol (COP-9, 2019), **dieldrin,** endosulfan (COP-5, 2011), **endrin, heptachlor, hexachlorobenzene (HCB),** gamma-hexachlorocyclohexane (γ-HCH, lindane) and by-products of lindane [alpha-hexachlorocyclohexane (α -HCH) and beta-hexachlorocyclohexane (β -HCH)] (COP-4, 2009), pentachlorophenol, its salts and esters (COP-7, 2015) **mirex, toxaphene**.

[2] tetra- and pentabromodiphenyl ethers (PBDEs) (COP-4, 2009), hexa- and heptabromodiphenyl ethers (PBDEs) (COP-4, 2009), decabromodiphneyl ether (COP-8, 2017), hexabromocyclododecane (HBCD) (COP-6, 2013), hexabromobiphenyl (COP-4, 2009), hexachlorobutadiene (COP-7, 2015), perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOS-F) (COP-4, 2009), perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds (COP-9, 2019), pentachlorobenzene (PeCB) (COP-4, 2009), **polychlorinated biphenyls (PCBs)**, polychlorinated naphthalenes (PCN) (COP-7, 2015), short-chain chlorinated paraffins (SCCPs) (COP-8, 2017).

[3] **hexachlorobenzene (HCB),** hexachlorobutadiene (COP-8, 2017), pentachlorobenzene (PeCB) (COP-4, 2009), polychlorinated naphthalenes (PCN) (COP-7, 2015), **polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-*p*-dioxins (PCDDs) and dibenzofurans (PCDFs)**.

first two phases of the GMP have been implemented during the period 2004-2017, with two sets of regional monitoring reports and global reports developed to date in the frame of the GMP and have informed the effectiveness evaluation under Article 16 of the Convention. The GMP Data Warehouse has been made operational during the second GMP phase and continued to support the regional organization groups in the work for the collection, processing, storing and presentation of monitoring data during the third phase of implementation of the GMP.

The present (third) monitoring report is synthesizing information from the first, the second and the third phase of the global monitoring plan and presents the most up-to-date findings on POPs concentrations in the Africa Region. While the first and the second monitoring reports, presented at the fourth and seventh meeting of the Conference of the Parties respectively, provided information as to the changes in concentrations of the chemicals initially listed in the Convention, as well as baseline information on some of the newly listed POPs, this third report builds on the increasing information base of POPs monitoring data and provides a further in-depth assessment of the changes measured over time in POPs concentrations, including time trends where available, as well as recent baseline information on the more recently 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	Africa Union
BCF	Bioconcentration Factor
BHC	Benzenehexachloride
BPH	Benzo (a)pyrene oxidation
CEE	Central and Eastern Europe
CEP	Caspian Environment Programme
CIS	Commonwealth of Independent States
COP	Conference of the Parties
CRM	Certified Reference Material
CTD	Characteristic Travel Distance
CV	Coefficient of Variation
DDD /DDE	Metabolites of DDT
DDT	Dichlorodiphenyltrichloroethane
DLPCBs	Dioxin-like PCBs
EDCs	Endocrine Disrupting Chemicals
EMAN	Ecological Monitoring and Assessment Network
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long-Range
EPER	European Pollutant Emission Register
ERL	Effects Range Low
ERM	Effects Range Median
EROD	7-ethoxyresorufin-O-deethylase
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
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
I-TEQ	International Toxicity Equivalence
KAW	Air/Water Partition Coefficient
KOA	Octanol/Air Partition Coefficient
Kow	Octanol/Water Partition Coefficient
LC50	Median Lethal Concentration
LD50	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	Multilateral Environmental Agreements
MEDPOL	Mediterranean Pollution Monitoring and Research Programme
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
NEPAD	New Partnerships for Africa's' Development
NGOs	Non-Governmental Organisations
NHATS	National Human Adipose Tissue Survey
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 Sulphonic Acid
PIC	Prior Informed Consent
POPs	Persistent Organic Pollutants (group of twelve as defined in the Stockholm Convention 2001)
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
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
t	Tonnes
TBBPA	Tetrabromobisphenol A
TCDD	Tetrachlorodibenzo-*p*-dioxin
TEL	Tetraethyllead
TEQ	Toxicity Equivalents
TOMPS	Toxic Organic Micropollutants Survey
TPT	Triphenyltin
	Transmission of Air Pollutants in Europe
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation
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 2014.
Phase III	Activities to support the Article 16 effectiveness evaluation that will be conducted by the Conference of the Parties at its tenth meeting, information collected between 2015 and 2018.

EXECUTIVE SUMMARY

This third monitoring report synthesizes information from the first, the second, and the third phases of the global monitoring plan and presents the current findings on POPs concentrations in the Africa Region. The third phase of the global monitoring plan focused on expanding the information base for assessing changes in POPs concentrations over time, covering all 30 substances or groups of substances listed as POPs in the Stockholm Convention (as of January 2020); the inclusion of the more recently listed POPs in ongoing monitoring activities represented a significant increase in the scope of the GMP. The work in the third phase was equally directed at further enhancing comparability within and across monitoring programmes through new inter-calibration studies, harmonizing data handling, and continued to ensure support to the collection, processing, storing and presentation of monitoring data in regions through the global monitoring plan data warehouse.

0.1: Contributing programmes

Strategic programmes that contributed to this third Africa regional POPs monitoring report were 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; The World Health Organization (WHO) for provision of mothers' milk data, and UNEP/GEF GMP2 project coordinated by UNEP Chemicals DTIE for provision of additional data for ambient air, mothers' milk, water and other media.

0.2: Key message from baseline concentrations

The ambient air, mother's milk and water monitoring data revealed environmental contamination by a wide range of persistent organic pollutants POPs listed in annexes A, B and C of the Stockholm Convention. POPs have potentials to build up in the environment, food chain, bio-accumulate in human tissues and induce adverse ill health conditions including cancer, reproductive failures, and suppress immune system. The findings raise environmental and health concerns, hence regional governments are encouraged to enhance enforcement measures to eliminate releases of POPs in their territories.

POPs levels in ambient air: Pesticides dominated all POPs levels in ambient air in majority of the sites, elevating their significance as POPs of priority to the region. Among all the pesticides, DDTs, endosulphan, HCHs, dieldrin, pentachlorobenzene and hexachlorobenzene registered the highest concentrations. The high presence of pesticides in ambient air could be attributed to the past application of these chemicals in agriculture and public health vector control. In addition stockpiles and contaminated soils in the region are potentials secondary sources of pesticides in ambient air.

Industrial POPs concentrations were dominated by PCBs and PFOS. Indicator PCBs recorded relatively higher concentrations than the dioxin like PCBs. For PFAS, the PFOS dominated the concentrations followed by PFOA and PFHxS. Potentials sources of PCBs in the region include leakages from old electric transformers where they were used as dielectric fluids, and contaminated soils.

Dioxins and furans were widely detected in most of the sites suggesting persistent sources of emissions of low levels of these compounds into ambient air. Dioxins and furans releases could be attributed to uncontrolled biomass burning and emissions from combustion of municipal,

industrial and medical wastes, as well as industrial thermal power generation processes that need to be managed in environmentally sound manner.

PBDEs were widely detected in all sites but at relatively low concentrations. BDE 209, 100, 99 and 47 dominated the levels of BDEs measured in ambient air. High prevalence of BDEs in all sites project to future significance of these emerging environmental pollutants since wastes containing these chemicals are gradually building up.

POPs levels in mothers' milk: A risk assessment of PCDDs, PCDFs and PCBs levels in mothers' milk samples from the region showed that the levels were significantly above those considered toxicologically safe, while **Σ**DDTs were below or around those considered safe for majority of the countries that participated in mothers' milk survey. Nevertheless the health benefits of breastfeeding are far above the health risks of POPs in mothers' milk breastfeeding is strongly encouraged, while measures to reduce POPs burden are instituted in the countries.

POPs levels in mothers' milk were dominated by pesticides, particularly the DDTs, followed by PFOS & PFOA, dioxin like PCBs, dioxins and furans, and short chain chlorinated paraffins.

Among the pesticides, DDT congeners and metabolites registered the highest concentrations followed by heptachlor, chlordane, dieldrin, beta-HCH, endosulphan sulphate and *cis*-heptachlor epoxide. The highest levels of DDTs were register in the second phase of GMP, whereas relatively lower levels were recorded in the third phase suggesting positive effects from the control measures instituted by countries to manage DDT.

Industrial POPs in mothers' milk were dominated by PFOS & PFOA, short chain chlorinated paraffins, and PCBs. Indicator PCBs had relatively higher concentrations compared to dioxin like PCBs. PBDEs levels were relatively lower than the other industrial POPs, with the congeners 189, 47 and 153 dominating the concentrations of PBDEs recorded in the mothers' milk samples.

PCDDs and PCDFs were widely detected in the mothers' milk samples from different countries in the region, though at lower concentrations compared to the rest of POPs. PCDDs registered dominance over the PCDFs in the mothers' milk sample. PCDDs/Fs contamination in mothers' milk sample suggest potential food chain contamination that requires delineation and elimination of the critical sources and pathways to protect infants from the risks associated with POPs.

POPs levels in water samples: PFAS compounds were the only POPs monitored in water samples, based on the GMP guidelines. The Concentration of PFAS in water were dominated by PFOS, PFOA, and PFHxS.

POPs in other media: POPs in other media were dominated by Pesticides, PCBs with lower levels of PBDEs, dioxins and furans.

03: Summary trends of POPs levels

Ambient air: Initial trends have begun to develop for a few POPs in ambient air for sites that have been in existence for over 10 years. Pesticides that registered at least 5% decline in levels included aldrin, endrin, oxychlordane, heptatachlor, *p,p'*-DDD, endosulphan I, and gamma-HCH.

PCBs have recorded lower decline with only the congeners 28, 138, and 153 recording 2.08% decline. Dioxin like PCBs that have started to decline include PCB 105, 118, and 156 congeners which recorded 1.44-4.17 % reduction. Only two PCDDs and five PCDFs have shown initial

decline between 2.63 -7.89%. PBDEs have recorded percent decline between 0-3.45% for the congers 28, 47, 99, 100, and 154, while no declines were established for BDE 17, 153 and 175/183. PFAS compounds did not show any significant trends in levels registered in the ambient air.

Mothers' milk: There were no trends in levels of POPs measured in the mothers' milk samples collected from the region for the period 2002-2019. This was partly attributed to lack of adequate datasets to conduct trend analysis. The regional countries have participated in a maximum of two mothers milk surveys, while 7/19 countries have only completed their first survey. Hence the countries are encouraged to participate in future mothers' milk survey to build adequate data that will allow assessment of regional trend of POPs levels.

Water: No trends were established in POPs levels in water due to inadequate long-term monitoring data for trends analysis. Continuation of water monitoring at the established sites is necessary to establish trends in POPs levels in the region.

04: Summary of evidence of long-range transport

The presence of POPs in remote sites is a primary indicator of long range transport of the chemicals in the region. Back trajectories analysis conducted for POPs levels in sites with over 10 years of monitoring revealed that transport of POPs across the regional sites is affected by a mixture of local and trans-boundary transport of air masses. Mt. Kenya and Reduit sites recorded the lowest POPs levels and are mainly affected by transport of air masses from the Indian Ocean. Brazaville, Abefeti, Accra and other sites are mainly affected by local transport of air masses and local activities. Bamako and Khartoum covered the largest geographic areas of continental Africa and are likely influenced by multiple sources and air masses, both local and abroad, and the impact of the Sarahan dust.

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

Air data

The third regional report received increased coverage of POPs monitoring sites in the region due to additional sites established under the UNEP/GEF GMP2 project. This helped to reduce the data gaps in ambient air that were encountered in the second report. The air data presented in this third regional report is moderately distributed across the sub-regions, however, there has been lack of consistence in some years as well as discontinuities of some sites, particularly in the Southern Africa sub-region. Major air data gaps were observed in Abono (Ghana), Lilongwe (Malawi), Cairo (Egypt), Kalahari, Molopo, Baberspan, Nooitgedacht (South Africa), and Khartoum (Sudan).

Additional data gaps were identified between the UNEP/GEF GMP 1 & 2 pilot projects for the period 2013-2016 when there was no monitoring at the UNEP/GEF initiated sites. Furthermore, there are uncertainties in continuation of the monitoring at the sites covered under UNEP/GEF GMP2 project since the project ended in 2020. Comparable monitoring activities require continuous supply of uniformly prepared sampling media and centralized analytical laboratories employing the same analytical protocol.

Mothers' milk data

Mothers' milk survey are dependent on the cooperation between WHO, the Stockholm Convention secretariat and UNEP/Chemicals, and the availability of funding from GEF. Up to

date only two mothers' milk survey have been conducted in the region, with 7/19 having participated in a single survey. The mothers' milk monitoring data collected so far is inadequate for trends analysis. Further financial support and cooperation of the strategic partners are necessary to ensure continuity in monitoring of POPs for mothers' milk.

Water data

Consistent water monitoring was effected under UNEP/GEF GMP2 project that cover a two year period 2017-2018. Additional data were collected through pilot studies in phase two of GMP in 2013/2014. Continuation of water monitoring at established sites will be critical to allow establishment of concentration trends in the future evaluations. However, this can only be achieved with provision of necessary financial resources to support field sample collection from far remote sites and analysis costs.

Other media data

Comparable data of POPs levels in other media have been produced through strategic programmes and activities. However, the data are not adequate nor do they cover all countries in the region. Further assessment of POPs in other media should be encouraged to help identify sources and critical paths of POPs levels measured in core media from the regional countries. The use of harmonized protocols for POPs sampling and analysis is encouraged to ensure comparability of POPs data in other media.

0.6: Summary of ongoing programs/activities

In the first, the second and the third phases of GMP, the Africa ROGs collaborated with several strategic partners to provide comparable POPs monitoring data for core media for effective implementation of monitoring activities. These included: RECETOX (Czech Republic) coordinating MONET_Africa programme; Global Atmospheric Passive Sampling (GAPS) programme coordinated by Environment Canada for ambient air data; The World Health Organization (WHO) for provision of mothers' milk data, and UNEP Chemicals and the GEF supporting implementation of the GMP 1&2 projects on capacity enhancement.

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 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 continue to 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.

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.

UNEP/GEF GMP2 project

The GEF/GMP2 project implemented in the period 2016-2010 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 countries that participated in mothers' milk sampling established capacity and contacts that should be maintained to provide a framework for future WHO human milk survey for POPs in the region to develop trends in mothers' milk samples.

Further, countries should participated in international inter-laboratory calibration exercises to evaluate their performance in POPs analysis. Future exercises will continue to improve the analytical performance of the laboratories.

The World Health Organization (WHO) mothers' milk survey

Countries participating in the first and second phase of mothers' milk samples collection applied WHO protocol, and the samples were analyzed centrally at the WHO reference laboratory. Twelve out of the nineteen participating countries completed a second mothers' milk survey. Further support is necessary to ensure subsequent mothers' milk surveys to establish trends in POPs levels and contribute effectively to the effectiveness evaluation of the Convention.

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 monitoring programme for POPs monitoring in other media, most of the activities are conducted following different QA&QC protocols and analytical methodologies.

0.6: Comment on the adequacy of monitoring arrangements for the purpose of effectiveness evaluation

POPs monitoring is both labour and financial resource intensive venture. Hence continuity and effectiveness of monitoring activities in the region require continued capacity building in terms of personnel training and retention, investment in analytical infrastructure and adequate financial resources to support recurrent expenses.

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 dioxins and furans, brominated flame retardants (PBDEs), Perfluorinated substances (such as PFOS, PFOA and PFHxS), short chain chlorinated paraffins (SCCPs), and polychlorinated naphthalenes (PCNs).

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, PCBs and PBDEs. However, the high resolution equipment such as HRGC/MS and HRLC/MS are necessary for analysis of complex POPs such as PCDDs, PCDFs, PFOS, SCCPs and PCNs are still lacking. Laboratories should continuously participate in inter-calibration/proficiency studies and accreditation to evaluate the competencies in POPs analysis in the core media and other media.

Financial resources

Financial resources to support continuous POPs monitoring is critical to enable field sample collection and analysis for ambient air, mothers' milk and water. Monitoring activities require heavy investment of financials resources to ensure high quality data are produced to influence sound policy decisions.

0.7: Recommendations for the future POPs management and monitoring

0.7.1 Recommendations from baseline levels of POPs

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, immune system, cancer and general wellbeing. POPs management activities should be mainstreamed in the national and regional development strategies such as Africa Agenda 2063, Libreville Declaration on Health and Environment Strategic Alliance (HESA) interventions for the period 2019-2029, and regional actions on Sustainable development goals.

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 minimize 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 minimizing their releases.

ii) The presence of PCBs in ambient air could suggest releases from old transformers and evaporation from contaminated soils. 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. Furthermore, countries are encouraged to promote PCB alternatives in electrical 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. 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.

iv) The presence of new industrial POPs such as PBDEs, 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 promote 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.

v) Some newly listed POPs such as SCCPs, PCNs have not yet included in the monitoring programmes due to lack of methodologies hence resources are required for method development and incorporation into monitoring activities.

POPs levels in mothers' milk

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

POPs levels in water

PFOS, PFOA and PFHxS and salts were detected in water from remote monitoring sites in the major the regional rivers and estuaries underpinning the 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.

POPs in other media

Other media including soil, fish, sediments and food stuff revealed contamination by POPs. There is need for follow up studies to delineate key sources and hot spots, and institute mitigation measures to eliminate releases of POPs at national levels.

0.7.2: Recommendations from temporal trends

Baseline data have been established for ambient air and initial trends have stated to emerge for a few POPs compounds. There is need to continue monitoring activities provide sufficient data for evaluation of temporal trends of POPs levels 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 from the first, the second and the third GMP phases, but the existing data are still inadequate for assessment of temporal changes in POPs levels over time. There is need for countries to participate in further mothers' milk surveys to provide additional data for evaluation of temporal trends of POPs levels in mothers' milk.

Comparable data for PFOS and salts in water from background sites established for first time in the region. Further monitoring activities are needed to provide sufficient data for analysis of temporal trends in concentrations.

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, while comparable data from UNEP/GEF pilot projects are for a short time period. There is need to apply harmonized protocols to allow evaluation of temporal trends.

0.7.3: Recommendations from long-range transport

Monitoring data have revealed POPs contamination of ambient air from remote sites, 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. There is need for building regional capacity for application and interpretation of long-range transport models to predict regional transport of POPs.

0.7.4: Recommendations from coverage and gaps

Air data coverage: Representative 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 and second mother's milk survey received considerable support and participation of the regional countries that allowed production of comparable POPs monitoring data. Countries are encouraged to continue supporting further survey to allow generation of adequate data for effectiveness evaluation. In addition, limited data exist in the Southern Africa sub-region that require increased participation of sub-regional countries to establish a more representative data coverage of POPs levels in mothers' milk.

Water data: Water has been collected under the UNEP/GEF GMP1 &2 projects and MONET Africa pilot study (six countries) that allowed establishment of baseline data. There is a need for continued monitoring of POPs at established sites to build adequate datasets to allow analysis of temporal trends in POPs levels in water.

Coverage for other media: Data for other media were obtained from countries that participated in the UNEP/GEF GMP1&2 project and regional studies. 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 application of the protocols developed in the GMP3 phase and repeat of similar matrices to allow comparison of temporal trends in POPs levels in other media.

0.7.5: Recommendations from capacity for POPs analysis

Human capacity

The Stockholm Convention is highly dynamic and new chemicals are regularly added to the annexes that require inclusion into monitoring activities. This necessitates continuous update of sampling and analytical methods for a large number of chemicals in the Convention Annexes A, B and C. Therefore, capacity building for POPs monitoring remains of high priority for all the regional countries. These include:

i) training in sample collection and preservation procedures for all POPs including new POPs in the core media and other media;
ii) training in sample preparation and analysis for all POPs including new POPs in the core media and other media;
iii) training in data interpretation and reporting following the established GMP guidelines;

iv) quality assurance and quality control protocols for POPs analysis in according to GMP guidelines; and
v) 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, PFOS, SCCPs, and PCNs. There is need for further capacity building to:

i) establish dedicated regional laboratories with necessary high resolution equipment for analysis of all POPs compounds;
ii) support regional approach to POPs monitoring by establishing regional programmes with standardized protocols for determination of POPs in core media and non-core media;
iii) involve national laboratories in regional programmes (e.g. proficiency testing and upgrading of laboratories);
iv) promote regional data sharing and storage capacities;
v) support sample banking for future evaluations;
vi) strengthen communication among the regional organization groups and focal points.

0.7.6: Recommendations for ongoing programs/activities

Strategic programmes have been instrumental towards achieving the successes in the first, second and third GMP phases. It is vital to ensure continuity of established monitoring sites and QA and QC protocols and standards for POPs monitoring to provide comparable monitoring data to detect temporal trends in POPs levels and assessment long-range transport for effectiveness evaluation of the Convention. It is important to ensure continuity of established monitoring activities to produce adequate data and information on POPs levels in core media and supportive data from other media in the regional. Accordingly, there is need to:

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

1 INTRODUCTION

The first phase of the GMP has been implemented during the period 2004-2009 and the second phase during 2010-2017, providing information on changes in concentrations of the 12 POPs initially listed in the Stockholm Convention and information on baseline concentrations of the 11 substances newly listed in the annexes to the Convention in 2009, 2011 and 2013. Two sets of regional monitoring reports and global reports have been developed to date in the frame of the GMP and have informed the effectiveness evaluation under Article 16 of the Convention.

The present (third) monitoring report synthesizes information from the first, the second, and the third phase of the global monitoring plan and presents the current findings on POPs concentrations in the Africa Region. While the first and second monitoring reports, presented at the fourth and seventh meeting of the Conference of the Parties respectively, provided information as to the changes in concentrations of the chemicals initially listed in the Convention, as well as baseline information on some of the newly listed POPs, this third report builds on the increasing information base of POPs monitoring data and provides a further in-depth assessment of the changes measured over time in POPs concentrations, including time trends where available, as well as recent baseline information on the more recently 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 (UNEP/POPS/COP.6/INF/31/Add.2).

At its seventh meeting held in May 2015, the Conference of the Parties, by decision SC-7/25, welcomed the second regional monitoring reports, and, at its eighth meeting held in May 2017, by decision SC-8/19, it welcomed the second global monitoring report which marked the end of the second phase of implementation of the GMP. COP-8 requested the Secretariat to continue to support the work on the GMP to provide relevant input to the process of effectiveness evaluation under Article 16 of the Stockholm Convention and ensure sustainability of POPs monitoring toward the third GMP phase.

Monitoring activities have been ongoing in the five UN regions to support POPs monitoring data generation for the third GMP phase. The global coordination group met four times over the period 2015-2018 in order to oversee and guide implementation of the third 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 ongoing 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 and second monitoring reports continued during the third phase, and new programmes have been identified to support the development of the third reports. Likewise, the continued operation of global and regional air monitoring programmes was a major pillar in the third 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 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. 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.

The GMP Data Warehouse has been made operational during the second GMP phase, supporting the regional organization groups in the work for the collection, processing, storing and presentation of monitoring data. 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 data warehouse was further enhanced and kept up-to-date to provide on-line access to the GMP monitoring data and enable data collection and processing during the third GMP phase and support the development of the third monitoring reports.

The process for updating the GMP guidance document has continued; information relevant to the POPs listed more recently in annexes to the Convention and on the chemicals recommended for listing or in the process of review by the POPs Review Committee has been included in the guidance. The Guidance on the Global Monitoring Plan for Persistent Organic Pollutants has been streamlined and updated in 2019 (UNEP/POPS/COP.9/INF/36) and provided a useful basis as the reference document for POPs monitoring in the third phase of the GMP, as well as for harmonized data collection, storage and handling.

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 including the Indian Ocean and Atlantic Ocean Island States is 21,787, 284 sq. km (UNEP, 2002), and the total population in 2016 was about 1.2 billion people living in 54 sovereign states, and approximately 40% of the regions populations is under 15 years (AU, 2017).

Under article 11 of the Protocol to the AU Constitutive Act, the official languages of the AU and all its institutions are Arabic, English, French, Portuguese, Spanish, Kiswahili and any other African language (AU, 2020). Each African country is constituted of many ethnic groups or subgroups that speak languages other than the official languages. Africa is the most multilingual continent in the entire world. It is estimated that around 2,000 languages are spoken throughout the many countries. The dominant conventional religions are Christianity and Islam, but traditional religions are still being adhered to in several communities.

Agriculture forms the backbone of the continent with most rural Africans being agrarian. The continent is rich in mineral resources, ranging from gold, diamond, bauxite, silver, to fossil fuels and other precious metals. These mineral resources are unevenly distributed in the continent.

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 in Addis Ababa, Ethiopia, by the 32 African states that had achieved independence at the time. A further 21 members joined gradually, reaching a total of 53 by the time of the AU's launch in 2002.4 In 2011, South Sudan became the 54th Member State, and, in 2017, Morocco became the 55th Member State (AU, 2020).

The objective of establishing the OAU was to achieve greater unity and solidarity and to promote political and socio economic development in Africa. The OAU operated on the basis of its Charter and the 1991 Treaty Establishing the African Economic Community (known as the Abuja Treaty). 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 (AU, 2020).

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 (AU, 2020).

The AU recognizes eight regional economic communities (RECs) that are primarily trade blocs and, in some cases, involve some political cooperation and monetary unions (UNCTAD, 2018; MIF, 2014). All the eight communities form the pillars of the African Economic Community (AEC). The eight RECs in Africa listed in chronological order are:

i) Economic Community of West African States (ECOWAS) established in 1975;
ii) Economic Community of Central African States (ECCAS) established in 1983;
iii) Arab Maghreb Union, Union du Maghreb Arabe in French, (UMA) established in 1989;
iv) East African Community (EAC) established in 1990.
v) Southern African Development Community (SADC) established in 1992;
vi) Common Market for Eastern and Southern Africa (COMESA) established in 1993;
vii) Intergovernmental Authority on Development (IGAD) established in 1996;
viii) Community of Sahel-Saharan States (CEN-SAD) established in 1998

The RECs are central to several AU transformative programs including the New Partnership for Africa's Development (NEPAD) adopted in 2001 and the AU's Agenda 2063 adopted by its Summit in January 2015, and its First Ten-Year Implementation Plan adopted by the 25th Summit of the AU in June 2015 (AU, 2020; UNITAD, 2018).

In 2013, Africa's political leadership acknowledged past achievements and challenges and rededicated itself to the Pan African vision of "an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena (AU, 2015). Hence barely fifty years after the first thirty-three (33) independent African states gathered in Addis Ababa to form the Organization of African Union, now the African Union, the continent is looking ahead to make significant political, social and economic development in the next fifty years (AU, 2015). The Summit tasked the African Union Commission (AUC), supported by the New Partnership for Africa's Development (NEPAD) Planning and Coordinating Agency (NPCA), the African Development Bank (AfDB) and the UN Economic

Commission for Africa (UNECA), to prepare a continental 50-year agenda through a people-driven process – hence Agenda 2063 (AU, 2015).

Agenda 2063, is the continent's shared strategic framework for inclusive growth and sustainable development, takes account of past achievements, challenges and opportunities at the national, continental and global levels to provide the basis and context in which the continent's transformation is being designed and implemented. The vision harnesses the continent's comparative advantages such as its people, history and cultures; its natural resources; its position and repositioning in the world to effect equitable and people-centred social, economic and technological transformation and the eradication of poverty. It seeks to fulfil the obligation to our children as an intergenerational compact, to develop Africa's human capital; build social assets, infrastructure and public goods; empower women and youth; promote lasting peace and security; build effective developmental states and participatory and accountable institutions of governance (AU, 2015).

Flagship programs to kick start implementation of Agenda 2063 include:

i) Eradicating poverty;
ii) Skills revolution and science, technology and innovation;
iii) Transforming, growing and industrializing economies through beneficiation of natural resources
iv) Consolidating the modernization of African Agriculture and Agribusiness through scaled up value addition and productivity;
v) Connecting Africa through world-class Infrastructure, with a concerted push to finance and implement the major infrastructure projects in: Transport: Energy and ICT;
vi) Fast tracking the establishment of a Continental Free Trade Area;
vii) Supporting young people as drivers of Africa's renaissance;
viii) Silencing the guns, to make peace a reality for all our people and by ending all wars, civil conflicts, human rights violations, humanitarian disasters and violent conflicts, and to prevent genocide;
ix) Achieving gender parity in public and private institutions, and the removal of all forms of gender discrimination in the social, cultural, economic and political spheres;
x) Introducing an African passport, issued by member states, capitalizing on the global migration towards e-passports, and starting with abolishing visa requirements for all African citizens in all African countries;
xi) Consolidating democratic and people–centered Africa, through the universal application of normative framework of the African Governance Architecture, and conducting free, fair and credible elections;
xii) Enhancing Africa's united voice in global negotiations, through pooled sovereignty, integration and the development of common African positions;
xiii) Strengthening domestic resource mobilization, through building continental capital markets and financial institutions, and reversing the illicit flows of capital from the continent.

Africa region is divided into Northern, Southern, Eastern, Western and Central Africa sub-regions (AU, 2020; AUDA-NEPAD, 2021) as illustrated in Figure 2.1 below.

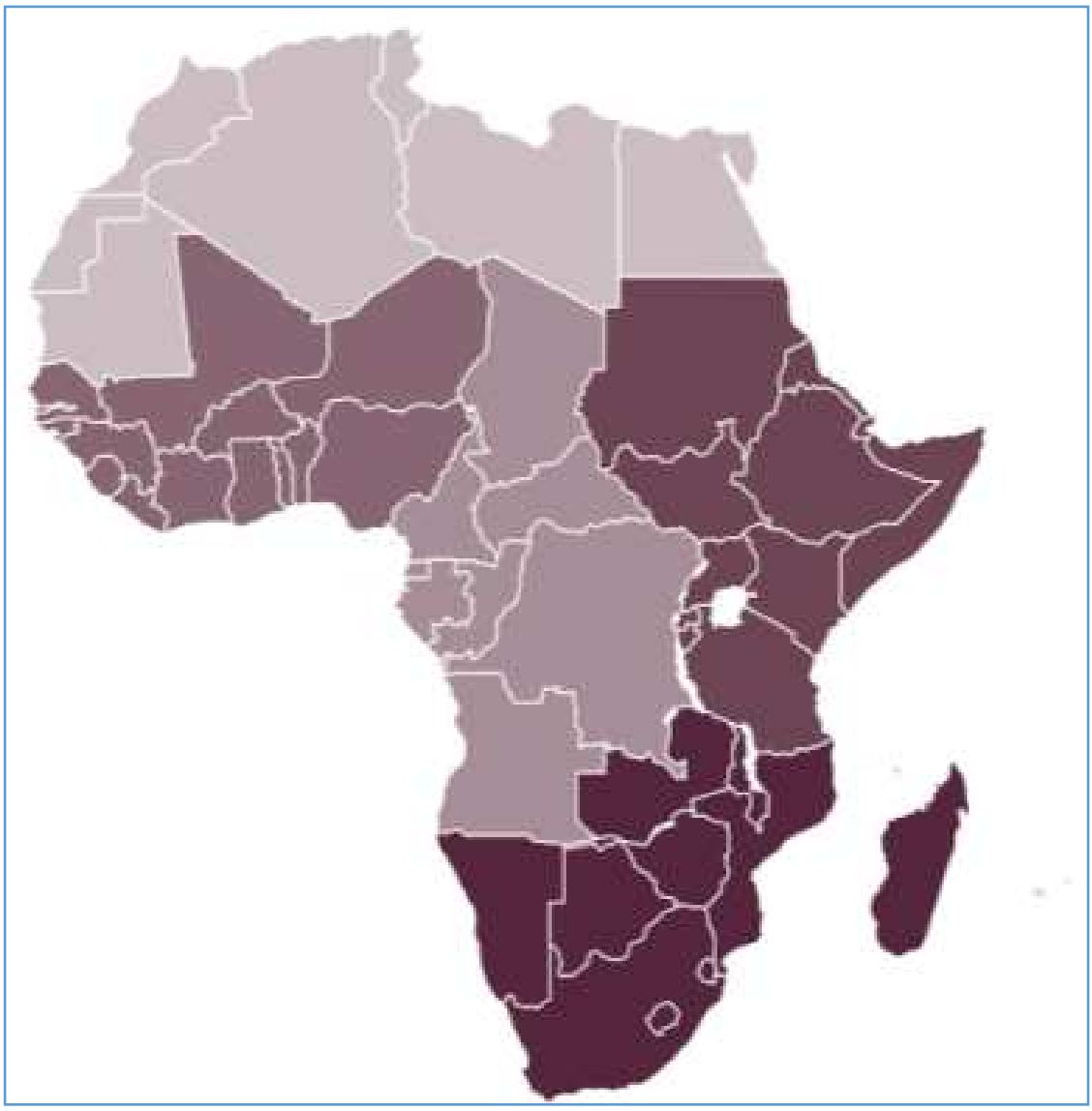


Figure 2.1: A map of Africa (AUDA-NEPAD, 2021)

2.3 Climatic and Geographical Characteristics

The realization of the possible threats of climate change to the region saw the AU establish a Committee of African Heads of State and Government on Climate Change (CAHOSCC) in July 2009 at its 13th Ordinary Session. The committee is mandated to spearhead the African Common Position on Climate Change and its key messages, and ensure that Africa speaks with one voice in global climate change negotiations (AU, 2020).

2.3.1 Climatic characteristics

Africa is one of the world regions most vulnerable to the impacts of climate change (IPCC, 2014, Niang et al. 2014). 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).

Sub-Saharan Africa (SSA) has a highly variable and unpredictable climate and is acutely vulnerable to floods and droughts for example. Recent 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 inter-tropical convergence zone (ITCZ) or monsoon trough dominates Africa's climate (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 (Wei & Bodoni, 2018). 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 ^{o}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 inter-tropical front (ITF), a confluence line between moist southwesterly monsoon winds and dry northeasterly – the Harmattan – at 15^{o}N (Taljaard, 1986; Shinoda and Kawamura, 1994).

2.3.2 Vegetation characteristics

The principal controls on the distribution of vegetation in Africa are total annual rainfall and the timing, duration and intensity of the dry seasons (Street-Perrott and Perrott, 1993). It has been noted that, according to the partly floristic and partly physiognomic vegetation classification of White (1983), the vegetation of Africa bears a close relationship to the large-scale climate of the continent (Street-Perrott and Perrott, 1993).

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

Africa contains some of the world's greatest rivers, which has implications for the trans-boundary transport of persistent organic pollutants. In all, six major networks drain Africa. With the exception of those draining into the Lake Chad basin, and those surrounding the Kalahari, all have outlets to the sea (UNEP, 2002).

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

The Rift Valley contains a series of great lake system includes lakes Turkana, Albert, Tanganyika, and Malawi. Lake Victoria, the largest lake in Africa with total area of 69,000 sq km, and it is the world's second largest freshwater by area. It is not part of the Rift Valley lake system and it occupies a shallow depression in the Eastern Highlands. It is 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

Sub-Sahara Africa (SSA) 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 (McKee et al., 2003), with significant implications for human impacts on species persistence into the future (Balmford et al., 2001). 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 (Kemper et al., 1999; Mentens and Lambin, 2000; Zhang et al., 2002). The problem of invasive alien species is also increasingly seen as a threat to biodiversity on the continent (Morrison et al., 2004; Le Maitre et al., 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 in the region. 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, 2002).

2.4 Agricultural and Industrial Activities

Agriculture is the biggest contributor to national GDPs of most African countries. However, over the past decades, industrialization is gaining ground in several countries. An overview of agricultural and industrial activities in Africa region is given below:

2.4.1 Agriculture

Agriculture forms one of the most significant sectors of the economies of all African countries, hence it contributes towards major continental priorities, such as eradicating poverty and hunger, boosting intra-Africa trade and investments, rapid industrialization and economic diversification, sustainable resource and environmental management, and creating jobs, human security and shared prosperity (Blein et al., 2013).

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 economy 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. The most widely used PTS pesticides including organochlorines are DDT, endosulfan, chlordane, lindane (HCH), heptachlor, toxaphene, HCB and aldrin (UNEP, 2002). 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:

- Agriculture contributes 20-40% to GDPs of most countries in Africa;
- Agriculture contributes to food security and sovereignty and is the main source of foreign exchange earnings in most African countries;
- Fisheries occupy an important place in several countries;
- 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 face 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.,)

2.4.2 Industry and energy

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. 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).

2.5. Environmental Health Scenario Links to POPs

Recognizing the significant environmental impacts on health and development, the Africa Union operationalized a Sub-Committee on Environmental Issues in 2018 (AU, 2018).

The region of Africa 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 sub-Saharan Africa's environmental health problems.

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, 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.

The use of DDT (Annex B) in agriculture has been banned in almost all countries, and 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 used or stocked 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.

According to Crop Life International, over 50,000 tonnes of obsolete pesticide waste had stockpiled across the African continent (Crop Life International, 2017; Mansour, 2009; FAO, 1998). To try and address the challenge the A*frica Stockpiles Programme* (ASP) was launched in 2005 to tackle the clean-up and disposal of obsolete pesticides in the region. However, by 2016 only approximately 4,000 tonnes of obsolete pesticides and contaminated soil had been remove, against a background of an estimated 50,000 tonnes of obsolete pesticides and contaminated soil in the region. In addition, separate decontamination efforts were also realized from FAO, GIZ, the Netherlands and CropLife International member companies that contributed reduction, but less than 5,000 tonnes (Crop Life International, 2017). This means that management of the large amount of the obsolete pesticide stockpile and contaminated soil is still a challenge to the region, and this could be a secondary source of contamination.

The main causes of accumulation of obsolete pesticides in Africa are:

- pesticides for locust and malaria control;
- prolonged storage of products under non optimal storage conditions;
- unnecessary donations, particularly under the KR2 scheme;
- banned, unlabeled or illegally imported products.

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: PCBs (mainly from electricity generating industry), HCB (also a PTS pesticide), pentachlorophenol (PCP) and phthalates, PFAS, SCCPs, PCNs and PAHs among others (UNEP, 2002). 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. Therefore, suitable storage facilities that comply with the obligations of the safe storage management plan of the Basel and Stockholm Conventions are 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, and mainly by women.

Contamination of the environment can also 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). Mining can also have a variety of detrimental environmental effects, including contamination of groundwater with heavy metals, and silting and sedimentation of riparian ecosystems. Medical waste incineration, lack of shredder 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, 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, 2002).

Waste electrical and electronic equipment (WEEE), end-of-life vehicles (cars, buses, mini-buses, trucks) and other articles (carpets, firefighting 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 brominated dioxins and furans.

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.

Photo 2.1 Open burning of waste at the Dandora dumpsite (Source: Kenya NIP, 2007)

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 Sub-Sahara 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 endosulphan in human breast milk in the region, in view of WHO's vigorous campaign that mothers breast milk is best for children. It was established by studies in South Africa that organochlorine pesticides (OCPs) can be transferred to infants *via* breast milk (UNEP, 2002).

It is to be noted that apart from POP pollution, Africa has to reckon with other major health issues; water in some parts of Africa is undrinkable due to contamination by bacteria, untreated or poorly treated sewage, heavy metals and silt from soil erosion, fertilizers and pesticides, mining tailings and industrial waste. The following can be given as a summary of the scenario in the region:

- Most African countries neither manufacture nor export chemicals but are importers;
- Food security being a priority, the potentials to use more pesticides is high;
- Malaria is still a leading killer disease, and the urge to use an effective insecticide such as DDT is high;
- Stocks of obsolete pesticides are still present in some African countries;
- POP contamination in environmental media is present but not inventorised;
- Both Agriculture and Industry can be responsible for hazardous chemicals pollution;

- Principal sources of PCBs in Africa are transformers and capacitors;
- Apart from pesticide poisoning, other hazardous chemicals including POP contamination in humans is not documented or reported;
- Some African countries still do not have in place monitoring schemes or even action plans on hazardous chemicals;
- Most African countries have developed or submitted their National Implementation Plans on POPs or and ratified the Stockholm Convention;
- Regulatory actions on hazardous chemicals are not undertaken by some countries;
- The WHO, RECETOX and other international Programs on the monitoring of POPs in breast milk and environmental media presently do not cover pollution hotspots all African countries.

The names of countries that have signed and ratified the Stockholm Convention as well as those that have transmitted their NIPs can be found in Stockholm Convention website at http://chm.pops.int/Implementation/NIPs/NIPTransmission/tabid/253/Default.aspx

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:

- Programs in place to dispose of obsolete stocks of pesticides and cleanup of contaminated sites;
- Development of action plans, monitoring schemes and programs on hazardous chemicals;
- Most countries have developed National Profiles to assess their countries' capacities for chemicals management;
- Some countries had or have on-going programs on Inventory of POPs and other hazardous chemicals;
- Some countries have established databases or registries on chemical imports, exports, use, incidents etc.;
- Regulatory actions are being taken by many countries on hazardous chemicals including POPs, particularly through the Rotterdam Convention requirements;
- Most countries have banned DDT in agriculture but some allow its use in vector control, especially in malaria cases;
- Pesticide Formulation Laboratories have been established by several African countries;
- Most African countries are signatories to chemical conventions; Bamako/Basel, Rotterdam, Stockholm, Vienna/Montreal, Kyoto Protocol;
- Most African countries participate in regional and international programs on chemicals regulation; IFCS, SAICM, GHS, PRTR, Risk Management of UNITAR; ASP, CILSS Common Regulations on Pesticide and other similar ones in other RECs;
- Most African countries have developed or are in the process of developing their NIPs on POPs;
- WHO Monitoring Program on POP in breast milk and human tissues, the RECETOX programs on POPs in environmental media, GAPS, UNEP/GEF Capacity building Programs, are on-going.

Given that human and environmental health in Africa is strongly 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 must be taken into consideration: lack of awareness, need for capacity building, need for technology transfer, need for stricter control of porous borders, need for domestication of Conventions, lack of availability and access to data, weak infrastructure such as limited analytical capacity of laboratories to measure POPs levels in human tissue and environmental media, and lack of environmentally friendly alternatives to some POPs such as DDT.

Furthermore, climate change and variability will have a direct impact on the semi volatile compounds such as POPs and affect both primary and secondary releases into the atmosphere. Accordingly to previous studies elsewhere, climate change will affect the rate of mobilisation from materials and stockpiles, as well as the use patterns of the primary sources, while for secondary sources the higher temperatures will increase POPs emissions by shifting the partitioning between soil-air and water-air (Lamol et al., 2009). In addition it is anticipated that climate change may increase incidences of vector borne diseases such as malaria which may influence the use of POPs such as DDT for control of malaria epidemics.

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: Cameroun, Kenya, Lesotho, Mali, Morocco and the Republic of Congo. 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 group

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) 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 Regional GCG members agreed to maintain the same strategy developed by ROGs in May 2018 with adjustment of timelines. 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	Cameroon	Kenya	Mali	Morocco	Lesotho
Democratic Republic of Congo Central African Republic Gabon Angola Sao Tome and Principe Equatorial Guinea Republic of Congo	Sudan Djibouti Somalia South Sudan Ethiopia Cameroon Chad Nigeria Ghana Benin Togo	Burundi Uganda Madagascar Rwanda Seychelles Eritrea Kenya Comoros	Niger Senegal Guinea Guinea-Bissau The Gambia Cape Verde Sierra Leone Liberia Côte d'Ivoire Burkina Faso Mali	Algeria Egypt Libyan Republic Tunisia Morocco Mauritania	Zambia Zimbabwe Mozambique Namibia Botswana Swaziland South Africa Lesotho Malawi Tanzania Mauritius

Each ROG member will be responsible for maintaining communication with the SC focal points and national contacts within the subregion. The ROG member will maintain contact with agencies implementing air, water and mothers milk under various strategic programmes and collection of readily available data on other media within the sub-region. The ROG members agreed to maintain communication with the Stockholm Convention Regional Centres in Kenya, Algeria, Senegal and South Africa.

3.4 Workshops and preparatory meetings

The ROG members participated in face-face workshops and meetings during the third evaluation phase to facilitate preparation of the regional report. The meetings were organized by the Stockholm Convention secretariat under BRS.

3.5 E-Forums

Apart from the face to face meetings, the ROG members have mostly depended on electronic framework to maintain communication within the region.

The ROG conducted online drafting workshop on 4th May 2021 to review the draft 3rd regional report prior to regional circulation in in the same month.

3.6 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, RECETOX, GAPs and WHO. The main strategic programmes that provided POPs data for the second evaluation included: MONET_Africa, GAPS, UNEP/GEF GMP2 project 2016/2020 for air data; UNEP/WHO and UNEP/GEF project 2016/2020 for mothers' milk data; and UNEP/GEF GMP2 project 2016/2020 and MONET Africa 2014 for PFOS levels in water.

1) The Secretariat of Stockholm Convention:

The secretariat supported strategic arrangements with key partners in the implantation of the first, the second and the third GMP activities.

2) GEF: Within the third GMP phase period GEF supported GMP2 project in the Africa region that were coordinated by UNEP Chemicals in 2016/2020.

3) UNEP Chemicals:

UNEP Chemicals coordinated the implementation of two GEF funded projects in the region to support capacity enhancement to analyse POPs. The project covered DR Congo, Ghana, Mali, Nigeria, Senegal, Togo, Egypt, Ethiopia, Kenya, Mauritius, Uganda, Tunisia, Tanzania, Morocco and Zambia. The project focused on Gap Analysis on the initial additional 9 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 GMP2 project 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 GMP2 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.

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 its effective participation in the third effectiveness evaluation, the African region continued the collaboration established with strategic partners for air, water and mothers' milk monitoring. These included RECETOX and GAPS for ambient air monitoring, and WHO for mothers' milk monitoring. In addition collaboration with UNEP Chemicals on the UNEP/GEF GMP2 project supported additional sites for air and water monitoring and mothers' milk survey which helped to provide comparable datasets, and to fill the data gaps identified in the second phase effectiveness evaluation.

4.1.1 Programs/activities related to air monitoring

The first and second 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 report received data from MONET Africa, GAPS and UNEP/GEF project 1. This 3rd regional monitoring report has benefited from additional data from MONET Africa, GAPS and UNEP/GEF project 2 from 2016-2020. Additional air sampling sites were created under the UNEP/GEF project 2 to fill the gaps experienced in the second monitoring report.

4.1.1.1 Global Atmospheric Passive Sampling Programme (GAPS)

GAPs was launched in January 2004 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. A list of countries participating in GAPS network is summarized in Annex Table A1.

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 the region and are useful for assessing temporal and spatial trends and regional and global transport of POPs in air.

4.1.1.1.1 Background

The background of GAPS is provided in the first and second regional monitoring reports (UNEP, 2009 & 2015). The 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. 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.

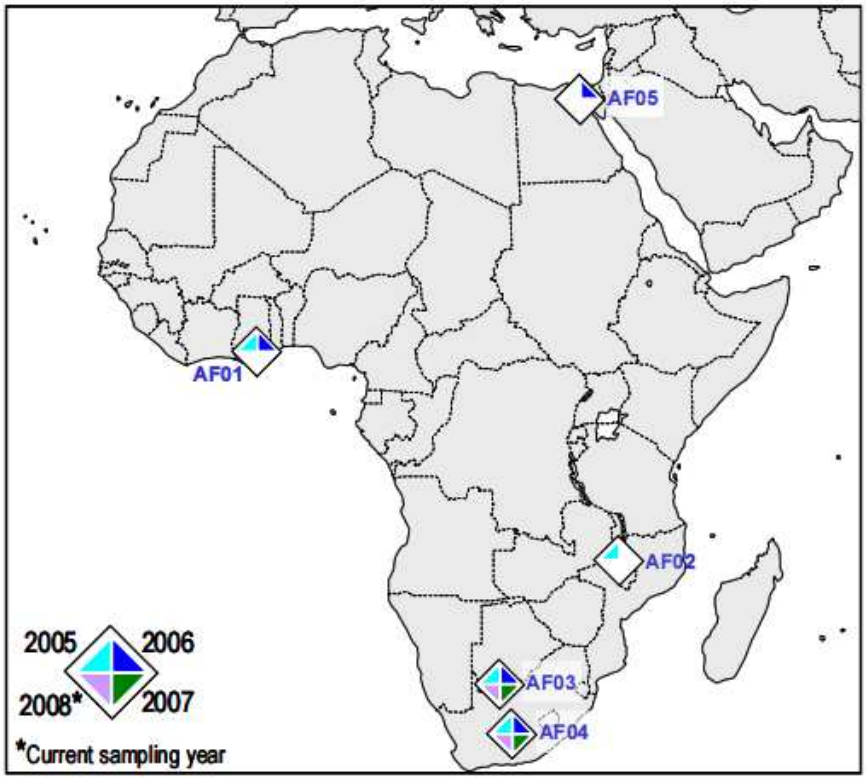


Figure 4.1 Sampling sites and sampling years in Africa

4.1.1.1.2 Sampling

The types of PAS used under the GAPS network are discussed in the first and second regional reports (UNEP, 2009 & 2015b). The network uses PUF-disk based samplers deployed for three-month periods to capture seasonal differences (Shoeib and Harner, 2002; Pozo et al., 2006), while the XAD sampler is exposed for a full year (Wania et al., 2003). The sampling devices used in the GAPS programme are illustrated in Figure 4.2 below (UNEP, 2019; Hayward et al., 2010).

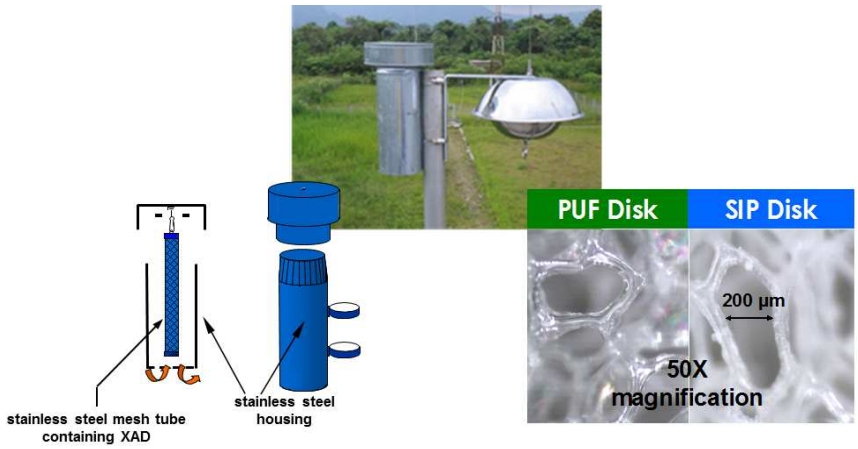


Figure 4.2 Sampling devices used in the GAPS programme

4.1.1.1.3 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 for the PUF-disk sampler were described in the first and second regional monitoring reports (UNEP, 2009 & 2015b). These include: field blanks, method blanks, instrument, surrogate spikes, matrix spikes, and field co-located samples.

4.1.1.1.4. 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.

4.1.1.1.5 Sample and data storage

Sample extracts were capped tightly in GC vials and stored in a freezer at a temperature of about -20°C. Further details are described in the first and second regional monitoring reports (UNEP, 2009 & 2015b).

4.1.1.2 Monitoring Network in the African continent (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.

During preparation for the 3rd regional monitoring report, the Africa Region collaborated with RECETOX through a programme entitled *Application of the passive sampler for monitoring of POPS in ambient* air monitoring network in the African continent (MONET_Africa) which covered the period 2015-2019. The thirteen countries that participated are shown in Figure 4.3. A list of countries participating in MONET_Africa monitoring network is summarized in Annex Table A1.

4.1.1.2.1. Key message

The first, the second and the current monitoring reports contribute towards Africa effectiveness evaluation reporting and provide the region with comparable 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 2008-2019. 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.

Figure 4.3 Map of the sampling sites in Africa (MONET 2010-2012)

4.1.1.2.2. 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

The goal of MONET_Africa network was described in the first and second monitoring reports (UNEP, 2009 & 2015b). 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. Further details are provided in the previous regional reports (UNEP, 2009 & 2015b). RECETOX also supports 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.

4.1.1.2.3. Sampling

Passive air sampling devices used under MONET_Africa consists of two stainless steel bowls attached to the common axes to form a protective chamber for the polyurethane foam filter (Figure 4.4). 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.

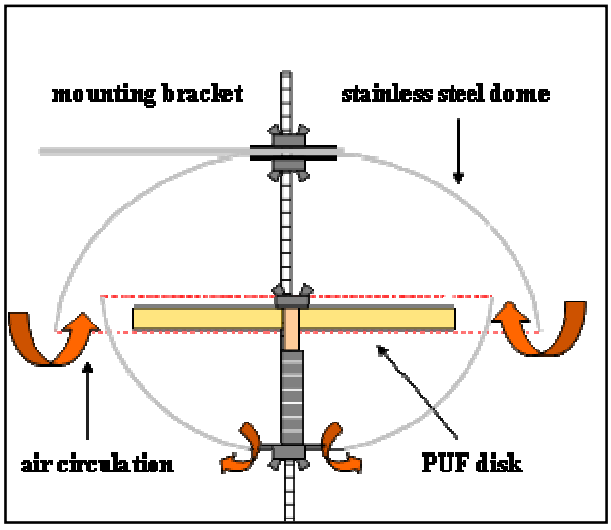


Figure 4.4 Schematic diagram of the passive air sampler used in MONET_Africa pogramme

Previous RECETOX studies (Klanova et al., 2008; Klanova et al., 2006; Klanova et al., 2007; Cupr et al., 2006; Lammel et al., 2009) confirmed that PAS are sensitive enough to mirror even small-scale differences, which makes them capable of monitoring spatial, seasonal and temporal variations (Přibylová et al., 2013). Passive samplers can be used for point sources evaluation on the scale of several square kilometers 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.

4.1.1.2.4. Sample analytical procedures

Analytical procedures used for POPs extraction, fractionation and analysis are described in the first and second regional monitoring reports (UNEP, 2009 & 2015b).

4.1.1.2.5 Quality Assurance and Quality Control

The QA &QC procedures have been described in the first and second regional reports (UNEP, 2009 & 2015b). These include the use of recoveries 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. Other components of QA & QC include laboratory blanks, and field blanks.

4.1.1.2.6 Generation of back trajectories

Trajectories were generated using the HYSPLIT model of the American National Oceanic and Atmospheric Administration, NOAA (NOAA, 2003). Description of back trajectories were presented in the first and the second regional reports (UNEP, 2009 & 2015b).

4.1.1.2.7 Data comparability

All samples collected from the MONET_Africa 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. In the period 2017-2018 MONET_Africa conducted field- and model-based calibration of polyurethane foam passive air samplers in different climatic regions comprising of Nairobi Kenya, Accra Ghana and Kositice Czech Republic to evaluate differences in sampler uptake performance (Bohlin-Nizzetto et al., 2020).

4.1.1.2.8 Sample and data storage

Sample extracts were capped tightly in Gas Chromatograghy vials and stored in a freezer at a temperature of about -20 ^{o}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.

4.1.2 Programs/activities related to human tissues (milk and blood)

4.1.2.1 Background

Comprehensive human milk monitoring programmes have been initiated by WHO. 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 four additional global surveys were completed in 2004-2007, 2008-2011, 2012-2015, 2017-2019. These studies significantly enlarged the geographical scope providing representative results for all regions of the globe and currently cover all 30 POPs listed in the Stockholm Convention.

Guidance

Under WHO, a protocol has been developed for sampling and sample preparation methodology for exposure studies of Persistent Organic Pollutants (Malisch et al., 2010; WHO, 2007). This protocol forms the basis for the human milk component of the GMP (UNEP, 2017). An online version of the protocol is available at http://www.who.int/foodsafety/chem/POPprotocol.pdf (see also Annex 3 in the GMP guidance).

The main objectives of these studies are: 1) to produce reliable and comparable data on concentrations of POPs in human milk for further improvement of health risk assessment in infants, 2) to provide an overview of exposure levels in various countries and geographical areas and to allow to draw conclusions on priorities for further follow-up in a country / region, 3) to determine trends in exposure levels.

4.1.2.2 Sampling

In order to promote reliability and comparability of results, samples are collected by the participating countries following a harmonized comprehensive protocol developed by WHO (WHO, 2007) and amended by UNEP (last amendment: see UNEP, 2019). Participating countries are encouraged to adhere as closely as possible to the protocol, which provides guidance on the number and type of samples, selection of donors, collection, storage and pooling of samples, and shipping of samples to the reference laboratory. For all studies, the following criteria for selection of donating mothers are stringently applied:

- They should be first time mothers;
- They should be healthy;
- They should be exclusively breastfeeding one child (i.e., no twins).

In order to get statistically reliable data, an appropriate number of individual donors must be recruited to provide samples for the survey. As a first approximation, a minimum of 50 individual samples is recommended for each country. Equal aliquots of these individual samples are mixed to form a representative composite sample (“pooled sample”). The power of the

survey can be increased by the inclusion of more than 50 individual samples and is encouraged. It is recommended to collect one representative individual sample per one million citizens. In particular, countries with populations greater than 50 million should include at least one additional participant per one million population over 50 million. Countries with populations well over 50 million (or with sufficient resources) are encouraged to prepare a second pooled sample (or more) if feasible.

4.1.2.3 QA/QC and data consistency / comparability

The representative pooled sample is analysed for the POPs listed in the Stockholm Convention by the reference laboratory. This approach has several advantages:

- The analysis of pooled human milk samples is also far less expensive than the analysis of all individual samples;
- It is easier for each donor to provide the lower volume of milk required for pooled analyses. Therefore, in comparison to analysis of individual samples, much more sample amount is available allowing a more comprehensive analysis with lower limits of quantification;
- To ensure the reliability of exposure data and to improve comparability of analytical results from different laboratories, a reference laboratory was selected based on inter-laboratory quality assessment studies. To further ensure consistency in measurements, all pooled samples are analyzed by the WHO/UNEP reference laboratories using validated methods;
- Aliquots of the individual samples can be analysed for analytes of interest by laboratories selected by the National Coordinator.

This combination of selection of a statistically reliable number of individual samples, preparation of a representative composite sample and analysis of the pooled sample for the 28 POPs listed in the Stockholm Convention by the reference laboratory is a very cost-effective way to derive information on the relevance of certain POPs in certain regions in humans as end-point of releases of POPs and to follow time trends.

QA/QC and comparability of the data in the frame of the programme is ensured by centralized analysis of the pooled sample. The State Institute for Chemical and Veterinary Analysis of Food (Germany) has met all the criteria for analyses of lipophilic POPs in human milk and was selected as a reference laboratory for the WHO exposure studies (WHO 2000, Van Leeuwen and Malisch, 2002). It is also the EU Reference Laboratory for halogenated persistent organic pollutants (POPs) in feed and food (COMMISSION REGULATION (EU) 2018/192). Proteinophilic POPs (e.g., PFOS) are analyzed at the MTM laboratory at the University of Orebro, Sweden.

4.1.2.4 Analytical procedures

The procedures for the analysis of POPs in human milk are described in detail the GMP guidance document (UNEP/POPS/COP.9/INF/36), Chapter 5 Analytical methodology. Details regarding newly listed POPs can also be found in Chapter 4 Sampling and sampling preparation methodology, Section 4.2, addressing human milk as a sampling medium (UNEP, 2019).

Benefit risk evaluation

Results of the WHO/UNEP Human Milk Survey for PCDDs, PCDFs, PCBs and DDTs were evaluated with particular focus on benefit–risk evaluation of breastfeeding (van den Berg et al., 2017).

4.1.2.5 Data storage

Data are stored at the GMP data warehouse, available at www.pops-gmp.org.

4.1.3 Programs/activities related to water

Comparable POPs data water media were provided by UNEP/GEF GMP2 project 2016-2020 and MONET_Africa programme for data collected in the second phase of GMP. 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.

4.1.3.1 Key message

The existing PFOS data for water was obtained from water sampling activities conducted under UNEP/GEF GMP1 & GMP2 projects and MONET Africa pilot water monitoring study applying active and passive sampling, respectively.

4.1.3.2 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 firefighting 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. 70 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 draft guidelines for PFOS analysis (UNEP, 2015a). Consequently, the open oceans water column has been suggested to be a final sink of PFASs, such as PFOA (Lohmann et al., 2013).

4.1.3.3 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., 2014). 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 1,000 mL high density polyethylene (HDPE) bottle to avoid sorption of PFOS and salts onto the container walls (UNEP, 2015a).

The sampling method applied under MONET_Africa water sampling have been described elsewhere (UNEP, 2015b). The water sampling exercise was conducted in 2013/2014 and deployed two passive water sampling devices: XAD and semi permeable membrane device (SPMD).

4.1.3.4. 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 draft guidelines for PFOS analysis (UNEP 2015a,).

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.

4.1.3.5 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.

4.1.3.6 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.

4.1.4 Programs/activities related to other media

4.1.4.1 Key message

Most regional countries have elaborated their National Implementation Plans (NIPs) under the Stockholm Convention, and outlined the need to build capacities for POPs analysis to contribute towards reporting of environmental levels. Data on POPs levels in other media particularly soil, sediment and biota is important, since they can provide objective indication of the sources of POPs concentrations measures in the core media. Hence, researchers from different institutions either individually or as teams have conducted assessment of POP including pesticides, PCBs and PBDEs. However, very limited work exist about dioxins and furans, PFOS, SCCPs and PCNs.

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 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.

4.1.4.2 Background

Comparable data from other media have been produced through the UNEP/GEF GMP2 project. The priority media included soil, sediments, fish, milk, eggs and other food stuff materials. Samples were collected by countries between 2017 and 2019 and analysed centrally at the backup laboratories established in the project, by UNEP Chemicals.

Further survey of reports from literature 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 POP pesticides, PCBs and PBDEs. 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 ROG decided to incorporate some monitoring data dealing with the contamination of soil, sediments and food (other media) by POPs pesticides in order to show relevant technical infrastructure that need to be strengthened to enable the region participate fully in future Effectiveness Evaluations.

4.1.4.3 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.

4.1.4.4 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.

4.1.4.5 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.

4.1.4.6 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 UNEP/GEF GMP 1& 2 project, and MONET Africa. UNEP/GEF GMP1 &2 capacity enhancement projects which covered soil, sediments, fish and food stuff for samples collected between 2010-2012 and 2017-2019. Samples were centrally analysed at MTM (for PFOS and related compounds, dl-PCBs, Dioxins and furans) and IVM (for OCPs, PCBs & PBDEs). The data produced from the backup laboratories were compared with those obtained from the regional laboratories that participated in the project as part of capacity assessment.

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. Access to laboratory databank 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 HRGC/MS and HRLC/MS 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 are not capable to analyse complex POPs such as dioxins/furans, PBDEs, PFOS, SCCPs among others. Although the region is gradually enhancing laboratory capacities for POPs analysis, there is still a need to invest heavily in building regional laboratory capacities to support activities under the NIPs and GMP (UNEP, 2015b).

4.4 Data handling and preparation for the regional monitoring report

Statistical consideration

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 third 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 third phase GMP are available in the guidance document (UNEP/POPS/COP.9/INF/36).

The information warehouse;

The GMP Data Warehouse has been made operational during the second GMP phase, supporting the regional organization groups in the work for the collection, processing, storing and presentation of monitoring data. 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 data warehouse was further enhanced and kept up-to-date to provide on-line access to the GMP monitoring data and enable data collection and

processing during the third GMP phase and support the development of the third monitoring reports.

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. It is available at www.pops-gmp.org.]

4.5 Preparation of the monitoring reports

The ROG members adopted similar framework followed in the first and second GMP phases to collect readily available data for the third monitoring report. Each ROG member was charged with responsibility collect readily available data that meet the established comparability criteria from the respective sub-region under his/her coordination. 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.

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) Relevant data for 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) 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, WHO, and UNEP/GEF GMP2 project 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 before transmittal 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 and second evaluation period, such as the southern and the Northern Africa sub-regions. 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.

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 warehouse 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. The data used in developing the third regional report were reviewed by the ROG members from in data warehouse.

Data storage

Data from regional GMP1, 2, and 3 monitoring activities are stored in the regional node setup in the GMP data warehouse accessed at http://www.pops-gmp.org/dwh. Further, training will be required for all ROG members and key stakeholders to be able to use the platform and the data stored in the regional node to promote information sharing within the region.

Accessibility to the Global database

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.

Drafting of the monitoring report

The Regional report was drafted by ROG members with the assistance of a consultant. 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 (UNEP, 2019).

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.
ix) The draft report was discussed during the ROG drafting meeting held online in April 2021, circulated and endorsed regionally in April/May 2021 before the final copy was submission to the Secretariat of the Stockholm Convention.

5 RESULTS

5.1 The results in context

This third regional POPs monitoring report builds on the information compiled in the first and second regional reports of 2009 and 2015, respectively. Hence the report synthesizes information from the first, second and third phases of the global monitoring plan and presents the findings on POPs concentrations and trends in the core media from the region.

The first and second regional monitoring reports provided the baseline data for the effectiveness evaluation as the first sets of available comparable information on concentrations of the chemicals in Annexes A, B and C in the environment and human matrices (within the timeframe 2003, plus or minus five years). In the third phase of GMP, attempts were made to fill the regional data gaps identified in the first and second regional monitoring reports for the reference timeframe. Accordingly, the first comparable information that becomes available will be used as the baseline in the respective sub-regions. Emphasis in the subsequent monitoring reports is geared towards trend detection based on the relevant baseline information and monitoring results.

<u>POPs in ambient air</u>

For ambient air, temporal trends are developing for some legacy POPs whose monitoring has been going on for a decade in the region. However, comparison of the levels across the sites is not very relevant since the sites cut across different settings such as remote, urban, rural and agricultural sites, while a few other sites could present impacted settings. The short sampling time span and discontinuities witnessed across some sampling sites hamper temporal trends analysis. Furthermore, some chemicals were only analysed at very few sites, while others were not analysed in some programmes. These make comparability of the results across the sites difficult. Therefore, future monitoring activities and sustainability efforts should focus on ensuring intra- and inter-program comparability, and building local capacities (trained personnel, travel funds, analytical infrastructures, etc.) to ensure consistence of the data produced.

The geographic coverage and gaps witnessed in the Second report from the North Africa sub-region have been filled through additional sites established during the third monitoring phase. However, geographical coverage in the Southern Africa region currently represent the weakest point due to discontinuity of some sampling sites in the sub-region under the GAPS monitoring network.

The presence of POPs in ambient air, water and human milk present a potential threat to the regional health and environment, and countries are encouraged to ramp up measures to control and eliminate POPs contamination in the environment. Focus should be given to potential secondary sources such as obsolete stock of the legacy POPs and contaminated soils.The most significant POPs in the ambient air were POPs pesticides, PCBs, dioxins/furans, PFOS and its salts and PFOS related compounds and their salts, while PBDEs registered relatively low but stable concentrations.

POPs in mothers' milk

The most significant POPs in mothers' milk samples were POPs pesticides, PCBs, dioxins/furans, short chain chlorinated paraffin, PFOS and its salts and PFOS related compounds and their salts, PBDEs registered relatively low but stable concentrations in mothers' milk.

POPs in water

The POPs levels in water were dominated by PFOFs and PFOA, while PFHxS recorded comparatively lower concentrations.

5.2 Review of concentrations and their changes over time in the region

5.2.1 Ambient air

The overview of the POPs in ambient air over the period 2008-2019 in the region is discussed below.

5.2.1.1 Aldrin

Aldrin levels in the period 2007-2019 ranged from 0.02- 1,261.79 pg/m^3 (Figure 5.2.2.1). The mean concentration in 2007 was 0.29 pg/m^3 (De Aar, South Africa). In 2008 the concentration varied from 1.03-26.17 pg/m^3, with the highest levels recorded in Tunis (Tunisia), followed by 15.91 pg/m^3 (Khartoum, Sudan), 5.20 pg/m^3 (Reduit, Mauritius), and 4.71 pg/m^3 (Darkar Ngoye, Senegal). Only two datasets were recorded in 2009 with mean aldrin concentrations of 0.29 pg/m^3 (De Aar, South Africa) and 0.49 pg/m^3 (Mt. Kenya, Kenya).

In 2010, aldrin levels varied from 1.48-4.28 pg/m^3. The highest concentrations recorded were 4.28 pg/m^3 (Abetefi, Ghana), 4.26 pg/m^3 (Bamako, Mali), 4.05 pg/m^3 (Dakar Ngoye/ Bambey, Senegal) and 4.01 pg/m^3 (Addis Ababa, Ethiopia). In 2011 the concentrations of aldrin ranged from 0.28- 43.01 pg/m^3. The highest levels were 43.01 pg/m^3 (Kinshasa, DRC), 2.05 pg/m^3 (Abetefi, Ghana), 1.65 pg/m^3 (Bamako, Mali) and 1.38 pg/m^3 (Brazzaville, Republic of Congo).

In 2012 aldrin levels were relatively lower with means varying from 0.07-0.92 pg/m^3, while in 2013 the concentrations ranged from 0.02-0.30 pg/m^3. 2014 had mean concentrations between 0.04-61.80 pg/m^3, while 2015 and 2016 registered levels between 0.03-0.07 pg/m^3, and between 0.03-0.26 pg/m^3, respectively. The mean concentrations recorded in 2017 ranged from 0.04-1,261.79 pg/m^3, with the highest levels measured in Abetefi, Ghana (1,261.79 pg/m^3), Kishasa, DRC (1,252.76 pg/m^3), and Lusaka, Zambia (1,021.90 pg/m^3).

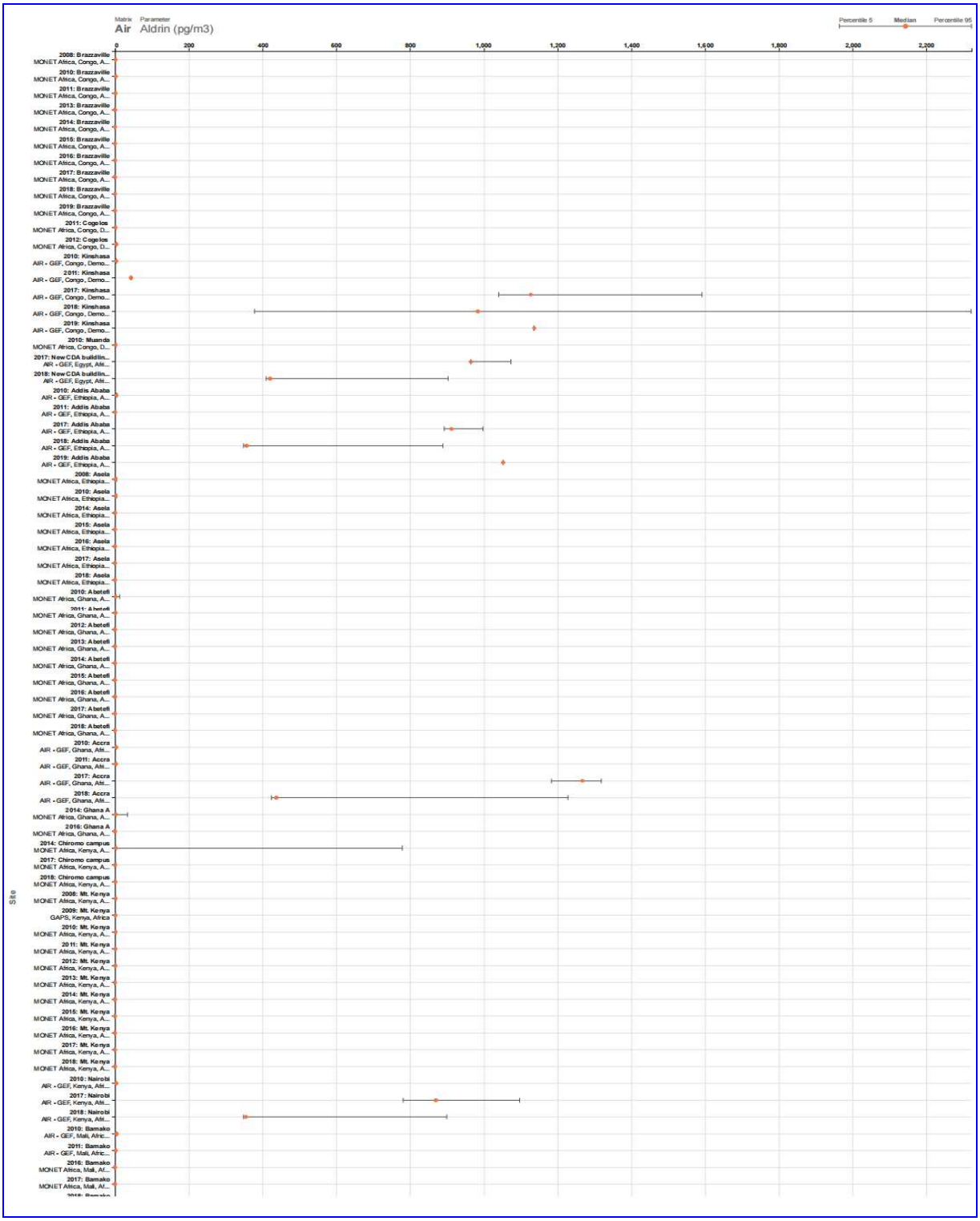


Figure 5.2.1.1 Concentrated of aldrin ambient air in Regional sites from 2007-2019.

2018 levels of aldrin ranged between 0.02-1,220.50 pg/m^3 with highest concentrations recorded at Kinshasa, (DRC), followed by 702.67 pg/m^3 (Reduit, Mauritius), 692.40 pg/m^3 (Lusaka, Zambia), and 638.98 pg/m^3 (Kouma-Konda, Togo) and 637.59 pg/m^3 (Abetefi, Ghana).

2019 registered five datasets with mean aldrin concentrations ranging between 0.10-1,242.58 pg/m^3. The highest levels were 1,242.58 pg/m^3 (Soroti, Uganda), 1,136.51 pg/m^3 (Kinshasa, DRC), 1,127.20 pg/m^3 (Vikuge, Tanzania). There was an increase in aldrin levels reported in 2017-2019 in some of the sites in the region that requires further investigation of the cause.

Gradual decrease in concentration was registered in 8.3% of the sites, while majority of the sites recorded no significant trend. Declining concentrations were recorded in Brazzaville (Republic of Congo), Asela (Ethiopia), Mt. Kenya (Kenya), Abetefi (Ghana), Reduit (Mauritius), Sheda (Nigeria) which are relatively remote and have been in operation for over 10 years.

5.2.1.2 Chlordanes

Chlordane compounds monitored in ambient air included cis- and trans- chlordanes and the oxychlordane.

Cis-Chlordane

Cis-chlordane concentrations in the regional sites for the period 2005 -2019 ranged from 0.01-16,974.29 pg/m^3.

Cis-chlordane datasets for 2004, 2005, 2006 and 2007 were obtained for samples from South Africa, Ghana, and Egypt. The specific concentrations recorded were 0.31 pg/m^3 (De Aar South Africa, 2004), while levels between 0.02-0.66 pg/m^3 were recorded in 2005 for Kalahari and De Aar (South Africa) and Abono (Ghana). In 2006 the concentrations ranged from 0.02-1.01 pg/m^3 recorded at De Aar and Kalahari (South Africa), Abono (Ghana) and Cairo (Egypt), while in 2007 *cis*-chlordane levels were between 0.17-0.18 pg/m^3 measured in samples from De Aar and Kalahari (South Africa).

In 2008 *cis*-chlordane levels ranged between 0.34 – 27.40 pg/m^3. The highest levels recorded were 27.40 pg/m^3 (Sheda, Nigeria), 14.46 pg/m^3 (Lusaka, Zambia), 7.38 pg/m^3 (Asela, Ethiopia), while the rest of the sites recorded levels between 0.34-2.29 pg/m^3.

In 2009 dataset showed *cis*-chlordane levels of 0.17 pg/m^3 for De Aar (South Africa) and 0.23 pg/m^3 for Mt. Kenya (Kenya). The mean concentrations of *cis*-chlordane for the period 2010-2014 ranged 1.60-14.33 pg/m^3 (2010), 0.01-3.74 pg/m^3 (2011), 0.37-0.72 pg/m^3 (2012), 0.16-0.40 pg/m^3 (2013) and 0.01-6.57 pg/m^3 (2014).

In the period 2015-2019 the mean levels of *cis*-chlordane ranged 0.04-44,109.93 pg/m^3. The concentrations in 2015 ranged between 0.10-4.54 pg/m^3. In 2016 the mean concentrations ranged 0.04-0.77 pg/m^3, while 2017 levels ranged 0.08- 19,697.60 pg/m^3. The highest levels were 19,697.60 pg/m^3 (Lusaka, Zambia), 6,056.46 pg/m^3 (Kabete, Kenya), 4,853.96 pg/m^3 (Addis Ababa, Ethiopia).

In 2018 the levels of *cis*-chlordane ranged from 0.12-16,974.29 pg/m^3. The highest levels were 16,974.29 pg/m^3 (Lusaka, Zambia), 4,109.93 pg/m^3 (Kinshasa, DRC), 3,309.48 pg/m^3 (Addis Ababa, Ethiopia) and 2,993.50 (Kabete, Kenya). Other sites recorded concentrations below 2,000.0 pg/m^3. Detailed levels of *cis*-chlordane in ambient air are illustrated in Figure 5.2.1.2.

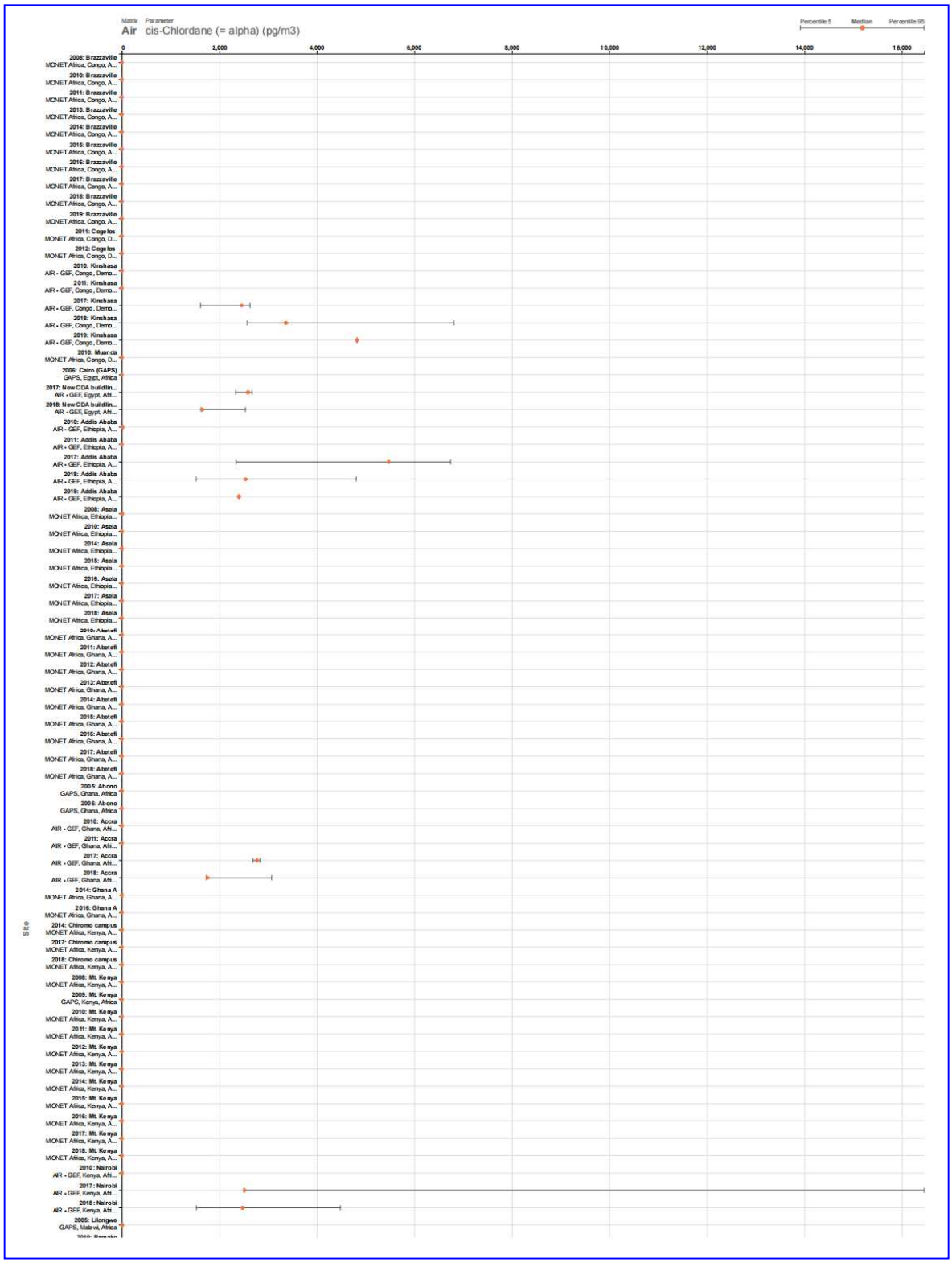


Figure 5.2.1.2 cis-chlordane concentration in ambient air

The 2019 data set had mean *cis*-chlordane levels between 0.41-4,823.00 pg/m^3, with highest levels as 4,823.00 pg/m^3 (Kinshasa, DRC), 2530.28 pg/m^3 (Soroti, Uganda), 2,438.90 pg/m^3 (Vikuge, Tanzania) and 2,403.85 pg/m^3 (Addis Ababa, Ethiopia).

Trans-Chlordane

The mean concentrations of *trans*-chlordane in ambient air for the period 2004-2019 ranged between 0.01-18,032.77 pg/m^3. Figure 5.2.1.3 illustrates the levels of *trans*-chlordane in ambient air.

The levels in 2004, 2005, 2006 and 2007 registered concentration ranges 0.31 pg/m^3 for 2004 in Der Aar, South Africa, 0.10-6.87 pg/m^3 for 2005, (De Aar and Kalahari (South Africa), Abono (Ghana), and Lilongwe (Malawi)), 0.14-0.28 pg/m^3 in 2006 for De Aar and Kalahari (South Africa), and 0.33-0.7 pg/m^3 in 2007 for De Aar and Kalahari (South Africa).

Trans-chlordane levels in 2008 ranged from 0.25- 11.28 pg/m^3. The highest levels recorded were 11.28 pg/m^3 (Lusaka, Zambia), 3.57 pg/m^3 (Asela, Ethiopia), 3.02 (Dakar Ngoye, Senegal), 2.60 (Baberspan, South Africa).

In 2009 the mean concentrations recorded were 0.10 pg/m^3 (Barberspan, South Africa) and 0.13 pg/m^3 (Mt. Kenya, Kenya). 2010 registered higher number of data sets with over 20 sites reporting. The mean concentrations ranged from 1.34-22.19 pg/m^3. Highest levels recorded were 22.19 pg/m^3 (Addis Ababa, Ethiopia), 15.78 pg/m^3 (Lusaka, Zambia), 12.58 pg/m^3 (Bamako, Mali), and 5.26 pg/m^3 (Accra, Ghana).

2011 levels of *trans*-chlordane varied between 0.01-10.53 pg/m^3. The highest concentrations recorded were 10.53 pg/m^3 (Lusaka, Zambia), 6.94 pg/m^3 (Bamako, Mali), and 3.92 pg/m^3 (Accra, Ghana). The mean concentrations in 2012, 2013 and 2014 ranged 0.28-1.30 pg/m^3, 0.05-1.07 pg/m^3, and 0.15-17.92 pg/m^3, respectively.

The concentration of *trans*-chlordane in the period 2015-2019 ranged from 0.06-18,032.77 pg/m^3. In 2015 the mean levels ranged 0.15-8.52 pg/m^3, while in 2016 the levels were between 0.11-2.65 pg/m^3.

2017 recorded *trans*-chlordane levels between 0.06 -17,600.69 pg/m^3. The leading levels were 17,600.69 (Lusaka, Zambia), 7,166.54 pg/m^3 (Addis Ababa, Ethiopia), 8,382.73 pg/m^3 (Kabete, Kenya) and 4,243.04 pg/m^3 (Soroti, Uganda).

In 2018, the mean levels of *trans*-chlordane ranged 0.02-18,032.77 pg/m^3. The leading levels registered were 18,032.77 pg/m^3 (Vikuge, Tanzania), 14,205.0 pg/m^3 (Lusaka, Zambia), 5,964.62 pg/m^3 (Accra, Ghana), 5,545.25 pg/m^3 (Kinshasa, DRC) and 5,066.18 pg/m^3 (Addis Ababa, Ethiopia).

Data for 2019 had concentrations ranging from 0.01-5,345.55 pg/m^3. The highest levels were 5,345.55 pg/m^3 (Vikuge, Tanzania), 3,415.49 pg/m^3 (Addis Ababa, Ethiopia), 3,400.41 pg/m^3 (Soroti, Uganda) and 3,233.05 pg/m^3 (Kinshasa, DRC). Figure 5.2.1.3 illustrates the levels of *trans*-chlordane in ambient air.

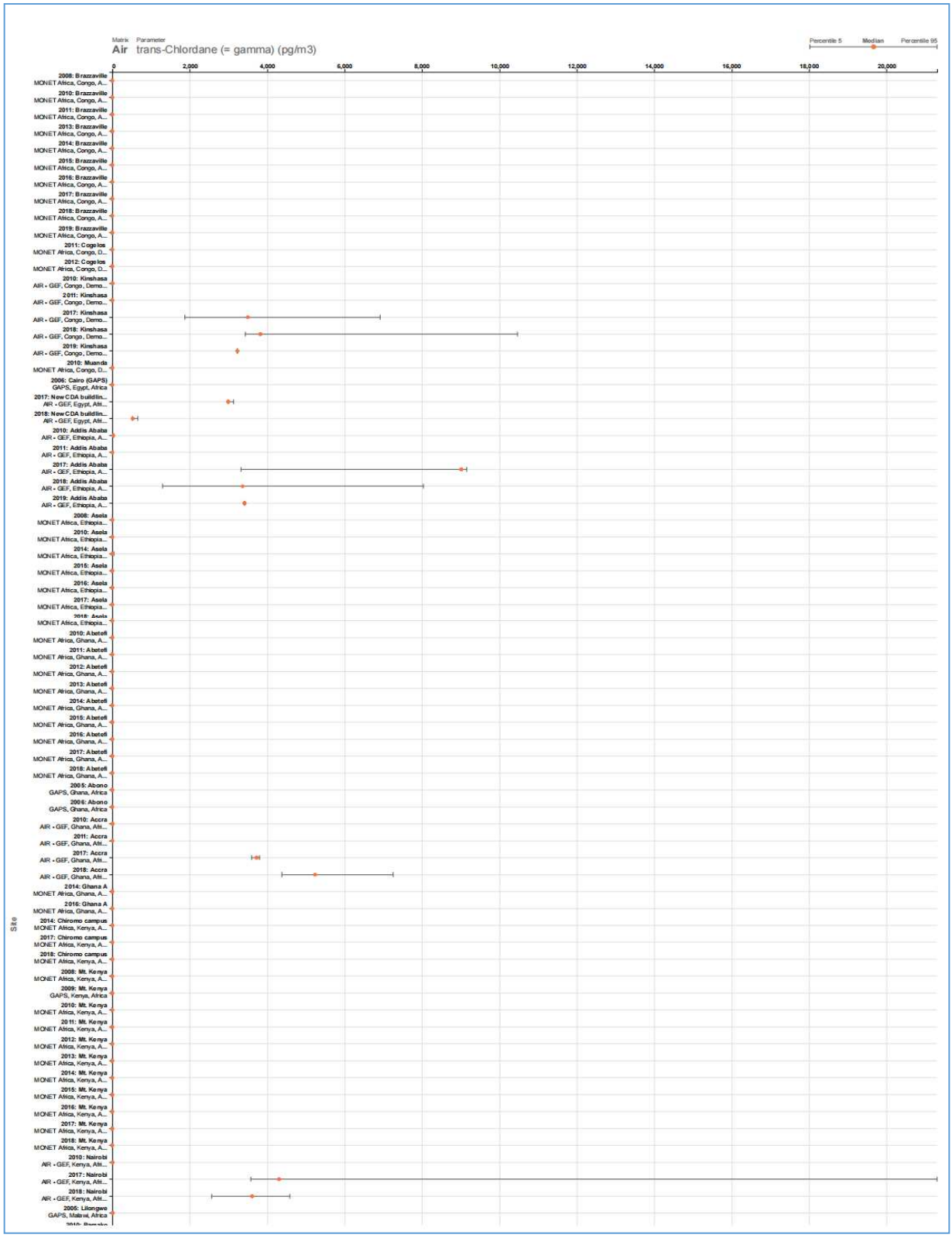


Figure 5.2.1.3 trans-Chlordane concentration in ambient air

Oxychlordane

Oxychlordane levels in ambient air for the period 2008-2019 varied between 0.01-9,981.28 pg/m^3. Declining trends were observed for Brazaville (Republic of Congo), Abetefi (Ghana), Mt. Kenya (Kenya), Reduit (Mauritius), Sheda (Nigeria) which had over 10 years of monitoring data (Figure 5.2.1.4).

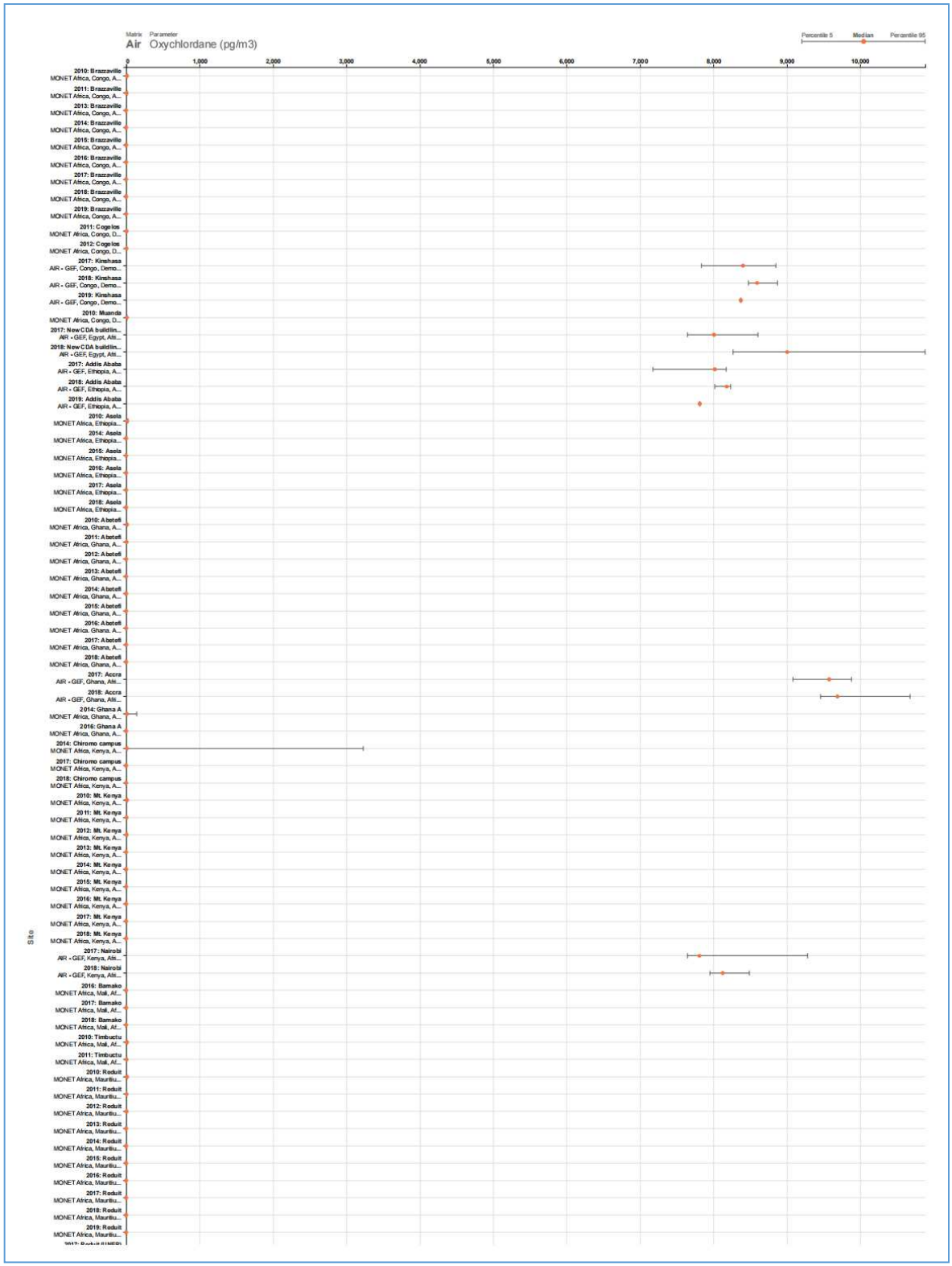
The concentration of oxychlordane in 2008 was 17.21 pg/m^3 and 17.43 pg/m^3, rerecorded in Barberspan and Molopo South Africa, respectively. 2009 had no data set recorded, while 2010 levels ranged from 8.46-14.82 pg/m^3.

The levels of oxychlordane in 2011, 2012, 2013 and 2014 ranged 3.79-5.43 pg/m^3, 0.03-5.24 pg/m^3, 0.02-0.18 pg/m^3, and 0.01-256.40 pg/m^3.

Oxychlordane concentrations for the period 2015-2019 ranged from 0.01-9,981.28 pg/m^3. The mean concentrations in 2015 and 2016 ranged 0.02-0.23 pg/m^3 and 0.02-0.22 pg/m^3 respectively representing among the lowest concentration ranges, except for 2013.

Oxychlordane levels in 2017 ranged from0.01-9,550.44 pg/m^3. The highest levels recorded were 9,550.44 pg/m^3 (Accra, Ghana), 9,131.93 (Lusaka, Zambia), 8,996.02 pg/m^3 (Kouma-Konda, Togo) and 8,841.77 pg/m^3 (Vikuge, Tanzania). The levels in 2018 ranged 0.02-9981.28 pg/m^3 with the leading concentrations recorded as 9,981.28 pg/m^3 (Accra, Ghana), 9,408.23 pg/m^3 (Kouma-Konda, Togo), 9,341.10 pg/m^3 (CDA, Egypt) and 8,813.40 pg/m^3 (Dakar Ngoye Bambey, Senegal).

In 2019 the levels of oxychlordane varied between 0.08-8,860.97 pg/m^3. The leading levels recorded were 8,860.97 pg/m^3 (Soroti), 8373.89 pg/m^3 (Kinshasa, DRC), and 7,812.48 pg/m^3 (Addis Ababa, Ethiopia). Figure 5.xx illustrates concentrations of oxychlordane in ambient air.



5.2.1.4 Oxychlordane concentration in ambient air

Cis-Nanochlor

The levels of *cis*-Nanochlor were analysed in samples in the period 2017-2019. The concentrations varied from 3,133.85-5,342.69 pg/m^3 (Figure 5.2.1.5). In 2017 the mean levels ranged 3,133.85-5342.69 pg/m^3. The leading levels were 5,342.69 pg/m^3 (Accra, Ghana), 5282.15 pg/m^3 (Kouma-Konda, Togo), 4919.56 pg/m^3 (Kinshasa, DRC) and 4834.87 pg/m^3 (Kabete, Kenya).

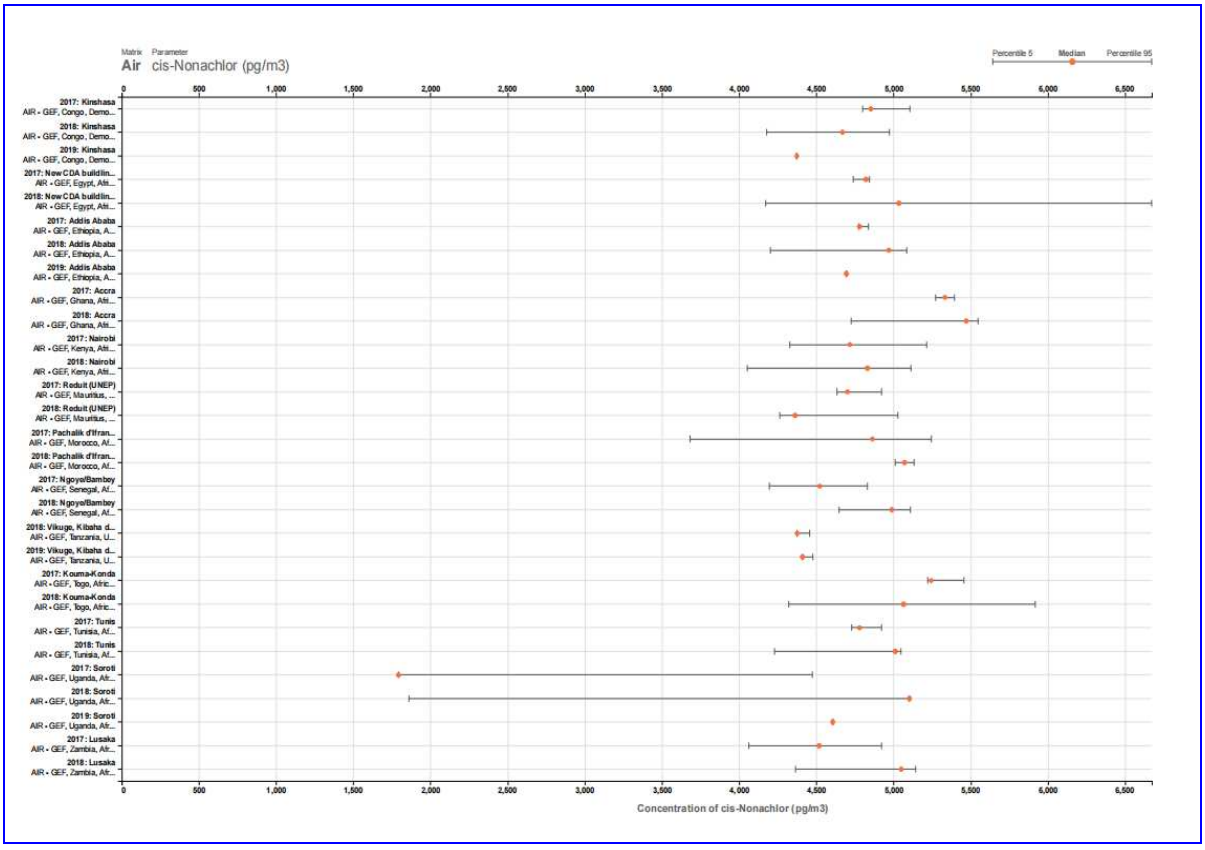


Figure 5.2.1.5 Cis-Nanochlor concentration in ambient air

2018 levels of *cis*-Nanochlor ranged from 4,022.88-5,310.22 pg/m^3 with the highest levels recorded in Accra Ghana (5,310.22 pg/m^3), CDA, Egypt (5,245.92 pg/m^3) and Kouma-Konda (5,101.53 pg/m^3). In 2019 concentrations ranged from 4,373.59-4,694.19 pg/m^3). The leading levels recorded included 4,694.19 pg/m^3 (Addis Ababa, Ethiopia), 4,605.66 pg/m^3 (Lusaka, Zambia) and 4432.59 pg/m^3 (Vikuge, Tanzania).

Trans-Nanochlor

The levels of *trans*-Nanochlor in ambient air for the period 2004-2019 varied from 0,004-17,351.05 pg/m^3. . The mean concentrations for 2004, 2005, 2006 and 2007 were 0.05 pg/m^3 (De Aar, South Africa), 0.06- 2.62 pg/m^3 (Kalahari and De Aar (South Africa), Abono (Ghana), and Lilongwe, Malawi), 0.06-0.96 pg/m^3 (De Aar and Kalahari (South Africa), Abono (Ghana), and Cairo (Egypt), and 0.69-1.06 pg/m^3 for Kalahari and De Aar (South Africa), respectively (Figure 5.2.1.6).

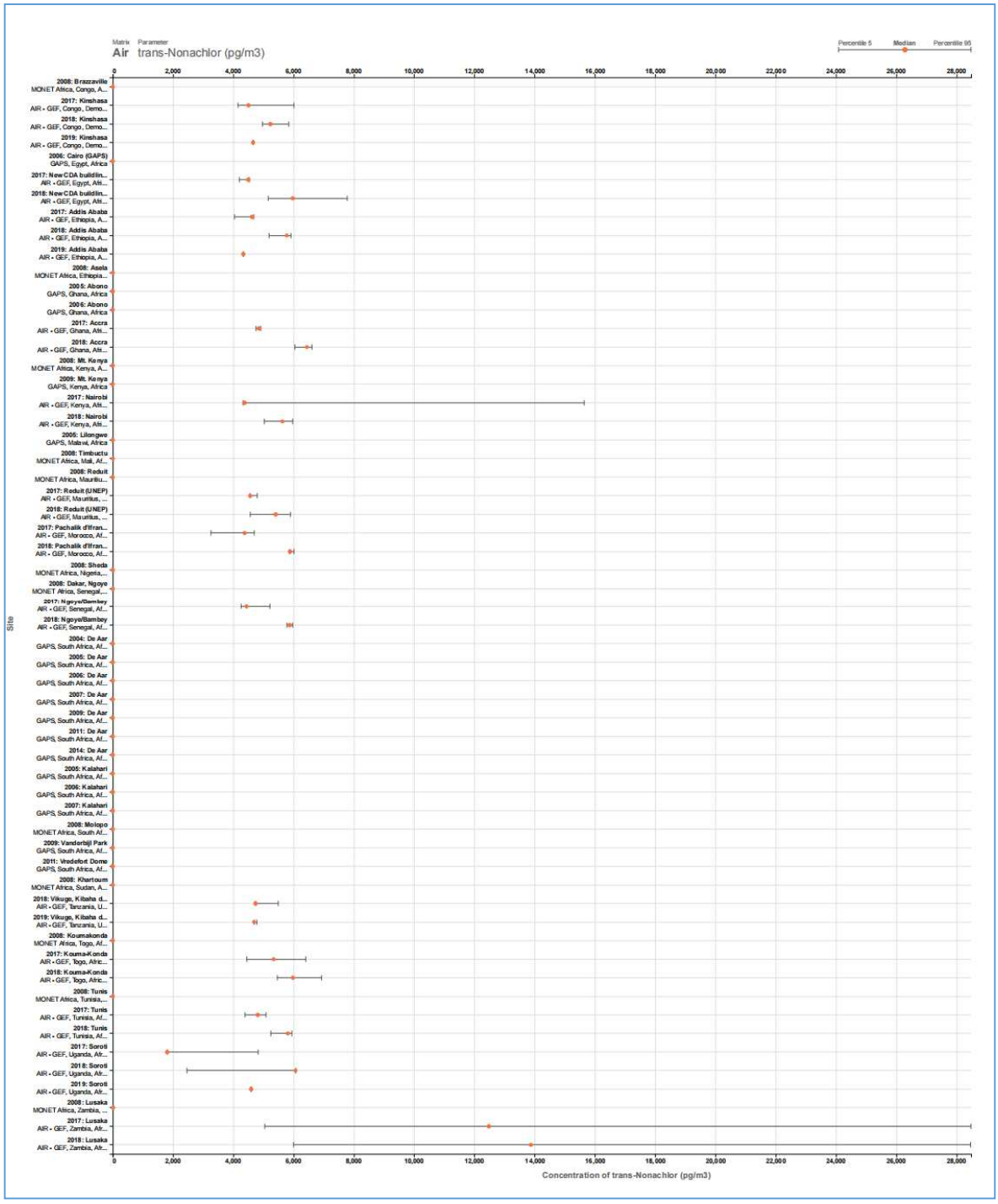


Figure 5.2.1.6 Trans-Nanochlor concentration in ambient air

The concentrations of trans-Nanochlor in 2008 varied from 1.38 -8.85 pg/m^3, while the levels in 2009 ranged 0.06-0.56 pg/m^3. The Period 2010-2016 had no levels of trans-Nanochlor analysed in the samples.

2017-2019 period had mean *trans*-Nanochlor concentrations between 3311.22- 17,551.05 pg/m^3. The mean concentrations in 2017 ranged 3,111.22-17,551.05 pg/m^3. The leading levels were 17,551.05 pg/m^3 (Lusaka, Zambia), 7278.74 pg/m^3 (Kabete, Kenya), and 5,204.95 pg/m^3 (Kouma-Konda, Togo).

In 2018 the concentrations of *trans*-Nanochlor varied between 4,866.30-16,781.77 pg/m^3 measured Soroti (Uganda) and Lusaka (Zambia), respectively. Medium concentrations were 6,400.14 pg/m^3 (Accra, Ghana), 6,245.02 pg/m^3 (CDA, Egypt) and 6,123.08 pg/m^3 (Kouma-Konda, Togo).

Four data sets were recorded in 2019 with mean concentrations of *trans*-Nanochlor between 4336.26-4718.00 pg/m^3. The lowest and the lowest levels were recorded in Addis Ababa (Ethiopia) and Vikuge (Tanzania), respectively.

5.2.1.3 Dieldrin

Dieldrin levels recorded in ambient air for the period 2004 – 2019 ranged between 0.18 - 124,479.48 pg/m^3 (Figure 5.2.1.7).

2004, 2005, 2006 and 2007 recorded mean concentrations of 0.26 pg/m^3 in 2004 (De Aar, South Africa), 0.23-204.18 pg/m^3 in 2005; 0.18-9.90 pg/m^3 in 2006 and 0.30-0.31 pg/m^3 in 2007. The levels in 2008 ranged between 0.42-137.06 pg/m^3. The leading concentrations were 137.06 pg/m^3 (Dakar Ngoye, Senegal), 39.88 pg/m^3 (Brazzaville, Republic of Congo), and 20.84 pg/m^3 (Lusaka, Zambia).

2009 recorded dieldrin levels between 0.40- 4.55 pg/m^3 with specific concentrations of 4.55 pg/m^3 (Mt. Kenya), 2.70 pg/m^3 (De Aar, South Africa), and 0.40 pg/m^3 (Cairo, Egypt). 2010 registered concentrations between 2.07 -93.88 pg/m^3. The highest levels were 93.88 pg/m^3 (Kabete, Kenya), 62.81 pg/m^3 (Bamako, Mali), 44.11 pg/m^3 (Kinshasa, DRC), and 34.63 pg/m^3 (Lusaka, Zambia) and 28.29 pg/m^3 (Accra, Ghana).

In 2011 dieldrin ranged from 1.74-27.04 pg/m^3 which was lower that the range recorded in 2010. Leading levels in 2011 were 27.04 pg/m^3 (Lusaka, Zambia), 24.97 pg/m^3 (Soroti, Uganda), 22.61 pg/m^3 (Kinshasa, DRC), 25.28 pg/m^3 (Brazzaville, Republic of Congo), and 21.39 pg/m^3 (Accra, Ghana).

2012 recorded mean concentrations between 1.45-4.18 pg/m^3, with specific levels 4.18 pg/m^3 (Sheda Abuja, Nigeria), 2.09 pg/m^3 (Mt. Kenya, Kenya), 1.84 pg/m^3 (Abetefi, Ghana) and 1.84 pg/m^3 (Khartoum, Sudan). 2013 and 2014 concentrations ranged between 0.98 -15.94 pg/m^3 and 0.30-37.32 pg/m^3, respectively.

The period 2015-2019, had mean concentrations of dieldrin between 0.05-124,479.48 pg/m^3. In 2015 the mean levels ranged 0.37-22.02 pg/m^3, while 2016 levels varied from 0.43-17.74 pg/m^3.

2017 recorded higher levels ranging from 0.15-124,479.48 pg/m^3, with specific concentrations of 124,479.48 pg/m^3 (Kabete, Kenya), 104,595.89 pg/m^3 (Kinshasa, DRC), 57,046.24 pg/m^3 (Lusaka, Zambia), 32,492.56 pg/m^3 (Addis Ababa, Ethiopia), 20,775.94 pg/m^3 (Accra, Ghana) and 12,420.59 pg/m^3 (Reduit, Mauritius).

2018 levels of dieldrin ranged from 0.17-91,699.21 pg/m^3. Leading levels were 91,699.21 pg/m^3 (Kabete, Kenya), 71,016.73 pg/m^3 (Lusaka, Zambia), 35,896.94 pg/m^3 (Addis Ababa, Ethiopia), 27,281.80 pg/m^3 (Vikuge, Tanzania) and 24,196.94 pg/m^3 (Kinshasa, DRC).

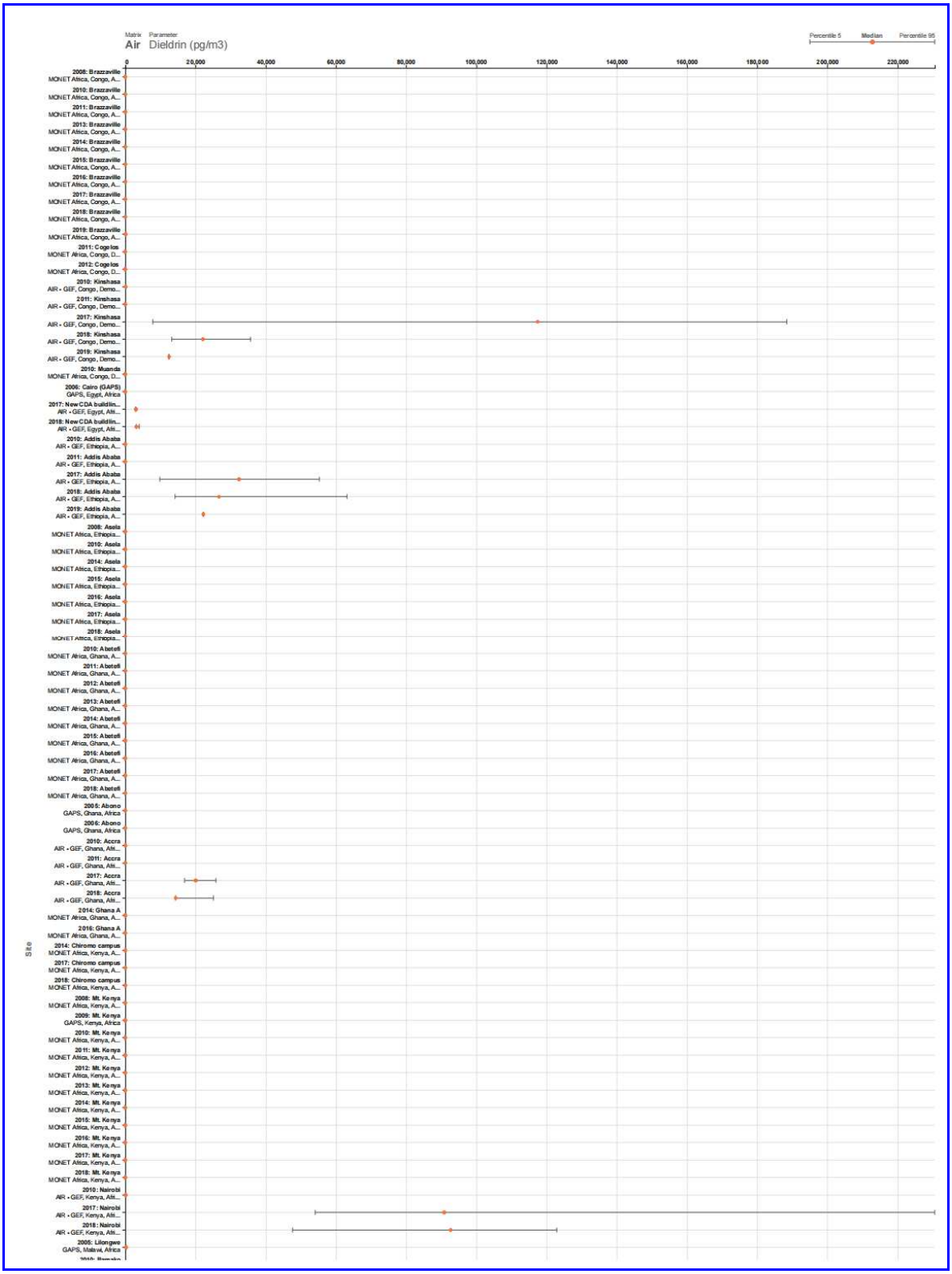


Figure 5.2.1.7 Dieldrin concentrations in ambient air

Data for 2019 had mean concentrations between 1.02-22,221.15 pg/m^3. Leading levels were 22,221.15 pg/m^3 (Addis Ababa, Ethiopia), 12,461.77 pg/m^3 (Kinshasa, DRC), 9,277.88 pg/m^3 (Vikuge, Tanzania), and 7,647.88 pg/m^3 (Kouma-Konda, Togo).

5.2.1.4 Endrin

Endrin levels in ambient air samples collected for the period 2008-2019 ranged from 0.01-13,402.08 pg/m^3. In 2008 the levels of endrin varied between 0.78-15.33 pg/m^3 with leading concentrations of 15.33 pg/m^3 (Barberspan, South Africa), 8.65 pg/m^3 (Molopo, South Africa), 7.74 pg/m^3 (Khartoum, Sudan), 4.47 pg/m^3 (Brazzaville, Republic of Congo). 2009 recorded no new data for endrin (Figure 5.2.1.8).

2010 concentrations of endrin ranged from 1.83-35.69 pg/m^3. Individual leading concentrations recorded in 2010 were 35.69 pg/m^3 (Asela, Ethiopia), 29.90 pg/m^3 (Khartoum, Sudan), 29.74 pg/m^3 (Timbuktu, Mali), and 28.55 pg/m^3 (Dakar Ngoye, Senegal). In 2011, the concentrations varied between 0.68-9.41 pg/m^3. The highest levels were 9.41 pg/m^3 (Abetefi, Ghana), 7.90 pg/m^3 (Brazzaville, Republic of Congo), 7.42 pg/m^3 (Noottgedatch, South Africa), and 6.48 pg/m^3 (Khartoum, Sudan).

2012 levels of endrin ranged between 0.09-39.86 pg/m^3, with individual concentrations of 39.86 pg/m^3 (Brazzaville, Republic of Congo), 6.42 pg/m^3 (Khartoum, Sudan), 6.14 pg/m^3. (Sheda, Nigeria), 6.00 pg/m^3 (Mt. Kenya) and 5.62 pg/m^3 (Reduit, Mauritius).

Concentration ranges for 2013, 2014, 2015, and 2016 were 0.03-0.54 pg/m^3, 0.01-486.93 pg/m^3 and 0.03-0.51 pg/m^3, and 0.03-0.32 pg/m^3, respectively.

In 2017 the mean levels ranged 0.06-6,008.36 pg/m^3. The highest levels recorded were, 6,008.36 pg/m^3 (CDA, Egypt), 5,458.19 pg/m^3 (Kinshasa, DRC), 1,945.61 pg/m^3 (Accra, Ghana), 1,861.90 (Kouma-Konda, Togo), and 1,835.99 pg/m^3 (Lusaka, Zambia).

In 2018 the mean levels of endrin ranged 0.02-13,402.08 pg/m^3. Lead levels were 13,402.08 pg/m^3 (Vikuge, Tanzania), 5,098.96 pg/m^3 (CDA, Egypt), and 3,281.41 pg/m^3 (Kinshasa, DRC).

2019 levels ranged between 0.05-4,177.85 pg/m^3, with the highest concentration recorded as 4,177.85 pg/m^3 (Vikuge, Tanzania), 1,837.15 pg/m^3 (Lusaka, Zambia), 1,614.02 pg/m^3 (Kinshasa, DRC), and 1462.92 pg/m^3 (Addis Ababa, Ethiopia).

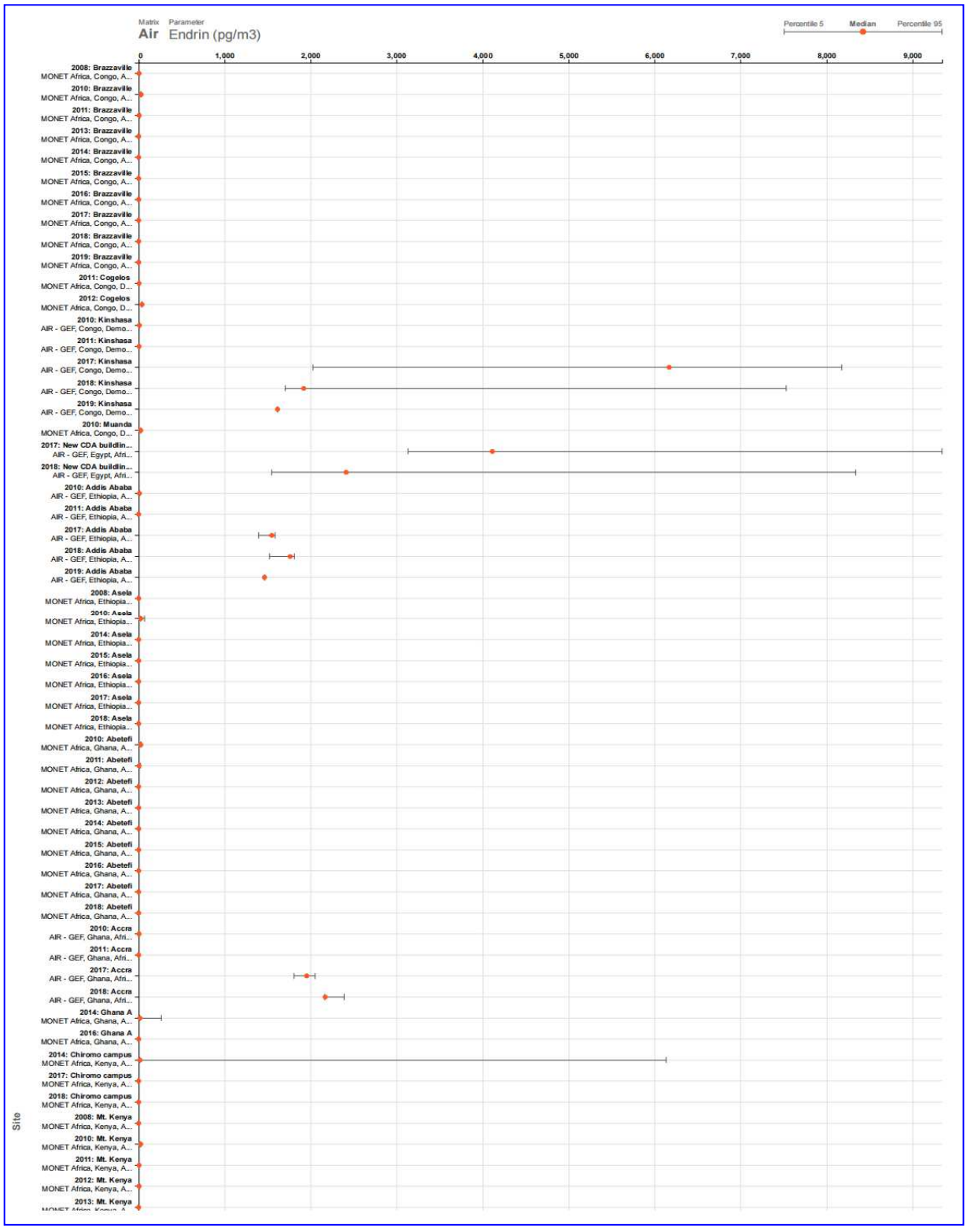


Figure 5.2.1.8 Endrin concentration in ambient air

5.2.1.5 Heptachlors

The levels of heptachlor in ambient air varied from 0.01-37,469.59 pg/m^3 in the samples collected from 2004-2019. 2004 data recorded heptachlor concentration of 0.17 pg/m^3 (De Aar, South Africa), while 2005, 2006 and 2007 recorded concentration ranges of 0.14-30.32 pg/m^3, 0.12-3.25 pg/m^3 and 0.19-0.20 pg/m^3, respectively for samples collected from South Africa, Ghana, Malawi and Egypt (Figure 5.2.1.9)

In 2008, the mean concentrations of heptachlor ranged 0.73-33.23 pg/m^3. The leading levels were 33.23 pg/m^3 (Dakar Ngoye, Senegal), 15.99 pg/m^3 (Khartoum Sudan), and 5.40 pg/m^3 (Brazzaville, Republic of Congo). The concentrations recorded in 2009 were 0.09, 0.12 and 0.13 pg/m^3 in samples from De Aar, Vanderbijl (South Africa) and Mt. Kenya (Kenya), respectively.

2010-2014 recorded lower levels of heptachlor ranging from 1.00-188 pg/m^3 (2010), 0.01-2.54 pg/m^3 (2011), 0.10-0.99 pg/m^3 (2012), 0.04-0.38 pg/m^3, and 0.06-31.06 pg/m^3 (2014).

The levels of heptachlor in the period 2015-2019 had mean concentrations that ranged 0.02-37,469.59 pg/m^3. The mean ranges recorded per year were 0.07-0.57 pg/m^3 (2015), 0.02-0.81 pg/m^3 (2016), 0.02-20,858.99 pg/m^3 (2017), 0.02-37,469.59 pg/m^3 (2018) and 0.02-15,850.09 pg/m^3 (2019).

Cis-Heptachlor epoxide

Cis-Heptachlor epoxide levels ranged between 0.03-7.21 pg/m^3 in the samples collected from 2004-2018. The mean levels recorded were 0.10 pg/m^3 in 2004 (De Aar, South Africa), 0.10 pg/m^3 in 2005 (for samples from South Africa, Ghana, Malawi and Egypt), 0.25 pg/m^3 in 2006 (De Aar, Kalahari, Lilongwe, Abono and Cairo), and 0.23 pg/m^3 in 2007 (for De Aar and Kalahari, South Africa). 2008 had no data collected, while 2009 datasets registered concentrations of 0.42 in all samples from Mt. Kenya and De Aar and Vanderbijl.

2010 and 2011 recorded the highest reporting of *cis*-heptachlor epoxide for data collected from UNEP/GEF GMP1 project with concentrations ranging from 0.84-7.14 pg/m^3 in 2010 and 0.24-6.57 pg/m^3 in samples collected in 2010. 2014 recorded two datasets with mean concentrations of 7.21 pg/m^3 (Ghana A) and 99.98 pg/m^3 (Chiromo, Kenya). The subsequent years 2015, 2017 and 2018 registered a single data set with concentrations of 0.03 pg/m^3 in 2015 (Ghana A), and 0.42 and 0.44 pg/m^3 in Chiromo (Kenya) for 2017 and 2018, respectively (Figure 5.2.1.10).

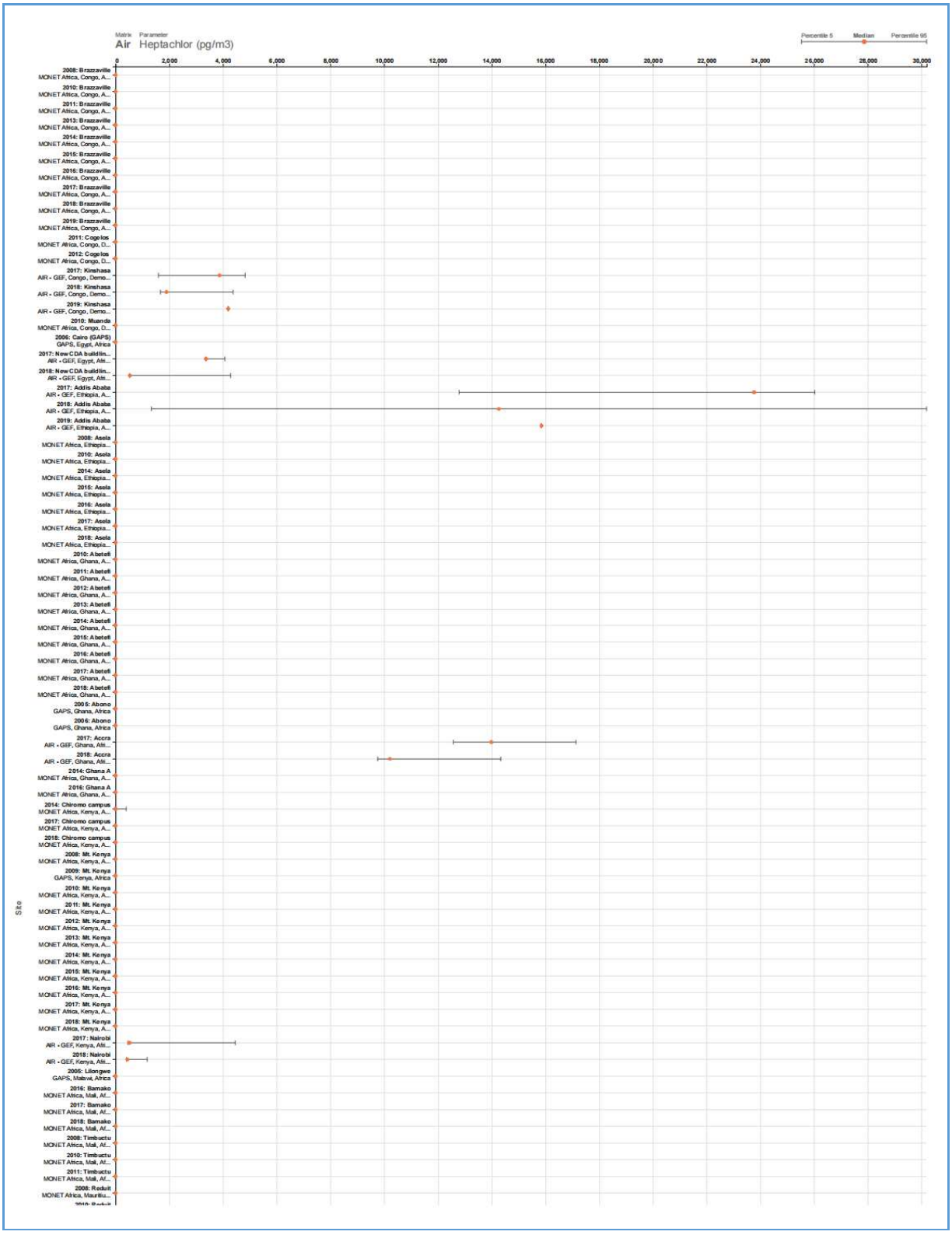


Figure 5.2.1.9 Heptachlor concentration in ambient air

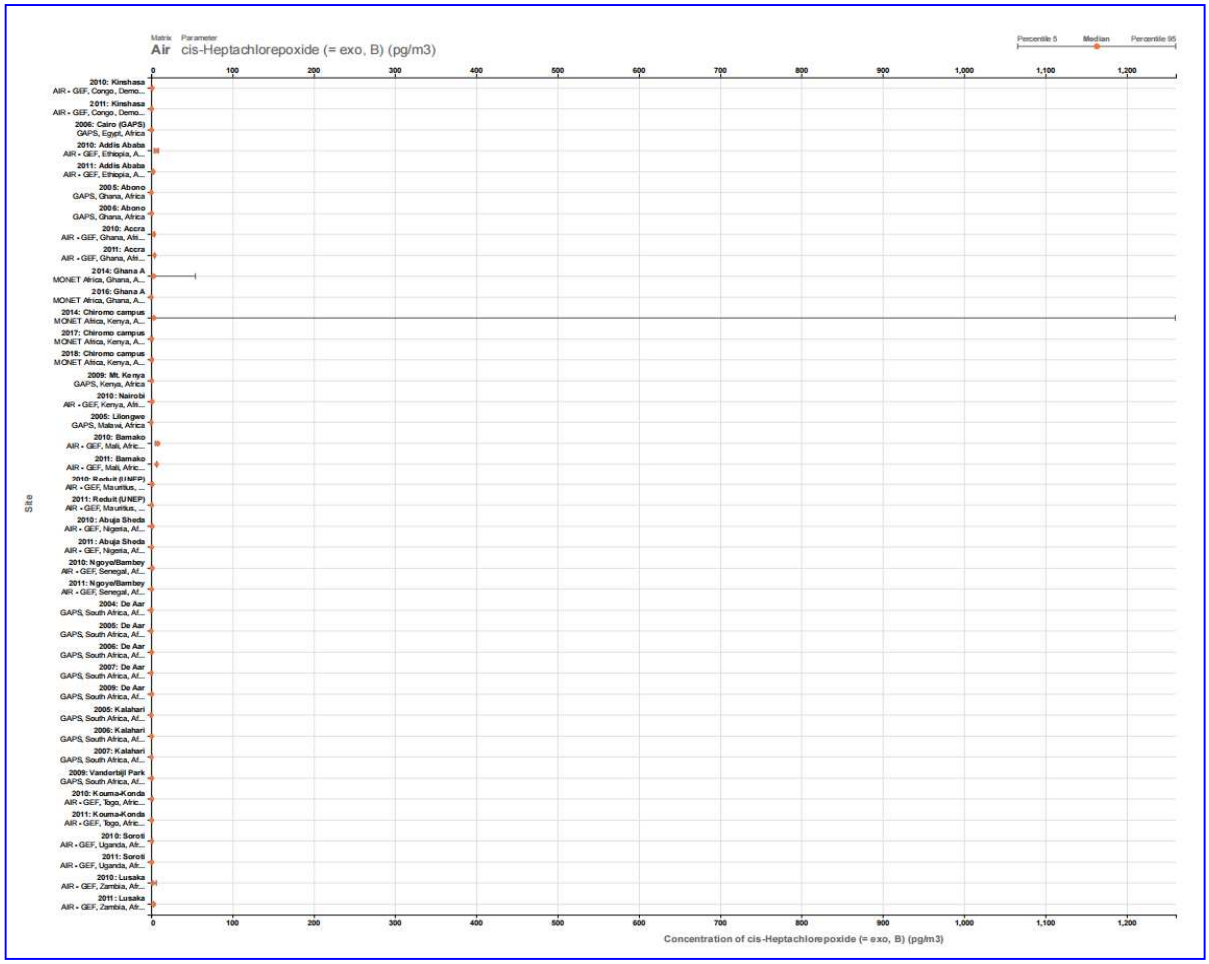


Figure 5.2.1.10 Cis-Heptachlor epoxide concentration in ambient air

Trans-Heptachlor epoxide

The levels of trans-Heptachlor epoxide were measured in only two sites for the period 2014-2018, with mean concentrations ranging from 0.02-507.14 pg/m^3. The levels in 2004 were 36.57 pg/m^3 and 507.14 pg/m^3 recorded in Ghana A and Chiromo, respectively. Concentrations in 2016, 2017 and 2018 were 0.04 (Ghana A), 0.02 and 0.04 pg/m^3 recorded in Chiromo (Kenya) for 2017 and 2018, respectively (Figure 5.2.1.11).

The sum Heptachlors

The sum-heptachlors (*cis*- and trans-heptachlor) levels were reported in 2005 (0.16-0.39 pg/m^3), 2006 (0.14-0.31 pg/m^3), and 2007 (0.21-0.22 pg/m^3). The levels in 2009 ranged 0.20-0.27 pg/m^3, while 2010 and 2011 recorded a single data set each with levels of 0.01 pg/m^3 each. The levels in 2014 ranged from 0.01-507.14 pg/m^3 while 2016 had concentration of 0.04 pg/m^3 (Figure 5.2.1.12).

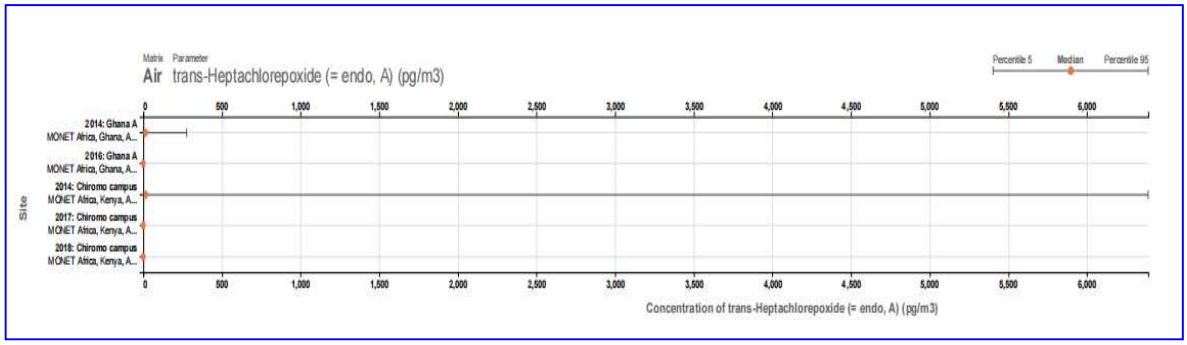


Figure 5.2.1.11 Trans-Heptachlor epoxide concentration in ambient air

Figure 5.2.1.12 shows the concentrations of sum 2 heptachlor epoxides in ambient air.

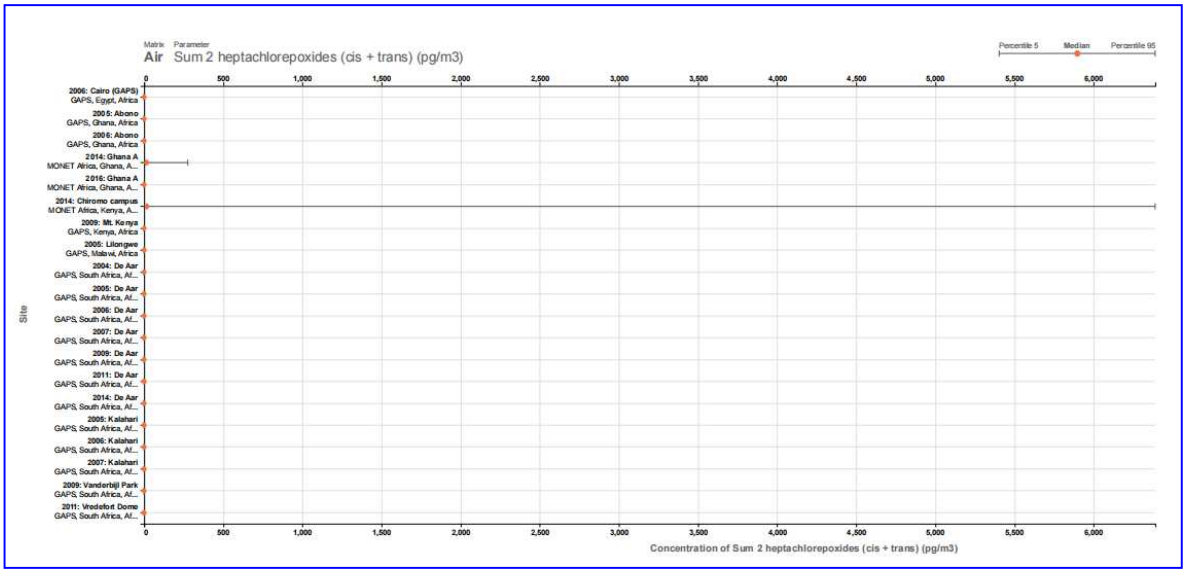


Figure 5.2.1.12 Sum-Heptachlor concentrations in ambient air

The overall trend analysis showed no significant trends in heptachlor and *cis*-heptachlor epoxide and trans-heptachlor epoxide.

5.2.1.6 Mirex

Mirex concentrations in air concentrations in air were monitored from 2010-2019 with mean levels ranging between 0.03-739.45 pg/m^3. Mirex levels in 2010 ranged from 1.02 -1.77 pg/m^3 with mean concentrations of 1.77 pg/m^3 (Dakar Ngoye, Senegal), 1.63 pg/m^3 (Reduit, Mauritius; and Bamako, Mali), and 1.59 pg/m^3 (Lusaka, Zambia). In 2011, the concentrations of mirex ranged from 0.52-0.78 pg/m^3, with mean levels of 0.86 pg/m^3 (Bamako, Mali), 0.78 pg/m^3 (Soroti, Uganda), and 0.69 pg/m^3 (Dakar Bambey, Senegal).

In 2014 the levels of mirex were 1.00 pg/m^3 and 13.92 pg/m^3 recorded in Ghana A and Chiromo (Kenya), respectively, while 2016 levels ranged 0.03-04 pg/m^3. The concentrations of mirex are shown in Figure 5.2.1.13.

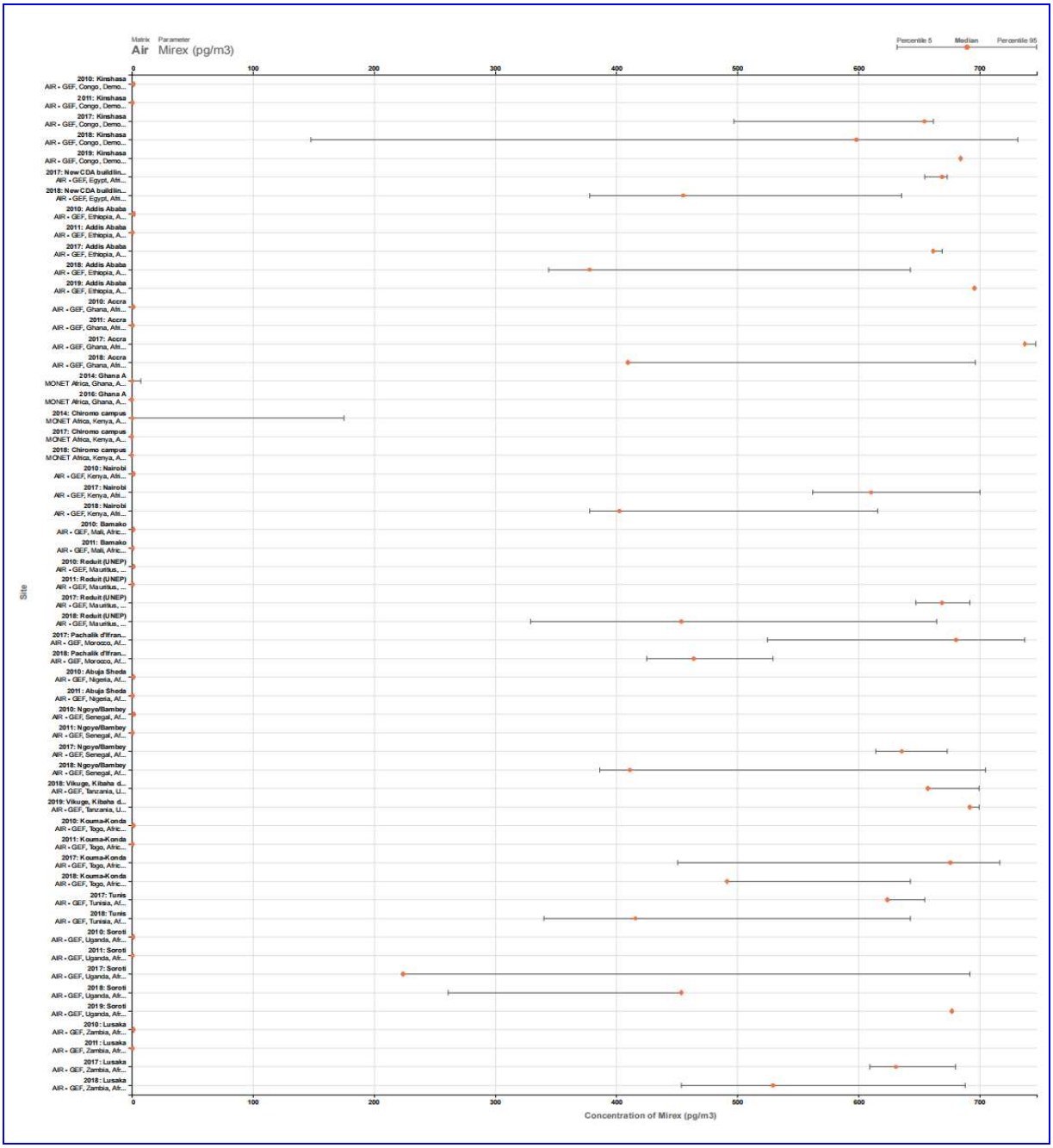


Figure 5.2.1.13 Mirex concentrations in ambient air

In the period 2017-2019 the concentration range was 0.04-695.75 pg/m^3. The concentrations in 2017 varied from 0.04-739.45 pg/m^3 with concentrations of 739.45 pg/m^3 (Accra, Ghana), 671.13 pg/m^3 (Reduit, Mauritius). Other sites that recorded concentrations above 600 pg/m^3 were

recorded in Kinshasa (DRC), CDA (Egypt), Kabete (Kenya), Pachalik (Morocco), Dakar Ngoye (Senegal), Kouma-Konda (Togo), Tunis (Tunisia) and Lusaka (Zambia).

5.2.1.7 Dichlorodiphenyltrichloroethane (DDT) and metabolites

Sum 6 DDTs

DDTs monitored in ambient air include *p,p'*-DDT, *p,p'*-DDE, *p,p'*-DDD, *o,p'*-DDT, *o,p'*-DDE *and o,p'*-DDD. The concentrations of DDTs in ambient air were dominated by *p,p'*-DDT, *p,p'*-DDE, *p,p'*-DDD, and *o,p'*-DDT.

The sum 6-DDTs in ambient air had mean concentrations between 3.68-671.647.12 pg/m^3. The sum 6 DDT levels in 2007 recorded 0.52-3.61 pg/m^3, and 25.28-79.00 pg/m^3 in 2009 (Figure 5.2.1.14).

The sum 6 DDTs levels ranged from 8.39-1,442.95 pg/m^3 in 2010 with highest levels recorded as 1442.95 pg/m^3 (Bamako, Mali), 736.75 pg/m^3 (Lusaka, Zambia), 461.41 pg/m^3 (Dakar Ngoye, Senegal), and 249.94 pg/m^3 (Addis Ababa, Ethiopia). In 2011, the mean levels ranged 3.68-357.71 pg/m^3, with mean concentrations of 428.95 pg/m^3 (Bamako, Zambia), 357.71 pg/m^3 (Lusaka, Zambia), 344.47 pg/m^3 (Kishasa, Zambia), and 289.19 pg/m^3 (Dakar Ngoye, Senegal).

In 2012 the sum 6 DDTs recorded was 409.10 pg/m^3 (Kinshasa, DRC), while levels between 5.28-17.19 pg/m^3 were recorded in 2014, and 6.46 pg/m^3 in 2016.

In 2017 the mean levels of sum 6 DDTs varied from 19,946.31-1,998,216 pg/m^3. The highest levels were 1,998,216 pg/m^3 (Kinshasa, DRC), 123,446.62 pg/m^3 (Lusaka, Zambia), 114,032.20 pg/m^3 (Kabete, Kenya), 64,486.12 pg/m^3 (Addis Ababa, Ethiopia), and 62,491.43 pg/m^3 (Soroti, Uganda).

2018 levels of sum 6 DDTs ranged from 22,122.05-472,015.59 pg/m^3. Leading concentrations recorded were 671,647.12 pg/m^3 (Vikuge, Tanzania), 145,476.66 pg/m^3 (Lusaka, Zambia), and 120,179.35 pg/m^3 (Addis Ababa, Ethiopia).

Sum 6 DDTs in 2019 had concentrations between 19,611.00-282,499.58 pg/m^3. The highest mean levels recorded in 2019 were 282,499.58 pg/m^3 (Kinshasa, DRC), 149,515.25 pg/m^3 (Vikuge, Tanzania), 55,205.24 pg/m^3 (Addis Ababa, Ethiopia), 23,058.87 pg/m^3 (Kouma-Konda, Togo), and 19,611.00 pg/m^3 (Soroti, Uganda).

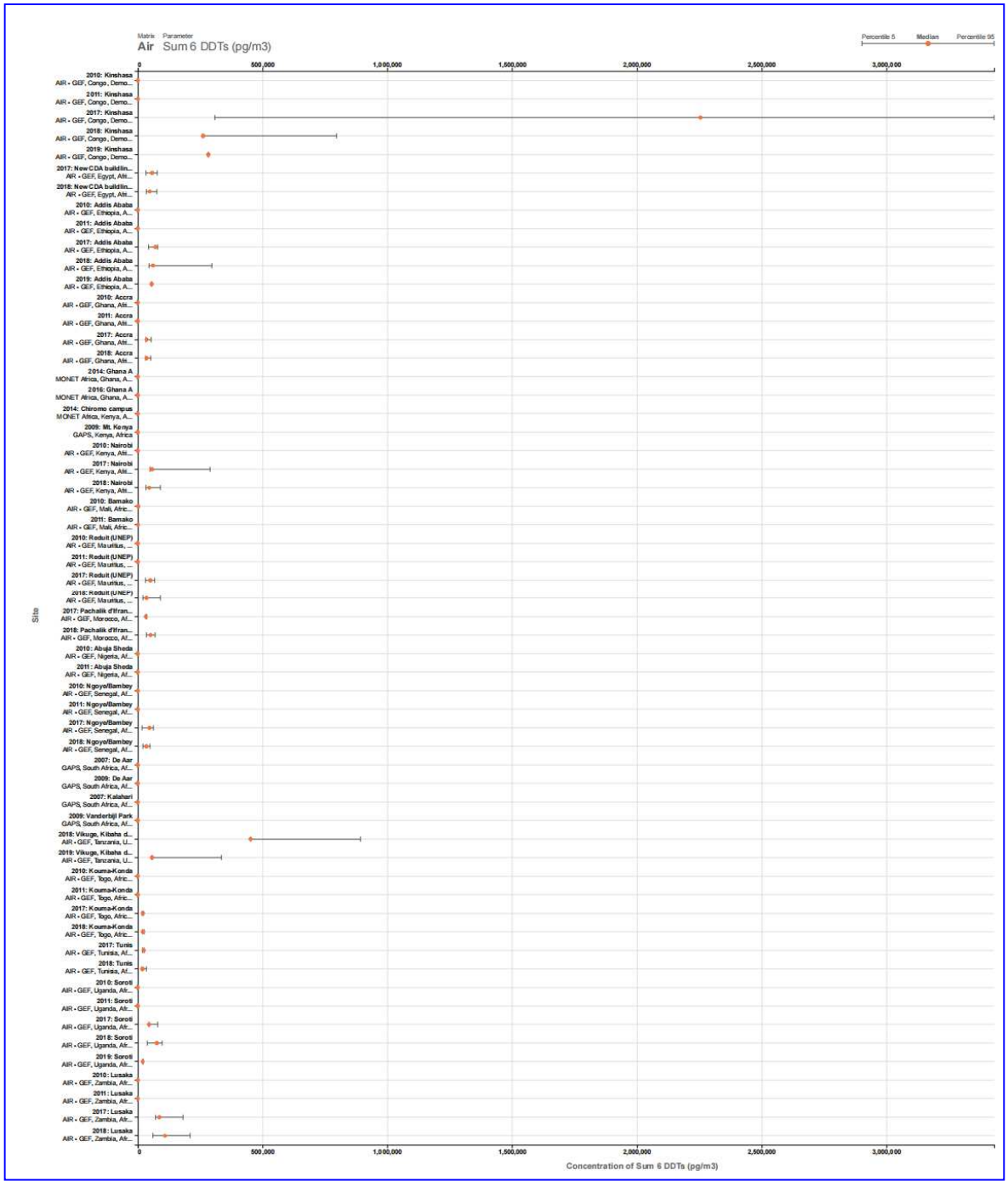


Figure 5.2.1.14 Sum 6-DDTs in ambient air

Figures 5.2.1.15-17 show additional datasets for DDTs concentration in the ambient air in the region.

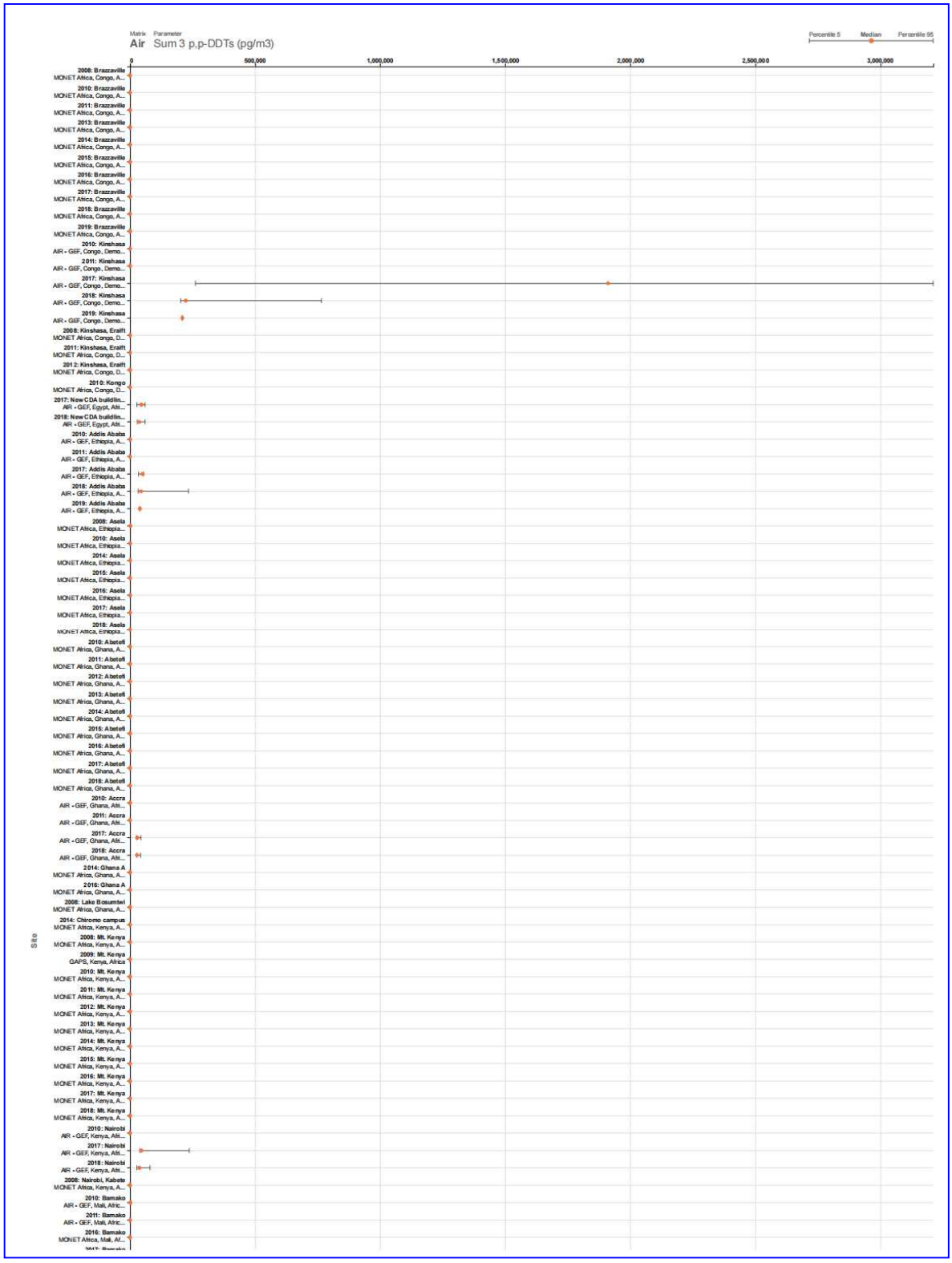


Figure 5.2.1.15 Sum 3DDTs concentration in ambient air

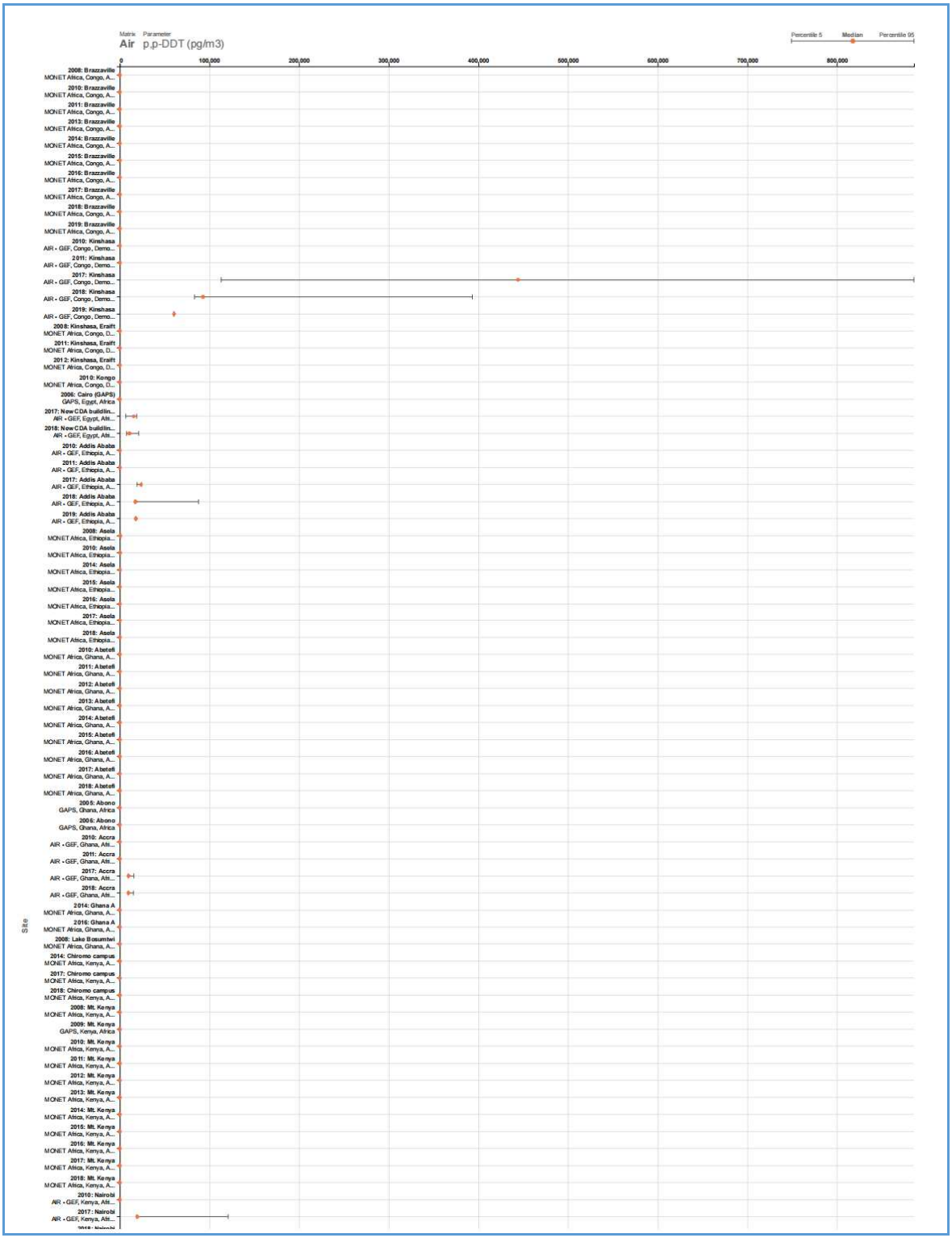


Figure 5.2.1.16 p,p'-DDT concentration in ambient air

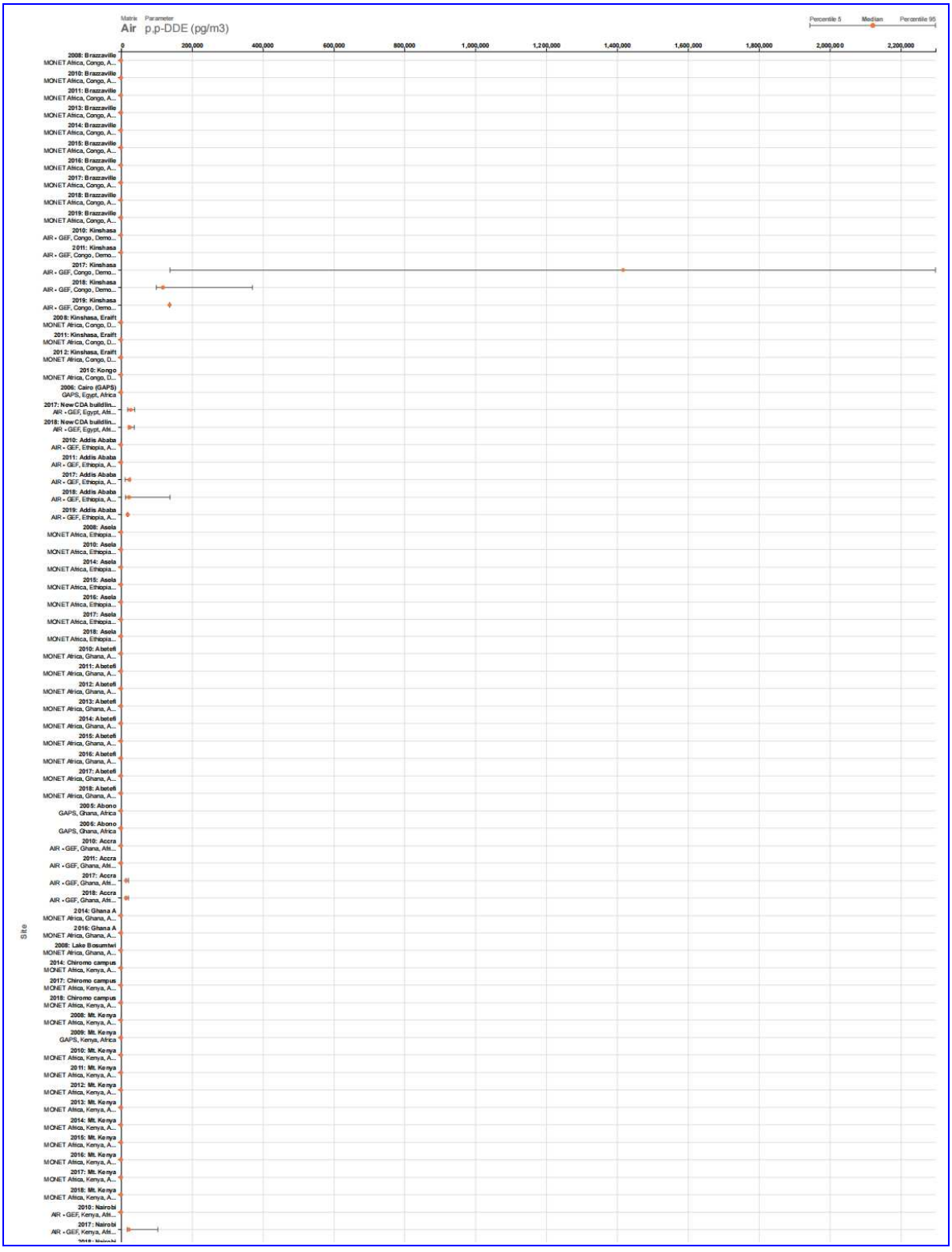


Figure 5.2.1.17 p,p'-DDE concentration in ambient air

5.2.1.8 Toxaphene

Toxaphene isomers 26, 50 and 62 were not analysed in the ambient air samples collected for the period 2008-2019.

5.2.1.9 Hexachlorobenzene (HCB)

Hexacholobenzene levels in the period 2008-2019 ranged between 1.54-83,156.27 pg/m^3. 2008 concentrations of HCB ranged from 13.27-36.10 pg/m^3. The highest levels recorded in 2008 were 36.10 pg/m^3 (Khartoum, Sudan), 31.11 pg/m^3 (Tunis, Tunisia), and 30.19 pg/m^3 (Asala, Ethiopia).

In 2009 no data set was recorded, while in 2010 the concentration ranged 6.12-23.32 pg/m^3. The leading levels of HCB in 2010 were 23.32 pg/m^3 (Addis Ababa, Ethiopia), 16.67 pg/m^3 (Mt. Kenya, Kenya), 14.98 pg/m^3 (Khartoum, Sudan), 14.59 pg/m^3 (Bamako, Mali) and 13.48 pg/m^3 (Kabete, Kenya).

In 2011 the mean concentrations of HCB ranged from 6.14-34.50 pg/m^3. The specific concentrations recorded were 34.50 pg/m^3 (Khartoum, Sudan), 15.86 pg/m^3 (Timbuktu, Mali), 12.10 pg/m^3 (Addis Ababa, Ethiopia), 10.32 pg/m^3 (Reduit, Mauritius), and 10.25 pg/m^3 (Soroti, Uganda).

In 2012 the mean levels of HCB varied from 5.40-36.81 pg/m^3. The highest concentrations measured were 36.81 pg/m^3 (Mt. Kenya, Kenya), 34.99 pg/m^3 (Khatoum, Sudan), 15.44 pg/m^3 (Reduit, Mauritius), and 11.52 pg/m^3 (Abetefi, Ghana).

2013 levels of HCB ranged between 7.45-40.55 pg/m^3, with the leading concentrations recorded as 40.55 pg/m^3 (Khartoum, Sudan), 28.77 pg/m^3 (Mt. Kenya, Kenya), 21.35 pg/m^3 (Reduit, Mauritius), and 14.73 pg/m^3 (Brazzaville, Republic of Congo).

In 2014, the concentrations of HCB ranged 4.42-36.35 pg/m^3. High levels recorded were 36.35 pg/m^3 (Marroco Observatory, Morocco), 36.20 pg/m^3 (Khartoum, Sudan), 34.02 pg/m^3 (Sheda, Nigeria), 32.68 pg/m^3 (Asela, Ethiopia), and 28.20 pg/m^3 (Mt. Kenya, Kenya).

2015 levels varied from 11.15 -25.82 pg/m^3. Highest levels recorded were 25.82 pg/m^3 (Maroco Observatory, Morocco), 25.35 pg/m^3 (Mt. Kenya, Kenya), and 18.17 pg/m^3 (Reduit, Mauritius).

The levels of HCB recorded in 2016 varied from 1.54-43.00 pg/m^3. The highest levels recorded were 43.00 pg/m^3 (Marroco Observatory, Morocco), 23.05 pg/m^3 (Mt. Kenya, Kenya), and 22.85 pg/m^3 (Bamako, Mali).

In 2017 concentrations of HCB ranged 7.03-65,001.01 pg/m^3, recorded in Abetefi (Ghana) and Tunis (Tunisia), respectively. Middle levels were 60,638.23 pg/m^3 (Accra, Ghana), 57,032.54 pg/m^3 (Pachalik, Morocco), 42,863.24 pg/m^3 (Kabete, Kenya), and 36,210.07 pg/m^3 (Addis Ababa, Ethiopia). In 2018, the mean concentrations ranged 6.35-83,156.27 pg/m^3 recorded in Abetefi, Ghana) and Pachalik (Morocco), respectively. Intermediate levels were 62,600.34 pg/m^3 (CDA, Egypt), 61,912.56 pg/m^3 (Tunis, Tunisia), 58,344.59 pg/m^3 (Kinshasa, DRC) and 36,450.56 pg/m^3 (Addis Ababa, Ethiopia). The levels of HCB are illustrated in Figure 5.2.1.18.

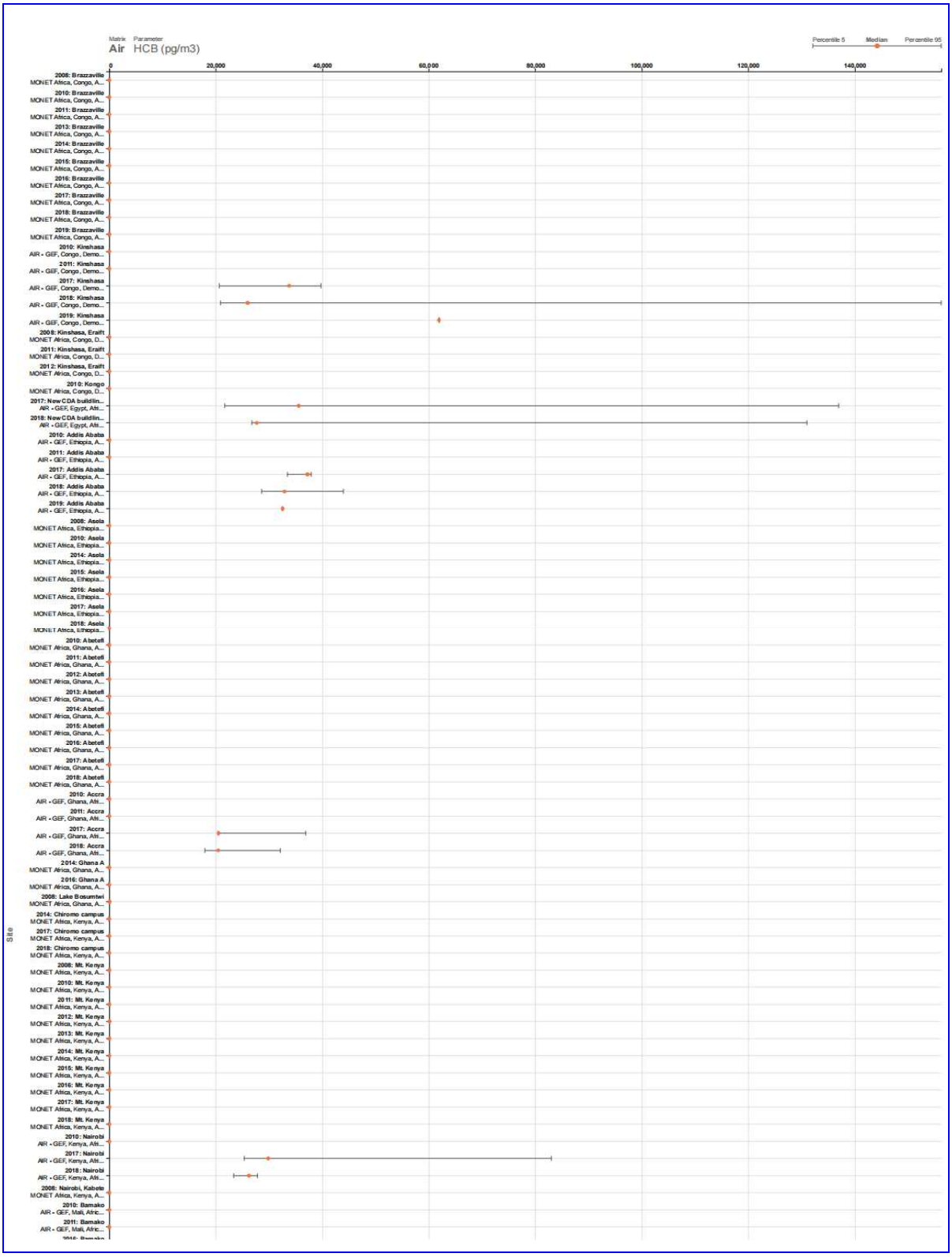


Figure 5.2.1.18 HCB concentrations in ambient air

Datasets for 2019 had HCB concentrations ranging from 8.82-61,924.69 pg/m^3 recorded in Brazzaville (Republic of Congo) and Kinshasa (DRC), respectively. Intermediate levels were 32,555.19 pg/m^3 (Addis Ababa, Ethiopia), 15,450.97 pg/m^3 (Vikuge, Tanzania) and 5,662.19 pg/m^3 (Lusaka, Zambia).

5.2.1.10 Polychlorinated biphenyls (PCBs)

Sum 6 PCBs

Indicator PCBs congeners analysed in ambient air samples included PCB 28, 52, 101, 138, 153 and 180. The sum 6 PCBs in the period 2004-2019 ranged from 0.28-737.57 pg/m^3. Sum 6 PCBs levels in 2004, 2005, 2006 and 2007 were 0.7.12 pg/m^3 (2004), 0.17- 3.53 pg/m^3 (2005), 0.13-19.76 pg/m^3 (2006), and 2.91-4.77 pg/m^3 (2007).

In 2008, the mean concentrations of sum 6 PCBs ranged from 5.23-737.57 pg/m^3 with the lowest and highest levels recorded in Timbuktu (Mali) and Dakar Ngoye (Senegal). Medium levels were 195.44 pg/m^3 (Kinshasa, DRC), 180.29 pg/m^3 (Khartoum, Sudan), 98.61 pg/m^3 (Tunis, Tunisia) and 83.53 pg/m^3 (Brazzaville, Republic of Congo). 2009 data set had only two records with 3.71 pg/m^3 (Mt. Kenya, Kenya) and 4.41 (Barber-span, South Africa).

2010 sum 6 PCBs ranged from 1.71-186.59 pg/m^3 recorded at Mt. Kenya (Kenya) and Kinshasa (DRC), respectively. Medium levels included 119.24 pg/m^3 (Lusaka, Zambia), 60.64 pg/m^3 (Bamako, Mali), 36.62 pg/m^3 (Khartoum, Sudan) and 30.85 pg/m^3 (Accra, Ghana).

The mean sum 6 PCBs levels in 2011, 2012, 2013 and 2017 ranged 1.31-783.96 pg/m^3, 2.20-52.51 pg/m^3, 0.30-71.02 and 0.67-84.04 pg/m^3, respectively. In 2015 and 2016 the mean sum 6 PCBs recorded ranged 0.60-323.11 pg/m^3 and 0.28-573.29 pg/m^3.

2017 sum 6 PCBs recorded concentrations between 0.94-388.32 pg/m^3 with the lowest and highest levels recorded at Reduit (Mauritius) and Kinshasa (DRC), respectively. Intermediate levels were 265.48 pg/m^3 (Tunis, Tunisia), 44.19 pg/m^3 (Brazzaville, Republic of Congo), and 17.66 pg/m^3 (Lusaka, Zambia).

In 2018 the concentrations of sum 6 PCBs ranged 0.52-626.65 pg/m^3 with the lowest and highest levels recorded in Reduit (Mauritius) and Kinshasa (DRC), respectively. Other relatively high levels recorded included 145.77 pg/m^3 (Tunis, Tunisia), 48.58 pg/m^3 (Brazzaville, Republic of Congo), 27.65 pg/m^3 (CDA, Egypt), 18.90 pg/m^3 (Pachalik, Morocco), 17.707 pg/m^3, (Accra, Ghana), 16.70 pg/m^3 (Soroti, Uganda), and 13.59 pg/m^3 (Lusaka, Zambia).

The 2019 datasets comprised of six reports that recorded sum 6 PCB ranging from 0.62-103.67 pg/m^3, recorded in Reduit (Mauritius) and Kinshasa (DRC), respectively. Intermediate concentrations were 29.03 pg/m^3 (Brazzaville, Republic of Congo), 2.90 pg/m^3 (Addis Ababa, Ethiopia), 2.17 pg/m^3 (Vikuge, Tanzania), and 1.82 pg/m^3 (Soroti, Uganda). The summary of the levels of sum 6 PCBs recorded in the region is provided in Figure 5.2.1.19.

Indicative trends have started to develop in 2% of the monitoring sites for indicator PCBs for PCB 28, PCB 101, PCB 138 and PCB 153. However, over 60% of the sites showed no significant trends, while 29.17% of the sites has no adequate data for trend analysis. Gradual development of trends are being seen the concentrations of PCBs in the region suggest positive effect of the steps taken under the convention to reduce PCB emissions into the environment.

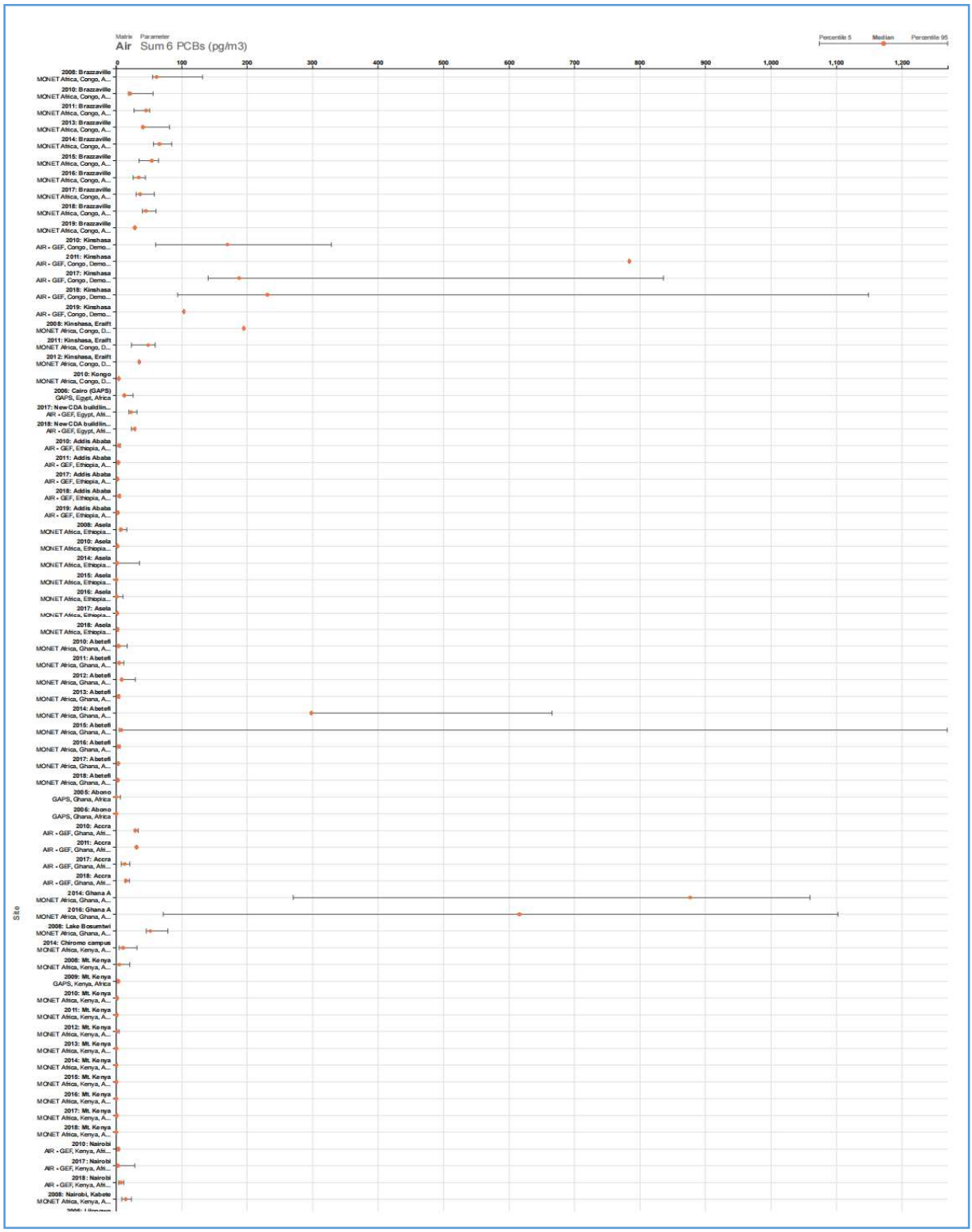


Figure 5.2.1.19 Sum 6 PCBs levels in ambient air

Larger declines were observed when cumulative effects were considered under sum 6 PCBs and sum 7 PCBs which registered 6.25 and 12.50% sites registered declining trends, respectively. However, the fact that majority of the sites did not record any significant indicate the need to boost regional efforts to ensure continuity and consistence in the monitoring activities.

Dioxin like PCBs (dl-PCBs) in ambient air

The dl-PCBs analysed included the congeners 77, 81, 105, 114, 118, 123, 126, 156, 157, 169, 175 and 189. The concentrations the sum 12 dl-PCBs in air varied between 179.41-815,960.04 fg/m^3 for samples collected in the period 2010-2014.

The concentrations of sum 12 dl-PCBs in 2010 varied from 143.60-8,692.19 fg/m^3, which were recorded in Reduit (Mauritius) and Kinshasa (DRC), respectively. In 2014, two datasets compiled had sum 12 PCB concentrations of 2,524.54 fg/m^3 (Chiromo Campus, Kenya) and 815, 960.04 fg/m^3 (Accra, Ghana). Figure 5.2.1.20 illustrates the concentrations of sum 12 PCBs in ambient air.

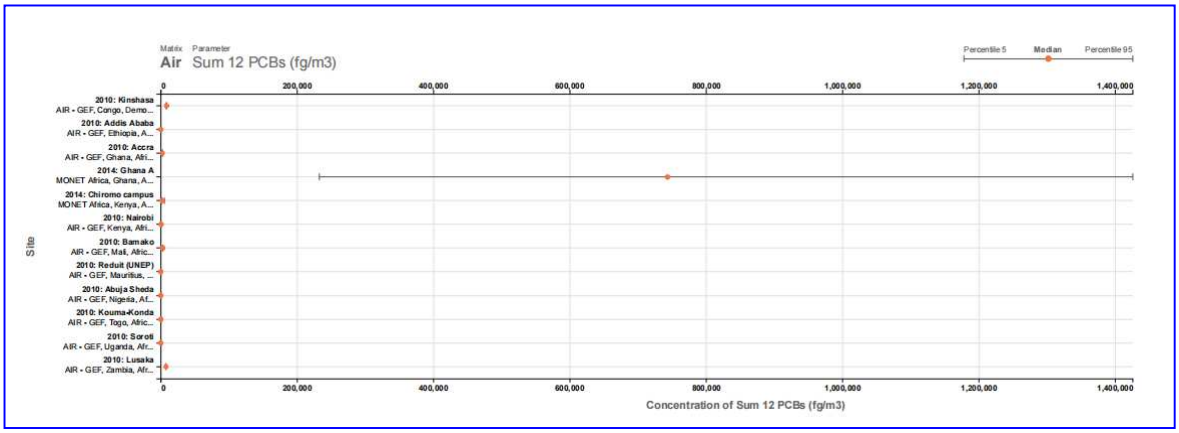


Figure 5.2.1.20 Sum 12 dl-PCBs Concentration in ambient air.

Dl-PCBs Toxic equivalent

The toxic equivalent of dl-PCBs computed based on WHO_{2005} guideline varied between 0.32-100.28 fg/m^3. 2010 recorded WHO_{2005} TEQs between 0.32-13.60 fg/m^3, while 2014 recorded levels between 4.90-100.28 fg/m^3. The levels of TEQs are illustrated in Figure 5.2.1.21.

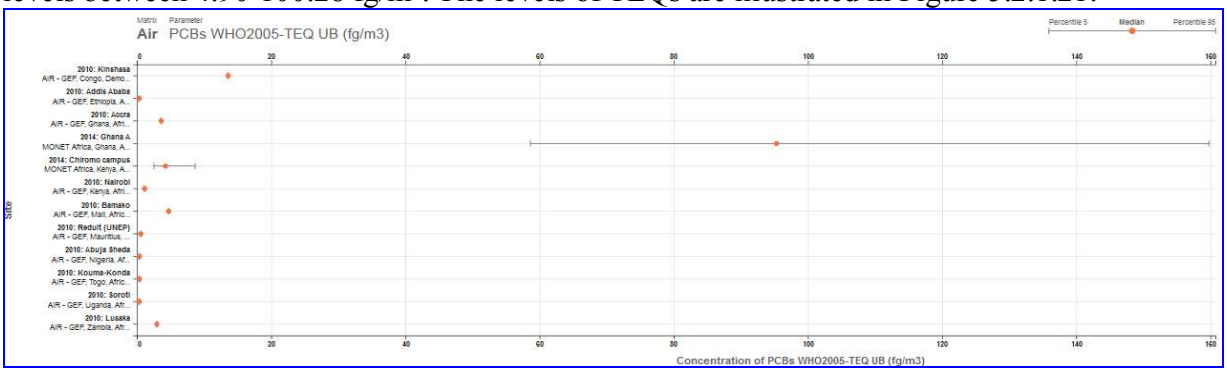


Figure 5.2.1.21 Dl-PCBs WHO2005 TEQs for ambient air

5.2.1.11 Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs)

PCDDs/Fs analysed in ambient air for the period 2008-2019 comprised of 7 PCDDs and 10 PCDFs. The concentrations of sum 17 PCDDs/Fs in the period 2008-2019 varied from 15.88-10,275.69 fg/m^3, with the lowest and highest measured in 2008 at Mt. Kenya (Kenya) and Dakar Ngoye (Senegal). The medium concentration of sum 17 PCDDs/Fs recorded in 2008 were 2,789.29 fg/m^3 (Khartoum, Sudan), 1,667.18 fg/m^3 (Tunis, Tunisia), 1,284.97 fg/m^3 (Brazzaville, Republic of Congo), and 610.56 fg/m^3 (Kouma-Konda, Togo). 2009 had no dataset for sum 17 PCDDs/Fs (Figure 5.2.1.22).

In 2010 dataset, sum 17 PCDDs/Fs recorded concentrations between 7.54 -4,005.90 fg/m^3, with the lowest and highest levels measured in samples from Kouma-Konda (Togo) and Brazzaville (Republic of Congo), respectively. Medium levels recorded in 2010 were 1,419.81 fg/m^3 (Khartoum, Sudan), 802.95 fg/m^3 (Dakar Ngoye, Senegal), 427.09 fg/m^3 (Timbuktu, Mali) and 388.54 fg/m^3 (Reduit, Mauritius).

The levels of sum 17 PCDDs/Fs recorded in 2011 ranged from 46.59 -2,579.23 fg/m^3, for samples from Mt. Kenya (Kenya) and Brazzaville (Republic of Congo), respectively. Intermediate levels recorded were 1,910.19 fg/m^3 (Khartoum, Sudan), 1,483.94 fg/m^3 (Kinshasa, DRC), and 584.40 fg/m^3 (Reduit, Mauritius).

In 2012, sum 17 PCDDs/Fs ranged from 30.51-1,782.75 fg/m^3, with the lowest and highest levels measured in Mt. Kenya (Kenya) and Khartoum (Sudan). The mean range concentrations recorded in 2012 had lower levels compared to 2010 and 2011. Medium concentrations recorded in 2012 were 937.93 fg/m^3 (Accra, Ghana), 814.73 fg/m^3 (Kinshasa, DRC), and 678.17 fg/m^3 (Reduit, Mauritius).

2013 dataset registered sum 17 PCDDs/Fs between 28.18 -1,307.24 fg/m^3, recorded in Mt. Kenya (Kenya) and Brazzaville (Republic of Congo), respectively.

Relatively high concentrations were recorded in 2014, with sum 17 PCDDs/Fs ranging between 41.86 -2,649.50 fg/m^3, with the lowest and highest levels measured in samples from Mt. Kenya (Kenya) and Accra (Ghana), respectively. Moderate levels were 2,370.39 fg/m^3 (Khartoum, Sudan), 1,517.00 fg/m^3 (Brazzaville, Republic of Congo), 1,244.18 fg/m^3 (Chiromo, Kenya), and 817.07 fg/m^3 (Reduit, Mauritius).

In 2015, the mean levels of sum 17 PCDDs/Fs varied from 38.12-1,558.27 fg/m^3 recorded in Mt. Kenya (Kenya) and Brazzaville (Republic of Congo), respectively. The medium levels recorded were 1,078.50 fg/m^3 (Marroco Observatory, Morocco), 1,043.55 fg/m^3 (Accra, Ghana), and 719.16 fg/m^3 (Reduit, Mauritius).

2016 mean concentrations of sum 17 PCDDs/Fs ranged from 52.90 -1,392.19 fg/m^3 recorded in Mt. Kenya (Kenya) and Bamako (Mali), respectively. Other high levels recorded were 1,016.16 fg/m^3 (Brazzaville, Republic of Congo), 688.70 fg/m^3 (Reduit, Mauritius), 402.76 fg/m^3 (Morocco Observatory, Morocco), and 366.73 fg/m^3 (Accra, Ghana).

2017 recorded seven datasets for of sum 17 PCDDs/Fs with levels between 39.42-1,924.06 fg/m^3 for Mt. Kenya and Bamako (Mali), with medium levels of 1,611.11 fg/m^3 (Reduit, Mauritius), 1,402.96 fg/m^3 (Brazzaville, Republic of Congo), and 358.51 fg/m^3 (Asela, Ethiopia).

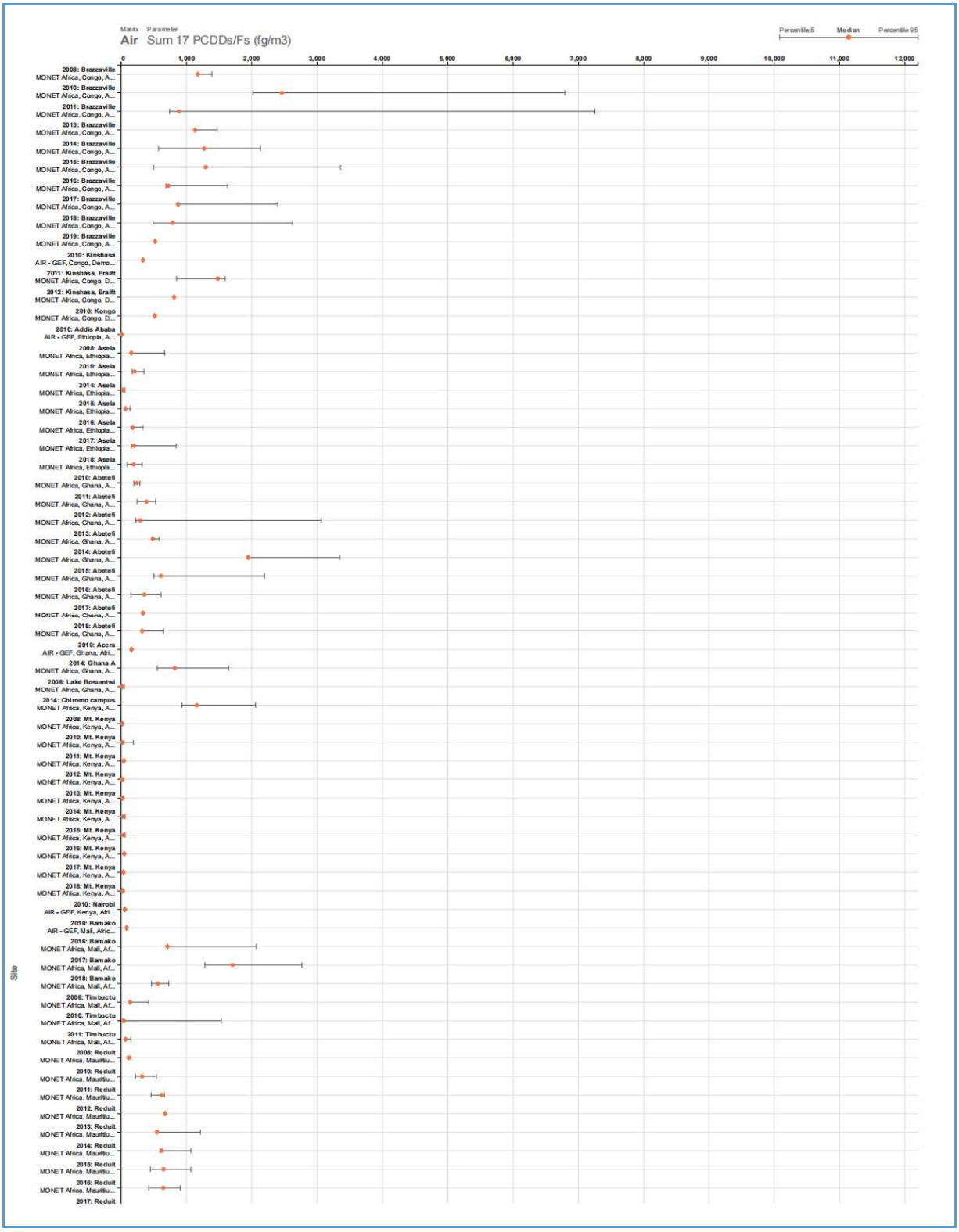


Figure 5.2.1.22 Sum 17 PCDDs/Fs concentration in ambient air

The mean concentrations recorded in 2018 varied from 26.48 -1,575.99 fg/m^3, for Mt. Kenya and Reduit (Mauritius), respectively. Intermediate levels recorded were 1,255.78 fg/m^3 (Brazzaville, Republic of Congo), 598.49 fg/m^3 (Bamako, Mali), and 489.25 fg/m^3 (Accra, Ghana).

Only two data sets for sum 17 PCDDs/Fs were recorded in 2019 with mean concentrations of 525.76 fg/m^3 (Brazzaville, Republic of Congo) and 191.42 fg/m^3 (Reduit, Mauritius). High prevalence of PCDDs/Fs in the region could be attributed to uncontrolled combustion activities such as biomass burning and forest fires (Lammel et al., 2013), among others. Generally the concentrations measured over the period suggest gradual development of declining trend of sum 17 PCDDs/Fs in ambient air in the region, especially for sites that have been in operation for over 10 years. Further monitoring activities are needed to develop long-term trends of PCDDs/Fs in the region.

PCDDs/Fs Toxic equivalent

The sum 17 PCDDs/Fs WHO_{2005} TEQ for POPs in ambient air for the period 2001- 2019 varied from 0.77 – 200.85 fg/m^3. The highest sum 17 PCDDs/Fs was recorded in Bamako (Mali), Reduit (Mauritius), Accra (Ghana), Brazaville (Republic of Congo) and Kinshasa (DRC) (Figure 5.2.1.23).

The highest levels of sum 7 PCDDs/Fs WHO_{2005} TEQ were recorded in Lusaka (Zambia) in 2018, Soroti (Uganda), Tunis (Tunisia) and Kouma-Konda (Togo) as illustrated in Figure 5.2.1.25.

The highest levels of sum 10 PCDFs WHO_{2005} TEQ ranged from 0.46 – 123.82 fg/m^3. . The highest levels were recorded in Darkar Ngoye (Senegal), followed by 111.62 fg/m^3 (Khartoum, Sudan), 110.48 fg/m^3 (Bamako, Mali) and 100.33 fg/m^3 (Reduit Mauritius). Medium levels were recorded in Brazaville (Republic of Congo), Chiromo (Kenya), and Accra (Ghana) (Figure 5.2.1.27).

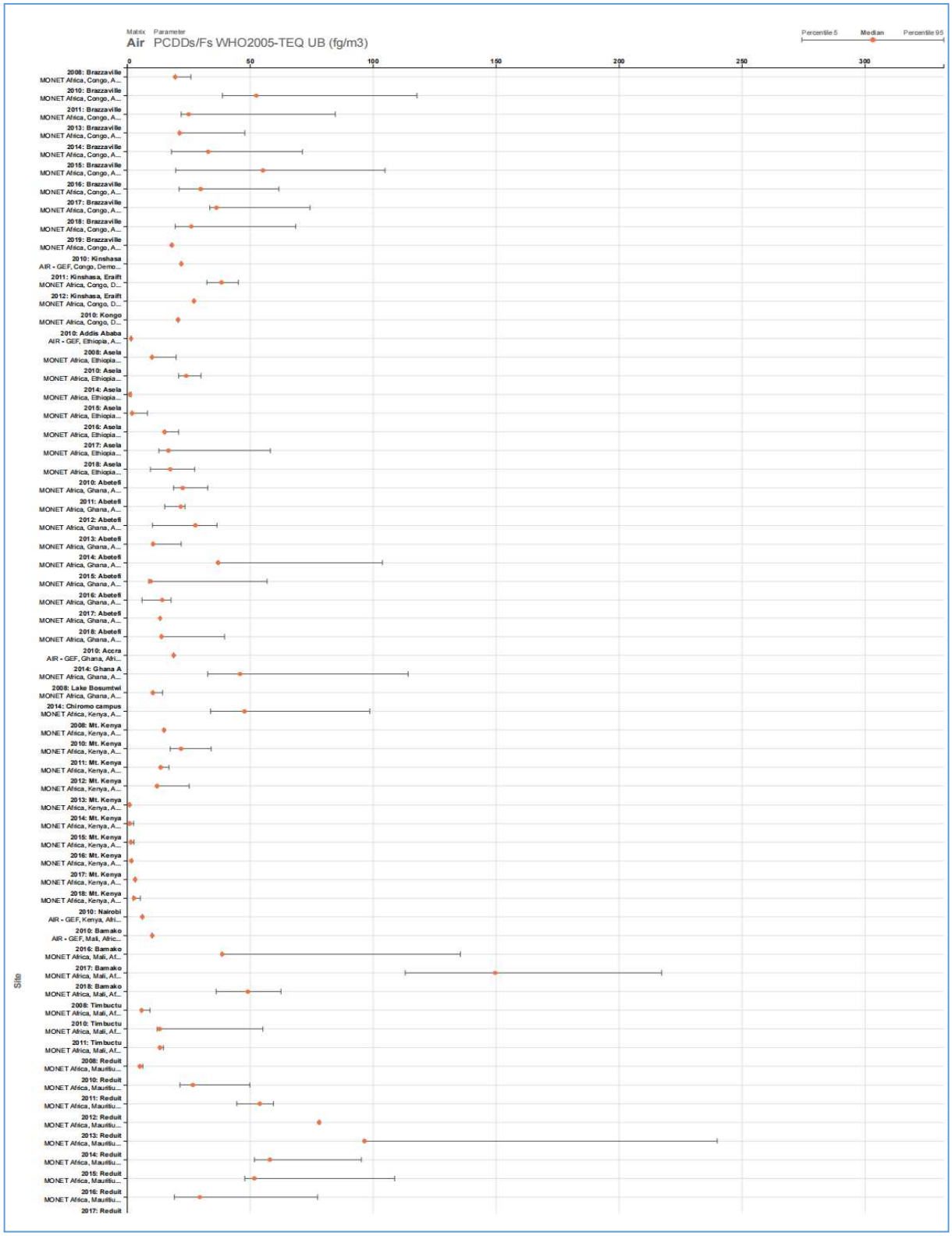


Figure 5.2.1.23 Sum 17 PCDDs/FsWHO2005 TEQ in ambient air

Figure 5.2.1.24 shows the summary of sum 7 PCDDs concentration in ambient air in ambient air.

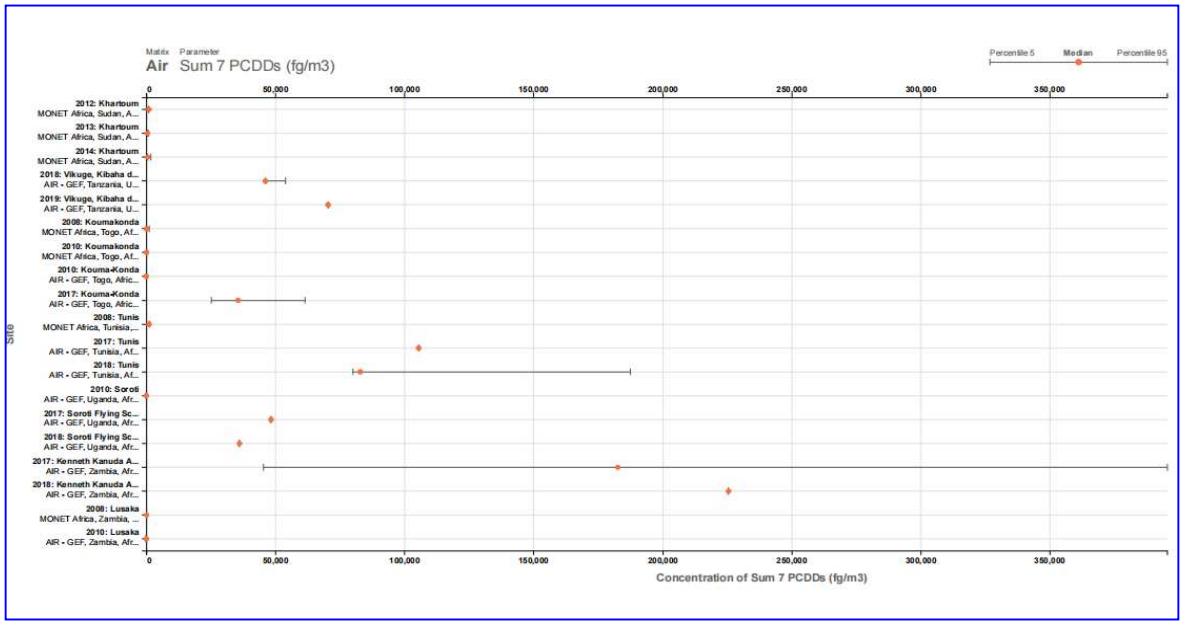


Figure 5.2.1.24 Sum 7 PCDDs concentration in ambient air

Figure 5.2.1.25 shows the sum 7 PCDDs$_{WHO2005}$ TEQ in ambient air

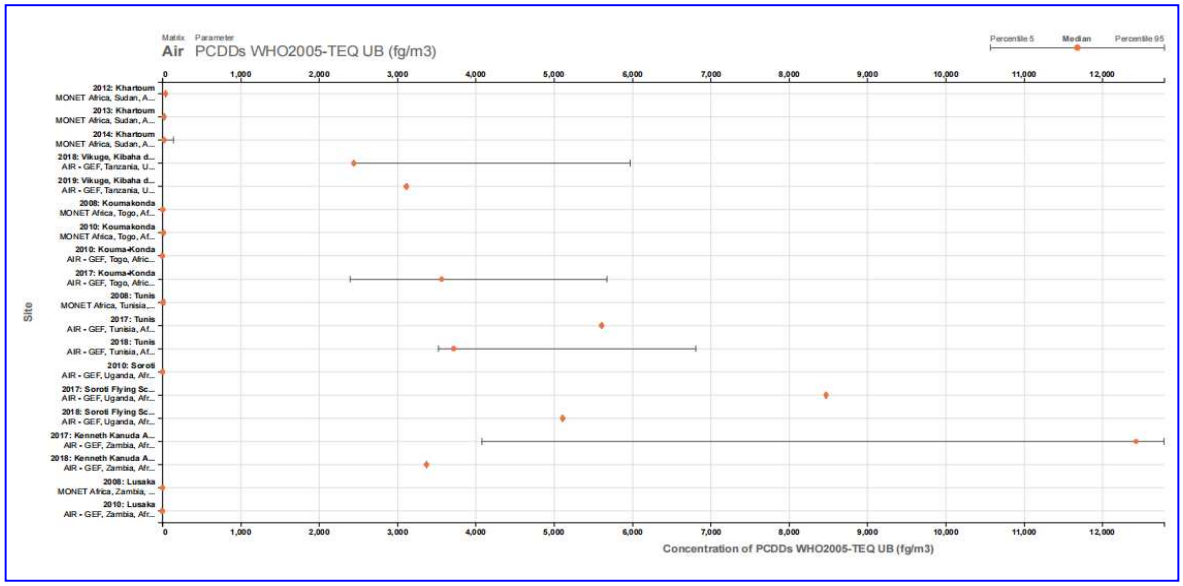


Figure 5.2.1.25 Sum 7 PCDDsWHO_{2005} TEQ in ambient air

Figure 5.2.1.26 shows the summary of the sum 10 PCDFs concentration in ambient air for the period 2008-2019

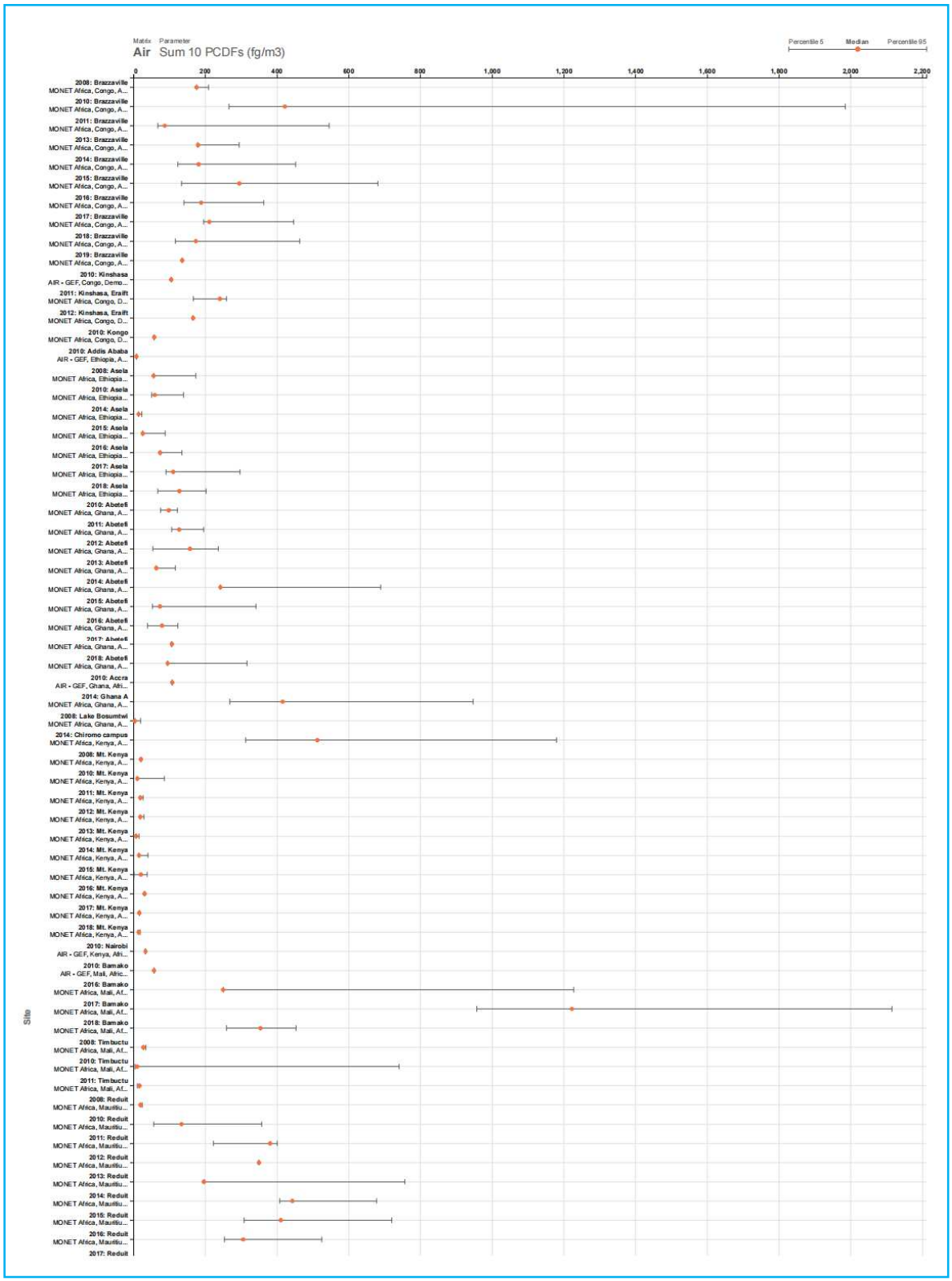


Figure 5.2.1.26 Sum 10 PCDFs concentration in ambient air

Figure 5.2.1.27 shows the summary of sum 10 $PCDFs_{WHO2005}$ TEQ in ambient air for the period 2008-2019.

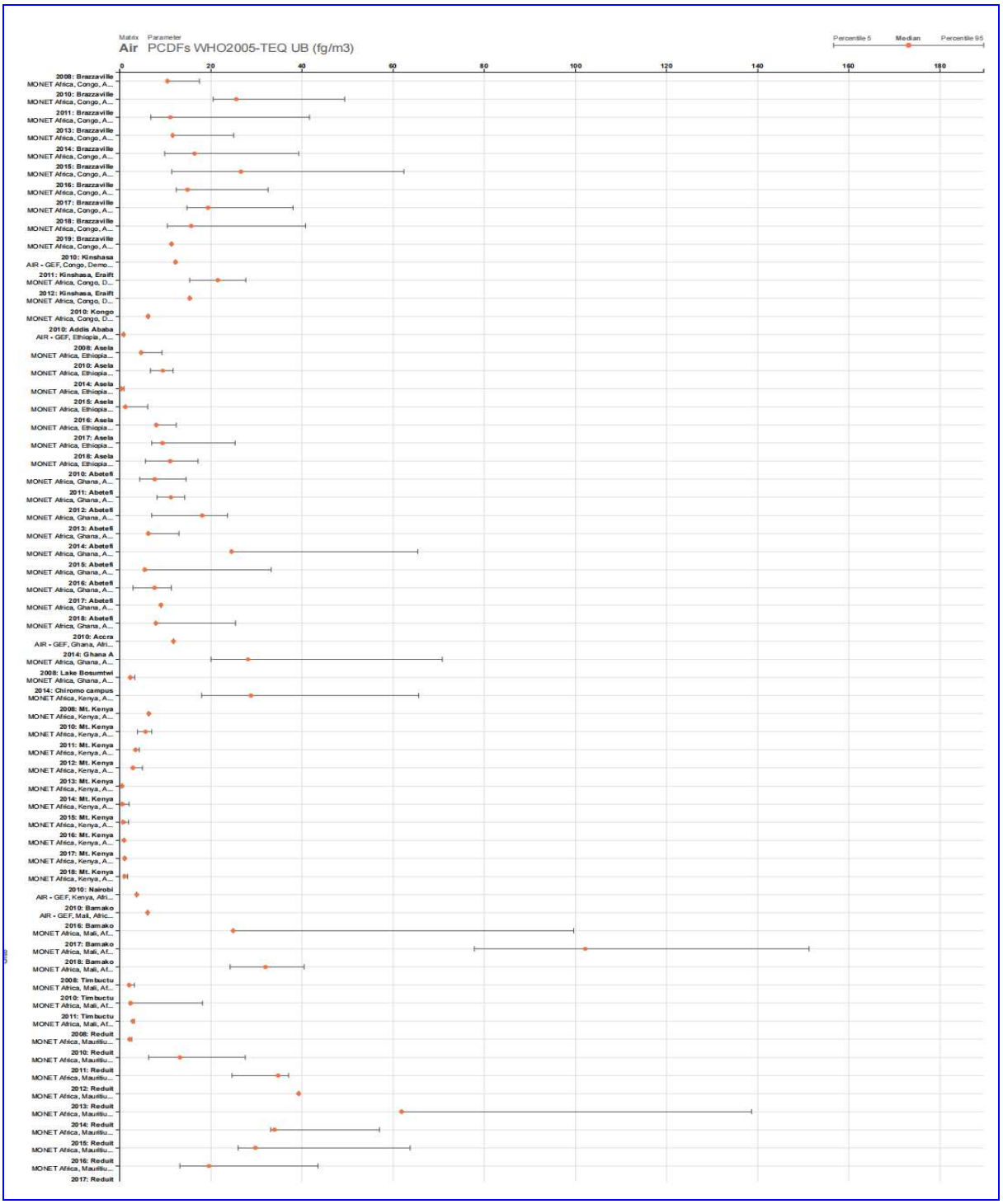


Figure 5.2.1.27 Sum 10 PCDFsWHO2005 TEQ in ambient air

New POPs in ambient air

5.2.1.13 Chlordecone

The concentrations of chlordecone in the region over the period 2008-2019 have only been analysed in two sites namely Accra Ghana (237.95 pg/m^3) and Chiromo, Kenya (3,300.30 pg/m^3. Both datasets are for 2014.

5.2.1.14 Endosulphans (*alpha*- and *beta*-Endosulphan, and endosulphan sulphate)

Endosulphan compounds monitored in the ambient air were the alpha- and beta-endosulphan, and endosulphan sulphate. Endosulphans levels were dominated by alpha-Endosulphan while the beta-endosulphan isomer and endosulphan sulphate recorded lower levels.

Alpha-endosulphan

The concentrations of *alpha*-endosulphan varied from 0.09-402,205.31 pg/m^3 for the period 2004-2019. The mean concentrations in 2004, 2005, 2006 and 2007 were 318.16 pg/m^3 (De Aar, South Africa) for 2004, 49.10-2194.82 pg/m^3 in 2005 recorded in Kalahari and Abono sites, respectively. In 2006 the levels ranged 51.23-1251.54 pg/m^3 recorded in Kalahari and Abono sites, respectively, while in 2007 the concentrations ranged from 29.73-138.30 pg/m^3 recorded in Kalahari and De Aar sites, respectively.

In 2008, the mean concentrations of *alpha*-endosulphan varied between 1.76-599.15 pg/m^3 recorded in Mt. Kenya and Dakar Ngoye, respectively. Medium levels recorded were 401.07 pg/m^3 (Asela, Ethiopia), 381.95 pg/m^3 (Kouma-Konda, Togo), 318.60 pg/m^3 (De Aar, South Africa), 163.85 pg/m^3 (Brazzaville, Republic of Congo), and 139.04 pg/m^3 (Tunis, Tunisia). 2009 registered reduced dataset with only three records reported. The mean levels ranged 59.21 - 115.84 pg/m^3 recorded in De Aar and Mt. Kenya sites, respectively. Medium level of 75.49 pg/m^3 was recorded in Vanderbijl site in South Africa.

2010 recorded mean concentrations of *alpha*-endosulphan between 9.14- 217.77 pg/m^3 with lowest and highest levels registered in Timbuktu (Mali) and Asela (Ethiopia). Intermediate concentrations recorded were 151.15 pg/m^3 (Sheda, Nigeria), and 122.56 pg/m^3 (Abetefi, Ghana), while majority of the sites had levels below 20 pg/m^3.

In 2011 the mean levels of *alpha*-endosulphan were between 4.44-103.42 pg/m^3 with the lowest and highest concentrations recorded in Timbuktu (Mali) and Khartoum (Sudan). The medium levels in 2011 were 41.73 pg/m^3 (Sheda, Nigeria), 28.87 pg/m^3 (Abetefi, Ghana), 32.34 Noottgedatch (South Africa) and 11.40 (Brazzaville, Republic of Congo).

2012, 2013, and 2014 recorded concentration ranges of 0.30-35.69 pg/m^3, 0.15-19.12 pg/m^3, and 0.04-593.39 pg/m^3, respectively. Medium levels in 2014 were 13.94 pg/m^3 (Chiromo, Kenya), 22.13 pg/m^3 (Khartoum, Sudan) and 12.07 pg/m^3 (Marroco Observatory, Morocco).

The concentrations of *alpha*-endosulphan recorded in 2015 ranged from 0.84-432.99 pg/m^3 with the lowest and highest levels recorded in Reduit (Mauritius) and Asela (Ethiopia), while in 2016 the mean levels varied from 0.09-47.54 pg/m^3, with lowest and highest levels recorded in Bamako (Mali) and Asela (Ethiopia). Figure 5.2.1.28 shows the levels of *alpha*-endosulphan in ambient air.

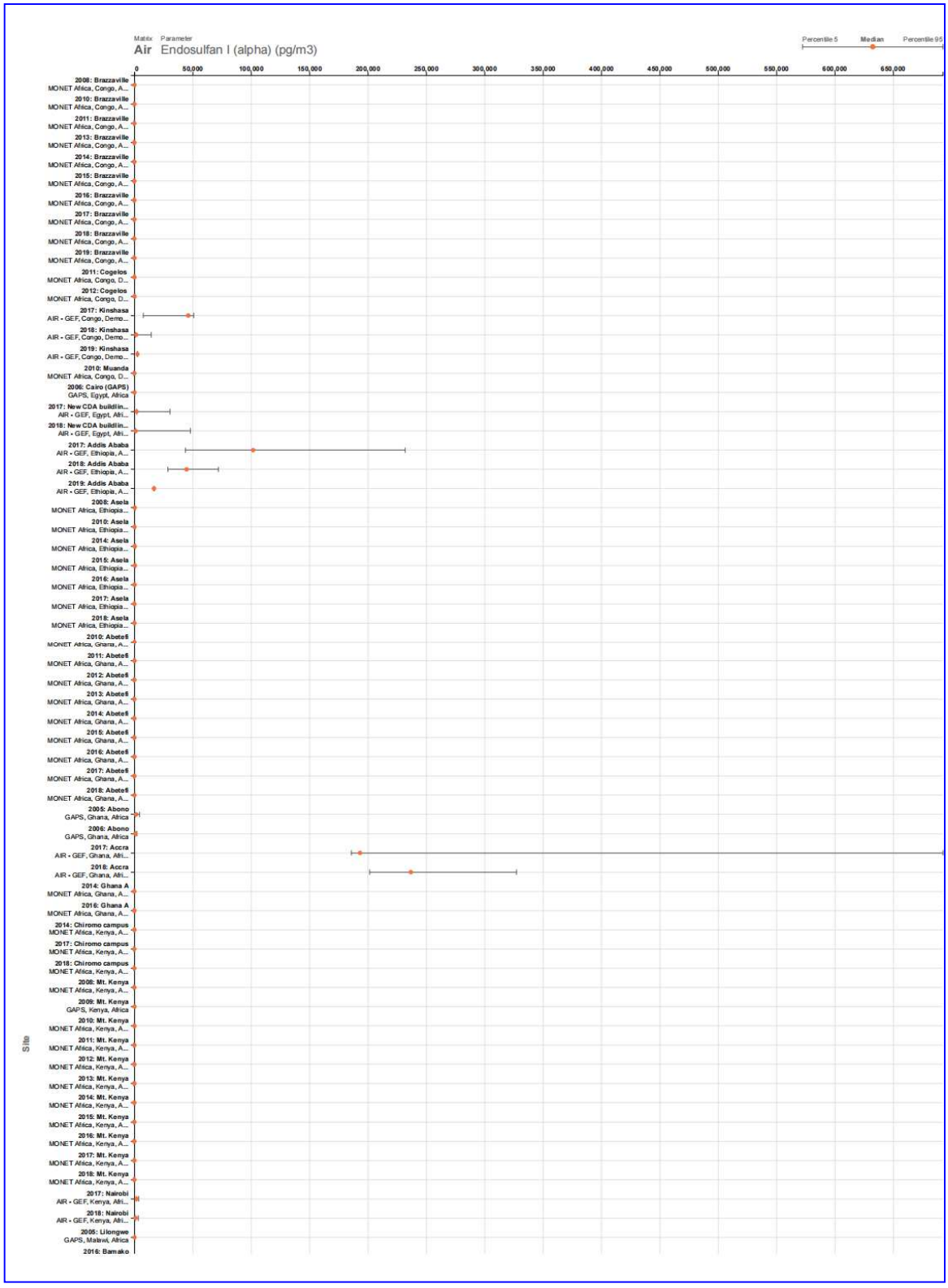


Figure 5. 5.2.1.28 Alpha-endosulphan concentration in ambient air

2017, 2018 and 2019 recorded relatively higher levels. In 2017 the mean levels varied from 0.08-402,205.31 pg/m^3 for Sheda (Nigeria) and Accra (Ghana). Intermediate levels were 125,882.05 pg/m^3 (Addis Ababa, Ethiopia), 23,005.17 pg/m^3 (Dakar Ngoye, Senegal), 17,423.72 pg/m^3 (KoumaKonda, Togo), and 11,514.37 pg/m^3 (CDA, Egypt).

In 2018 the mean concentrations of *alpha*-endosulphan ranged from 0.27 -263,147.89 pg/m^3 for Reduit (Mauritius) and Accra (Ghana), respectively. Intermediate levels included 51,771.89 pg/m^3 (Addis Ababa, Ethiopia), 15,219.85 pg/m^3 (KoumaKonda, Togo), 12,871.83 pg/m^3 (CDA, Egypt) and 5,046.93 pg/m^3 (Kinshasa, DRC).

2019 recorded five datasets for alpha-endosulphan with mean levels between 0.33-16,822.97 pg/m^3 recorded in Reduit (Mauritius) and (Addis, Ababa, Ethiopia). Medium levels in 2019 were 5,462.83 pg/m^3 (Vikuge, Tanzania), and 2,715.52 pg/m^3 (Kinshasa, DRC).

Beta endosulphan

The levels of beta-endosulphan ranged between 0.03-770.38 pg/m^3 for the data collected in the period 2004-2018. In 2004 a single dataset was recorded with a mean concentration of 25.69 pg/m^3 (De Aar, South Africa). 2005 dataset had mean concentrations ranging from 1.71-770.38 pg/m^3, with the lowest and highest levels registered in Kalahari and Abono sites, respectively. Medium levels in 2005 were 14.46 pg/m^3 (Lilongwe, Malawi), and 1.90 pg/m^3 (Kalahari, South Africa) (Figure 5.2.1.29).

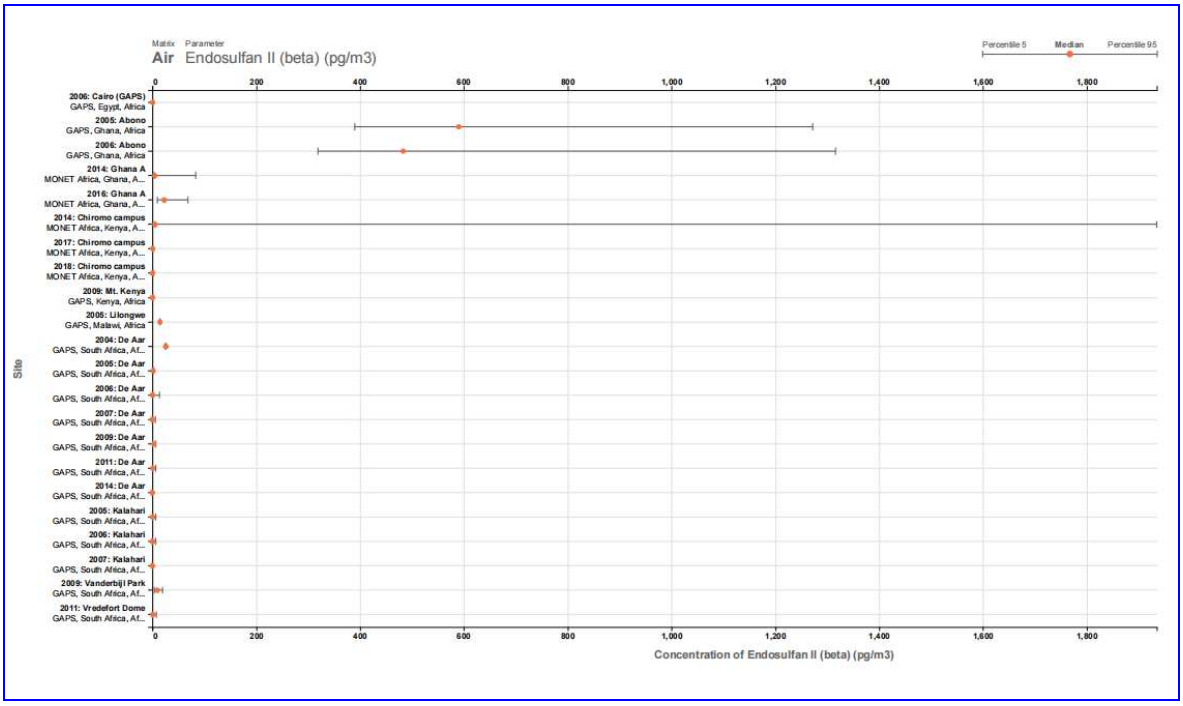


Figure 5.2.1.29 Beta endosulphan concentration in ambient air

In 2006 registered four datasets with mean levels varying between 0.19 -663.78 pg/m^3 recorded in Cairo (Egypt) and Abono (Ghana), while intermediate levels were 3.92 pg/m^3 and 2.18 pg/m^3 for De Aar and Kalahari, South Africa.

Two dataset were recorded in 2007 with mean concentrations of 0.05 pg/m^3 and 1.46 pg/m^3 for De Aar and Kalahari, Respectively. Records for 2009, 2011 and 2014 were 0.19-11.45 pg/m^3, 2.41-2.44 pg/m^3, and 0.03-153 pg/m^3, respectively.

2016, 2017 and 2018 registered a single dataset each with mean concentrations of 28.62 pg/m^3 for Accra (Ghana) in 2016, and 0.66 pg/m^3 and 0.57 pg/m^3 recorded in 2017 and 2018 for Chiromo (Kenya), respectively.

Endosulphan sulphate

Endosulphan sulphate had mean concentrations between 0.04-52.92 pg/m^3 for the period 2004-2018. 2004 recorded endosulphan sulphate concentration of 1.74 pg/m^3 (De Aar, South Africa), while 2005, 2006 and 2007 had mean concentrations ranging 0.04-52.92 for De Aar and Abono in 2005, 0.50-73.10 pg/m^3 for Kalahari and Abono in 2006, and 0.75-1.59 pg/m^{3}for Kalahari and De Aar in 2007.

2008 record was for Mt. Kenya with mean concentration of 0.10 pg/m^3, while 2009 recorded two datasets with mean levels of 0.07 pg/m^3 (Dar Aar) and 1.06 pg/m^3 (Vanderbijl park). The two sites in 2009 also recorded the only two datasets in 2011 with mean concentrations of 2.43 pg/m^3 and 0.76 pg/m^3, respectively.

2014 recorded three datasets for endosulphan sulphate with concentrations of 0.07 pg/m^3 (De Aar, South Africa), 25.73 pg/m^3 (Accra, Ghana) and 356.93 pg/m^3 (Chiromo, Kenya).

2016, 2017 and 2018 recorded a single dataset each with concentrations of 0.26 pg/m^3 in 2016 (Accra Ghana), 0.10 pg/m^3 and 0.11 pg/m^3 for Chiromo, in 2017 and 2018 respectively (Figure 5.2.1.30).

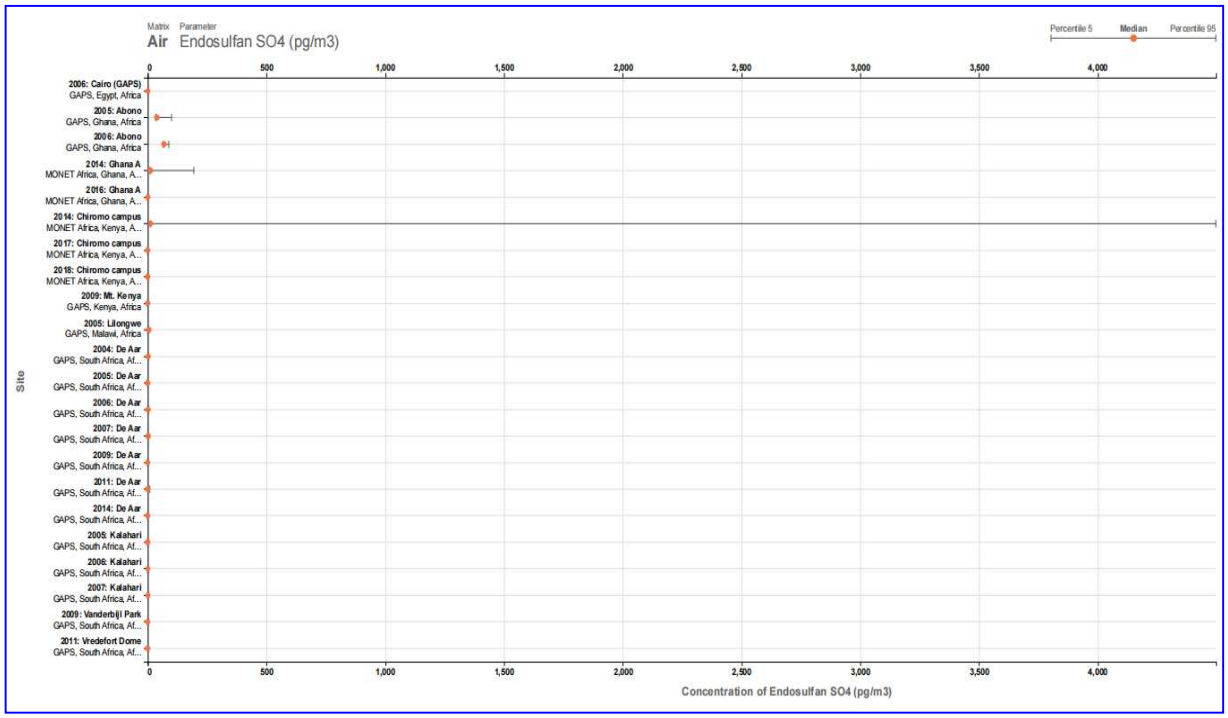


Figure 5.2.1.30 Endosulphan sulphate concentration in ambient air

5.2.1.15 Hexabromobiphenyl (HBB = PBB 153)

The HBB levels in ambient air were monitored in the period 2017-2019, with mean concentrations ranging from 0.15-1.91 pg/m^3. In 2017 the mean levels varied from 0.15-0.52 pg/m^3, with the lowest levels recorded in Kinshasa (DRC), whereas the highest were in KoumaKonda (Togo) and Accra (Ghana).

In 2018 the mean levels of HBB ranged from 0.39-1.91 pg/m^3 for Soroti (Uganda) and Kinshasa (DRC), respectively. 2019 registered four datasets with concentrations varying from 0.15-0.50 pg/m^3 with the lowest and highest levels recorded in Kinshasa (DRC) and Addis Ababa (Ethiopia). The levels of HBB measured in the regional sites are illustrated in Figure 5.2.1.31.

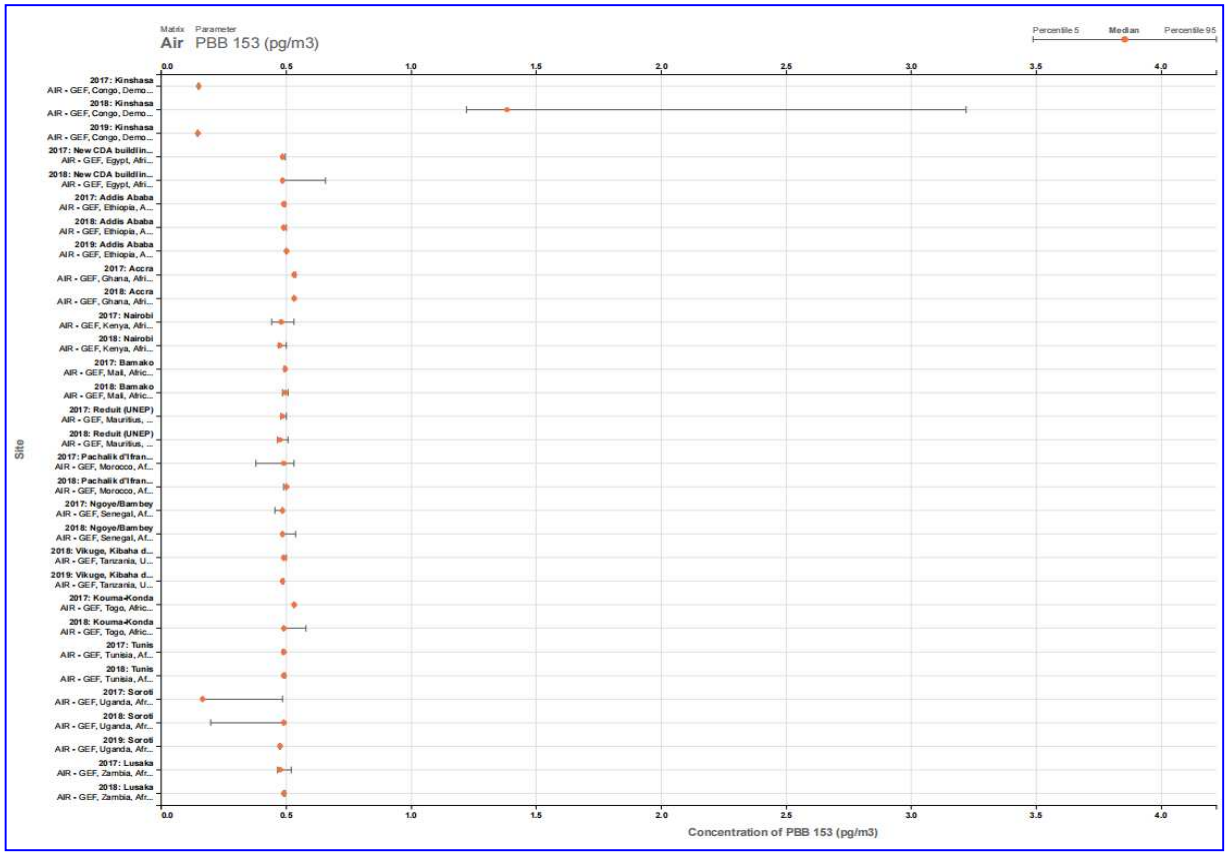


Figure 5.2.1.30. HBB levels concentration in ambient air

5.2.1.17 Hexabromocyclododecanes (HBCD)

HBCD isomers monitored in the ambient air for the period 2017-2019 were Alpha-, beta- and gamma-HBCD. The highest levels were observed for gamma-HBCD and alpha-HBCD compared the beta-HBCD isomer.

Alpha-HBCD

The concentration varied from 0.04-47,788.55 pg/m^3 in the period 2014-2019. The levels measured in 2014 were 0.04-1.66 pg/m^3 recorded in De Aar (South Africa) and Accra (Ghana) respectively, while 0.3 pg/m^3 was recorded in Accra (Ghana) in 2016.

The mean concentrations in 2017 ranged 112.93-47,788.55 pg/m^3 which were measured in Soroti (Uganda) and Lusaka (Zambia), respectively. Intermediate levels recorded in 2017 were 5,082.60 pg/m^3 (CDA, Egypt), 4,574.21 pg/m^3 (Kinshasa, DRC), 3,419.76 pg/m^3 (KoumaKonda, Togo) and 1,621.78 pg/m^3 (Tunis, Tunisia). 2018 datasets had mean concentrations of *alpha*-HBCD ranging from 254.84 -49,307.02 pg/m^3 recorded in Kabete (Kenya) and Lusaka (Zambia), respectively. Medium levels observed were 21,961.06 pg/m^3 (Vikuge, Tanzania), 6,484.18 pg/m^3 (KoumaKonda, Togo), and 6,046.92 pg/m^3 (CDA, Egypt), 3,969.13 (Dakar Ngoye, Senegal), 3,886.97 pg/m^3 (Kinshasa, DRC), 1,191.93 pg/m^3 (Addis Ababa, Ethiopia), and 1,148.07 pg/m^3 (Tunis, Tunisia). The rest of the sites had concentrations less than 1,000.0 pg/m^3.

In 2019 only four datasets were recorded with mean concentration of *alpha*-HBCD ranging between 276.01- 2,821.62 pg/m^3 recorded in Vikuge (Tanzania) and Addis Ababa, Ethiopia), while intermediate levels were 732.02 pg/m^3 (Soroti, Uganda) and 739.84 pg/m^3 (Kinshasa, DRC). The levels of *alpha*-HBCD are illustrated in Figure 5.2.1.32.

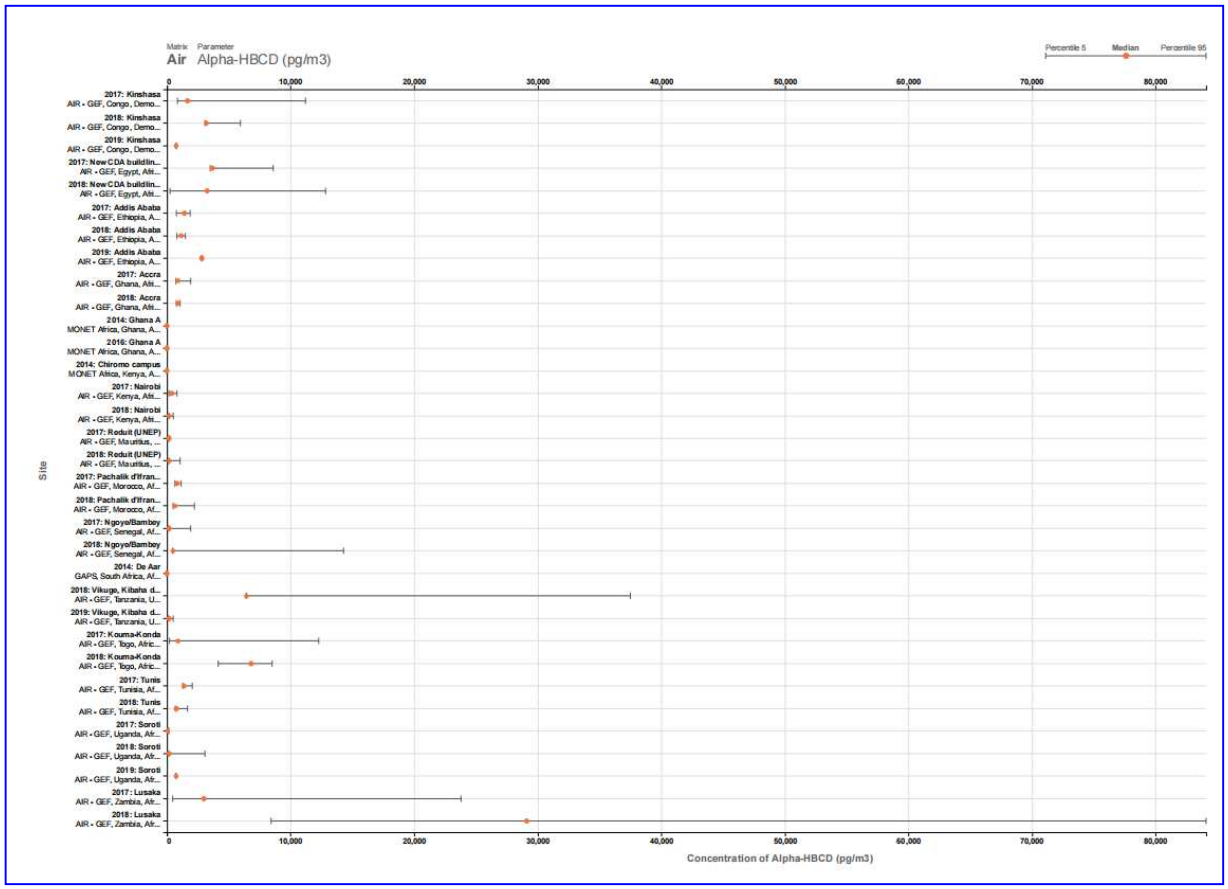


Figure 5.2.1.32. Alpha-HBCD concentration in ambient air

Beta-HBCD

The concentration of beta-HBCD was monitored in ambient air samples in the period 2014-2019, and mean levels ranged from 0.03-14,109.47 pg/m^3. 2014 recorded only three datasets for beta-

HBCD with means concentrations of 0.03 pg/m^3 (De Aar, South Africa), 0.14 pg/m^3 (Chiromo, Kenya) and 0.51 pg/m^3 (Accra, Ghana), while 2016 registered a single dataset with mean concentration of 0.09 pg/m^3 (Accra, Ghana).

In 2017 the mean concentrations of *beta*-HBCD ranged from 112.93-2,222.60 pg/m^3, with the lowest and highest levels measured in Soroti (Uganda) and Lusaka (Zambia), respectively. The medium levels were 1,621.83 pg/m^3 (Kouma-Konda, Togo), 824.53 pg/m^3 (Kinshasa, DRC), 803.35 pg/m^3 (CDA, Egypt), and 343.57 pg/m^3 (Accra, Ghana).

2018 *beta*-HBCD concentrations varied from 282.53-14,109.47 pg/m^3 suggesting an elevation in the concentrations measured in the region. The highest and lowest levels were recorded in Kabete (Kenya) and Lusaka (Zambia) sites, respectively. Intermediate concentrations were 9,934.52 pg/m^3 (Vikuge, Tanzania), 3,578.89 pg/m^3 (Kouma-Konda (Togo), 1,498.28 pg/m^3 (Kinshasa, DRC) and 1,495.99 pg/m^3 (CDA, Egypt).

2019 registered only four datasets with mean concentrations of *beta*-HBCD between 168.89 - 966.31 pg/m^3 recorded in Vikuge (Tanzania) and Addis Ababa (Ethiopia), respectively. Medium levels were 665.86 pg/m^3 (Kinshasa, DRC) and 512.42 pg/m^3 (Soroti, Uganda). The levels of beta-HBCD are illustrated in Figure 5.2.1.33.

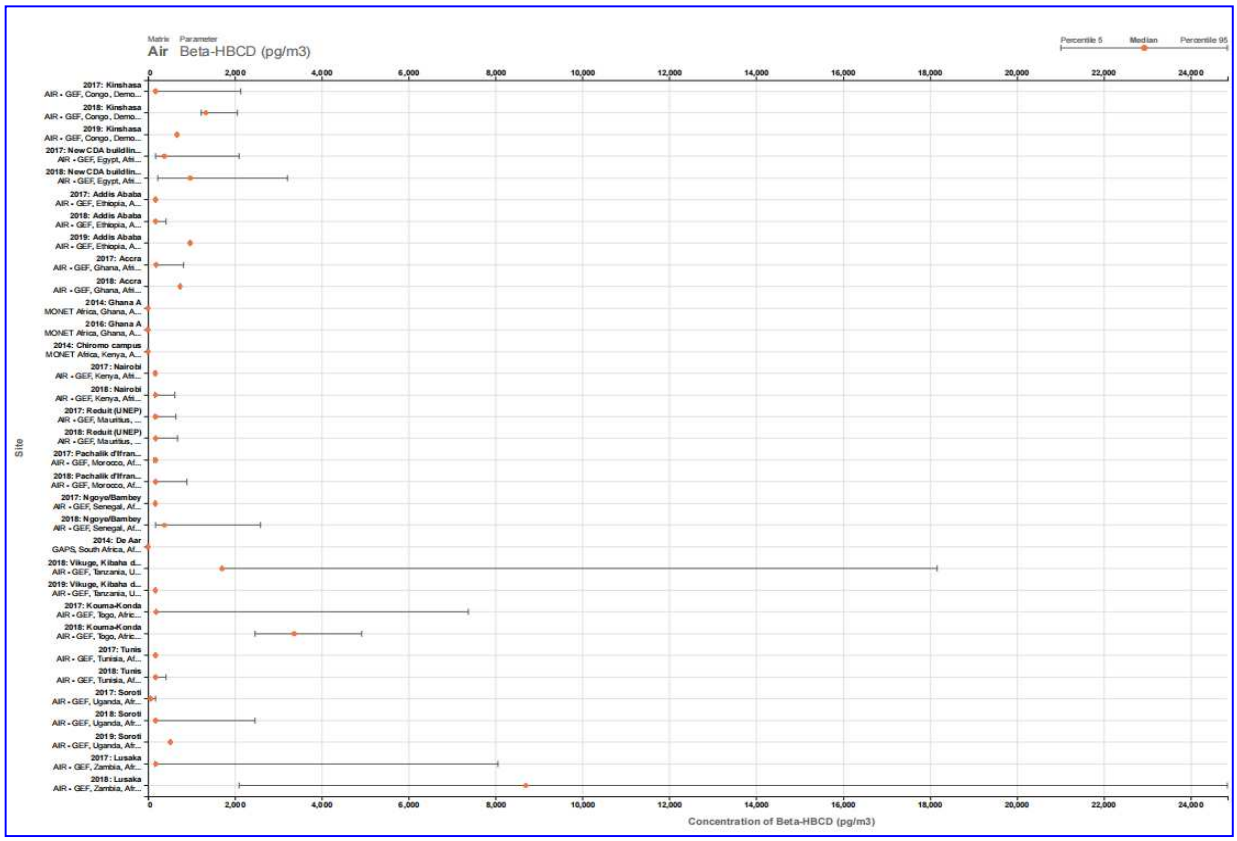


Figure 5.2.1.33 beta-HCBD concentration in ambient air

Gamma-HBCD

Gamma-HBCD levels in ambient air for the period 2014-2019 ranged from 0.03-49,339.42 pg/m^3. The mean concentrations in 2014 ranged from 0.03-4.63 pg/m^3 with the lowest and highest levels recorded in De Aar (South Africa) and Accra (Ghana). 2016 had a single dataset for gamma-HBCD with a mean concentration of 0.46 pg/m^3 (Accra, Ghana).

In 2017, the mean levels ranged from 161.87- 9,325.49 pg/m^3 recorded in Pachalik (Morocco) and Kouma-Konda (Togo), respectively. Intermediate concentrations recorded were 986.30 pg/m^3 (Accra, Ghana), 848.02 pg/m^3 (Kouma-Konda (Togo), 762.21 pg/m^3 (Kinshasa, DRC), and 641.24 pg/m^3 (Lusaka, Zambia). The summary of *gamma*-HBCD levels are given in Figure 5.2.1.34.

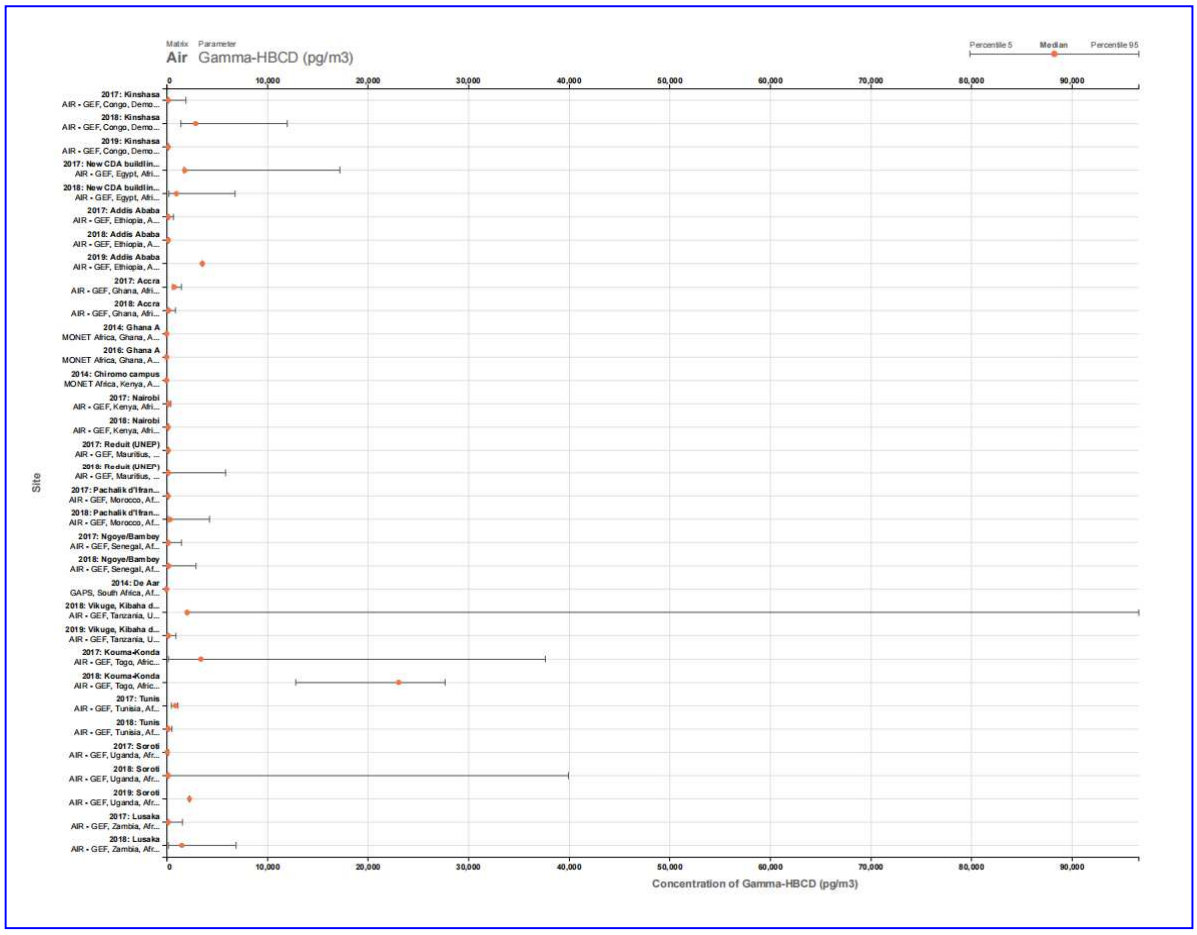


Figure 5.2.1.34. Gamma-HBCD concentration in ambient air

2018 dataset had mean levels between 167.92-49,339.42 pg/m^3 recorded in Kabete (Kenya) and Vikuge (Tanzania), respectively. Medium levels were 21,205.32 pg/m^3 (Kouma-Konda, Togo), 13,427.52 pg/m^3 (Soroti, Uganda), 5,052.85 pg/m^3 (Kinshasa, DRC), 3,496.98 pg/m^3 (CDA, Egypt), and 3,180.90 pg/m^3 (Lusaka, Zambia).

2019 had mean concentrations of gamma-HBCD between 166.47-3,556.04 pg/m^3 with the lowest and highest levels recorded in Kinshasa (DRC), and Addis Ababa (Ethiopia). Medium levels were 414.63 Vikuge (Tanzania) and 2,269.28 pg/m^3 (Soroti, Uganda).

5.2.1.18 Hexachlorocyclohexanes (HCHs)

The HCHs isomers monitored in ambient air in the period 2004-2019 included *alpha-, beta-* and *gamma*-HCH. All the Isomers of HCHs registered significantly high concentrations in ambient air.

Alpha-HCH

Alpha-HCH levels in ambient air ranged from 0.22-102,901.75 pg/m^3 in the period 2004-2019. The mean concentrations of *alpha*-HCH in 2004, 2005, 2006 and 2007 were 58.28 pg/m^3 (De Aar, South Africa) in 2004, 0.10-27.26 pg/m^3 in 2005, 0.08-23.42 pg/m^3 in 2006 and 1.21-26.96 pg/m^3 in 2007.

In 2008, the mean levels of *alpha*-HCH ranged from 2.59-5723.50 pg/m^3 with the lowest and highest concentrations reported in Reduit (Mauritius) and Tunis (Tunisia), respectively. In 2009 three datasets were registered and the mean concentrations varied between 1.66-7.01 pg/m^3.

2010 and 2011 registered increased datasets due to the contribution of additional monitoring sites from the UNEP/GEF GMP1 project. The mean levels ranged from 2.04-106.84 pg/m^3. 2011 recorded concentrations between 0.66-49.65 pg/m^3, while the levels in 2012 had mean concentrations ranging from 0.90-4.00 pg/m^3. In 2013 and 2014, the mean levels of *alpha*-HCH varied from 0.64-17.53 pg/m^3, and 0.22-10.17 pg/m^3, respectively. *Alpha*-HCH levels in 2015 ranged from 0.42-4.69 pg/m^3, while in 2016, the mean concentrations varied from 0.11-3.62 pg/m^3.

2017-2019 period registered increased levels of *alpha*-HCH in some sites although the levels in background sites remained relatively low. The mean concentrations in 2017 ranged from 0.22-27,110.88 pg/m^{3}with the lowest and highest levels recorded in Abetefi (Ghana) and CDA (Egypt). Medium levels recorded were 12,522.97 pg/m^3 (Dakar Ngoye Bambey, Senegal), 8,091.69 pg/m^3 (Addis Ababa, Ethiopia), 7,809.96 pg/m^3 (Tunis, Tunisia), 7,473.68 pg/m^3 (Lusaka, Zambia), and 5,930.96 pg/m^3 (Kinshasa, DRC).

In 2018 the levels of *alpha*-HCH ranged from 0.26-102,901.75 pg/m^3 with the lowest and highest levels measured in Reduit (Mauritius) and Vikuge (Tanzania). Intermediate concentrations recorded were 17,006.63 pg/m^3 (CDA, Egypt), 7,903.43 pg/m^3 (Tunis, Tunisia), 7,412.41 pg/m^3 (Dakar Ngoye Bambey, Senegal), 7,223.15 pg/m^3 (Pachalik, Morocco), 7,203.35 pg/m^3 (Addis Ababa, Ethiopia) and 6,879.57 pg/m^3 (Kinshasa, DRC).

In 2019 the mean levels of ranged between 0.35-32,348.67 pg/m^3 recorded in Reduit (Mauritius) and Kinshasa (DRC), respectively. High levels recorded were 24,506.87 pg/m^3 (Vikuge, Tanzania), and 4,910.06 pg/m^3 (Addis Ababa, Ethiopia). The concentrations of *alpha*-HCH are illustrated in Figure 5.2.1.35 below.

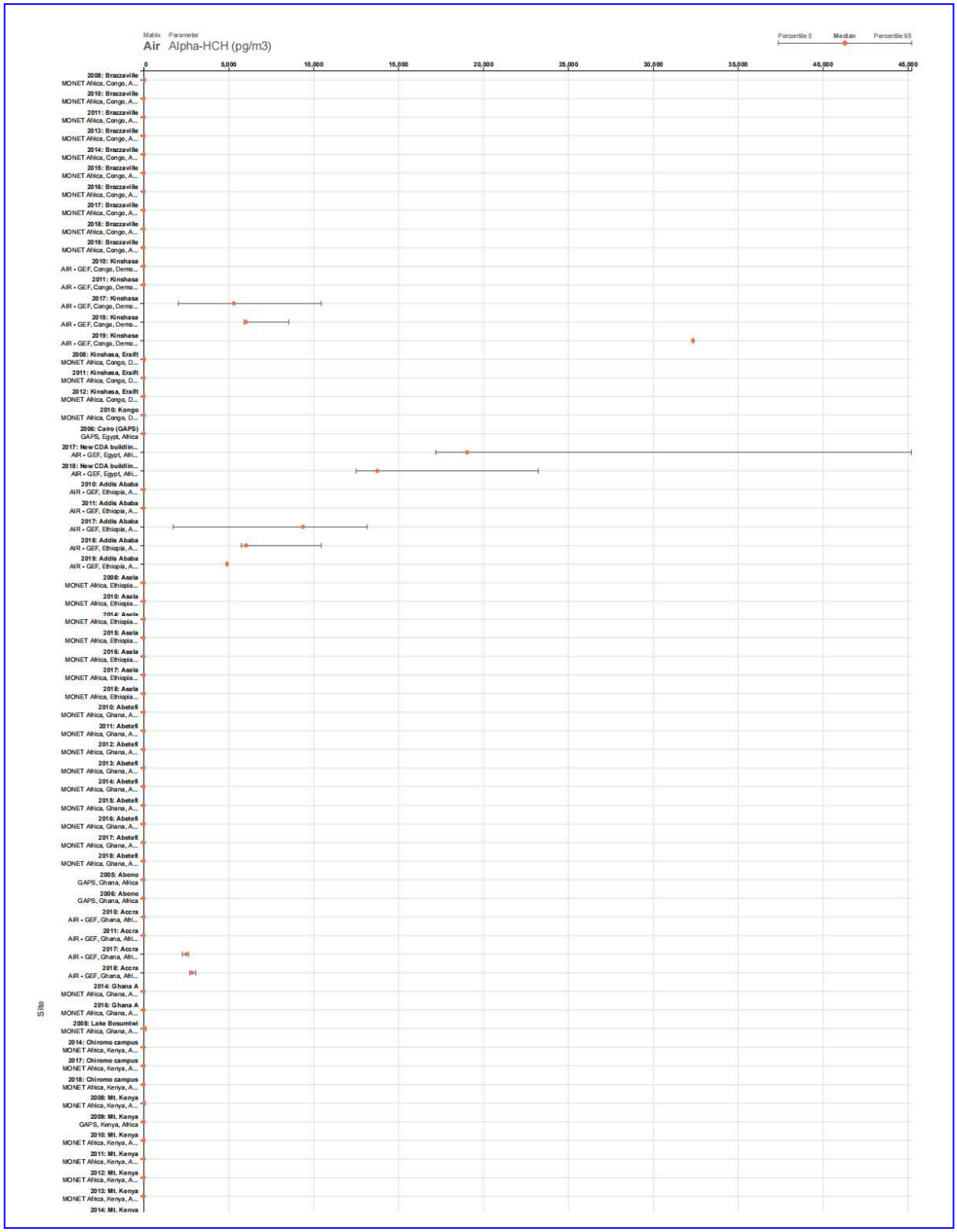


Figure 5.2.1.35 Alpha-HCH concentration in ambient air

***Beta*-HCH**

Beta-HCH mean concentrations in the period 2007-2019 ranged between 0.10-297,356.98 pg/m^3. In 2007 the mean concentration was 0.39 pg/m^3 recorded at both De Aar and Kalahari sites (South Africa). 2008 mean concentrations ranged 0.39-903.84 pg/m^3 with lowest and highest levels recorded in Asela and Tunis, respectively.

2009 mean levels of *beta*-HCH recorded concentrations of 2.23 pg/m^3 (Mt. Kenya), 5.33 pg/m^3 (De Aar, South Africa) and 8.69 pg/m^3 (Nooitgedacht, South Africa). 2010 recorded *beta*-HCH concentrations ranging from 0.04-38.67 pg/m^3 recorded in Sheda (Nigeria) and Dakar Ngoye (Senegal). In 2011 the mean concentrations from 0.40-7.62 pg/m^3, while 2012 had mean concentrations between 0.42-7.14 pg/m^3.

2013 and 2014 recorded mean concentrations ranging from 0.12-13.36 pg/m^3 and 0.10-13.62 pg/m^3, respectively. 2015 and 2016 recorded relatively lower concentrations with mean levels ranging from 0.17-1.94 pg/m^3 and 0.07-2.56 pg/m^3, respectively.

Elevated levels were recorded in the period 2017-2019, with mean levels in 2017 ranging 23,631.96 pg/m^3 with the lowest and highest concentrations in Abetefi (Ghana) and Dakar Ngoye/Bambey (Senegal). Medium levels in 2017 were 10,300.68 pg/m^3 (CDA, Egypt), 6,269.70 pg/m^3 (Accra, Ghana) and 5,943.22 pg/m^3 (Lusaka, Zambia).

2018 concentrations of *beta*-HCH registered concentrations between 0.05-297,356.98 pg/m^3 with the lowest and highest concentrations recorded in Mt. Kenya and Vikuge, respectively. Intermediate concentrations recorded were 8,861.00 pg/m^3 (CDA, Egypt), 6,380.05 pg/m^3 (Accra, Ghana), and 6,133.70 pg/m^3 (Kouma-Konda, Togo).

In 2019, the mean concentrations varied from 0.11-57,424.34 pg/m^3 recorded in Reduit (Mauritius) and Vikuge (Tanzania), while intermediate levels were 6,425.12 pg/m^3 (Kinshasa, DRC), 5,718.89 pg/m^3 (Soroti, Uganda), and 5,425.12 pg/m^3 (Addis Ababa). Figure 5.2.1.36 shows the levels of *beta*-HCH recorded in the ambient air.

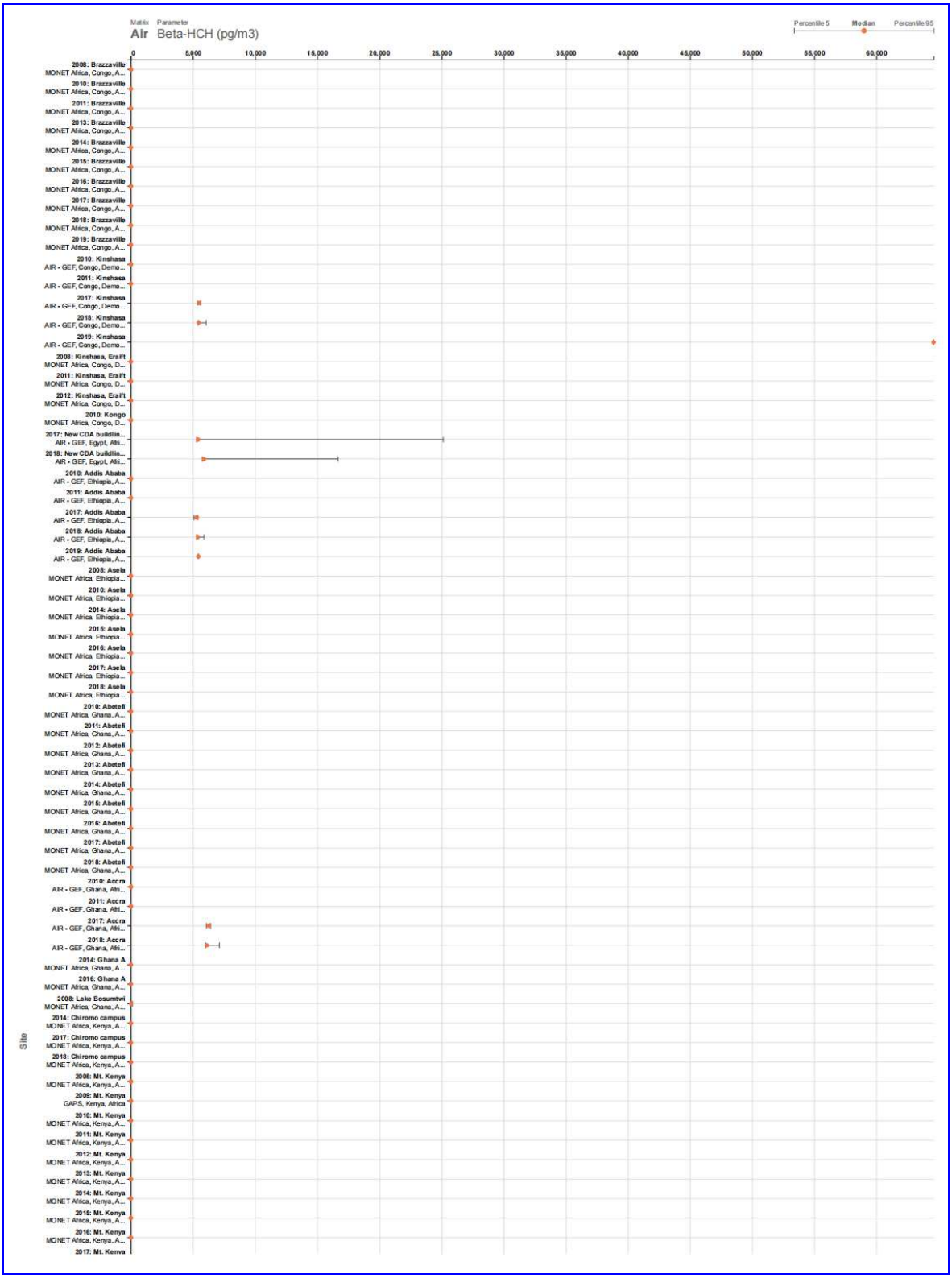


Figure 5.2.1.36 beta-HCH concentration in ambient air

***Gamma*-HCH**

The mean concentrations of *gamma*-HCH in the period 2004-2019 ranged from 0.26-279,255.87 pg/m^3. Concentrations recorded in the period 2004-2007 were 42.00 pg/m^3 (De Aar, South Africa) in 2004, 0.65-37.26 pg/m^3 in 2005, 1.41-15.78 pg/m^3 in 2006 and 0.59-27.59 pg/m^3 in 2007. In 2008, the mean levels of *gamma*-HCH ranged from 21.27-9,753.12 pg/m^3 with the lowest and highest concentrations recorded in Timbuktu (Mali) and 9.753.12 pg/m^3 (Tunis, Tunisia). 2009 recorded mean levels from 2.54-80.51 pg/m^3, while 2010 registered levels between 2.18-44.75 pg/m^3.

Data sets for 2011, 2012, 2013 and 2014 registered concentrations ranging from 1.48-23.39 pg/m^3, 4.82-18.93 pg/m^3, 1.82-291.72 pg/m^3, and 3.62-76.49 pg/m^3, respectively.

In 2015 and 2016, the mean levels of *gamma*-HCH ranged from 2.30-16.29 pg/m^3, and 0.26-14.95 pg/m^3, respectively.

2017-2019 recorded elevated levels in some sites, whereas background sites had relatively low concentrations. In 2017 the mean levels recorded ranged from 1.44-126,007.09 pg/m^3 recorded in Sheda (Nigeria) and Lusaka (Zambia) respectively. Medium levels in 2017 were 30,890.01 pg/m^3 (Kinshasa), 20,725.49 pg/m^3 (Addis Ababa), 14,580.26 pg/m^3 (Reduit, Mauritius), and 11,631.20 pg/m^3 (CDA, Egypt).

2018 levels varied from 0.42-279,255.87 pg/m^3 with the lowest and highest concentrations measured in Mt. Kenya (Kenya) and Vikuge (Tanzania), respectively. Intermediate levels were 20,750.84 pg/m^3 (Kinshasa, DRC), 20,133.12 pg/m^3 (Addis Ababa, Ethiopia), 16,125.91 pg/m^3 (Lusaka, Zambia), 13,107 pg/m^3 (Reduit GEF site, Mauritius), 12,174.39 pg/m^3 (Kouma-Konda, Togo), and 10,106.22 pg/m^3 (Accra, Ghana).

2019 dataset had mean concentrations of *gamma*-HCH ranging from 1.61-183,672.09 pg/m^3 with the lowest and highest levels recorded in Reduit (Mauritius) and Vikuge (Tanzania), respectively. High levels of 85,245.13 pg/m^3 (Kinshasa, DRC), 12,407.77 pg/m^3 (Addis Ababa), and 5,794.12 pg/m^3 (Soroti, Uganda). The concentrations of *gamma*-HCH are summarized in Figure 5.2.1.37.

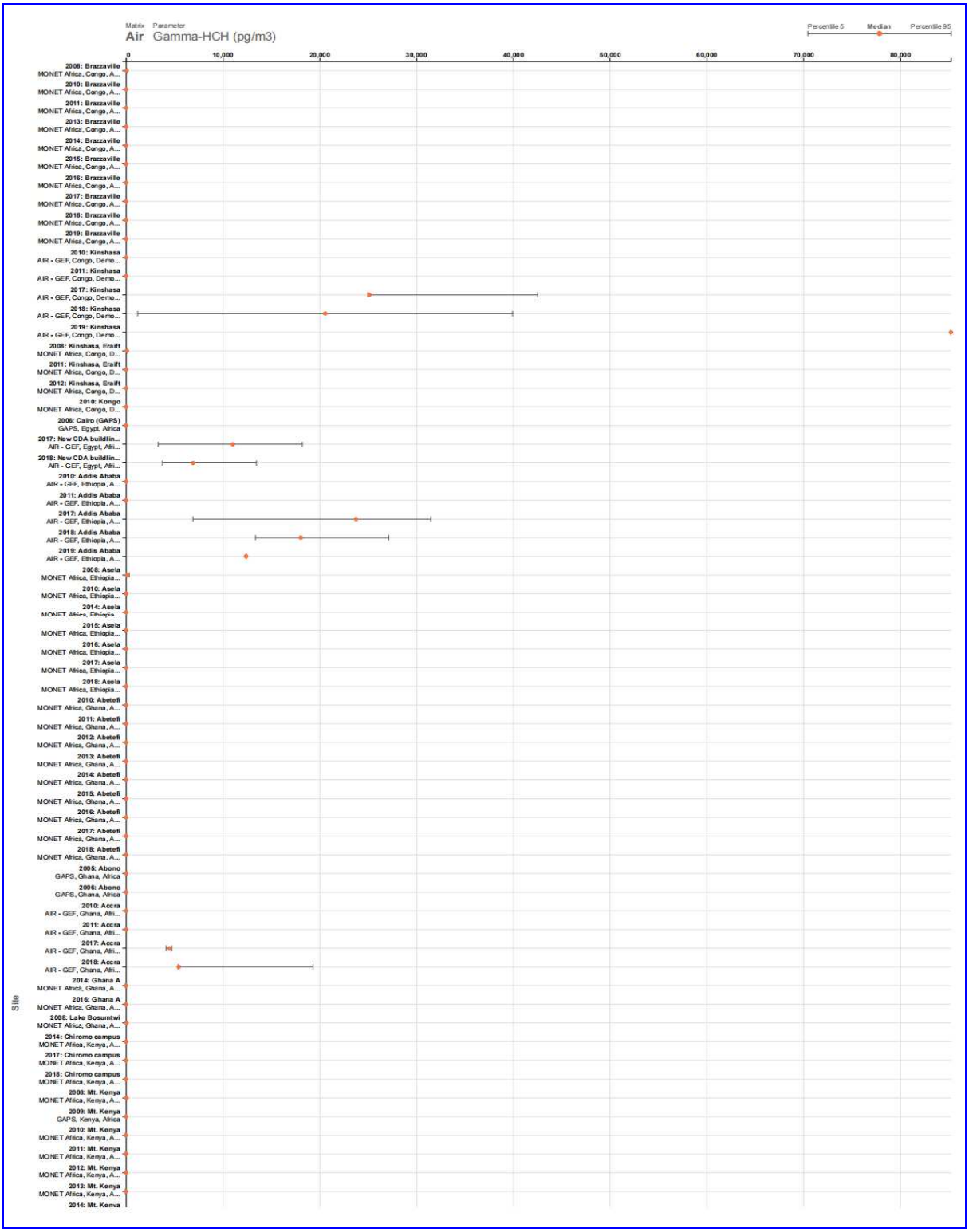


Figure 5.2.1.37 Gamma-HCH concentration in ambient air

5.2.1.19 Pentachlorobenzene (PeCB)

PeCB data sets collected in the period 2008-2019 had mean concentrations ranging from 2.58-205,628.46 pg/m^3. In 2008 the mean levels of PeCB in ambient air ranged from 8.62-95.53 pg/m^3 with the lowest and highest levels recorded in Mt. Kenya and Tunis samples. Medium concentrations recorded were 44.32 pg/m^3 (Khartoum, Sudan) 27.70 pg/m^3 (Kouma-Konda, Togo), 20.97 pg/m^3 (Brazzaville, Republic of Congo) and 18.54 pg/m^3 (Kinshasa, DRC). No dataset were recorded in 2009.

In 2010, the mean levels of PeCB ranged 3.81-29.88 pg/m^3 recorded in Abetefi (Ghana) and Khartoum (Sudan), while in 2011 the levels ranged from 2.01-57.98 pg/m^3 recorded in Nooitgedacht (South Africa) and Khartoum, respectively. The levels recorded in 2012 ranged from 2.00-72.88 pg/m^3 recorded in Nooitgedacht and Abetefi, respectively. 2013 and 2014 had mean concentrations ranging from 7.46 -71.35 pg/m^3 for Mt. Kenya and Khartoum, respectively, while 2014 recorded 0.64-65.61 pg/m^3 for Chiromo (Kenya) and Khartoum, respectively.

In 2015, PeCB concentrations varied from ranged from 9.25-46.16 pg/m^3 with the lowest and highest levels reported for Mt. Kenya and Abetefi sites, respectively. The medium levels recorded were 23.86 pg/m^3 (Brazzaville, Republic of Congo), 21.82 pg/m^3 (Reduit, Mauritius) and 20.55 pg/m^3 (Sheda, Nigeria).

PeCB levels in 2016 were relatively lower with concentrations ranging from 0.42-35.51 pg/m^3 recorded in Accra (Ghana) and Bamako (Mali), respectively. Medium levels in 2016 were 20.71 pg/m^3 (Brazzaville, Republic of Congo), 19.62 pg/m^3 (Marocco Observatory, Morocco), 17.25 pg/m^3 (Sheda, Nigeria) and 16.09 pg/m^3 (Abetefi, Ghana).

The levels of PeCB in the period 2017-2019 recorded an increase in some sites, although a number of background sites retained lower concentrations. The mean levels in 2017 ranged from 2.38 -205,628.46 pg/m^3 with the lowest and highest levels recorded in Chiromo (Kenya) and CDA (Egypt) sites, respectively. The intermediate levels recorded included 123,063.10 pg/m^3 (Kinshasa, DRC), 57,362.19 pg/m^3 (Accra, Ghana), 44,113.25 pg/m^3 (Tunis, Tunisia), 39,006.65 pg/m^3 (Lusaka, Zambia), 37,140.46 pg/m^3 (Kabete, Kenya), and 32,204.94 pg/m^3 (Addis Ababa, Ethiopia).

In 2018, the mean concentrations of PeCB ranged 1.45-207,723.10 pg/m^3 recorded in Chiromo (Kenya) and CDA (Egypt) sites, respectively. The intermediate levels were 111,645.83 pg/m^3 (Accra, Ghana), 106,279.71 pg/m^3 (Kinshasa, DRC), 38,881.30 pg/m^3 (Dakar Ngoye, Senegal), 36,942.32 pg/m^3 (Tunis, Tunisia) and 34, 269.33 pg/m^3 (Addis Ababa).

2019 data sets had mean concentrations between 7.70-158,661.01 pg/m^3, with the lowest and highest concentrations recorded in Reduit and Kinshasa, respectively. Intermediary levels were 33,507.34 pg/m^3 (Addis Ababa), 15,836.61 pg/m^3 (Soroti), and 10.269.92 pg/m^3 (Vikuge). The concentrations of PeCB recorded in the region are summarised in Figure 5.2.1.38.

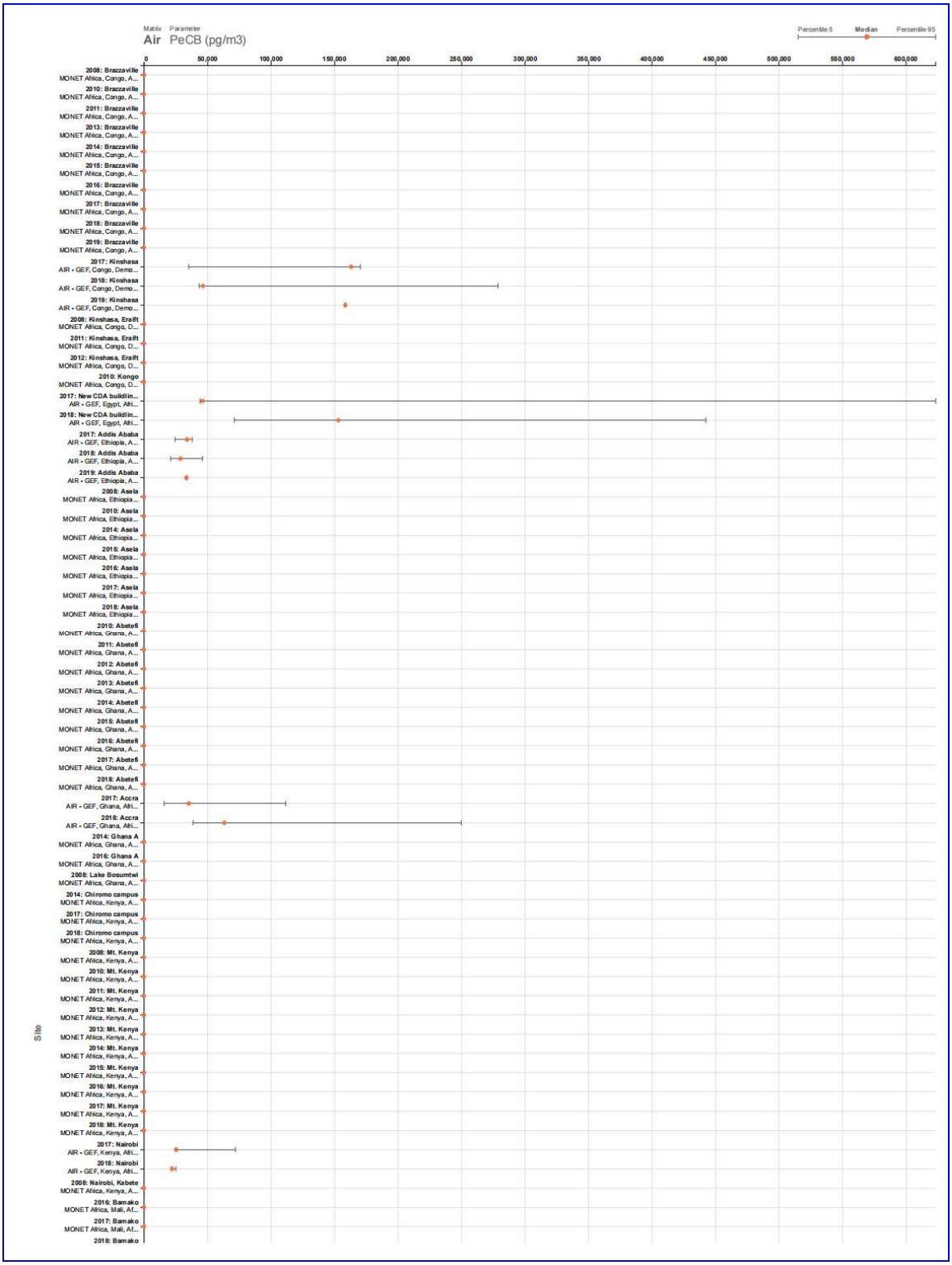


Figure 5.2.1.38. PeCB Concentration in ambient air

5.2.1.20 Polybrominated Diphenyl Ethers (PBDEs =BDEs)

The congeners of PBDEs monitored in ambient air included 17, 28, 47, 99, 100, 153, 154, 175/183, and 209. Majority of the monitoring datasets are for the period 2010-2019, with BDE 209 and 99 dominating the concentrations of BDEs recorded in ambient air.

BDE 17

The levels of BDE 17 in the period 2017-2019 ranged from 0.43-0.63 pg/m^3. Mean levels in 2017 ranged from 0.43-0.64 pg/m^3, recorded in Soroti and Bamako sites, respectively. In 2018 the concentrations of BDE 17 varied from 0.61-0.63 pg/m^3, while 2018 dataset had only three records with equal concentrations of 0.61 pg/m^3 recorded in Addis Ababa, Vikuge and Soroti (Figure 5.2.1.39).

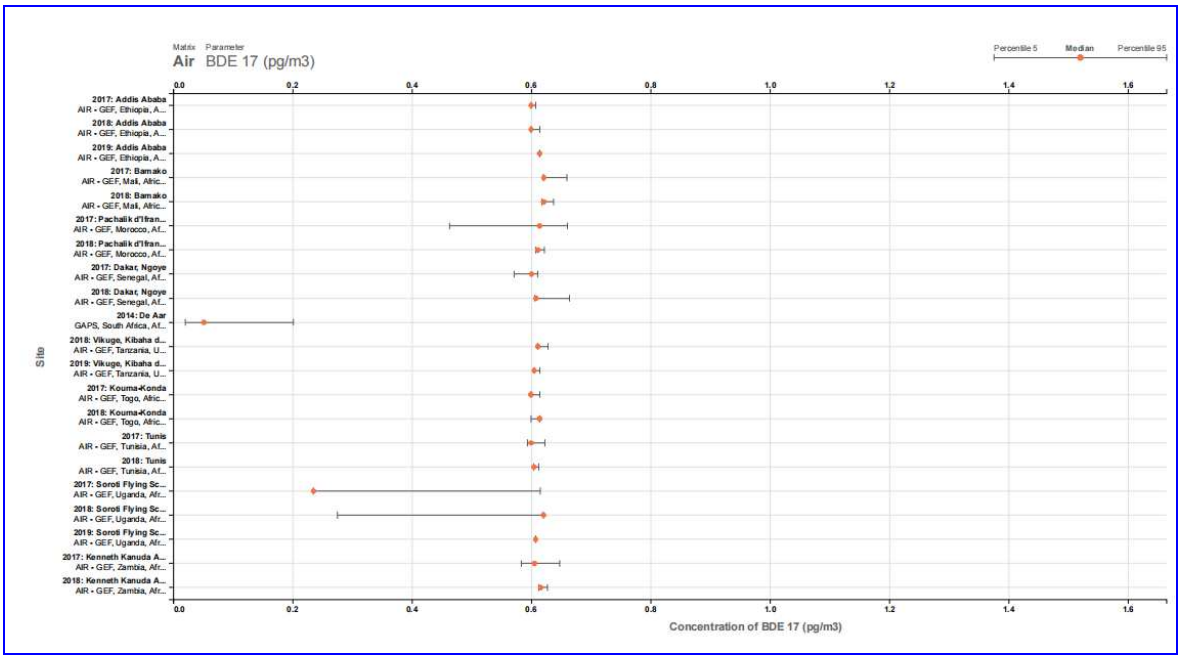


Figure 5.2.1.40 BDE 17 concentration in ambient air

BDE 28

The levels of BDE 28 in the period 2010-2019 ranged from 0.01-1.18 pg/m^3. Mean levels in 2010, 2011, 2012, 2013 and 2014 ranged from 0.02-1.14 pg/m^3, 0.003-0.61 pg/m^3, 0.004-0.67 pg/m^3, 0.01-1.04 pg/m^3, and 0.004-1.21 pg/m^3, respectively. In the period 2015 and 2016, the mean levels of BDE 28 ranged between 0.06-1.37 pg/m^3 in 2015 and 0.001-0.76 pg/m^3, respectively.

2017, 2018 and 2019 concentrations of BDE 28 ranged from 0.01-1.17 pg/m^3, 0.05-1.17 pg/m^3, and 0.06-1.16 pg/m^3, respectively. The results suggest relatively stable concentrations of BDE 28 in the regional ambient air (Figure 5.2.1.41).

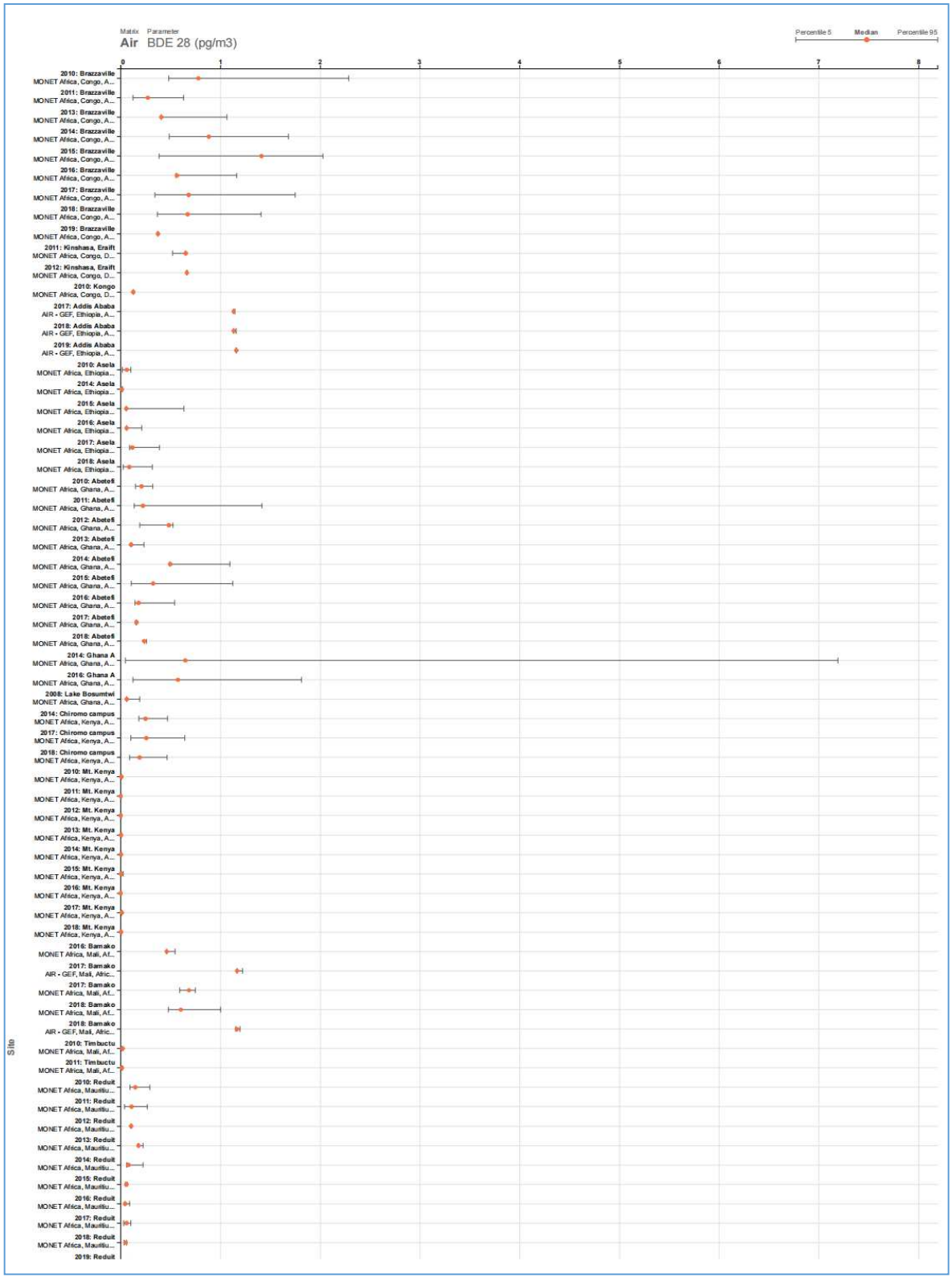


Figure 5.2.1.41 BDE 28 concentration in ambient air.

BDE 47

The mean concentrations of BDE 47 in ambient air ranged from 0.04-4.77 pg/m^3, in the period 2004-2019. The levels recorded in 2004, 2005 and 2008 were 0.01 pg/m^3 (De Aar), 0.01-1.10 pg/m^3, and 0.14 pg/m^3 (Molopo), respectively.

In 2010 the mean concentration of BDE ranged from 0.13-4.35 pg/m^3, recorded in samples from Chiromo and Khartoum sites, respectively. The medium concentrations measured were 3.68 pg/m^3 (Reduit, Mauritius), 2.40 pg/m^3 (Brazzaville, Republic of Congo), and 1.12 pg/m^3 (Mt. Kenya).

2011, 2012, 2013 and 2014 recorded mean concentrations ranging from 0.04 -3.62 pg/m^3, 0.06-4.13 pg/m^3, 0.42-3.96 pg/m^3, and 0.15-6.41 pg/m^3, respectively. In 2015 and 2016 the mean concentrations of BDE 47 ranged from 0.09-4.30 pg/m^3, and 0.11-2.64 pg/m^3, respectively.

The period 2017-2019 also recorded relatively stable concentrations with annual means ranging from 0.06-3.05 pg/m^3 in 2017, 0.04-2.61 pg/m^3 in 2018 and 0.38-1.68 pg/m^3 in 2019. The concentrations of BDE 47 were relatively low and stable throughout the period, with the lowest levels recorded at Mt. Kenya, for most of the period. Figure 5.2.1.42 shows part of the levels of BDE 47 measured in ambient air in the region.

BDE 99

The period 2004-2019 recorded BDE 99 concentrations between 0.05-6.30 pg/m^3 in ambient air. The levels of BDE 99 in the period 2004-2008 were 0.02 pg/m^3 (De Aar) for 2004, 0.02-0.70 pg/m^3 for 2005, and 0.23-1.26 pg/m^3 for 2008. In 2010, the concentrations measured ranged from 0.15-6.30 pg/m^3 recorded in Nooitgedacht and Khartoum, respectively. Figure 5.2.1.43 illustrates the levels of BDE 99 in ambient air.

The mean concentrations of BDE 99 for the period 2011-2014 ranged between 0.06-5.00 pg/m^3 in 2011, 0.09-6.31 pg/m^3 in 2012, 0.68-6.18 pg/m^3 in 2013 and 0.40-4.45 pg/m^3 in 2014, showing low but relatively stable concentrations in ambient air.

In 2015 and 2016 the mean levels varied from 0.10-4.46 pg/m^3, and 0.10-3.70 pg/m^3, respectively. 2017, 2018 and 2019 recorded mean concentrations ranging from 0.37- 2.81 pg/m^3, 0.05-2.61 pg/m^3, and 0.37-1.28 pg/m^3, respectively. The results suggest low, but relatively stable concentrations with no significant decline in the levels.

BDE 100

The mean concentrations of BDE 100 varied between 0.01-12.52 pg/m^3 for samples collected in the period 2004-2019. Concentrations recorded in in the period 2004-2008 were 0.02 pg/m^3 (De Aar) for 2004, 0.02-1.70 pg/m^3 in 2005, and 0.04-0.26 pg/m^3 in 2008. The periods 2006, 2007 and 2009 recorded no dataset for BDE 100. The period 2010-2014 had mean BDE 100 levels ranging from 0.04-1.25 pg/m^3 (2010), 0.01-12.52 pg/m^3 (2011), 0.01-1.06 pg/m^3 (2012), 0.15-1.22 pg/m^3 (2013) and 0.06-1.53 pg/m^3 in 2014. 2015-2019 also recorded relatively stable concentrations with no significant declines in concentrations. The mean levels in 2015 ranged from 0.01-1.17 pg/m^3 with lowest and highest levels measured at Mt. Kenya and Brazzaville sites respectively, while intermediary levels were 0.75 pg/m^3 (Marocco Observatory), 0.60 pg/m^3 (Asela), and 0.59 pg/m^3 (Abetefi). In 2016 and 2017 the mean levels ranged from 0.02-0.67 pg/m^3, and 0.03-2.10 pg/m^3. 2018 and 2019 also recorded comparable concentrations with mean concentrations ranging 0.01-1.69 pg/m^3, and 0.08-0.48 pg/m^3, respectively. No significant

decline in concentration levels of BDE 100 were observed in the ambient air in the period 2004-2019. Figure 5.2.1.42-44 illustrate levels of BDE 47, 99 and 100, respectively.

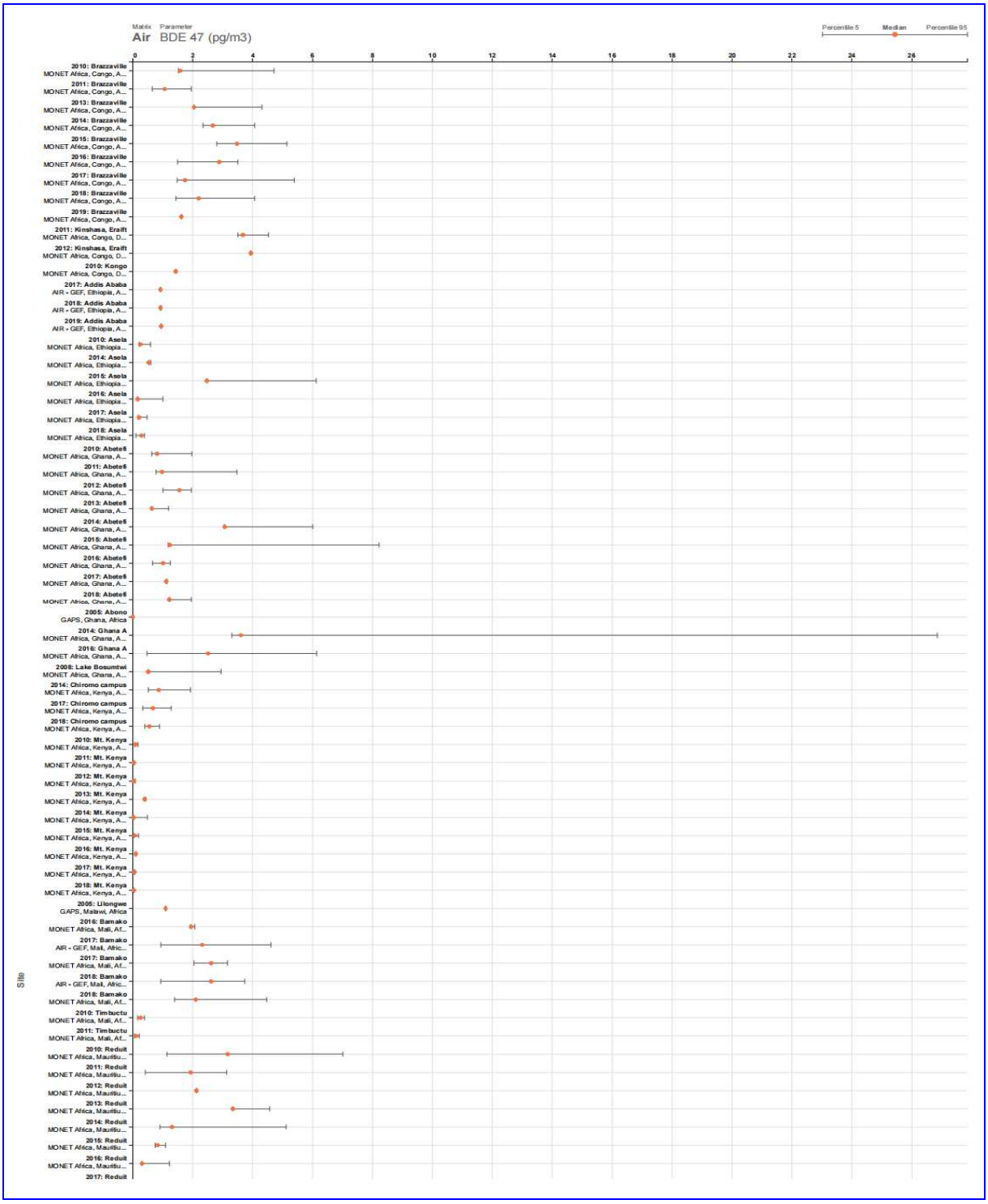


Figure 5.2.1.42 BDE 47 concentration in ambient air

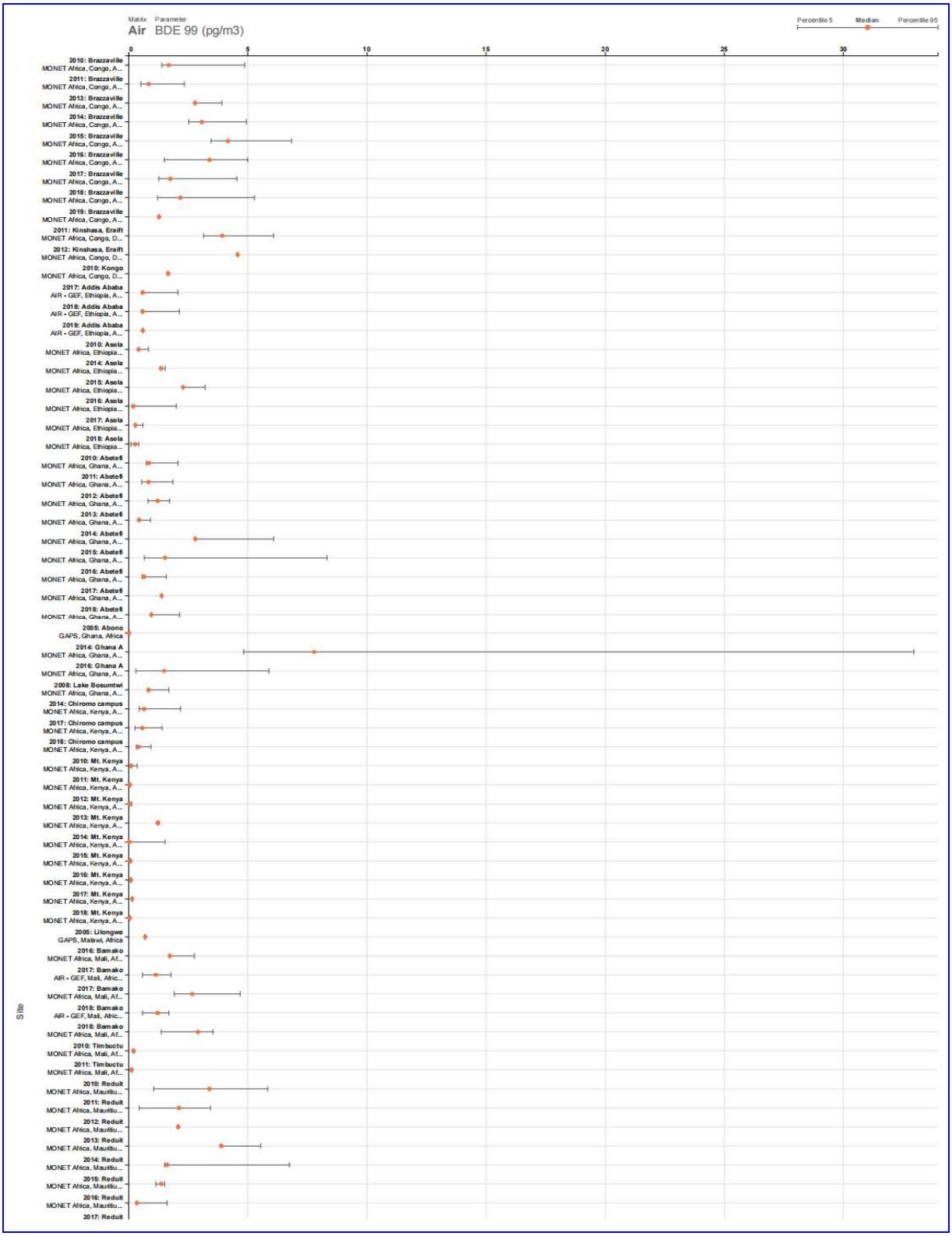


Figure 5.2.1.43 BDE 99 concentration in ambient air

Figure 5.2.1.44 BDE 100 concentration in ambient air

BDE 153

The mean concentrations of BDE 153 in ambient air varied from 0.02-3.29 pg/m^3 in the samples collected in the period 2008-2019. Concentrations recorded in the period 2008 ranged from 0.07-0.15 pg/m^3 recorded in Molongo and Lake Bosumtwi sites (Figure 5.2.1.45).

In 2010 the concentrations varied between 0.04-2.04 pg/m^3 recorded in Timbuktu and Khartoum sties, respectively. In 2011 BDE 153 levels varied from 0.04-1.71 pg/m^3 recorded in Timbuktu and Khartoum, respectively. The levels in 2012, 2013 and 2014 ranged 0.10-1.82 pg/m^3, 0.13-2.19 pg/m^3, and 0.09-3.29 pg/m^3, respectively, with highest levels recorded in samples from Khartoum, site.

In the period 2015-2019 the mean levels of BDE 153 recorded exhibited relatively stable concentrations in ambient air. The concentration levels in the period 2015-2019 ranged from 0.03-0.47 pg/m^3 for 2015, 0.03-0.73 pg/m^3 in 2016, 0.06-0.86 pg/m^3 (2017), 0.02-1.17 pg/m^3 (2018) and 0.05-0.87 pg/m^3 in 2019.

BDE 154

BDE 154 recorded mean concentrations between 0.02-1.94 pg/m^3 in the period 2008-2019. The concentrations recorded in 2008 ranged from 0.05-0.15 pg/m^3 for Molopo and Lake Bosumtwi sites, respectively.

2010 levels varied between 0.03-1.34 pg/m^3 recorded at Timbuktu and Khartoum sites, respectively, with medium levels of 0.85 pg/m^3 (Brazzaville), 0.37 pg/m^3 (Renduit), and 0.35 pg/m^3 (Betefi). In the period 2011- 2014, the mean concentrations of BDE 154 varied from 0.04-1.23 pg/m^3 in 2011, 0.05-1.40 pg/m^3 in 2012, 0.15-1.86 pg/m^3 in 2013, and 0.06-1.94 pg/m^3 in 2014. The highest levels in the period were recorded in samples from Khartoum site.

In the period 2015-2019 comparable levels of BDE 154 were recorded with relative stability suggesting no significant declining trends. The levels in 2015 ranged 0.02-1.52 pg/m^3. The mean levels in the period 2016-2019 ranged from 0.02-1.09 pg/m^{3}for 2016, 0.07-1.40 pg/m^3 in 2017, 0.03-1.12 pg/m^3 for 2018 and 0.13-1.10 pg/m^3 in 2019 (Figure 5.2.1.46).

BDE 175/183

Relatively less datasets were recorded for BDE175/183 compared to the rest of BDEs monitored in the ambient air, with measurements conducted in the period 2014-2019. The overall mean concentrations of BDE 175/183 ranged from 0.17-2.13 pg/m^3 in the period 2014-2019. In 2014, a single dataset was recorded for De Aar with mean concentration of 0.17 pg/m^3. In 2017 the concentrations recorded ranged from 1.38-2.11 pg/m^{3}with the lowest and highest levels measured in Soroti and Pachalik sites, respectively.

2018 recorded mean BDE175/183 concentrations ranging from 1.67-2.13 pg/m^3 for Soroti and Dakar Ngoye, while medium levels were 2.11 pg/m^3 (Pachalik, Koum-Konda and Bamako), and 2.10 pg/m^3 recorded in Addis Ababa and Vikuge sites (Figure 5.2.1.47).

In 2019, the mean levels of BDE 175/183 ranged from 2.02-2.13 pg/m^3 recorded in Soroti and Addis Ababa sites, respectively. Medium level recorded was 2.07 pg/m^3 (Vikuge). The results of BDE concentrations revealed low but persistently stable concentrations in ambient air across the sampling period. Figures 5.2.1.45-47 show levels of BDE congeners 153, 154 and 175/183, respectively.

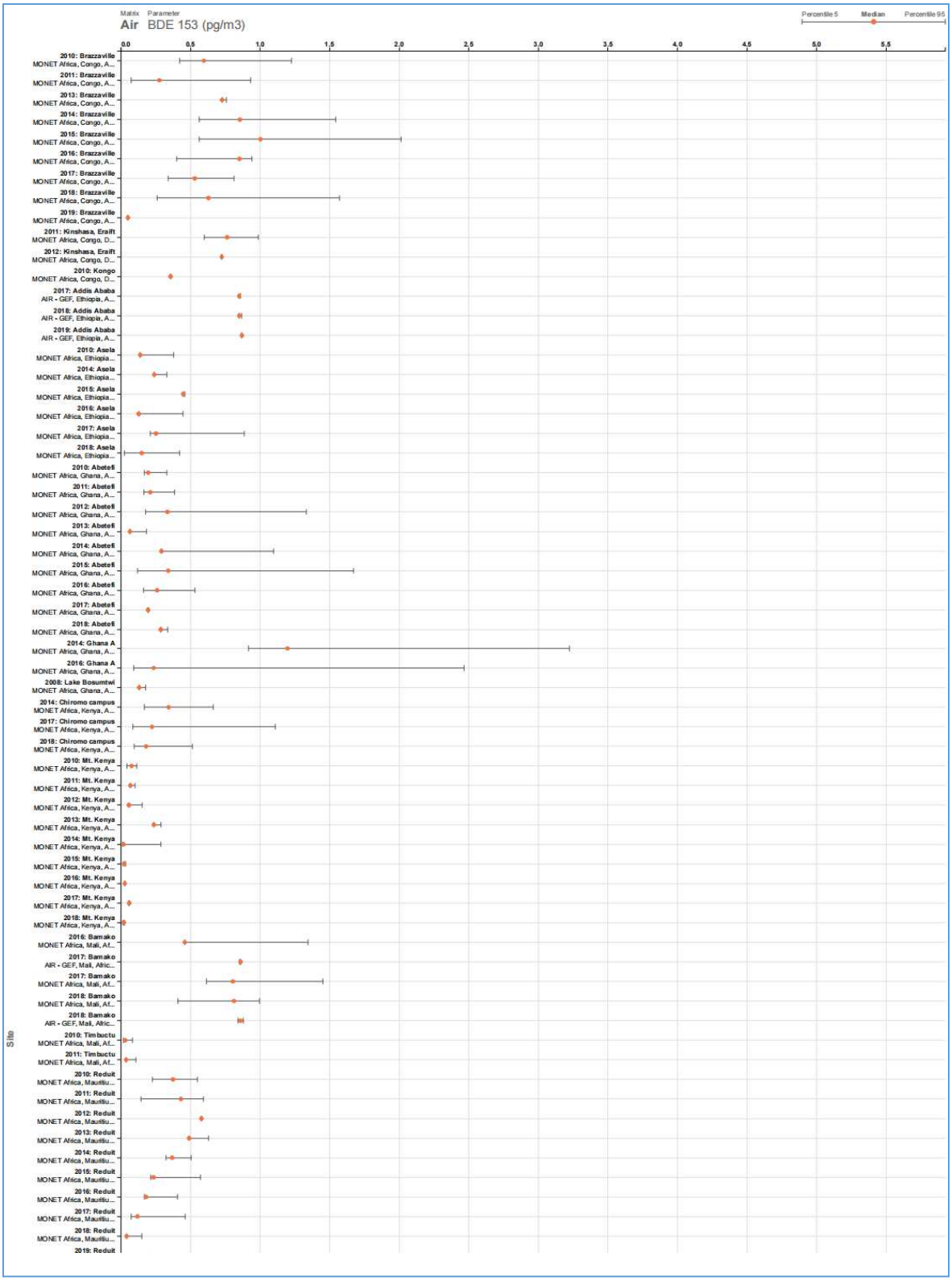


Figure 5.2.1.45 BDE 153 concentration in ambient air

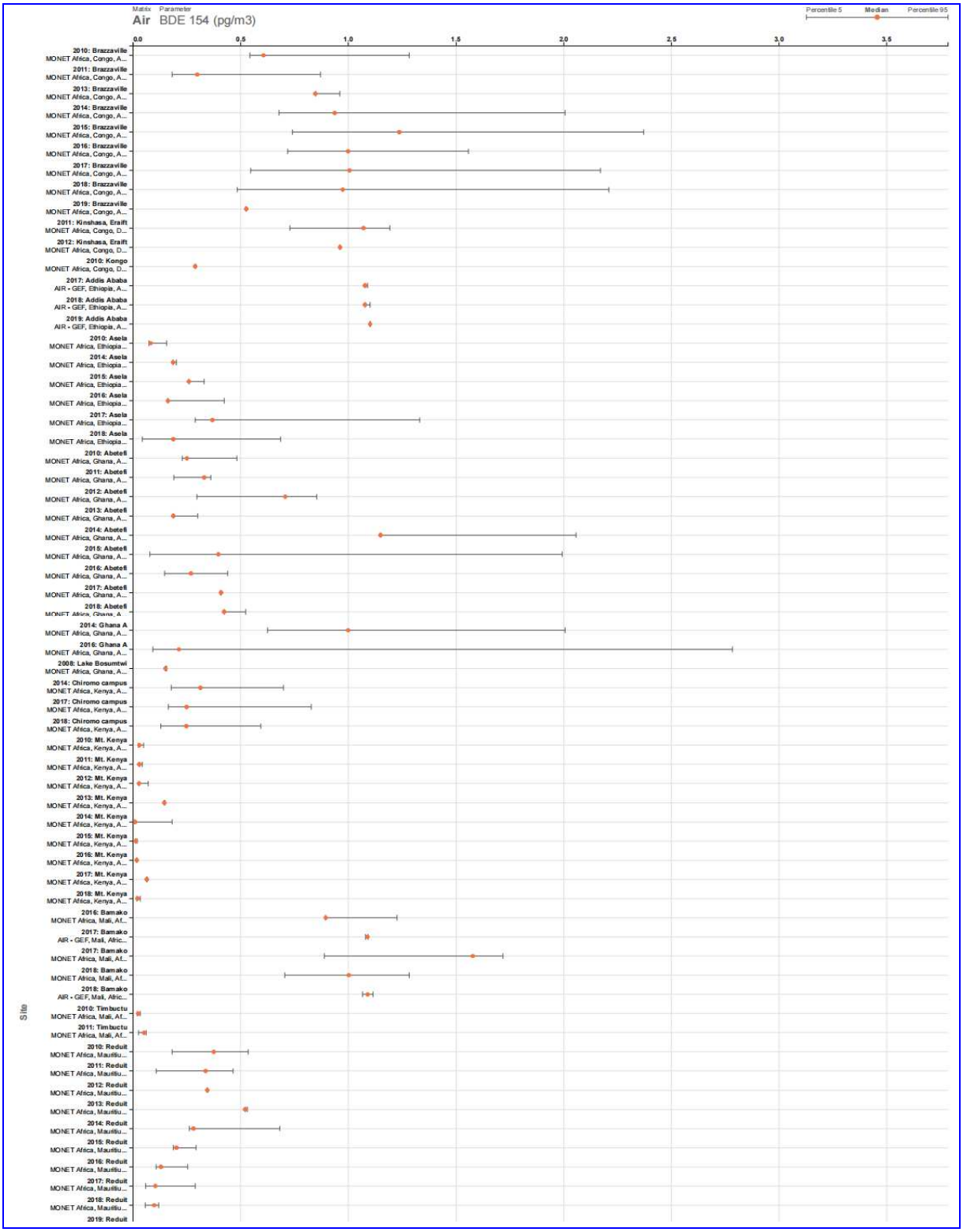


Figure 5.2.1.46 BDE 154 concentration in ambient air

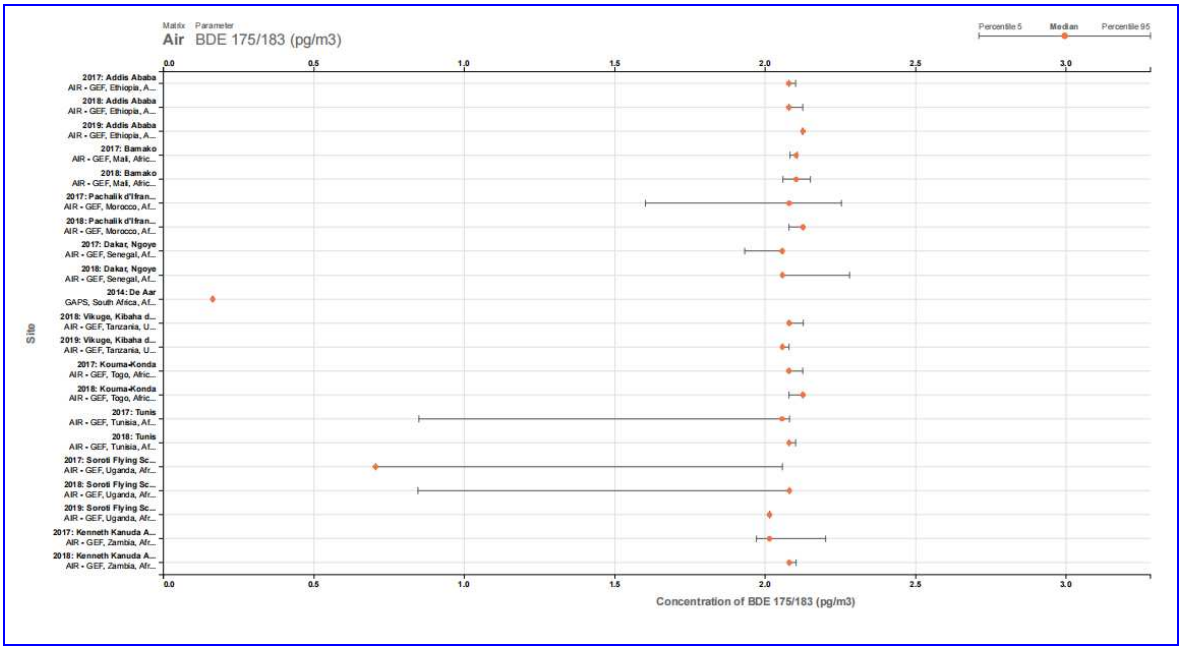


Figure 5.2.1.47 BDE 175/183 concentration in ambient air

BDE 209

BDE 209 levels were monitored in ambient air in the period 2013-2019, and recorded the highest levels in the ambient air compared to the rest of BDE congeners, with the mean concentrations ranging between 0.50-226.35 pg/m^3.

In 2013 the average concentration of BDE 209 ranged from 4.49-8.04 pg/m^3 with the lowest and highest levels recorded in Chiromo and Accra sites, respectively. 2014 and 2016 recorded a single data set each with mean concentration of 0.50 pg/m^3 (De Aar, South Africa), and 1.87 pg/m^3 (Accra, Ghana), respectively.

In 2017 the averaged levels of BDE 209 ranged from 3.56 -133.01 pg/m^3 recorded in Soroti and Lusaka sites respectively. The medium levels recorded in 2017 were 18.53 pg/m^3 (Accra, Ghana), 13.38 pg/m^3 (Tunis, Tunisia) and 13.29 pg/m^3 (Kinshasa, DRC).

2018 recorded relatively higher concentrations with annual average levels ranging from 4.30-226.35 pg/m^3 recorded in Soroti and Lusaka sites, respectively. Intermediate concentrations in 2018 were 99.08 pg/m^3 (Brazzaville), 94.51 pg/m^3 (CDA, Egypt), 20.94 pg/m^3 (Vikuge, Tanzania), and 19.63 pg/m^3 (Dakar Ngoye/Bambey, Senegal).

In 2019, the mean concentration ranged from 5.19-17.12 pg/m^3 recorded in Soroti and Addis Ababa sites, respectively. The medium levels were 9.03 pg/m^3 (CDA, Egypt), 5.32 pg/m^3 (Vikuge, Tanzania) and 5.24 pg/m^3 (Brazzaville, Republic of Congo). Figure 5.2.1.48 shows the levels of BDE 209 recorded in ambient air.

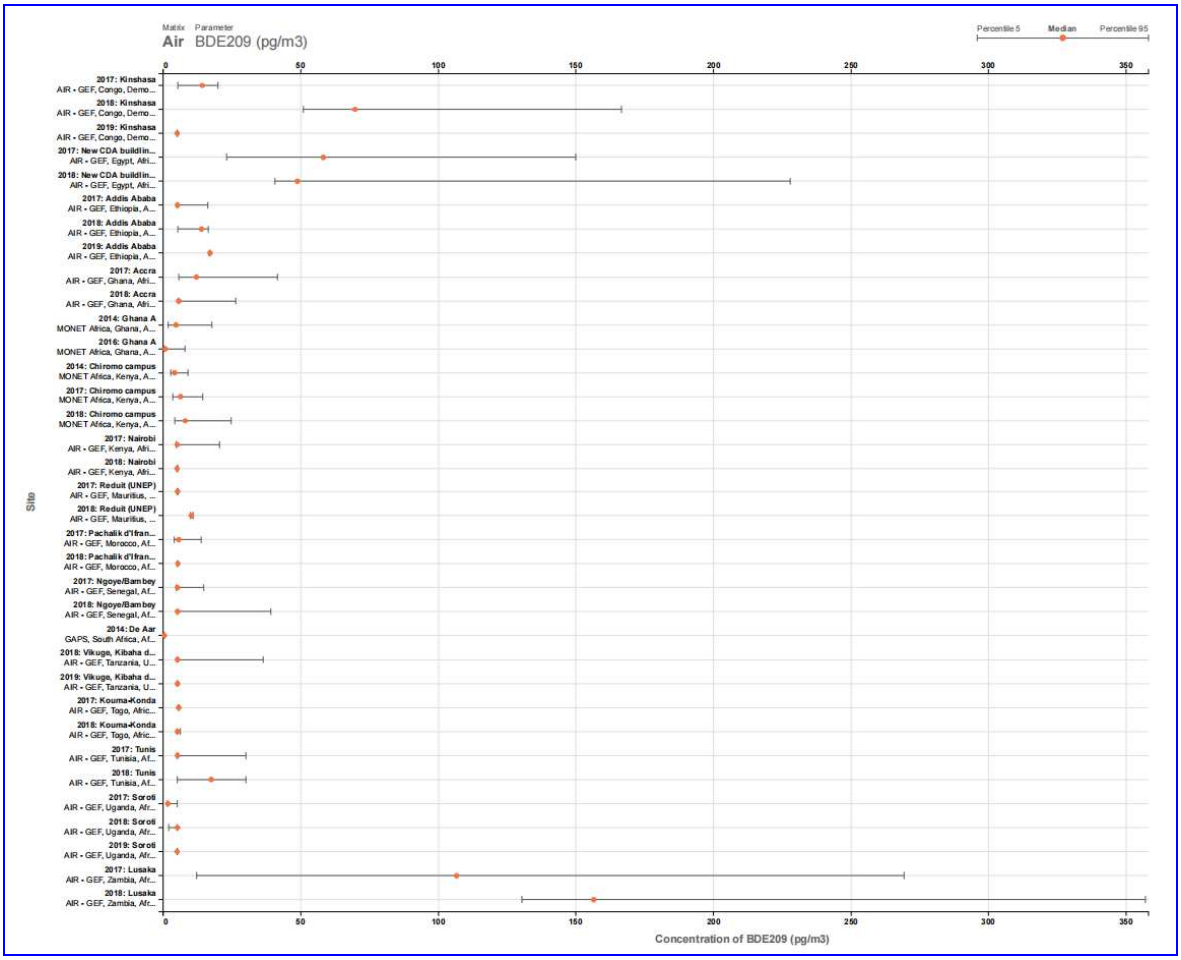


Figure 5.2.1.48 BDE 209 concentration in ambient air

5.2.1.21 Perfluorooctane sulfonic acid (PFOS)

The mean concentrations of PFOS in ambient air for the period 2017-2019 ranged from 30.15-163,929.37 pg/m^3. 2017 recorded levels ranging from 30.15 -77,578.76 pg/m^3, with the lowest and highest levels recorded in Chiromo and Lusaka sites, respectively. Intermediate concentrations recorded were 7,693.11 pg/m^3 (CDA, Egypt), 1,609.02 pg/m^3 (Accra Ghana), and 1,165.85 pg/m^3 (Pachalik, Morocco) and 1,094.76 pg/m^3 (Kinshasa, DRC).

In 2018 the mean concentrations varied from 35.84-163,929.37 pg/m^3 recorded in Chiromo and Lusaka sites, respectively. Medium concentrations recorded were 3,008.64 pg/m^3 (CDA, Egypt), 1,538.58 pg/m^3 (Kinshasa, DRC), and 1,534.83 pg/m^3 (Dakar Ngoye/Bambey, Senegal).

In 2019, four datasets were recorded with mean concentrations between 315.20-577.38 pg/m^3 for Addis Ababa and Soroti sites, respectively. The intermediate level were 444.44 pg/m^3 and 423.41 pg/m^3 recorded in Abuja (Nigeria) and Kinshasa (DRC), respectively. Figure 5.2.1.49 summarises the concentrations of PFOS in ambient air.

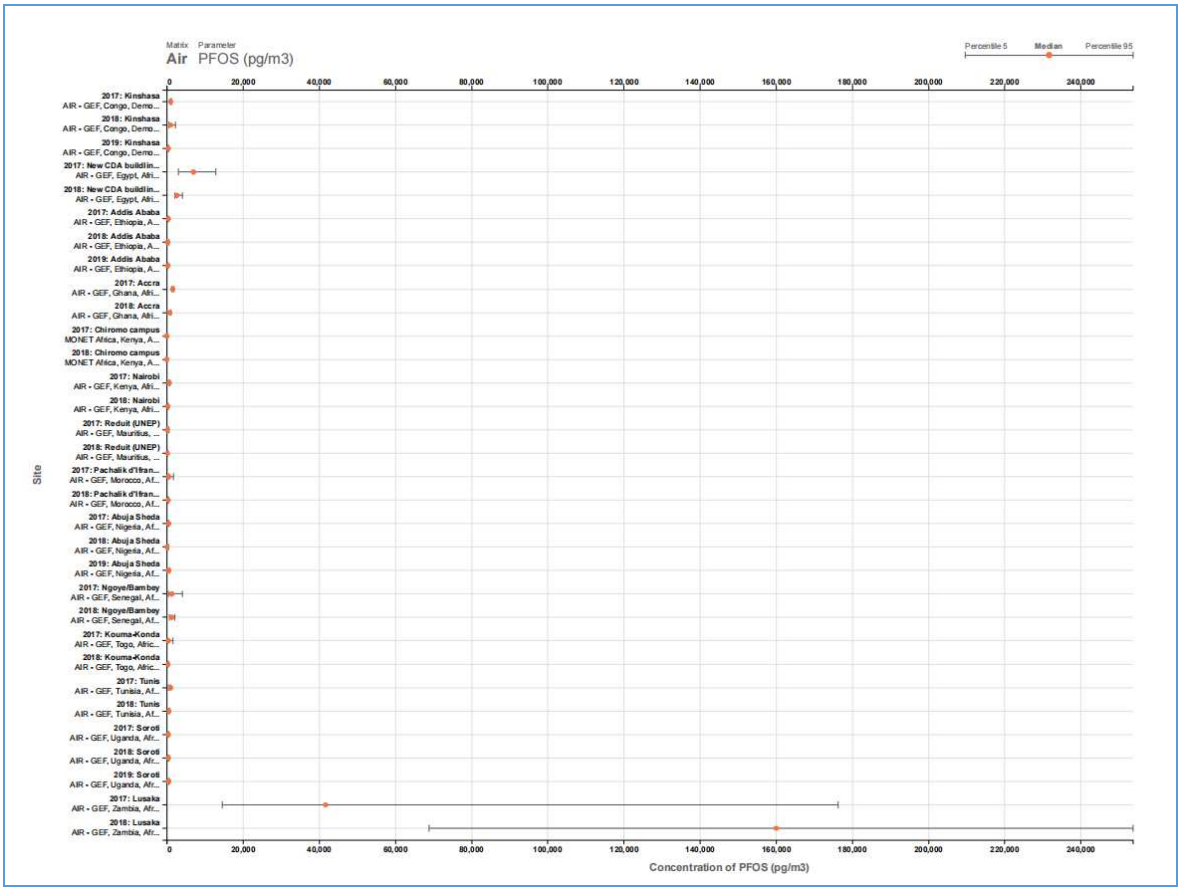


Figure 5.2.1.49 PFOS concentration in ambient air

5.2.1.22 Perfluorooctanoic acid (PFOA)

PFOA levels in the regional ambient air were recorded in 2014 and 2018 at Chiromo site, with mean concentrations of 6.38 pg/m^3 and 16.90 pg/m^3, respectively (Figure 5.2.1.50).

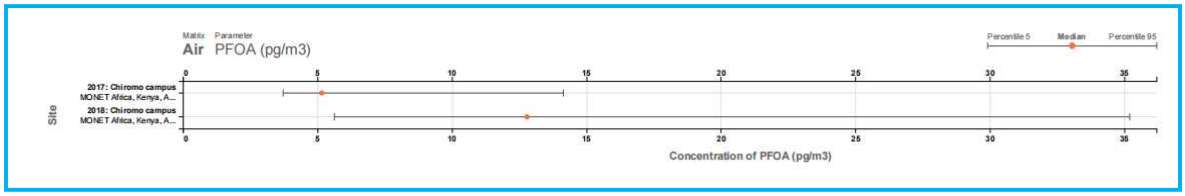


Figure 5.2.1.50 PFOA concentration in ambient air

5.2.1.23 Perfluorohexane Sulfonic Acid (PFHxS)

The levels of PFHxS were recorded for Chiromo site in 2014 and 2018 with mean concentrations of 2.40 pg/m^3 and 2.96 pg/m^3, respectively (Figure 5.2.1.51).

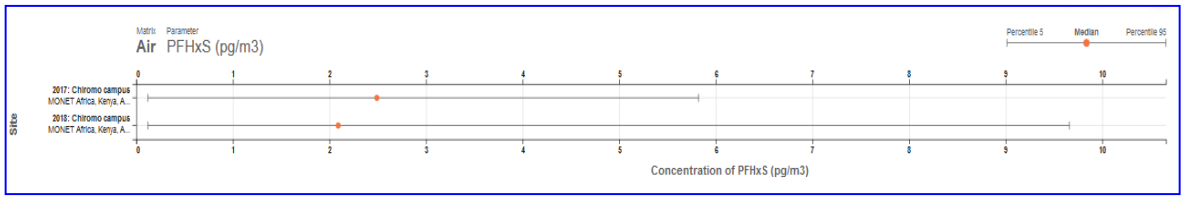


Figure 5.2.1.51 PFHxS concentration in ambient air

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

The discussion below provides an overview of the POPs levels measured in ambient air per participating country sites.

i) POPs Levels in Ambient Air in Republic of Congo

In the Republic of the Congo, POPs monitoring was carried out at Brazzaville site in the period 2008, 2010, 2011, 2013 and 2014-2019. POPs pesticides detected included aldrin, chlordanes, dieldrin, endrin, heptachlor, DDTs, HCB, endosulphans, PeCB, and HCHs. Industrial POPs detected at the site were dominated by PCBs, with relatively stable concentrations across the years. The sum 6 PCBs levels was 83.53 pgm^3 in 2008 reducing gradually to 23.03 pg/m^3 in 2019. PBDEs levels were detected at low concentrations across the years. PCDDs/PCDFs and dioxin like PCBs were also detected in significant amounts at the site.

The presence of Annex A pesticides, Annex A industrial chemicals as well as dioxins and furans at Brazzaville which is an urban site corroborated the fact that the site was impacted by agricultural, industrial and unsound wastes disposal activities.

POPs with emerging declining concentrations were$\sum_{12}$dl-PCBs, $\sum_6$PCBs, $\sum_7$PCDDs, $\sum_{10}$PCDFs, $\sum_3$endosulphans, $\sum_4$HCH, beta-HCH, alpha-HCH, while POPs with no significant declining trends were $\sum_9$PBDEs, BDE 209, PeCB, dieldrin, endrin, mirex, $\sum_3$chlordanes and $\sum_3$HBCD.

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

In DRC, the monitoring sites included Cogelos, Kinshasa, Kinshasa Ereift and Muanda for the sampling campaigns in 2008, 2010, 2011 and 2012. Muanda site data were collected only for 2010, while Kinshasa recorded the longest monitoring activities in the period 2010, 2011, 2017-2019.

Most POPs pesticides detected at Kinshasa site included aldrin, chlordanes, dieldrin, endrin, heptachlor, mirex, DDTs, endosulphans, HCHs, HCB and PeCB. Industrial POPs detected were dominated by PCBs and PFOS, while PBDEs registered low levels. Dioxins and furans, and dl-PCBs were also widely detected across the years. The same contaminants were found at the site of Cogelos in 2011 and 2012. At the site of Kinshasa Ereift, the most prevailing contaminants were Annex A industrial chemicals (HCB, PCBs and PBDEs), PCDDs/Fs and HCHs.

At Kinshasa site, POPs with declining trends were PCBs and HBB 153, while increasing or no declining trends were observed for aldrin, dieldrin, chlordane, heptachlor, endrin, DDTs, HCB, endosulphans, HBCDs, HCHs, PeCB, and PBDEs, PCDDs/Fs, and PFOS. The period 2017-2018 recorded relatively higher levels of these POPs in the samples.

All the sites in DRC were urban background sites, hence 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 pesticide like endosulphan, aldrin, endrin, heptachlor might originate from previous applications of these POPs in agriculture and releases from contaminated soils.

iii) POPs levels in ambient air in Egypt

POPs monitoring in ambient air in Egypt has been recorded in Cairo in 2006 and 2008 and CDA new building from 2017-2018. Important POPs pesticides detected were Aldrin, chlordanes, dieldrin, endrin, heptachlor, DDTs, HCB, pentachlorobenzene, endosulphan, alpha, beta and gamma-HCH isomers.

Industrial POPs were dominated by PCBs, while low levels of PBDEs also recorded at the site. PCDDs/Fs and dl-PCBs were also recorded in ambient at low concentrations. No declining trends were observed at the site partly due to short duration of monitoring.

iv) POPs levels in ambient air in Ethiopia

POPs monitoring in Ethiopia has been undertaken at two sites namely Addis Ababa and Asela from 2008, 2010, 2011, 2014-2018 for Asela, and 2010, 2011, and 2017-2019 for Addis Ababa. At the Addis Ababa site, the contaminants detected included Annex A pesticides, Annex B pesticides, PCBs and dioxins and furans. POPs pesticides detected at Asela site included Aldrin, chlordanes, dieldrin, endrin, heptachlor, DDTs, HCB, endosulphans, HCHs and PeCB. The major industrial POPs detected were PCBs and PBDEs, while UPOPs were PCDDs/Fs and dioxin like PCBs.

Asela sites registered declining trends in concentrations of $\sum_{12}$ dl-PCBs, $\sum_{6}$PCBs, $\sum_{7}$PCDDs, $\sum_{9}$PBDEs, BDE 209, $\sum_{3}$HBCD, $\sum_{6}$DDTs, $\sum_{3}$endosulphans, $\sum_{4}$HCHs, and HCB. POPs that showed increasing or no significant reduction in concentrations were dieldrin, heptachlor, $\sum_{10}$PCDFs, PeCB and $\sum_{3}$ chlordanes.

Sampling at Addis Ababa and Asela sites showed that HCB, gamma-HCH, alpha-endosulphan, PCBs, DDTs as well as dioxins and furans were the main POPs of concern.

v) POPs levels in ambient air in Ghana

POPs monitoring was undertaken at three sites in Ghana namely, Bono (2005-2006), Abetefi and Accra. Sampling at Abetefi site was conducted in 2008, 2010-2018. The main POPs detected were dieldrin, alpha-endosulphan, PCDDs, PCDFs, gamma-HCH, HCB, endrin and oxychlordane were the most important contaminants analysed. Initial declining temporal trends are emerging for dieldrin, $\sum_{4}$HCHs, $\sum_{3}$ endosulphan, $\sum_{3}$chlordane, $\sum_{3}$-endosulphan, $\sum_{6}$ DDTs, $\sum_{3}$ HBCDs, $\sum_{6}$ PCBs, $\sum_{12}$ dl-PCBs and BDE 209.

No significant reduction $\sum_{10}$ PCDFs, $\sum_{9}$ PBDEs, while increasing trend was observed for $\sum_{7}$ PCDDs, $\sum_{17}$ PCDDs/Fs, HCB, mirex and $\sum_{3}$heptachlor.

Sampling at Accra site was conducted in 2010. 2011, 2017 and 2018. The most important POPs detected were aldrin, chlordanes, dieldrin, endrin, heptachlor, mirex, DDTs, HCB, PeCB, alpha-endosulphan and HCHs. Industrial POPs were dominated by PCBs, while PBDEs were prevalently detected at low levels. UPOPs detected included dioxins and furans, and dioxin-like PCBs.

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 alpha endosulphan, HCHs, DDTs (pesticides), PCBs (industrial chemicals) and dioxins and furans. Relatively high concentrations of POPs pesticide were detected in the period 2017-2018 at the Accra site.

vi) POPs levels in ambient air in Kenya

POPs sampling campaigns in Kenya have been conducted at Mt. Kenya, Kabete and Chiromo sites. Mt. Kenya recorded the longest monitoring data from 2008-2019, while Kabete sites had monitoring activities in 2010, 2011, and 2017-2019. Chiromo site monitoring was in 2014, 2017 and 2018. Mt. Kenya site recorded POPs pesticides namely aldrin, chlordanes, Dieldrin, endrin, heptachlor, PeCB, endosulphans, HCHs among others. Toxaphene and mirex have not been reported at the site. Industrial POPs recorded at Mt. Kenya site were dominated by PCBs, while PBDEs were generally at low levels. Low levels of PCDDs/Fs and dioxin like PCBs were also detected at the site.

Mt. Kenya generally recorded one of the lowest POPs concentrations in the Africa region, with declining trends emerging for most POPs $\sum_{12}$ dl-PCBs, $\sum_{6}$ PCBs, $\sum_{7}$ PCDDs, $\sum_{10}$ PCDDs, $\sum_{17}$ PCDDs/Fs, $\sum_{9}$ PBDEs, BDE 209, $\sum_{3}$ HBCD, $\sum_{6}$ DDTs, $\sum_{3}$ endosulphan, $\sum_{4}$ HCHs, $\sum_{3}$chlordanes, dieldrin, and $\sum_{3}$heptachlor. No significant to increasing trend was detected for PeCB.

Kabete site recorded relatively higher concentrations of POPs than Mt. Kenya which could be attributed to closeness to urban and agricultural activities. Major POPs at the site were POPs pesticides namely DDTs, aldrin, chlordanes, dieldrin, heptachlor, endrin, HCB, endosulphans, HCHs, PeCB, while lower levels of mirex and toxaphene were also detected. Industrial POPs detected at the site were dominated by PCBs, while lower levels of PBDEs were also detected. PCDDs /Fs and dioxin like PCBs were recorded at levels higher than Mt. Kenya site.

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 movement of air masses as a component of the long range transport of POPs to this remote site.

vii) POPs levels in ambient air in Mali

At the Bamako site sampling was recorded at two sites namely Timbuktu and Bamako. However sampling at Timbuktu was discontinued in 2011. Sampling at Bamako was conducted in 2010, 2011, 2016-2018. POPs pesticides detected at Bamako site were aldrin, chlordanes, dieldrin, endrin, heptachlor, DDTs, HCB, endosulphans, HCHs, PeCB and mirex.

Industrials POPs were dominated by PCBs and while low levels of PBDEs were also detected with relatively stable concentrations across the years. PCDDs/Fs and dioxin like PCBs were also detected in the ambient air from the site.

Initial declining trends at the site have started to emerge for chlordanes, dieldrin, PCBs, while increasing or no declining trends were observed for endrin, heptachlor, DDTs, HCB, PeCB, and PBDEs and PCDDs/Fs.

Sampling of ambient air at the Timbuktu site was conducted in 2008, 2010 and 2011, and thereafter discontinued due to security reasons. The site also recorded one of the lowest levels of various Annex A pesticides were found including HCB, HCH, alpha endosulphan, oxychlordane,

endrin, dieldrin, and aldrin in the region. Industrial POPs including PCBs and PBDEs were also detected, as well as the UPOPs such as PCDDs/Fs and dl- PCBs.

Sampling of Ambient air in Mali from 2008 to 2018 at Bamako and Timbuktu sites showed that almost all POPs were present but the most important ones were PCBs, DDTs, HCB, dieldrin, endrin, PeCB, alpha-endosulfan, PBDEs and dioxins and furans.

viii) POPs levels in ambient air in Mauritius

Ambient air sampling sites in Mauritius were Reduit and Reduit GEF sites. At Reduit site sampling was conducted in 2008, 2010-2019. Almost all Annex A pesticide were detected at the site including aldrin, chlordanes, dieldrin, endrin, heptachlor, DDTs, HCB, PeCB, endosulphans and HCHs, while the industrial POPs were dominated by PCBs, while low levels of PBDEs were also recorded across the sampling years. PCDDs/Fs and dioxin like PCBs were recorded at relatively lower levels than POPs pesticides and indicator PCBs.

POPs with emerging declining change in concentrations were observed for $\sum_{12}$ dl-PCBs, $\sum_{6}$ PCBs, dieldrin, $\sum_{4}$HCHs, $\sum_{3}$ endosulphans, $\sum_{6}$ DDTs, HCB, BDE 209, $\sum_{9}$ PBDEs, while increasing levels were observed for $\sum_{7}$ PCDDs, $\sum_{10}$ PCDFs, X the $\sum_{3}$chlordanes, $\sum_{3}$heptachlors, $\sum_{3}$ HBCD and $\sum_{12}$ dl-PCBs, and PeCB.

For the sampling conducted under the UNEP/GEF project in 2010 and 2011, 2017 and 2018. Various Annex A pesticides were found including mirex, HCHs, dieldrin, endrin, chlordanes, heptachlor, as well as DDTs. The industrial chemicals detected included PCBs and PBDEs, while unintentional POPs namely dioxins (sum of 7 PCDDs) and furans (sum of 10) were among the major contaminants.

In general Mauritius sites showed that the prevailing POPs in ambient air were pesticides DDTs, endrin, endosulfan, HCB, PCBs, dioxins and furans. There was an increase in the levels of POPs pesticides aldrin, chlordanes, dieldrin, endrin, heptachlor, mirex, DDTs, dioxins and furans over the sampling periods 2017-2018 at Reduit GEF site that needs to be checked to establish the cause.

ix) POPs levels in ambient air in Morocco

Two monitoring sites in Morocco were Marocco Observatory and Pachalik d'Ifrane. Sampling at Marocco observatory was effected in 2014-2016. Major POPs pesticides at the site were aldrin, chlordanes, dieldrin, endrin, heptachlor, HCB, endosulphan, HCHs and PeCB.

Sum 17 PCDDs/Fs ranged between 207.88-1,078.50 pg/m^3. PBDEs concentrations ranged between 0.01-3.70 pg/m^3.

Monitoring at Pachalik d'Ifrane site was conducted in 2017 and 2018. Major POPs pesticides detected at the site were aldrin, chlordanes, dieldrin, endrin, mirex, heptachlor, DDTs, HCB, PeCB, endosulphan and HCHs,

Industrial POPs were dominated by PCBs and PFOS, while lower levels of PBDEs were also recorded at the site. Indicator PCBs were detected at relatively lower concentrations compared to the POPs pesticides with sum 6 PCB ranging between 17.49-18.90 pg/m^3, while PBDEs were relatively lower concentration 0.45-7.98 pg/m^3. PFOS levels in air were 1,165.85 pg/m^3 and 376.8 pg/m^3 in 2017 and 2018, respectively. UPOPs detected included PCDDs/Fs and dl-PCBs.

Important POPs in Morocco ambient air sites were DDTs, aldrin, chlordanes, dieldrin, endrin, heptachlor, HCB, PeCB, alpha endosulphan, HBCDs, HCHs, PCBs, PFOS and PCDDs/Fs.

x) POPs levels in ambient air in Nigeria

POPs monitoring in Nigeria was conducted two sites namely Sheda and Abuja. Sampling at Sheda was conducted in 2008, 2010-2012 and 2014-2017. POPs pesticides detected were aldrin, chlordanes, dieldrin, endrin, heptachlor, HCB, HCH, and alpha-endosulphan, DDT. Industrial POPs were dominated by PCBs, along with low levels of PBDEs. Dioxins and furans and dl-PCBs were found in relatively lower concentrations.

POPs with emerging declining concentrations $\sum_{12}$ dl-PCBs, $\sum_{6}$ PCBs, $\sum_{7}$PCDDs, $\sum_{10}$ PCDFs, BDE 209, $\sum_{3}$endosulphans, $\sum_{4}$ HCHs, $\sum_{6}$ DDTs, dieldrin, $\sum_{3}$heptachlor, mirex. POPs with increasing or no significant declining trends were HCB, PeCB, $\sum_{9}$PBDEs and $\sum_{3}$chlordanes.

Sampling at Abuja Sheda site was conducted in 2010-2011, and 2017-2018. Major POPs detected were: POPs pesticides aldrin, chlordanes, dieldrin, endrin, Mirex, DDT, HCB, HCHs, endosulphan. Industrial POPs detected were dominated by PCBs and PFOs, and PBDEs. UPOPs detected included dl PCBs (Annex A industrial chemicals), dioxins and furans (Annex C) chemicals. In general, ambient air was predominantly contaminated by DDTs, PeCB, HCHs, *alpha*-endosulphan, PCBs, PBDEs, PFOS and dioxins and furans.

xi) POPs levels in ambient air in Senegal

POPs monitoring in Senegal was at two sites namely Dakar Ngoye and Ngoye Bambey. Monitoring at Dakar Ngoye was conducted in 2008, 2010. The following Annex A pesticides were detected: aldrin, chlordanes, dieldrin, endrin, HCB, HCHs and *alpha*-endosulphan. 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), PBDEs.

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 pg/m^3 in 2008 to 17.44 pg/m^3 in 2010.

At the site of Ngoye Bambey, sampling took place in 2010, 2011, 2017 and 2018. POPs pesticides detected were aldrin, chlordanes, dieldrin, endrin, mirex, HCB, HCHs (Annex pesticides), DDTs (Annex B). Industrial POPs were dominated by PCBs, PFOS and low levels of PBDEs. POPs detected at high levels were HCHs, *alpha*-endosulphan, dieldrin, DDTs, PCBs, dioxins and furans, all of them in decreasing concentration over the sampling period.

xii) POPs levels in ambient air in South Africa

Sampling in South Africa took place at 3 sites: Nooitgedacht (2010-2012), De Aar (2004-2007, 2009, 2011, 2014) and Vanderbijil Park (2009). At the site of Nooitgedacht, the pesticides detected were aldrin, chlordanes, dieldrin, endrin, HCB, heptachlor, HCH and *alpha*-endosulphan. The prevailing ones were alpha-endosulphan, HCB, gamma-HCH and oxychlordane, the latter two ones with a decreasing trend.

Industrial POPs were dominated by PCBs were mainly represented by PCBs indicators (sum of PBDEs were also detected in low concentrations. Dioxins and furans were among the most important POPs. Dioxins increased while furans remained stable over the sampling period. Sampling at the sites of De Aar and Vanderbijil Park in 2009 showed that aldrin, dieldrin, HCHs,

endosulphans, DDTs and PCBs were the most important POPs. Of these, the prevailing ones were DDTs, HCH and alpha-endosulphan.

xiii) POPs levels in ambient air in Sudan

In Sudan, sampling took place in Khartoum for the period 2008, 2010-2014. Khartoum is an urban industrial background. Most of the POPs with variable contamination levels were detected in ambient air except DDTs, dl-PCB and Mirex. Aldrin, chlordane, dieldrin, endrin, HCB, HCHs, heptachlor and alpha-endosulphan were the most important pesticides detected.

POPs contamination that had started to develop declining trends included dieldrin, $\sum_6$DDT, $\sum_4$HCHs, $\sum_3$endosulphans, $\sum_6$ PCBs and $\sum_7$ PCDDs and $\sum_{10}$ PCDFs and heptachlor while increasing trends were observed for $\sum_9$ PBDEs, HCB and PeCB.

Industrial POPs chemicals detected including PCBs, PBDEs had lower levels compared to the levels of other POPs detected in Sudan. Dioxins and furans were also detected initially at high levels but gradually showed a decline over the sampling period.

xiv) POPs levels in ambient air in Tanzania

Monitoring in Tanzania was conducted at Vikuge site for the period 2018 and 2019. POPs pesticides detected were aldrin, chlordanes, dieldrin, endrin, heptachlor, mirex, DDTs, HCB, PeCB, HCHs and endosulphans.

Industrial POPs were dominated by PCBs and PFOS, while PBDEs were detected at relatively lower concentrations. Unintentional POPs detected included the dioxins and furans, and dioxin-like PCBs. Due to short monitoring period, no attempt was made to rationalize the trends in POPs levels at the site.

xv) POPs levels in ambient air in Togo

Monitoring in Togo was conducted at Kouma-konda site for the period 2008, 2010-2011, and 2017-2018. The POPs pesticides detected at the site included aldrin, chlordanes, dieldrin, mirex, DDTs, HCB, endosulphan, HCHs, PeCB. Industrial POPs detected were dominated by PCBs, while PBDEs were only detected at relatively lower concentrations. Dioxins and furans and sum of 17 PCDDs/Fs with high concentrations.

Increasing no declining trends was observed for majority of the POPs pesticides aldrin, chlordanes, dieldrin, mirex, DDTs, HCB, endosulphan, HCHs, PeCB comparing the data for first and second GMP phases against the data collected in the period 2017-2018. Further monitoring is necessary to track the changes observed in 2017-2018.

PBDEs recorded relatively lower but stable concentrations across the sampling years suggesting future significance in pollution monitoring.

xvi) POPs levels in ambient air in Tunisia

Sampling in Tunisia was conducted at Tunis site in the period 2008, 2017 and 2018. POPs pesticides detected were aldrin, chlordanes, dieldrin, endrin, heptachlor, mirex, DDTs, HCB, endosulphans, HCHs and PeCBs.

Industrial POPs were dominated by PCBs, with low levels of PBDE congers observed across the sampling years. PCDDs/Fs and dioxin like PCBs were also detected at low levels at the site.

Due to short monitoring duration no attempt was made to rationalise the trends in levels of the POPs detected at the site.

xvii) POPs levels in ambient air in Uganda

POPs monitoring in Uganda was conducted at Soroti site in the period 2010, 2011, 2017-2019. POPs pesticides detected were aldrin, chlordanes, DDTs, dieldrin, endrin, HCB, heptachlor, mirex, HCHs, endosulphan, PeCB, and POP-PBDEs were not found at the Soroti site.

Under GMP monitoring activities industrial POPs detected were dominated by PCBs and PFOS, while PBDEs were at relatively lower levels. Dioxins and furans were also detected in the site implying contribution of combustion activities to the POPs load in the country.

Most important pollutants were DDTs, aldrin, *cis* and *trans* chlordane, oxychlordane, dieldrin, endrin, heptachlor, mirex, alpha endosulphan, HBCDs, HCB, HCHs, and indicators PCBs, PFOS, PBDEs, dioxins and furans and dl-PCBs.

Local studies conducted in Uganda have also reported different groups of POPs in atmospheric environment (Arinaitwe et al., 2014, 2016 & 2018).

xvii) POPs levels in ambient air in Zambia

In Zambia POPs monitoring was conducted at Lusaka site for the period 2008, 2010-2011 and 2017-2018. POPs pesticides detected included aldrin, chlordanes, dieldrin, endrin, heptachlor, mirex and DDTs,

Industrial POPs were dominated by PCBs and PFOS, while low levels of PBDEs were also detected in the ambient air samples. UPOPs were dominated by PCDDs/Fs and dl-PCBs in the ambient air.

The most important contaminants were DDTs, chlordanes, aldrin, heptachlor, mirex, dieldrin, HCB, HCH (pesticides), PCBs indicators (sum of 6) and dioxins (sum of 7 PCDDs) and furans (sum of 10 PCDFs).

Air contamination from research activities

Apart from the GMP data research activities have also recorded contamination of air by POPs in the regional countries. These include South Africa (Garrison et al., 2014; Katima et al., 2018), West Africa (Gioia et al., 2011), Hogarh et al., 2014 & 2018; Isogai et al., 2018), Uganda (Arinaitwe et al., 2018; 2014 & 2013), Developing countries (Bogdal et al., 2013), comparison of POPs uptake performance by PUFs in different climatic regions in Africa and Europe (Boliliu-Nizzetto et al., 2020), and air contamination by OCPs in Ghana (Adukumi et al., 2012). In Algeria a study conducted by Moussaoui et al. (2012) at urban and industrial sites in 2009 found PCDD/Fs and dl-PCBs TEQs ranging from 249 to 923 fg/m^3. POPs pesticides have also been reported in ambient air in Botswana (Shunthirasingham et al., 2010).

5.2.2 POPs levels in mothers' milk samples

A total of 19 regional countries participated mothers' milk survey for POPs monitoring for the period 2001-2019. Out of these twelve countries completed two rounds of mothers' milk survey cycles, while seven have only participated in a single cycle of mothers milk monitoring. To date all the five sub-regions (Eastern, Western, Central, Southern, Northern, and Small Island states) have been represented by at least one country mothers' milk data set, achieving sub-regional baseline data, compared to the second regional report of 2015 where data gaps were encountered

in the Southern Africa sub-region. Figure 5.2.2.1 below shows the countries that have participated in the previous mothers' milk survey, highlighted in black.

Figure 5.2.2.1 Countries that contributed mothers' milk data for the period 2002-2019

The specific countries that participated in the mothers' milk survey between 2001- 2019 were DR Congo, Cote d'Ivoire, Djibouti, Egypt, Ethiopia, Ghana, Kenya, Mali, Mauritius, Morocco, Niger, Nigeria, Senegal, Sudan, Tanzania, Togo, Tunisia, Uganda and Zambia. Table 5.2.2.1 shows the years of reporting and the total number of sampling surveys/cycles made per country.

Table 5.2.2.1. Countries participation in mothers' milk survey for POPs monitoring

	2001	2006	2008	2009	2010	2011	2012	2015	2017	2018	2019	Reporting Cycles
DR Congo				X					x			2
Cote d'Ivoire					x			x				2
Djibouti						x						1
Egypt	x										x	2
Ethiopia							x				x	2
Ghana				x							x	2
Kenya				x							x	2
Mali				x							x	2
Mauritius				x						x		2
Morocco											x	1
Niger						x						1
Nigeria			x								x	2
Senegal				x						x		2
Sudan		x										1
Tanzania											x	1
Togo					x				x			2
Tunisia											x	1
Uganda				x						x		2
Zambia											X	1

The participation of regional countries in the mothers' milk survey have enabled the region to build baseline data for POPs levels in mothers' milk. However, the data available so far is from short period of monitoring and not adequate to determine trends in POPs levels. Hence the countries are encouraged to participate in further surveys to enable the region to establish trends of POPs levels in the mothers' milk. This will go a long way to establish effectiveness of the convention and POPs management strategies put in place in protecting human health and the environment from the toxic effects associated with POPs.

5.2.2.1 Aldrin

The concentrations of aldrin were below the limit of quantification (<0.25 ng/g fat) in all mothers' milk samples collected from the regional countries for the period 2001-2019. The findings could be attributed to its fast metabolic biotransformation activity mainly in the liver through cytochrome P450 driven epoxidation process to form dieldrin (McManus et al., 1984; Limbosch, 1983; Wolf and Strecker, 1985).

5.2.2.2 Chlordane

The chlordanes compounds monitored in mother's milk samples were cis-chlordane, trans-chlordane and oxychlordane. Both *cis*- and *trans*-isomers registered levels below 0.25 ng/g fat in all the samples collected from 2001 to 2019. However, the oxychlordane registered levels between bdl and 13.19 ng/g fat. In 2001, 2006 and 2008, the levels of oxychlordane were 1.0 ng/g fat (Egypt), 13.19 ng/g fat (Sudan) and 2.49 ng/g fat (Nigeria). Figure 5.2.2.2 illustrates the concentrations of Chlordane in samples from the regional countries.

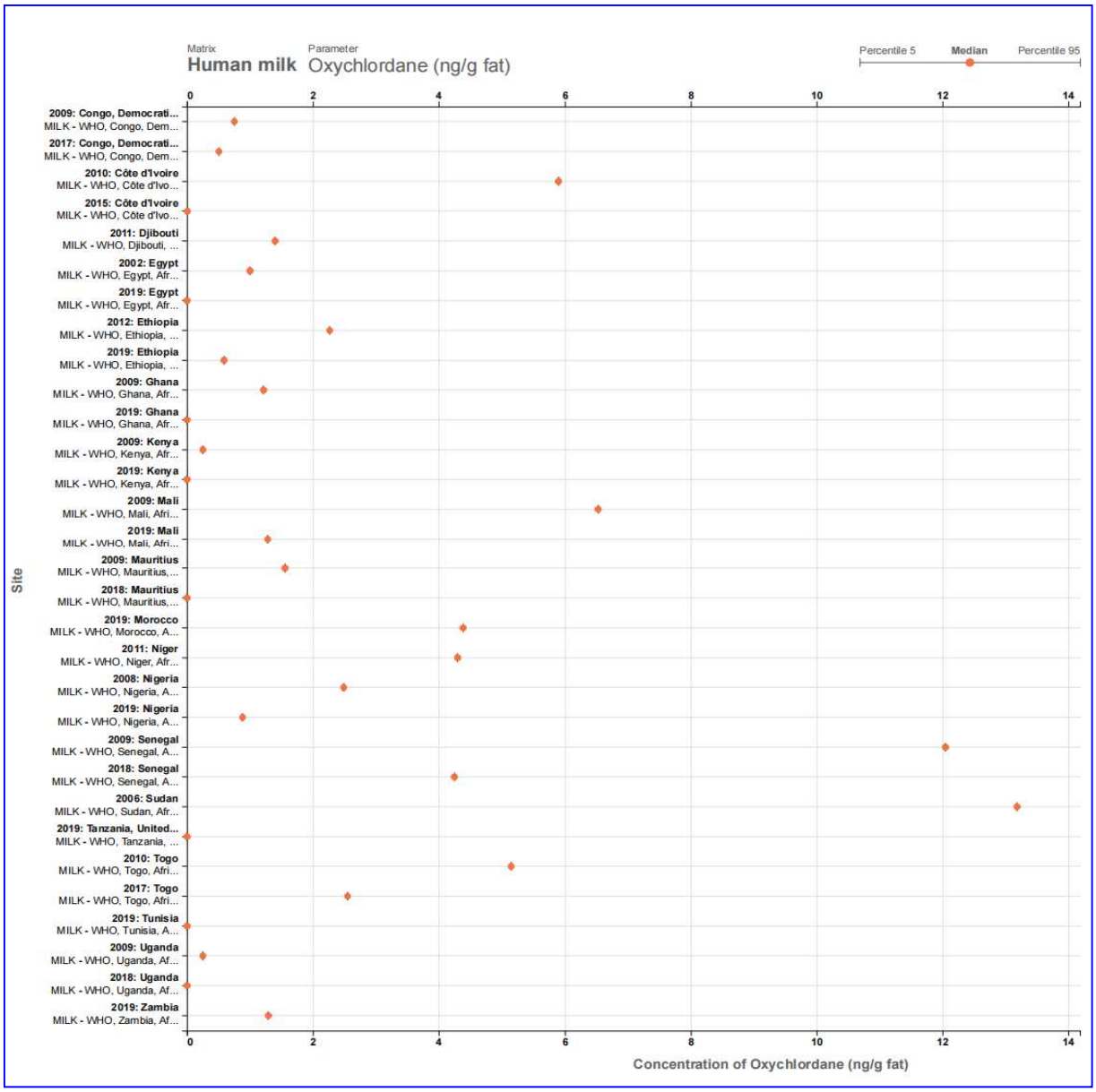


Figure 5.2.2.2 Oxychlordane concentration in mothers' milk.

In 2009 the data from seven countries revealed oxychlordane concentration range between 0.25-12.05 ng/g fat. Levels above 5 ng/g fat were registered in Senegal (12.05 ng/g fat) and Mali (6.53

ng/g fat), while medium levels between 0.25-1.56 ng/g fat were recorded in DR Congo, Ghana, Kenya, Mauritius and Uganda. In 2010 data were made available for samples from Cote d'Ivoire (5.90 ng/g fat), Niger (4.30 ng/g fat) and Togo (5.15 ng/g fat).

2011 registered two data sets with 1.40 ng/g fat (Djibouti) and 4.30 ng/g fat (Niger), while 2012 and 2015 registered a single data set each, 2.27 ng/g fat (Ethiopia) and 0.03 ng/g fat (Cote d'Ivoire), respectively. 2017 registered two data sets from DR Congo (0.50 ng/g fat) and Togo (2.55 ng/g fat), while 2018 recorded three data sets from Senegal (4.25 ng/g fat), and Mauritius and Uganda, both recording levels below the limit of detection.

In 2019 nine countries reported mothers' milk data, with mean oxychlordane concentrations from bdl – 4.39 ng/g fat. The highest levels were 4.39 ng/g fat (Morocco), 1.29 ng/g fat (Zambia), and 1.28 ng/g fat (Mali). Levels between <LOQ- 0.88 ng/g fat were recorded in Egypt, Ghana, Kenya, Nigeria, Tanzania, Tunisia and Uganda.

The data revealed that countries participating in the second round of milk survey had lower levels of oxychlordane compared to the levels recorded in their first cycle, suggesting a positive outcome of the measures put in place to reduce contamination levels.

5.2.2.3 Dieldrin

The levels of dieldrin in mothers' milk samples collected from 2001-2019 ranged from below detection limit to 11.21 ng/g fat. Data set for 2002 was obtained from Egypt (0.25 ng/g fat) while 2006 data was from Sudan (1.39 ng/g fat). Subsequent report was in 2008 for samples from Nigeria (4.10 ng/g fat). Consistent effort under Stockholm Convention Secretariat and UNEP/GEF projects increased countries participating in WHO mothers' milk survey for 2008/2009 with 7 countries recording mothers' milk data. The highest concentrations in 2009 were 11.21 ng/g fat (Mali), followed by 5.11 ng/g fat (Kenya), 3.06 ng/g fat (Senegal), 2.54 ng/g fat (Uganda), 2.48 ng/g fat (Mauritius), 1.29 ng/g fat (Ghana), and 1.11 ng/g fat (DR Congo).

In 2010 mothers' milk data for dieldrin were obtained from Cote d'Ivoire (4.61 ng/g fat) and Togo (2.36 ng/g fat), while in 2011 Djibouti and Niger provided data mothers' milk data with concentrations of 0.67 ng/g fat and 2.15 ng/g fat, respectively.

2012 and 2015 recorded data from Ethiopia (0.25 ng/g fat) and Cote d'Ivoire (<0.01 ng/g fat), respectively. The years 2013, 2014 and 2016 had no data set reported, while in 2017 only DR Congo and Togo reported new data sets with dieldrin concentrations of 0.83 ng/g fat and 0.89 ng/g fat respectively, for samples from their second cycle of mother's milk survey.

2018 and 2019 registered increased number of counties participating in the mother's milk survey through the UNEP/GEF GMP2 project 2016-2020. The 2018 data for dieldrin in mothers' milk came from Senegal (1.94 ng/g fat), Uganda (0.56 ng/g fat) and Mauritius (0.50 ng/g fat). The levels were relatively lower than those reported in their first round of mothers' milk survey, as illustrated in Figure 5.2.2.3.

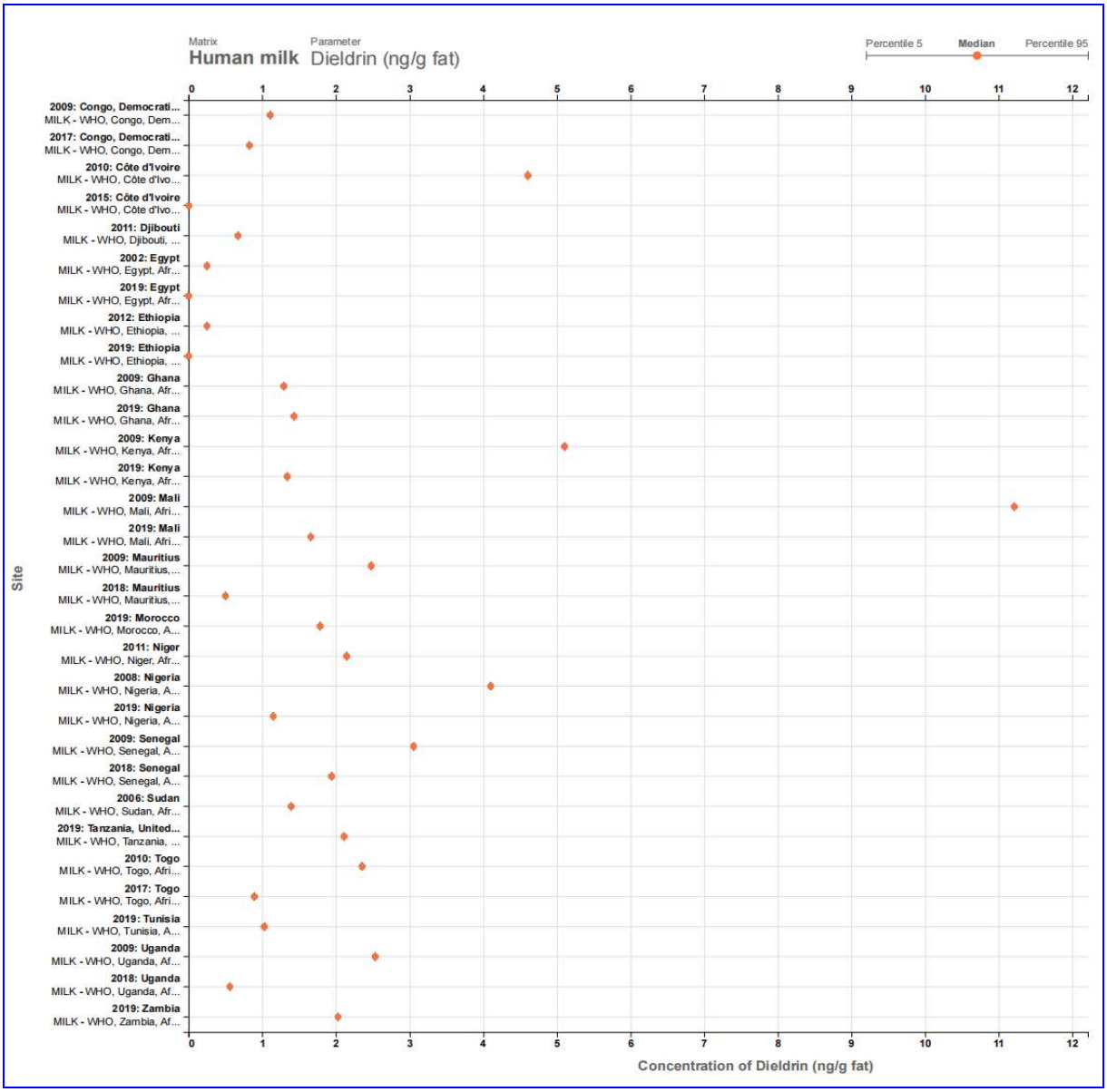


Figure 5.2.2.3 Dieldrin concentration in mothers' milk samples

2019 recorded 10 participating countries. The highest concentrations of dieldrin were 2.11 ng/g fat (Tanzania), 2.03 ng/g fat (Zambia), 1.79 ng/g fat (Morocco) and 1.66 ng/g fat (Mali). The rest of the countries had levels between bdl- 1.43 ng/g fat (Egypt, Ethiopia, Ghana, Kenya, Nigeria and Tunisia.

The contrast in the levels of dieldrin and aldrin observed in the mothers' milk could be explained by differences in use patterns and metabolic transformation of aldrin and dieldrin. Additional contributing factors could include direct sources of dieldrin in the environment from previous applications of the compound as an insecticide against a variety of insect pests including termites and soil dwelling insects and in wood preservation. The long environmental persistence allows the POPs to contaminate other media and accumulation in the food chain. In animals, dieldrin is metabolized in the liver and excreted, with its metabolites, primarily through the faeces. The

major metabolite is 9-hydroxy dieldrin, but also excretion of small amounts of trans-6,7-hydroxy dieldrin, dicarboxylic acids and bridged pentachloroketone have been reported in laboratory animals, and the ratios between the amounts of the various metabolites produced differ for different animals (WHO, 1989).

5.2.2.4 Endrins

Endrin concentrations in mothers' milk were below LOQ (<0.25 ng/g fat) in all samples collected in the period 2002-2019, for all participating countries namely DR Congo, Côte d'Ivoire, Djibouti, Egypt, Ethiopia, Ghana, Kenya, Mali, Mauritius, Morocco, Niger, Nigeria, Senegal, Sudan, Tanzania, Togo, Tunisia, Uganda, and Zambia, for the period 2001-2019.

5.2.2.5 Heptachlors

Heptachlor compounds monitored in mothers' milk for the period 2002-2019 included heptachlor and heptachlor epoxides (*cis*-heptachlor epoxide and *trans*-heptachlor epoxide).

Heptachlor

The mean levels of heptachlor varied between <0.25 -13.76 ng/g fat for samples collected in the period 2006- 2019. The data set for 2006 had concentration of 2.17 ng/g fat (Sudan).

2008 recorded levels below the limit of detection (0.25 ng/g fat) for samples from Nigeria.

In 2009 quantifiable levels were 1.36 ng/g fat (DR Congo) and 0.47 ng/g fat (Senegal), while samples from Ethiopia, Ghana, Kenya, Mali, Mauritius and Uganda had concentrations <0.25 ng/g fat.

2010 dataset had mean concentrations of <0.25 ng/g fat (Cote d'Ivoire) and 1.85 ng/g fat (Togo), while 2011 recorded levels <0.25 ng/g fat for both samples from Djibouti and Niger.

2012 dataset recorded mean concentration of 13.76 ng/g fat (Ethiopia). Samples collected in subsequent years recoded heptachlor levels below LOQ (0.25 ng/g fat) in 2015 (Cote d'Ivoire), 2017 (DR Congo and Togo), 2018 (Mauritius, Senegal and Uganda), and 2019 (Egypt, Ethiopia, Ghana, Kenya, Mali, Morocco, Nigeria, Morocco, Tanzania, and Zambia). The levels of heptachlor in mothers' milk samples are summarised in Figure 5.2.2.4.

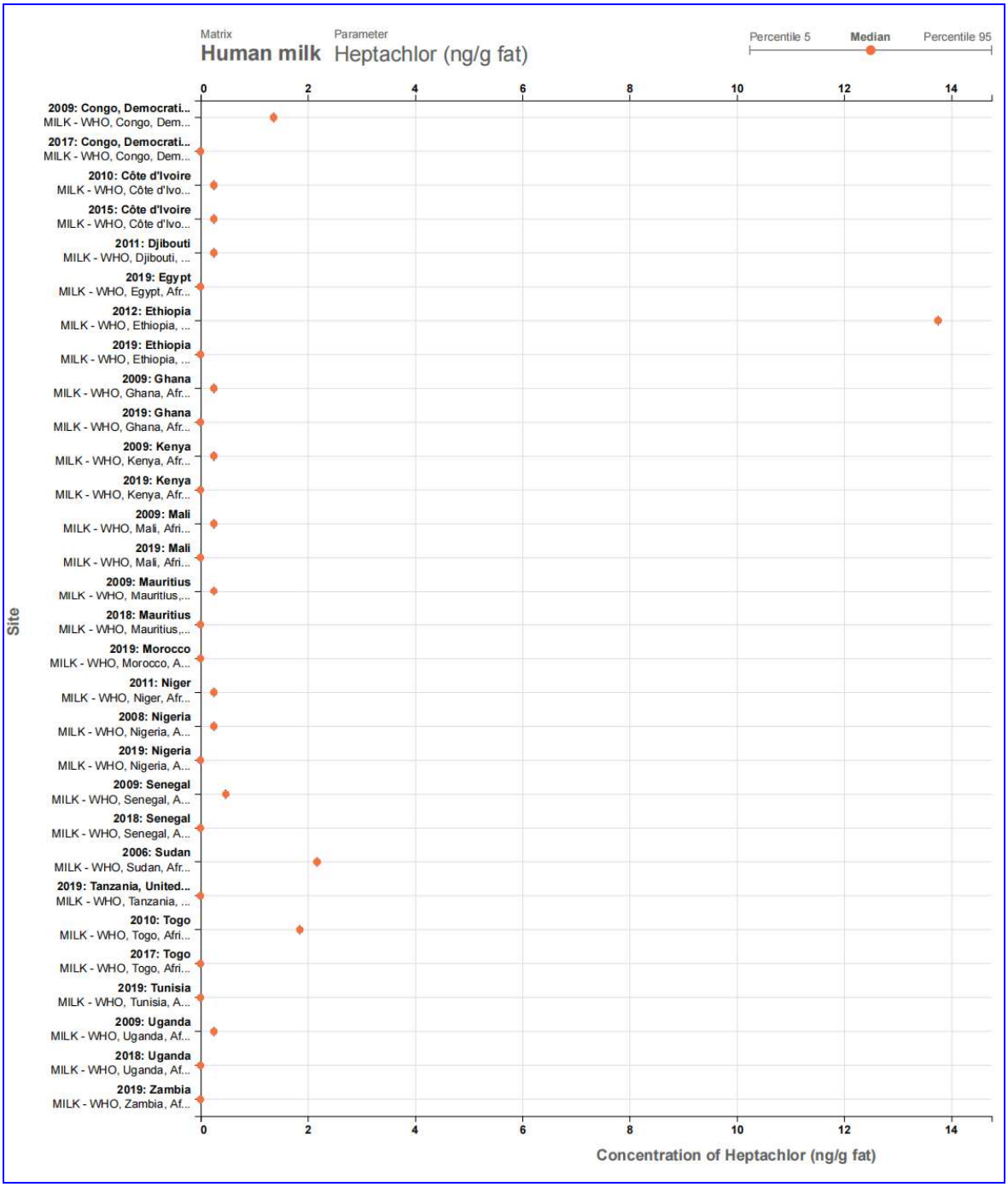


Figure 5.2.2.4 Heptachlor concentration in mothers' milk samples

Heptachlor epoxides

The two isomers of heptachlor epoxide monitored in mothers' milk were *cis* and *trans*-heptachlor epoxides. The levels were dominated by the *cis*-heptachlor epoxide while the *trans* heptachlor epoxide isomer recorded levels below 0.25 ng/g fat in all samples in the period 2002-2019.

In 2002 the data set for *cis*-heptachlor epoxide had mean levels <0.25 ng/g fat (Egypt). In 2006 and 2008, quantifiable levels were reported in Sudan (3.63 ng/g fat) and Nigeria (0.94 ng/g fat). Figure 5.2.2.5 illustrates the levels of *cis*-heptachlor epoxide recorded in the mothers' milk samples.

The levels in 2009 ranged between <0.25- 3.31 ng/g fat. National mean concentrations were 3.31 ng/g fat (Mali), 1.35 ng/g fat (Senegal), and 0.91 ng/g fat (Ghana). DR Congo, Kenya, Mauritius, and Uganda recorded levels below LOQ (<0.25 ng/g fat).

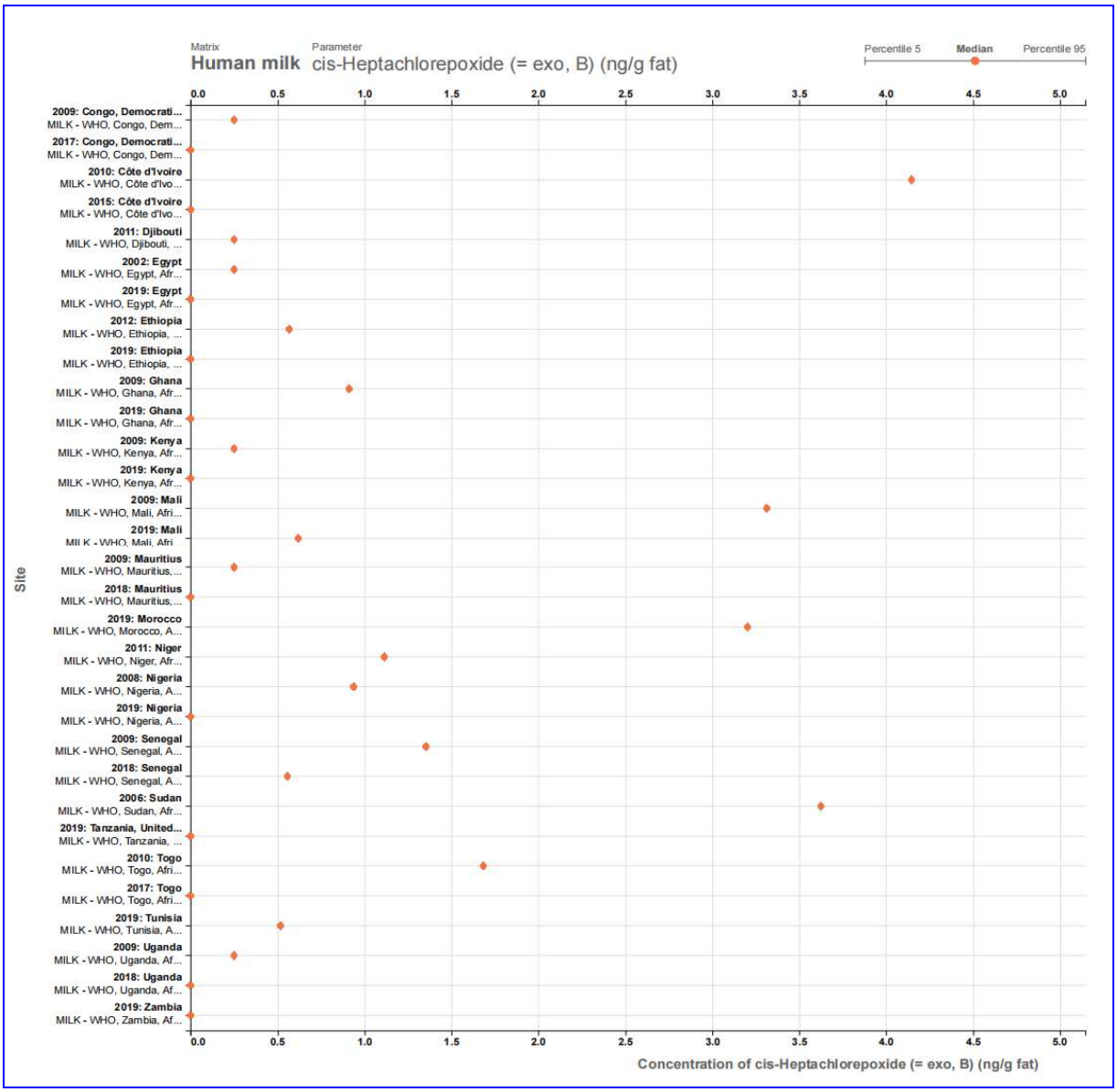


Figure 5.2.2.5 Cis-heptachlor epoxide concentration in mothers' milk samples

In 2010 the mean *cis*-heptachlor epoxide levels were 4.15 and 1.68 ng/g fat recorded in Cote d'Ivoire and Togo, respectively, while 2011 recorded <0.25 ng/g fat (Djibouti) and 1.11 ng/g fat (Niger). 2012 had a single data set from Ethiopia with mean *cis*-heptachlor epoxide concentration of 0.57 ng/g fat.

2015 and 2017 samples recorded levels below LOQ (<0.25 ng/g fat) for Cote d'Ivoire in 2015, and DR Congo and Togo in 2017.

2018 datasets with quantifiable levels were for samples from Senegal (0.56 ng/g fat), while samples from Mauritius and Uganda had mean concentrations below LOQ (0.25 ng/g fat).

In 2019 quantifiable levels were recorded in Morocco (3.20 ng/g fat), Mali (0.62 ng/g fat) and Tunisia (0.52 ng/g fat). Egypt, Ethiopia, Ghana, Kenya, Nigeria, Tanzania, and Zambia recorded levels below LOQ (<0.25 ng/g fat).

5.2.2.6 Mirex

All mothers' milk datasets for the period 2002-2019 contained mirex levels below LOQ (0.25 ng/g fat) for all participating countries namely Côte d'Ivoire, DR Congo, Djibouti, Egypt, Ethiopia, Ghana, Kenya, Mali, Mauritius, Morocco, Nigeria, Niger, Senegal, Sudan, Tanzania, Togo, Tunisia, Uganda and Zambia.

5.2.2.7 Dichlorodiphenyltrichlorethane (DDT) isomers and metabolites

DDT isomers and metabolites monitored in mothers' milk included *p,p'*-DDT, *p,p'*-DDE, *p,p'*-DDD, *o,p'*-DDT, *o,p'*-DDE and *o,p'*-DDD. The sum 6 DDT ($\sum_6$DDT) concentrations in the samples collected through the national surveys conducted for the period 2001-2019 ranged from 0.44 – 22,285.94 ng/g fat.

Data for DDT in 2001, 2006 and 2008 data was registered for Egypt ($\sum_6$DDT =357.75 ng/g fat), Sudan ($\sum_6$DDT= 1,175.96 ng/g fat) and Nigeria ($\sum_6$DDT= 777.63 ng/g fat), respectively.

In 2009 $\sum_6$DDT ranged from 210.52 – 1,742.68 ng/g fat, with the highest levels registered as 1,742.68 ng/fat (Mauritius), 1,668.96 ng/g fat (Mali), 1,356.62 ng/g fat (Uganda). Medium concentrations (210.52 – 812.78 ng/g fat) were recorded in DR Congo, Ghana, Kenya and Senegal.

The subsequent years 2010 and 2011 registered two national data sets each with Cote d'Ivoire ($\sum_6$DDT=973.17 ng/g fat) and Togo ($\sum_6$DDT= 1,615.01 ng/g fat) reporting in 2010 while Djibouti ($\sum_6$DDT= 1,000.73 ng/g fat) and Niger ($\sum_6$DDT= 724.63 ng/g fat) were reported in 2011.

Datasets for 2012, 2015 and 2017 were recorded from Ethiopia ($\sum_6$DDT= 22,285.94 ng/g fat) and Cote d'Ivoire ($\sum_6$DDT = 0.44 ng/g fat) reporting in 2012 and 2015, respectively, while DR Congo ($\sum_6$DDT = 177.03 ng/g fat) and Togo ($\sum_6$DDT = 568.01 ng/g fat) reported datasets for their second cycle of national survey conducted in 2017.

In 2018, three countries that ported mothers' milk data sets were Uganda ($\sum_6$DDT= 96.00 ng/g fat), Senegal ($\sum_6$DDT= 172.81 ng/g fat) and Mauritius ($\sum_6$DDT=506.17 ng/g fat). The levels reported in 2018 revealed declining concentrations compared to those measured in their 1st cycle in 2009.

In 2019 a total of 10 countries' provided data sets with the national sum ($\sum_6$DDT) concentrations ranging from 15.16- 6,560.47 ng/g fat. The highest levels were $\sum_6$DDT= 6,560.47 ng/g fat (Ethiopia), $\sum_6$DDT= 502.91 ng/g fat (Zambia), $\sum_6$DDT= 493.37 ng/g fat (Mali), $\sum_6$DDT= 341.18 ng/g fat (Tanzania), and $\sum_6$DDT= 214 ng/g fat (Morocco). The rest of the countries recorded $\sum_6$DDT concentrations between 15.16 – 88.99 ng/g fat (Egypt, Ghana, Kenya, Nigeria and

Tunisia). The levels of sum 6 DDTs recorded in the region are summarised in Figure 5.2.2.6 below.

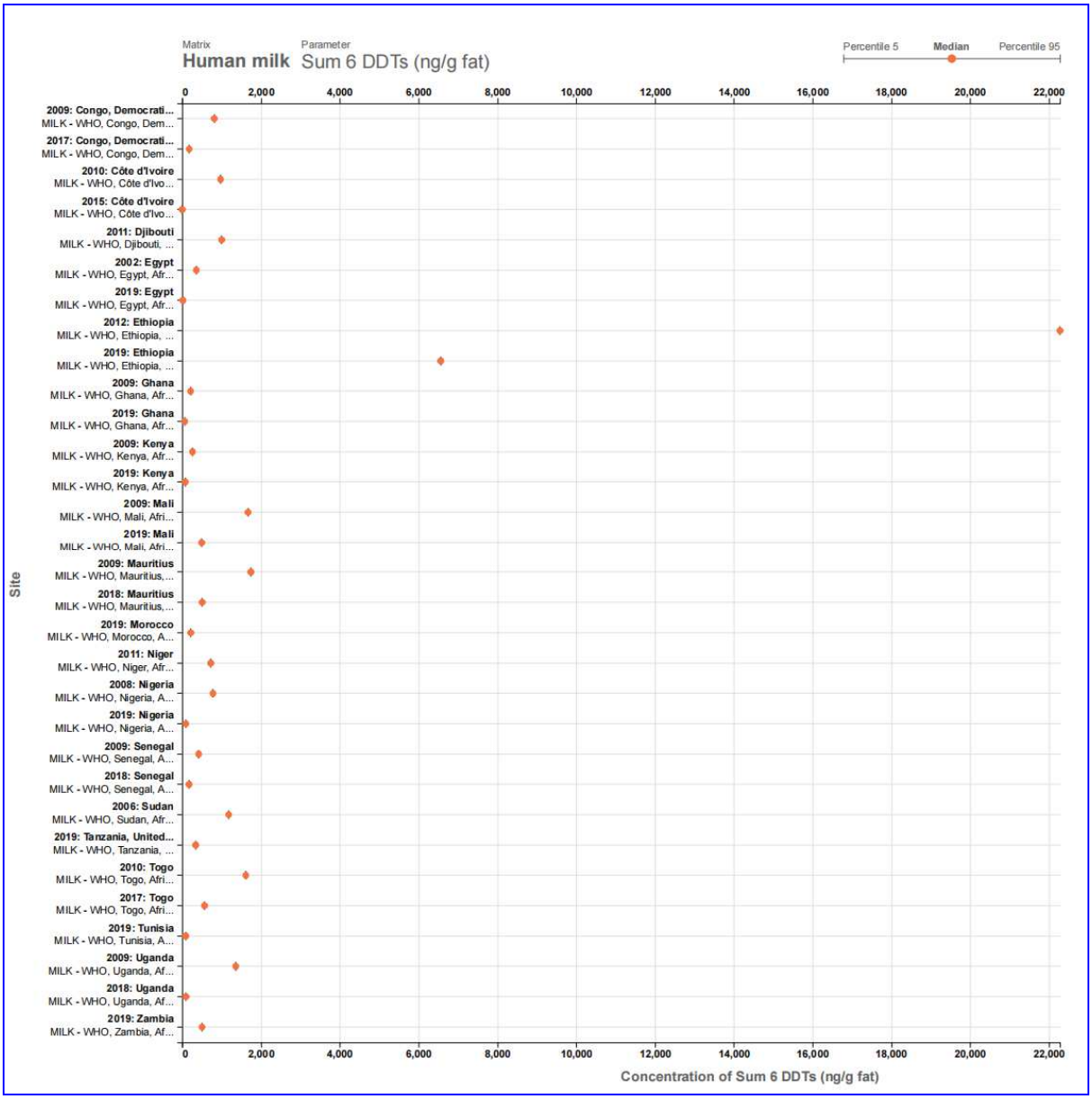


Figure 5.2.2.6 Sum 6 DDT concentration in mothers' milk samples

Sum DDT$_3$ in mothers' milk

The sum 3 DDTs (*p,p'*-DDT, *p,p'*-DDE and *p,p'*-DDE) ranged between 0.44-21,293 ng/g fat confirming the dominance of the *p,p'*-DDTs among the levels measured for the sum 6 DDT. Figure 5.2.2.7 shows the levels of sum 3 DDT in the mothers' milk samples.

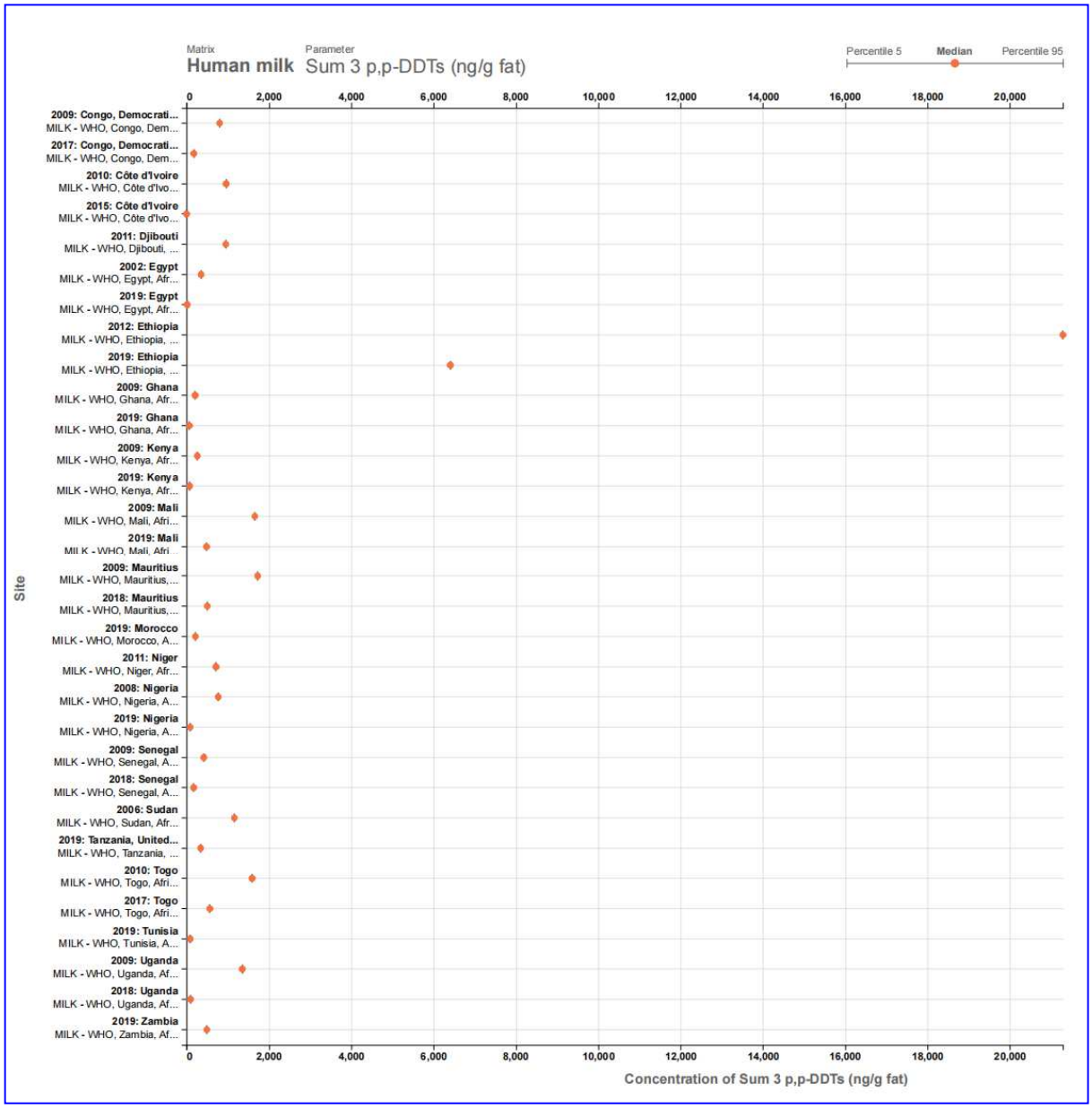


Figure 5.2.2.7 Sum 3 DDTs concentration in mothers' milk samples

Individual concentration of DDT compounds were dominated by *p,p'*-DDT (0.36-10,734.04 ng/g fat) and *p,p'*-DDE (0.40 -10,518.07 ng/g fat), followed by *o,p'*-DDT (0.004-965.10 ng/g fat), *p,p'*-DDD (<0.25-41.38 ng/g fat), *o,p'*-DDE (<0.25 -13.76 ng/g fat) and *o,p'*-DDD (<0.25-13.56 ng/g fat). Declining concentrations were recorded in the countries participating in the second cycle of the national milk survey as shown by concentrations recorded in 2015, 2017, 2018 and 2019 against the earlier years. The detailed levels of *p,p'*-DDT and *p,p'*-DDE in mothers' milk are shown in Figures 5.2.2.8 and 5.2.2.9 below.

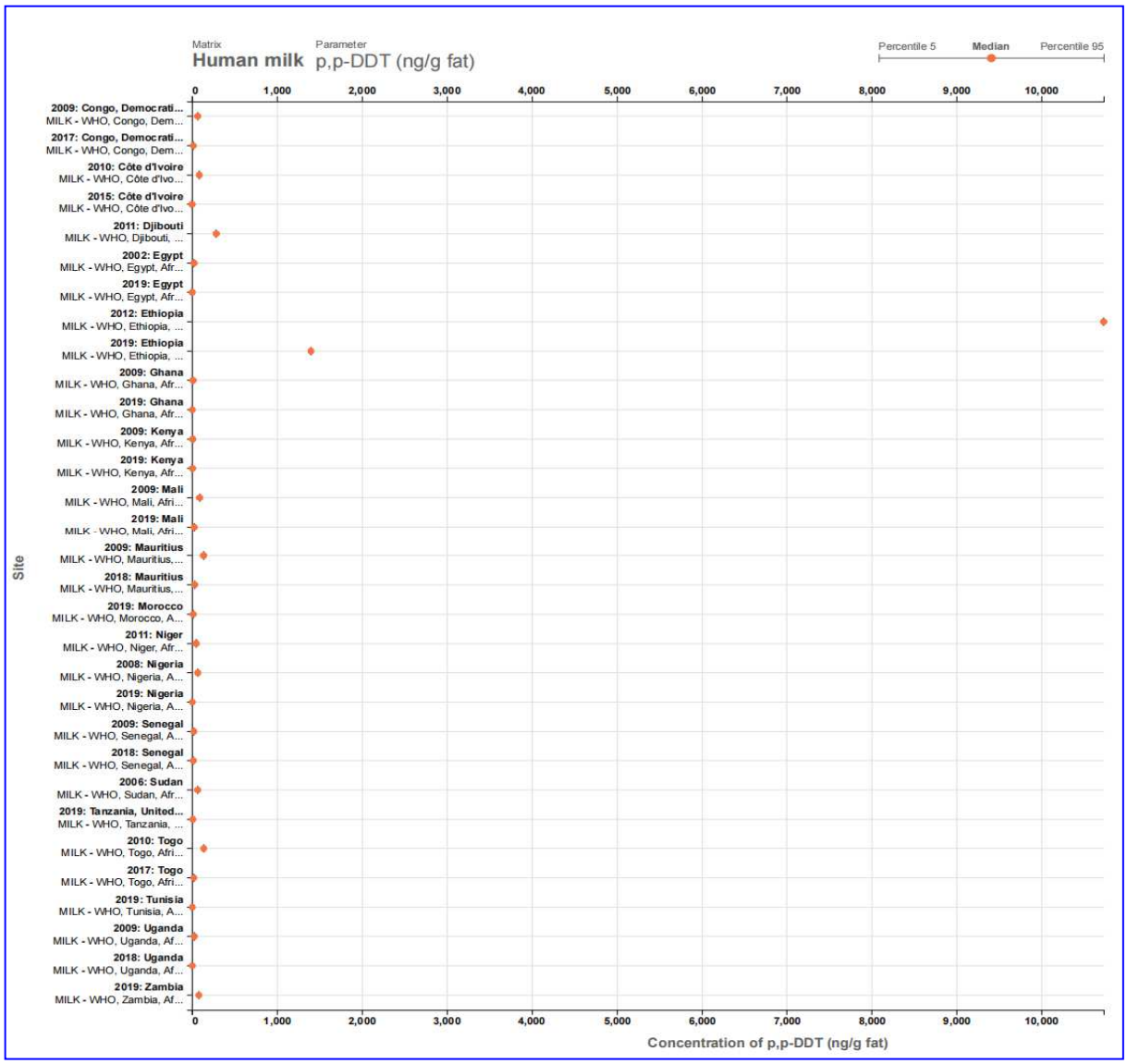


Figure 5.2.2.8 p,p'-DDT concentration in mothers' milk samples

Figure 5.2.2.9 shows the levels of *p,p'*-DDE measured in mothers' milk samples collected from regional countries in the period 2002-2019.

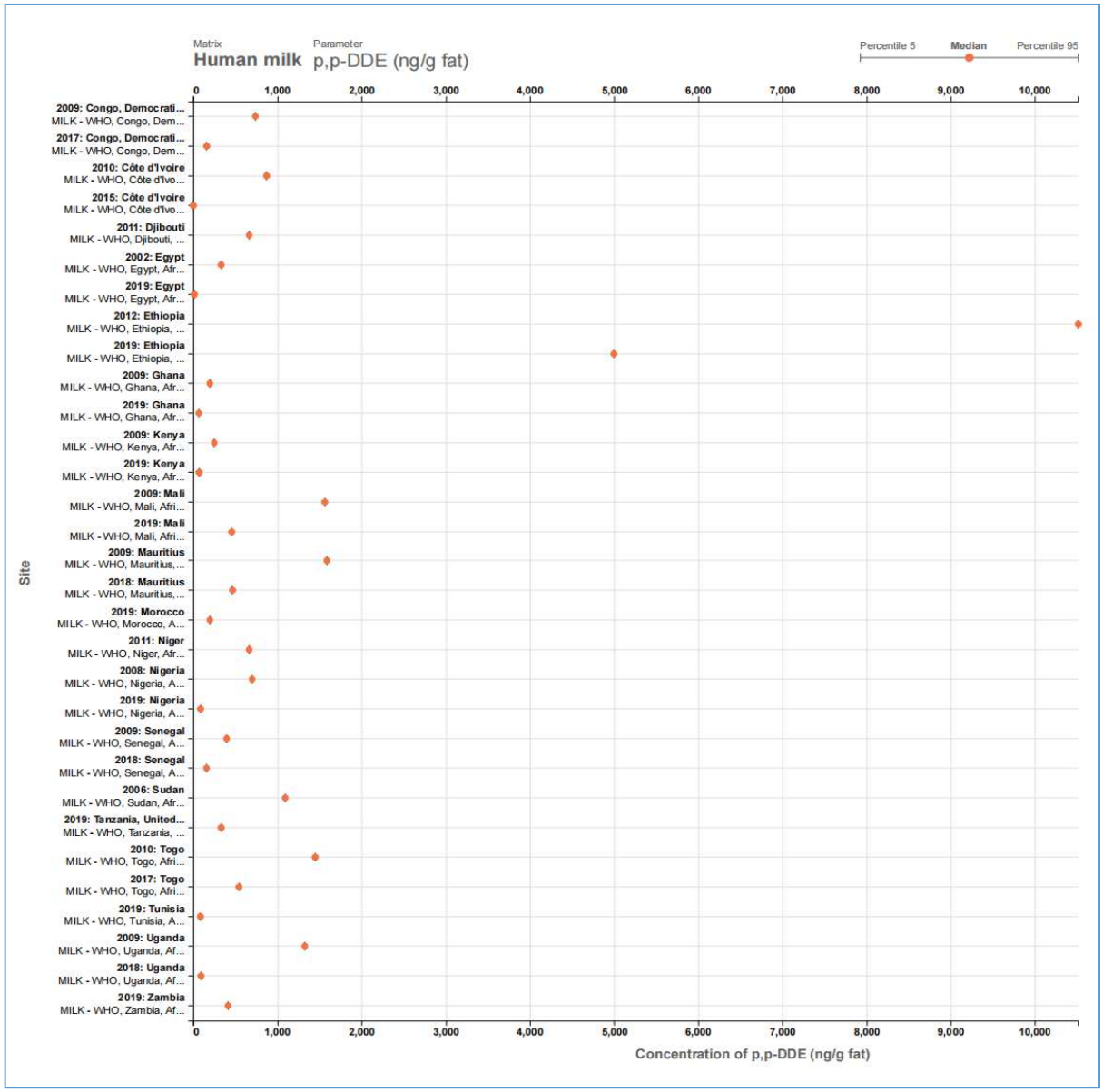


Figure 5.2.2.9 p,p'-DDE concentration in mothers' milk samples

At regional level, no significant trends have been established for the concentrations of DDT isomers and metabolites in mothers' milk. This could be attributed to limited number of data sets in the region, since most of the countries (12) had only participated in two cycles of mothers' milk survey, while seven out of the nineteen countries have only participated in a single survey. Further participation in mothers' milk survey will be required to start developing trends of POPs levels in mothers' milk.

5.2.2.8 Toxaphene

Toxaphene isomers monitored in mothers' milk samples collected from 2001- 2019 were palar 26, 50 and 62.

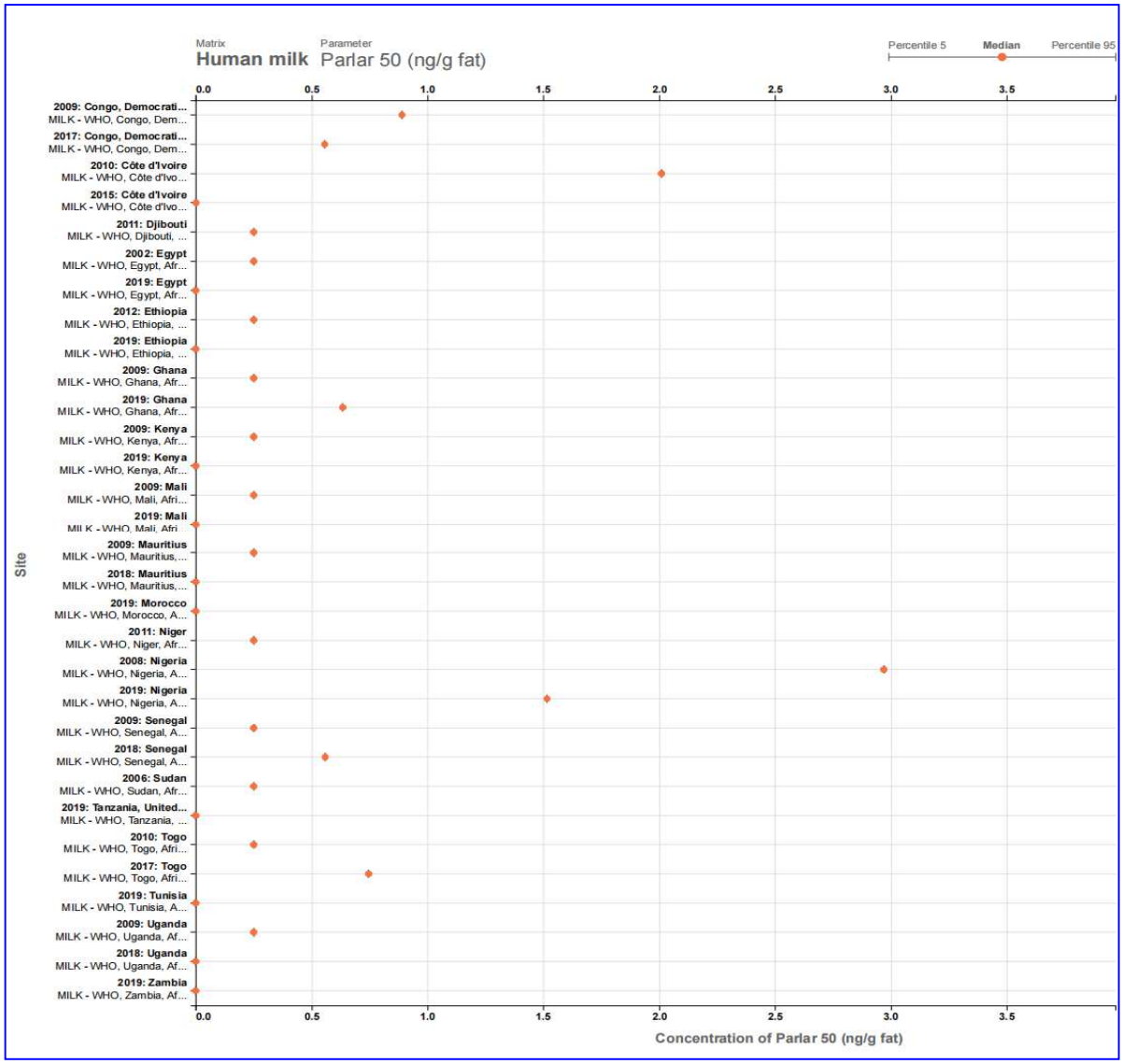


Figure 5.2.2.10 Palar 50 in mothers' milk samples

Palar 26 isomer was reported in national samples from DR Congo in 2009 at concentration of 0.51 ng/g fat, Cote-d'Ivoire in 2010 at 0.82 ng/g fat, and Nigeria in 2008 and 2019 at concentrations of 1.09 ng/g fat and 0.77 ng/g fat, respectively. All other samples collected from 2001-2019 recorded levels of palar 26 below 0.25 ng/g fat. Quantifiable levels of palar 50 isomer were recorded in samples from DR Congo in 2009 and 2017 at concentrations of 0.89 and 0.56 ng/g fat, respectively. In Nigeria, concentrations of palar 50 were recorded in 2009 and 2019 at 2.97 and 1.52 ng/g fat, respectively. Other countries with measurable levels of palar 50 were Cote d'Ivoire in 2010 (2.01 ng/g fat), Ghana in 2019 (0.63 ng/g fat), Senegal in 2018 (0.56 ng/g fat) and Togo in 2017 (0.75 ng/g fat). The rest of the countries had levels below the limit of detection (<0.25 ng/g fat). Figure 5.2.2.10 shows the levels of palar 50 in mothers' milk samples. Palar 62 isomer registered levels below the limit of detection (<0.25 ng/g fat) for the samples collected from all countries for the period 2001-2019.

5.2.2.9 Hexachlorobenzene (HCB)

The levels of HCB in mothers' milk samples for the period 2001-2019 ranged between 1.26-5.03 ng/g fat. Declining levels of HCB in mothers' milk were recorded in national datasets from countries participating in the second survey compared to the levels reported in the first survey.

HCB levels in 2001, 2006 and 2008 were 3.75 ng/g fat (Egypt), 3.20 ng/g fat (Sudan) and 5.03 ng/g fat (Nigeria), respectively. In 2009 HCB levels ranged between 1.73-4.01 ng/g fat with the highest recorded in Mauritius, followed by 3.71 ng/g fat (Senegal), and 3.10 ng/g fat (Kenya). The rest of the countries had levels between 1.73-2.49 ng/g fat (DR Congo, Ethiopia, Mali and Uganda). Detailed levels of HCB are summarised in Figure 5.2.2.11.

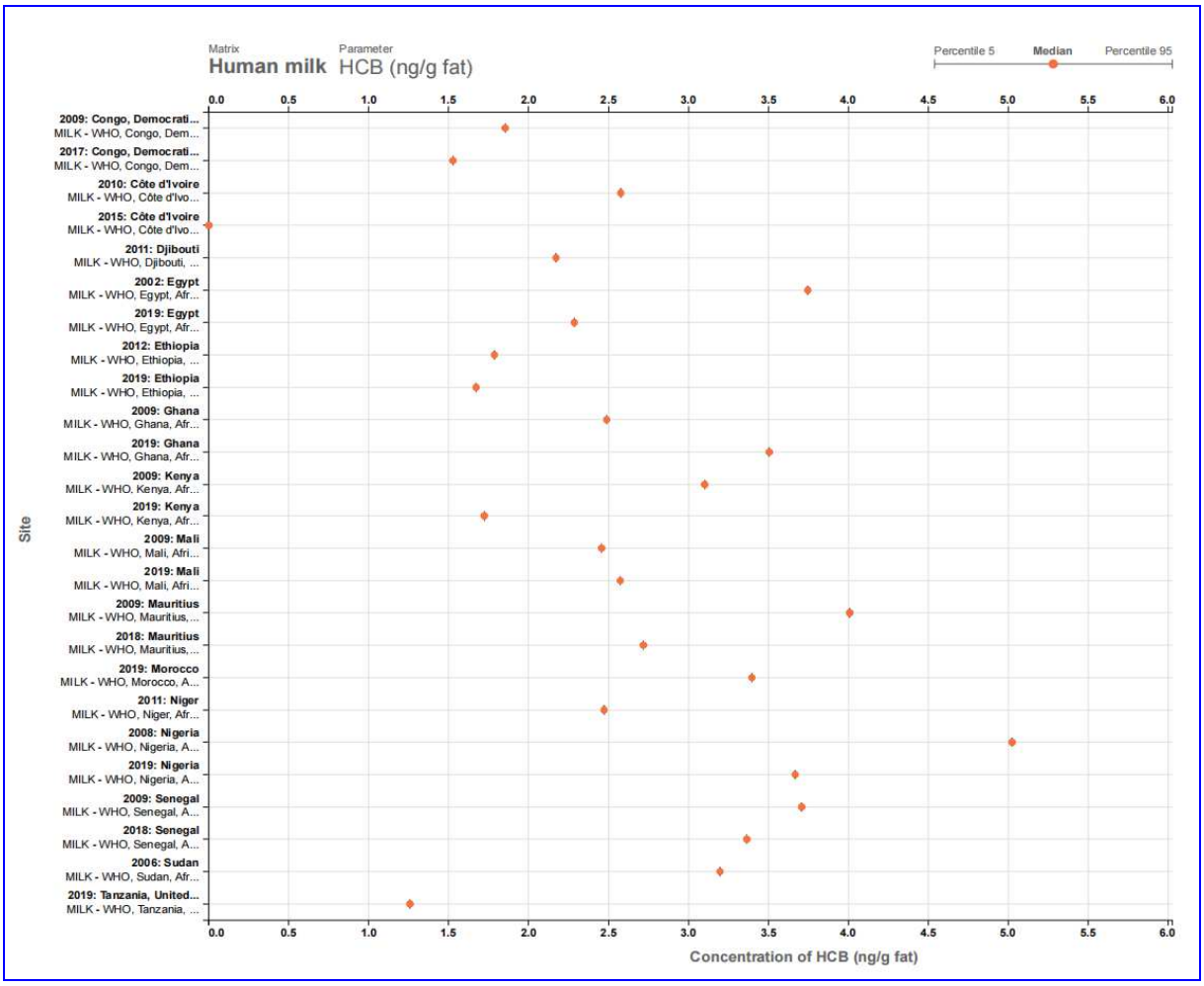


Figure 5.2.2.11 Concentration of HCB in mothers' milk samples

In 2010, 2011 and 2012 the concentrations were 2.58 ng/g fat and 1.63 ng/g fat recorded in Cote d'Ivoire and Togo (for 2010); 2.18 ng/g fat and 2.48 ng/g fat recorded in Djibouti and Niger (2011); and 1.79 ng/g fat reported in Ethiopia in 2012. A single dataset was collected in 2015 was from Cote d'Ivoire, with HCB concentration of 0.003 ng/g fat. In 2017 the concentration of HCB in mothers' milk samples were recorded for DR Congo (1.53 ng/g fat) and Togo (1.91 ng/g fat).

2018 data sets came from Mauritius (2.72 ng/g fat), Senegal (3.37 ng/g fat) and Uganda (1.67 ng/g fat). These levels were lower than the HCB concentrations reported by these countries in their 1st survey.

In 2019 mothers' milk data had concentration of HCB ranging from 1.26 – 3.67 ng/g fat. The highest levels of HCB were 3.67 ng/g fat (Nigeria), 3.51 ng/g fat (Ghana), 3.40 ng/g fat (Morocco), and 3.24 ng/g fat (Tunisia). Medium concentrations from 1.29- 2.89 ng/g fat were recorded in the rest of the countries (Egypt, Ethiopia, Kenya, Mali, Tanzania and Zambia).

5.2.2.10 Polychlorinated biphenyls (PCBs)

Indicator PCB congeners monitored in mothers' milk 28, 52, 101, 105, 138 and 180. The levels of sum 6 PCBs ($\sum_6$PCB) in mothers milk for the period 2001- 2019 ranged between 2.15- 90.28 ng/g fat. The dataset for $\sum_6$PCB levels in mothers' milk in 2006 and 2008 were reported for samples from Sudan $\sum_6$PCB = 49.16 ng/g fat, and Nigeria $\sum_6$PCB = 50.16 ng/g fat, respectively.

The levels of $\sum_6$PCB in 2009 ranged from 4.32 – 65.81 ng/g fat. The highest concentrations reported were $\sum_6$PCB = 65.81 ng/g fat (Senegal), $\sum_6$PCB = 31.72 ng/g fat (Ghana), $\sum_6$PCB = 30.97 ng/g fat (DR Congo, and $\sum_6$PCB = 25.29 ng/g fat (Mali). Medium levels ($\sum_6$PCB 4.32- 10.21 ng/g fat) were recorded in Kenya, Mauritius and Uganda.

2010 datasets were provided by Cote d'Ivoire ($\sum_6$PCB = 51.09 ng/g fat) and Togo ($\sum_6$PCB = 37.74 ng/g fat), while datasets for 2011 were recorded for samples from Djibouti (($\sum_6$PCB = 14.38 ng/g fat) and Niger ($\sum_6$PCB = 30.49 ng/g fat). In 2012 the only dataset was for samples from Ethiopia ($\sum_6$PCB = 2.15 ng/g fat).

Sum 6 PCBs dataset recorded in 2015 was for samples from Cote d'Ivoire with $\sum_6$PCB = 50.78 ng/g fat, which was comparable to the levels measured in the 1st survey in 2011.

Dataset for 2017 had $\sum_6$PCB levels of 13.97 ng/g fat and 22.46 ng/g fat recorded for DR Congo and Togo, respectively.

In 2018 sum indicator PCBs ranged between $\sum_6$PCB = 2.46 – 90.28 ng/g fat recorded in Senegal (90.28 ng/g fat), Mauritius (5.87 ng/g fat) and Uganda (2.46 ng/g fat).

In 2019 the sum 6 PCBs ranged between $\sum_6$PCB = 3.39 - 60.69 ng/g fat. The highest levels recorded were $\sum_6$PCB = 60.69 ng/g fat (Morocco), $\sum_6$PCB = 52.97 (Tunisia), $\sum_6$PCB = 14.51 ng/g fat (Nigeria), $\sum_6$PCB = 14.15 ng/g fat (Mali) and $\sum_6$PCB = 13.74 ng/g fat (Ghana). Figure 5.2.2.12 shows the $\sum_6$PCB levels in mothers' milk between 2001 and 2019.

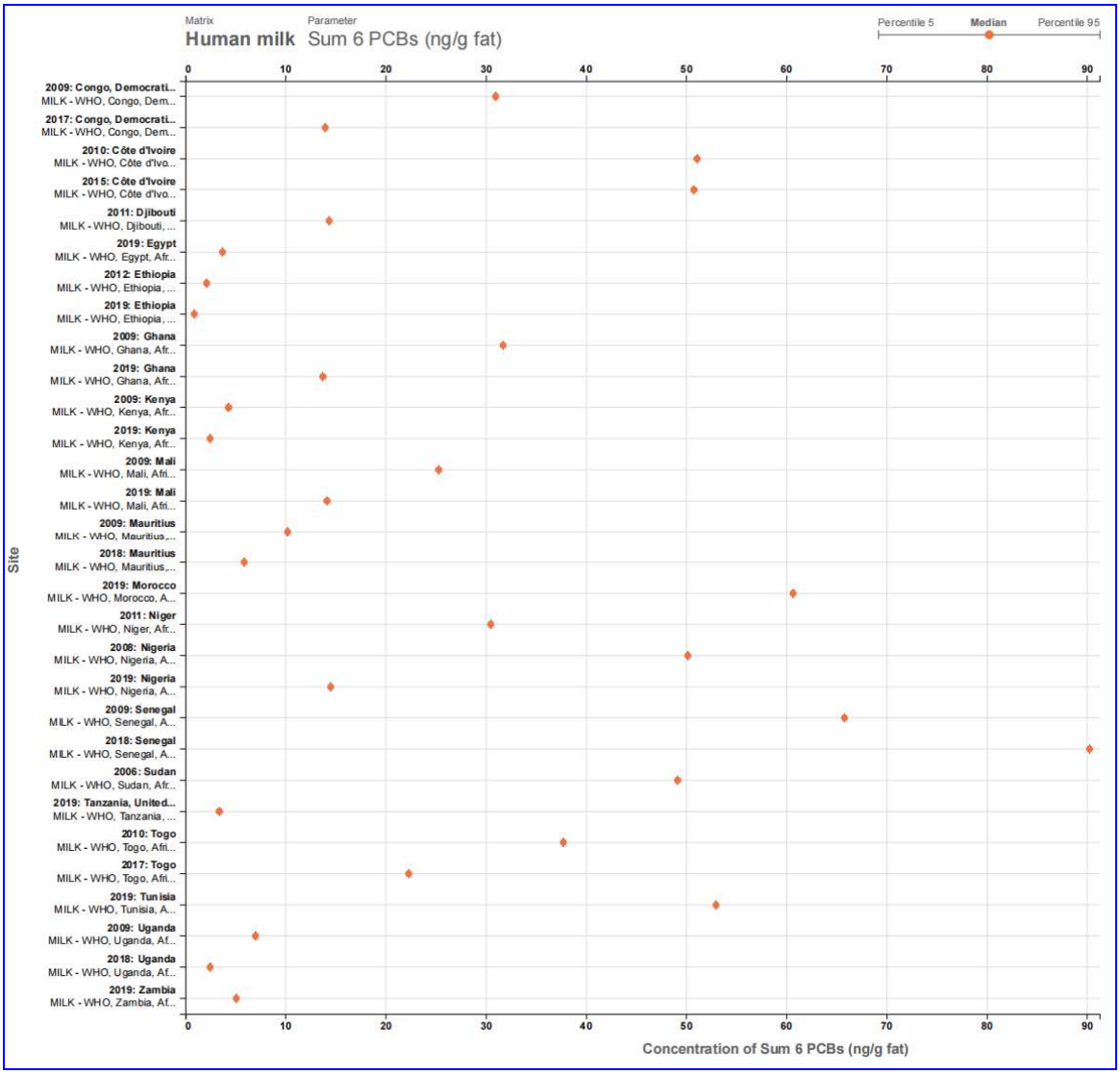


Figure 5.2.2.12 Sum 6 PCBs concentration in mothers' milk.

Individual indicator PCBs were dominated by PCB 153, 180 and 138 compared to lighter congeners 28, 52 and 101. The overall trend followed PCB 153> PCB180> PCB138 >PCB 28> PCB 101 >PCB 52. The mean levels for individual indicator congeners ranged were PCB 153 (0.25 – 40.42 ng/g fat), PCB 180 (0.13 – 26.92 ng/g fat), PCB 138 (0.19-22.09 ng/g fat), PCB 28 (0.18-1.54 ng/g fat), PCB 101 (0.04-1.37 ng/g fat), and PCB 52 (0.04-0.43 ng/g fat). Figure 5.2.2.13 shows the levels of PCB 153 in mothers' milk from the region for the period 2006-2019.

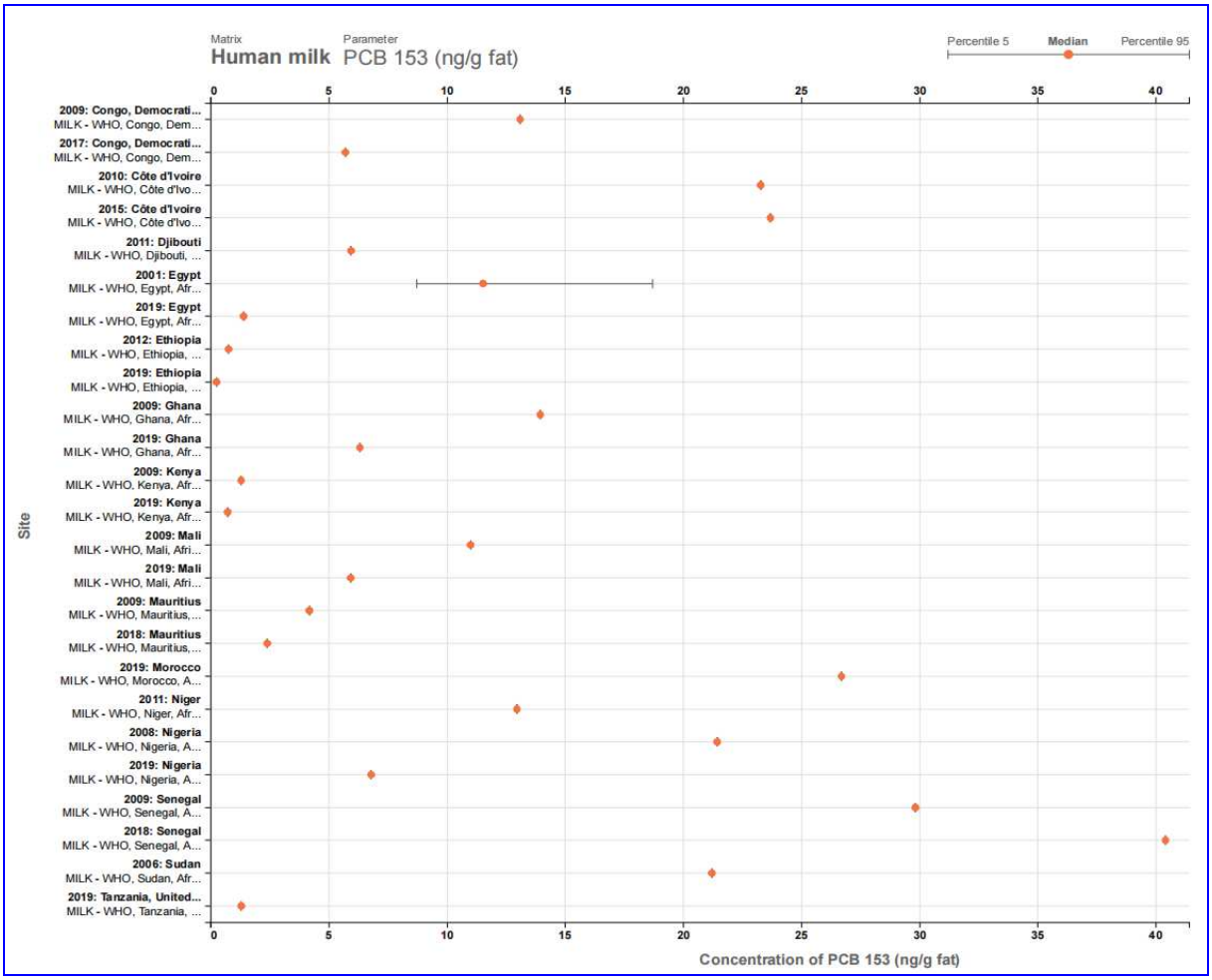


Figure 5.2.2.13 Levels of PCB 153 congener in mothers' milk samples

Regional trend analysis for indicator PCBs in the mothers' milk samples collected from the region for the period 2001-2019 revealed no significant trend (Figure 5.2.2.16). This was attributed to lack of sufficient long-term dataset for POPs levels in mothers' milk. Twelve out of the nineteen countries (63%) had only achieved two cycles of sampling while 37 % had only participated in a single cycle of mothers' milk sampling. Consequently, regional countries are encouraged to participate in further mothers' milk sampling survey to build adequate data for trend analysis.

5.2.2.11 Dioxin-like PCBs (dl-PCBs)

The dl-PCB congeners monitored in mothers' milk samples were PCBs 77, 81, 126, 169, 105, 114, 118, 123, 156, 157, 167 and 189. The sum of 12 dioxin like PCBs ($\sum_{12}$dl-PCB) in mothers' milk collected in the period 2006-2019 varied between $\sum PCB_{12}$ = 736.56 -15,930.58 pg/g fat.

The 2006 data set had concentration of $\sum_{12}$dl-PCB = 15,930.58 ng/g fat (Sudan), while 2008 data recorded sum concentration $\sum_{12}$dl-PCB = 11,887.23 pg/g fat for Nigeria. In 2009 the sum concentrations varied from $\sum PCB_{12}$ = 1,324.76 – 9,589.08 pg/g fat. The highest levels recorded were $\sum_{12}$dl-PCB = 9,589.08 pg/g fat (Senegal), $\sum_{12}$dl-PCB = 6,507.79 pg/g fat, $\sum_{12}$dl-PCB =

5,491.67 pg/g fat (Ghana), $\sum_{12}$dl-PCB = 3,724.76 pg/g fat (Mali). Medium concentrations ranged between $\sum_{12}$dl-PCB =1,324.76 -2,723.12 pg/g fat (Figure 5.2.2.14).

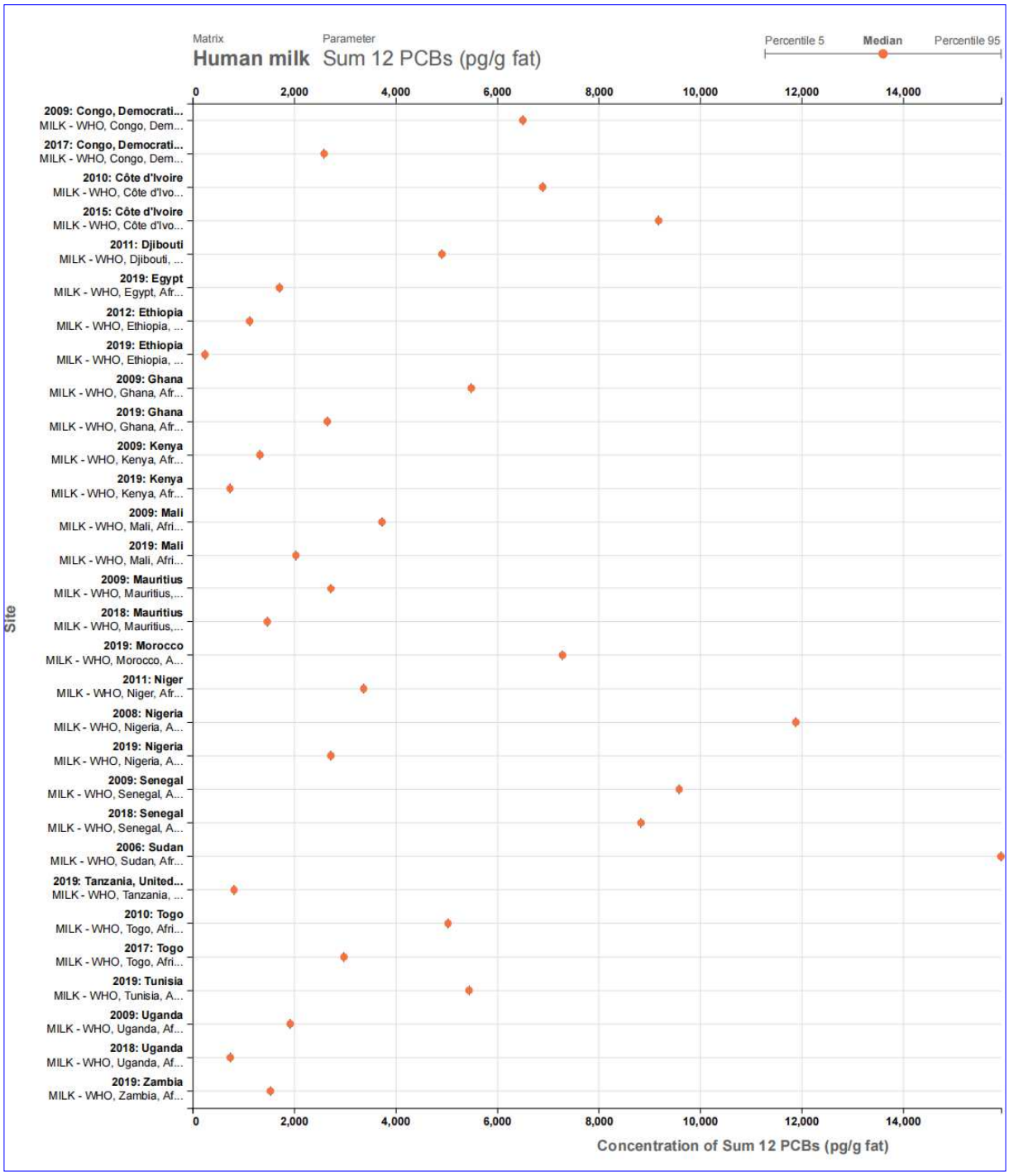


Figure 5.2.2.14 Concentrations of sum 12 dl-PCB in mothers' milk samples

Datasets for 2010 had $\sum_{12}$dl-PCB = 6,900.68 pg/g fat (Cote d'Ivoire) and $\sum_{12}$dl-PCB = 5,034.18 pg/g fat (Togo). In 2011 the levels of $\sum_{12}$dl-PCB = 4,911.72 pg/g fat and $\sum_{12}$dl-PCB = 3,370.10 pg/g fat (Togo), while the 2012 dataset had $\sum_{12}$dl-PCB =1,125.51 pg/g fat (Ethiopia).

In 2015 the sum 12 dl-PCB dataset recorded concentration of $\sum_{12}$dl-PCB = 9,183.94 pg/g fat (Cote d'Ivoire), while 2017 datasets were for samples from DR Congo ($\sum_{12}$dl-PCB = 2,587.79 pg/g fat) and Togo (2,982.02 pg/g fat).

2018 datasets recorded concentrations of $\sum_{12}$dl-PCB =1472.70 pg/g fat (Mauritius), $\sum_{12}$dl-PCB = 8,836.05 pg/g fat (Senegal) and $\sum_{12}$dl-PCB = 742.28 pg/g fat (Uganda), which revealed declining trend for the second cycle compared to the levels recorded in the first cycle.

In 2019 the concentrations ranged between $\sum_{12}$dl-PCB = 736.56– 7,286.94 pg/g fat. The highest levels recorded were $\sum_{12}$dl-PCB = 7,286.94 pg/g fat (Morocco), $\sum_{12}$dl-PCB = 5,447.97 pg/g fat (Tunisia), $\sum_{12}$dl-PCB = 2,721.67 pg/g fat (Nigeria), $\sum_{12}$dl-PCB = 2,653.63 pg/g fat (Ghana), and $\sum_{12}$dl-PCB =2,036.72 pg/g fat (Mali), while medium concentrations were recorded in Egypt ($\sum_{12}$dl-PCB =1,712.97 pg/g fat), Ethiopia ($\sum_{12}$dl-PCB =244.38 pg/g fat), Kenya ($\sum_{12}$dl-PCB =736.56 pg/g fat), Tanzania ($\sum_{12}$dl-PCB =816.60 pg/g fat) and Zambia ($\sum_{12}$dl-PCB = 1,532.37 pg/g fat).

Similarly, comparison of data for countries participating in a second cycle of survey revealed declining concentrations in 2019 compared to levels recorded in the first round of mothers' milk survey.

Individual concentrations of dl-PCBs in mothers' milk

Individual concentrations of dl-PCB congeners in mothers' milk were dominated by PCB 118 (165.95-8,877.35 pg/g fat), PCB 156 (19.33-3,010.30 pg/g fat), PCB 105 (43.46-1,823.21 pg/g fat) and PCB 167 (4.50-787.31 pg/g fat). Medium levels between 100.0 -500.0 pg/g fat were recorded for PCB 189 (2.29-394.36 pg/g fat), PCB157 (2.34-390.60 pg/g fat), PCB 114 (2.37-234.71 pg/g fat) and PCB 123 (1.22-148.79 pg/g fat). Concentrations below 50.0 pg/g fat were recorded for PCB 126 (2.22-40.80 pg/g fat), PCB 169 (1.38-22.80 pg/g fat), PCB 77 (1.81-19.42 pg/g fat), and PCB 81 (0.49-4.25 pg/g fat). Figure 5.2.2.15 shows the distribution of PCB 118 in mothers' milk samples collected from 2006-2019.

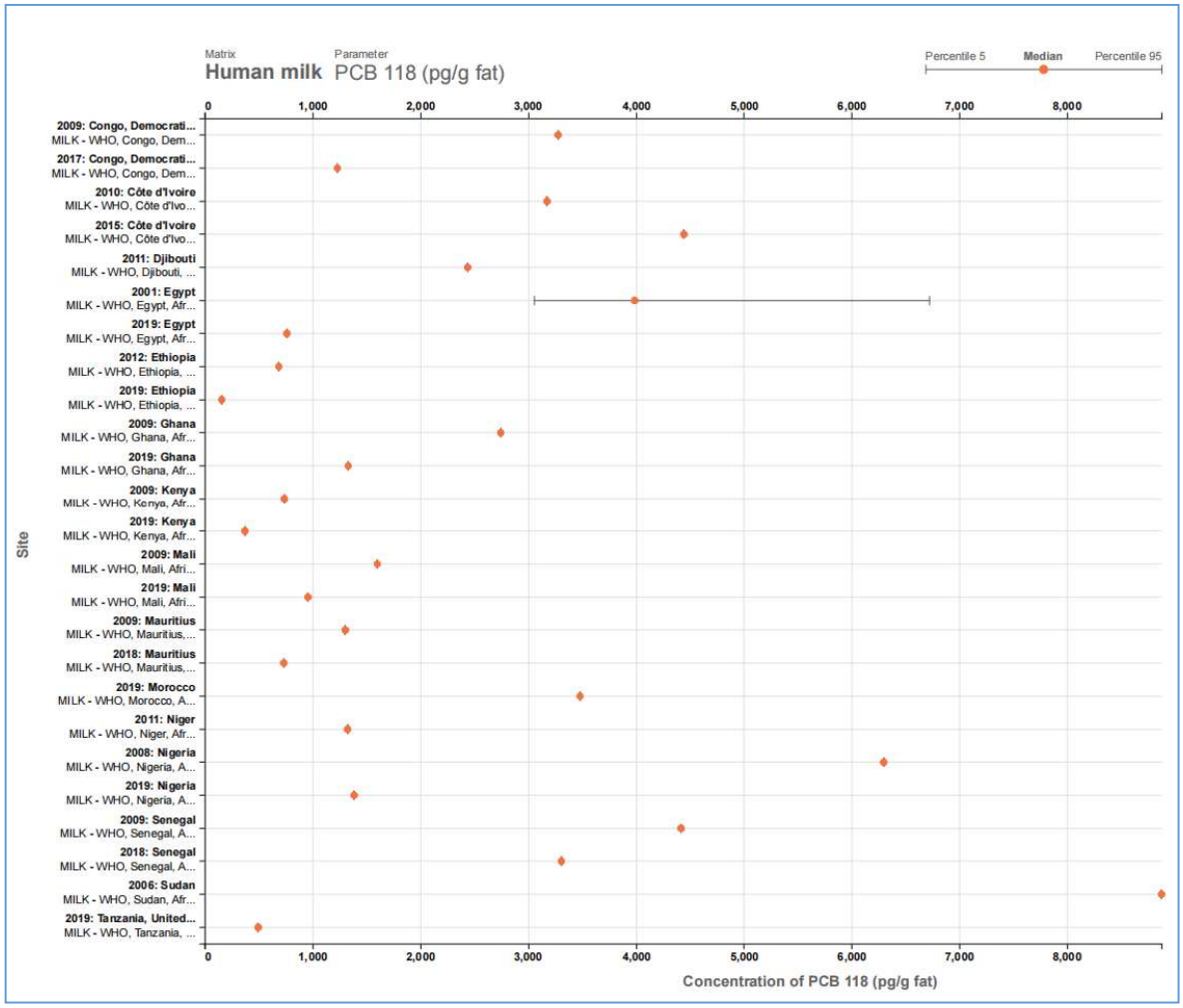


Figure 5.2.2.15 Levels of PCB 118 in mothers' milk samples 2006-2019

Dioxin-like PCBs Toxic Equivalents

The dl-PCB WHO_{2005}-TEQs upper bound levels ranged from 0.27-3.89 pg/g fat for the samples collected in the period 2006-2019. The level of dl-PCB WHO 2005-TEQs in 2006 was 1.71 pg/g fat (Sudan), and 2.85 ng/g fat (Nigeria) in 2008. In 2009, the levels ranged from 0.71-3.39 pg/g fat measured in samples from Uganda and Senegal, respectively.

In 2010, 2011, 2012 and 2015 the highest levels of dl-PCB WHO 2005-TEQs were 3.30 pg/g fat (Togo), 1.96 pg/g fat (Djibouti), 0.53 pg/g fat (Ethiopia) and 2.47 pg/g fat (Cote d'Ivoire), respectively.

The range of dl-PCB WHO_{2005}-TEQs in 2017, 2018 and 2019 were 0.89-1.01 pg/g fat, 0.35-2.62 pg/g fat and 0.27-3.70 pg/g fat, respectively. Figure 5.2.2.16 illustrates the dl-PCB WHO_{2005}-TEQs in mothers' milk samples.

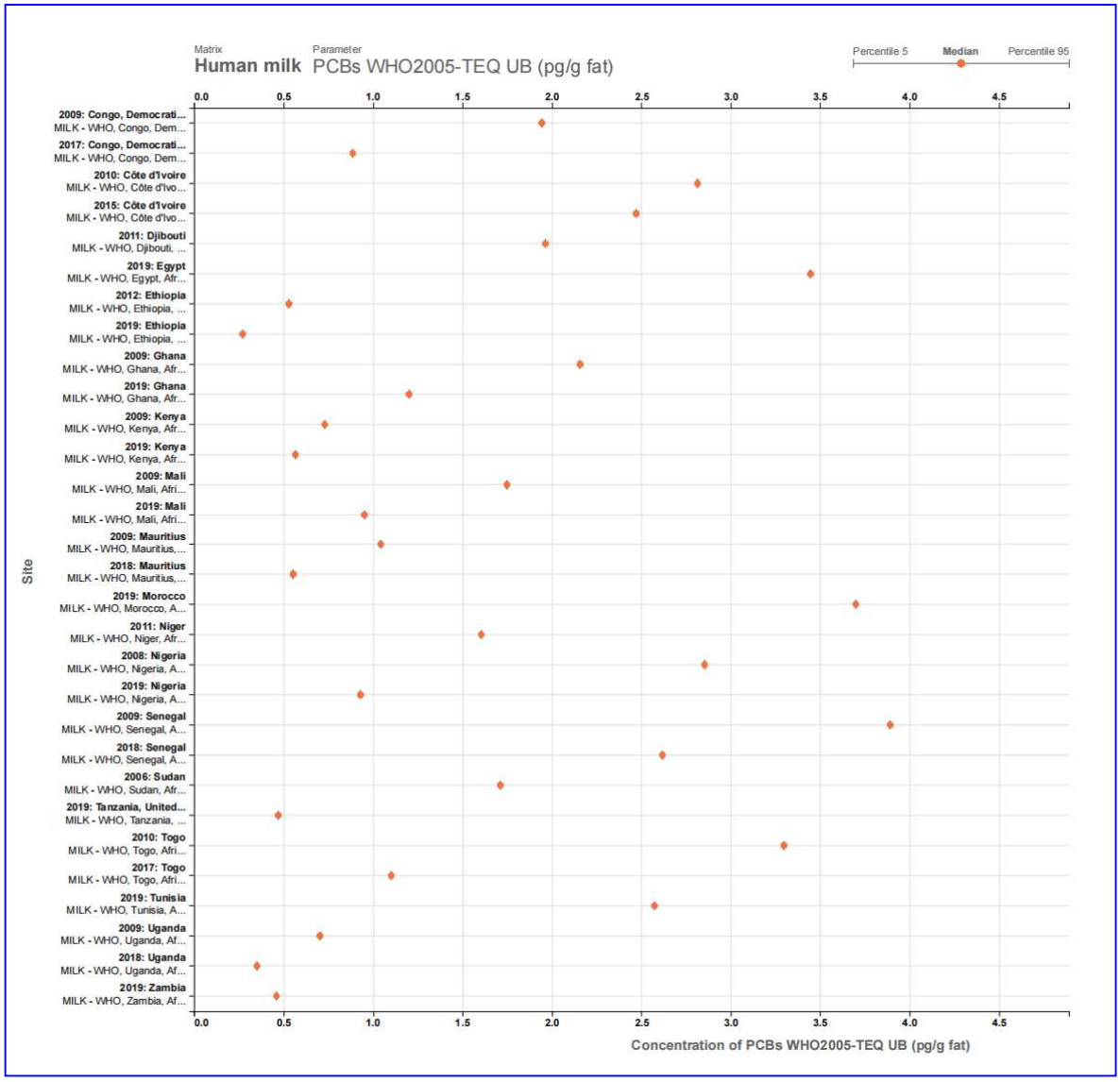


Figure 5.2.2.16 dl-PCB WHO_{2005}-TEQs in mothers' milk samples

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

A total of 7 PCDDs and 10 PCDFs were monitored in the mothers' milk samples for the period 2001- 2019. The concentrations of PCDDs/Fs were dominated by PCDDs compared to PCDFs.

Sum 17 PCDDs/Fs concentrations in mothers' milk samples

The mean concentrations of sum 17 PCDDs/Fs ($\sum_{17}$PCDDs/Fs) in mothers' milk varied from 14.78-472.64 pg/g fat. These levels were 10 to 100 times lower than the sum concentrations measured for dl-PCBs in the same mothers' milk samples, although PCDDs/Fs are considered more toxic and hence pose higher risk. The concentrations of sum 17 PCDDs/Fs in mothers' milk samples were recorded from Egypt in 2001 ($\sum_{17}$PCDDs/Fs = 145.00 pg/g fat), Sudan in

2006 ($\sum_{17}$PCDDs/Fs = 48.04 pg/g fat), and Nigeria in 2008 ($\sum_{17}$PCDDs/Fs = 96.68 pg/g fat). In 2009 eight countries provided mothers' milk data. The levels of sum 17 PCDDs/Fs ranged from $\sum_{17}$PCDDs/Fs = 48.74 -472.64 pg/g fat. The highest levels recorded were $\sum_{17}$PCDDs/Fs = 472.64 9 pg/g fat (DR Congo), $\sum_{17}$PCDDs/Fs = 220.52 pg/g fat (Senegal), and $\sum_{17}$PCDDs/Fs = 121.45 pg/g fat (Mali). The rest of the countries had levels between $\sum_{17}$PCDDs/Fs = 48.74-96.67 pg/g fat, with Ghana ($\sum_{17}$PCDDs/Fs = 60.70 pg/g fat), Kenya ($\sum_{17}$PCDDs/Fs = 70.64 pg/g fat), Mauritius ($\sum_{17}$PCDDs/Fs = 96.67 pg/g fat), Niger ($\sum_{17}$PCDDs/Fs = 55.91 pg/g fat) and Uganda ($\sum_{17}$PCDDs/Fs = 48.74 pg/g fat). The sum 17 PCDDs/Fs levels in 2010, 2011 and 2012 were $\sum_{17}$PCDDs/Fs = 253.76 pg/g fat and $\sum_{17}$PCDDs/Fs = 62.97 pg/g fat for Cote d'Ivoire and Togo in 2010, respectively, $\sum$PCDDs/Fs$_{17}$ = 268.94 pg/g fat (Djibouti) and $\sum_{17}$PCDDs/Fs = 55.91 pg/g fat (Niger) in 2011, and $\sum_{17}$PCDDs/Fs = 18.23 pg/g fat for Ethiopia in 2012.). Figure 5.2.2.17. illustrates the levels of sum 7 PCDDs in mothers' milk samples.

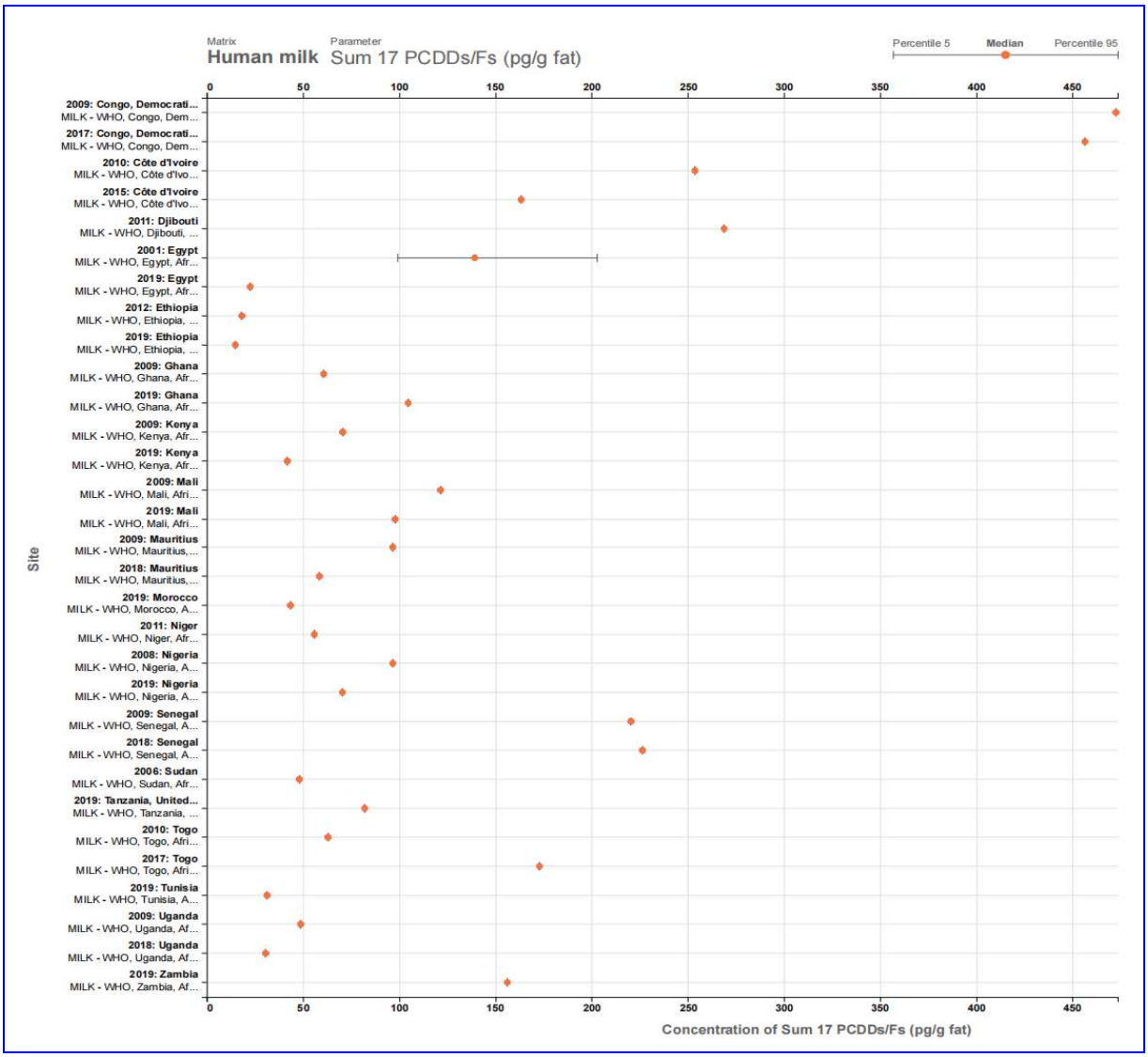


Figure 5.2.2.17 Sum 17 PCDDs/Fs in mothers' milk samples

Sum 7 PCDD concentrations in mothers' milk samples

The concentrations of PCDDs dominated the PCDDs/Fs levels measured in mothers' milk from the region. The sum 7 PCDDs levels ranged from $\sum_7$PCDD = 9.43 -465.16 pg/g fat for the period 2002-2019 (Figure 5.2.2.18). Sum 7 PCDDs data for 2002, 2006, 2008 were provided by Egypt ($\sum_7$PCDD = 76.29 pg/g fat), Sudan ($\sum_7$PCDD = 35.11 pg/g fat) and Nigeria ($\sum_7$PCDD = 89.72 pg/g fat), respectively. In 2009 the levels ranged from $\sum_7$PCDD = 45.43 -465.16 pg/g fat. The highest levels measured were in DR Congo ($\sum_7$PCDD = 465.16 pg/g fat), Senegal ($\sum_7$PCDD = 209.37 pg/g fat), and Mali ($\sum_7$PCDD = 113.26 pg/g fat). Medium levels were measured in Ghana (53.60 pg/g fat), Kenya ($\sum_7$PCDD = 66.02 pg/g fat), Mauritius ($\sum_7$PCDD = 90.91 pg/g fat), and Uganda ($\sum_7$PCDD = 45.43 pg/g fat).

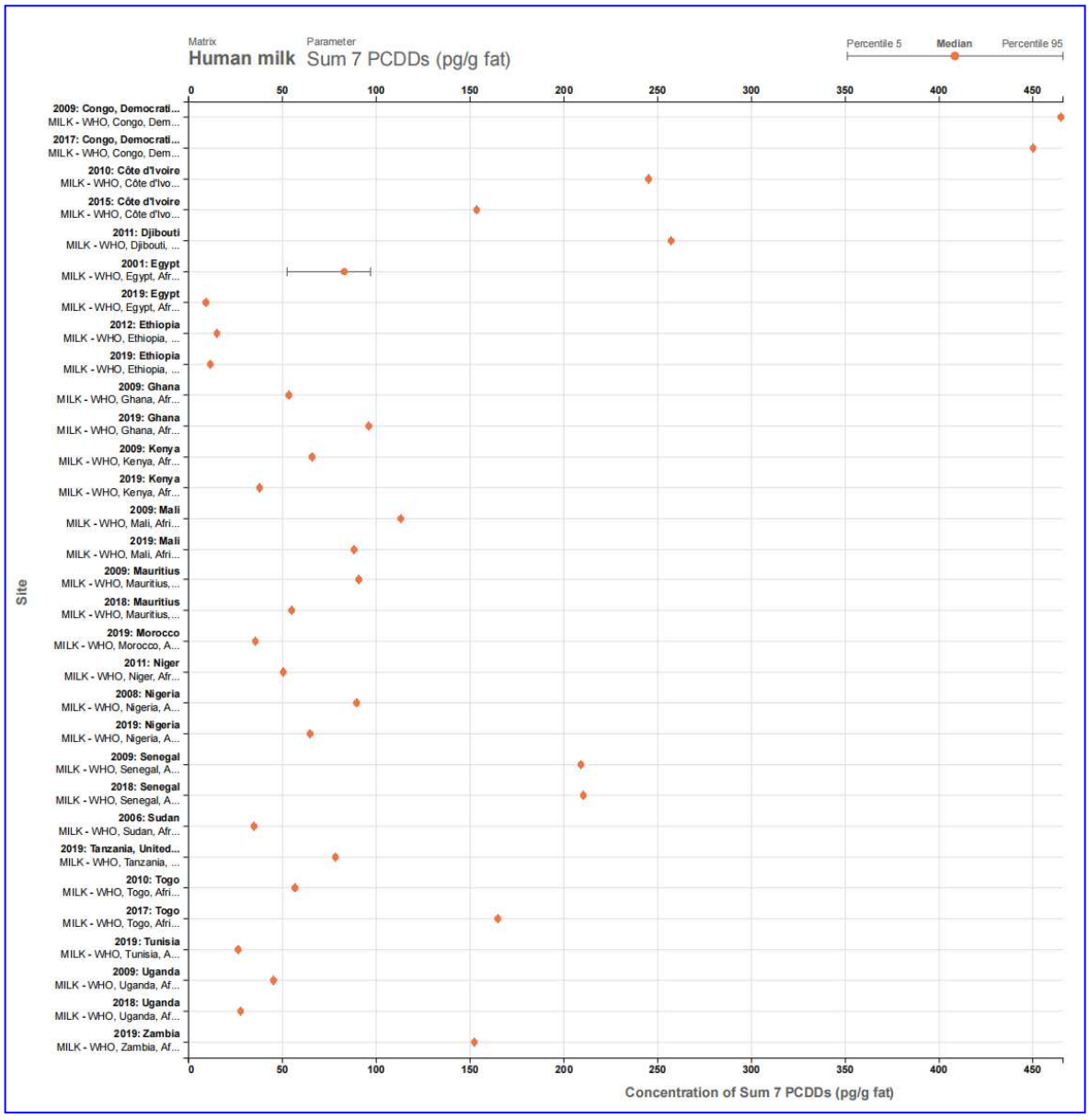


Figure 5.2.2.18 Sum 7 PCDDs in mothers' milk samples

Data for 2010, 2011, 2012 and 2015 were obtained from Cote d'Ivoire ($\sum_7$PCDD = 245.35 pg/g fat) and Togo ($\sum_7$PCDD = 56.87 pg/g fat) for 2010, Djibouti ($\sum_7$PCDD = 257.40 pg/g fat) and Niger ($\sum_7$PCDD = 50.70 pg/g fat) for 2011, while Ethiopia ($\sum_7$PCDD = 15.31 pg/g fat) and Cote d'Ivoire ($\sum_7$PCDD = 153.78 pg/g fat) were recorded in 2012 and 2015, respectively. The sum 7 PCDDs in 2017 were 450.39 pg/g fat and 165.03 pg/g fat for DR Congo and Togo, respectively, while in 2018, the datasets recorded were 55.10 pg/g fat (Mauritius), 210.57 pg/g fat (Senegal) and 27.95 pg/g fat (Uganda).

The levels of sum 7 PCDDs in 2019 ranged from $\sum_7$PCDD = 9.43 -152.45 pg/g fat. The highest levels recorded were 152.45 pg/g fat (Zambia), 96.25 pg/g fat (Ghana), 78.50 pg/g fat (Tanzania) and 64.95 pg/g fat (Nigeria) and 58.42 pg/g fat (Mali). Levels below 50 pg/g fat were recorded in Egypt (9.43 pg/g fat), Ethiopia (11.75 pg/g fat), Kenya (38.06 pg/g fat), Morocco (35.72 pg/g fat), and Tunisia (26.61 pg/g fat)

Sum 10 PCDFs concentrations in mothers' milk samples

The levels of sum 10 PCDFs in mothers' milk samples collected in the period 2002-2019 ranged from $\sum_{10}$PCDF= 2.58 -57.74 pg/g fat. The levels were relatively lower compared to the concentrations of the sum 7 PCDDs recorded in the same mothers' milk samples. Sum 10 PCDFs in 2002, 2006 and 2008 were 57.74 pg/g fat (Egypt), 12.93 pg/g fat (Sudan) and 6.96 pg/g fat (Nigeria), respectively.

The levels of sum 10 PCDFs in 2009 ranged between 3.31-11.15 pg/g fat, with the highest concentrations measured in Senegal ($\sum_{10}$PCDF = 11.15 pg/g fat), DR Congo ($\sum_{10}$PCDF = 7.49 pg/g fat), Mali ($\sum_{10}$PCDF = 8.19 pg/g fat), Ghana ($\sum_{10}$PCDF = 7.10 pg/g fat), and Mauritius ($\sum_{10}$PCDF = 5.76 pg/g fat). Other countries reporting in 2009 measured sum 10 PCDFs levels below 5.0 pg/g fat with Kenya ($\sum_{10}$PCDF = 4.62 pg/g fat), and Uganda ($\sum_{10}$PCDF = 3.31 pg/g fat).

2010, 2011, 2012 and 2015 registered concentrations of sum 10 PCDFs as 8.41 pg/g fat (Cote d'Ivoire) and 6.10 pg/g fat (Togo) in 2010, 11.54 pg/g fat (Djibouti) and 5.21 pg/g (Niger) in 2011, while 2.92 pg/g fat (Ethiopia) and 9.60 pg/g fat (Cote d'Ivoire) were recorded in 2012 and 2015, respectively. In 2017 the levels were reported by DR Congo ($\sum_{10}$PCDF = 6.18 pg/g fat) and Togo ($\sum_{10}$PCDF = 7.85 pg/g fat). In 2018 the levels of sum 10 PCDFs were 3.41 pg/g fat (Mauritius), 15.91 pg/g fat (Senegal) and 2.58 pf/g fat (Uganda).

2019 data had sum 10 PCDFs ranging between 3.03 -13.05 pg/g fat. The highest levels measured were $\sum_{10}$PCDF = 13.05 pg/g fat (Egypt), $\sum_{10}$PCDF = 9.46 pg/g fat (Mali), $\sum_{10}$PCDF = 8.34 pg/g fat (Ghana), $\sum$PCDF$_{10}$ = 7.74 pg/g fat (Morocco), and $\sum$PCDF$_{10}$ = 5.56 pg/g fat (Nigeria). Levels below $\sum_{10}$PCDF = 5.0 pg/g fat were recorded in Ethiopia ($\sum_{10}$PCDF = 3.03 pg/g fat), Kenya ($\sum_{10}$PCDF = 3.73 pg/g fat), Tanzania (3.53 pg/g fat), Tunisia (4.66 pg/g fat) and Zambia ($\sum_{10}$PCDF = 3.72 pg/g fat). Figure 5.2.2.19 shows the levels of sum 10 PCDFs in mothers' milk samples.

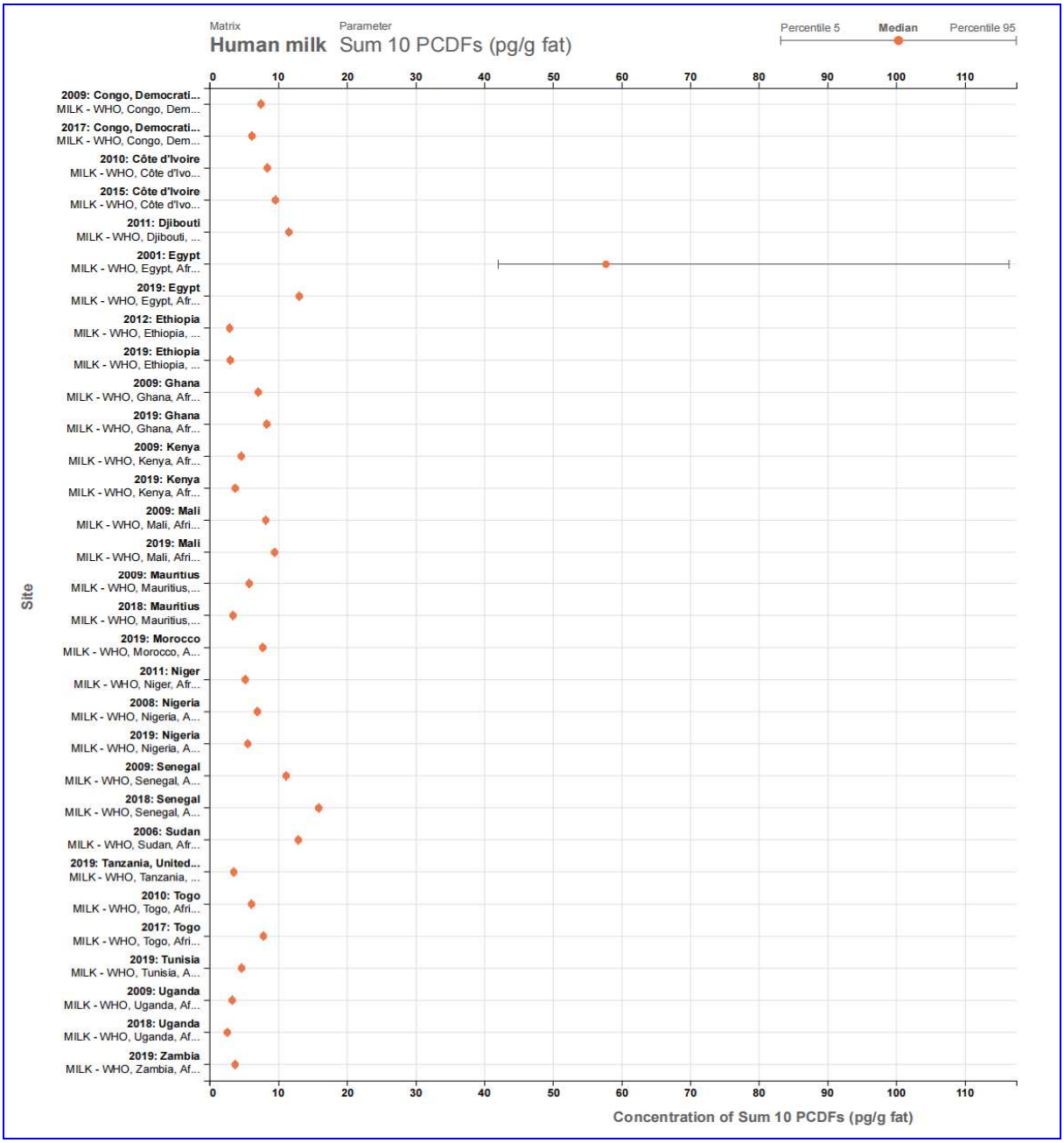


Figure 5.2.2.19 Sum 10 PCDFs in mothers' milk samples

PCDDs/Fs Toxic Equivalents

The PCDDs/Fs WHO_{2005} TEQs for the mothers' milk samples in the period 2001-2019 ranged from 1.01-21.38 pg/g fat. The individual groups TEQs had PDDDs WHO_{2005} TEQs levels between 0.58-11.23 pg/g fat and PCDFs WHO_{2005} TEQs levels between 0.37-11.03 ng/g fat.

201, 2006, 2008 PCDDs/Fs WHO_{2005} TEQs levels were 21.38 pg/g fat (Egypt), 5.09 pg/g fat (Sudan) and 2.71 pg/g fat (Nigeria), respectively. In 2009 the PCDDs/Fs WHO_{2005} TEQs ranged between 1.31-12.13 pg/g fat. The highest values were 12.13 pg/g fat (DR Congo), 6.47 pg/g fat

(Senegal), 3.47 pg/g fat (Mali), with the rest of the countries recording lower levels between 1.31-2.73 pg/g fat (Ghana, Ethiopia, Kenya and Uganda).

In 2010, 2011, 2012 and 2015 the highest PCDDs/Fs WHO_{2005} TEQs levels were 10.62 pg/g fat (Cote d'Ivoire), 4.06 pg/g fat (Djibouti), 1.01 pg/g fat (Ethiopia) and 8.61 pg/g fat (Cote d'Ivoire second survey). In 2017, 2018 and 2019 the mean PCDDs/Fs WHO_{2005} TEQs levels measured ranged between 3.32-9.97 pg/g (Togo and DR Congo), 1.24-5.74 pg/g fat (Uganda, Mauritius and Senegal) and 1.02-5.59 pg/g fat (Ethiopia, Zambia, Kenya, Tanzania, Tunisia, Nigeria, Ghana, Mali, Morocco, and Egypt) respectively. Figure 5.2.2.24 illustrates the PCDDs/Fs WHO2005 TEQs in mothers' milk samples from the region. The WHO_{2005} TEQs for PCDDs/Fs were three to six times higher compared to the dl-PCBs TEQs showing higher health risk posed by PCDDs/Fs.

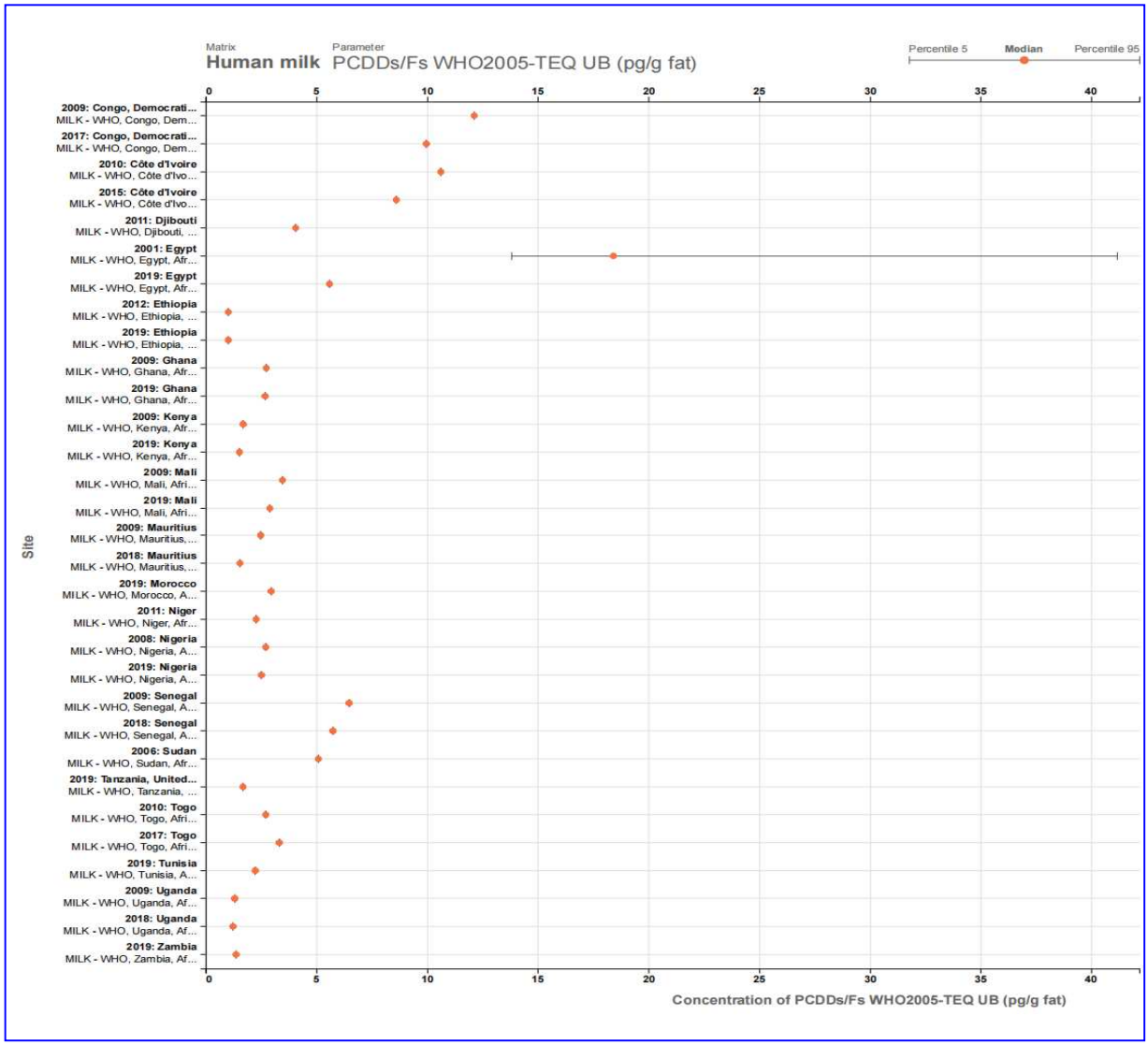


Figure 5.2.2.20 PCDDs/Fs WHO2005 TEQs for mothers' milk samples

New POPs levels in mothers' milk samples

5.2.2.13 Chlordecone

No detectable levels were measured in mothers' milk samples collected from the region for the period 2002- 2019.

5.2.2.14 Endosulphans levels in mothers' milk samples

Endosulphan isomers monitored in mothers' milk samples were alpha endosulphan (endosulphan I) and beta endosulphan (endosulphan II), and the endosulphan sulphate.

Alpha endosulphan levels of 2.0 ng/g fat was detected in Nigeria in 2008. Subsequent cycles and years of monitoring registered alpha endosulphan levels below the LOQ (<0.025 ng/g fat).

Beta endosulphan levels in the region were below the LOQ (<0.25 ng/g fat) in all mothers' milk samples collected in the region for the period 2002-2019.

Measurable levels of endosulphan sulphate were reported in 2006 in Sudan (1.30 ng/g fat), 2008 in Nigeria (4.50 ng/g fat) and in 2019 in Ethiopia (0.54 ng/g fat). The rest of the samples collected from the regional countries for the period 2002-2019 registered levels of endosulphan sulphate below the LOQ (<0.25 ng/g fat).

5.2.2.15 Hexabromobiphenyl (HBB)

The HBB concentrations in mothers' milk samples for the period 2002-2019 remained low, with most of the countries registering levels below 0.25 ng/g fat. Only DR Congo recorded measurable levels of 0.95 ng/g fat in 2009.

5.2.2.16 Hexabromocyclododecanes (HBCDs)

Two isomers of the HBCD analysed in the mothers' milk samples were alpha-HBCD, beta-HBCD and gamma-HBCD. The levels were dominated by the alpha isomer compared to the gamma isomer.

Gamma-HBCD

Gamma HBCD levels in milk samples ranged from <LOQ to 0.11 ng/g fat. The highest levels were recorded in DR Congo at 0.11 ng/g fat in 2009, and in Mauritius at 0.10 ng/g fat in the same year. Concentrations of 0.05 ng/g fat were recorded in 2009 in Kenya, Senegal and Uganda, in Cote d'Ivoire and Togo in 2010, and in Djibouti and Niger in 2011.

2015 levels of 0.03 ng/g fat were recorded in Cote d'Ivoire, while levels <LOQ were recorded in 2017 in DR Congo and Togo, 2018 in Mauritius, Senegal and Uganda, and in 2019 in Egypt, Ethiopia, Ghana, Kenya, Mali, Morocco, Nigeria, Tunisia, Tanzania and Zambia.

Beta-HBCD

The levels of beta-HBCD in mothers' milk samples collected in the period 2009-2019 were below the LOQ (0.05 ng/g fat) for all countries.

Alpha HBCD

The concentration of alpha HBCD in mothers' milk collected between 2008- 2019, and varied from bdl- 1.34 ng/g fat. The levels in 2008 were measured in Nigeria (1.10 ng/g fat).

In 2009, mean levels of alpha HBCD ranged from 0.05-1.34 ng/g fat. The highest concentrations registered were 1.34 ng/g fat (Ghana), 1.23 ng/g fat (Mauritius), and 0.58 ng/g fat (DR Congo). Levels below 5.0 ng/g fat were recorded in Kenya (0.12 ng/g fat), Senegal (0.48 ng/g fat) and Uganda (0.05 ng/g fat).

In 2010, 2011, 2012 and 2015 alpha HBCD levels were recorded in samples from Cote d'Ivoire (0.58 ng/g fat) and Togo (0.59 ng/g fat) for 2010, and Djibouti (0.14 ng/g fat) and Niger (0.41 ng/g fat) in 2011. Concentration of 1.0 ng/g fat was recorded in samples from Cote d'Ivoire in 2015, while 0.20 ng/g fat and 0.50 ng/g fat were recorded in DR Congo and Togo in 2017, respectively.

In 2018 the levels of alpha HBCD were reported for Mauritius (0.30 ng/g fat) and Senegal (0.10 ng/g fat), whereas the concentration in mothers' milk from Uganda were below the limit of quantification (<LOQ).

2019 levels of HBCD ranged from <LOQ -0.80 ng/g fat, with highest levels recorded as 0.80 ng/g fat (Egypt), 0.7 ng/g fat (Nigeria), and 0.30 ng/g fat (Ghana). Countries that recorded levels <LOQ were Ethiopia, Kenya, Mali, Morocco, Tanzania, Tunisia and Zambia (Figure 5.2.2.21).

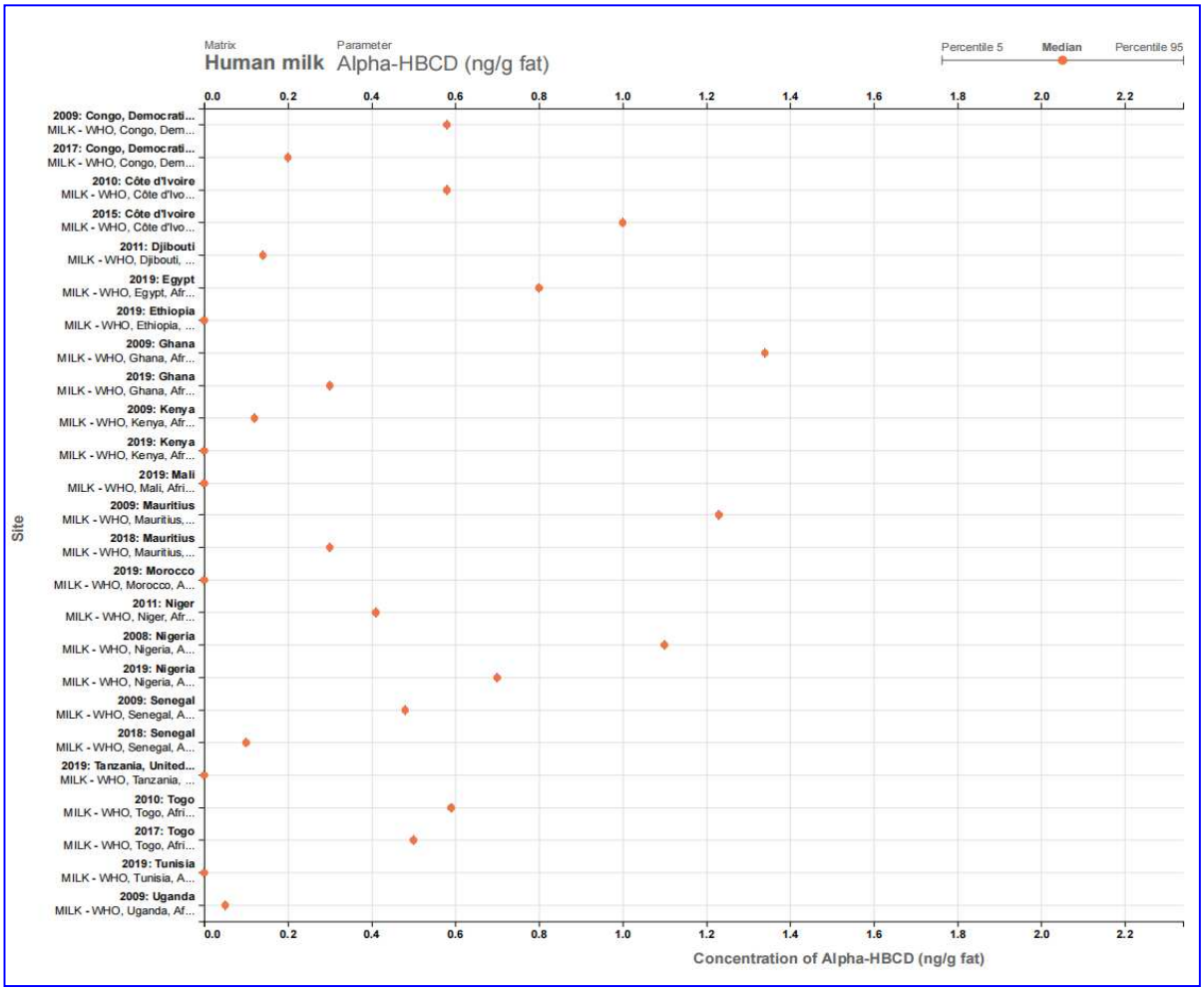


Figure 5.2.2.21 Levels of alpha HBCD in mothers' milk samples

5.2.2.17 Hexachlorocyclohexanes (*alpha*-HCH, *beta*-HCH, *gamma*-HCH)

HCHs isomers monitored in mothers' milk were alpha, beta and *gamma*-HCH. The concentrations of HCHs were dominated by beta HCH followed by *gamma*-HCH while the alpha isomer recorded the lowest concentrations. The overall concentrations of HCH ranged between <LOQ -51.25 ng/g fat for beta HCH,

Alpha-HCH levels in the mothers' milk ranged between <0.25 -1.11 ng/g fat for the period between 2002 and 2019. The highest levels were recorded in Togo in 2017 at concentration of 1.11 ng/g fat, Egypt at 1.00 ng/g fat in 2002 and 0.56 ng/g fat in 2019, DR Congo in 2017 at 0.50 ng/g fat and Senegal in 2009 at concentration of 0.46 in 2009. The rest of the countries and surveys reported levels of *alpha*-HCH below <0.25 ng/g fat for the period between 2002 -2019.

Gamma-HCH levels ranged from <0.25 – 2.26 ng/g fat for samples collected in the period 2002-2019. In 2002 gamma-HCH was reported by Egypt only at concentration of 2.5 ng/g fat. In 2006 only Sudan reported POPs data in mothers' milk with gamma HCH concentration of 0.25 ng/g fat, while in 2008 only Ghana and Nigeria provided data for POPs in mothers milk with *gamma*-HCH concentrations of 0.66 ng/g fat and 0.25 ng/g fat, respectively. 2009 had six countries reporting POPs in mothers milk with highest *gamma*-HCH concentrations being 2.26 ng/g fat (Kenya), 1.10 ng/g fat for Mauritius and 0.64 ng/g fat for Uganda. Lower concentrations were recorded in Senegal (0.03 ng/g fat), Dr Congo (0.25 ng/g fat), and Mali (0.25 ng/g fat).

Cote d'Ivoire and Togo were the only countries that report POPs in mothers' milk in 2010 with *gamma*-HCH concentrations of 1.98 ng/g fat and 4.81 ng/g fat respectively, while in 2011 only Niger and Djibouti reported POPs levels in mother's milk with concentrations below 0.25 ng/g fat for both countries. In 2012, only Ethiopia provided POPs data for mothers' milk with *gamma*-HCH levels at 0.25 ng/g fat. No reports for POPs levels were recorded for the years 2013, 2014 and 2016. In 2015 only Cote d'Ivoire reported POPs levels in mothers' milk with *gamma*-HCH concentration of 0.25 ng/g fat for the samplers collected during the second milk survey.

DR Congo and Togo provided data in 2017 for the samples collected in their second survey of mothers' milk, of which the levels of *gamma*-HCH were below the limit of detection. In 2019 only Egypt had detectable levels of *gamma*-HCH at 0.74 ng/g fat, while samples from Ethiopia, Ghana, Kenya, Mali, Nigeria, Uganda had levels below the limit of detection. The results show declining trend of *gamma*-HCH at individual country levels as illustrated in Figure 5.2.2.22 below. This could be attributed to positive effects of the measures the countries are putting in place to manage POPs in the region.

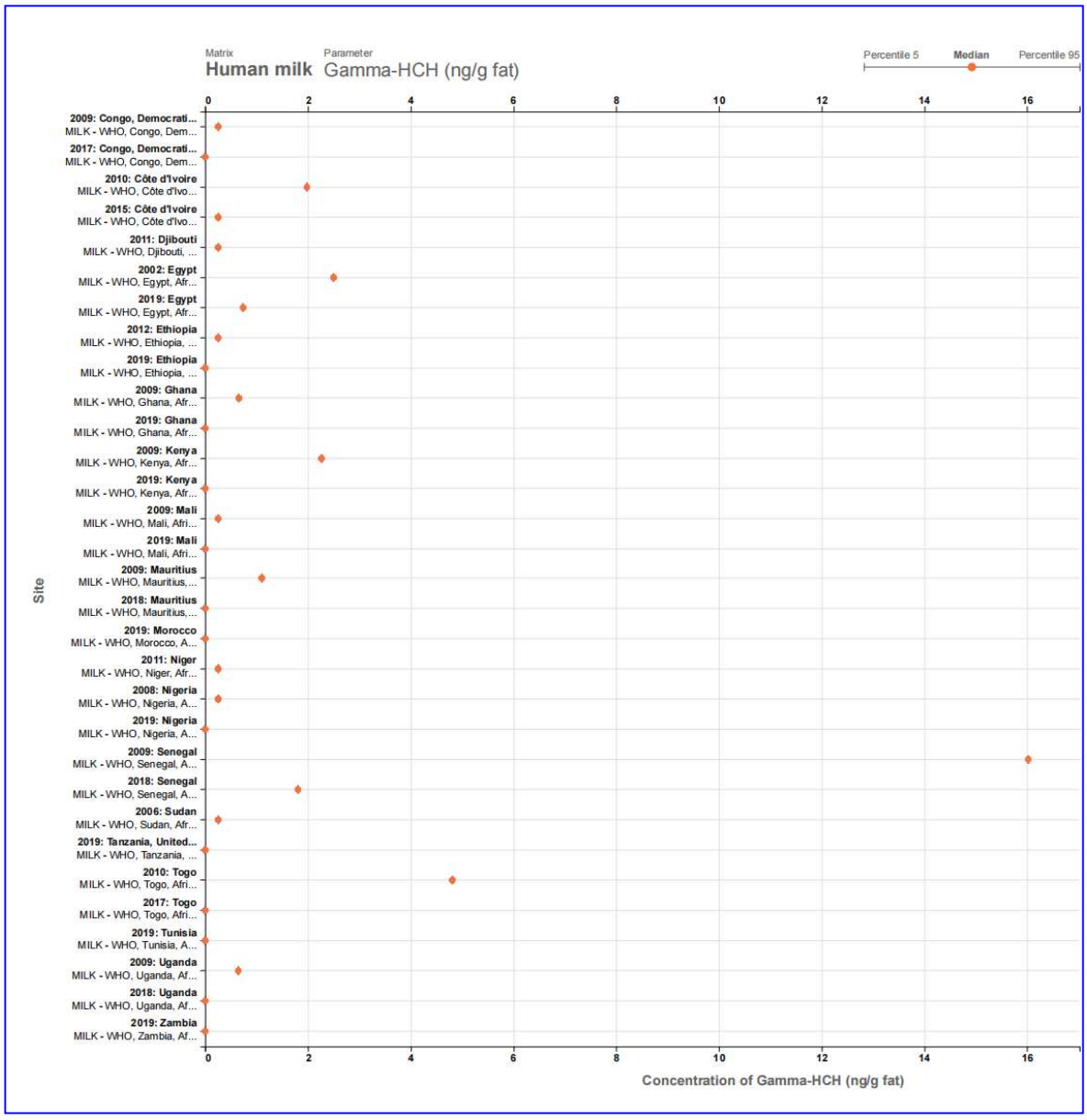


Figure 5.2.2.22 Levels of Gamma-HCH in mothers' milk samples

Beta-HCH

Beta-HCH levels ranged from <0.25 – 51.25 ng/g fat with the highest levels detected in Egypt in 2002 (51.25 ng/g fat), Senegal in 2009 (48.28 ng/g fat), Sudan in 2006 (36.51 ng/g fat), Mali 2009 (25.87 ng/g fat), Nigeria in 2008 (28.74 ng/fat) and Mauritius in 2009 (20.96 ng/g fat). The concentrations recorded in the second survey between 2015 and 2019 were lower than the levels recorded in the first survey conducted between 2002 and 2012. Figure 5.2.2.23 shows levels of beta-HCH in mothers' milk samples.

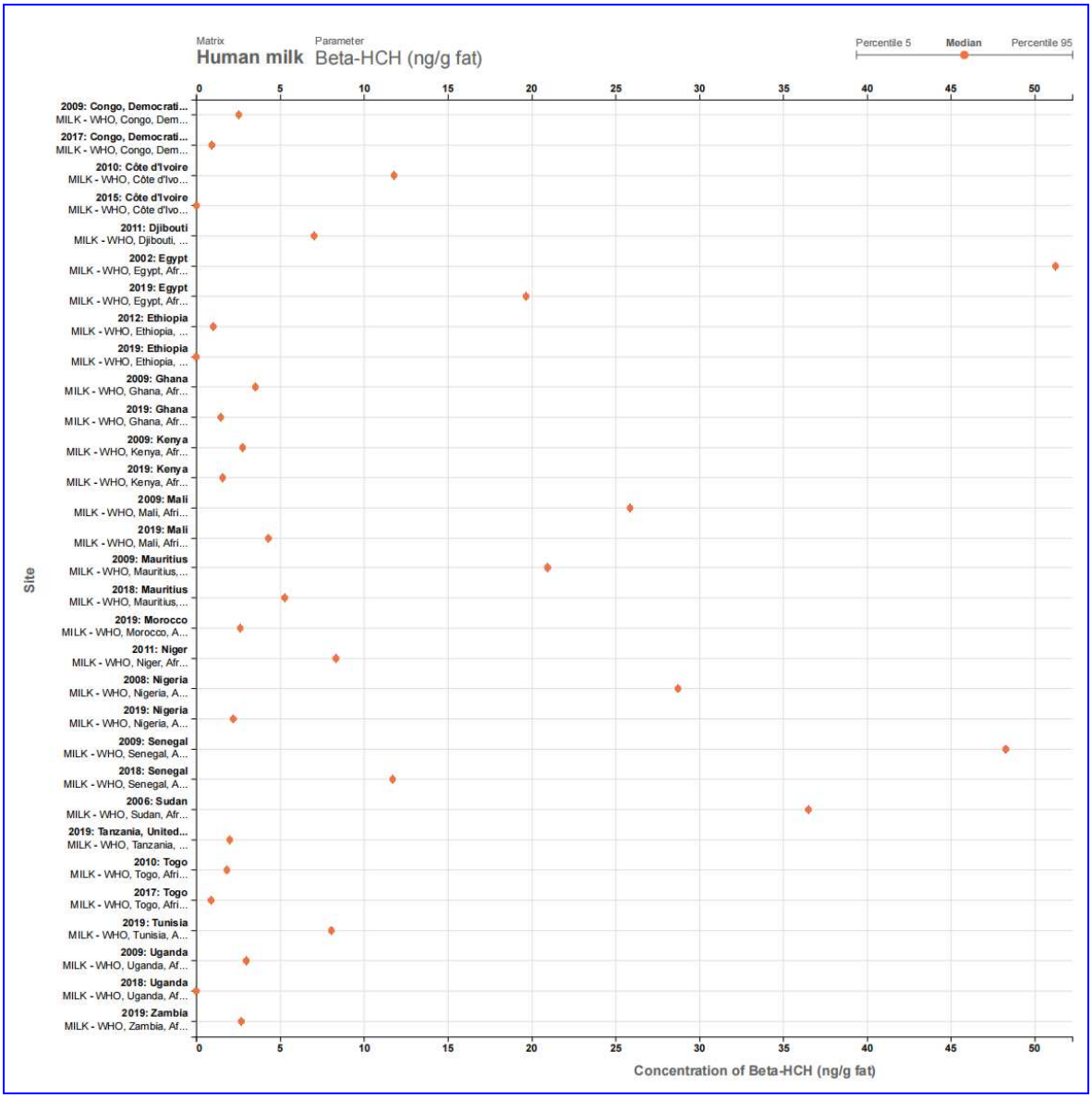


Figure 5.2.2.23 Levels of Beta-HCH in mothers' milk samples

5.2.2.18 Pentachlorobenzene (PeCB)

Detectable levels of PeCB in mothers' milk samples were reported in samples collected from Togo in 2017 at concentration of 0.68 ng/g fat. The rest of the countries had concentrations of PeCB below 0.25 ng/g fat, for both first and second rounds of mothers' milk survey.

5.2.2.19 Polybrominated Diphenyl Ethers (PBDEs) Levels in mothers' milk

PBDE congeners monitored in mother's milk samples included the BDE 17, 28, 47, 99, 100, 153, 154 and 175/183. The levels of BDEs in mothers' milk were relatively low compared to other industrial POPs in the region. The concentrations of BDEs in most of the countries in the region were dominated by BDE 47 congener and ranged between 0.09-1.6 ng/g fat, BDE 153

(0.08-0.5 ng/g fat) and BDE 99 (0.04-0.44 ng/g fat) for the samples collected in the period 2008 - 2019.

BDE 17

BDE 17 levels ranged between 0.001-0.08 ng/g fat in samples collected for the period 2008-2011. 2008 dataset was recorded for Nigeria (0.01 ng/g fat). In 2009 BDE 17 levels ranged from 0.001-0.04 ng/g fat. Measurable levels were reported in DR Congo (0.03 ng/fat), Ghana (0.04 ng/g fat), Kenya, Mauritius and Senegal recorded 0.001 ng/g fat each, while Uganda had 0.03 g/g fat. In 2010 BDE 17 datasets were reported for Cote d'Ivoire (0.001 ng/g fat) and Togo (0.04 ng/g fat), while in 2011 the concentrations were 0.03 ng/g fat and 0.08 ng/g fat recorded in Djibouti and Niger, respectively.

BDE 28

BDE 28 was analysed in samples collected in the period 2008-2011, and had mean concentrations between 0.03-0.12 ng/g fat. Concentration in 2008 was 0.09 ng/g fat (Nigeria). The levels in 2009 ranged from0.03 -0.12 ng/g fat. Individual countries recorded 0.12 ng/g fat (DR Congo), 0.12 ng/g fat (Ghana), 0.10 ng/g fat (Uganda), 0.05 ng/g fat (Kenya), 0.04 ng/g fat (Senegal) and 0.03 ng/g fat (Mauritius).

Data for BDE 28 in 2010 and 2011 were 0.06 ng/g fat (Cote d'Ivoire) and 0.09 ng/g fat (Togo) for 2010, while 2011 recorded 0.07 ng/g fat (Djibouti) and 0.10ng/g fat (Niger).

BDE 47

The BDE 47 congener dominated the BDE levels in mothers' milk among all the congeners monitored, with concentrations ranging between 0.09-1.6 ng/g fat for the period 2008-2019. Concentration in 2008 was 1.28 ng/g fat (Nigeria).

In 2009 the mean levels of BDE 47 ranged between 0.34-1.60 ng/g fat with highest levels recorded in DR Congo (1.60 ng/g fat), Uganda (1.40 ng/g fat), Ghana (1.26 ng/g fat), and Kenya (0.57 ng/g fat). Mauritius and Senegal recorded 0.34 ng/g fat and 0.35 ng/g fat, respectively.

2010 recorded data sets from two countries namely Cote d'Ivoire (0.51 ng/g fat) and Togo (0.94 ng/g fat), while 2011 had Djibouti (0.95 ng/g fat) and Niger (0.68 ng/g fat).

BDE 47 levels in 2015 were recorded for the single sample from Cote d'Ivoire (0.55 ng/g fat), while 2017 recorded two data sets from DR Congo (1.36 ng/g fat) and Togo (0.41 ng/g fat).

2018 levels were reported in Mauritius (0.12 ng/g fat), Senegal (0.71 ng/g fat) and Uganda (0.67 ng/g fat). Mauritius and Uganda recorded lower levels in their second survey compared to the first survey conducted in 2009.

In 2019, the levels of BDE 47 ranged between 0.13 – 1.18 ng/g fat. The highest values were recorded in Ghana (1.18 ng/g fat), Zambia (1.06 ng/g fat), Tanzania (0.82 ng/g fat), Kenya (0.77 ng/g fat) Mali (0.61 ng/g fat), and Nigeria (0.63 ng/g fat). The rest of the countries reported lower levels with Egypt (0.13 ng/g fat), Ethiopia (0.09 ng/g fat), Morocco (0.22 ng/g fat) and Tanzania (0.26 ng/g fat) as illustrated in Figure 5.2.2.24.

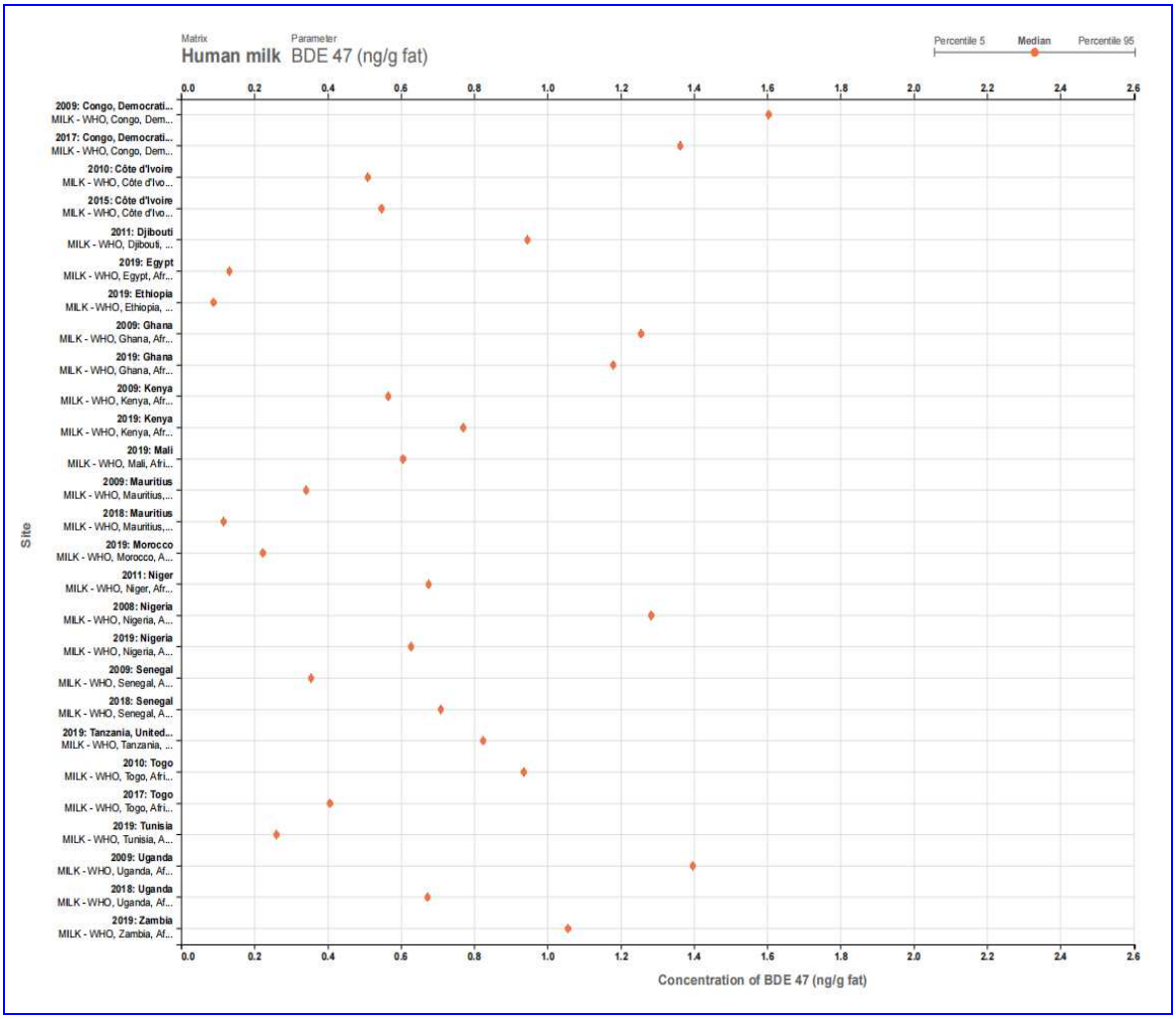


Figure 5.2.2.24 Levels of BDE 47 in mothers' milk samples (2008-2019)

BDE 99

The mean concentrations of BDE 99 ranged between 0.04-0.44 ng/g fat for the samples collected in the period 2008- 2019. 2008 levels were recorded for the sample from Nigeria (0.22 ng/g fat).

In 2009 the concentrations of BDE 99 ranged between 0.10- 0.44 ng/g fat. High concentrations recorded were 0.44 ng/g fat (DR Congo), 0.34 ng/g fat (Uganda), 0.29 ng/g fat (Ghana). Kenya recorded 0.10 ng/g fat, while 0.10 ng/g fat was recorded for both Mauritius and Senegal samples.

In 2010 and 2011, two data sets were recorded for each year, with 0.19 ng/g fat (Cote d'Ivoire) and 0.29 ng/g fat (Togo) in 2010, while 0.27 ng/g fat (Djibouti) and 0.22 ng/g fat (Niger) were recorded in 2011.

2015, 2017 and 2018 had concentrations of BDE 99 at 0.14 ng/g fat (Cote d'Ivoire) in 2015, 0.33 and 0.15 ng/g fat recorded in DR Congo and Togo in 2017, while 0.05, 0.42 and 0.20 ng/g fat were recorded for Mauritius, Senegal and Uganda samples in 2018, respectively.

The concentrations of BDE 99 in mothers' milk in 2019 ranged between 0.08-0.33 ng/g fat. Both Ghana and Zambia recorded 0.33 ng/g fat, while lower concentrations were reported in Egypt

(0.13 ng/g fat), Ethiopia (0.04 ng/g fat), Kenya (0.19 ng/g fat), Mali (0.17 ng/g fat), Morocco (0.08 ng/g fat), Nigeria (0.19 ng/g fat), Tanzania (0.28 ng/g fat) and Tunisia (0.10 ng/g fat) as illustrated in Figure 5.2.2.25.

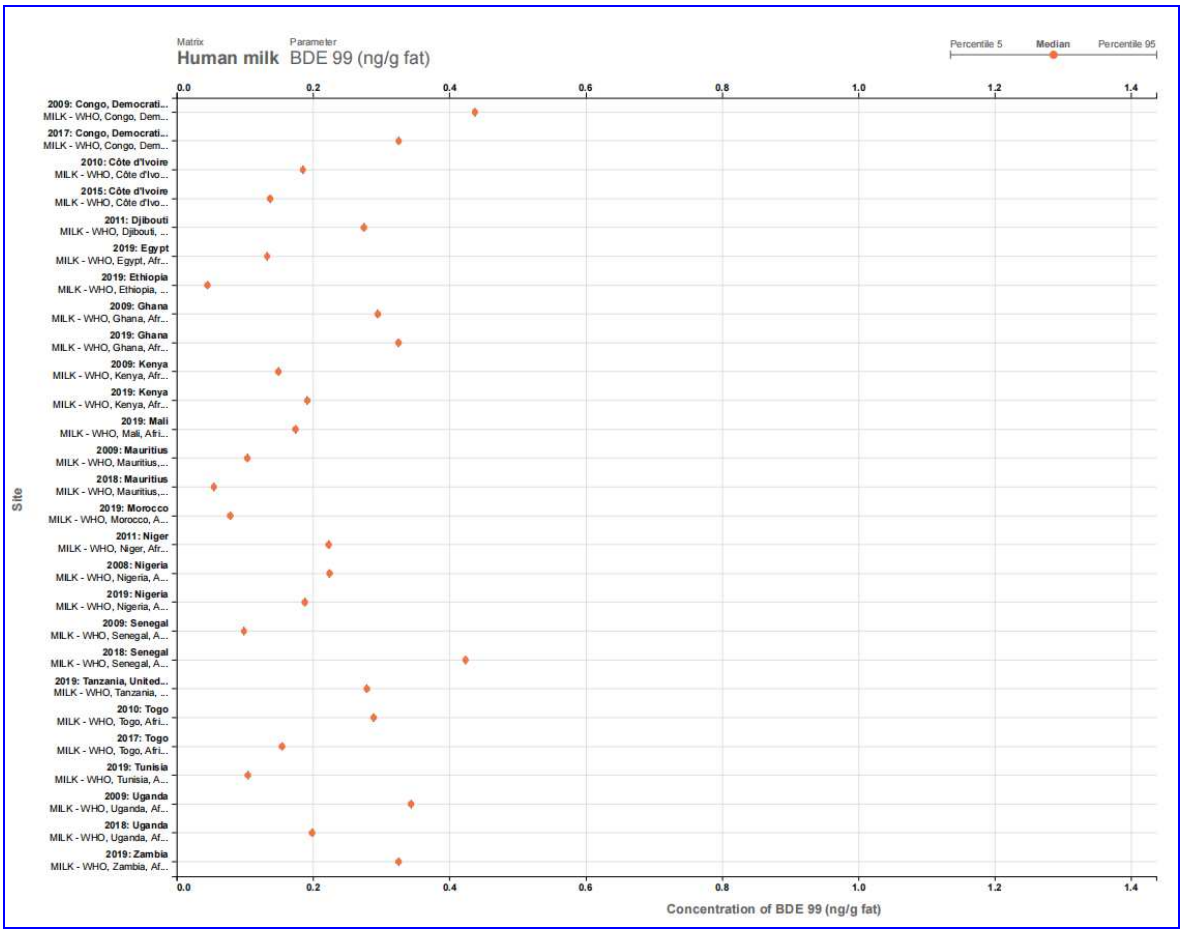


Figure 5.2.2.25 Levels of BDE 99 in mothers' milk samples

BDE 100

The mean concentrations of BDE 100 in mothers' milk samples from the region ranged between 0.02-0.29 ng/g fat for the period 2008-2019. The single dataset for 2008 was provided for sample from Nigeria (0.29 ng/g fat).

In 2009 the mean levels of BDE 100 ranged between 0.08-0.28 ng/g fat. Individual national levels constituted 0.28 ng/g fat (DR Congo), 0.26 ng/g fat (Ghana), 0.17 ng/g fat (Uganda) and 0.12 ng/g (Senegal). Lower levels were reported for Kenya (0.07 ng/g fat) and Mauritius (0.08 ng/g fat).

BDE 100 levels in 2010 were 0.09 ng/g fat (Cote d'Ivoire) and 0.17 ng/g fat (Togo), while in 2011 the concentrations measured were 0.19 ng/g fat (Djibouti) and 0.09 ng/g fat (Niger).

2015 dataset had concentration (0.12 ng/g fat), while 2017 recorded 0.21 ng/g fat (DR Congo) and 0.11 ng/g fat (Togo). In 2018, three datasets were recorded with BDE 100 concentrations of 0.05, 0.20 and 0.10 ng/g fat for Mauritius, Senegal and Uganda, respectively.

2019 dataset for BDE 100 had mean concentrations between 0.02- 0.24 ng/g fat. The highest levels recorded were 0.24 ng/g fat (Ghana), 0.19 ng/g fat (Nigeria), 0.18 ng/g fat (Zambia), 0.17 ng/g fat (Kenya) and 0.15 ng/g fat (Tanzania). Lower levels were recorded in Egypt (0.05 ng/g fat), Ethiopia (0.02 ng/g fat), Morocco (0.06 ng/g fat), and Tunisia (0.08 ng/g fat). Figure 5.2.2.26 shows the levels of BDE 100 in mothers' milk samples.

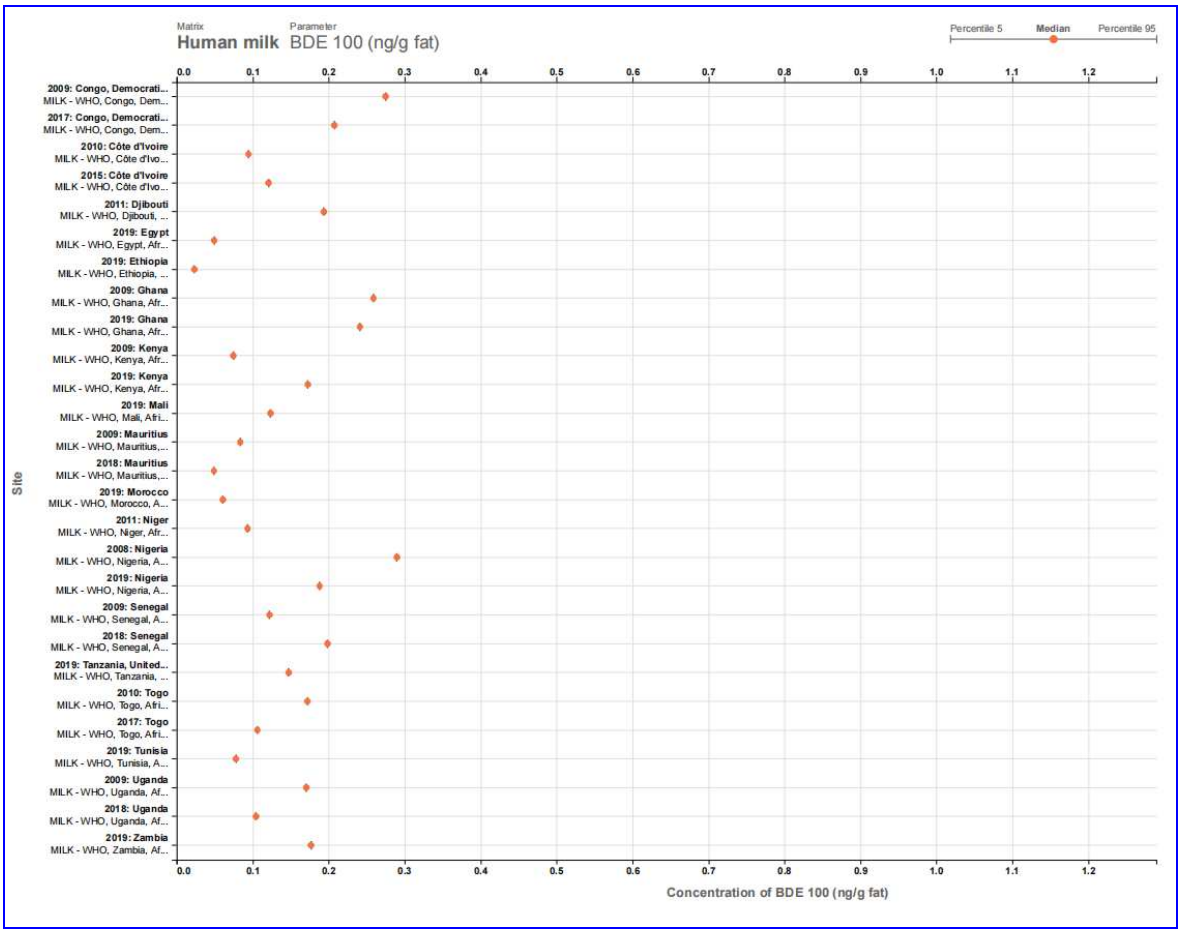


Figure 5.2.2.26 Levels of BDE 100 in mothers' milk samples

BDE 153

BDE 153 congener in mothers' milk for the period 2008-2019 had mean concentrations between 0.08- 0.50 ng/g fat. 2008 levels for BDE 153 were 0.40 ng/g fat (Nigeria). The levels in 2009 ranged between 0.14- 0.50 ng/g fat which were registered in DR Congo (0.50 ng/g fat), Ghana (0.32 ng/g fat), Senegal (0.21 ng/g fat), Uganda (0.17 ng/g fat), while Kenya and Mali recorded concentration of 0.14 ng/g fat each.

In 2010 the mean concentrations of BDE 153 were 0.20 ng/g fat and 0.21 ng/g fat recorded in Cote d'Ivoire and Togo, respectively, while 2011 levels were 0.36 ng/g fat and 0.32 ng/g fat recorded in Djibouti and Niger, respectively. The levels of BDE 153 are summarised in Figure 5.2.2.27.

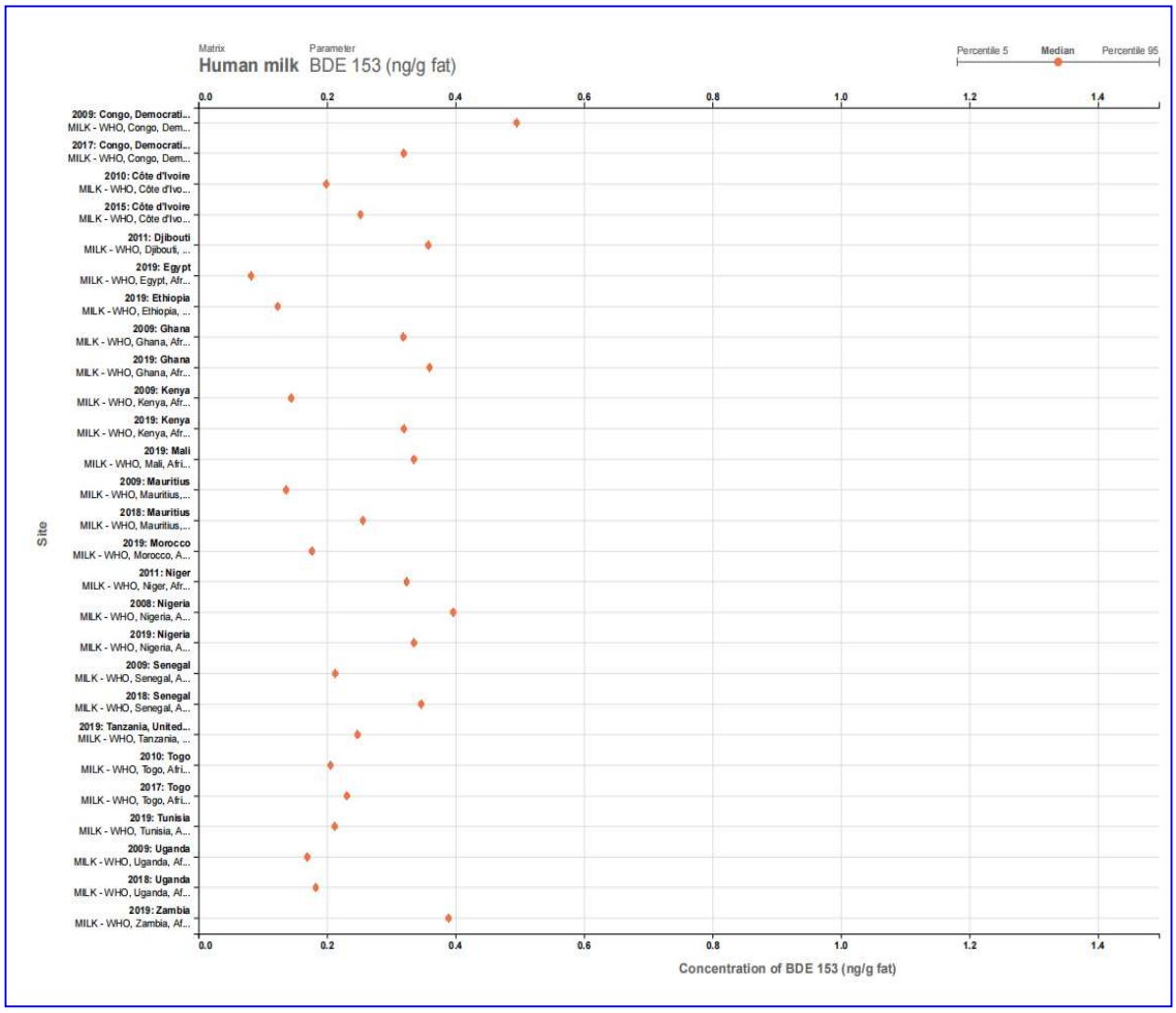


Figure 5.2.2.27 Levels of BDE 153 in mothers' milk samples

In 2015 Cote d'Ivoire reported the dataset for her second mothers' milk survey with concentration of 0.25 ng/g fat, while 2017 registered concentrations of 0.32 and 0.23 ng/g fat recorded in samples from DR Congo and Togo, respectively.

In 2018 the concentrations of BDE 153 were 0.26, 0.35 and 0.18 ng/g fat recorded in Mauritius, Senegal and Uganda, respectively.

Datasets for 2019 were contributed by 10 countries, and national mean concentrations ranging between 0.08-0.39 ng/g fat. Highest levels recorded were 0.39 ng/g (Zambia), 0.36 ng/g fat (Ghana), 0.34 ng/g fat (Mali and Nigeria), and 0.32 ng/g fat (Kenya). Lower concentrations were measured in samples from Egypt (0.08 ng/g fat), Ethiopia (0.12 ng/g fat), Morocco (0.18 ng/g fat), Tanzania (0.25 ng/g fat) and Tunisia (0.21 ng/g fat).

BDE 154

The levels of BDE 154 in mothers' milk samples for the period 2008-2019 had mean concentrations between 0.01-0.05 ng/g fat. In 2008 the single data set for BDE 154 from Nigeria

recorded concentration of 0.02 ng/g fat. In 2009 the BDE 154 levels were reported by six countries with mean concentrations between 0.003-0.04 ng/g fat. The highest levels recorded were 0.04 ng/g fat (Ghana), 0.02 ng/g fat (DR Congo and Uganda), 0.01 ng/g fat (Mauritius), while lower levels were recorded in Kenya and Senegal at 0.03 ng/g fat each. Figure 5.2.2.28 shows the levels of BDE 153 recorded in mothers' milk samples.

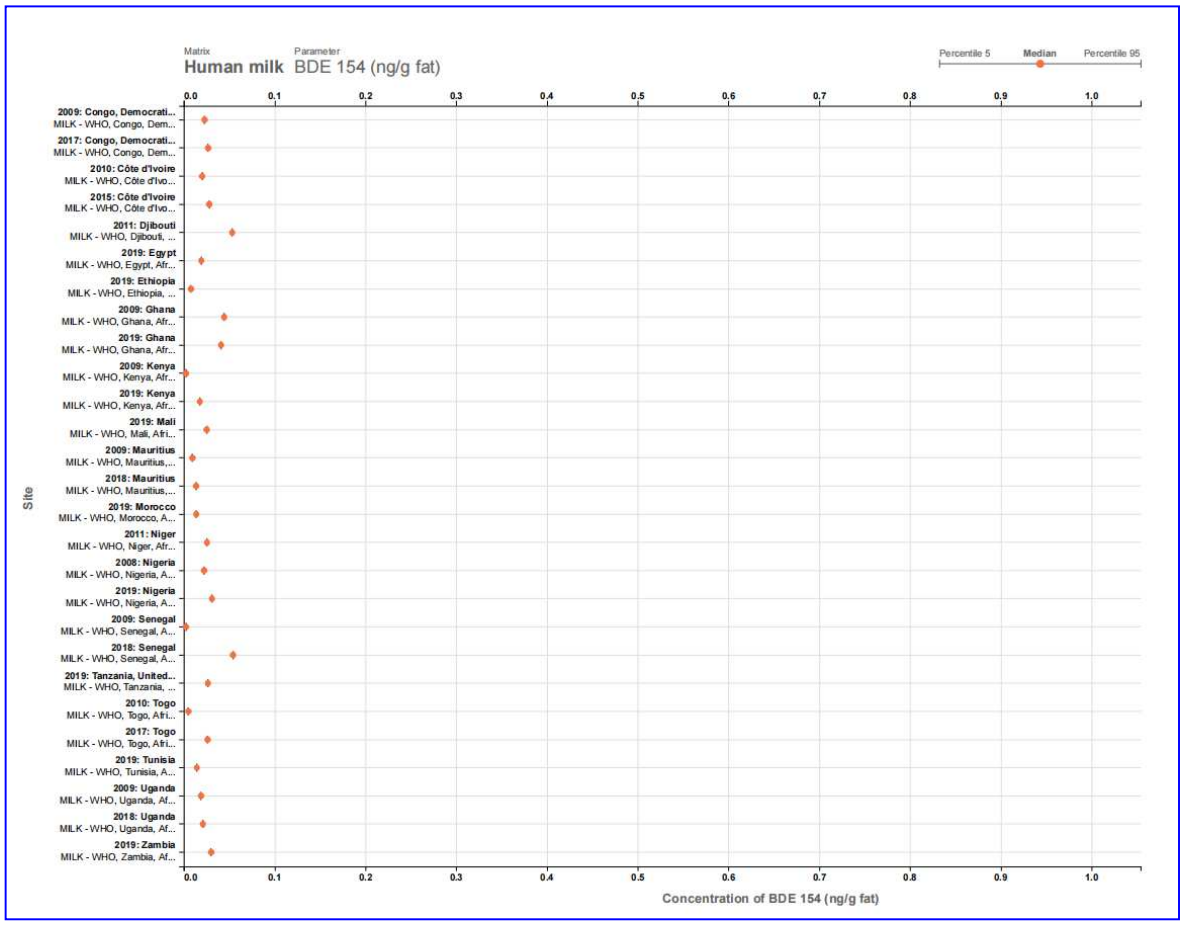


Figure 5.2.2.28 Levels of BDE 154 in mothers' milk samples

2010 and 2011 data had concentrations of BDE 154 at 0.02 and 0.01 ng/g fat in samples from Cote d'Ivoire and Togo in 2010, while 0.05 and 0.03 ng/g fat were recorded in Djibouti and Niger samples in 2011, respectively.

Cote d'Ivoire recorded BDE 153 conger concentration of 0.03 ng/g fat in 2015 samples, while both DR Congo and Togo had concentrations of 0.03 ng/g fat in 2017 samples. In 2018 the concentrations of BDE 153 in mothers' milk sample were 0.01, 0.02 and 0.05 ng/g fat recorded in samples from Mauritius, Uganda and Senegal, respectively.

2019 levels of BDE 153 ranged between 0.01-0.04 ng/g fat. Individual country concentrations recorded were 0.01 ng/g fat (Ethiopia, Morocco and Tunisia), 0.02 ng/g fat (Egypt and Kenya), 0.03 ng/g fat (Mali, Nigeria, Tanzania and Zambia), and 0.04 ng/g fat (Ghana).

BDE 175/183

The levels of BDE 175/183 congeners in mothers' milk samples were recorded in the period 2015-2019. The mean concentrations ranged between 0.03-0.18 ng/g fat. In 2015 the concentration of BDE/175/183 was 0.11 ng/g fat (Cote d'Ivoire), while in 2017, two data sets were reported for DR Congo (0.07 ng/g fat) and Togo (0.07 ng/g fat). 2018 dataset for BDE 175/183 had concentrations of 0.04, 0.05 and 0.07 ng/g fat for samples from Mauritius, Uganda and Senegal, respectively.

In 2019, the dataset for BDE 175/183 had mean concentrations between 0.03-0.18 ng/g fat, with individual country concentrations measured at 0.18 ng/g fat (Zambia), 0.13 ng/g fat (Tanzania), 0.11 ng/g fat (Mali), 0.10 ng/g fat (Ethiopia, Ghana and Tunisia), 0.08 ng/g fat (Nigeria and Kenya), 0.05 ng/g fat (Morocco) and 0.03 ng/g fat (Egypt). Figure 5.2.2.29 shows the levels of BDE 175/183 measured in mothers' milk samples.

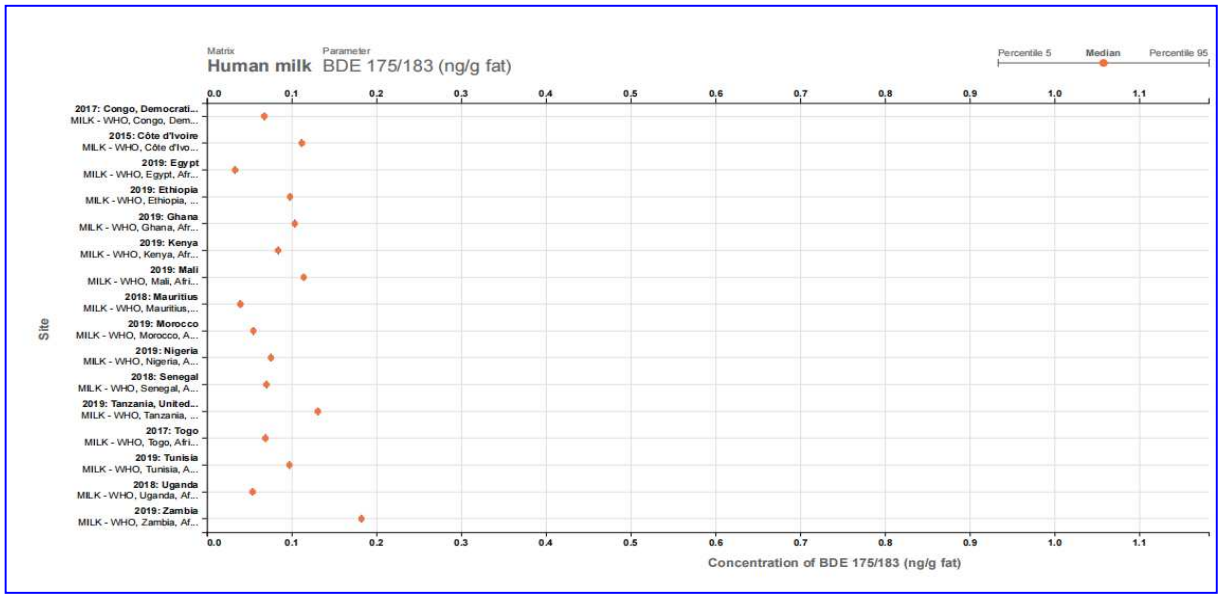
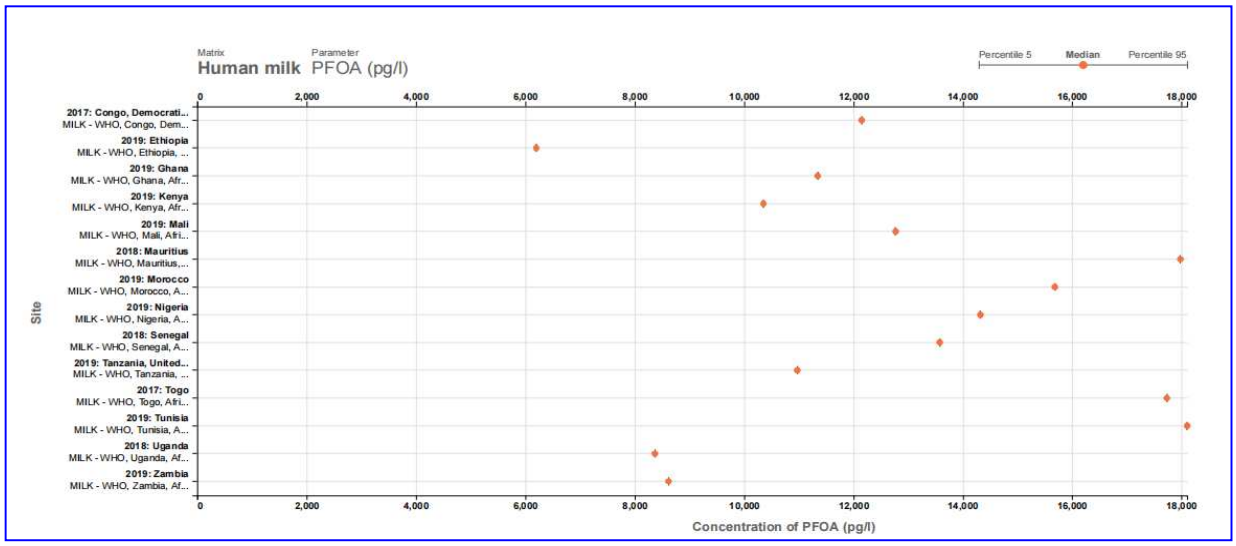


Figure 5.2.2.29 Levels of BDE 175/183 in mothers' milk samples

5.2.2.20 Perfluorooctane Sulfonic Acid (PFOS), its salts and related Compounds in mothers' milk

The PFAS compounds analysed in mothers' milk included Perfluorooctane Sulfonic Acid (PFOS), Perfluorooctainoic Acid (PFOA) and Perfluorohexanesulfonate (PFHxS). The concentration of were dominated by PFOS and PFOA, while PFHxS levels were below the limit of detection (<2,750 pg/L).

The concentration of PFOS in mothers' milk samples ranged between <3,100 – 21,886 pg/L for samples collected between 2017 and 2019. Data for 2017 was provided for samples collected from DR Congo and Togo with concentrations of <3,100 pg/L and 12,834 pg/L respectively. In 2018 three countries provided data for PFOS in mothers' milk namely Mauritius (12,772 pg/L), Senegal (10,230 pg/L) and Uganda (<3,100 pg/L).



2019 recorded the highest number of mothers' milk samples with eight countries providing mothers' milk samples namely Ethiopia (9,114 pg/L), Ghana (15,562 pg/L), Mali (21,886 pg/L), Morocco (13,578 pg/L), Nigeria (10,416 pg/L), Tanzania (7,502 pg/L) and Tunisia (19,778 pg/L), while both Kenya and Zambia recorded levels below 3,100 pg/L as illustrated in Figure 5.2.2.30 below.

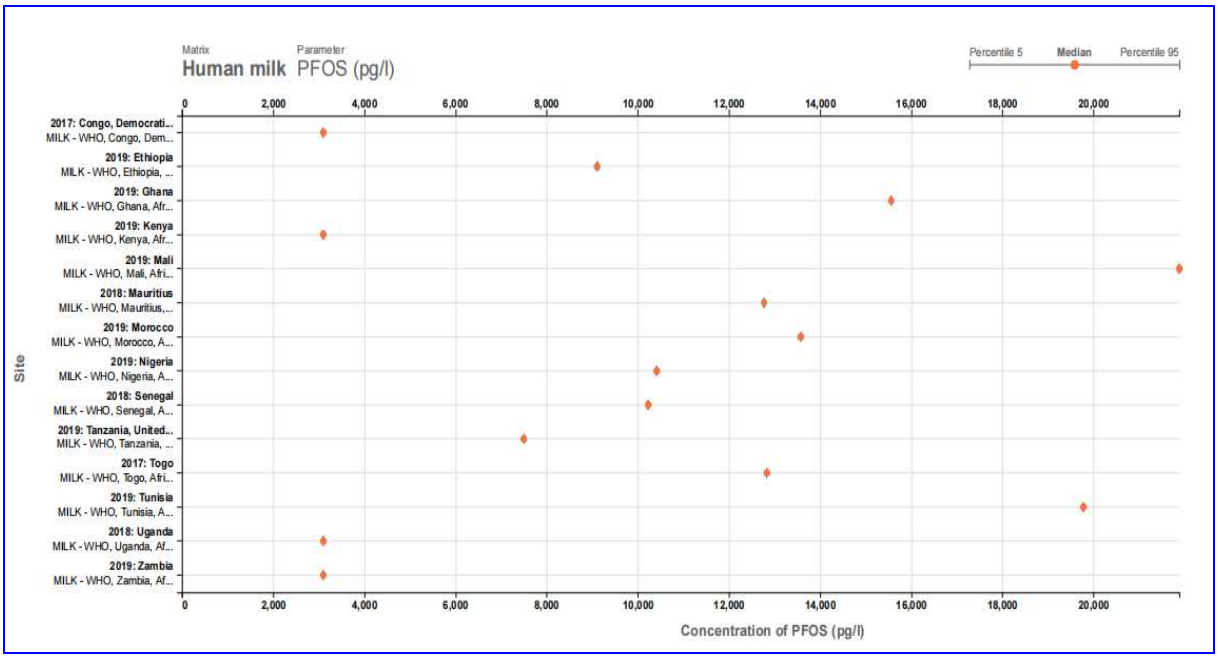


Figure 5.2.2.30 Levels of PFOS in mothers' milk samples

The concentrations of PFOA in mothers' milk ranged between 6,200-18,104 pg/g fat making it second to PFOS among the per-fluorinated (PFAS) compounds monitored. 2017 data came from DR Congo (12,152 pg/L) and Togo (17,732 pg/L), while 2018 data included Mauritius (17,980 pg/L), Senegal (13,578 pg/L) and Uganda (8,370 pg/L). Figure 5.2.2.31 shows the levels of PFOA in mothers' milk samples.

Figure 5.2.2.31 Levels of PFOA in mothers' milk samples

In 2019, nine countries provided data for PFOA in milk with the highest levels being 18,370 pg/L recorded in Tunisia, 15,686 pg/L (Morocco), 14,322 pg/L (Nigeria), 12,772 pg/L (Mali) and 11,346 pg/L (Ghana). Middle levels were recorded in Kenya (10,354 pg/L), Tanzania (10,974 pg/L), and Zambia (8,618 pg/L), while the lowest was 6,200 pg/L recorded in Ethiopia. Data for PFOA was from a single round of survey per country and hence attracted no further comparison with the previous data sets for any trend in levels.

5.2.2.21 Short Chain Chlorinated Paraffins (SCCPs) in mothers' milk

The concentrations of sum SCCP in mothers' milk were relatively high compared to other industrial POPs like PBDEs. The mean sum concentrations ranged between 39.76 -121 ng/g fat for samples collected between 2017 and 2019. Data for SCCPs for 2017 were provided for samples collected from DR Congo and Togo with SCCP levels of 50.24 ng/g fat and 39.76 ng/g fat respectively.

Dataset for SCCPs in mothers' milk in 2018 were contributed by Mauritius and Uganda, and had mean concentrations of 111.44 ng/g fat and 46.37 ng/g fat, respectively.

2019 data was provided for samples collected from Ethiopia (70 ng/g fat), Ghana (77 ng/g fat), Kenya (56 ng/g fat), Mali (69 ng/g fat) Morocco (66 ng/g fat), Nigeria (51 ng/g fat), Tanzania (121 ng/g fat) Tunisia (51 ng/g fat) and Zambia (112 ng/g fat). The overview of the levels of SCCPs in the regional mothers' milk samples are summarised in Figure 5.2.2.32 below.

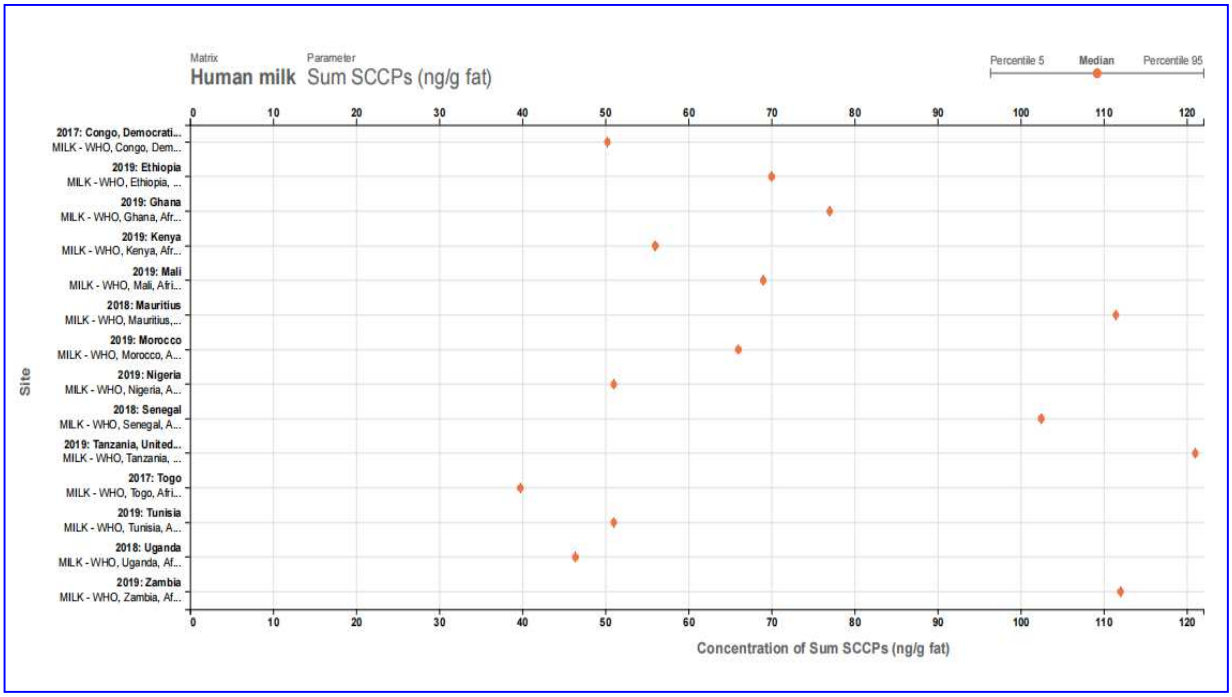


Figure 5.2.2.32 Levels of sum SCCPs in mothers' milk samples

Research data on mothers' milk and blood contamination

Data from research activities have also revealed POPs contamination in mothers' milk from the region. PCBs in mothers' milk was reported in Ghana by Asamoah et al. (2018) and Wittsiepe et al. (2015) for PCB contamination in blood from Ghana.

A risk–benefit assessment PCDDs, PCDFs, PCBs and DDT in mothers' milk

A risk assessment PCDDs, PCDFs and PCBs levels in mothers' milk samples from the region showed that the levels were significantly above those considered toxicologically safe, while **Σ**DDTs were below or around those considered safe for majority of the countries for the sample collected from 2002-2019. The levels agree with the findings made by Van den Berg et al. (2017). The summary of safety standards and equivalent TEQs and concentrations in mothers' milk are summarised below.

1) WHO safety standard for PCDD/PCDF/PCB (TEQ) based on perinatal effects in rodents and monkeys is TDI of 1–4 pg/kg bw day which translates to equivalent milk PCDD/PCDF/PCB (TEQ) level of 0.2–0.9 pg/g lipid (WHO, 2000).
2) US-EPA safety standard for PCDD/PCDF/PCB (TEQ) based on postnatal/childhood exposure to humans is RfD (proposed) of 0.7 pg/kg bw day which translates to equivalent milk PCDD/PCDF/PCB (TEQ) level of 0.2 pg/g lipid Postnatal/childhood exposure humans (USEPA, 2010).
3) ATSDR safety standard for PCDD/PCDF/PCB (TEQ) based on postnatal effect in monkeys is MRL subchronic of 1 pg/kg bw day which translates to equivalent milk PCDD/PCDF/PCB (TEQ) level of 0.2 pg/g lipid (ATSDR, 1998).
4) ATSDR safety standard for total PCBs based on postnatal effect in monkeys is MRL subchronic 0.03 µg/kg bw day which translates to equivalent milk total PCBs level of 7 ng/g lipid (ATSDR, 2004).
5) WHO safety standard for DDT based on developmental toxicity in rats is TDI of 10 µg/kg bw day which translates to equivalent milk DDT level of 2,300 ng/g lipid (WHO, 2001).

It should be emphasized that health benefits of breastfeeding are far above the health risks of POPs in mothers' milk, hence WHO and other bodies involved in developing the safety standards encourage breastfeeding, while measure to reduce POPs burden are instituted in the countries. Breastfeeding has been reported to reduce a large variety of health problems in early childhood, including the risk of acute otitis media, nonspecific gastroenteritis, severe lower respiratory tract infections, atopic dermatitis, asthma (young children), obesity, possibly type 1 and 2 diabetes, childhood leukemia, SIDS and necrotizing enterocolitis (Ip et al., 2007).

A study by Chen and Rogan (2004) showed the benefits of breastfeeding with respect to overall postnatal survival and hospitalization, with a 30–40 % reduction in overall neonatal mortality and sudden infant death when breastfeeding. Further Talayero et al. (2006) in a study undertaken in Spain indicated that 30 % of the neonatal hospital admissions could be avoided for every additional month of breastfeeding.

5.2.3 Concentrations of POPs in water

Comparable regional data on PFOS and salts was mainly obtained from samples collected from the large rivers and estuaries within the region. The main programmes that provided water data were MONET Africa for 2013 and 2014 data, and UNEP/GEF GMP2 project for 2017-2019 data sets. Available data extend from 2013 (Egypt), 2014 (Congo, Kenya, Mauritius, Morocco and

Nigeria) obtained through MONET Africa programme. Data for 2017-2019 was obtained from UNEP/GEF GMP2 project and covered sites in Egypt, Ghana, Kenya, Tunisia and Zambia.

5.2.3.1 PFOS in water

From 2013-2019 PFOS levels have been monitored at nine sites consisting of the major Rivers and the river estuaries within the region. There were no significant trends in PFOS in all the sites (Figure 5.2.3.1).

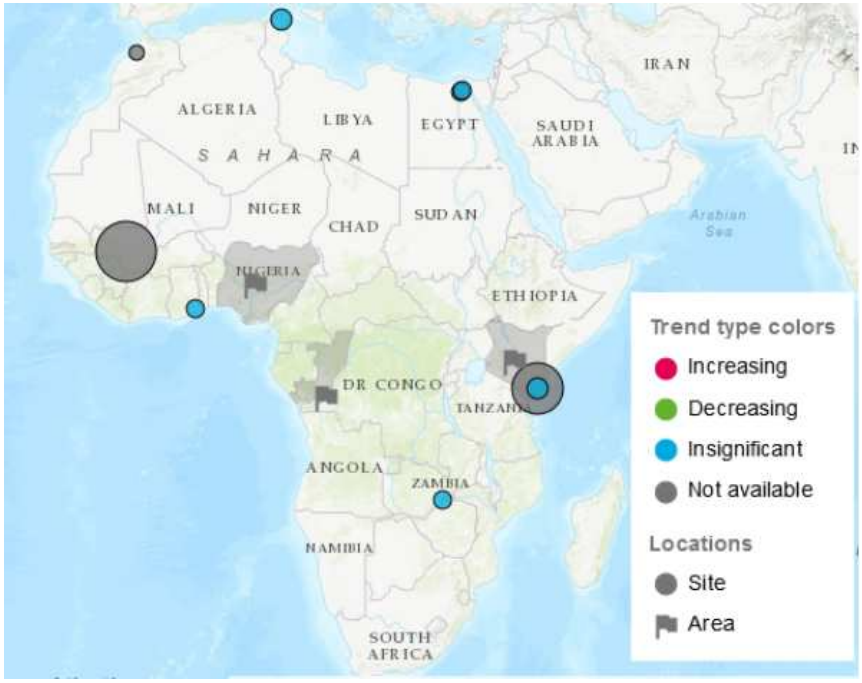


Figure 5.2.3.1 Water sampling sites under UNEP/GEF GMP2 project 2016-2020.

PFOS levels in water

For the period 2013-2019 the highest concentration of PFOS in water ranged from 35.00-1,919 pg/L. PFOS data for 2013 and 2014 were collected under MONET Africa programme from 5 sites with the highest concentration 1,390.60 pg/L (Nigeria), followed by 260.0 pg/L (Kenya), 242 pg/L (Mauritius) while both DR Congo and Morocco sites recorded 35 pg/L.

2013 data was submitted for samples from Abu Rawash site (Egypt) with PFOS concentration of 514 pg/L. In 2014 four data set were recorded with mean concentrations ranging between 35-1390.60 pg/L. Specific national levels of PFOS reported in water were 1390.6 pg/L (Nigeria), 242.8 pg/L (Mauritius), 260.0 pg/L (Kenya), while both Morocco and Congo recorded concentrations of 35 pg/L.

In 2017 the implementation of UNEP/GEF GMP2 project expanded water sampling to major Rivers covering the sub regions in the West, North, South, East and Central Africa, which saw additional 5 sites that expanded the data set. 2017 recorded six datasets with mean concentrations of PFOS ranging between 336.13-1919.04 pg/L. National annual mean concentrations recorded in 2017 were 1,919.04 pg/L (Sabaki River, Kenya), 999.90 pg/L (Kafue site along Zambezi River, Zambia), 619.32 pg/L (Quede site, Tunisia), 537.46 pg/L (R. Volta, Ghana), 363.48 pg/L (Senegal) and 336.13 pg/L (R. Nile, Egypt).

In 2018 the annual mean concentrations of PFOS were 1327.97 pg/L (Sabaki River Mouth, Kenya) followed by 646.66 pg/L (Qued site, Tunisia), 271.00 (River Nile, Egypt), 241.90 pg/L (Senegal), 150.07 pg/L (River Volta site, Ghana) and 98.39 pg/L (Kafue site, Zambia). In 2019, datasets had mean concentrations of 912.77 pg/L (Sabaki River, Kenya) and 378.08 pg/L (River Nile, Egypt). Figure 5.2.3.2 shows the concentrations of PFOS in regional waters in the period 2013-2019.

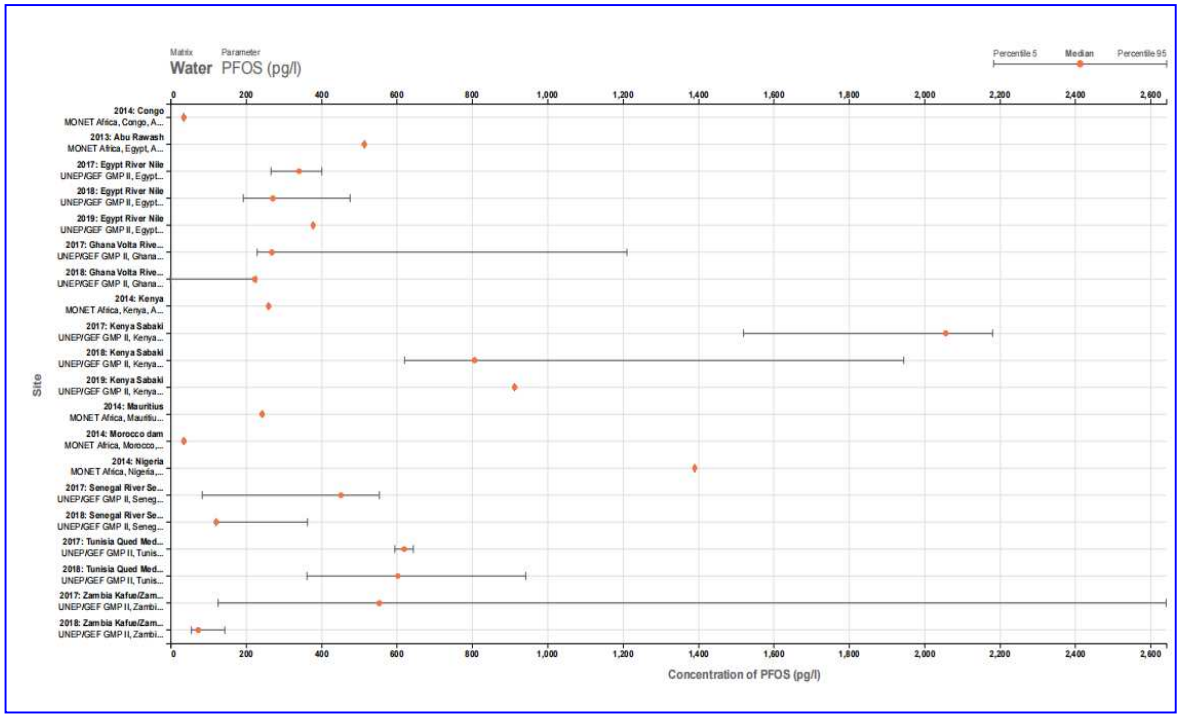


Figure 5.2.3.2 Concentration of PFOS in water samples

5.2.3.2 PFOA concentrations in water

The Concentration of PFOA in the regional water samples collected between 2013 -2019 ranged between 30-3,170 pg/L. 2013 recorded concentration of 179.2 pg/L (Abu Rawash, Egypt), while 2014 dataset had mean levels between 30-3,170 pg/L. The country specific mean concentrations were 3,170 pg/L (Nigeria), 486 pg/L (Athi River, Kenya), 194.20 pg/L (Congo), 110 pg/L (Morocco) and 30 pg/L (Mauritius).

2017 data set recorded mean PFOA concentrations between 119.86 -2054.78 pg/L, with national mean concentrations of 2054.78 pg/L (Sabaki River, Kenya), 1062.63 pg/L (Qued site, Tunisia), 398.23 pg/L (R. Nile, Egypt), 310.87 pg/L (R. Volta, Ghana), 209.65 pg/L (Kafue Zambezi R. Zambia) and 119.86 pg/L (Senegal). The Concentrations of PFOA in water samples in 2018 ranged between 87.18- 2026.56 pg/L. The highest levels were 2026.56 pg/L (Sabaki River, Kenya), 1229.46 pg/L (Qued site, Tunisia), 594.32 pg/L (R. Nile, Egypt), 221.35 pg/L (R. Volta, Ghana), 119.63 pg/L (Kafue Zambezi R. Zambia) and 87.18 pg/L (Senegal).

2019 dataset recorded for PFOA were 997.80 pg/L (Sabaki River, Kenya) and 716.44 pg/L (R. Nile, Egypt). Figure 5.2.3xx shows levels of PFOA in regional water bodies in the period 2013-2019. Figure 5.2.3.3 shows the levels of PFOA recorded in water samples.

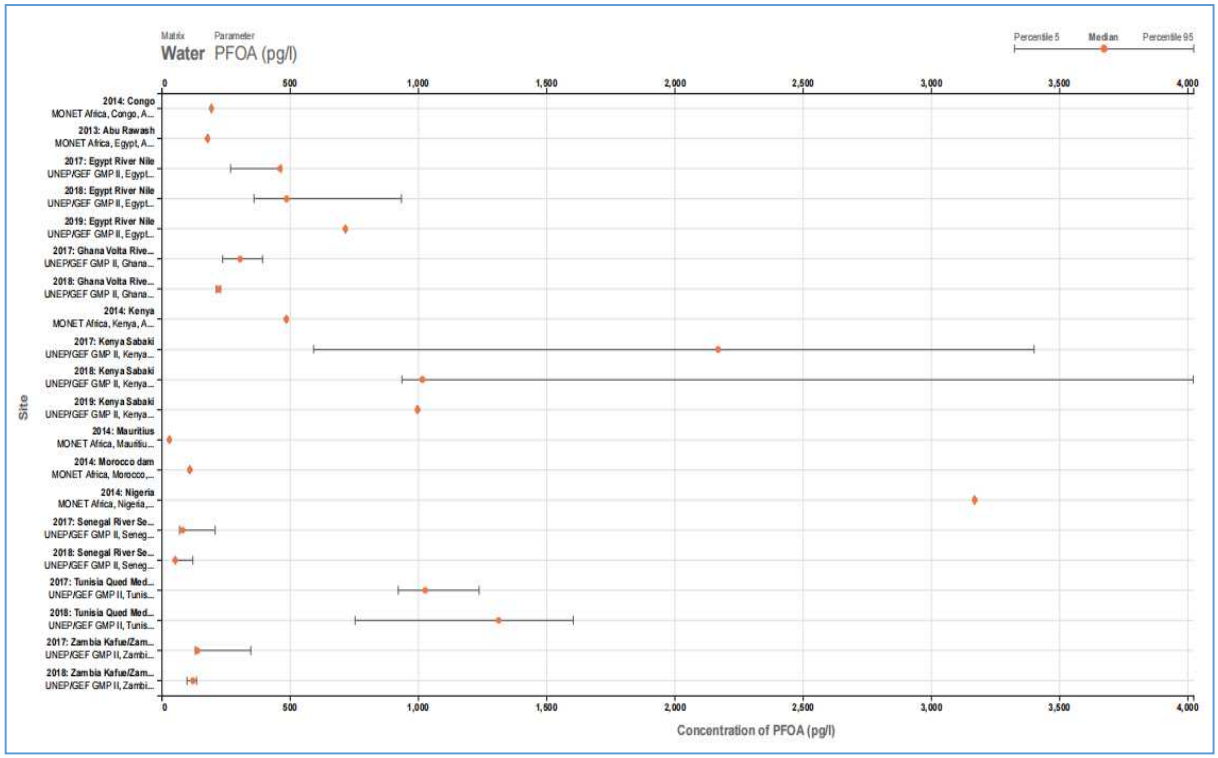


Figure 5.2.3.3 Concentration of PFOA in water samples

5.2.3.3 PFHxS concentrations in water

PFHxS levels ranged between 11.25- 1,043.44 pg/L for samples collected for the period 2013-2019. 2013 data for PFHxS were 15 pg/L (Abu Rawash, Egypt). 2014 mean levels of PFHxS ranged between 15-1,048 pg/L with country specific concentrations of 1,048 pg/L (Nigeria), 144 pg/L (Athi River, Kenya), 95.4 pg/L (Mauritius), while both Morocco and Egypt recorded 15 pg/L.

In 2017 the mean levels of PFHxS ranged between 11.25-1,043.44 pg/L for six countries with levels 1,043.44 pg/L (Sabaki River, Kenya), 109.74 pg/L (R. Zambezi, Zambia), 83.83 pg/L (Qued site, Tunisia), 55.61 pg/L (R. Volta, Ghana), 49.23 pg/L (R. Nile, Egypt), and 11.25 pg/L (Senegal).

2018 levels of PFHxS ranged between 13.15 -978.09 pg/L. National concentrations reported were 978.09 pg/L (Sabaki River, Kenya), 107.36 pg/L (Qued site, Tunisia), 51.87 pg/L (R. Nile, Egypt), 33.95 pg/L (R. Volta, Ghana), 31.30 pg/L (R. Zambezi, Zambia), and 13.15 pg/L (Senegal).

In 2019 the levels of PFHxS were reported for samples from Kenya (327.97 pg/L) and Egypt (152.92 pg/L). The levels of PFHxS measured in water are illustrated in Figure 5.2.3.4.

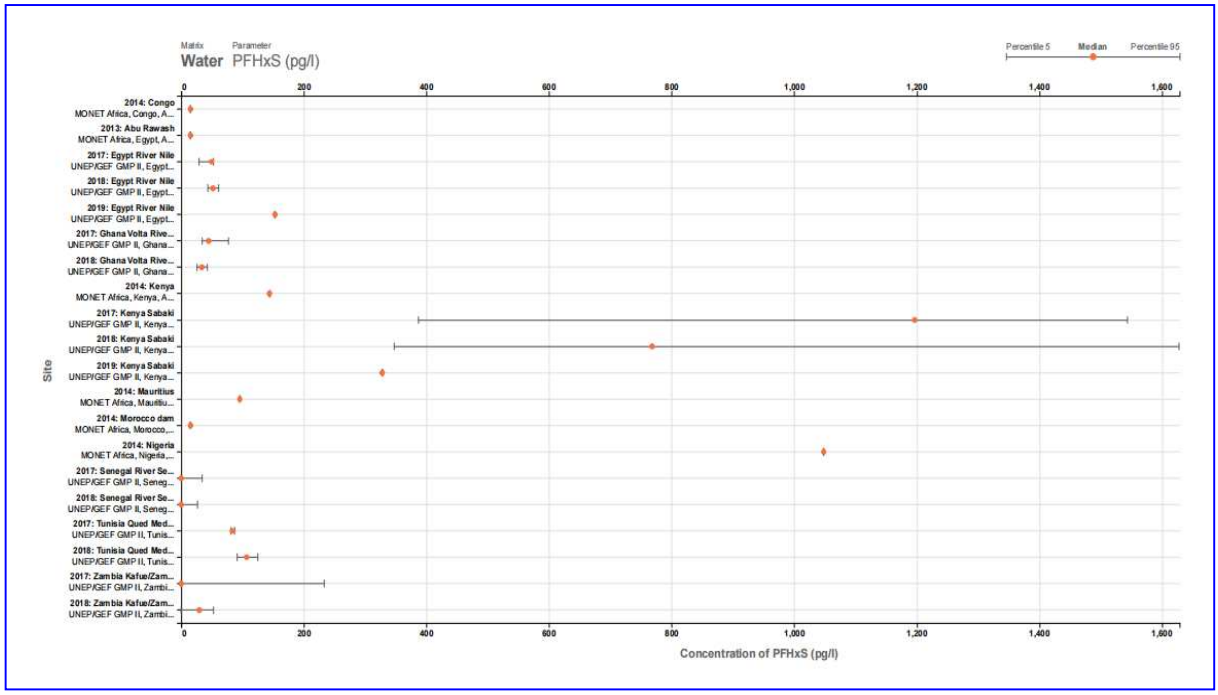


Figure 5.2.3.4 Concentration of PFHxS in water samples

5.2.3.4 PFOSA, NMeFOSA, and NEtFOSA levels in water

PFOSA, NMeFOSA, and NEtFOSA were monitored in water in in 2013 and 2014 and recorded concentrations below LOQs of 2.0 pg/L, 100 pg/L and 50 pg/L, respectively, for samples collected from Egypt (in 2013) and Congo, Kenya, Mauritius, Morocco and Nigeria.

Trend Summary for PFOS, salts and PFOS related compounds in water

No significant trend were observed in the levels of PFOS, its salts and PFOS related compounds in water from the region. This was associated with the limited data collected so far on PFOS and salts concentrations in water. Figure 5.2.3.5 below shows the overall trend summary of PFOS, its salts and related compounds in samples collected under the GMP activities in the region 2013-2019.

Water contamination from research publications

Several studies have reported water contamination by POPs in the region. Mudumbi et al. (2014) reported PFOS in rivers in the in the Western Cape (South Africa) and found relatively high concentrations (<0.03-182 ng/L). Orata et al. (2009) reported PFOS in rivers draining into Winam Gulf of lake Victoria. In Tanzania Kihampa et al. (2011) reported pesticide residues in four rivers running through an intensive agricultural area, Kilimanjaro region.

5.2.4 POPs in other media

5.2.4.1 Overview of POPs in other media

Analytical data from UNEP/GEF GMP projects and regional research activities have revealed wide contamination of environmental media such as soil, sediments, fish, water, feed stuff among others by a variety of POPs compounds. The presence of POPs in other media is

important since it provides supplementary information that can help in the interpretation of the POPs levels detected in the core media. The discussion below summarises the findings of POPs in other media from the region.

Soil contamination

Soil contamination by POPs has been widely reported in research activities suggesting possible accumulation of POPs in the agricultural soils. Tue et al. (2016) reported PBDEs in soil from open burning of e-wastes in Ghana. In addition, contamination of dumpsites by PBDEs from e-waste was also reported by Akortia et al. (2017). In Tanzania, DDT residues ranging from 10.02 to 116 µg/kg dry weight (dw) in soil and 7.5 to 564.2 µg/kg dw in sediments have been reported in Eastern Lake Tanganyika (Mahugija et al. 2017). Other studies by Kihampa and RamMato (2009) reported OCPs in soil along the old obsolete pesticides storage site at old Korogwe in Tanzania.

Fish and other food stuff contamination

Fish and food stuff contamination by POPs has been reported in several research publications from the region. Adukumi et al. (2010) reported PCBs and PCDDs/Fs in fish from Ghana. Afful et al. (2010) reported OCPs concentrations in fish ranging from 0.3 to 71.3 µg/kg. Gbeddy et al. (2012) also reported OCPs in African catfish muscle, Nile tilapia Muscle and gills from the middle Volta basin, while Darko et al. (2008) reported OCPs in fish, sediments and water from Lake Bosomtwi, Ghana. A recent study by Danladi and Akoto, (2021) reported OCPs ranging 7 - 1.026 µg/kg in fish from Vea Irrigation Reservoir, Ghana. In Uganda, Ssebugere et al. (2013) reported fish contamination by PCBs and PCDDs/Fs for samples collected from Lake Victoria. Orata et al. (2008) reported Perfluorooctanoic acid and perfluorooctane sulfonate in Nile Perch and tilapia from Winum gulf of Lake Victoria. In other studies POP pesticides were reported in *Solanum lycopersicum L*. and *Capsicum annuum L* fruits from a local market survey in Nigeria (Benson et al. 2011). Vaccher et al. (2020) reported PCDDs/Fs, PCBs, PBDEs, and perfluoroalkylated substances in food stuffs comprising of fish, eggs, dairy milk, nuts and seeds from Benin, Cameroon, Mali and Nigeria. A review of POPs studies in Ghana by Bruce-Vanderpuije et al. (2019 per- and poly-fluoroalkyl sulphonates (PFASs) and dichlorodiphenyldichloroethane (DDD) in water, polychlorinated and polybrominated dibenzo-p-dioxins and furans (PCDD/Fs and PBDD/Fs) in e-waste soils, and polybrominated diphenyl ethers in aquatic organisms and dairy products. In Nigeria, Okoya et al. (2013) reported OCPs in Sediment-Dwelling Animals from Mangrove Areas of the Calabar River. Owusu- Boateng et al. (2013) reported OCPs in cabbage from farms along River Oyansia, Accra-Ghana.

Sediment contamination

Contamination of sediments by POPs has been reported in several studies. Verhaert et al. (2013) reported PCB contamination in sediments and fish from DR Congo. Further studies by La Guardia et al. (2013) reported PBDEs in sediments samples from South Africa. Adebayeyo et al. (2011) reported OCPs pollution of water, sediments, Fin and Shell-fish samples from Lagos Lagoon Complex, Nigeria. In Kenya contamination of sediments from Nairobi River was reported by Ndunda et al. (2018). Further study by Orata et al. (2011) reported 'Perfluorinated Compounds contamination and distribution in sediments from Lake Victoria Winum gulf. Pelig-Ba (2011) reported OCPs in sediments and irrigation water from Tono and Vea in the Upper East of Ghana

5.2.4.2 Concentrations in other media from UNEP/GEF pilot projects

i) Basic POPs in national samples from Egypt

Samples from Egypt comprising of baby milk, fish meal and dry soil analysed for POPs recorded low levels in baby milk with most of the analytes below detection limit. POPs in fish meal ranged from bdl to 9.9 ng/g, whereas the POPs levels in agricultural soils were between bdl and 1.60 ng/g.

ii) Basic POPs in national samples from Ethiopia

Sediment samples from Ethiopia registered basic POPs from bdl and 47 ng/g for OCPs and bdl to 0.1 ng/g for PCBs. The major pesticides detected were *p,p′*-DDT, *p,p′*-DDE and HCB.

iii) Basic POPs in national samples from Kenya

Samples from Kenya included fish, sediments and soil. Dieldrin, *p,p′*-DDE and *p,p′*-DDT were detected in soil and sediments. The levels of pesticides and PCBs in fish ranged from bdl to 0.03 ng/g. OCP and PCBs levels in sediments ranged from bdl to 1.5 ng/g, showing relatively higher levels sediments compared concentrations measured in fish samples.

The soil samples recorded the highest OCPs levels compared to 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

Samples from Mauritius included sediments and fish fillet. POP pesticides in sediments ranged between bdl and 14 ng/g. PCBs varied from bdl to 0.08 ng/g in the same matrix. The concentration of OCPs in fish fillet varied from bdl to 0.33 ng/g, whereas PCB concentrations ranged from bdl to 0.10 ng/g. The main pesticides detected in the national samples were *p,p′*-DDT, *p,p′*-DDE, *p,p′*-DDD and HCB.

v) Basic POPs in national samples from Uganda

Samples from Uganda included fish and sediments. OCPs in fish ranged from bdl to 0.19 ng/g, whereas PCBs ranged from bdl to 0.08 ng/g. OCPs in sediments varied from bdl to 0.35 ng/g, and bdl to 0.05 ng/g 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 from Zambia recorded POPs bdl to 0.1 ng/g for OCPs and from bdl to 0.10 ng/g in the case of PCBs in soil. Contamination in sediments ranged from bdl to 1.2 ng/g for OCPs and bdl to 0.06 ng/g for indicator PCBs.

5.3 Long-range transport

Analysis of back trajectories identifying potentials transport of the POPs in regional sites for ambient air were presented in the first and second regional reports (UNEP, 2009 & 2015b). Furthers trajectories have not be carried out in the current report. However, whereas the back trajectories identified the source areas for background sites, the data cannot be extrapolated to identification of POPs sources from industrial, residential and other hot spot areas that may influence emissions and local transport. Furthermore, local meteorological such as temperature,

sunshine, wind speed and direction, precipitation and deposition, that are known to influence fate and life time of the compounds in the atmosphere, need to be captured during ambient air sampling activities.

5.4 Challenges to implementing GMP in the Region

The ROG members identified several challenges affecting POPs monitoring in the region that need to be considered in future activities.

i) **Increasing number of new POPs chemicals**: The number of listed POPs has increased from the initial 12 legacy compounds to 28 in the third GMP phase. As more chemicals are added there is increasing pressure on monitoring activities as new sampling and analytical methodologies may be required as well additional suitable matrices for their monitoring.

ii) **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.

iii) **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.

iv) **Lack of long-term 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.

v) **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.

vi) 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 and 2017-2019 since the samples were collected within the same timeframe and analysed centrally.

vii) **Data gaps in some sub-regions:** Whereas major data gaps have been filled in the third phase of GMP, only one country participated in the mothers' milk survey from the Southern Africa sub-region. This creates challenges regarding representativeness of the POPs levels in the sub-region that needs to be improved. More countries in the sub-region are encouraged to participate in future mothers' milk survey to build more representative dataset.

viii) **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.

ix) **Sustainability of existing programmes.** The goal of the global monitoring plan is to provide sufficient data for determination of trends in POPs levels in the core media. Long-term sustainability of the initiated monitoring activities remains a priority to the region to allow effectiveness evaluation of the Convention. Whereas initial trends have begun to emerge for a few legacy POPs, the existing comparable data for air, mothers' milk and water are not adequate allow analysis of temporal trends and long-range transport of POPs. Therefore resources are required to ensure continuity of the monitoring activities including sampling, analysis and data storage in order to establish trends in POPs levels.

x) 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 Summary of the baseline concentrations

Baseline concentrations for core media namely ambient air, mothers' milk and water have been established in all the sub-regions using the data from first, second and third phase of the GMP.

A) POPs levels in air

I) Ambient air monitoring data revealed wide presence of various POPs indicating significant environmental contamination. POPs have potentials to build up in the food chain, and henceforth in the human tissues when contaminated food stuff is consumed. This can eventually induce ill health effects in the populations. Hence the findings raise environmental and health concerns as these chemicals are persistent, bio-accumulative, toxic, and have propensity to undergo long-range atmospheric transport from their points of release.

II) Pesticides dominated all POPs levels in ambient air for majority of the sites, elevating their significance as POPs of priority to the region. Among all the pesticides, DDTs, endosulphan I, HCHs, Dieldrin, pentachlorobenzene and hexachlorobenzene recorded the highest levels in ambient air.

III) The high presence of pesticides in ambient air could be attributed to the past widespread use of these compounds in agriculture and public health vector control in the region. In addition emissions from contaminated soils and stockpiles could be potentials sources of the high levels of pesticides in ambient air.

IV) Industrial POPs concentration in ambient air were dominated by PCBs and PFOS. Among the indicator PCBs were relatively higher than the dioxin like PCBs, PFOS dominated over PFOA and PFHxS concentrations.

V) Dioxins and furans were detected at relatively higher frequency but lower concentrations in most of the sites suggesting persistent sources of emissions into the ambient air. These could

be attributed to biomass burning and emissions from municipal, industrial and medical wastes that need to be managed in environmentally sound manner.

VI) PBDEs were widely detected in all sites but at relatively lower concentrations. BDE 209, 100, 99 and 47 dominated the levels of BDEs measured in ambient air. High prevalence of BDEs in all sites could project to potential future significance of these emerging environmental pollutants.

B) POPs levels in mothers' milk

I) A risk assessment PCDDs, PCDFs and PCBs levels in mothers' milk samples from the region showed that the levels were significantly above those considered toxicologically safe, while **Σ**DDTs were below or around those considered safe for majority of the countries that participated in mothers' milk survey in the region. However, the health benefits of breastfeeding are far above the health risks of POPs in mothers' milk, hence WHO and other bodies involved in developing the safety standards encourage breastfeeding, while measures to reduce POPs burden are instituted in the countries.

II) POPs levels in mothers' milk were dominated by pesticides particularly DDTs and their metabolites, then PFOS & PFOA, SCCPs, PCBs, PCDDs/Fs and PBDEs.

III) Among the pesticides DDT congeners and metabolites registered the highest concentrations followed by heptachlor, chlordane, dieldrin, *beta*-HCH, endosulphan sulphate and *cis*-heptachlor epoxide. The highest levels of DDTs were register in the second phase of GMP, whereas declining levels were recorded in the third phase.

IV) Industrial POPs in mothers' milk were dominated by PFOS & PFOA, SCCPs and PCBs. Indicator PCBs had relatively higher concentrations in mothers' milk compared to dioxin like PCBs.

V) PBDEs levels were detected at relatively lower concentrations than the other industrial POPs, with PCB 189, 47 and 153 dominating the concentrations of PBDEs recorded in the samples.

VI) PCDDs and PCDF registered generally lower concentrations than all the other POPs in mothers' milk samples. However, these compounds were widely present in all mothers' milk samples indicating persistent sources of contamination in the region. PCDDs/Fs levels were dominated by PCDDs over the PCDFs.

C) POPs levels in water samples

PFAS compounds were the only POPs monitored in water samples, based on the GMP guidelines. The Concentration of PFAS in water were dominated by PFOS, PFOA, and PFHxS.

D) POPs levels in other media (*space holder*)

Other media were dominated by POPs pesticides and PCBs and low levels of dioxins and furans, PBDEs.

6.2 Summary of evidence of temporal trends

6.2.1 Summary trends of POPs levels in ambient air

Initial trends have begun to emerge for POPs levels in ambient air for sites that have been in existence for over 10 years. For pesticides, compounds that registered at least 5% decline in

levels include aldrin, endrin, oxychlordane, heptachlor, *p,p'*-DDD, endosulphan I, and gamma-HCH.

PCBs recorded much lower decline with only PCB congeners 28, 138, and 153 recording 2.08% decline in levels. Dioxin like PCBs that have started to decline include PCB 105, 118, and 156 with 1.44-4.17 % decline. Only two PCDDs and five PCDFs showed emerging declining trends with percent reduction between 2.63 -7.89%.

PBDEs recorded percent decline between 0-3.45% for the congers 28, 47, 99, 100, and 154, while no declining trends were established for BDE 17, 153 and 175/183. PFAS compounds did not show any significant trends in the levels registered in the regional ambient air.

Summary of temporal trends in POPs levels at selected sites

Trends in POPs levels have started to emerge for regional sites with over 10 years of monitoring data, under MONET_Africa programme (White et al., 2020). Figure 6.2.1 summarises the key sites where trends have started to emerge. The key groups of POPs with initial declining trends emerging include the sum 6 PCBs, sum 4 HCHs, sum 3 endosulphans and sum 6 DDTs, while no significant decline or increasing trends were observed for sum 17 PCDDs/Fs and Sum 9 PBDEs.

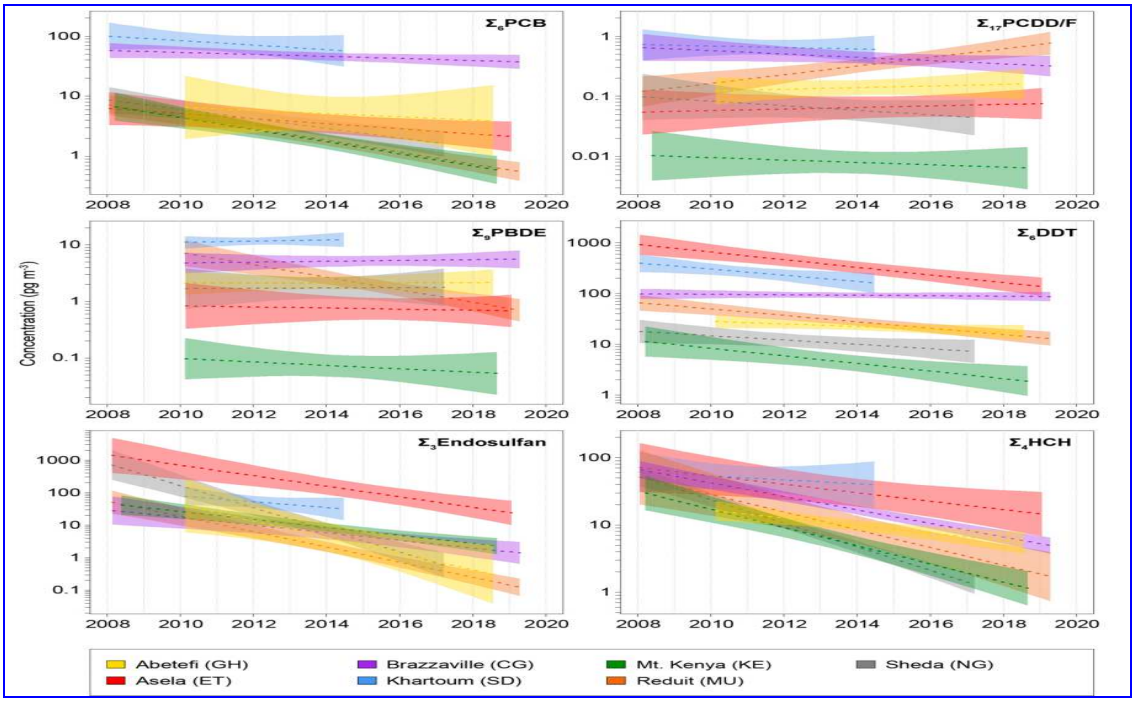


Figure 6.2.1 Overview of selected site trends for key POPs in Africa Region (Adapted from White et al., 2020)

6.2.2 Summary trends of POPs levels in mothers' milk

There were no emerging trends in POPs levels detected in the mothers' milk samples collected from the region for the period 2002-2019. This was partly attributed to lack of adequate datasets to allow trend analysis. The regional countries have participated in a maximum of two mothers' milk survey cycles that amount to two data points per country per POP compound which is insufficient for trend analysis. In addition, 7/19 countries that participated in the mothers' milk

survey had only concluded their first cycle of the survey. Figures 6.2.2-10 illustrate the summary of POPs trend for each compound monitored in ambient air, mothers' milk and water.

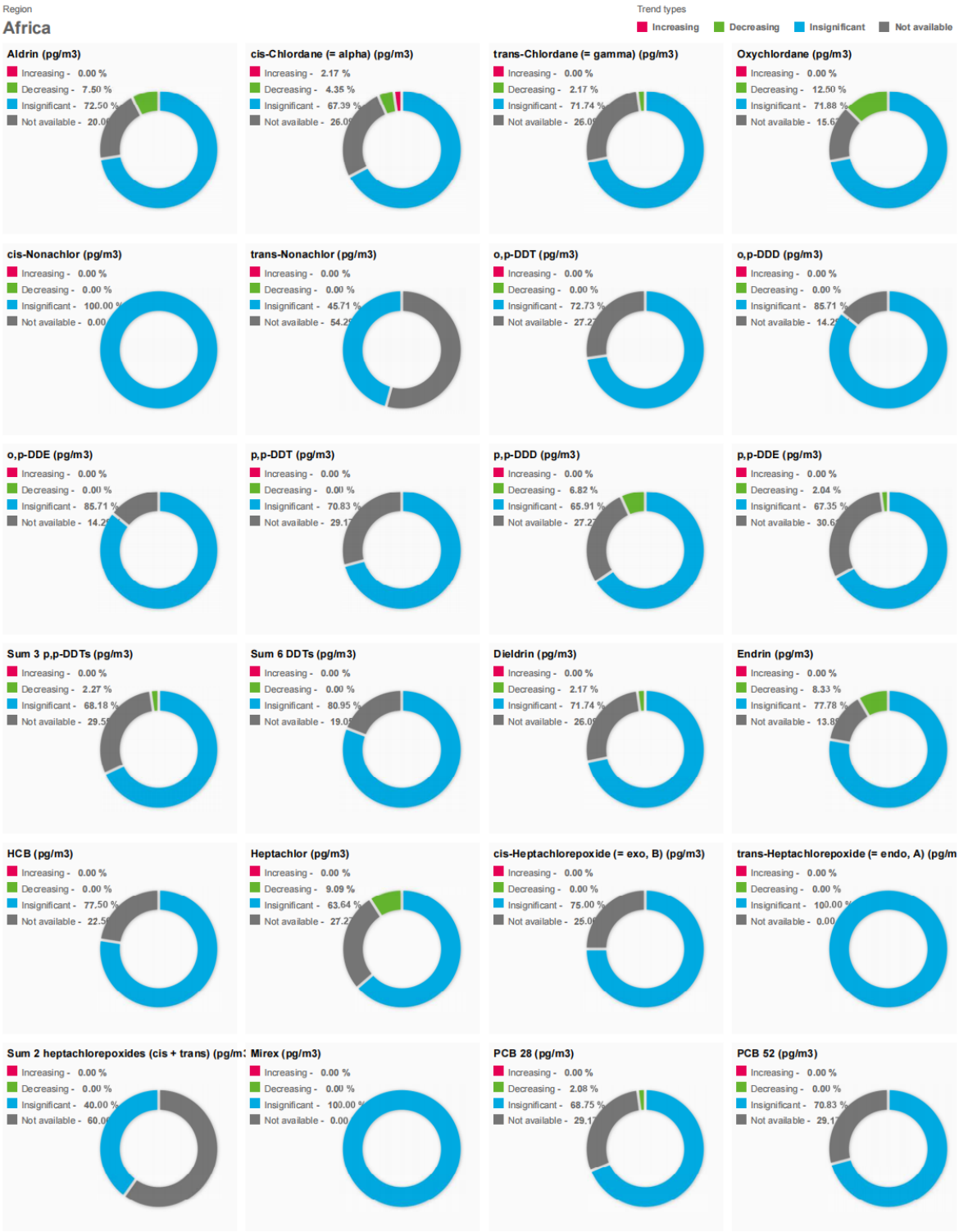


Figure 6.2.2 Trend summary for POPs pesticide levels in ambient air

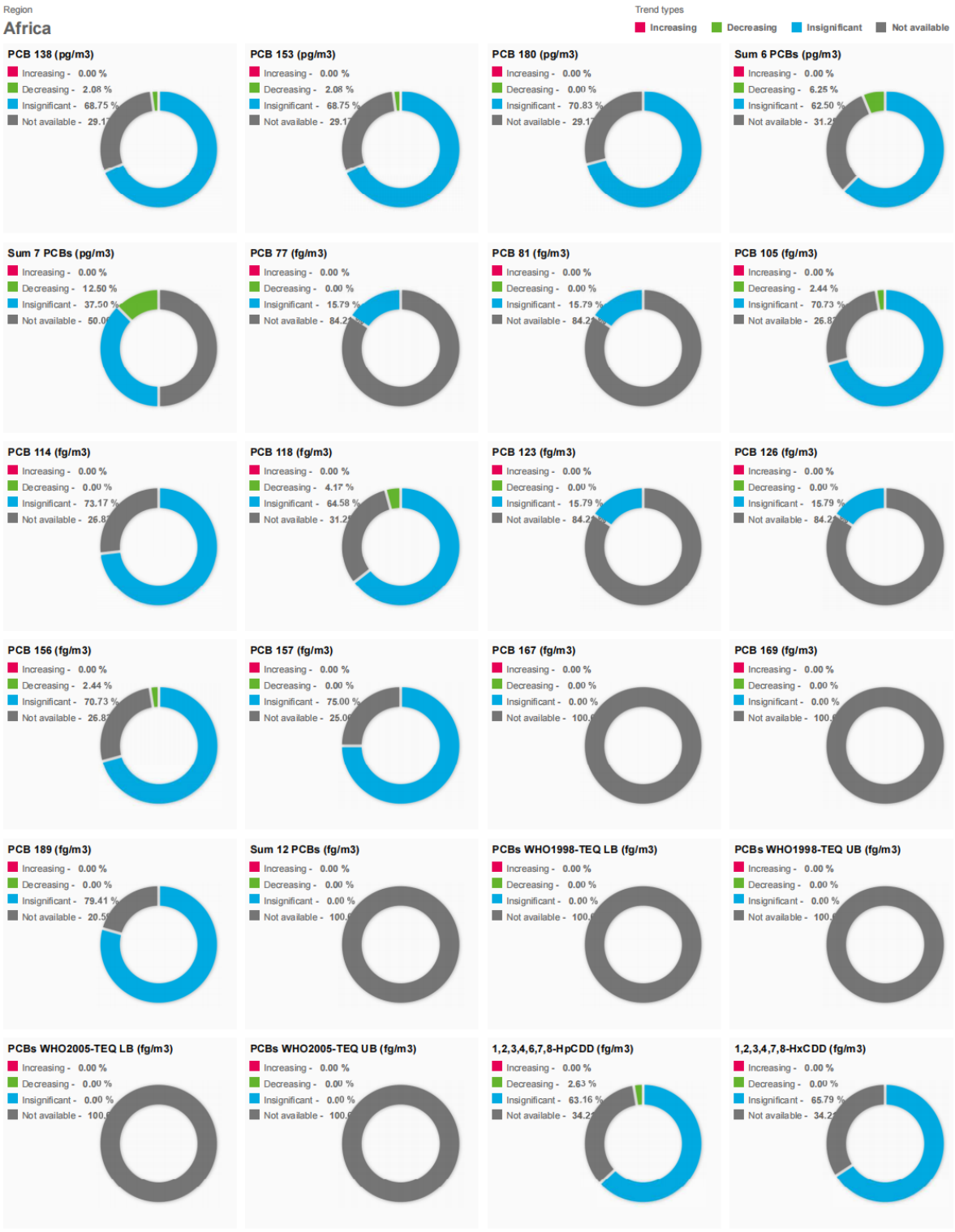


Figure 6.2.3 Trend summary for POPs pesticide levels in ambient air

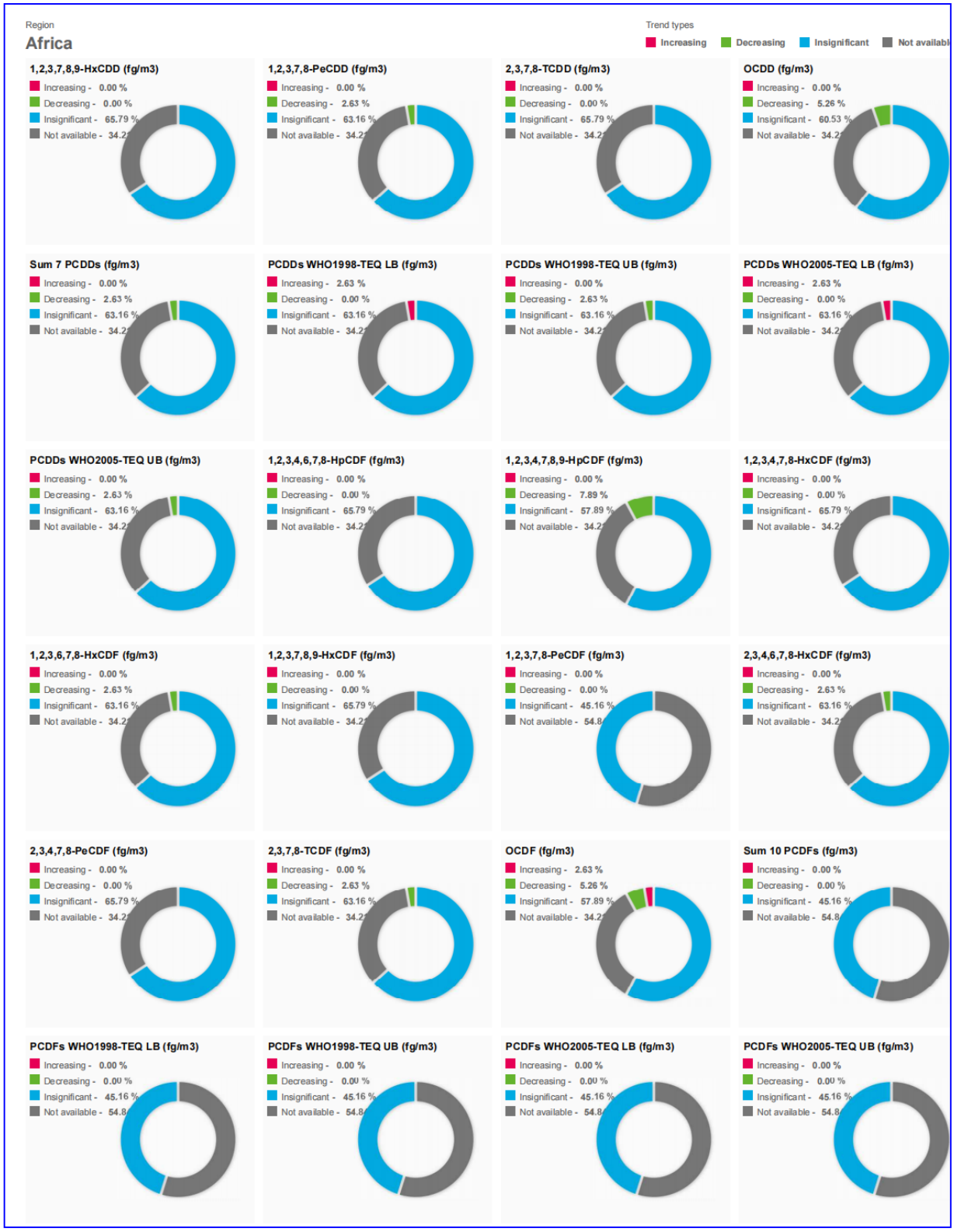


Figure 6.2.4 Trend summary for POPs pesticide levels in ambient air

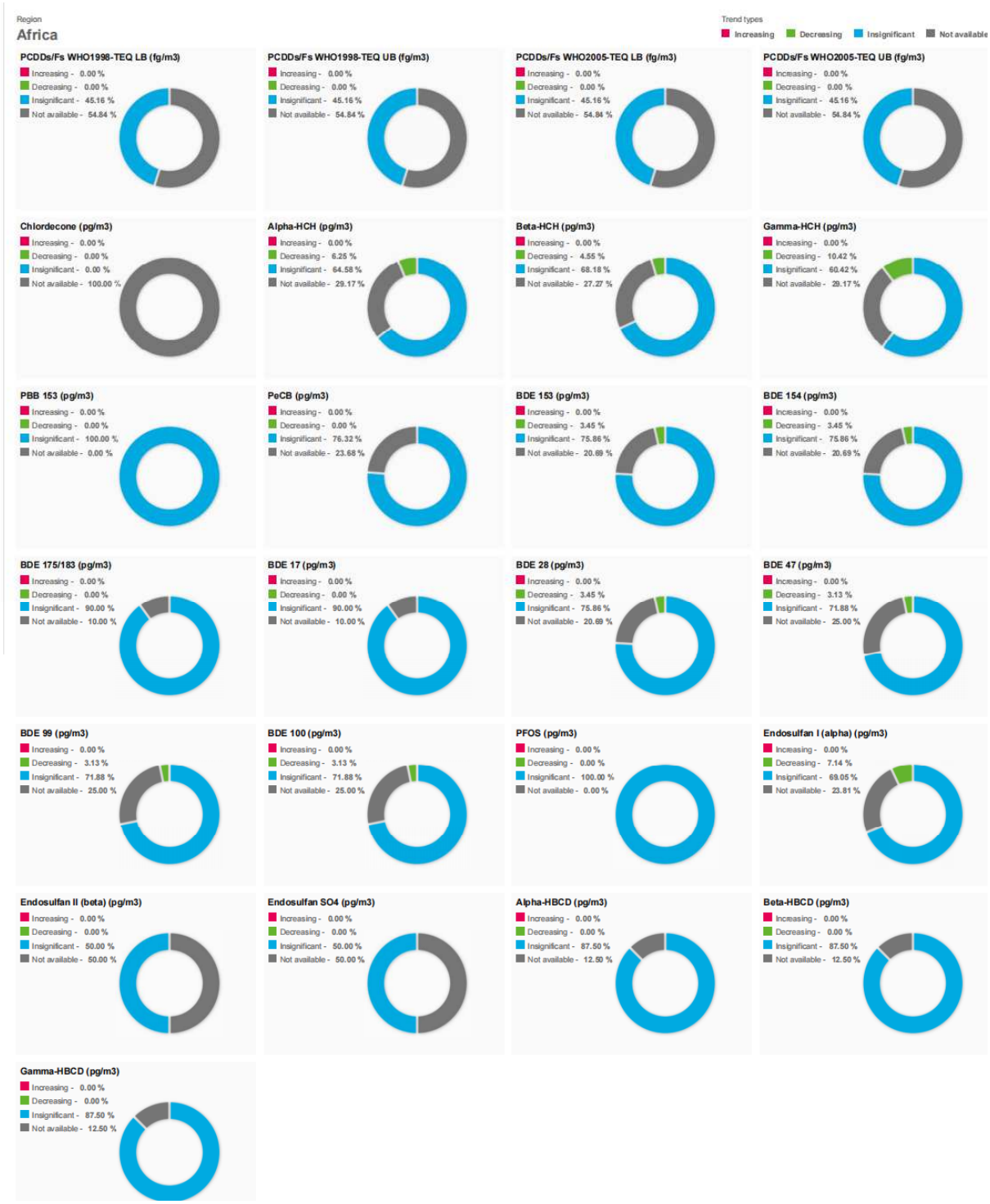


Figure 6.2.5 Trend summary for POPs levels in ambient air

Trend summary in POPs levels in mothers' milk samples

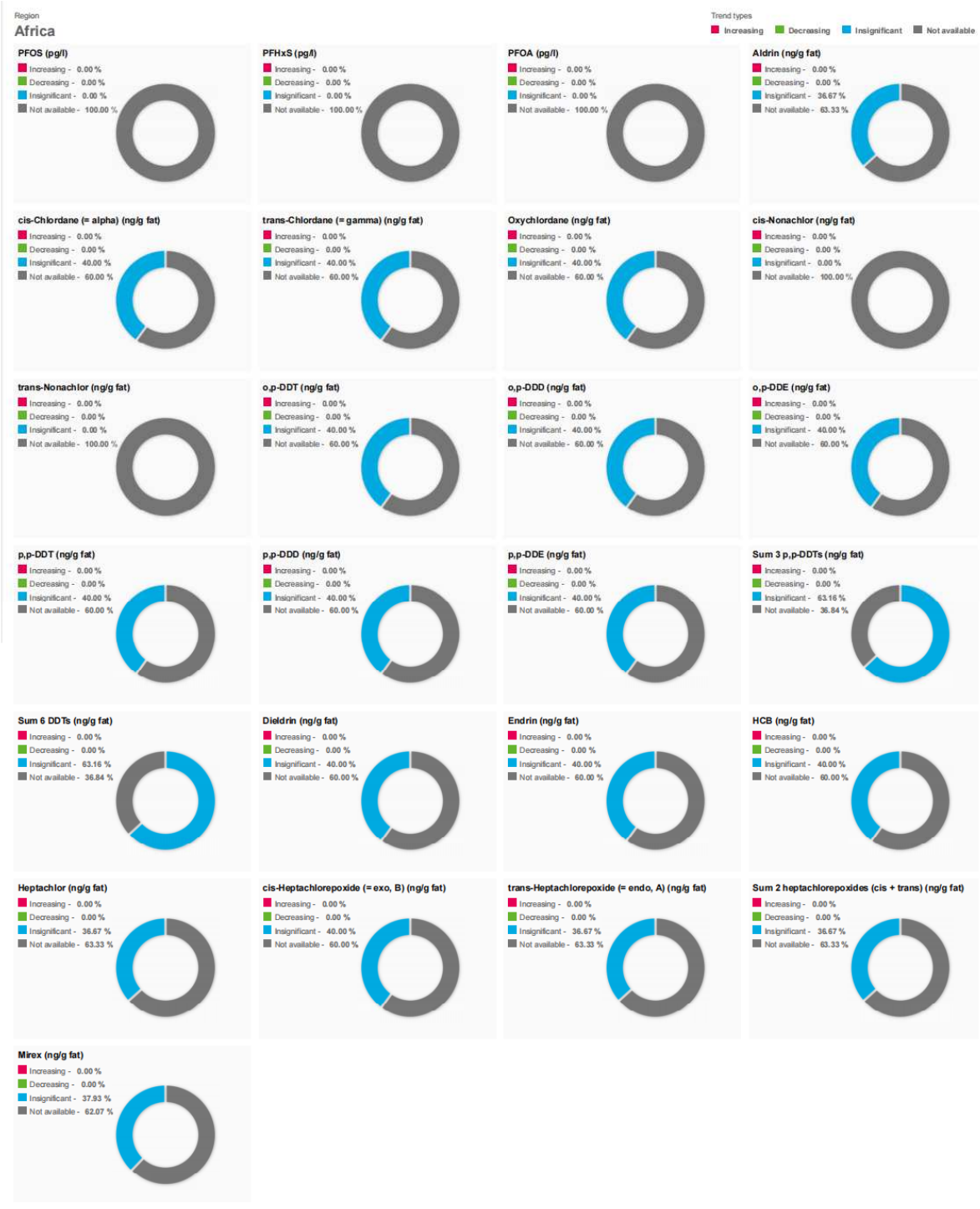


Figure 6.2.6 Trend summary for POPs pesticide levels in mothers' milk

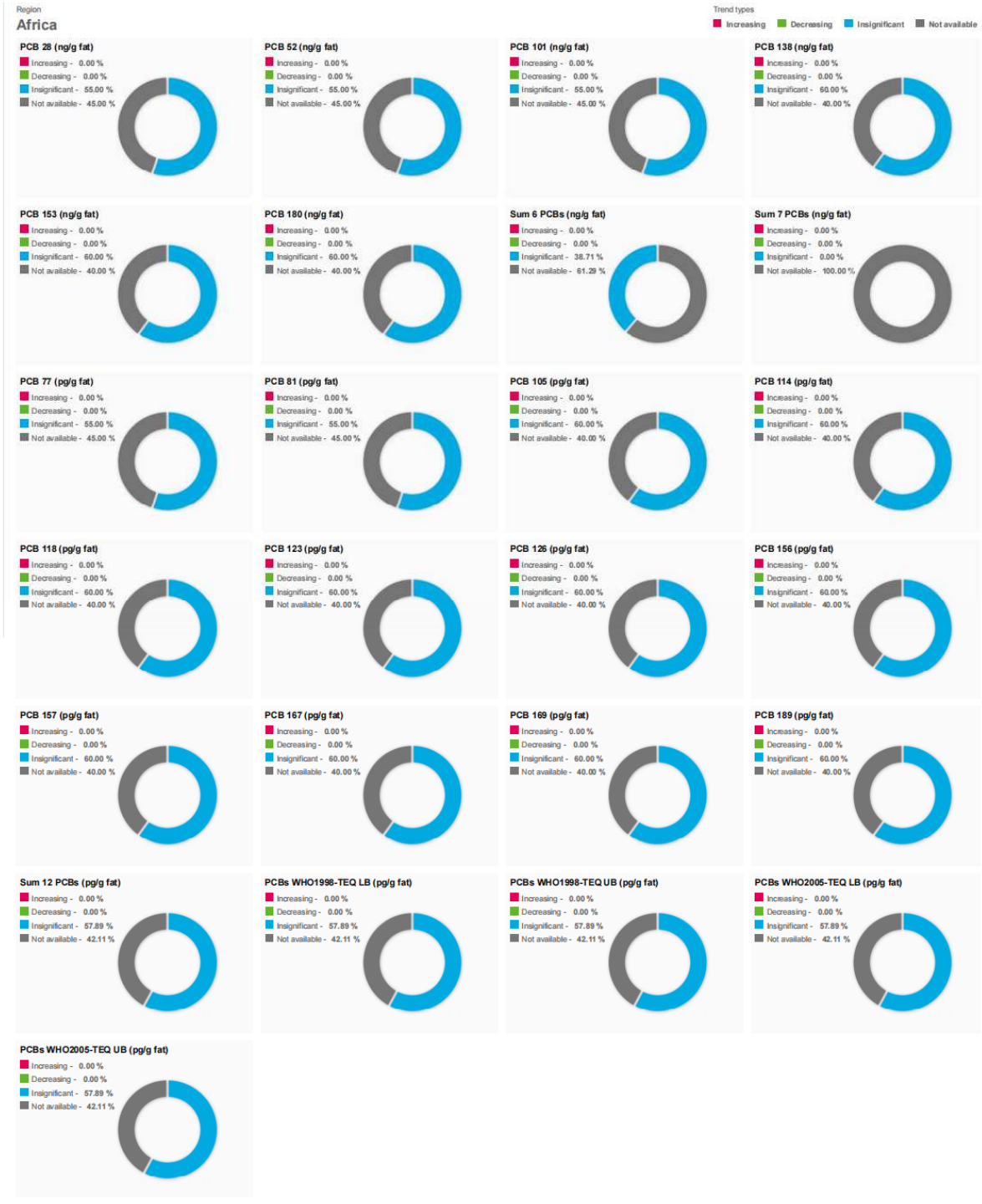


Figure 6.2.7 Trend summary for POPs pesticide levels in mothers' milk

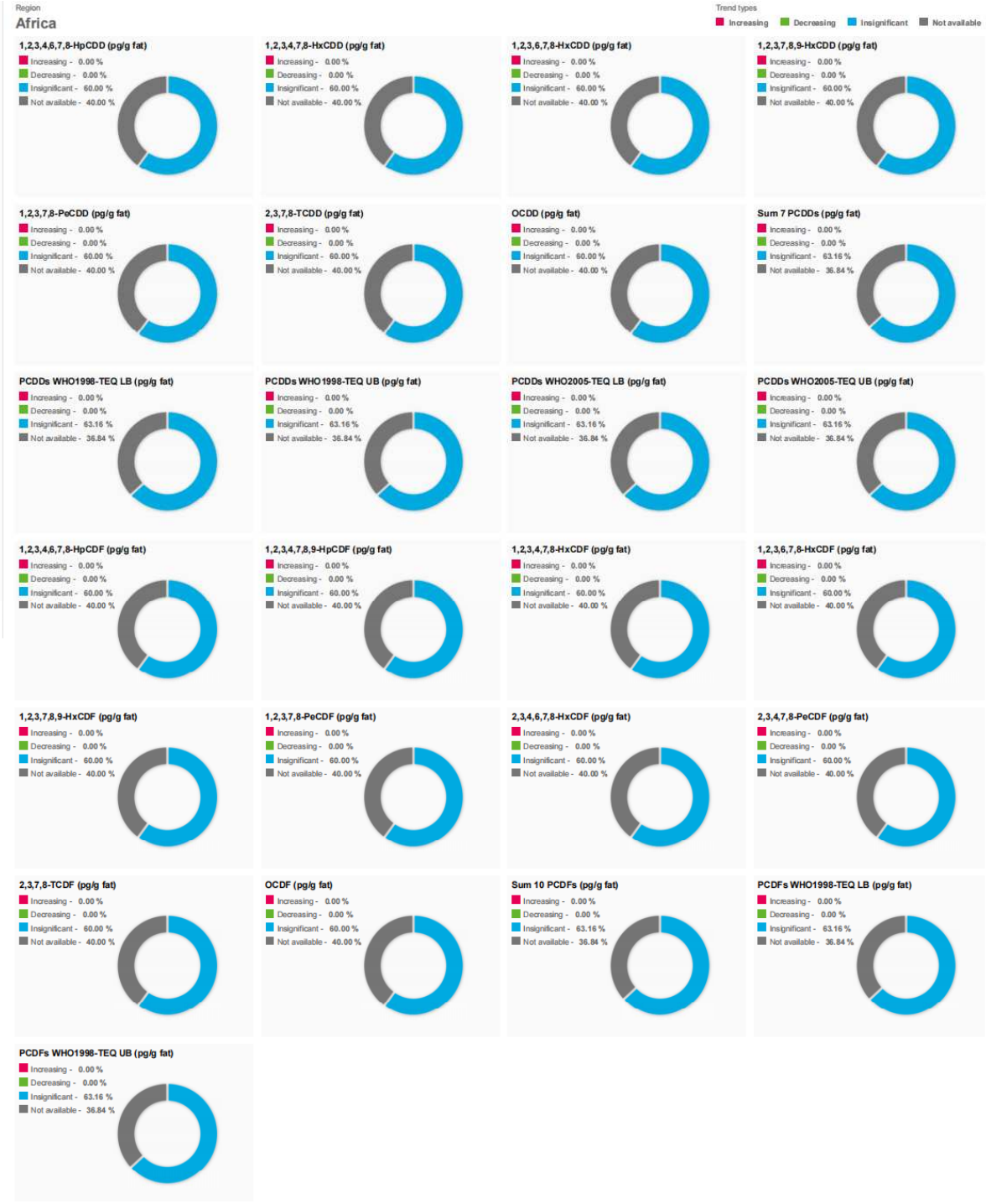


Figure 6.2.8 Trend summary for POPs pesticide levels in mothers' milk

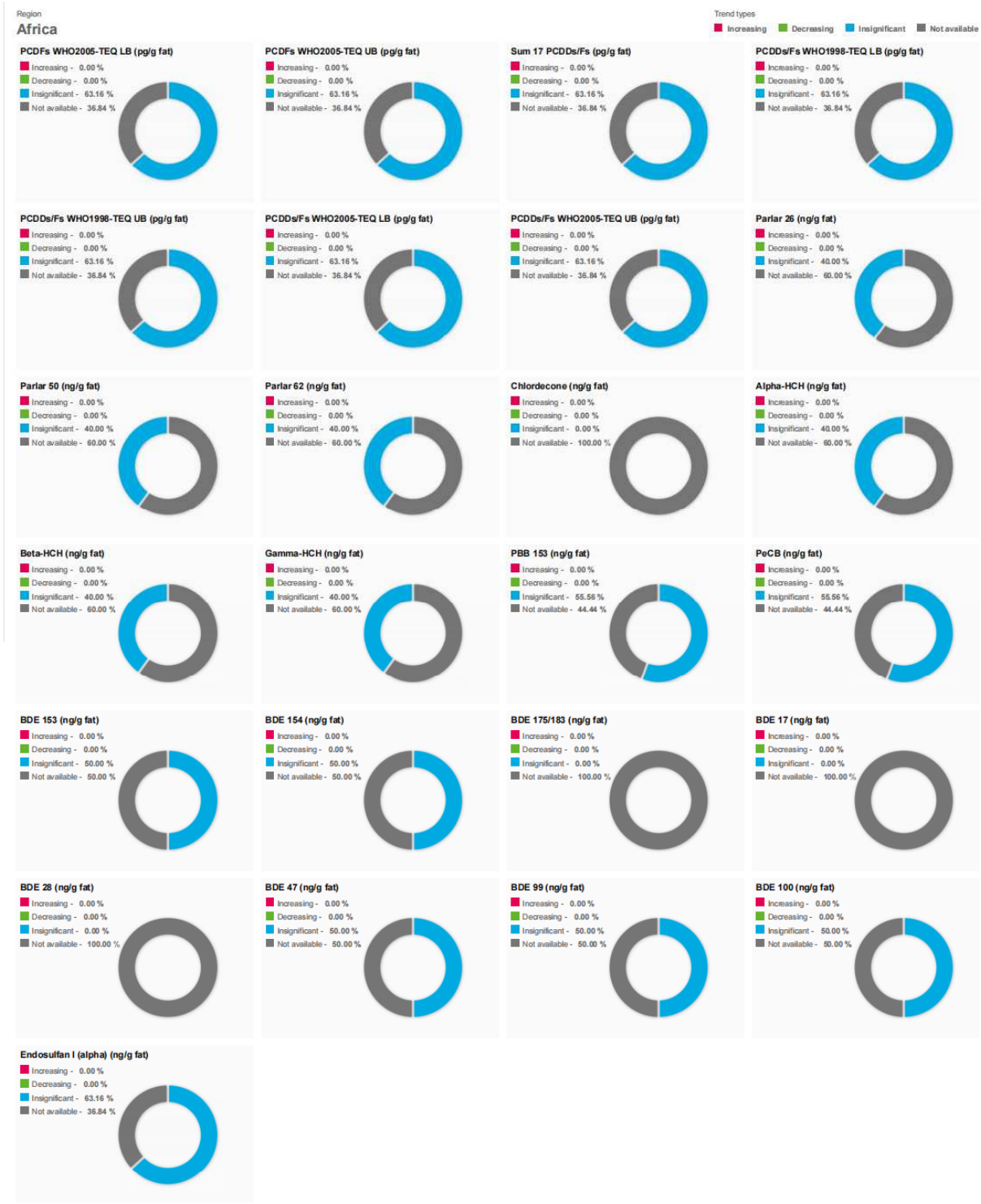


Figure 6.2.9 Trend summary for POPs levels in mothers' milk

6.2.3 Summary trends of POPs levels in water

No trends were established in POPs levels in water due to inadequate monitoring data for trends analysis. Continuation of water monitoring at the established sites is necessary to establish trends in POPs levels in the region.

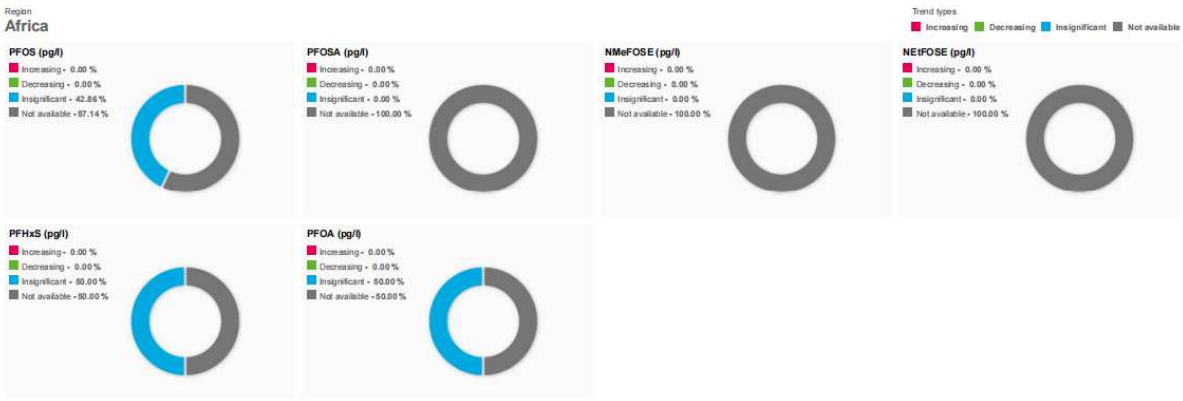


Figure 6.2.10 Trend summary for POPs pesticide levels in mothers' milk

6.3 Summary of evidence of long-range transport

The initial analysis of back trajectories were presented in the first and second regional reports that revealed influenced by climatological factors on POPs transport (UNEP, 2009 & 2015b).

Recent detailed regional long-range transport of POPs levels in the ambient air has been published by White et al. (2020) and revealed a mixed scenario of sources affecting the POPs levels at different sites. Figure 6.3.1 summarises the density heat map of 120-h back-trajectories for each MONET_Africa site in Africa modelled every 3 h for 365 days (January− December 2018) using HYSPLIT (v.4.2.0, NOAA). Mt. Kenya and Reduit sites recorded the lowest POPs concentrations. Mt Kenya site mainly received air flows from either the NE or SE along the coast of East Africa and across the Indian Ocean year-round suggesting long range transport as a major source of POPs at the site. Reduit mainly received air flows arriving the Southern Ocean and no other major land masses year-round. From the modeled air masses Bamako and Khartoum covered the largest geographic areas of continental Africa and are likely influenced by multiple sources, both local and abroad, and the impact of the Sarahan dust. Brazzaville recorded the highest atmospheric levels of most POPs, with minimal changes as well as temporal trends indicating significant active local emissions. Agbogbloshie e-waste recycling is one of the most significant point sources of POPs and its effect on atmospheric POP emissions is expected to be primarily carried northeast across the rest of Accra year-round, but and also affect POPs levels at Abetefi, through the air masses received in the period November −January.

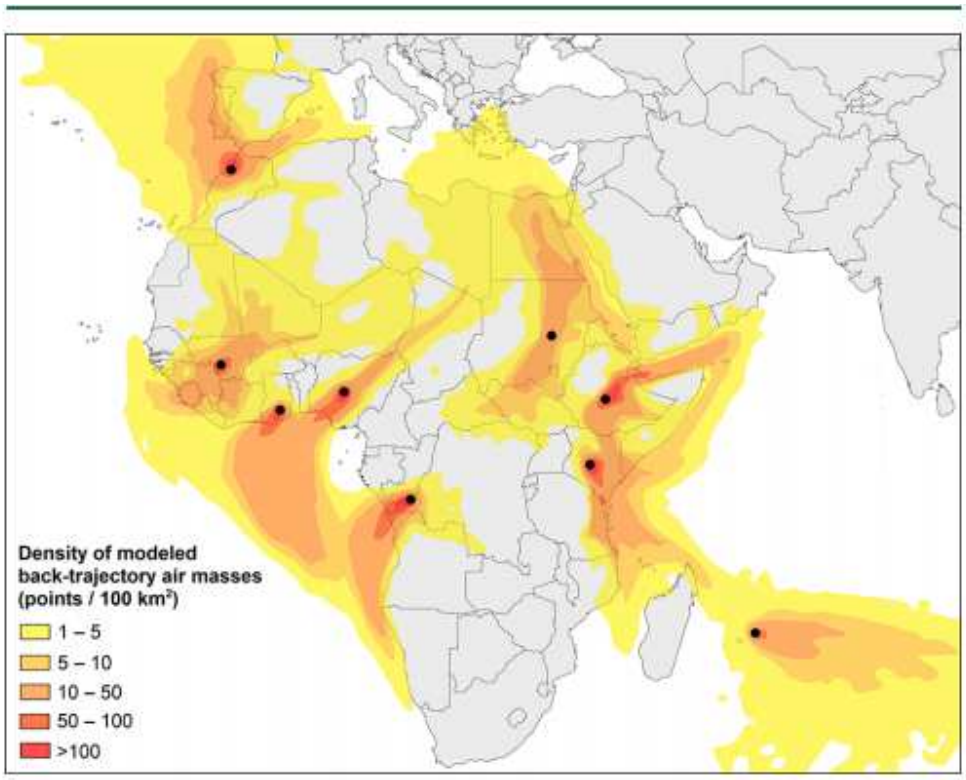


Figure 6.3.1 Density heat map from back trajectory analysis of POPs in ambient air for MONET Africa sites (adapted from White et al., 2020).

6.4 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 gaps in data coverage and the resources needed to overcome the gaps

The third regional report received increased coverage of POPs monitoring sites in the region due to additional sites established under the UNEP/GEF GMP2 project, reducing the data gaps in ambient air that were encountered in the second report.

Coverage of air sampling is moderately distributed across the sub-regions, however, there has been lack of consistence in some years as well as discontinuities of some initial sites, particularly in the Southern Africa sub-region.

The GAPS progrogramme has had discontinuities in majority of the sites in the region that include Abono (Ghaana), Lilongwe (Malawi), Cairo (Egypt), Kalahari, Molopo, Baberspan, Nooitgedacht (South Africa) which is likely to create a big data gap in the future monitoring phases.

UNEP GEF GMP projects data are for the period 2017-2018 and 2011-2012, with data gaps experienced for the period 2013-2016. From the end UNEP/GEF GMP2 project in 2020, there are uncertainties in continuation of the monitoring at the established sites due to discontinuities in supplies for PUF disks until another UNEP/GEF project is developed and implemented or intermediate arrangements are put in place. The summary below shows data coverage, consistency and gaps, and duration of POPs monitoring activities in air per site (Figures 6.3.1).

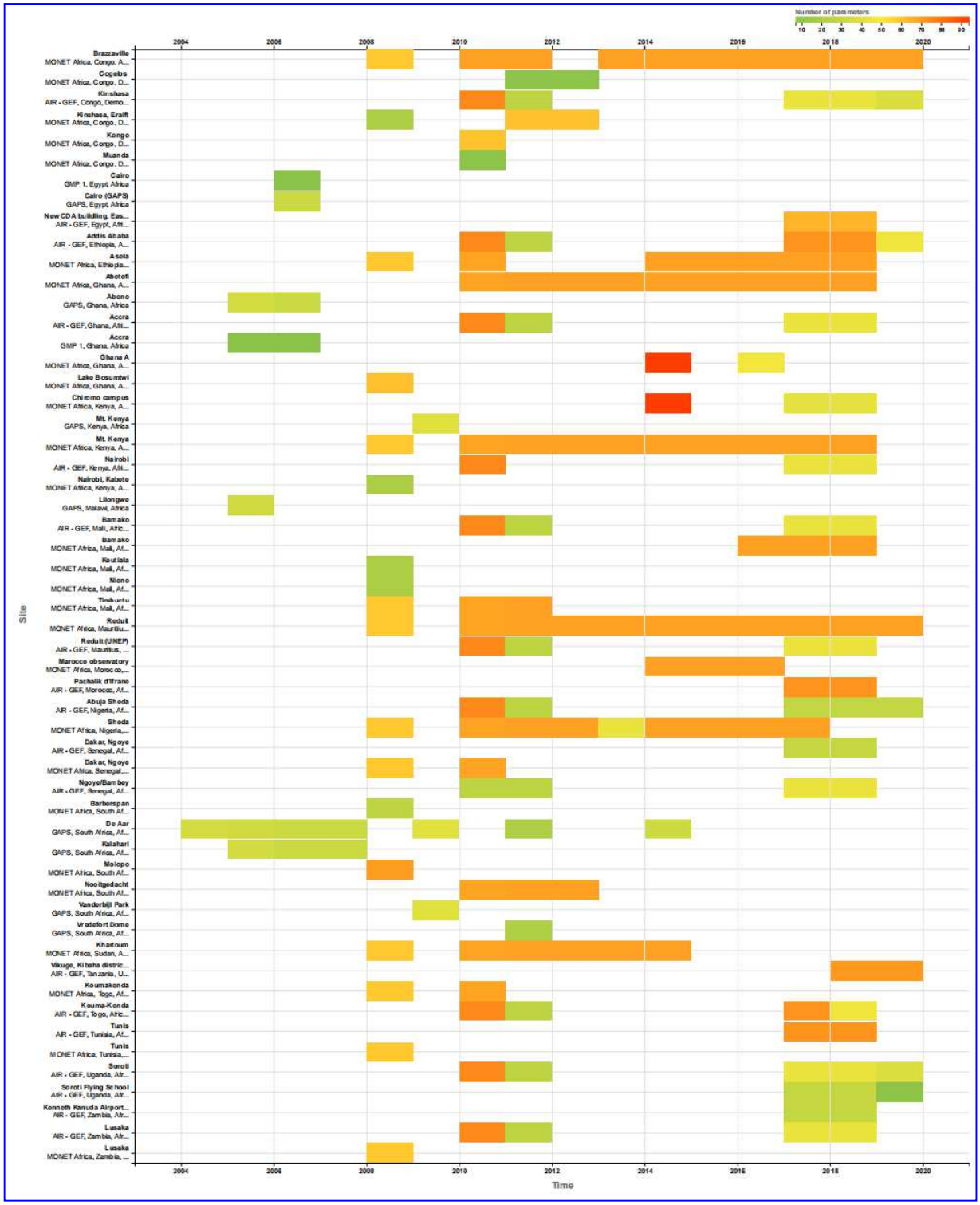


Figure 6.3.1 Available data and data gaps in air monitoring

ii) Mothers' milk gaps in data coverage and the resources needed to overcome the gaps

Mothers' milk survey are dependent on the cooperation between WHO, the SC secretariat and UNEP/Chemicals, and availability of funding from GEF. Up to date only two mothers' milk survey have been conducted in the region, with 7/19 having participated only in a single survey. The mothers' milk monitoring data collected so far are not adequate for analysis of trends in POPs levels, hence further financial support and cooperation of the strategic partners is necessary to ensure continuity in monitoring of POPs in mothers' milk. The sampling period for mothers' milk survey per country is illustrated below (Figure 6.3.2).

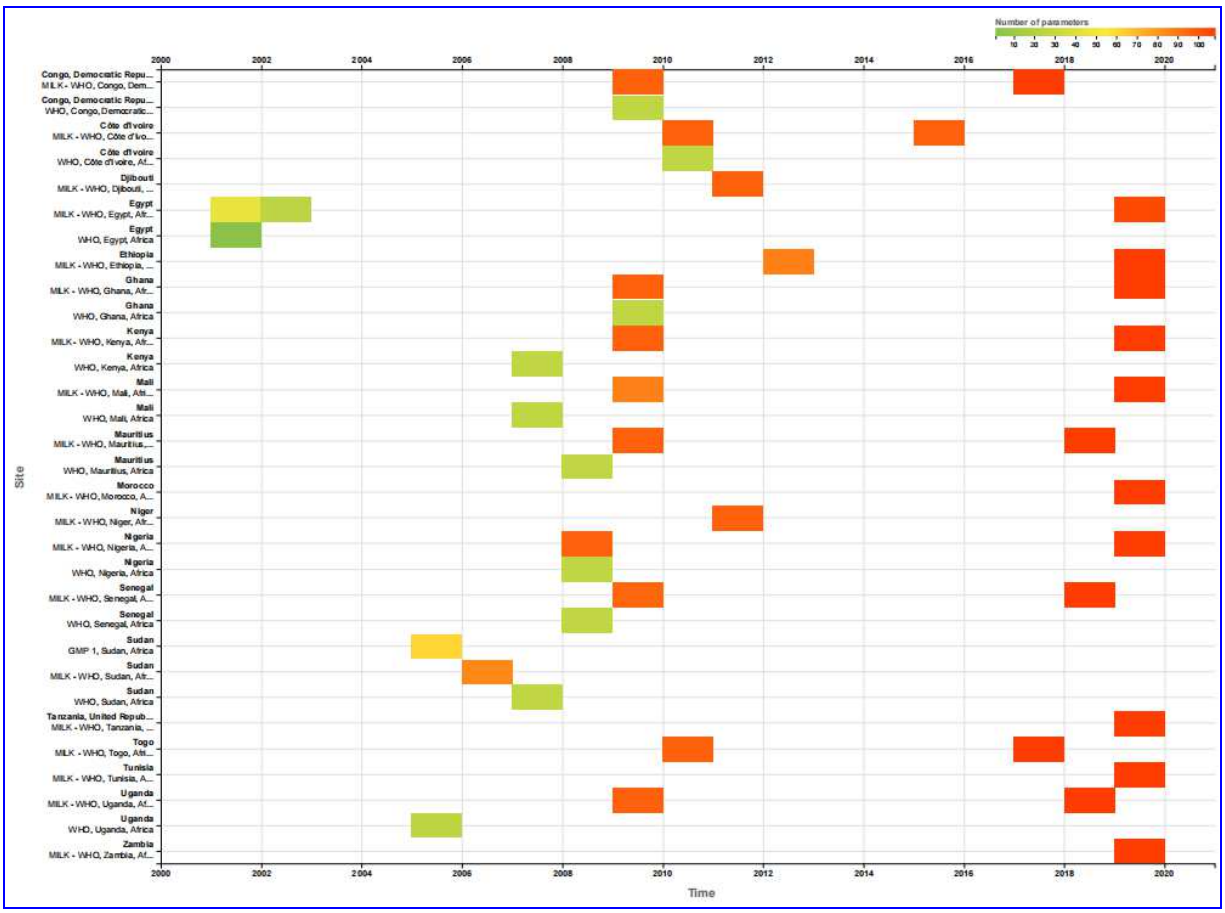


Figure 6.3.2 Available monitoring data and data gaps in mothers milk monitoring

iii) Water gaps in data coverage and the resources needed to overcome the gaps

Consistent water monitoring was effected under UNEP/GEF GMP2 project 2016-2020 that covered a two year period 2017-2018 of POPs monitoring in water. Additional data were collected through pilot studies in 2013/2014 under GPM phase two activities. Continuation of water monitoring at established sites should be highly encouraged to build on existing data and allow establishment of trends of POPs levels in water in the future evaluations. Adequate financial resources will be needed to support field sample collection from far remote sites and analysis costs. Water sampling periods per sites are summarized in the Figure below.

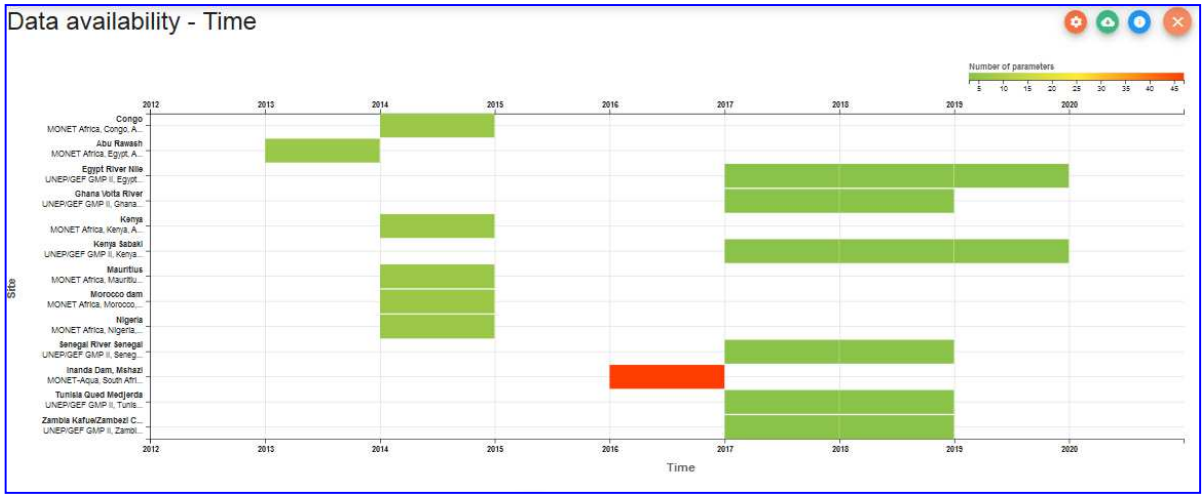


Figure 6.3.3 Available monitoring data and data gaps in water monitoring

6.5 Summary of ongoing programs/activities

In the first, the second and the third phases of GMP, the Africa ROGs collaborated with several strategic partners to enable effective implementation of monitoring activities. These included: RECETOX (Czech Republic) coordinating MONET_Africa programme; Global Atmospheric Passive Sampling (GAPS) programme coordinated by Environment Canada for ambient air data; The World Health Organization (WHO) for provision of mothers' milk data, and UNEP Chemicals and the GEF supporting implementation of the GMP 2 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 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

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.

Further, countries participated in international inter-laboratory calibration exercises to evaluate their performance in POPs analysis. Future exercises will continue to improve the analytical performance of the laboratories.

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 followed the WHO protocol. Majority of the participating countries have conducted the second mothers' milk survey. Further support is necessary to ensure subsequent mothers' milk surveys to establish trends in POPs levels and contribute effectively to the effectiveness evaluation of the Convention.

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.

6.6 Comment on the adequacy of monitoring arrangements for the purpose of effectiveness evaluation

Continuity and effectiveness of monitoring activities in the region are dependent on adequacy of human, technical and financial resources to support monitoring activities.

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, PFOS, SCCPs and PCNs 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, PCBs and PBDEs. However, the high resolution equipment such as HRGC/MS and HRLC/MS are necessary for analysis of complex POPs such as PCDDs, PCDFs, PFOS, SCCPs and PCNs are lacking.

Laboratories must continuously participate in inter-calibration/proficiency studies under the to evaluate the competencies in analysis of POPs in the core media namely ambient air, mothers' milk and water, as well as other media such as soil and sediments, which established the need for further capacity building.

iii) Financial resources

Financial resources to support continuous POPs monitoring is critical to enable field sample collection and analysis for ambient air, mothers' milk and water. Monitoring activities require heavy investment of financials resources to ensure robust analytical capacities and highly trained personnel to provide high quality data that will guide policy decisions.

6.7 Recommendations for the future

i) 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.

ii) POPs activities could be included under the national/regional activities to implement the 2008 Libreville Declaration on Health and environment strategic Alliance (HESA). The recommendations of the report can be taken up by the Africa Union Sub-Committee on Environmental Issues which was operationalized in 2018.

6.7.1 Recommendations from POPs baseline levels

6.7.1.1 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 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. 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.

iv) The presence of new industrial POPs such as PBDEs, 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.

vi) Some newly listed POPs such as SCCPs, PCNs have not yet included in the monitoring programmes due to lack of methodologies hence resources are required for method development and incorporation into monitoring activities.

6.7.1.2 POPs in mothers' milk

i) Several POPs including Pesticides, PCBs, PBDEs, PFOS and SCCPs 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.

ii) There is need to delineate and prioritize key exposure pathways for POPs in the region and implement mitigation measures to reduce and eliminate POPs exposure to human and environment.

6.7.1.3 POPs in water

i) The results of water monitoring in regional major rivers and estuaries showed PFOS and salts, and PFOS related compounds and their salts in water from background sites underpinning the potential threat of exposure to human. Stringent regulations for water and wastewater should be developed to control releases of industrial POPs into water systems.

ii) 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.

6.7.1.4 POPs in other media

Comparable sampling and analytical methods should be applied in monitoring other media to allow comparisons across the region.
In addition, national priority sites such as dumpsites, industrial, obsolete dumpsites and residential areas could be targeted to assess the effectiveness of the measures put in place to eliminate POPs releases in the environment.

Priority foods stuffs should be analysed to evaluate the potentials critical pathways leading to POPs levels in mothers' milk samples.

6.7.2 Recommendations from evidence of temporal trends

Baseline data have been established for ambient air and initial trends have stated to emerge for a few POPs compounds. Continuation of air monitoring is recommended to provide sufficient data for evaluation of temporal changes in POPs levels 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 from the first, the second and the third GMP phases, but the existing data are still 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 baseline data for PFOS and salts in water from background sites have been established for first time in the region. Further monitoring activities are needed to provide sufficient data for analysis of temporal trends in concentrations.

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 and application of harmonised protocols to allow evaluation of temporal trends.

6.7.3 Summary of evidence of long-range transport

Monitoring data have revealed POPs contamination of ambient air from remote sites, 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 of POPs in the region.

Further, the existing data for several sites 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.

6.7.4 Recommendations on data coverage and gaps

i) Air data coverage

Representative 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.

iii) Water data

Water has been collected under the UNEP/GEF GMP1 &2 projects and MONET Africa pilot study (six countries) that have allowed development of baseline data across all the sub-regions. Whereas the existing data represent indicative baseline for PFOS in water, there is need for continued monitoring of POPs at established sites to allow establishment temporal trends of POPs levels in water.

iv) Coverage for other media

Data for other media were obtained from countries that participated in the UNEP/GEF GMP2 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 application of the protocols developed in the GMP3 phase and repeat of similar matrices to allow comparison of temporal trends in POPs levels in other media.

6.7.5 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:

i) training in sample collection and preservation procedures for all POPs including new POPs in the core media and other media;

ii) training in sample preparation and analysis for all POPs including new POPs in the core media and other media;

iii) training in data interpretation and reporting following the established GMP standards;

iv) quality assurance and quality control protocols for POPs analysis in according to GMP guidelines; and

v) 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, PFOS, SCCPs and PCNs. There is need for further capacity building to:

i) establish dedicated regional laboratories with necessary high resolution equipment for analysis of all POPs compounds;
ii) 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;
iii) involve national laboratories in regional programmes (e.g. proficiency testing and upgrading of laboratories);
iv) promote regional data sharing and storage capacities;
v) support sample banking for future evaluations;
vi) strengthen communication among the regional organization groups and focal points.

6.7.6 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:

i) Support continuation of established air monitoring programmes such as MONET Africa, GAPS and UNEP/GEF established sites in the region;
ii) Facilitate the parties to participate in the subsequent rounds of WHO mother's milk surveys;
iii) Support continuation of established water monitoring sites to provide data for PFOS and other polar POPs in water according to GMP guidance;
iv) Provide resources for POPs monitoring activities in other media in the region as foreseen in GMP guidance and the NIPs;
v) Include newly listed POPs in ongoing monitoring programmes to ensure continuity in data production;
vi) Support data storage and sample banking for retrospective analyses of new POPs and future verification of the data.

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APPENDIX

Appendix Table A.1 List of sampling sites for air, water and mothers' milk

Name	site.nameOriginal	Latitude	Longitude	Region	Country	Site type	Potential source	Sea	Data source	Water type	Monitoring network	Matrix	Created	Updated
Federal Ministry of Environment, Brown Building, 432 Abuja,		9.038667	7.46725	Africa	Nigeria	Urban			GMP3		UNEP/GEF GMP II	Air	9. 2. 2021 06:01.03	9. 2. 2021 06:01.03
Kouma-Konda		6.95	0.583333	Africa	Togo	Rural			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Kenneth Kanuda Airport, Lusaka		-15.32585	28.44723	Africa	Zambia	Rural			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Soroti Flying School		1.720833	33.616666666667	Africa	Uganda	Rural			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Tunis		36.836638888889	10.211388888889	Africa	Tunisia	Urban			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Vikuge, Kibaha district		-6.7883333333333	38.863333333333	Africa	Tanzania, United Republic of	Rural			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Dakar, Ngoye		14.635	-16.429722222222	Africa	Senegal	Rural			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Vacoas-Phoenix, Mauritius		-20.29717	57.4983	Africa	Mauritius	Rural			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Pachalik d'Ifrane		33.526783	-5.107577	Africa	Morocco	Rural			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Bamako		12.6589	-7.9422	Africa	Mali	Urban			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Nairobi, Kabete		-1.2494444444444	36.7425	Africa	Kenya	Urban			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Accra		5.65	-0.16666666666667	Africa	Ghana	Urban			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Addis Ababa		9.0184236944444	38.818540138889	Africa	Ethiopia	Urban			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
New CDA buildling, Eastern Cairo		29.993438888889	31.585258333333	Africa	Egypt	Rural			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Kinshasa		-4.35	15.283333333333	Africa	Congo, Democratic Republic of	Urban			GMP3		UNEP/GEF GMP II	Air	29. 1. 2021 09:06.46	29. 1. 2021 09:06.46
Kouma-Konda		6.95	0.583333	Africa	Togo	Rural			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.44	18. 1. 2021 11:49.44
Kenneth Kanuda Airport, Lusaka		-15.32585	28.44723	Africa	Zambia	Rural			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.44	18. 1. 2021 11:49.44
Soroti Flying School		1.720833	33.616666666667	Africa	Uganda	Rural			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.44	18. 1. 2021 11:49.44
Tunis		36.836638888889	10.211388888889	Africa	Tunisia	Urban			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.44	18. 1. 2021 11:49.44
Vikuge, Kibaha district		-6.7883333333333	38.863333333333	Africa	Tanzania, United Republic of	Rural			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.44	18. 1. 2021 11:49.44
Dakar, Ngoye		14.635	-16.429722222222	Africa	Senegal	Rural			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.44	18. 1. 2021 11:49.44
Vacoas-Phoenix, Mauritius		-20.29717	57.4983	Africa	Mauritius	Rural			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.44	18. 1. 2021 11:49.44
Pachalik d'Ifrane		33.526783	-5.107577	Africa	Morocco	Rural			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.44	18. 1. 2021 11:49.44
Bamako		12.6589	-7.9422	Africa	Mali	Urban			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.43	18. 1. 2021 11:49.43
Nairobi, Kabete		-1.2494444444444	36.7425	Africa	Kenya	Urban			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.43	18. 1. 2021 11:49.43
Accra		5.65	-0.16666666666667	Africa	Ghana	Urban			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.43	18. 1. 2021 11:49.43
Addis Ababa		9.0184236944444	38.818540138889	Africa	Ethiopia	Urban			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.43	18. 1. 2021 11:49.43
New CDA buildling, Eastern Cairo		29.993438888889	31.585258333333	Africa	Egypt	Rural			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.43	18. 1. 2021 11:49.43
Kinshasa		-4.35	15.283333333333	Africa	Congo, Democratic Republic of	Urban			GMP3		AIR - GEF	Air	18. 1. 2021 11:49.43	18. 1. 2021 11:49.43
Kouma-Konda		6.95	0.583333	Africa	Togo	Rural			GMP3			Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Kenneth Kanuda Airport, Lusaka		-15.32585	28.44723	Africa	Zambia	Rural			GMP3			Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Soroti Flying School		1.720833	33.616666666667	Africa	Uganda	Rural			GMP3			Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Tunis		36.836638888889	10.211388888889	Africa	Tunisia	Urban			GMP3		AIR - GEF	Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Vikuge, Kibaha district		-6.7883333333333	38.863333333333	Africa	Tanzania, United Republic of	Rural			GMP3		AIR - GEF	Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Dakar, Ngoye		14.635	-16.429722222222	Africa	Senegal	Rural			GMP3			Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Vacoas-Phoenix, Mauritius		-20.29717	57.4983	Africa	Mauritius	Rural			GMP3			Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Pachalik d'Ifrane		33.526783	-5.107577	Africa	Morocco	Rural			GMP3		AIR - GEF	Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Bamako		12.6589	-7.9422	Africa	Mali	Urban			GMP3			Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Nairobi, Kabete		-1.2494444444444	36.7425	Africa	Kenya	Urban			GMP3			Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26

Accra		5.65	-0.16666666666667	Africa	Ghana	Urban			GMP3			Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Addis Ababa		9.0184236944444	38.818540138889	Africa	Ethiopia	Urban			GMP3			Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
New CDA buildling, Eastern Cairo		29.993438888889	31.585258333333	Africa	Egypt	Rural			GMP3		AIR - GEF	Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Kinshasa		-4.35	15.283333333333	Africa	Congo, Democratic Republic of	Urban			GMP3			Air	21. 12. 2020 10:42.26	21. 12. 2020 10:42.26
Vanderbijl Park	Vanderbijlpark	-26.775138888889	27.884472222222	Africa	South Africa	Remote	Natural		GMP3		GAPS	Air	27. 3. 2020 20:26.35	27. 3. 2020 20:26.35
Cairo (GAPS)	Cairo	30.140330520603	31.619150005146	Africa	Egypt	Rural	Agricultural		GMP3		GAPS	Air	27. 3. 2020 19:49.00	27. 3. 2020 19:49.00
Abono	Accra	6.532571	-1.430115	Africa	Ghana	Rural	Agricultural		GMP3		GAPS	Air	27. 3. 2020 00:01.00	27. 3. 2020 00:01.00
Ghana A	Ghana A	8.14674	-1.154304	Africa	Ghana				GMP3		MONET Africa	Air	22. 5. 2020 11:11.57	22. 5. 2020 11:11.57
Chiromo campus	Chiromo campus	-1.271917	36.804	Africa	Kenya				GMP3		MONET Africa	Air	22. 5. 2020 11:11.57	22. 5. 2020 11:11.57
Marocco observatory	Marocco observatory	33.925	-6.758	Africa	Morocco				GMP1/2 Primary		MONET Africa	Air	17. 4. 2020 09:50.09	17. 4. 2020 09:50.09
Vredefort Dome	Vredefort Dome	-27.001347561502	27.499682774669	Africa	South Africa	Remote	Natural		GMP3		GAPS	Air	27. 3. 2020 20:36.49	27. 3. 2020 20:36.49
Lilongwe	Lilongwe	-14.183332932132	33.783331681998	Africa	Malawi	Remote	Natural		GMP1/2 Primary		GAPS	Air	10. 3. 2020 00:05.57	27. 3. 2020 00:00.59
De Aar	De Aar	-30.665003484727	23.99300124738	Africa	South Africa	Remote	Natural		GMP1/2 Primary		GAPS	Air	10. 3. 2020 00:05.57	26. 3. 2020 23:42.03
Kalahari	Kalahari	-25.866666960839	22.899999923472	Africa	South Africa	Remote	Natural		GMP1/2 Primary		GAPS	Air	10. 3. 2020 00:05.57	27. 3. 2020 00:00.59
Lusaka	Lusaka	-15.316667	28.45	Africa	Zambia				GMP1/2 Primary		MONET Africa	Air	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Kalahari	Kalahari	-25.866666960839	22.899999923472	Africa	South Africa	Remote	Natural		GMP1/2 Primary		GAPS	Air	10. 3. 2020 00:05.57	27. 3. 2020 00:00.59
De Aar	De Aar	-30.665003484727	23.99300124738	Africa	South Africa	Remote	Natural		GMP1/2 Primary		GAPS	Air	10. 3. 2020 00:05.57	26. 3. 2020 23:42.03
Lilongwe	Lilongwe	-14.183332932132	33.783331681998	Africa	Malawi	Remote	Natural		GMP1/2 Primary		GAPS	Air	10. 3. 2020 00:05.57	27. 3. 2020 00:00.59
Vredefort Dome	Vredefort Dome	-27.001347561502	27.499682774669	Africa	South Africa	Remote	Natural		GMP3		GAPS	Air	27. 3. 2020 20:36.49	27. 3. 2020 20:36.49
Marocco observatory	Marocco observatory	33.925	-6.758	Africa	Morocco				GMP1/2 Primary		MONET Africa	Air	17. 4. 2020 09:50.09	17. 4. 2020 09:50.09
Chiromo campus	Chiromo campus	-1.271917	36.804	Africa	Kenya				GMP3		MONET Africa	Air	22. 5. 2020 11:11.57	22. 5. 2020 11:11.57
Ghana A	Ghana A	8.14674	-1.154304	Africa	Ghana				GMP3		MONET Africa	Air	22. 5. 2020 11:11.57	22. 5. 2020 11:11.57
Tunisia	Tunisia	33.7931605	9.5607653	Africa	Tunisia				GMP3		MILK - WHO	Human milk	20. 5. 2020 18:57.01	20. 5. 2020 18:57.01
Zambia	Zambia	-13.1403507	27.8493049	Africa	Zambia				GMP3		MILK - WHO	Human milk	20. 5. 2020 18:57.01	20. 5. 2020 18:57.01
Morocco	Morocco	31.794525	-7.0849336	Africa	Morocco				GMP3		MILK - WHO	Human milk	20. 5. 2020 18:57.01	20. 5. 2020 18:57.01
United Republic of Tanzania,	United Republic of Tanzania,	-6.3728253	34.8924826	Africa	Tanzania, United Republic of				GMP3		MILK - WHO	Human milk	20. 5. 2020 18:57.01	20. 5. 2020 18:57.01
Uganda	Uganda	1.52	32.67	Africa	Uganda				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Uganda	Uganda	1.52	32.67	Africa	Uganda				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Togo	Togo	8.52	1.15	Africa	Togo				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Senegal	Senegal	14.43	-14.45	Africa	Senegal				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Senegal	Senegal	14.43	-14.45	Africa	Senegal				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Sudan	Sudan	14.6	30.3	Africa	Sudan				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Sudan	Sudan	14.6	30.3	Africa	Sudan				GMP1 Aggregated		GMP 1	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Sudan	Sudan	14.6	30.3	Africa	Sudan				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Nigeria	Nigeria	9.58	7.92	Africa	Nigeria				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Nigeria	Nigeria	9.58	7.92	Africa	Nigeria				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Niger	Niger	17.37	9.77	Africa	Niger				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Mauritius	Mauritius	-20.252	57.596	Africa	Mauritius				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Mauritius	Mauritius	-20.252	57.596	Africa	Mauritius				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Mali	Mali	17.83	-1.67	Africa	Mali				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Mali	Mali	17.83	-1.67	Africa	Mali				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Kenya	Kenya	0.53	37.88	Africa	Kenya				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Kenya	Kenya	0.53	37.88	Africa	Kenya				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Ghana	Ghana	8.21	-1.1	Africa	Ghana				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Ghana	Ghana	8.21	-1.1	Africa	Ghana				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Ethiopia	Ethiopia	9.04	39.68	Africa	Ethiopia				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Egypt	Egypt	26.4	29.7	Africa	Egypt				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Egypt	Egypt	26.4	29.7	Africa	Egypt				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Djibouti	Djibouti	11.754	42.5	Africa	Djibouti				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Côte d'Ivoire	Côte d'Ivoire	7.42	-5.63	Africa	Côte d'Ivoire				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Côte d'Ivoire	Côte d'Ivoire	7.42	-5.63	Africa	Côte d'Ivoire				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Congo, Democratic Republic of	Congo, Democratic Republic of	-2.75	23.84	Africa	Congo, Democratic Republic of				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Congo, Democratic Republic of	Congo, Democratic Republic of	-2.75	23.84	Africa	Congo, Democratic Republic of				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Congo, Democratic Republic of	Congo, Democratic Republic of	-2.75	23.84	Africa	Congo, Democratic Republic of				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Congo, Democratic Republic of	Congo, Democratic Republic of	-2.75	23.84	Africa	Congo, Democratic Republic of				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Côte d'Ivoire	Côte d'Ivoire	7.42	-5.63	Africa	Côte d'Ivoire				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Côte d'Ivoire	Côte d'Ivoire	7.42	-5.63	Africa	Côte d'Ivoire				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Djibouti	Djibouti	11.754	42.5	Africa	Djibouti				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Egypt	Egypt	26.4	29.7	Africa	Egypt				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57

Egypt	Egypt	26.4	29.7	Africa	Egypt				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Ethiopia	Ethiopia	9.04	39.68	Africa	Ethiopia				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Ghana	Ghana	8.21	-1.1	Africa	Ghana				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Ghana	Ghana	8.21	-1.1	Africa	Ghana				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Kenya	Kenya	0.53	37.88	Africa	Kenya				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Kenya	Kenya	0.53	37.88	Africa	Kenya				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Mali	Mali	17.83	-1.67	Africa	Mali				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Mali	Mali	17.83	-1.67	Africa	Mali				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Mauritius	Mauritius	-20.252	57.596	Africa	Mauritius				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Mauritius	Mauritius	-20.252	57.596	Africa	Mauritius				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Niger	Niger	17.37	9.77	Africa	Niger				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Nigeria	Nigeria	9.58	7.92	Africa	Nigeria				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Nigeria	Nigeria	9.58	7.92	Africa	Nigeria				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Sudan	Sudan	14.6	30.3	Africa	Sudan				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Sudan	Sudan	14.6	30.3	Africa	Sudan				GMP1 Aggregated		GMP 1	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Sudan	Sudan	14.6	30.3	Africa	Sudan				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Senegal	Senegal	14.43	-14.45	Africa	Senegal				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Senegal	Senegal	14.43	-14.45	Africa	Senegal				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Togo	Togo	8.52	1.15	Africa	Togo				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Uganda	Uganda	1.52	32.67	Africa	Uganda				GMP1/2 Primary		MILK - WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Uganda	Uganda	1.52	32.67	Africa	Uganda				GMP1 Aggregated		WHO	Human milk	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Tanzania, United Republic of	Tanzania, United Republic of	-6.3728253	34.8924826	Africa	Tanzania, United Republic of				GMP3		MILK - WHO	Human milk	20. 5. 2020 18:57.01	20. 5. 2020 18:57.01
Morocco	Morocco	31.794525	-7.0849336	Africa	Morocco				GMP3		MILK - WHO	Human milk	20. 5. 2020 18:57.01	20. 5. 2020 18:57.01
Zambia	Zambia	-13.1403507	27.8493049	Africa	Zambia				GMP3		MILK - WHO	Human milk	20. 5. 2020 18:57.01	20. 5. 2020 18:57.01
Tunisia	Tunisia	33.7931605	9.5607653	Africa	Tunisia				GMP3		MILK - WHO	Human milk	20. 5. 2020 18:57.01	20. 5. 2020 18:57.01
Name	**site.nameOriginal**	**Latitude**	**Longitude**	**Region**	**Country**	**Site type**	**Potential source**	**Sea**	**Data source**	**Water type**	**Monitoring network**	**Matrix**	**Created**	**Updated**
Senegal River Senegal		15.98611111	-16.515278	Africa	Senegal	Sub-urban		Atlantic ocean	GMP3	Surface seawater - costal	UNEP/GEF GMP II	Water	20. 1. 2021 09:20.42	20. 1. 2021 09:20.42
Zambia Kafue/Zambezi Confluence		-15.9500556	28.923777777778	Africa	Zambia	Rural			GMP3	Surface water - river	UNEP/GEF GMP II	Water	27. 11. 2020 20:11.59	27. 11. 2020 20:11.59
Tunisia Oued Medjerda		37.022788	10.140758	Africa	Tunisia	Rural	Agricultural		GMP3	Surface water - river	UNEP/GEF GMP II	Water	27. 11. 2020 20:11.59	27. 11. 2020 20:11.59
Kenya Sabaki		-3.161389	40.134356	Africa	Kenya	Remote		Indian ocean	GMP3	Surface water - estuary	UNEP/GEF GMP II	Water	27. 11. 2020 20:11.59	27. 11. 2020 20:11.59
Ghana Volta River		6.125092	0.123497	Africa	Ghana	Sub-urban	Natural		GMP3	Surface water - river	UNEP/GEF GMP II	Water	27. 11. 2020 20:11.58	27. 11. 2020 20:11.58
Egypt River Nile		30.136667	31.294167	Africa	Egypt	Urban	Residential		GMP3	Surface water - river	UNEP/GEF GMP II	Water	27. 11. 2020 20:11.58	27. 11. 2020 20:11.58
Inanda Dam, Mshazi	Inanda Dam, Mshazi	-29.707166666667	30.867027777778	Africa	South Africa				GMP3	Surface water - lake	MONET-Aqua	Water	5. 6. 2020 09:13.38	5. 6. 2020 09:13.38
Sotuba	Sotuba	12.66825	-7.91672	Africa	Mali				GMP2 Aggregated		GMP UNEP	Water	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Sabaki River Mouth	Sabaki River Mouth	-3.16139	40.13056	Africa	Kenya				GMP2 Aggregated		GMP UNEP	Water	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Nigeria	Nigeria	8.881	7.062	Africa	Nigeria				GMP1/2 Primary		MONET Africa	Water	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Mauritius	Mauritius	-20.26	57.56	Africa	Mauritius				GMP1/2 Primary		MONET Africa	Water	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Morocco dam	Morocco dam	33.93	-6.75	Africa	Morocco				GMP1/2 Primary		MONET Africa	Water	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Kenya	Kenya	-0.03	37.22	Africa	Kenya				GMP1/2 Primary		MONET Africa	Water	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Abu Rawash	Abu Rawash	30.059	31.077	Africa	Egypt				GMP1/2 Primary		MONET Africa	Water	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Congo	Congo	-4.281	15.244	Africa	Congo				GMP1/2 Primary		MONET Africa	Water	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Sabaki River Mouth	Sabaki River Mouth	-3.16139	40.13056	Africa	Kenya				GMP2 Aggregated		GMP UNEP	Water	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Sotuba	Sotuba	12.66825	-7.91672	Africa	Mali				GMP2 Aggregated		GMP UNEP	Water	10. 3. 2020 00:05.57	10. 3. 2020 00:05.57
Inanda Dam, Mshazi	Inanda Dam, Mshazi	-29.707166666667	30.867027777778	Africa	South Africa				GMP3	Surface water - lake	MONET-Aqua	Water	5. 6. 2020 09:13.38	5. 6. 2020 09:13.38