THE GREATER ACCRA REGIONAL AIR QUALITY MANAGEMENT PLAN

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FOREWORD

Air is an essential natural resource for human well-being and vital for the survival of the entire ecosystem. Air quality is therefore essential in sustaining continuous existence. It is imperative that the quality of air is preserved to promote sustainable development and ensure good quality of life.

In the urban areas of Ghana, particularly Accra, air quality continues to deteriorate rapidly due to uncontrolled urbanisation. Exhaust and non-exhaust emissions from the transport sector, wind-blown dust from unpaved surfaces, household air pollution (open burning of waste and cooking with biomass), and industrial emissions among others have resulted in high levels of air pollution (particulate matter) with its associated negative health outcomes.

The need for comprehensive data driven actions to control emissions from the identified sources in order to protect human life and the environment from the harmful effects of the pollutants cannot be overemphasised. The actions require a coordinated plan, thus the development of this Air Quality Management Plan (AQMP). The plan seeks to delve into the major contributors to air pollution and measures that can be implemented to ensure that air pollution levels in the Greater Accra Region meet the requirements of the National Ambient Air Quality Standard.

This AQMP is a revised version of the 2018 edition of the Air Quality Management Plan for the Greater Accra Metropolitan Area (GAMA). It has five (5) main goals and for each, there is a set of objectives and activities to be carried out by various stakeholders within specific timeframes. It also sets indicators to help track performance and assess the outcomes. It further provides technical, logistic, and financial support and requirements for its implementation.

The plan is intended for implementation by the stakeholders identified in the action plan. The involvement of every stakeholder in the implementation of the plan is therefore critical in achieving the objectives of the plan.

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EXECUTIVE DIRECTOR
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Our sincere gratitude also goes to the members of the Air Quality Management Plan Review Committee in Ghana for their immense contribution to the development of this second edition of the AQMP: Esi Nerquaye-Tettteh (EPA), Dr. Allison Hughes, (Physics Department, University of Ghana), Dr. Reginald Quansah (University of Ghana), Dr. Mary Ashinyo (Ghana Health Service), Emmanuel Egya-Appoh (former Head of Environmental Quality and Laboratory Services Department, EPA), Frank Alormene (EPA), Saeed Foroco (EPA), Selina Amoah (EPA), Mawuli Gbekor (EPA), Jerry Asumbere (EPA), Maxwell Sunu (EPA), John Nyante (EPA), Benjamin Essien (EPA), Peter Ohene-Twum (EPA), Godfred Saviour Azaglo (EPA), Abdalla S. Abubakar (EPA) and Kingsley Mawuli Amega (EPA).

For all the stakeholders who were involved in the review of the document, we appreciate the invaluable contributions that helped in finalising the AQMP: Attorney General's Department, Ministry of Local Government, Decentralisation and Rural Development, Metropolitan, Municipal and District Assemblies in the Greater Accra Region, Greater Accra Regional Coordinating Council, Driver, Vehicle and Licencing Authority, Energy Commission, National Petroleum Authority, Motor Transport and Traffic Directorate of the Police Service, National Road Safety Authority, Ghana National Fire Service, Ghana Highway Authority, Ghana Atomic Energy Commission, Ghana News Agency and Ministry of Transport.

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µg/m3	microgram per cubic meter
AAAG	Automobile Assemblers Association of Ghana
AAP	Ambient Air Pollution
AIDS	Acquired Immunodeficiency Syndrome
AG	Attorney General
AQ	Air Quality
AQI	Air Quality Index
AQMP	Air Quality Management Plan
BC	Black Carbon
BenMap	Environmental Benefits Mapping and Analysis Programme
BenMap-CE	Environmental Benefits Mapping and Analysis Programme- Community Edition
BOST	Association of Oil Marketing Companies (OMC
BRT	Bus Rapid Transit
CAP	Climate Action Plan
CEPS	Customs Excise and Preventive Service
CID	Criminal Investigation Department
COPERT	Computer Programme to calculate Emissions from Road Transport
CSIR	Council for Scientific and Industrial Research
CSO	Civil Society Organizations
DANIDA	Danish International Development Agency
DUR	Department of Urban Roads
DVLA	Driver and Vehicle Licensing Authority
EC	Energy Commission
ECOWAS	Economic Community of West African States
EPA	Environmental Protection Agency
ESPA	Environmental Service Providers Association
FEM	Federal Equivalent Monitor
GAEC	Ghana Atomic Energy Commission
GAMA	Greater Accra Metropolitan Area
GCMS	Gas Chromatograph and Mass Spectrometry
GDP	Gross Domestic Product
GFEI	Global Fuel Economy Initiative
GHACCO	Ghana Alliance for Clean Cook Stoves
GHS	Ghana Health Services
GMA	Ghana Meteorological Agency
GNA	Ghana News Agency
GNFS	Ghana National Fire Service
GNPC	Ghana National Petroleum Commission
GRA	Ghana Revenue Authority
GSA	Ghana Standards Authority
GTZ	German Corporation for International Cooperation
HAP	Household Air Pollution
HIV	Human Immunodeficiency Virus
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
KITE	Kumasi Institute of Technology, Energy and Environment
L/min	Liters per min
LCS	Low-cost Sensor
LEAP	Long-range Energy Alternatives Planning

LEAP-IBC	Long-range Energy Alternatives Planning- Integrated Benefits Calculator
LI	Legislative Instrument
LPG	Liquified Petroleum Gas
MESTI	Ministry of Environment Science Technology and Innovation
MMDAs	Metropolitan, Municipal, and District Assemblies
Mn	Manganese
MoE	Ministry of Energy
MoH	Ministry of Health
MLGDRD	Ministry of Local Government, Decentralisation and Rural Development
MoT	Ministry of Transport
NDPC	National Development Planning Commission
N-FRM	Near- Federal Reference Method
NGO	Non-Governmental Organization
NO2	Nitrous Oxides
NPA	National Petroleum Authority
NRSA	National Road Safety Authority
O3	Ozone
Pb	Lead
PM	Particulate Matter
PM10	Particulate matter with effective size of less than 10 microns
PM2.5	Particulate matter with effective size of less than 2.5 microns
PMEH	Pollution Management and Environmental Health
PMF	Positive matrix factorization
Ppm	Parts per million
QA/QC	Quality Assurance/ Quality Control
RCC-GAR	Regional Coordinating Council of the Greater Accra Region
SC	Steering Committee
SEI	Stockholm Environment Institute
SLCP	Short-Lived Climate Pollutants
SNAP	Strengthening National Action Plan
SO2	Sulphur Dioxide
TAS	Tactical Air Sampler
UG	University of Ghana
UN	United Nations
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
US	United States
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	World Health Organization
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

Ambient (outdoor) and household (indoor) air pollution are currently the most significant environmental contributors to premature death in Africa, outpacing the impact of malaria and Human Immunodeficiency Virus-Acquired Immunodeficiency Syndrome (HIV-AIDS). Yet for many governments in Africa, addressing air pollution is not a pressing concern. According to available statistics, one in eight of current global deaths is as a result of exposure to air pollution- either ambient air pollution (AAP) or household air pollution (HAP) (WHO (2014a, 2014b). Together, AAP and HAP cause almost 7 million premature deaths per year. The estimated economic cost of this mortality rate dwarfs those from unsafe sanitation or underweight children. Over 45,000 African children under the age of five (5) years die annually due to air pollution (WHO 2012), one of the highest regional child mortality rates in the world. In 2015, Pneumonia led to the death of 500,000 children under five (5) years of age in sub-Saharan Africa, with air pollution being the lead contributor to this disease.

Estimates of the economic cost of indoor and outdoor air pollution to Africa are approximately $250 billion annually (Roy, 2016). In the Ghanaian context, the economic cost associated with air pollution is estimated at US$2.5bn, equivalent to 4.2% of GDP (World Bank Country Environmental Analysis, April 2020)

The growing rural-urban migration and increase in population in Ghana, may exacerbate the already inadequate infrastructure available to manage pollution in urban areas. The cities of Accra and Tema host most of the country's industries, some of which use old technologies and emit pollutants above the permissible levels. The vehicle fleet of Ghana continues to increase with the population of registered vehicles as of 2020 being 2.754million (DVLA 2020). The Greater Accra Metropolitan Area (GAMA) has the highest number of registered vehicles of about 1.387605 million (50.3% of the national fleet). These issues, including those associated with the informal settlements arising from rural-urban migration, if not addressed holistically, could pose serious risk to ambient air quality and public health in the Greater Accra Region.

EPA estimates that 2,800 lives were lost in 2015 in the Greater Accra Region due to air pollution. This number is projected to increase to approximately 4,600 premature deaths per year by 2030, if no action is taken to reduce current and projected air pollution levels. Implementing this Air Quality Management Plan can reduce the 2030 estimate by 430 each year. Additionally, negative health outcomes associated with air pollution, such as Asthma cases, missed school and workdays, can be reduced.

The development of this comprehensive Air Quality Management Plan (AQMP) for the Greater Accra Region is a step towards addressing the negative impacts related to air pollution. This plan complements the National Development Planning Commission's process which seeks to encourage the Local Government to take up the development challenges of their jurisdiction and improve the lives of citizens. Key features of this plan include:

- baseline air quality characterization and projected emission trends;
- health burden estimates;
- source-specific and ambient air quality standards;
- air quality monitoring network;
- the goals and objectives of the AQMP;
- gaps and issues affecting air quality management; and
- detailed implementation plan to address the gaps.

The plan is expected to be updated in five years to take advantage of emerging issues, technologies, and statistics to ensure the continual improvement of air quality and its attendant health implications in the Greater Accra Region.

1.0 INTRODUCTION

The Environmental Protection Agency (EPA) of Ghana was established by an Act of Parliament, EPA Act 1994, Act 490 to be the lead government institution for environmental protection in Ghana. The mission of EPA Ghana is to co-manage, protect and enhance the country's environment and seek common solutions to global environmental problems. To achieve this goal, the Agency collaborates with other government agencies and institutions, foreign and multi-national bodies for the purpose of performing its functions which include controlling the volume, types, constituents, and effects of waste discharges, emissions, deposits, or any other source of pollutants, and of substances which are hazardous or potentially dangerous to the quality of the environment, or a segment of the environment; promote studies, research, surveys and analyses, for the improvement and protection of the environment, and the maintenance of sound ecological systems in Ghana among other functions.

The Agency has made significant efforts to control air pollution in Ghana since 1994. Specifically, several programmes aimed at the prevention, control, and management of air emissions from the transport, mining, energy, manufacturing sectors and human settlements among others, were implemented. As part of the air quality management programme, an active environmental permitting and inspection system has been developed nationwide, to control industrial air emissions. Over the years, the Agency has received support through its strategic international partners including United States Environmental Protection Agency (USEPA), World Health Organisation (WHO), United Nationa Environment Programme (UNEP), United Nations Industrial Development Organization (UNIDO), Danish International Development Agency (DANIDA), Japan International Cooperation Agency (JICA) and the World Bank among others, to undertake air pollution control programmes in Ghana.

Even though some progress has been made to control air pollution, significant gaps remain. To help address some of the gaps, the Agency in collaboration with international partners, introduced the development, and implementation of air quality management plans to control air pollution in specific areas. The first Air Quality Management Plan (AQMP) was developed for the Greater Accra Metropolitan Area (GAMA) as a pilot. The coverage increased in this second edition (Figure 1). The AQMP seeks to clarify and analyze series of new measures proposed by the Agency to further reduce emissions from vehicles, industrial, and other anthropogenic source. The ultimate goal of the plan is to reduce human and environmental exposure to particulate matter (PM) and other air pollutants in the Greater Accra region, from both AAP and HAP sources. Although the original plan identified only open burning as a HAP source, household cooking has been added to the HAP category. The first AQMP (2018) developed by EPA Ghana in collaboration with the United States Environmental Protection Agency (USEPA) leveraged USEPA's significant and broad experience in air quality management. Earlier collaborations with USEPA have provided significant contributions towards the development of an air quality monitoring system for the Accra Metropolitan Area, which has since been expanded and continues to provide valuable data to characterize current conditions with respect to ambient particulate matter (PM). Data collected from the Greater Accra Metropolitan Area (GAMA) was used for the Baseline Assessment and Analysis.

This AQMP focuses on the Greater Accra Region for the following reasons:

- Current conditions characterized by more than fifteen (15) years of PM data from air quality monitoring exceed the Ghana Standards and WHO guidelines for PM and therefore present an unacceptable health burden for the population of Accra.
- The health burden associated with high PM concentrations has clear economic implications for the Greater Accra Region, limiting productive hours which could be available for working or schooling, and presenting a direct social and economic cost for respiratory health treatments.

Without action, economic growth could lead to higher emissions from the transport, industrial, and household sectors in particular, worsening air quality over time.

This revised AQMP has been developed with the support of The World Bank, through the Pollution Management and Environmental Health (PMEH) programme. The stakeholders who contributed to the development of the plan are indicated in appendix 1

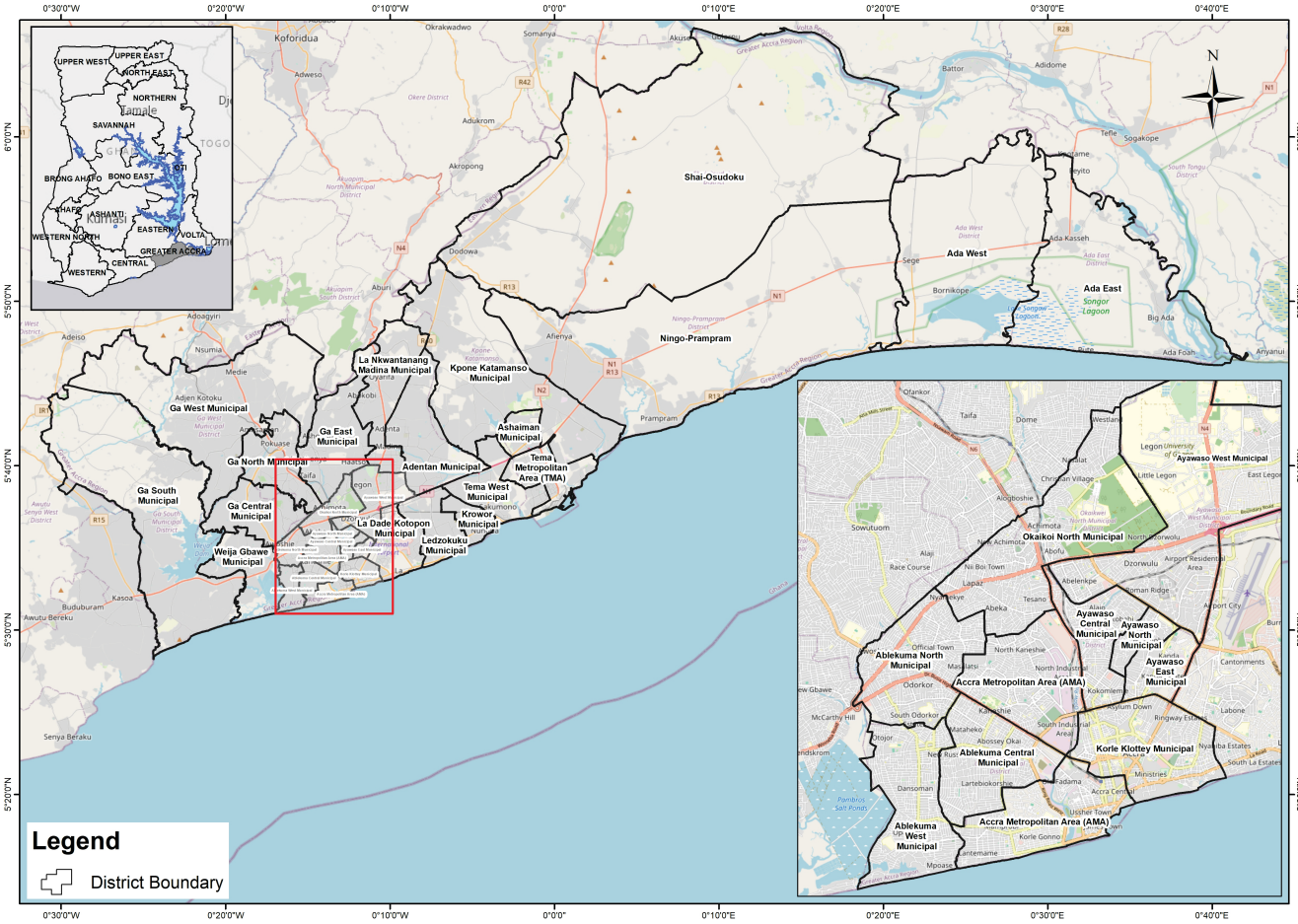


Figure 1: Map of Greater Accra Region

2.0 AIR QUALITY PROGRAMMES AND INITIATIVES

The Agency in collaboration with some stakeholders, has implemented a number of programmes/initiatives to manage air quality. These are outlined in the foregoing sections.

2.1 Air Quality Management Efforts

2.1.1 Key Interventions

Some key functions of EPA include the development of a comprehensive environmental quality database to guide policy formulation and implementation, prescription of standards, and guidelines, with respect to the pollution of air and water, land, and any other forms of environmental pollution, such as the discharge of waste, and the control of toxic substances. Interventions to enhance air quality management include the following:

- The EPA collaborated with USEPA and USAID to build and establish local capacity in air quality monitoring and data analysis in 2005. The output formed the basis for the development of an Air Quality Management Strategy for Ghana.
- WHO, under the Urban Health Initiative project, worked with EPA, the Ghana Health Services and the Accra Metropolitan Assembly on how to reduce deaths and diseases associated with air and climate pollutants, and to enhance health co-benefits from policies and measures to tackle air and climate pollution in Accra.
- Environment 360 in collaboration with the EPA initiated interventions on open burning in Jamestown and its environs to promote awareness to reduce open burning of waste;
- US EPA, Carnegie Mellon, and Columbia University deployed a network of low-cost sensors in Accra to generate relevant data for research and decision-making;
- University of Massachusetts Amherst, implemented a project on air quality measurement, which collected continuous data on $PM_{2.5}$, NO_x, and black carbon at 150 sites across Ghana. This generated high-resolution land use regression models to understand local health impacts and to analyze the relationship between air pollution exposure and respiratory infections in children born to exposed mothers;
- C40 implemented the Air Quality in Climate Action Planning Project (CAP-AQ). The project estimated the air quality and health implications of Accra's climate change mitigation scenarios, as published in the Paris-compatible Climate Action Plan;
- SEI supported the deployment of low-cost sensors and development of city level emissions inventory specific to Accra and the Greater Kumasi area;
- World Bank and Industrial Economics, worked with EPA to deploy two (2)Federal Equivalent Method (FEM) continuous air quality monitors at two monitoring sites and gravimetric monitors (at three sites) in Accra; provided training and maintenance of laboratory instruments necessary for gravimetric analysis of filter-based air quality samples and supported data management, analysis, and source apportionment efforts of the Agency.
- The US Embassy in Accra deployed one FEM continuous air quality monitor at the Embassy to collect data on particulate matter and make the data available online;
- Industrial Economics Incorporated provided support to the USEPA and the World Bank for their engagements with EPA to draft the first AQMP and to install new air quality monitors for the expansion of EPA's air quality monitoring network;
- EPA has implemented and enforced industrial emissions guidelines through the permitting process;
- In collaboration with other stakeholders including the Driver Vehicle and Licensing Authority (DVLA), Ministry of Transport, National Petroleum Authority (NPA) and Ghana Standards Authority (GSA), vehicular emissions and fuel quality standards have been developed, Sulphur content in fuel has been set, there is the gradual introduction of cleaner vehicle technologies. The vehicle inspection process which focusses on vehicle safety and roadworthiness amongst others, provides opportunity for the incorporation of emissions testing as part of the vehicle registration and annual renewal of road worthy certificate process.
- EPA in collaboration with Ghana Standards Authority and other relevant stakeholders (Appendix 2-4) developed the Ghana Standard for Environmental and Health Protection-Requirements for Ambient Air Quality and Point Source/Stack Emissions (GS1236:2019), and Ghana Standard for Motor Vehicle

Emission Control (GS1219:2018), which were in the gazette in 2019. The standards were developed using data collected by EPA, local publications and that from other countries, research findings, comparison and adoption of standards from both developed and developing countries, research findings, and international standards. Regulations required to support the implementation of the standards are being finalised.

- Development of the first AQMP under the USEPA Mega City project to identify and implement interventions to manage the increasing air pollution in the Greater Accra Metropolitan Area (GAMA)

2.1.2 Training/Capacity Building Programmes

The USEPA supported EPA Ghana to build its capacity in Air Quality Monitoring in Accra. The Climate and Clean Air Coalition and the USEPA in collaboration with EPA under the Air Quality Megacity Partnership Project for Africa, organized a two-day training workshop on Air Quality Management Planning and Short-Lived Climate Pollutant (SLCP) under the Strengthening National Action Plan (SNAP) for both local and foreign stakeholders. The stakeholders were trained in the application of relevant tools (BenMap) and chemical analysis to simulate actions to address air pollution in the Greater Accra Metropolitan Area; and development of communication and public participation plans for air quality management in GAMA. The AQMP communication plan was developed in November 2018.

Training was also conducted in collaboration with USEPA, and the University of Ghana, to standardize laboratory techniques for analysis of air quality monitor filters, enhance the functioning of laboratory equipment at EPA, and to improve the capabilities of the Agency to conduct laboratory analyses needed for source apportionment.

2.1.3 GAMA Air Quality Network

At the end of 2022, there were five (5) Federal Reference regulatory grade continuous air quality monitors located in Greater Accra, and operated by EPA, the University of Cape-Coast and the US Embassy; fifteen gravimetric air monitors, twenty-two low-cost air sensor monitors deployed in the Greater Accra Region. The air monitors include, state of the art FEM and regulatory grade monitor (T640), the BAM monitor, Aethelometer (AE33), Tactical Mini-Vol air samplers (Gravimetric for mass particulate matter concentrations), ARA Mini-Vol air samplers (gravimetric for chemical analysis), High Volume samplers, Tapered Element Oscillating Microbalance (TEOM) and Low-cost sensor monitors. Details of the equipment used by EPA and the quality assurance/control protocols are presented in Appendix 5

Currently EPA has sixteen (16) air monitoring sites: three (3)in residential areas, two (2) in industrial areas, one (1) in a commercial area, and ten (10) by the roadside along specific corridors. Six (6)of the roadside sites were selected as part of the Bus Rapid Transit (BRT) system under the Urban Transport Programme. Ten (10) of these monitoring sites are permanent. Figure 2 provides the air quality monitoring sites by land use.

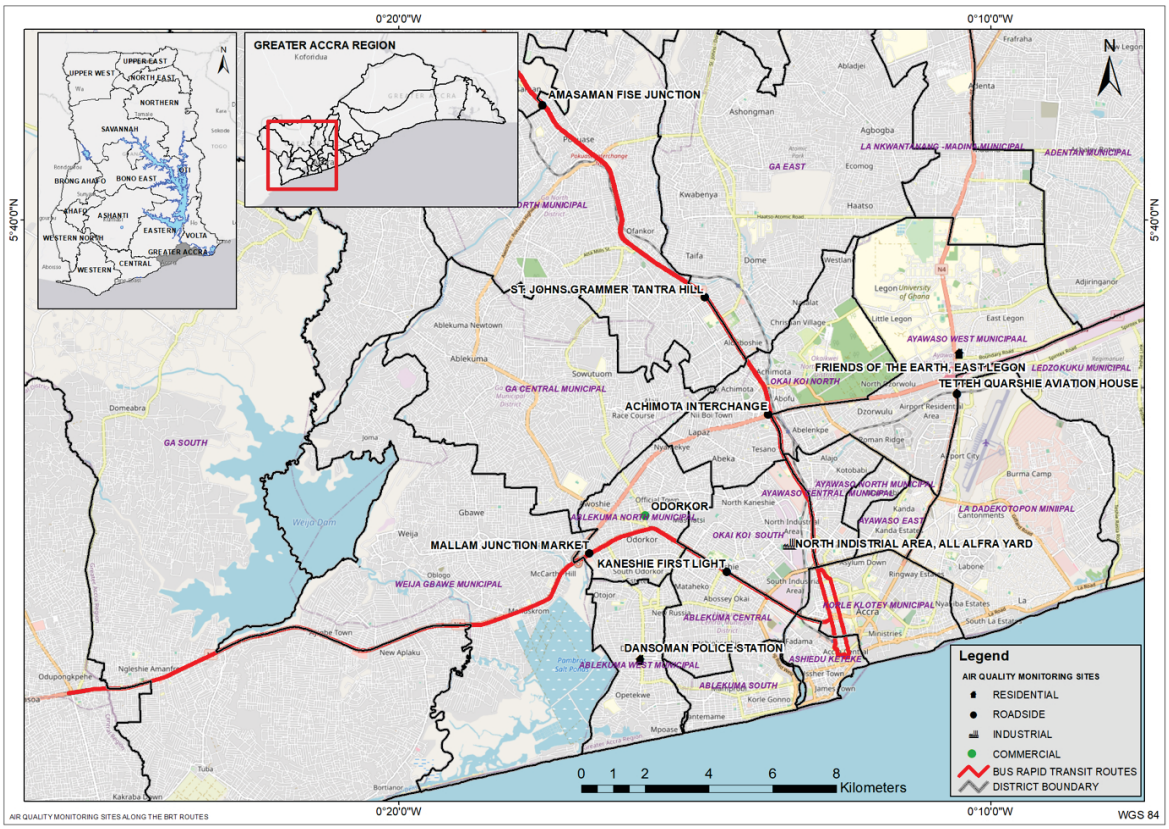


Figure 2: Air Quality Monitoring Sites by Land Use Category

Ghana's air monitoring site selection criteria is based on urban scale best practices (4km apart). A new corridor to the Northeastern end of Accra and Tema, where there are no monitoring stations have been proposed. Figure 3 shows the locations of historical, current and proposed monitoring sites.

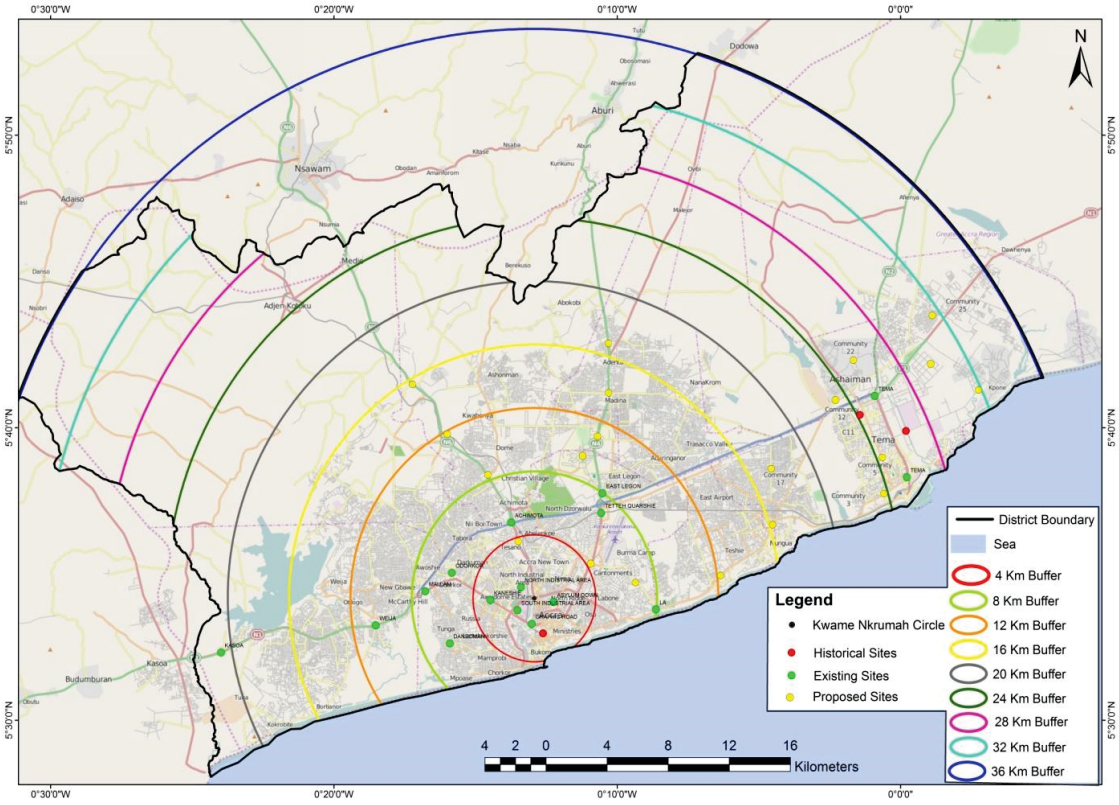


Figure 3: Historical, Current, and Proposed Air Monitoring Sites (March 2022)

Additionally, in August 2018, EPA deployed eighteen (18) low-cost PM air sensor network in Accra to complement the existing network of air quality monitors. This was to enhance local air quality management capacity by enabling the Agency to measure $PM_{2.5}$ in real time, characterize its spatial variability and communicate air quality information to the public.

Since 1997, EPA partnered with the World Bank, United States Agency for International Development (USAID) and USEPA to monitor air quality parameters including sulfur dioxide, carbon monoxide, black carbon, PM_{10}, ozone, lead, manganese, nitrogen dioxide and total suspended particulate matter in residential, commercial, industrial, and roadside locations in Accra. The results indicated that the prime parameter of concern is particulate matter. Analysis of the data collected provided support for the initiation of the AQMP. A summary of the monitoring activities is presented in Table 1.

Table 1: History of Air Quality Monitoring Efforts in Ghana and Accra

YEAR	ORGANIZATION / SPONSORSHIP		MONITORED POLLUTANTS												LOCATION	
			SO2	O3	CO	BC	MN	PB	NO2	NOX	PM10	PM2.5	TSP	OTHER*		
1997	World Bank, EPA: AQM Program		■		■	■					■		■		Accra, Tema, Takoradi, Kumasi and Tarkwa	
1998			■		■	■					■		■			
1999			■		■	■					■		■			
2000			■		■	■					■		■			
2001			■		■	■					■		■			
2002	EPA: Lead Phase -out Baseline Monitoring							■							Accra, roadside locations	
2003								■								
2004	USAID, USEPA, EPA Ghana: AQM Capacity Building Program		■	■	■		■	■		■	■					A growing number of monitoring sites in Accra: Residential East Legon Dansoman Asylum Down Industrial North Industrial Area South Industrial Area Commercial Odorkor Roadside Kaneshie First Light Tetteh Quarshie Labadi Road Achimota (2006) Mallam (August 2008) Graphic Road (2009), Weija, Kasoa (2013), Tantra Hill and Amasaman (October 2015)
2005		EPA Indoor AQ Monitoring			■										Accra, five residences	
2006		Outside Research: Arku et al.	■	■	■		■	■		■	■				Jamestown/Ussher town and Nima	
2007		Outside Research: Dionisio et al.	■	■	■		■	■		■	■	■			Jamestown/Ussher town, Nima, Asylum Down, East Legon	
		Outside Research: Zhou et al.				■	■	■			■	■				
2008		Outside Research: Zhou et al.	■	■	■	■	■	■		■	■	■		■	Jamestown/Ussher town, Nima, Asylum Down, East Legon	
2009			■	■	■		■	■		■	■					
2010			■	■	■		■	■		■	■					
2011			■	■	■		■	■		■	■					
2012			■	■	■		■	■		■	■					
2013			■	■	■		■	■		■	■					
2014			■	■	■		■	■		■	■					
2008 - 2015		Urban Transport Program	■	■	■				■		■	■			Accra, five major traffic route roadside locations	
2015	EPA, MTTD	Motor vehicle exhaust emission testing programme	■	■	■				■		■	■		xx	Accra, and All Regional capitals	
2015 - 2018	USEPA, EPA	Mega city AQM. Capacity building & publication of maiden GAMA AQMP in 2018	■	■	■				■		■	■		xx	Accra	
2017	EPA, NPA, GSA	Fuel Sulphur reduction programme	■	■	■				■		■	■		xx	National	
2018	USEPA, US Department of State	Capacity building, AQM using Low - cost sensors; open burning awareness creation program with Environment 360	■	■	■				■		■	■		x	Accra, James Town, Chorkor	

YEAR	ORGANIZATION / SPONSORSHIP		MONITORED POLLUTANTS												LOCATION	
			SO2	O3	CO	BC	MN	PB	NO2	NOX	PM10	PM2.5	TSP	OTHER*		
2017 - 2018	UN Environment , GFEI, EPA. Ministry Of Transport	Sustainable Low emission Transport programme: cleaner bus standards and sustainable transport; vehicle inventory and policy strategies for fuel economy standards												x x	Accra and National	
2019 - 2022	US Department of State, USEPA	Air Quality Modelling and Forecasting, Data Management & Communication												x x	Accra and National	
2016 - 2020	WHO	UHI on Ambient Air Pollution and Health. Health and Economic impact on transport interventions in Greater Accra												x x	Accra Metropolitan Area	
2020	World Bank	Capacity building and Installation of 2 FEMS and data management												x	UG and Adabraka	

* Other elements monitored are sodium (Na), magnesium (Mg), aluminum (Al), silicon, (Si), sulfur (S), chlorine (Cl), potassium (K), calcium (Ca), titanium (Ti), vanadium (V), chromium (Cr), nickel (Ni), iron (Fe), copper (Cu), zinc (Zn), and bromine (Br) and Manganese (Mn).

International Partnership project for comprehensive monitoring

External academic research

2.2 Status of Implementation of the Maiden AQMP

The implementation of the activities in the first AQMP (2018) was affected by the Covid-19 pandemic. However, some achievements were chalked from implementation which include the following:

1. EPA collaborated with Environment 360, a local non-governmental organization and implemented a pilot project to monitor particulate levels, organized educational events and developed educational materials to address open burning of trash in the Jamestown neighborhood.
2. EPA collaborated with the World Bank to install two new regulatory-grade Federal reference continuous monitors for $PM_{2.5}$, PM_{10}, black carbon, and meteorological variables. The monitors were installed at University of Ghana, Legon and St. Joseph Basic School, Adabraka. Data collected will provide air quality index (AQI) to the public to empower them to make informed decisions as well as for epidemiological studies.
3. EPA, with support from the World Bank, deployed three new gravimetric $PM_{2.5}$ samplers at the Adabraka, University of Ghana, and Dansoman sites to collect filter samples for source apportionment analyses.
4. EPA in collaboration with USEPA University of Ghana, University of Cape Coast, Columbia University and University of Massachusetts (Amherts), among others undertook air sensor intercomparison assessment and developed corrective factors for a number of low-cost air quality sensors to ensure regulatory acceptability and decision-making. The report has since been published.
5. EPA in collaboration with the Ghana Standards Authority, has published two key standards; Ghana Standard for Environment and Health Protection – Requirements for Ambient Air Quality and Point Source/Stack Emissions (GS 1236:2019) and Ghana Standard for Environment and Health protection – Requirements for Motor Vehicle Emissions (GS 1219:2018), to control the emission levels from various sources aimed at ensuring clean air and protection of the environment and public health.
6. Eighteen Clarity nodes low-cost air sensors donated by Stockholm Environment Institute (SEI) of the University of York were deployed in Accra, Tema, and Kumasi. SEI also supported capacity enhancement programmes for Ghanaian scientists and local government officials on air pollution monitoring and the application of the LEAP-IBC Tools for pollution inventory in Accra and Kumasi.

7. US Government funded a capacity building programme in air quality modelling, forecasting and data management, for officials from EPA, Academia, Ghana Meteorological Agency, Ghana Health Services and Ghana Atomic Energy Commission.
8. Under the Urban Health Initiative, WHO with funding from Climate Clean Air Coalition, supported EPA, Ghana Health Service, Ghana Meteorological Services, Academia and the Accra Metropolitan Assembly to understand the impact of air pollution on health, and processes that support sustained engagement needed to evaluate and promote health, air and climate protecting policies and interventions. The findings of the initiative have since been published.
9. The US Embassy commissioned a Federal Equivalent Monitor (FEM) for air quality monitoring in addition to the EPA State-of-the-Art air quality monitoring equipment in Accra in 2020.
10. A number of publications were made to support the global air pollution management agenda.
11. EPA has worked with the U.S. Environmental Protection Agency (USEPA) to deploy a series of low-cost sensors within GAMA, creating a sensor network to supplement the regulatory-grade air quality monitors.

2.3 AQMP (Second Edition) Development Process

This second edition of the AQMP was developed through a process of collaboration and consultation with stakeholders including academia, CSOs, policy makers, regulators, MDAs, MMDAs, etc. Details of the analytical steps or process is captured in the maiden AQMP.

Information gathered from the emissions source contribution, air quality monitoring data and estimation of current and projected burden of air quality on the population were used to develop goals and objectives to address the issues through a detailed implementation plan.

The air quality baseline characterization reflects current emission sources, current trends and projected air quality levels, as well as implications on public health. The baseline characterization further includes the state of air quality and EPA's capacity for air quality monitoring.

3.0 AIR QUALITY BASELINE CHARACTERIZATION

3.1 Emission Sources and Initiatives

Air pollution in the Greater Accra Region is generated from both man-made and natural sources. The man-made sources include point sources (e.g. industrial sites), mobile sources (vehicles), non-mobile sources (generators, construction equipment etc.), area sources (cook stoves, charcoal production, open burning of wastes etc.) whereas the naturally occurring sources are from harmattan wind-blown dust and sea salt. Some of these sources are common among developing cities in Africa, while others are specific to Accra or the West African coast.
The predominant wind direction in Accra and its environs (south-east) could potentially bring polluted air from the industrial areas in Accra and Tema to other places.

The population of Accra increased from 1.7 million in 2000 to 2.1 million (out of the 4 million recorded for the Greater Accra Region) in 2010 (GSS, 2012). Almost half of the households in the Greater Accra Area/Region use charcoal (45.4 percent) or wood (3.5 percent) as their main cooking fuel (GSS, 2012). Accra also faces challenges due to high population density, urban slums and significant traffic problems. Air pollution issues related to vehicular emissions and cook stoves are likely to become increasingly significant as the population and housing density continues to grow in a limited land space.

Access to electricity in Ghana is an important indicator of economic development and reflects an opportunity to centralize emissions at larger power generation stations. However, increased access to electricity may also signal the need to control emissions at these power generation facilities and also regulate the increased use of generators in residential and industrial settings. The shift from hydropower to thermal generation to meet the increasing electricity demand requires a combination of measures including increased deployment of fossil fuel which implies increased emissions, and/or deployment of renewable power generation and improvement of energy use efficiency.
In 2011, the Driver and Vehicle Licensing Authority (DVLA) commenced a pilot programme to include emissions testing in the annual Road Worthiness Certification test, on advisory note. Vehicle testing centers established under the auspices of the DVLA were permitted by EPA to install emission testing equipment. The centers, however, could not operate as a result of a lack of national motor vehicle emission standards. With the publication of the Motor Vehicular Emission Standard (GS1219:2018), it is expected that the Testing Centers will become operational.

The World Bank funded the Urban Transport Project which started in 2007 and was aimed at further reducing vehicular emissions through traffic engineering improvements, regulation of public transportation, and implementation of a Bus Rapid Transit (BRT) system on selected road corridors in Accra. The proposed BRT system under the World Bank funded Urban Transport Project (now called Quality Bus Services) started running on one of the four selected road routes (Accra Central Business District to Amasaman). Roadside air quality monitoring has been an integral part of the transport sector plans.

Following the successful elimination of lead (Pb) from gasoline, EPA worked with the National Petroleum Authority (NPA) and the Ghana Standards Authority (GSA) to reduce the sulfur content in fuels. In January 2014, the national specifications for maximum sulfur content in diesel was reduced from 5000 parts per million (ppm) to 3000 ppm. Along with Nigeria and other members of the Economic Community of West African States (ECOWAS), Ghana was to meet the Afri-4 diesel fuel specification of 50 ppm maximum or lower by 2020 (Abidjan Agreement, 2009; ECOWAS Communique, 2016). Ghana has since 2017 published and implemented new Sulphur standards of 50ppm in diesel and regular petrol fuel and 10ppm in premium petrol. Additionally, Ghana has Published National Fuel quality policy (2018) and a refinery investment plan is required to implement Afri-4. As was the case with the elimination of lead (Pb) in gasoline, lower Sulfur in fuels will improve fuel economy, engine performance and durability, and at the same time improve roadside air quality and public health.

Initiative to improve air quality in the transport sector has been driven by EPA and its stakeholders. However, in household cooking, the initiatives are driven by Ghana Energy Commission, Non-Governmental Organizations (NGOs) such as the Global Alliance for Clean Cookstoves and the Ghana Alliance for Clean Cook stoves (GHACCO) and researchers among others. The initiatives include the replacement of traditional cook stoves with more efficient biomass stoves (Gyapa cook stoves, etc.) and Liquefied Petroleum Gas stoves in households in the

country as part of the efforts to provide 50 percent of Ghana's population with access to clean cooking solutions. Others areas include the development and testing of the improved cook stove technologies and transitioning to LPG stoves; information campaigns designed to raise awareness of the health risks of indoor air pollution from traditional cookstoves; and empowerment of women and children, who experience the highest levels of exposure, to be advocates for clean cook stoves in their communities (Global Alliance for Clean Cookstoves, 2015b).

In 2012, Ghana became a founding member of the Climate and Clean Air Coalition (CCAC) to Reduce Short-Lived Climate Pollutants (SLCP), an initiative by UNEP. Through this group, Ghana has hosted and attended several international workshops that promote awareness on SLCPs including black carbon, a large contributor to particulate matter in Accra, and bringing together government officials to share effective management techniques.

Ghana was the first developing country to join Sustainable Energy for All (SE4ALL), a UN sponsored global initiative aiming for universal sustainable energy use by 2030 (International Energy Agency (IEA) and the World Bank, 2015). The Renewable Energy Act of 2011 (Act 832) was passed to encourage development of energy from renewable sources and the National Gas Master Plan (2015) was to ensure availability and use of gas for transportation and electricity generation. This has the potential of reducing air emissions.

Increasing the share of renewable energy is becoming more important as expanding access to electricity to all households in Ghana is also a priority issue. Between 1990 and 2012, the percentage of the population with access to electricity more than doubled, and the percentage of the population with access to non-solid cooking fuel increased even more dramatically as seen in Table 2. In 2021, Greater Accra Region recorded the highest percentage of 96.1%) in the use of electricity as main source of lighting and 68.2% in the use of non-solid fuel (LPG) for cooking (PHC, 2021). The improved fuels are more efficient than traditional biomass sources, and because they burn more completely, they produce less black carbon and particulate matter.

Table 2: Growth of access to Electricity in Ghana, 1990-2021

PERCENT OF GHANAIAN POPULATION WITH:	TOTAL					RURAL	URBAN
	1990	2000	2010	2012		2021	2021
Access to electricity [1]	31%	45%	61%	64%		72.6%	95.2%
Access to non-solid fuel (LPG)[2]	2%	8%	15%	17%	36.9%	14.8%	51.3%
[1] Data are from the WHO Global Health Observatory at http://apps.who.int/gho/data/node.main.134?lang=en (accessed 15 January 2015). [2] Data are from UNICEF Multiple Indicators Cluster Survey (MICS 2010) and PHC, 2021 Source: International Energy Agency (IEA) and the World Bank 2015							

3.2 Expected emission trend

The Government of Ghana under the Strengthening National Action Plan (SNAP 2013), projected that total black carbon emissions from transport sources throughout the country are expected to increase by up to 9-fold. While the growth of emissions specifically in Accra may diverge from the country-wide projection, it is reasonable to expect that mobile source activity (vehicle miles traveled - VMT) will increase in Accra across all vehicle classes. Estimates in the SNAP suggest that shifts to BRT and changes in emissions factors, such as the fleet turnover and new generations of cars are imported, could provide some counterbalance to these trends. The counterbalance, however, may not be significant without further interventions to reduce emissions from the sector. Currently, about 96 percent of total emissions for passenger vehicles is emitted from vehicle stock manufactured prior to 1996 (Government of Ghana 2013).

Increased industrialisation will also lead to increase in industrial emissions and calls for integration of best practices and pollution control measures to address the issue.

It is also projected that, the baseline emissions from household sources will continue to increase, as population increases, if they remain uncontrolled and efforts to transition to cleaner fuels like LPG and more efficient cookstoves are unsuccessful.

3.3 State of Ambient Air Quality

Data collected from EPA's air quality monitoring sites show high levels of $PM_{2.5}$ across monitoring locations. From 2020 to 2022, monitor readings at roadside locations showed concentrations well above the $PM_{2.5}$ standard set by both Ghana Standard (35µg /m^3) and the World Health Organization (WHO) (25µg/m^3, 24-hr mean). Very few readings met the $PM_{2.5}$ standard. Concentrations at monitoring sites away from major roads were relatively lower than that of the roadsides. The annual mean values were greatly influenced by the Harmattan wind- blown dust. Elemental and gaseous concentrations (Pb, Mn, SO_2, NO_2, and O_3) were generally lower than Ghana Standard/WHO guidelines. To estimate $PM_{2.5}$ concentrations from the monitored PM_{10} concentrations in the Greater Accra region, the relationship $PM_{2.5} = 0.61*PM_{10}$ developed from a co-located academic study (Dionisio et al., 2010) was applied. The estimated annual average $PM_{2.5}$ concentrations for 2020-2022 are shown in Table 3.

Table 3: Estimated Annual Average $PM_{2.5}$ Concentrations in 2020-2022 at EPA Monitoring Sites.

SITE NAME	CATEGORY	Zonal Classification	2020 ESTIMATED $PM_{2.5}$ CONCENTRATION (µg/m^3)	2021 ESTIMATED $PM_{2.5}$ CONCENTRATION (µg/m^3)	2022 ESTIMATED $PM_{2.5}$ CONCENTRATION (µg/m^3)
Tetteh Quarshie Interchange	Non-permanent	Roadside	91.98	100.31	89.01
Achimota Interchange	Non-permanent	Roadside	65.88	N/A	N/A
Odorkor	Permanent	Commercial	52.21	N/A	N/A
South Industrial Area	Permanent	Industrial	50.3	N/A	N/A
North Industrial Area	Permanent	Industrial	49.89	N/A	N/A
East Legon (Friends of the Earth)	Permanent	Residential	53.17	N/A	N/A
Labadi T-Junction	Non-permanent	Roadside	196.8	N/A	N/A
Dansoman	Permanent	Residential	30.74	33.43	33.43
Kaneshie First Light	Non-permanent	Roadside	99.06	116.41	88.42
Amasaman*	Non-permanent	Roadside	59.17	84.72	69.73
Tantra Hill	Non-permanent	Roadside	43.3	59.31	N/A
Mallam Junction	Non-permanent	Roadside	61	N/A	87.26
Graphic Communication Group of Companies	Non-permanent	Roadside	106.1	121.32	107.40
Weija	Non-permanent	Roadside		N/A	N/A
Kasoa	Non-permanent	Roadside	67.1	N/A	N/A

* Average concentration from Jan-Oct

EPA also reports air pollution levels (particulate matter) through an Air Quality Index (AQI) which communicates health risk based on the concentration of monitored pollutant. Roadside AQI was the worst, with over 17.29% of measurements signifying unhealthy conditions or above for most of the population (Table 4). Note that residential readings refer to ambient air conditions within residential neighborhoods and not indoor air quality.

Table 4: Air Quality Index Results by Monitor Location from 2014 updated to 2022.

		ROADSIDE		RESIDENTIAL		COMMERCIAL		INDUSTRIAL	
		N[1]	%[2]	N	%	N	%	N	%
0-50	Good	311	12.0%	178	39.12%	6	11.32 %	73	30.03%
51-100	Moderate	1317	50.83%	249	54.73%	36	67.92 %	185	59.11%
101-150	Unhealthy for Sensitive Groups	515	19.88%	23	5.05%	6	11.32 %	22	7.02%
151-200	Unhealthy	254	9.80%	3	0.66%	3	5.66%	2	0.64%
201-300	Very Unhealthy	94	3.63%	1	0.22%	0	0%	4	1.28%
301-500	Hazardous	100	3.86%	1	0.22%	2	3.75%	6	1.92%
	Unhealthy or above		17.29%		1.10%		9.41%		3.83%

[1] Number of monitor readings
[2] Percentage of total reading per location
Source: EPA, 2022

In addition to EPA's monitoring, a group of researchers have conducted a series of studies on air pollution in Accra to collect primary data on air quality, which provide information on localized air pollution conditions. A study by Arku et al. (2008) collected data in two low-income neighborhoods of Accra in 2006. Arku et al. recommended further research on the distribution of sources between and within neighborhoods and across time of day, as well as a more detailed analysis of the particle composition.

Another study (Dionisio et al., 2010) examined intra-neighborhood patterns with stationary and mobile data collected in 2007, across four neighborhoods of Accra. Potential sources of PM were identified based on a visual survey at several data collection points each sampled day. The study found a strong positive relationship between wood and charcoal stoves, congested and heavy traffic and trash burning and local particulate matter pollution. Rooney et al., (2012) used the same monitoring data as Dionisio et al., (2010) along with geographic information on the location of wood and charcoal stoves, and other large PM sources, along the mobile data collection route, as well as census data on other household fuel use and trash burning habits. The authors of this study concluded that the density of wood stoves, fish smoking, and trash burning is related to higher levels of $PM_{2.5}$, and road capacity and road surfaces were related to PM_{10} levels.

Zhou et al. (2013) collected monitoring data from the same four neighborhoods for one year, from September 2007. This study includes an in-depth analysis of the chemical composition of the particulate matter, as suggested in Arku et al., (2008), to estimate the contribution of various sources to the total particulate matter.

As shown in Figure 4, crustal sources are the largest contributors of both $PM_{2.5}$ and PM_{10} in the Accra Metropolitan Area during the harmattan season, with significant contributions from aged biomass particles, road dust and vehicles. In non-harmattan months, aged biomass is generally the largest contributor to $PM_{2.5}$, although sea salt, road dust and vehicle emissions are also large contributors in certain neighborhoods. These results are generally consistent with the source attribution findings in the earlier studies, where proximity of wood stoves to the monitoring site was found to be a strong indicator of PM concentrations. Sea salt, road dust, vehicle emissions, and crustal sources are all equal contributors to PM_{10}; however, the distribution varies across neighborhoods.

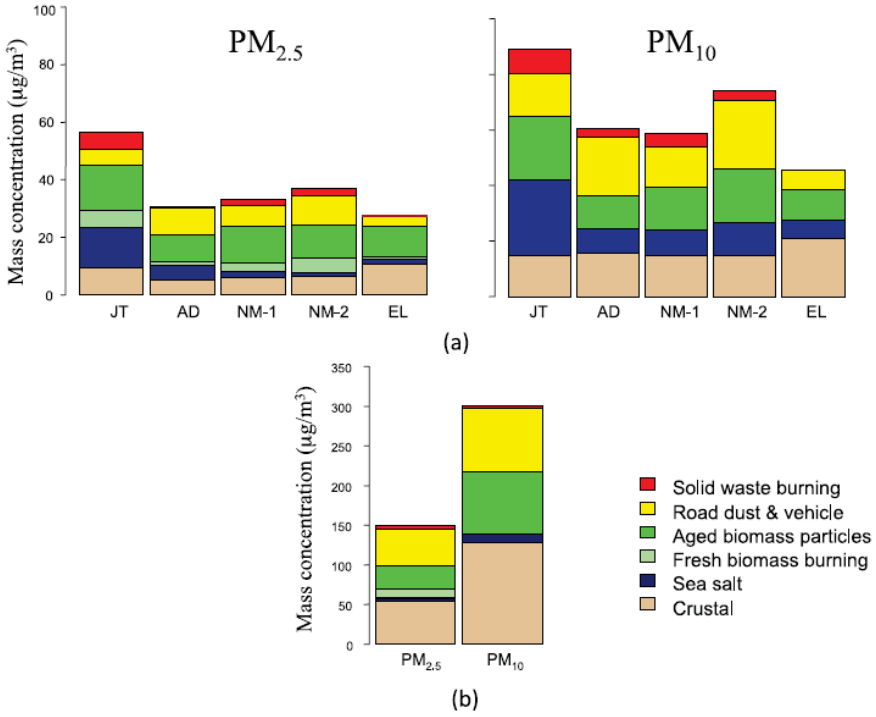


Figure 4: Particulate Matter by Source for non-harmattan and harmattan Months

Another source apportionment study conducted by Ofosu et al., (2012) in the Ashaiman Municipality, north of the Tema Industrial Area showed a higher influence of industrial sources on ambient air quality in the air-shed, an indication that this area appears to be one of the main beneficiaries of actions to limit industrial emissions as outlined in this AQMP. The study which was conducted at a residential site (February-August 2008) adjusted the sampling during the harmattan period (February and March) to avoid overloading the capacity of the instruments to accurately measure ambient air. The team used a standard form of source attribution (positive matrix factorization (PMF)) to identify the contribution of eight anthropogenic and biogenic sources. The result is indicated in Table 5.

[1]Fresh biomass particles are the direct result of biomass burning. Aged biomass particles are residual biomass particles that transform over time. Contributions of pollution sources during (a) non-Harmattan months, and (b) peak Harmattan (25 December 2007 to 30 January 2008). Figure 4(a) displays concentrations by neighborhood: Jamestown/Ussher town (JT), Asylum Down (AD), Nima (NM-1 and NM-2), and East Legon (EL).

Source: Zhou et al. (2013)11

Table 5: Average source contributions (%) to $PM_{2.5}$ mass concentrations in the Ashaiman district

Emissions Source Category	Estimated Source Contribution to Ambient $PM_{2.5}$ Concentration
Industrial emissions	11%
Fresh sea salt	16%
Diesel	18%
Biomass	9.5%
Two stroke engines	5.1%
Gasoline	16%
Aged sea salt	6.2%
Soil dust	18%

Source: Ofosu et al. (2012)

The EPA with support from the World Bank, installed two (2) new state-of-the-art real-time monitors, for the measurement of $PM_{2.5}$, PM_{10}, black carbon, and meteorological variables. The sites are located at University of Ghana, Legon and St. Joseph's Roman Catholic Basic School, Adabraka (Figure 5). The sites were chosen based on EPA's monitoring objectives and the ability to collect representative air quality samples at the appropriate spatial scale.

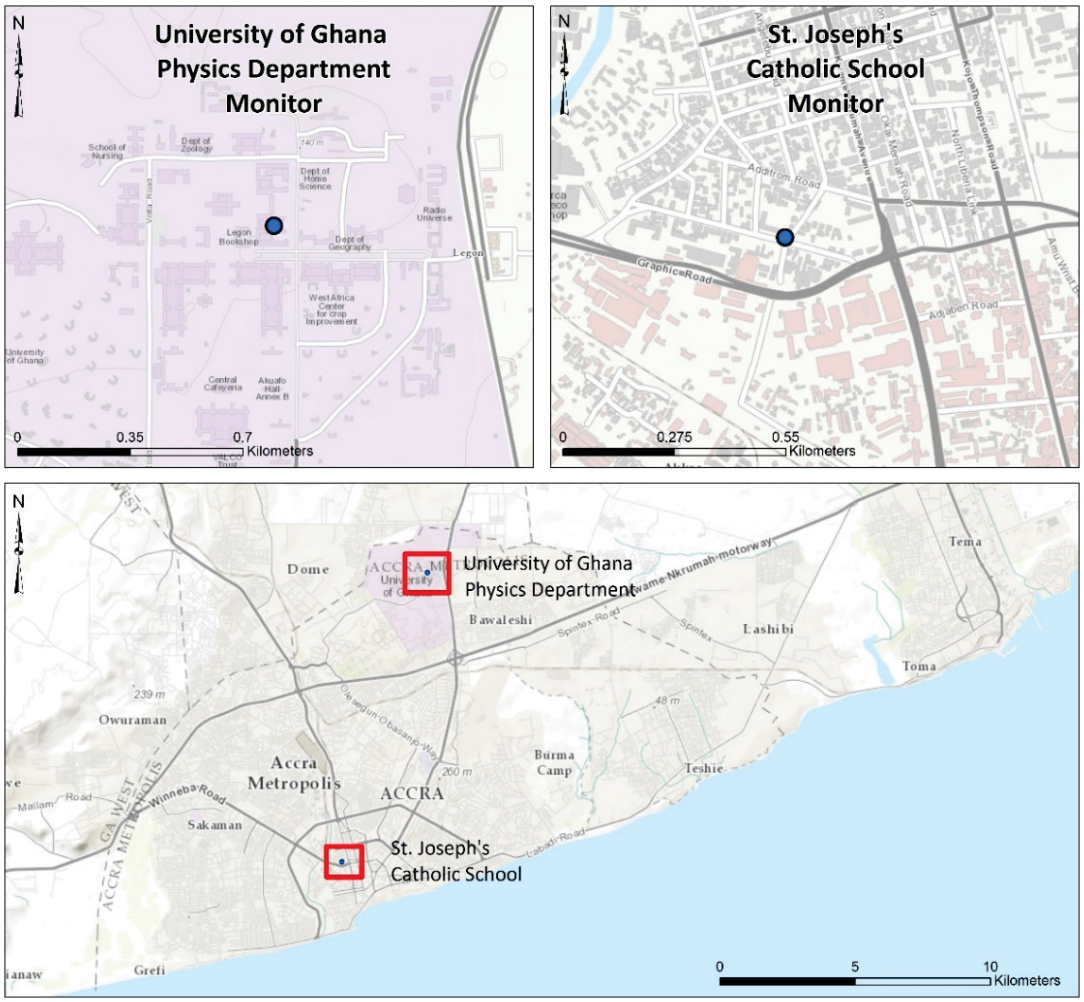


Figure 5: Location of continuous monitoring sites

Air quality monitoring was carried out from July 2018 to December 2022. However, some of the low-cost sensors were relocated resulting in data gaps within the period (April 28th to May 3rd, 2019). Therefore, annual estimated averages were available for one full year at only five (5) sites where the sensors were not relocated. The estimated annual averages from 2018 – 2020 are presented in Table 7 whilst Table 8 presents the Air Quality Index for the same period.

Table 6: Estimated Annual Average $PM_{2.5}$ concentrations from 2018 - 2020 at EPA's Low-Cost Sensor Monitoring Sites

SITE NAME	CATEGORY	ESTIMATED $PM_{2.5}$ CONCENTRATION (µg/m³)				
		2018	2019	2019	2020	2020
		July – Dec	Jan - April	May – Dec	Jan – Feb	Mar-Dec
Tetteh Quarshie Interchange	Roadside	33.2	33.6		53.7	*N/A*
Achimota Interchange	Roadside	32.3	33		60.8	*N/A*
Odorkor	Stationary	30.2	29.4		*N/A*	
North Industrial Area	Stationary	15.9	22.6	27.8	64	*N/A*
Dansoman	Stationary	16.8	19.4	19.5	53.8	*N/A*

Table 7: Air Quality Index Results of Monitor Location updated from July 2018 to December 2020

		2018* N[1] (%[2])	2019 N (%)	2020* N (%)
0-50	Good	223 (10%)	627 (11%)	0 (0%)
51-100	Moderate	1462 (68%)	3695 (67%)	422 (59%)
101-150	Unhealthy for Sensitive Groups	254 (12%)	551 (10%)	208 (29%)
151-200	Unhealthy	188 (9%)	260 (5%)	36 (5%)
201-300	Very Unhealthy	11 (1%)	60 (1%)	0 (0%)
301-500	Hazardous	3 (0.1%)	309 (6%)	53 (7%)
	Unhealthy or above	10%	12%	12%

*Monitor data is not available for the full year. 2018 data represents July – December; 2020

[1] Number of monitor readings

[2] Percentage of total reading per location

The US Embassy installed a continuous PM monitor in Accra in January 2020. The data is uploaded automatically to AirNow, an online international air quality data management system. The EPA uses this data in combination with data from its continuous air quality monitors to better understand the distribution of air pollution within Accra. Figure 7 shows the location of the US Embassy monitor in relation to EPA's two (2) FEM monitors. Table 9 presents the monthly average $PM_{2.5}$ concentrations across the three monitor locations for the overlapping months of available data.

[2] https://www.airnow.gov/international/us-embassies-and-consulates/#Ghana$Accra

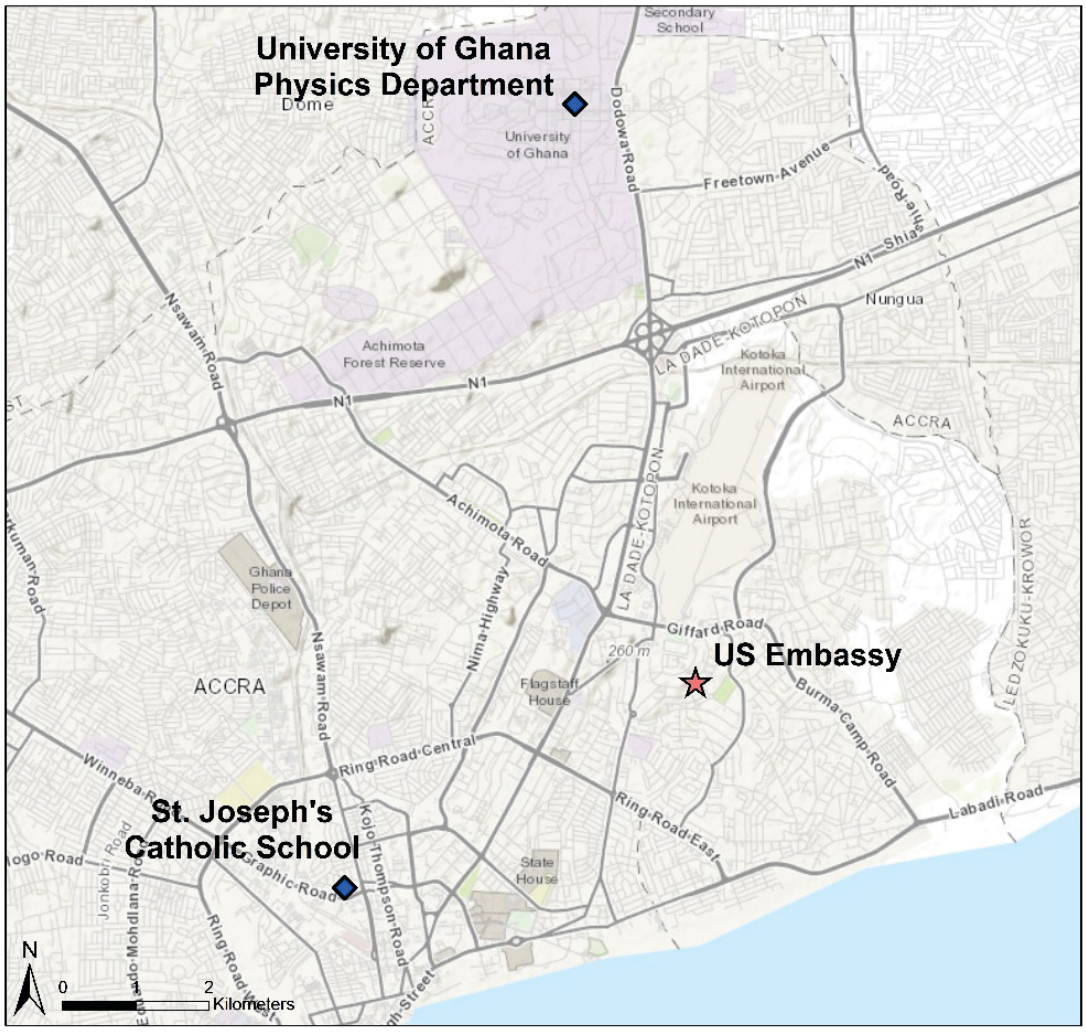


Figure 6: US Embassy and EPA continuous Air Quality Monitor Locations

Table 8: 2021 and 2022 Monthly Average $PM_{2.5}$ concentrations across 3 continuous monitoring sites in Accra

Month	University of Ghana		Average PM 2.5 (µg/m³)			
			Adabraka		US Embassy	
	2021	2022	2021	2022	2021	2022
January	56.9	97.6	62.2	88.7	41.5	69.7
February	39.4	64.1	46.1	55.1	32.0	45.5
March	31.7	*	39.8	*	28.1	25.3
April	27.1	*	34.1	*	24.7	18.8
May	13.7	*	23.7	*	11.2	14.0
June	26.2	*	41.7	*	62.2	15.1
July	24.1	15.3	42.2	*	76.5	18.9
August	24.4	13.8	40.9	30.9	64.3	21.1
September	16.4	9.2	26.1	*	55.4	21.2
October	15.7	12	25.8	*	52.3	11.9
November	23.8	17	35.0	28	71.7	21.3
December	72.6	39	70.8	*	130.3	36.0
YTD Average	**32.0**		**43.2**		**40.38**	

**The monitoring gaps were due to faulty equipment and scheduled maintenance programme*

3.4 Health Implications of the Baseline Air Quality Scenarios

The USEPA supported the EPA to estimate the health implications of the baseline air quality using the BenMAP-CE air quality impact estimation tool. The analysis which used the full set of non-roadside air quality monitors' results for 2015, reflects the burden of particulate matter air pollution within the Greater Accra Metropolitan Area (GAMA).

The analysis also projected $PM_{2.5}$ concentrations for the years 2020 and 2030 by assuming a 1% annual growth rate in PM concentrations through to 2030. This PM concentration growth rate was based on analysis of historical trends in PM_{10} concentrations from the EPA network, and an estimated relationship between historical PM concentrations and historical GDP per capita in the Greater Accra Region. This data was utilized in combination with a World Bank forecast of GDP in Ghana, and the Ghana Statistical Service's forecast for population growth in the Greater Accra Region to project a baseline of PM concentration in the future.

In addition, the estimates made use of a national-scale projection of population from the Global Burden of Disease study, and district level population estimates from the Ghana Statistical Service, adjusted where necessary, to reflect historically higher growth rates in the Greater Accra Region relative to the rest of the country. These assumptions were consistent with a "no further controls" projection of air quality for the major point, mobile and area sources contributions to air quality. The results for the cause-specific premature mortality category of health effects are provided in Table 10.

Cohen et al. (2015) estimated the health burden attributable to $PM_{2.5}$ for cause-specific mortality, including chronic obstructive pulmonary disease, ischemic heart disease, cerebrovascular disease, lower respiratory infection, and lung cancer. While most air pollution epidemiology studies are performed in the US or Europe and relate mortality to a lower range of $PM_{2.5}$ concentrations, the authors calculated integrated exposure response (IER) functions to estimate the relative risk of mortality across the global range of ambient $PM_{2.5}$ concentrations. Using a greater range of ambient $PM_{2.5}$ concentrations provides a linear relationship between exposure and health impacts at lower concentrations that flattens (i.e., the effect attenuates) at higher concentrations, similar to those concentrations measured in Accra. The IER was used to estimate cause-specific mortality impacts from current and estimated future-year $PM_{2.5}$ concentrations in the Greater Accra Region.

[3] EPA's monitor network is over-representative of roadside PM concentrations, as 10 of 15 currently active monitors are cited at roadside locations. This analysis aims to capture the baseline health burden associated with the population's exposure to PM concentrations. Within GAMA, many people live and work very near to roadways, and as such, included all monitored PM measurements in the baseline health analysis. Outside of GAMA, people are less exposed to roadside PM concentrations. To estimate population exposure to PM outside of GAMA, average non-roadside monitor concentrations were applied.

[4] The monitor network is centralized within GAMA of the Greater Accra Region.

[5] The statistical analysis of PM monitor data over time and its relationship to GDP/capita trends in Ghana also controls for the location of the monitor (roadside and residential). The result of this analysis is an estimated elasticity of PM_{10} concentrations with respect to GDP/capita of 0.28 – in other words, for each percentage increase in per capita GDP, we could expect a 0.28 percent increase in PM_{10} concentrations. The forecast of GDP/capita is based on a World Bank GDP forecast to 2020 (see https://data.worldbank.org/country/ghana) and a Ghana Statistical Service forecast of population for the Greater Accra region, also to 2030. The resulting GDP per capita forecast is an increase of just over 4% annually, which we project to 2030. Application of the elasticity of 0.28 to the estimated GDP/capita yields a forecast increase of both PM_{10} and $PM_{2.5}$ of 1% annually.

Table 9: Estimates of Premature Mortality Associated with Particulate Matter Exposure in the Greater Accra Region for 2015, 2020, & 2030

Health Endpoint	Epidemiological Study	Age Range	2015 Air Pollution Attributable Incidence	2020 Air Pollution Attributable Incidence	2030 Air Pollution Attributable Incidence
Mortality, Chronic Obstructive Pulmonary Disease	Cohen et al., 2015	30-99	210	230	350
Mortality, Ischemic Heart Disease	Cohen et al., 2015	25-99	810	870	1300
Mortality, Cerebrovascular Disease	Cohen et al., 2015	25-99	590	660	970
Mortality, Lower Respiratory Infection	Cohen et al., 2015	30-99	1200	1300	1900
Mortality, Lung Cancer	Cohen et al., 2015	30-99	47	55	84
Total Mortality for Causes Listed Above			2800	3100	4600

Note: Columns may not add to totals due to rounding of figures. The total mortality estimate provided is relevant for the five specific causes of death listed in the table. There is evidence that air pollution may also increase the risk of mortality from other causes of death not listed above, however the Cohen et al. (2015) study and available baseline incidence data in Ghana does not currently support development of an estimate that reflects other causes of mortality not listed here.

The EPA also analyzed an alternative air quality scenario which incorporates the estimated effects of the emission reduction from industrial, transport, and residential open burning of waste expected to be achieved by implementation of the AQMP. This alternative scenario reflects lower PM concentrations than the baseline forecast. To estimate the impacts of the AQMP on the transport, industrial, and residential sectors, the future year estimated air quality concentrations was rolled back by 10% in 2020 and 20% in 2030. These estimated rollbacks reflect a detailed analysis of emissions data for these sectors, and the effect of the AQMP measures in reducing these emissions, combined with the source apportionment studies summarized in Section 3.2, which are used to estimate the effect of emissions reductions by sector on ambient concentrations. The analysis concluded that cause-specific mortalities associated with $PM_{2.5}$ will potentially decrease by 430 in 2030.

3.5 Capacity Assessment

EPA and other research institutions have the capacity which can be accessed to enhance air quality management efforts in Accra. Table 11 provides a summary of capabilities for each major component of a complete air quality management system.

Table 10:Available Air Quality Management Capacity

MANAGEMENT SYSTEMS	INITIAL ASSESSMENT OF STATUS	CAPACITY GAPS
Policies, Laws and Regulations	The EPA Act 490 was passed in 1994, and Environmental Assessment Regulations (LI1652), 1999 enacted to implement the Act. Hazardous and Electronic Waste Control and Management Act, 2016, Act 917 and the Hazardous, Electronic and Other Waste (Classification), and Management Regulations 2016, LI 2250 passed for the sustainable management of hazardous and other wastes to prevent any harmful effects on public health & environment. Ghana Standard for Environment and Health Protection-Requirements for Ambient Air Quality and Point Source/Stack Emission were published in 2019 and Ghana Standard for Environment and Health Protection-Requirements for Motor Vehicle Emissions provide for actions against air pollution. EPA Act Mandates EPA to prescribe guidelines and standards to control emissions, discharges of all forms of hazardous wastes including health care, municipal and industrial. EPA Act has jurisdiction over Industrial sources and regulatory control over Local Governments (prescription of waste management guidelines and enforcement etc.) Local Governance Act, Act 936 of 2016 and Public Health Act 2012, Act 851 have operational jurisdiction over Municipal wastes, open burning, and health protection. Section 107 of the Minerals and Mining Act, 2006 (Act 703) as amended by the Minerals and Mining (Amendment) Act, 2019 (Act 995) requires mining companies to take measures to prevent or minimize air pollution resulting from their activities. Section 1 of the Ghana National Climate Change Policy highlights the impact of climate change on air quality and human health. It also highlights that climate change can worsen air pollution by increasing the frequency and severity of extreme weather events such as droughts and wildfires. National Environmental Policy identifies the need for all Ghanaians to work towards achieving clean air for all The policy identified activities that affect air quality as mining, industry, oil & gas and chemicals management	Regulations have been developed yet to be passed by parliament to implement the Ambient Air Quality & Point Source and Motor Vehicle Emission Standards. Authorities established in the Acts do not apply to municipal waste burning in Accra and surroundings . EPA Act has no jurisdiction on household air pollution and household emissions sources. Absence of an air quality policy Other activities that impact on air quality like open burning, vehicular emissions etc. were not articulated

MANAGEMENT SYSTEMS	INITIAL ASSESSMENT OF STATUS	CAPACITY GAPS
Emission Inventory	COPERT was used for mobile source emissions inventory in 2008. LEAP-IBC is being used to characterize emission sources associated with energy use and wastes among others. Some information on emission rates at industrial sources is available from EPA Ghana compliance monitoring activities. Some information is available on emissions rates from vehicles from a national scale pilot test of emissions measurement; and in the 4th National GHG Communication	There has not been any update since 2008. LEAP estimates are at the national scale but have recently been upgraded for urban scale or district level. In addition, more detailed spatial resolution is needed. The LEAP-IBC tool was used by C40 and EPA to estimate mass emissions by source category for $PM_{2.5}$, SO_2, NO_2, VOCs and ammonia etc., in the Greater Accra and Ashanti Regions. A comprehensive inventory for industrial and transport emissions has been established in the National GHG Communication report. However, a data management system for the emissions inventory would be required.
Ambient Air Quality and Point source Monitoring	There is available data for key pollutants in particular PM_{10} and $PM_{2.5}$, for a number of monitoring sites in Accra Aside from monitors located at residential, commercial, industrial areas, others are sited along roadside (to characterize transport sources). Data are supplemented by additional information from low-cost sensors and short-term research studies that can be used for better source apportionment.	Speciated PM data needed for reliable source apportionment seems to be limited to short-term research studies. Air quality monitoring data is not available for Tema, which is home to a significant number of Greater Accra's industrial point sources. Additional monitoring of residential areas is needed to better understand pollutant exposures in highly populated* areas away from busy roadways. Monitoring networks do not cover the entire region and need to be expanded.
Air Pollution Dispersion/Fate and Transport Modeling	Some initial estimates using reduced-form methods will be possible using the district level LEAP-IBC software	Not yet attempted. An emissions inventory is needed to perform this function.
Data Analysis and Interpretation	Air Monitoring data has been properly characterized and interpreted.	Additional effort could enhance source apportionment, exposure assessments, and baseline health effects characterization.

MANAGEMENT SYSTEMS	INITIAL ASSESSMENT OF STATUS	CAPACITY GAPS
Public Participation and Environmental Justice	AQ information from EPA's gravimetric monitoring sites has been made available since 2006 through EPA's annual reports. Since 2023, AQI from the real time FEM monitors has been communicated to the public on daily basis via social media handles.	The AQ index for the Gravimetric sites is not reported in real-time. AQI's from LCS monitoring sites are not communicated to the public.
Control Strategy Planning and Development	Lead has been phased out from petrol (2004) and Sulphur content in fuel limited to a maximum of 50ppm (2017). Standard laboratories are available in Ghana for testing Sulphur levels in fuels. New environmental quality standards for ambient air quality and point source emissions (2019); and motor vehicle emissions (2018) have been published for implementation.	Regulations for operationalizing the Ghana Standards is to be passed by parliament.
Compliance and Enforcement Measures	Ambient air quality and point source emission standards are implemented by EPA as part of permit compliance and enforcement. Assistance provided through the DVLA and local police and the National Road Safety Authority on-road vehicle inspections.	The absence of air quality and motor vehicle emission regulations. Vehicle inspections or roadworthiness do not incorporate emissions testing as part of the annual inspection process.

4.0 GAPS AND ISSUES

The existing monitoring network has been operational since 1997. Challenges in collecting air quality data include disruptions due to the non-availability of locally sourced spare parts, consumables, funding gaps, inadequate equipment, malfunctioning or stolen/vandalism of equipment, duplication of roles/efforts instead of collaborating to share responsibilities etc.

There is currently no standard for Household Air Pollution (HAP). In the interim, the proposed HAP guidelines is 30 $\mu g/m^3$ for indoor air quality guideline or an emissions rate not exceeding 0.23 mg/min in an unvented room or 0.80 mg/min in a vented room for $PM_{2.5}$.

Prior to setting the standard, an additional indoor particulate matter monitoring and evaluation is required. [6]Consideration may include a fuel-based guideline and the feasibility and potential for the enforcement of the guideline by EPA and/or local government.

Other gaps identified include:

- Limited monitoring of ambient and household air pollution;
- Lack of district level inventory including data management systems;
- Access to laboratory facilities;
- Access to air quality health data;
- Lack of air quality policy and regulations to enforce the air quality and vehicular emission standards;
- Communication of air quality information to the public; and
- Duplication of efforts.

These gaps need to be addressed to further enhance the ability to implement the monitoring plan towards achieving the permissible limits in the Ghana Standard by 2028. Details of these gaps are discussed in 4.1-4.7:

4.1 Limited Ambient and Household AQ monitoring and governance

The EPA, in partnership with some stakeholders, have developed air quality monitoring network in Accra. However, most of the monitoring sites are located along the roadside in Accra. Additional monitoring networks are therefore required in other areas such as industrial areas in Tema, has highly populated residential areas, commercial areas etc and also build capacity to enable monitoring and communication of results in "real-time" to alert the public.
On HAP, there is the need to develop guidelines, build capacity on household emissions and health, conduct studies as well as, set-up HAP monitoring network in the Greater Accra Region for household AQ monitoring.

4.2 District Level Emissions Inventory and Data Management System

A comprehensive emissions inventory for the Greater Accra Region is required to better characterize the major sources of air pollution in the Region. In general, emissions inventories incorporate four elements:

1. **Mobile source inventory.** It is not practical to measure pollutants from all mobile sources. Emissions from vehicles are estimated from data on the population of vehicles (by vehicle class), estimates of their activity (where, when, and how far they are driven), and the emissions characteristics of those vehicles. For a comprehensive inventory, "non-road" sources may be included to cater for activities of combustion engines in construction equipment, farm equipment, mining equipment, and other small engines (including generators). There is the need to update vehicular emissions inventory conducted in the past.

2. **Point source inventory.** Point sources are stack emissions from industrial processes and fuel burning installations from some industrial and commercial undertakings. The total emissions from a large point source may include fugitive emissions. For example, petroleum refineries have significant emissions from stacks and flares, as well as leaks around seals and from product storage containers.

[6]See memorandum of April 14, 2021 to Justice Odoi and Gary Kleiman, World Bank Group, from Jim Neumann, Stefani Penn, Niamh Micklewhite, and Henry Roman, Industrial Economics Incorporated, "Household Air Pollution Exposure Policy Guideline for Accra, Ghana.,"

3. **Area source inventory.** Area sources are small sources of air pollution which by themselves may not emit very much but, when accumulated, account for a significant portion of total emissions. Area sources are often too small or too numerous to be inventoried individually. Examples of area sources include: industrial processes such as, electroplating, metal parts cleaning, small scale metal smelting, commercial cooking using biomass, bakeries; emissions from consumer products, such as adhesives, sealants and paints; fuel use; forest and wildfires; gasoline and diesel stations; and dry cleaners.

4. **A biogenic inventory.** Biogenic emissions are emissions which originate from non-anthropogenic sources. These include sources such as forests which emit some VOCs airborne particulates such as sea salt and crustal material.

In relation to mobile source inventory, significant efforts have been made in the recent past to develop a national emissions inventory, focused on on-road sources, and using the COPERT software tool, with information from the Driver Vehicle and Licensing Authority (DVLA). An update is however required.

The COPERT tool which was used in the Strengthening National Action Plan (SNAP, 2013) work focuses on national emissions volumes and does not appear to have been deployed at the urban scale for Accra, nor the finer geographical detail that would be desired to support urban scale air quality modeling.

For major energy-using or electric energy generating sources, the Long-range Energy Alternatives Planning system (LEAP) can be used for first-order estimates of emissions of a wide range of pollutants that contribute to ambient air pollution and climate change. Additionally, the LEAP system can be applied for small-scale energy production (e.g. diesel generators), household energy use, biomass burning, industrial point sources such as, the oil refineries, alumina smelting, steel, and food processing industries, among others. Some of these sources may be less suitable for analysis in the LEAP framework but may be addressed using standard throughput driven emissions factors for first estimates of emissions potential, such as, the United States AP-42 factors.

A further significant step which can advance emissions inventory capabilities is to implement a data management system for emissions data from environmental reports submitted to EPA, to subject the data to modeling, and the application of the LEAP tool. EPA has begun work with a coalition of groups, led by WHO, and the World Bank, to obtain and build capacity in implementing a data management system for this purpose.

4.3 Access to Laboratory Facilities

EPA requires capacity building to enhance local laboratory analysis to ensure a continuous PM data gathering; and gain the necessary skills in speciation analysis to provide better source apportionment results (using elemental/organic carbon differentiation, and both metals and organic analyses as "signature" constituents).

4.4 Access to Suitable Air Quality Health-Related Data

The current Ghana Health Service (GHS) data management system collects health data of ailments derived from various sources, but does not provide the true reflection of respiratory incidences from air pollution. The District Health Data collection system requires improvement to include data collection on targeted health issues associated with air pollution related health ailments.

4.5 Air Quality Policy and Regulations

The EPA per its mandate is monitoring air quality and has developed standards to regulate emission levels, yet there is the need for an Air Quality Policy to be developed to provide the national focus for Air Quality Management. There are however, several sectoral policies which impact positively on air quality though they are not specifically targeted at air quality.

There is the need to initiate discussions on whether a separate air quality policy is needed. Regulations are being developed to facilitate the enforcement of the standards and improve air quality

4.6 Communication of AQ Information to the Public

Data collected from air quality monitoring activities are required to be communicated to the public to enable them to take the necessary precautions to reduce the impact of air pollution on their health. Currently, AQI from only one monitoring station is communicated to the public.

4.7 Duplication of Efforts

Several individuals are currently involved in air quality monitoring in the city of Accra. However, the deployment of the sensors is done without recourse to the Agency leading to over concentration of efforts particular areas to the exclusion of others.

5.0 GOALS AND OBJECTIVES OF THE GREATER ACCRA AQMP

The Greater Accra Air Quality Management Plan (AQMP) is aimed at promoting clean air for all by identifying the issues affecting air quality in the Greater Accra Region. The plan proposes actions that could help address the issues and identifies relevant stakeholders to implement the actions to bring the air quality levels into compliance with the national air quality standards.

The overall goal of the Greater Accra Air Quality Management Plan (AQMP) is to ensure that the ambient particulate air quality in the Greater Accra is brought into compliance with the GS 1236 by 2030, and the state of compliance maintained as the region develops economically, socially and environmentally. This will reduce human and environmental exposure to particulate matter (PM) and other air pollutants in the Greater Accra Region, from both AAP and HAP sources.

The overall goal will be attained by addressing the following five (5) sub-goals:
Goal 1: Ensure ambient concentrations of particulate matter in the Greater Accra Region comply with GS 1236 due to emission reductions.
Objectives:

- Develop regulations to implement Air Quality and Vehicular Emissions Standards
- Review and implement air quality and vehicular emissions Standards
- Address emission from point sources
- Reduce dust from paved and unpaved roads
- Ensure supply of high-quality fuels (50ppm maximum Sulphur content in fuels)
- Ensure that Vehicular Exhaust (Tailpipe) emissions comply with standards
- Control and minimize emissions from industrial sources and hazardous waste
- Address and manage HAP

Goal 2: Ensure collaborative governance to promote the implementation of the AQMP.
Objectives:

- Ensure good governance through collaboration among key stakeholders
- Enforce laws and regulations
- Align the objectives of the AQMP with national development goals.

Goal 3: Ensure that Air Quality Management in the Greater Accra region is supported by effective systems, reliable tools, adequate resources, and competent staff in all Metropolitan, Municipal and District Assemblies.
Objectives:

- Collect, manage, and disseminate air quality information
- Collate data on HAP
- Develop data sharing and confidentiality framework
- Enhance monitoring capabilities
- Enhance the use of tools for emission inventory and AQ forecasting
- Integrate data and findings from climate change greenhouse gas emissions reduction efforts in air quality management planning
- Update information on the impact of air quality on health

Goal 4: Air Quality decision-making is informed by sound research and development.
Objectives:

- Coordinate and align public health and air quality research to the requirements of the AQMP
- Develop local capabilities and enhance data availability to conduct source specific emissions analyses
- Utilize existing monitoring information to identify patterns and trends that can inform AQMP review

- Develop local capacity to perform source apportionment and PMF
- Upgrade EPA Laboratory to perform source apportionment

Goal 5: Awareness, knowledge and understanding on air quality amongst decision-makers, stakeholders, and the public in the Greater Accra region is enhanced.
Objectives:

- Promote awareness among the general public
- Promote implementation of the AQMP

6.0 IMPLEMENTATION PLAN

The outlined implementation plan is designed to explore the major contributors to air pollution, activities required for mitigation, responsibilities of stakeholders, indicators and the timeframe to track progress of the implementation plan and the attainment of the goals.

Responsibilities of stakeholders are further divided into two: mandatory (core) and participatory (supporting). Stakeholders with mandatory responsibility are to initiate actions, while those with participatory responsibilities are to provide support to implement the activities.

Table 11: GOAL 1 - Ensure Ambient concentrations of particulate matter in the Greater Accra Region comply with GS 1236

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME FRAMES	INDICATORS	NEEDS
Initiate the development of air quality policy	• Initiate discussions on the need for air quality policy • Implement outcomes of the discussions	MESTI	Key stakeholders	2026	Stakeholder workshop organised	Partner funding required
Develop regulations to implement AQ Standards	●Develop draft regulations ●Conduct stakeholder engagement on the draft regulation ●Undertake follow ups to ensure passage of regulations. ●Implement the Air Quality Standard and Regulation	EPA	MESTI, MMDAs, GHS, Academia, Industries, GSA, AG	Development of draft regulation and stakeholder engagement ongoing Regulation passed by December 2024. AQ regulations Implemented by June 2025	Regulations developed. Regulation Passed Regulation Implemented.	Partner funding required
Review of Air Quality Standard	●Review of GS 1236:2019 (Include annual value for $PM_{2.5}$ etc.,) ●Undertake stakeholder engagement to finalise the processes. ●Gazette revised Standard. ●Implement revised Standard.	EPA	GSA, MESTI, MMDAs, GHS, Academia, Industries, Research Institutions, Ministry of Local Government, Office of the Head of Local Government	GS 1236:2019 revised by 2025	GS 1236:2019 revised and	Partner funding required

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME FRAMES	INDICATORS	NEEDS
Address Emission from point sources	●Continue to implement permitting regime for undertakings which generate air emissions. ●Conduct emissions inventory for point sources. ●Enforce the EA provision to ensure installation of appropriate air pollution control systems ●Ensure emissions from point sources comply with GS 1236:2019	EPA	Industries, MMDA's, DVLA, Ghana Civil Aviation, Authority	●2024-2028 (ongoing) ●Emission Inventory conducted by 2025. ●Installation of appropriate air pollution control system ongoing. ●2024-2028 (ongoing)	●Industries operate with valid permits. ●Emission Inventory Report published, and database developed. ●Appropriate pollution control systems installed. ●Point source emissions complied with GS 1236:2019.	Partner support required
Develop regulations to implement Motor Vehicle Standard	●Develop draft regulation ●Conduct stakeholder engagements on the draft regulations ●Undertake follow up to ensure passage of regulations. ●Implement the MotorVehicle Emission Standard and Regulations ●Ensure that vehicle testing centres are all equipped with functional emission testing equipment ●Conduct inventory of testing centers on the availability of the required testing equipment	EPA	DVLA, Motor Traffic Transport Division (MTTD) of Ghana Police, Academia, Research Institutions, MMDAs, GHS, Ministry of Transport, Transport Unions, Automobile Assemblers Association of Ghana (AAAG),GRA, CEPS, AG	●Development of draft regulation and stakeholder engagement ongoing ●Regulation passed by December 2024. ●Motor Vehicle emissions regulations implemented by June 2025 ●Installation of emission testing equipment in vehicle testing center ongoing.	●Regulations developed. ●Regulations passed/enacted. ●Regulations Implemented. ●At least 60% of vehicles pass the emission test by 2027. ●Inventory conducted	Partner support required

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME FRAMES	INDICATORS	NEEDS
				●Include installation of emission testing equipment in EPA permitting conditions ●Create awareness on the Standards ●Conduct annual inventory of testing centres		
Review and Implement the revised Motor Vehicle Emissions Standard	●Review of GS 1219:2018 ●Undertake Stakeholder engagement ●Gazette revised Standard ●Implement the revised Standard	EPA, GSA	MESTI, DVLA, Motor Traffic Transport Division (MTTD)of Ghana Police, Academia, Research Institutions, MMDAs, GHS, Ministry of Transport,	GS 1219:2018 revised by 2025	GS1219:2018 gazette	
Reduce dust from paved and unpaved roads	●Consult with relevant stakeholder on ways to reduce dust. ●Regular sweeping of paved roads.	Ministry of Roads and Highways, DUR, Ghana Highways Authority, MMDAs	EPA, Environmental Service Providers Association (ESPA)	2024-2028 (On-going)	●Number of consultative meetings held. ●Number of consultation reports. ●PM concentrations at roadside locations reduced.	On-going, partner Support required

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME FRAMES	INDICATORS	NEEDS
	●Work with Department of Urban Roads (DUR) and Ghana Highways Authority to reduce the length of unpaved roads and improve grassing of roadsides . ●Ensure MMDAs acquire appropriate mechanized sweepers					
Ensure supply of high-quality fuels (50ppm maximum Sulphur content in fuels)	Monitor imports of 50 ppm Maximum Sulphur content in fuels	NPA	EPA, Ministry of Energy, GNPC, Energy Commission, Parliament of Ghana Petroleum Importers Association, African Refiners Association, Tema Oil Refinery, DVLA, GSA, BOST, Association of Oil Marketing Companies (OMC), COPEC, GRA	●Monitoring of imported fuels ongoing ●Refineries to produce fuels with lower Sulphur content by 2025	•Sulphur content of fuel in the market not exceeding 50 ppm	On-going. Objective in process. Local Refineries given waivers to produce a maximum of 1500ppm sulphur content fuels till December 2024
Ensure Vehicular Exhaust (Tailpipe) Emissions compliance	Monitor vehicles tail pipe emissions once a year for private vehicles and twice a year for commercial vehicles	EPA DVLA	Transport Unions, Vehicle Inspection Centers, MMDAs, MTTD, NRSA, Ghana Automobile Distribution Association,	2024 - 2028 (ongoing)	●Vehicles Tail Pipe Emissions Report published, and database developed.	Objective in process and partner funding required to complete. Emission testing is currently on advisory role awaiting passage of the vehicular emission regulations

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME FRAMES	INDICATORS	NEEDS
Control and minimize emissions from Industrial sources	Conduct industrial compliance monitoring, and enforcements. Conduct verification, Review and auditing of air quality data. Develop and publish a compliance league table annually	EPA	Industries	2024 - 2028 (ongoing)	●Quarterly industrial compliance carried out with report available. ●Quarterly returns from industries submitted, reviewed and feedback provided for at least 80% of reporting industries. ●Verification, review, and auditing reports available ●At least 80% of industries comply with permit conditions. ●At least 80% of non-compliant industries sanctioned.	On-going
Control and minimize emissions from Hazardous waste	Enforce the Hazardous and Electronic Waste Control and Management Act, 2016 (Act 917) and LI 2250 by: •Building capacity of all stakeholders on the Act 917 & LI 2250	EPA MESTI	Ghana Revenue Authority (customs Division) Scrap Dealers Association, MMDAs, Research Institution, CSO, ESPA	ongoing	•No. of enforcement actions taken •No. of capacity building programmes & participants •No. of awareness creation programmes & target groups	Partner funding required

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME FRAMES	INDICATORS	NEEDS
	•Create awareness on the Act 917 & LI 2250 •Implement measures to prohibit open burning •Promote establishment of collection centers and holding centers •Conduct monitoring of emissions				•No. of enforcement actions taken •No. of capacity building programmes & participants •No. of awareness creation programmes & target groups •No. of collection and holding centers established.	
Control open burning of waste	•Enforce of Local Governance Act •Work with MMDAs to enact and enforce by-laws to regulate open burning. •Implement awareness creation initiatives on open burning •Promote waste segregation to initiate reuse/recycling to reduce open burning. •Promote creation of local focal groups in communities and train them to serve as watchdogs against open burning.	EPA, MMDAs, Ministry of Sanitation and Water Resources, Ministry of Local Government and Rural Development	NGOs/CSO, Traditional Authorities GHS, Academia, ESPA, Ministry of Education, GNFS	2024 - 2028 (ongoing)	●By-laws enacted. ●No. of open burning incidence reported. ●No. of awareness creation programmes and target groups ●Components of solid waste segregated and reused/recycled. ●No. of Local focal groups created and trained.	Partner funding required

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME FRAMES	INDICATORS	NEEDS
Address HAP, including from cooking sources	•Develop guidelines for HAP. •Identify and engage all stakeholders	EPA, Energy Commission	MMDA's, universities/research institutions and foreign partners, NGOs- Ghana Alliance for Clean Cook stove and Fuels (GHACCO),	Develop guidelines by 2027	●HAP guidelines developed. ●Stakeholders engaged.	Partner funding required
Manage HAP	•Conduct Household Air Pollution Assessment in low, medium and high-income homes •Conduct air pollution health risk assessment •Develop guidelines for HAP management. •Generate database on stoves and their performance/efficiency. •Promote the use of improve cookstoves in homes and commercial food joints. •Create awareness on HAP	EPA, MMDAs, Energy Commission, GHS	CSO/NGO (Ghana Clean Cooking Alliance), Research Institutions, Communities	2024 - 2028 (ongoing)	•Air pollution and health risk assessments conducted. •Guidelines for HAP management developed. •No. of homes and commercial food joints using improved cookstoves and fuels •Database on stoves and their performance generated. •No. of Awareness creation programmes and target groups	Partner funding required. Capacity building required support required (Equipment, training, testing and evaluation, awareness creation etc.,)

Table 12: GOAL 2 - Ensure Collaborative Governance to Promote the Implementation of the AQMP

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	NEEDS
Ensure good governance through collaboration among key stakeholders for implementation of vehicular emissions regulations.	·Conduct joint mandatory inspections and monitor emission from vehicles. ·Create database on inspection and monitoring results and analyze data. ·Integrate emission testing as part of requirement for road worthiness. ·Conduct on-road vehicular emissions tests. ·Prepare annual reports on status of implementation of the activities.	DVLA, EPA, Ministry of Transport, Vehicle testing Centers	•MTTD •Transport Unions •MMDAs •Automobile Assembly Association •National Road Safety Authority	2024-2028 (on-going)	•Vehicular inspections and emissions database developed. •Emissions testing integrated into road worthy certification. •No. of on-road tests conducted. •Data analyzed and report generated biannually.	Partner support required
Enforce vehicular emissions regulations	·Ensure Road Worthy Certificates are renewed (6 months for commercial, and 12 months for private vehicles) Conduct on-road vehicular emissions test.	DVLA, EPA, National Road Safety Authority, MTTD,CID	Transport Unions, Vehicle Assembly Associations, Ministry of Transport, National association of garages	2024-2028	•No. of road worthy certificates issued. •No. of vehicles that complied with mandatory vehicle emission standards. •Data from on-road test analyzed and reported.	Partner funding and support required
Cordination of deployment of sensors	Cordinate the deployment of sensors to avoid duplication	EPA	Actors in air quality monitoring	2024-2025	Framework for sensor deployment developed	Partner support required

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	NEEDS
Enforce laws on open burning	•Enforce relevant laws and regulations •Enact and enforce of by-laws to regulate open burning. ●Undertake awareness creation initiatives ●Conduct monitoring and evaluation	MMDAs, Ghana National Fire Service	EPA, Traditional Authorities, NADMO	2024-2028	●By-laws enacted. ●No. of open burning incidence reported. ●No. of awareness creation programmes and target groups	Support required.
Align the objectives of the AQMP with national development goals.	•Engage NDPC on integration of the AQMP objectives into national planning guidelines. •Integrate AQMP into guidelines for preparing district medium term development plans. •Create awareness on the AQMP in the MMDAs	NDPC, EPA, MMDAs	Ministry of Local Government and Rural Development, RCC	2023-2027	•NDPC engaged. •AQMP integrated into Guidelines for preparing district medium term development plans. •Number of District Assemblies in GAR that integrate the AQMP into their district medium term development plans. •Number of Awareness creation programmes and MMDAs	Partner funding required

Table 13: GOAL 3 - Ensure that Air Quality Management in the Greater Accra Region is supported by Effective Systems, Reliable Tools, Adequate Resources and Competent Staff in all MMDAs in Greater Accra.

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	NEEDS
Collect, manage, and disseminate air quality information	·Consider the use of AirNow as a data management system for the Regulatory grade monitors ·Store data temporary at Campbel Konect Cloud site for access by EPA and partners. ·Access Non-Regulatory data from the network of Low-cost sensors deployed by EPA (Data temporarily stored in cloud). ·Non-Analyse and disseminate air quality information to the public	EPA, GHS	UG, Ghana Atomic Energy Commission, Ghana Meteorological Agency,	2024-2028 (ongoing)	•AirNow data Management system considered, and decision taken. •Data temporary stored at Campbel Konect Cloud site. •Non-regulatory data accessed from LSC network. •Data analyzed and results disseminated to the public.	Partner funding required to secure dedicated server.
Collate data on HAP	·Collate data on HAP including data by researchers. ·Integrate additional data on HAP emissions database	EPA, Energy Commission	Academia, research institutions, GHS(Kintampo and Navorongo Health Research Centre), GTZ, World Bank, NGOs (Netherlands development Agency, Ghana Alliance for Clean Cook Stove etc.	2024-2028	•HAP data collated. •HAP data integrated into emissions database	Funding and support required

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	NEEDS
Develop data sharing and confidentiality framework	Develop a framework that outlines data sharing, types of data, types of uses, etc. and protocols for obtaining access to data	EPA	Relevant stakeholders identified in this document	December 2025	Data sharing framework developed	Funding required
Enhance monitoring capabilities	•Develop a curriculum for training and capacity building •Build human capacity for operation and maintenance of air quality monitoring systems (AQMS) •Acquire and deploy more AQMS •Build capacity for data collection, analysis, and reporting. •Extend the coverage of the air quality monitoring networks in the GAR	EPA	MMDAs, Industry, Academia, Research Institutions, NGOs, General Public	2024-2028	•Curriculum developed •No. of people trained. •No. of relevant institutions trained •No. of AQMS acquired and deployed in the GAR	Partner funding and technical support required

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	NEEDS
Enhance the use of tools for emission inventory and AQ forecasting	Employ the use of tools such as the Geos-CF, LEAP-IBC for emission inventory and forecasting air quality in GAR	EPA, Energy Commission, NPA	GHS, MMDA's, Ministry of Energy, Academia, Researchers, and other partners	2024- 2028	relevant tools used to forecast AQ in GAR	Technical support required.
Integrate data and findings from climate change greenhouse gas emissions reduction efforts in air quality management planning	•Train EPA staff on use of methods for assessing co-benefits of GHG reduction activities in air quality management. •Analyse the co-benefits of at least one NDC or GHG action	EPA, C40	Ministry of Energy, academia Development Partners	2027	•No. of EPA staff trained on use of methods for assessing co-benefits of at least one NDC or other GHG action. •No. of NDCs or GHG actions analyzed, and co-benefits identified	Technical support and partner funding required
Update information on the impact of air quality on health	•Gather morbidity and mortality data related to air pollution. •Analyse AQ and morbidity/mortality data for GAR	EPA, GHS, Tertiary Hospitals	Ministry of Health, Ghana Statistical Service, academia, research institutions, NGOs and other Partners	2024- 2028	•Data on morbidity and mortality related to air pollution documented. •Health effects from air pollution determined.	Technical support and partner funding required

Table 14: GOAL 4 – Ensure that Air Quality Decision-making is Informed by Sound Research.

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	NEEDS
Coordinate and align public health and air quality research to the requirements of the AQMP	• Compile and review research works on air quality and public health to inform future research directions and decision - making. • Make research funding accessible and research findings published and disseminated	EPA,	GHS, Academia and research institutions and other relevant stakeholders	2024 - 2028	•Research works compiled and reviewed and documented. •Research findings published.	Partner funding required
Develop local capabilities and enhance data availability to conduct source specific emissions analyses that specify cost, benefits, and monetize benefits of new air quality improvement actions	Develop local capabilities, at EPA, in academia, NGOs, private sector etc, to assess proposed investments or regulatory actions such as NDCs, that improve air quality {AQ benefits may be primary (e.g,. emissions limits) or secondary (e.g, transportation decarbonization) objective of action or investments }	EPA	University of Ghana, WHO (see specific WHO Urban Health Initiative examples of benefit cost analyses here: Health and economic impacts of transport interventions in Accra, Ghana: https://apps.who.int/iris/handle/10665/338963).	2024- 2028	Report on capacity development programmes developed and published. Analyses of proposed investments completed and published	Donor funding needed for training and pilot analyses implementation.
Utilize existing monitoring information to identify patterns and trends that can inform AQMP review	Develop and implement a plan on the use of existing monitoring information. Perform trend analysis on historical AQ data and GDP	EPA	USEPA, GHS, Academia, Research Institutions GSS	2026	• Plan on use of existing information developed. • AQ and GDP trends analysis performed and published.	Technical support required
Develop local capacity to perform source apportionment and PMF	Train local personnel on source apportionment and PMF	EPA, Academia, GAEC	Development Partners	2025	No. of Local personnel trained on Source apportionment.	Technical support and partner funding required
Upgrade EPA Laboratory to perform source apportionment	• Procure and install specific equipment identified in a UG report on laboratory capabilities (e.g., for GCMS, AAS) • Train staff on the use of the equipment procured	EPA	Academia and research institutions , Development Partners	2027	• Needed equipment procured and installed • No. of staff trained on the use of the equipment procured.	Laboratory equipment, technical support and partner funding required

Table 15: GOAL 5 – Ensure that Awareness, Knowledge and Understanding amongst Decision-Makers, Stakeholders, and the General Public in the Greater Accra Region is enhanced

OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	NEEDS
Promote awareness among public	• Develop brochure that documents EPA air quality management success stories • Update website • Use the print and electronic media to disseminate information	EPA	Development Partners GHS, RCC-GAR	2024-2027	• Two-page brochure published. • Website updated. • No. of print and electronic media engagements	Technical support and partner funding required
Promote implementation of the AQMP	•Constitute a steering and Technical Committees at EPA and institutional levels to oversee implementation of the AQMP. •Develop and implement a plan	EPA Steering Committees	Relevant Stakeholders	2024	• Steering Committee formed. • SC Implementation plan developed	Funding required
	•Create awareness for all stakeholders on the aspects of the AQMP that relates to them. •Involve decision makers by assigning roles to them or encouraging them to be part of committees. •Establish inter-ministerial committee on air quality .	EPA, Steering Committees	Ministry of Energy, MoT, MoH/GHS, MoLGRD/MMDAs, NDPC, DVLA, Road Safety Commission, MTTD, NPA, Ghana Standards Authority, Energy Commission, NGOs/CSOs, Industry	2024-2028	• No. of stakeholder engagements • No. of stakeholders engaged.	Funding required

7.0 MONITORING AND EVALUATION

A steering Committee would be constituted to oversee the implementation of the plan. Members of the committee would be drawn from the stakeholders involved in the implementation of the plan, including the media. Working groups would also be established to facilitate implementation of actions in specific sectors, to initiate the programmes and monitor the level of implementation on regular basis.

Evaluation programmes would be instituted at the working group and steering committee levels, to assess the AQMP thoroughly using an agreed checklist based on the indicators. Working groups would be required to document implementation progress and the challenges identified.
Following the comprehensive evaluation, goals and objectives would be amended as needed and activities updated.

Figure 7 provides a summary of the cycle of air quality management goals envisioned. Steps 1 through 3, have been used to formulate the Plan. Available air quality data and information have been used to assess the current situation, identify key sources and prioritize actions for implementation to reduce emissions. This Plan represents the first step in acting (Step 4).

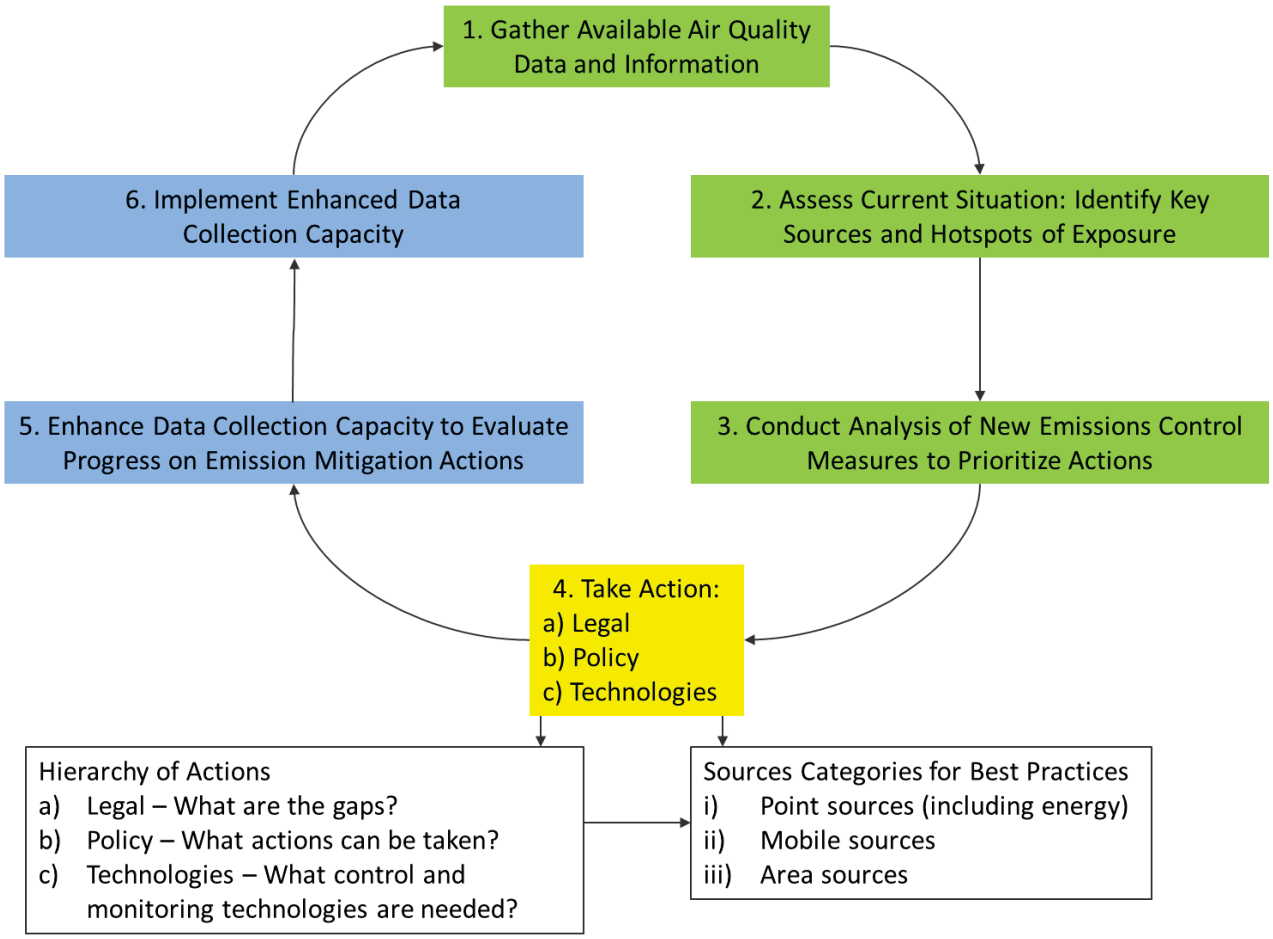


Figure 7: Schematic of the Air Quality Management Planning Process

This AQMP will be the central focus in evaluating progress toward the achievement of air quality goals in the GAR in the next five (5) years. Any section may be reviewed during implementation as a result of new exigencies and findings. The review will also take into consideration the progress of implementation of the improvement actions identified. Data collected within the period would be evaluated to further assess whether the actions taken were adequate in achieving the $PM_{2.5}$ and PM_{10} standards.

The review will also evaluate the state of emission drivers, including growth in emissions rates, air pollutant exposures and impacts on the economy. Additionally, the evaluation will include an update on the availability of financing for implementation of the plan and transition to new technologies and improvement in fuel quality.

REFERENCES

Abidjan Agreement, (2009). West and Central Africa Regional Framework Agreement on Air pollution.

Arku, R. E., Vallarino, J., Dionisio, K. L., Willis, R., Choi, H., Wilson, J. G., ... & Ezzati, M. (2008). Characterizing air pollution in two low-income neighborhoods in Accra, Ghana. Science of the total environment, 402(2), 217-231.

Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, Balakrishnan K, Brunekreef B, Dandona L, Dandona R, Feigin V, Freedman G, Hubbell B, Jobling A, Kan H, Knibbs L, Liu Y, Martin R, Morawska L, Pope CA 3rd, Shin H, Straif K, Shaddick G, Thomas M, van Dingenen R, van Donkelaar A, Vos T, Murray CJL, Forouzanfar MH. (2017) Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. Lancet. 389(10082):1907-1918. doi: 10.1016/S0140-6736(17)30505-6.

Delapena, S., R. Piedrahita, A. Pillarisetti, C. Garland, M. E. Rossanese, M. Johnson, and D. Pennise. 2018. Using personal exposure measurements of particulate matter to estimate health impacts associated with cooking in peri-urban Accra, Ghana. *Energy for Sustainable Development*, 45: 190-197.

Dionisio, K. L., Rooney, M. S., Arku, R. E., Friedman, A. B., Hughes, A. F., Vallarino, J., ... & Ezzati, M. (2010). Within-neighborhood patterns and sources of particle pollution: mobile monitoring and geographic information system analysis in four communities in Accra, Ghana. Environmental health perspectives (Online), 118(5), 607.

ECOWAS Communique (2016): promotion of Low Sulphur Fuels by ECOWAS Countries
Ghana Statistical Service (GSS). (2012). 2010 Population and Housing Census: Summary Reprot of FinalResults. May 2012. Available from http://www.statsghana.gov.gh/docfiles/2010phc/Census2010_Summary_report_of_final_results.pdf

Ghana Statistical Service (2011). Ghana Multiple Indicator Cluster Survey with an enhanced Malaria Module and Biomarker: Monitoring the Situation of Children and Women in Ghana. Final Report. Available at: www.statsghana.gov.gh/nada/index.php/catalog/88/download/365

Global Alliance for Clean Cookstoves. (2015a). Clean Cookstoves and Fuels: A Catalog of Carbon Offset Projects and Advisory Service Providers. 2nd Edition.

Global Alliance for Clean Cookstoves. (2015b). Country Profiles: Ghana. An Initiative hosted by the United Nations Foundation. http://cleancookstoves.org/country-profiles/focus-countries/1-ghana.html. Accessed 25 August 2015.

Health Effects Institute. 2020. State of Global Air 2020. Available: www.stateofglobalair.org [accessed 03/17/2021]

International Energy Agency (IEA) and the World Bank. 2015. "SustainableEnergy for All 2015—Progress Toward Sustainable Energy" (June), World Bank, Washington, DC. Doi: 10.1596/978-1-4648-0690-2 License: Creative Commons Attribution CC BY 3.0 IGO

Ofosu, Francis G, Philip K. Hopke, Innocent J.K. Aboh, Samuel A. Bamford. 2012. Characterization of fine particulate sources at Ashaiman in Greater Accra, Ghana. Atmospheric Pollution Research 3:301-310.

Rooney, M. S., Arku, R. E., Dionisio, K. L., Paciorek, C., Friedman, A. B., Carmichael, H., ... & Ezzati, M. (2012). Spatial and temporal patterns of particulate matter sources and pollution in four communities in Accra, Ghana. Science of the Total Environment, 435, 107-114.

Roy, R. (2016), "The cost of air pollution in Africa", *OECD Development Centre Working Papers*, No. 333, OECD Publishing, Paris, https://doi.org/10.1787/5jlqzq77x6f8-en.

Santos AC, Nonvignon J, Blankson P-K, Johnson A, Aikins M. Economic costs of air pollution in Accra, Ghana. Geneva: World Health Organization; 2020. License: CC BY-NC-SA 3.0 IGO.

The World Bank. (2015) Ghana Urban Transport Project (P100619): Implementation Status & Results Report. Available at http://www.worldbank.org/projects/P100619/ghana-urban-transport-project?lang=en.

The World Bank Group. (2020). Ghana Country Environmental Analysis. Washington, D.C.

World Health Organization. (2005). Air Quality Guidelines Global Update, Report on a Working Group meeting, Bonn, Germany, 18-20 October 2005. Geneva.

World Health Organization. March 2014a. Household air pollution and health. WHO Fact sheet N°292. Available at: http://www.who.int/mediacentre/factsheets/fs292/en/

World Health Organization. March 2014b. Ambient (outdoor) air quality and health. WHO Fact sheet N°313. Available at: http://www.who.int/mediacentre/factsheets/fs313/en/

Zhou, Z., Dionisio, K. L., Verissimo, T. G., Kerr, A. S., Coull, B., Arku, R. E., ... & Ezzati, M. (2013). Chemical composition and sources of particle pollution in affluent and poor neighborhoods of Accra, Ghana. Environmental Research Letters, 8(4), 044025.

APPENDICES

Appendix 1: Stakeholders involved in the preparatory work and drafting of the AQMP:

- EPA;
- Ghana Health Service;
- Ministry of Environment, Science Technology and Innovation;
- Space Science Systems Research Institute;
- Accra Metropolitan Assembly;
- Driver Vehicle Licensing Authority;
- National Petroleum Authority;
- Ghana Meteorological Agency (GMA);
- Ghana Atomic Energy Commission,
- Ghana News Agency (GNA);
- Global Alliance for Clean Cookstoves (Ghana);
- USEPA and;
- University of Ghana

Appendix 2: Stakeholder involved in the review of the air quality guidelines into standards

- EPA;
- Ghana Health Services;
- KITE;
- DVLA;
- Ghana Meteorological Agency (GMA);
- MESTI;
- Accra Metropolitan Assembly;
- Council for Scientific and Industrial Research (CSIR) ;
- Tema Oil Refinery (TOR);
- Ghana Police Service;
- Earth Service (NGO);
- Friends of the Earth (NGO);
- ITDP/CCE;
- Ghana News Agency (GNA);
- Attorney General's Department;
- University of Ghana (UG);
- Enterprise-Works Ghana;
- Ministry of Roads and Transport; and
- Ghana Atomic Energy Commission (GAEC).

Appendix 3: Composition of National Technical Committee for Standard Development

- GSA;
- EPA;
- Ministry of Environment, Science, Technology and Innovations (MESTI) ;
- Ghana Atomic Energy Commission;
- University of Ghana (School of Public Health and Institute of Environmental and Sanitation Studies);
- University of Cape Coast (Department of Environmental and Biological Studies);
- Envaserv Consult;
- National Petroleum Authority;
- Accra Metropolitan Assembly (AMA) and;
- Driver Vehicle License Authority

Appendix 4: National Stakeholders for the Review of Standards

- Academia/Research
- Industry
- Policy makers (MESTI, Ministry of Transport);
- Local Governments (MMDA)
- Private sector etc.

Appendix 5: Air Quality Equipment and Protocols

A. Continuous FEM monitors

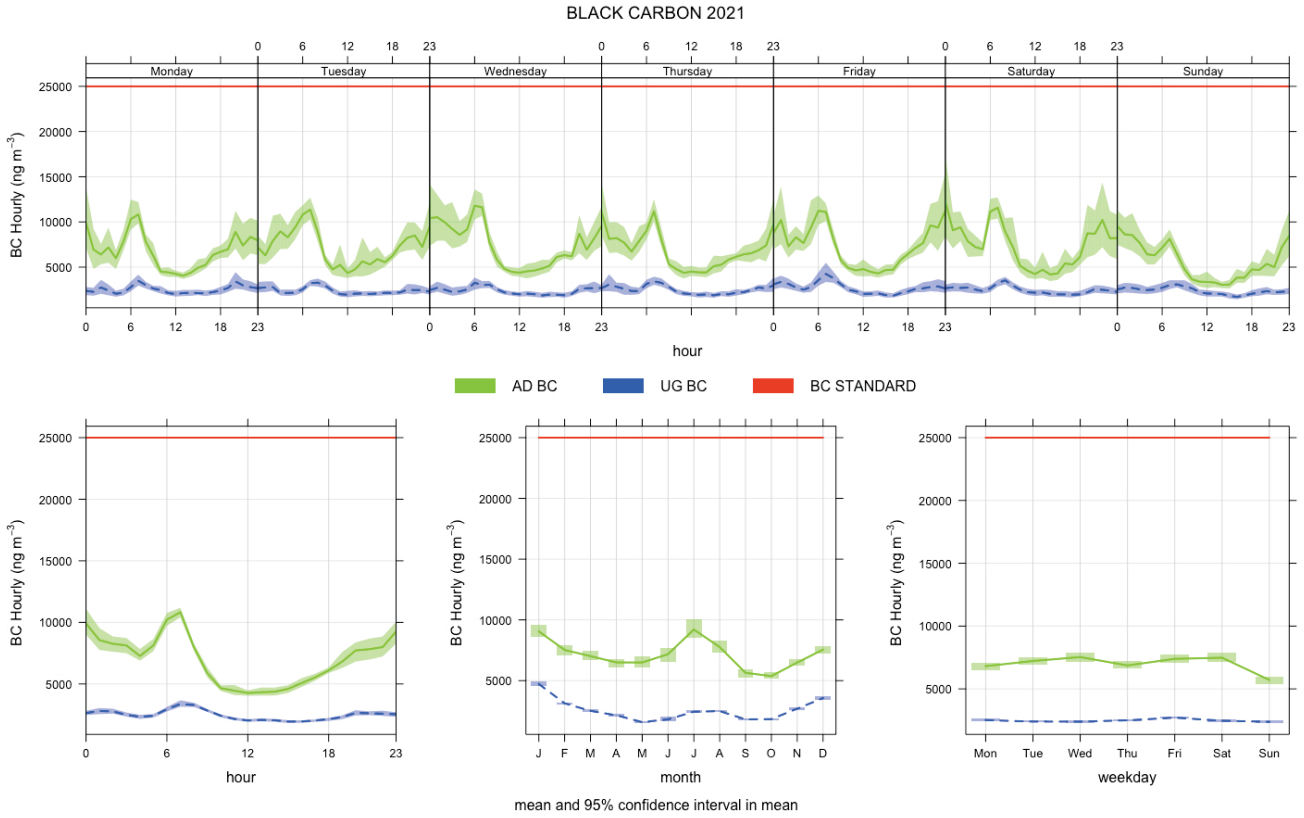
As of December 2022, Ghana had four (4) federal reference regulatory grade continuous air quality monitors located at Adabraka, University of Ghana (UG), the U.S. Embassy and Korle Klottey Municipal Assembly. The Ababraka monitoring site is located in a Roman Catholic Basic school compound within a mixed commercial and residential area, with notable sources of air pollution emanating from vehicular traffic, cook stoves and open burning of wastes. The University of Ghana (UG) air monitoring site is in the Physics Department of Legon campus located towards the northern portion of the study area, where fewer nearby sources of air pollution are available. The US Embassy site is located in the Cantonments, a residential area with fewer vehicular emissions and less open burning. All the monitors located at the four sites measure $PM_{2.5}$. Additionally, the UG and Adabraka sites monitor PM_{10} and black carbon (BC), and meteorological parameters like temperature, relative humidity, pressure, wind speed and wind direction. Federal particulate matter continuous monitors (Teledyne API T640 monitor improves upon the BAM, as it produces 1-minute rather than 1-hour data), Black Carbon analyzers (Magee Scientific AE33) and R.M. Young weather stations (with high accuracy temperature, relative humidity, wind speed and wind direction probes that meets or exceeds USEPA and World Meteorological Organization specifications) have been set up to provide quality data/information. Data from the continuous monitoring equipment can provide diurnal patterns of pollution to ensure a better understanding of human exposure burdens. The T640 uses Broadband Scattered Light to allow measurements over a range of particle sizes more accurately than monochromatic light and produces PM concentration data minute or hourly basis.

Continuous PM_{10} data could be used to calibrate gravimetric PM_{10} filter-based samples for in-field methods, transport, and storage procedures. This aethalometer includes air flow rates between two and five L/min, drawing air through a reinforced glass-fiber/PTFE filter tape to collect aerosols. A detector reads attenuation of multiple wavelengths of light through aerosols compared to a reference to provide continuously corrected measurements. The AE33 measures wavelengths from 370 nm to 950 nm (but BC is measured at 880 nm) at a rate of 1 Hz, and records 1-second or 1-minute data onto a local data logger, data can be transferred via Ethernet or via USB drive. The AE33 has a 1-hour detection limit of <0.005 $\mu g/m^3$ and can measure BC from 0.01 to more than 100 $\mu g/m^3$. This new measurement of BC can bolster the current Greater Accra Region AQMP with information on the impacts that Accra's air emissions may have on climate change and the role EPA can take in monitoring and subsequently reducing the city's carbon footprint.

Continuous measurement data have been collected since January 2021 at the Adabraka and UG sites, and since January 2020 at the Embassy site.

Continuous monitors show diurnal patterns across sites, with the most prominent peak at each site near 6:00am and a fewer peak hours before midnight. The Adabraka site has consistently higher PM concentrations compared to the University of Ghana (for both PM_{10} and $PM_{2.5}$) and U.S. Embassy (for just $PM_{2.5}$) sites.

Generally, BC concentrations were significantly higher at the Adabraka site than the UG site. BC concentrations at Adabraka site have a bimodal pattern with peaks at 06:00 GMT and 23:00 GMT and a relatively constant concentration over the course of the week. At the UG site, there are muted peaks in concentrations at 06:00 and 22:00 GMT. The hourly variations averaged across days of the week, confirm a bimodal pattern for the Adabraka site and less significantly hourly differences for the UG site. (See below)



B. Gravimetric integrated samplers

Three new gravimetric $PM_{2.5}$ ARA N-FRM of flow rate 16.7 L/min gravimetric integrated samplers and three Airmetrics MiniVol (5.0 L/min) provided by EPA were deployed at Adabraka, University of Ghana and Dansoman air monitoring sites. Each of the gravimetric samplers collect $PM_{2.5}$ on both Teflon and quartz filters. These samplers are deployed to collect 24-hour sample every six (6) days, and the filters collected, stored, and analyzed in the laboratory at EPA to identify metallic, organic, and ionic species collected. These activities will provide datasets with measurements of 24-hour average $PM_{2.5}$ gravimetric mass and elements, ions, and chemical species to be determined via analytical laboratory methods to augment the gravimetric $PM_{2.5}$ and PM_{10} monitors which EPA already has, (efforts) and provide for additional locations and samples for source apportionment measurements of metals, major ion species as well as organic markers.

The integrated gravimetric $PM_{2.5}$ measurements would be achieved using differential total mass measurements on the Teflon filters in a controlled environmental chamber within EPA's laboratory. EPA will utilize quartz filters to analyze the organics portion of the collected aerosol using gas chromatography mass spectrometry (GCMS) methods to quantify specific organic compounds. From the quartz filter analysis, the Agency would quantify targeted alkanes, alkanoic acids, PAHs, Hopanes, and methoxyphenols consistent with current source apportionment practices. Additionally, selected plastic burning tracers would be quantified to assess waste burning emissions contributions.

C. Low-cost sensors

In 2018, EPA deployed ten Clarity Node low-cost sensors (LCS) among other sensors from other institutions in Accra. Most of the sensors are densely located at the city centre. Currently, there are twelve (12) sensors deployed across the Greater Accra Region. With the Reference instrumentation installed and calibrated, EPA would use the newly established monitors to validate the operation, and develop calibration adjustments for low-cost sensors for future deployment in Ghana. The low-cost sensors (clarity node, purple air, and modular air) were collocated with the reference monitor at the UG site and correction factors were developed. Annual average PM_{10} concentrations from the low-cost sensors in 2019 was 37.0 $\mu g/m^3$. Comparatively lower to the gravimetric samplers and continuous monitors which recorded concentrations of 234.0 $\mu g/m^3$ within the same period.

D. QA/QC Protocols

Continuous monitors

The two (2) new monitoring sites located at the University of Ghana, and Adabraka, house the T640 PM monitor, the AE33 aethalometer for BC, meteorological instruments, and gravimetric samplers. Siting is an important consideration in the acquisition of air quality datasets, as the validity of the conclusions is dependent upon the representativeness of the sample. These sites were selected based on EPA's monitoring objectives, and the ability to collect representative air quality samples on the appropriate spatial scale. The following guidelines were considered in the choice of these monitor site locations: populated areas with high pollution; areas on the periphery of the region to understand the quality of air entering the region (to analyze background concentrations); to evaluate progress made in attaining the desired air quality to evaluate implemented control strategies (US EPA, 2017).

Monitors are housed in air-conditioned shelters to prevent their exposure to weather conditions. Various Standard Operation Procedures (SOPs) and Quality Assurance Project Plans were followed during monitor installations, calibrations, and troubleshooting. Training of EPA and UG technical staff was conducted to achieve the needed assurances and controls. The air quality instruments will be calibrated and operated in accordance with the USEPA's draft SOP for the T640 and STI's internally generated SOP for the AE33. Calibration of the T640 will include pressure sensor calibration, temperature sensor verification, flow calibration (of both the sample and bypass flows), a leak check, and SpanDust™ calibration. Calibration of the AE33 will include a leak check, a flow calibration, and a calibration of the optical sensor using the Neutral Density Optical Filter kit.

Gravimetric samplers

ARA N-FRM and TAS MiniVol samplers would be set at flow rates of 16.7 L/min and 5 L/min respectively, to meet the US-EPA operational specifications for PM_{10} and $PM_{2.5}$ air sampling.

All critical air sampling parameters (flow rate, temperature, barometric pressure, wind speed, wind direction, relative humidity, and accumulated volume) are to be continuously monitored and logged as time indexed 5-min averages to validate the sample. ARA N-FRM and TAS MiniVol samplers use Teflon-coated glass and pure quartz filters respectively. To maintain flow and run efficiently of ARA, filters with a maximum pressure drop (with a clean filter) of 30 cm H_2O column at 16.67 L/min clean air flow should be used. The right timer settings should be ensured. Support lithium batteries should be installed to ensure that the monitors operate effectively when AC power is off.

In conformance with US-EPA guidance, the ARA N-FRM Samplers would be calibrated yearly using an ARA FTS Flow Calibrator.

Filter handling

Filters should be held in aluminum filter holders manufactured for a tight seal with no contamination of the filter media. The filter holder is designed to use common EPA specified 47mm cassettes for $PM_{2.5}$ sampling. The filter cassettes are cleaned of dust before use.

Lab analysis

CU-Boulder Organics Extraction Procedure Using Dichloromethane (DCM) provides stepwise procedures used for methylene chloride (DCM) organics extraction on quartz filters for $PM_{2.5}$. The extraction procedure involves preparations of various chemicals and tools, preparation and labeling, rinsing of laboratory wares, spiking the samples with internal standards, extraction and first blow-down, and final blow-down and transfer to GC/MS vials. Samples are analyzed for organics, inorganics and metals using GCMS, Ion chromatograph and AAS or metallizer. Lab filter analysis form is used to request for type of analysis.

Low-cost sensors

Calibration

The low-cost sensors would be collocated for a minimum of two weeks at the UG and Adabraka sites in order to capture a range of concentrations and meteorological conditions for the development of the correction factors.

(vi) Data management systems

Continuous monitors

All measurements would be logged on a Campbell Scientific CR1000X datalogger at averaging intervals of one-, five-, and 60-minutes. The data would be automatically transmitted to STI by accessing the CR1000X using LoggerNet via a cellular modem. Once data is on STI's servers, raw data would be archived and ingested into the AirNow-International database. Currently, data is stored in Campbel Scientific cloud system pending the availability of USEPA Air Now cloud system.

Gravimetric integrated samplers

Data is stored in the Environmental Quality Department database system for further analyses using Microsoft Excel.

Low-cost sensors

Data is stored in Clarity Movement cloud and assessed as CSV file with permission from the Movement. The data is analyzed using R-studio.