World Health Organization

# Ambient air pollution and health in Accra, Ghana

Pierpaolo Mudu

WHO URBAN HEALTH INITIATIVE

ACCRA METROPOLITAN ASSEMBLY

ENVIRONMENTAL PROTECTION AGENCY, GHANA

Ghana Health Services
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TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

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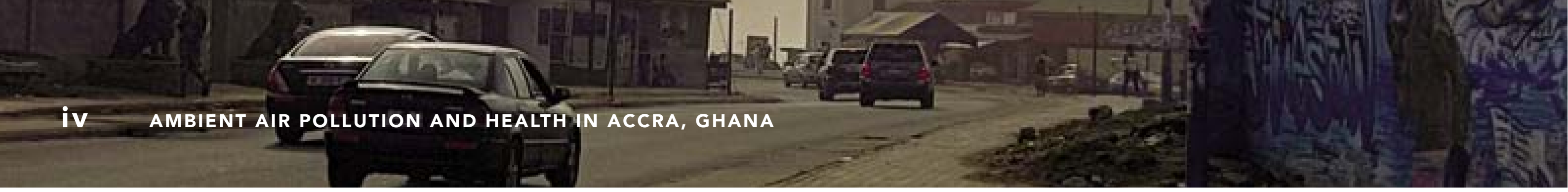




# FOREWORD

The business of protecting the citizens of Ghana from environmental risks represents a fundamental challenge for many of us. The Ghana Environmental Protection Agency (EPA-Ghana) works to accelerate sustainable development by 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 and impact negatively on climate change. EPA-Ghana recognizes pollution as both an environmental and social problem that leads to a multitude of adverse effects on human health, ecosystems and the climate. Today, air pollution is one of the biggest environmental threats to public health in Ghana, shortening the lives of tens of thousands of citizens each year. The Ghanaian public often express concerns about the health effects associated with exposures to air pollution, but are sceptical about the level of understanding and evaluation of the existing risks. EPA-Ghana has dedicated significant resources to monitor and control air pollution in the country, and the progress made to date has been remarkable, but there remains much to do. Although we have a better control of the risks which constitute a major public health threat, the need to strengthen our existing capacity and strategies remains.

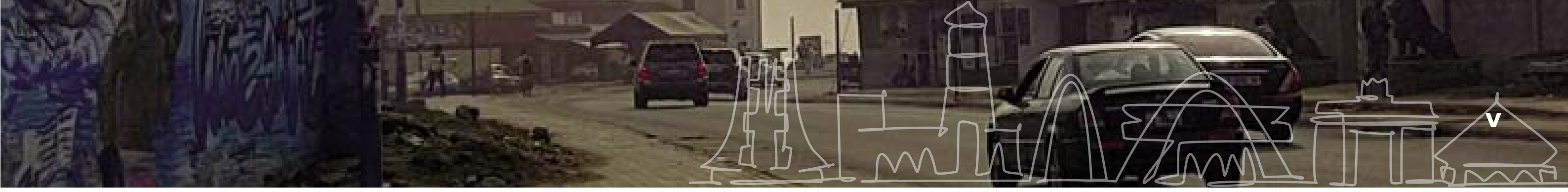
This report has come at an opportune time as it provides a direction for our country to take regarding how policies should respond to the challenge of tailoring interventions to mitigate the environmental and health threats that we face. A critical part of our ability to inform citizens about the risks of air pollution, resides in refining the scientific base underlying risk assessment. Organizing our policies based on a functional response, guided by the latest evidence, rather than responding reactively to emergencies, is a necessary goal to focus our actions.

We know that the effects of air pollution on human health are particularly serious for those who are already vulnerable because of their age or pre-existing health problems. This report indicates the substantial gains to be made in public health resulting from improvements in air quality for the population of Accra. Reductions in premature mortality, morbidity and increased average life expectancy are fundamental targets to be incorporated in the work of the environmental sector in collaboration with public health actors including the Ghana Health Service, School of Public Health and the Environmental Health Division of the District Assemblies among others.

This report is not simply a set of analyses and suggestions, but provides a valuable aid to decision-makers grappling with decisions on how much to invest in air pollution reduction policies. This report therefore provides useful expert guidance to inform those decisions.

We are thankful to the World Health Organization for this timely and concise report.

**Emmanuel Appoh**
Head/Environmental Quality Department
Ghana Environmental Protection Agency





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The preliminary results of the analysis were presented at the Accra Metropolitan Assembly in August 2018, at the session on "Understanding the impacts of air pollution on health – enhancing actions for improving air quality in GAMA", within the US Environmental Protection Agency Megacities, Climate and Clean Air Coalition (CCAC), Urban Health Initiative (UHI), World Bank Joint Workshop Series.

This work was supported by the Climate and Clean Air Coalition through the grant provided for the Urban Health and SLCP Reduction project in Accra.

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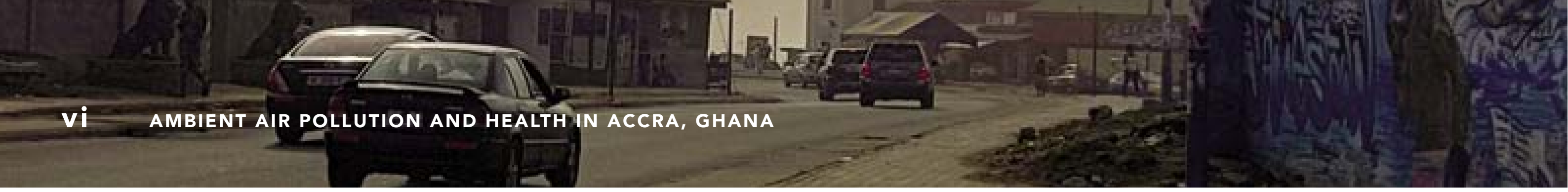
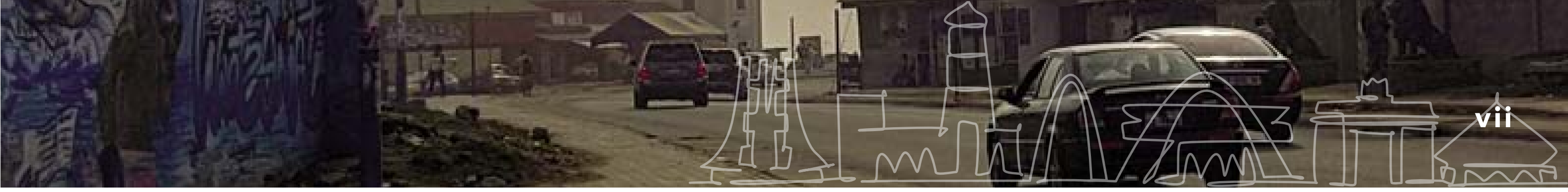



# ABBREVIATIONS

| | |
|---|---|
| ALRI | acute lower respiratory infection |
| AMA | Accra Metropolitan Assembly |
| AQG | Air quality guidelines (WHO) |
| ASDR | age-specific death rates |
| BRT | bus rapid transit |
| CAMS | Copernicus Atmosphere Monitoring Service |
| CCAC | Climate and Clean Air Coalition |
| CI | confidence interval |
| CO | carbon monoxide |
| COPD | chronic obstructive pulmonary disease |
| CVD | cardiovascular disease |
| DALY | disability-adjusted life year |
| GAMA | Greater Accra Metropolitan Area |
| GBD | Global Burden of Disease |
| IER | integrated exposure response |
| IHD | ischaemic heart disease |
| NCD | noncommunicable disease |
| $NO_2$ | nitrogen dioxide |
| $O_3$ | ozone |
| PM | particulate matter |
| QBS | quality bus system |
| RR | relative risk |
| SES | socioeconomic status |
| $SO_2$ | sulfur dioxide |
| UHI | Urban Health Initiative |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| USAID | United States Agency for International Development |
| WHO | World Health Organization |
| WMO | World Meteorological Organization |
| YLL | years of life lost |





# EXECUTIVE SUMMARY

The aim of this report is to estimate the impact of air pollution on health in Accra, Ghana.

Accra is a city that has grown enormously in the last decades. According to the last available census, in 2010, the total population of the Greater Accra Metropolitan Area (GAMA) was approximately 4 million, including 1.85 million in the city of Accra.

The levels of air pollution are affected by seasonal variation. In particular, during the dry season (November-March) there are high peaks due to desert dust. Nevertheless, throughout the year, anthropogenic sources of air pollution are responsible for keeping average values high and for serious health impacts. Data on air pollution were gathered from different sources, including official monitoring stations and satellites. For the health risk assessment, two values were collected and considered:

- for the city of Accra: $PM_{10}$ average equal to 81.1 µg/m$^3$ (converted into $PM_{2.5}$ 49.47 µg/m$^3$ mean concentration value), from residential monitoring stations in 2014–2015; and
- for the whole Greater Accra region: $PM_{2.5}$ average equal to 36.02 µg/m$^3$, from satellite data from 2014 and 2015.

Population data were taken from the 2010 census. Data on mortality were also available from the Ghana Statistical Services, but more detailed health statistics, such as cause-specific mortality or hospitalization data, were unavailable. Different scenarios were run to estimate the impact of air pollution. Scenarios included analysis of reduction of current levels to reach WHO Air quality guidelines (AQG) ($PM_{2.5}$ = 10 µg/m$^3$) and interim targets ($PM_{2.5}$ = 15 µg/m$^3$; $PM_{2.5}$ = 25 µg/m$^3$; $PM_{2.5}$ = 35 µg/m$^3$) and a 10% reduction of current $PM_{2.5}$ levels.

In summary, the scenario estimates produced the following outputs:

- There are several data issues, both for air pollution and health data. Mortality data from official sources for adults are probably underestimated. Cause-specific mortality data are not available at city level. Nevertheless, some estimates for cardiovascular disease (CVD) can provide an idea of the relevance of ischaemic heart disease (IHD).
- Levels of air pollution in Accra are significantly high and concentrations of $PM_{2.5}$, on average, after conversion from $PM_{10}$ from ground monitoring stations, are approximately 49.47 µg/m$^3$.
- Levels of air pollution in Greater Accra are high and concentrations of $PM_{2.5}$, on average, from satellite modelling, are approximately 36.02 µg/m$^3$.

- According to the last census, in 2010, the population of the city of Accra is nearly 1.85 million, with that of GAMA at 4 million. Projections estimate the population in 2030 at around 2.9 million for the city of Accra and 6.3 million for GAMA.

- In Greater Accra, the 2015 levels of air pollution – in excess of those recommended by the WHO AQG will be responsible over a period of 10 years for almost 70 000 years of life lost in the adult (25+) population.

- Various scenarios of air pollution reduction indicate that reaching WHO AQG could potentially prevent 1790 deaths annually in Greater Accra.

- Household air pollution is an issue due to the significant use of solid fuels.

The conclusion outlines a number of recommendations, focusing on:

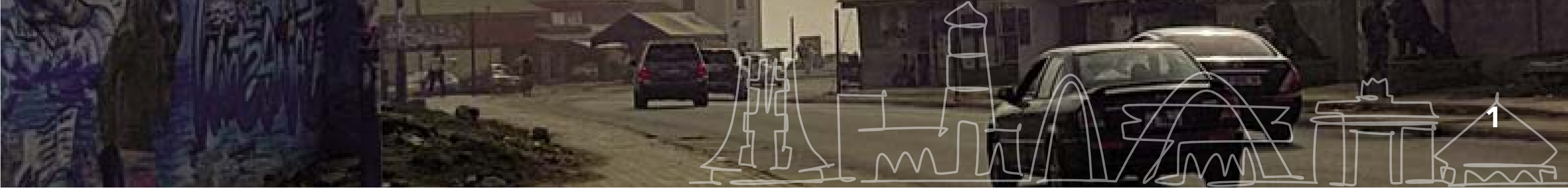
- monitoring stations network;

- collection of health statistics;

- availability of data to the public;

- air quality standards; and

- measures to be taken to decrease exposure levels.



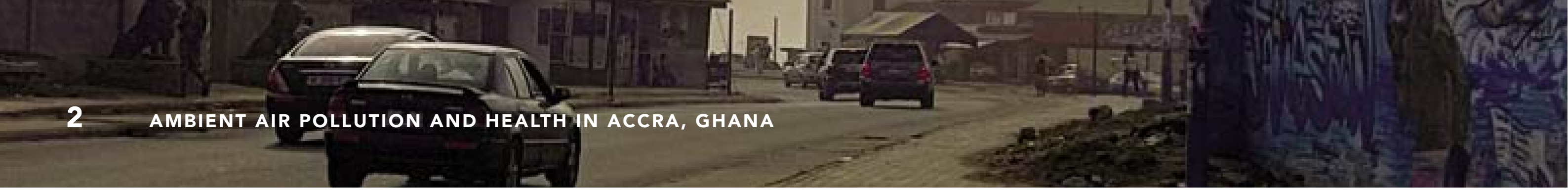


# 1. INTRODUCTION

The aim of this report is to estimate the impact of air pollution on health in contemporary Accra, Ghana.

Accra is a city that has experienced rapid urbanization with evident urban sprawl (Grant, 2009; Codjoe et al., 2014). Overall, the total population of Greater Accra (4 010 054) is mainly urban (3 630 955) rather than rural (379 099) (Ghana Statistical Services, 2012). In 2011, the estimated population living in slums, within the Accra Metropolitan Assembly (AMA) boundaries, made up 38.4% of the population, occupied 15.7% of the land, and had a population density of 608 people per hectare (UN-Habitat, 2011). The diffusion of slums has been a feature of the development of Accra and some neighbourhoods, such as Nima, Old Fadama and Old Tulaku, have been investigated in detail (Owusu et al., 2008; Stacey, 2019; Tutu and Stoler, 2016).

The levels of air pollution are of concern for public health (Odonkor and Mahami, 2020). Several sectors contribute to generate levels significantly higher than those recommended by WHO Air quality guidelines (AQG) (WHO Regional Office for Europe, 2006).



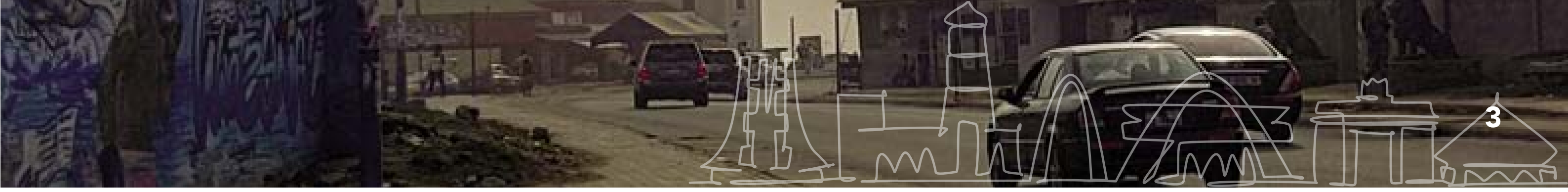


# 2. LEGAL FRAMEWORK

The main laws that govern air quality in Ghana are the Environmental Protection Agency Act 1994 (Act 490), and the Environmental Assessment Regulations 1999 (LI 1652), which regulates industrial activities. Ghana published standards for Environment and Health Protection – Requirements for Ambient Air Quality and Point Source/Stack Emissions (GS 1236) in 2019, and for motor vehicle emissions (GS 1219) in 2018.

New regulations to protect public health and the environment are about to be finalized and due to be passed by Parliament by the end of 2020. In 2018 and 2019 the Ghana Environmental Protection Agency (EPA-Ghana)[1] published the Air Quality Management Plan and associated communication plan for the Greater Accra Metropolitan Area (GAMA) to be adopted by the authorities. These regulations and legislation draw inspiration from Articles 36 (9) and 41 (k) of the National Constitution, which place responsibility for environmental protection on both the state and the citizens.

[1] Throughout the text the acronym EPA-Ghana instead of Ghana-EPA has been adopted, due to the similarity with GEPA – Ghana Export Promotion Authority.




# 3. AIR POLLUTION: DATA SOURCES

For decades, air pollution was usually monitored via ground stations and occasionally with mobile devices. The last two decades have experienced a revolution in the measurement of air pollution data due to the refinement of satellite technology and the availability of low-cost devices. Knowledge of air pollution levels is fundamental to protect public health. In this section we will discuss the availability of data for Accra and the indication they give on the exposure of people.

## 3.1 Source of data: official monitoring stations

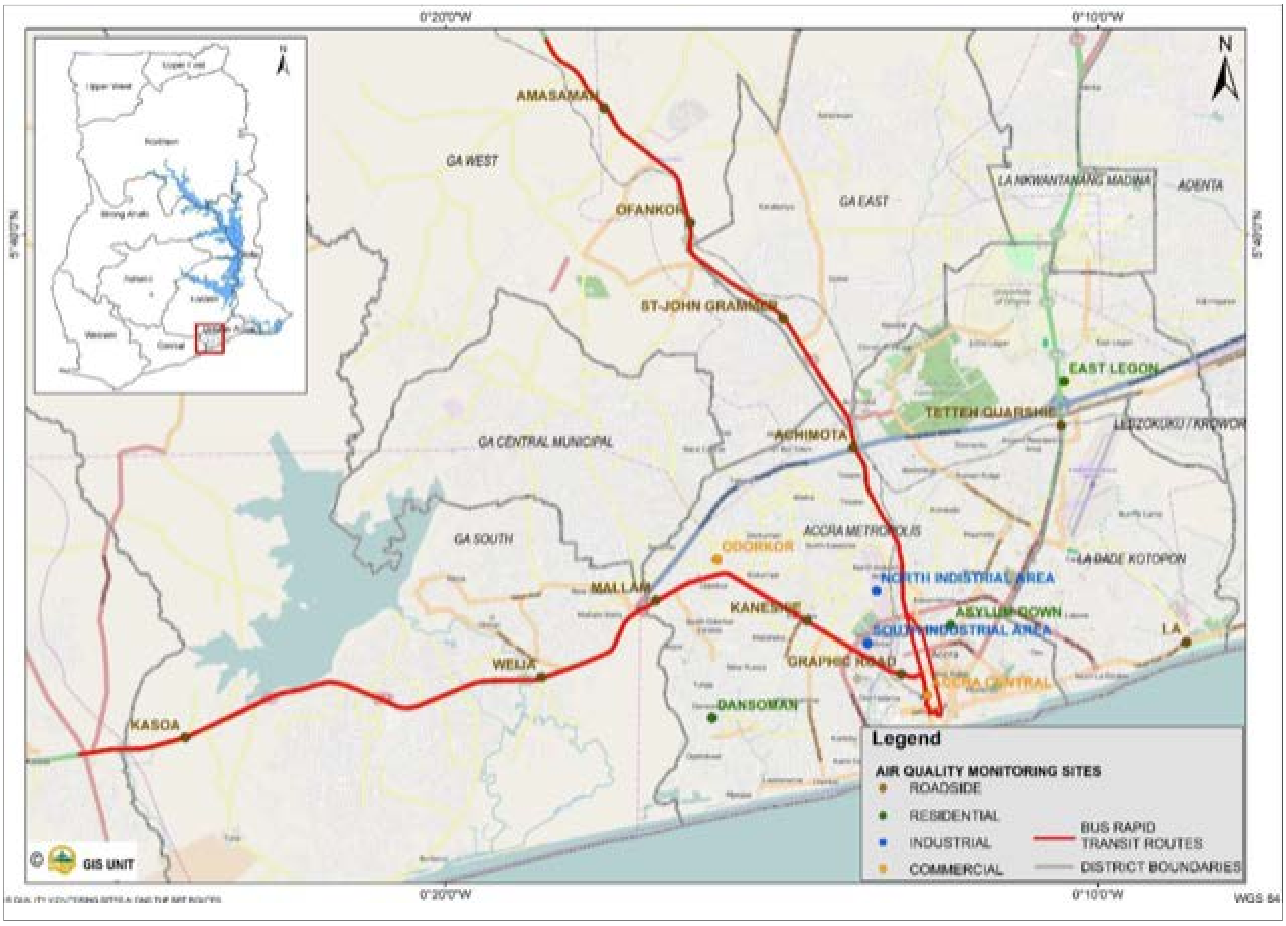
Ghana started collecting and reporting air pollution data in 1997 (Nerquaye-Tetteh, 2009) and has since continued through close collaboration with international bodies. In July 2004, the US Environmental Protection Agency (US EPA), United States Agency for International Development (USAID) and the United Nations Environment Programme (UNEP) selected Accra as one of two cities in Africa to benefit from an air quality monitoring capacity building project which was implemented in 2005. The monitoring campaign produced data that were made public (Nerquaye-Tetteh, 2009). The observations during the dry season (November to March) show a huge increase in $PM_{10}$ due to desert dust; there is a substantial difference between the dry season and the wet season (April to October). In the dry season, the winter average monthly estimates of concentrations are around 100 μg/m$^3$ and in January 2007 and January 2008 concentrations were close to or even exceeded 400 μg/m$^3$ (Nerquaye-Tetteh, 2009).

Overall, data on air pollution in Accra are not easily accessible, though it has to be recognized that Accra is in a better position compared with other African cities, because of the existence of a long tradition of measurements and analysis of air pollution data (Schwela, 2012). Currently, the official EPA-Ghana website for Accra does not report data on ambient air pollution. Nevertheless, some data have been shared and thanks to EPA-Ghana some values have been made available for this project (see Fig. 3.1 and Tables 3.1 and 3.2).

In 2012, there were 11 active monitoring sites:

- residential (3)
- commercial (2)
- industrial (2)
- roadside (4).

**Fig. 3.1 Accra air quality monitoring sites, 2015**




*Source:* EPA-Ghana.

Roadside stations were also placed along the bus rapid transit (BRT) corridor, which was due to begin service in 2016. Levels of particulate matter $PM_{10}$ along the BRT route were measured and showed extremely high values of exposure for the population. Operating between Accra and Amasaman (20 km north of Accra city), the BRT became a quality bus system (QBS) because it did not meet international standards of having specially designed lanes. It is important to note that a substantial contribution to $PM_{10}$ is from surface road resuspension (i.e. dust resulting, for example, from construction sites and unpaved roads, car tyres and brake pads and by wind erosion processes) not from exhaust emissions, or housing and industrial emissions. More recent data supplied by EPA-Ghana provide just annual means of $PM_{2.5}$ for 2015, 2016, 2017 and 2018 (see Table 3.2). The annual $PM_{2.5}$ data are derived from the 6-day monitoring regimes across the whole year.

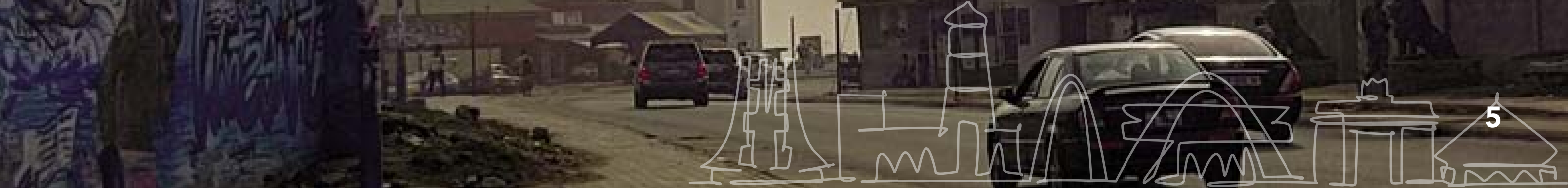




**Table 3.1 $PM_{10}$ measurements: roadside and other monitoring stations, 2012–2015**

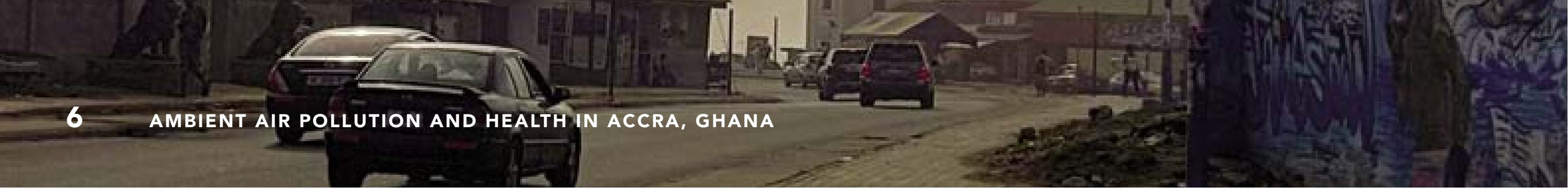
| Monitoring station | 2012 | | 2013 | | 2014 | | 2015 | | Location |
|---|---|---|---|---|---|---|---|---|---|
| | No. (%) of samples collected | Annual mean $PM_{10}$ concentration (µg/m³) | No. (%) of samples collected | Annual mean $PM_{10}$ concentration (µg/m³) | No. (%) of samples collected | Annual mean $PM_{10}$ concentration (µg/m³) | No. (%) of samples collected | Annual mean $PM_{10}$ concentration (µg/m³) | |
| **First Light** | 54/61 (88.5%) | 174 | 53/60 (88%) | 177 | NA | NA | 10/60 (16%) | 180.6 | Traffic |
| **Shangri La** | 57/61 (93.4%) | 151 | 56/60 (93.3%) | 168 | 50/61 (82%) | 170 | 51/60 (85%) | 153 | Traffic |
| **Achimota** | 29/61 (47.5%) | 107 | 44/60 (73.3) | 145 | 49/61 (80%) | 165 | 52/60 (86%) | 143 | Traffic |
| **La Palm** | 55/61 (90.1%) | 150 | 53/60 (88.3%) | 203 | 53/61 (86.9%) | 191 | 14/60 (23%) | 322 | Traffic |
| **Mallam Market** | NA | NA | 55/60 (91.7%) | 198 | 45/61 (73.8%) | 189 | 50/60 (83%) | 148 | Traffic |
| **Graphic** | 56/61 (91.8%) | 178 | 52/60 (86.7%) | 204 | 37/61 (60.7% ) | 187 | 48/60 (80%) | 164 | Traffic |
| **Weija Junction** | NA | NA | 51/60 (85%) | 259 | 34/61 (55.7%) | 251 | 53/60 (88%) | 257 | Traffic |
| **Kasoa** | NA | NA | 43/60 (71.7%) | 168 | 49/61 (80%) | 175 | 43/60 (71%) | 170 | Traffic |
| **Tantra Hill** | NA | NA | NA | NA | NA | NA | 10/60 (16%) | 206 | Traffic |
| **Amasaman** | NA | NA | NA | NA | NA | NA | 10/60 (16%) | 281 | Traffic |
| **Dansoman** | NA | NA | NA | NA | 21/61 (34%) | 67 | 9/60 (15%) | 114 | Residential |
| **North Industrial Area** | 27/61 (44%) | 138 | NA | NA | 27/61 (44%) | 135 | 17/60 (28%) | 85 | Industrial |
| **South Industrial Area** | NA | NA | NA | NA | 22/61 (36%) | 79 | 26/60 (43%) | 89 | Industrial |
| **Odorkor** | NA | NA | NA | NA | 29/60 (48%) | 108 | 12/60 (20%) | 162 | Commercial |

*Source:* Emmanuel Appoh (EPA-Ghana, 2018).

**Table 3.2 Overall annual mean for $PM_{2.5}$ in four Accra metros, 2015, 2016, 2017, 2018**

| Year | Annual mean for $PM_{2.5}$ (µg/m³) |
|---|---|
| 2015 | 78.17 |
| 2016 | 97.39 |
| 2017 | 93.30 |
| 2018 | 79.87 |

*Source:* Emmanuel Appoh (EPA-Ghana).





In September 2016, the World Meteorological Organization (WMO) reported in their *Report of WMO mission to Accra, Ghana related to air quality information services* that:

> *"It has been informed by the head of the EPA-Ghana, Mr. Emmanuel Appoh, that there are 15 monitoring stations available in Accra. Initial 5 are located at permanent sites (Residential, Commercial and Industrial) and collecting data since 2005 whereas the remaining 10 are along major road routes of Accra including the proposed path of Bus Rapid Transit corridors and are highly biased towards transport emissions. The roadside monitoring stations were set-up from 2009–2015). All of these 15 stations are based on traditional high volume sampling (HVS) and Minivol technique of gravitational methodology, which is considered to be outdated. Sampling is roughly 1 data point per day from each station and measures 24-hour average $PM_{10}$. There is a plan to install 2 online analyzers at the University of Ghana and Adabraka in 2020. Some scattered measurements of Ozone, CO and BC exist but they are not sure about them. There is just one Weather station at the Airport in Accra operated by the Ghana Meteorological Agency. The AWS weather measurements are compulsory for any air quality assessment service. The data generated above remains confined to local station and local EPA generates some air quality information with a week lag time using this data in a limited manner. There is no organized mechanism for collation of data and assessing the air quality at common platform due to lack of dynamic communication system and mechanism in place. […]"*

EPA-Ghana, in collaboration with US EPA, is working on an air quality management plan for GAMA. This plan was prepared in 2017, launched in 2018 and due to be implemented for 10 years.

## 3.2 Source of additional data: scientific literature or satellite monitoring

**Research surveys**

Several short-term monitoring campaigns have measured levels of air pollution in specific locations in Accra. For example, levels of PM were measured via four monitoring stations in James Town/Usher Town and Nima in a 3-week period between 30 June 2006 and 20 July 2006 (Arku et al., 2008). The measurements were: $PM_{10}$ 93.6 μg/m$^3$ in James Town and 59.3 μg/m$^3$, 57.9 μg/m$^3$ and 80.7 μg/m$^3$ in Nima; $PM_{2.5}$ 40.2 μg/m$^3$ in James Town and 22.3 μg/m$^3$, 22.7 μg/m$^3$ and 26.6 μg/m$^3$ in Nima.

For 80 households in four study neighbourhoods (James Town/Usher Town, Asylum Down, Nima and East Legon), measurements of 48-hour integrated $PM_{2.5}$ and $PM_{10}$ concentrations were carried out in cooking areas. Over the same 48-hour period, there were continuous measurements of $PM_{2.5}$ in both cooking and living areas. Cooking area PM was the lowest in the high socioeconomic status (SES) neighbourhoods with geometric means of 25 μg/m$^3$ (95% CI: 21–29) and 28 μg/m$^3$ (95% CI: 23–33) for fine and coarse PM ($PM_{2.5}$ and $PM_{2.5–10)}$ respectively (Zhou et al., 2011). Particulate matter levels were highest in the two low SES slums, with geometric means reaching 71 μg/m$^3$ (95% CI: 62–80) and 131 μg/m$^3$ (95% CI: 114–150) for fine and coarse PM (Zhou et al., 2011). After adjustment for other factors, such as smoking or meteorology, living in a community where all households use biomass fuels is associated with 1.5 to 2.7 times higher PM levels in models with and without adjustment for ambient PM (Zhou et al., 2011).

In 2007, a single week of morning and afternoon mobile and stationary air pollution measurements from four study neighbourhoods (one neighbourhood measured in April and three in July-August) produced geometric means of $PM_{2.5}$ and $PM_{10}$ along the mobile monitoring path equal to 21 and 49 μg/m$^3$, respectively, in the neighbourhood with the highest SES; and 39 and 96 μg/m$^3$, respectively, in the neighbourhood with the lowest SES and highest population density (Dionisio et al., 2010). Particulate matter samples were taken between September 2007 and August 2008 in the four neighbourhoods. "During Harmattan, crustal particles accounted for 55 μg/m$^3$ (37%) of fine particle $PM_{2.5}$ mass and 128 μg/m$^3$ (42%) of $PM_{10}$ mass. Outside Harmattan, biomass combustion, which was associated with higher black carbon, potassium and sulfur, accounted for between 10.6 and 21.3 μg/m$^3$ of fine particle mass in different neighbourhoods, with its contribution largest in the poorest neighbourhood" (Zhou et al., 2013). Other results were published with analysis on PM over 22 months with monitors placed at 11 residential or roadside monitoring sites in four neighbourhoods of varying SES and biomass fuel use. Particulate matter concentrations were highest in late December and January, due to dust blown from the Sahara. Excluding this period, annual $PM_{2.5}$ ranged from 39 to 53 μg/m$^3$ at roadside sites and 30 to 70 μg/m$^3$ at residential sites; mean annual $PM_{10}$ ranged from 80 to 108 μg/m$^3$ at roadside sites and 57 to 106 μg/m$^3$ at residential sites. The low-income and densely populated neighbourhood of James Town/Usher Town had the single highest residential PM concentration. There was less difference across traffic sites. Daily PM increased at all sites at daybreak, followed by a midday peak at some sites, and a more spread out evening peak at all sites (Dionisio et al., 2010).

A sampling campaign of air pollution was carried out in Ashaiman (8 km to the north of the Tema commercial centre and about 30 km from central Accra), from February to August 2008. The average $PM_{2.5}$ obtained for the sampling period was 21.6 μg/m$^3$ (Ofosu et al., 2012).

Low-cost sensors were also tested for few days in some studies for carbon monoxide (CO), sulfur dioxide ($SO_2$) and nitrogen dioxide ($NO_2$) (Paulos, et al., 2007). Recently a cross-sectional study was conducted among street traders (vendors/hawkers) operating along selected traffic routes (Amegah et al., 2021).

**Satellite data**

The WMO has made data analysis for the Greater Accra region available to WHO for the period between 1 January 2015 and 31 December 2016 from the Copernicus Atmosphere Monitoring Service (CAMS) global system.[1] The analyses show the contributions of different components of PM (dust, black carbon, organic matter, sulfates) to $PM_{2.5}$ and $PM_{10}$, their concentrations and time variability. Seasonally, dust from the desert dominates, and the highest figures are in the Harmattan season (see Figs. 3.2 and 3.3). Also included in the WMO output are several important gaseous pollutants: CO, $NO_2$, ozone ($O_3$) and $SO_2$.

[1] All concentrations are instantaneous (not time-averaged), covering 3-hour intervals. All the values are in micrograms per m$^3$. The modelled data are based on the "best guess" about emissions from global emission inventories for anthropogenic emissions, and simulated emission intensities for natural emissions depend on meteorological conditions for the corresponding time. These simulations are via the Global C-IFS model, with resolutions of about 40 km. Thus, they can be considered only as space-averaged concentrations for the city area, not for local/street increments. To get higher resolution data other regional models need to be considered.

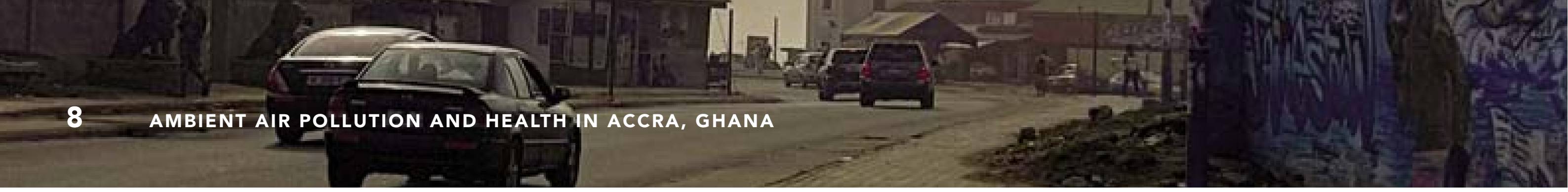
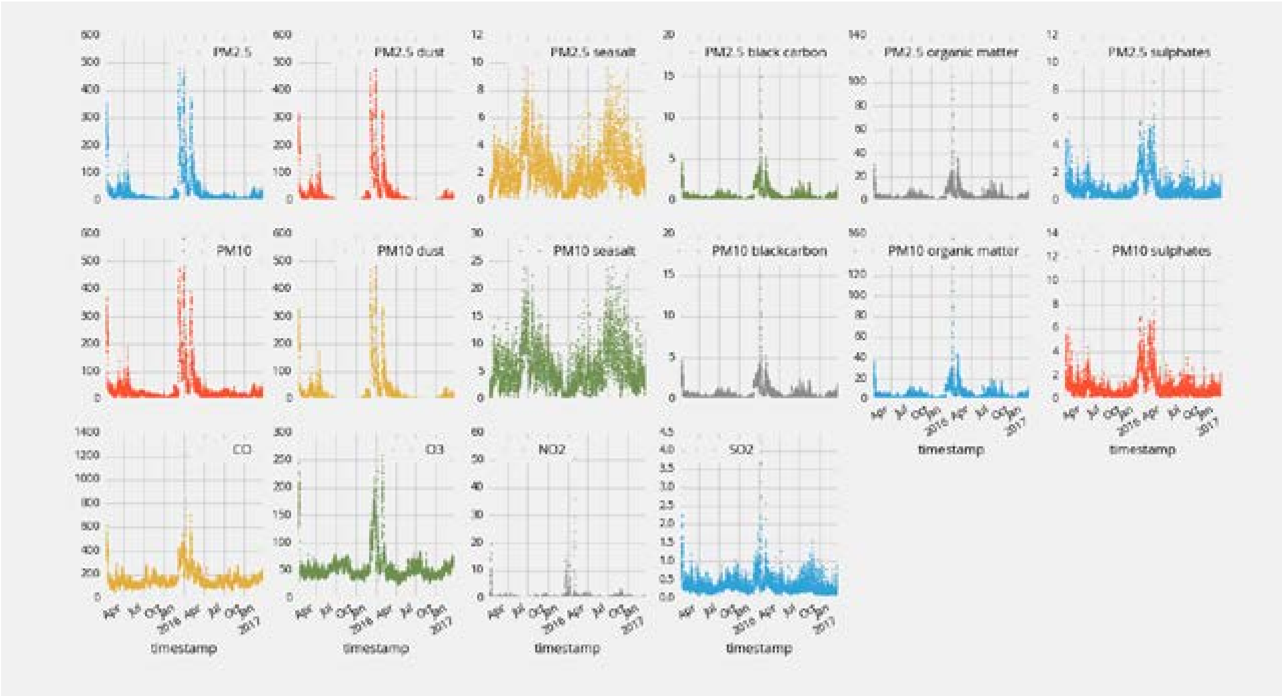


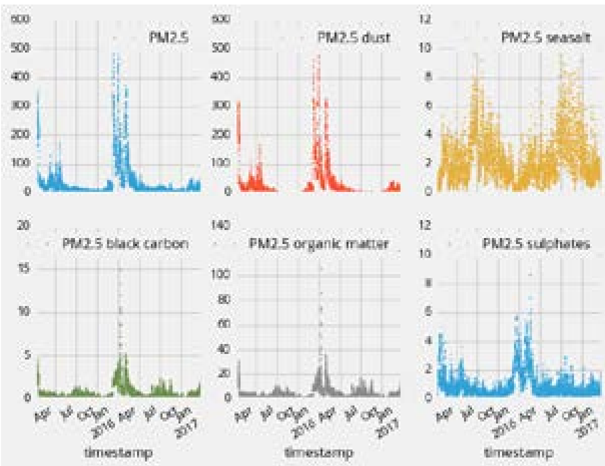


**Fig. 3.2 Greater Accra Region satellite data estimates for the concentrations of PM (and its components), CO, $O_3$, $NO_2$ and $SO_2$, 2015–2016**




*Source:* WMO/GAW SAG-applications, powered by ECMWF and the Copernicus Atmosphere Monitoring Service.

**Fig. 3.3 $PM_{2.5}$ composition detail, January 2015 to December 2015**




In summary, for the extended Accra region, we have some results using hourly concentration data that help us frame the urban situation (see Figs. 3.4 and 3.5).

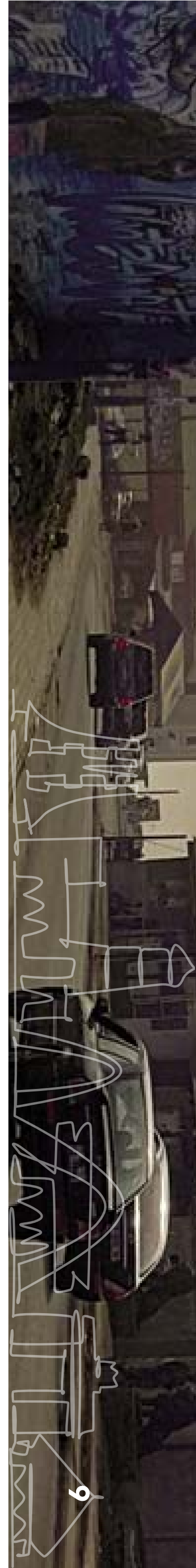


**Fig. 3.4 $PM_{2.5}$ time series of concentration values (red line indicates 20 µg/m³), 2015–2016**

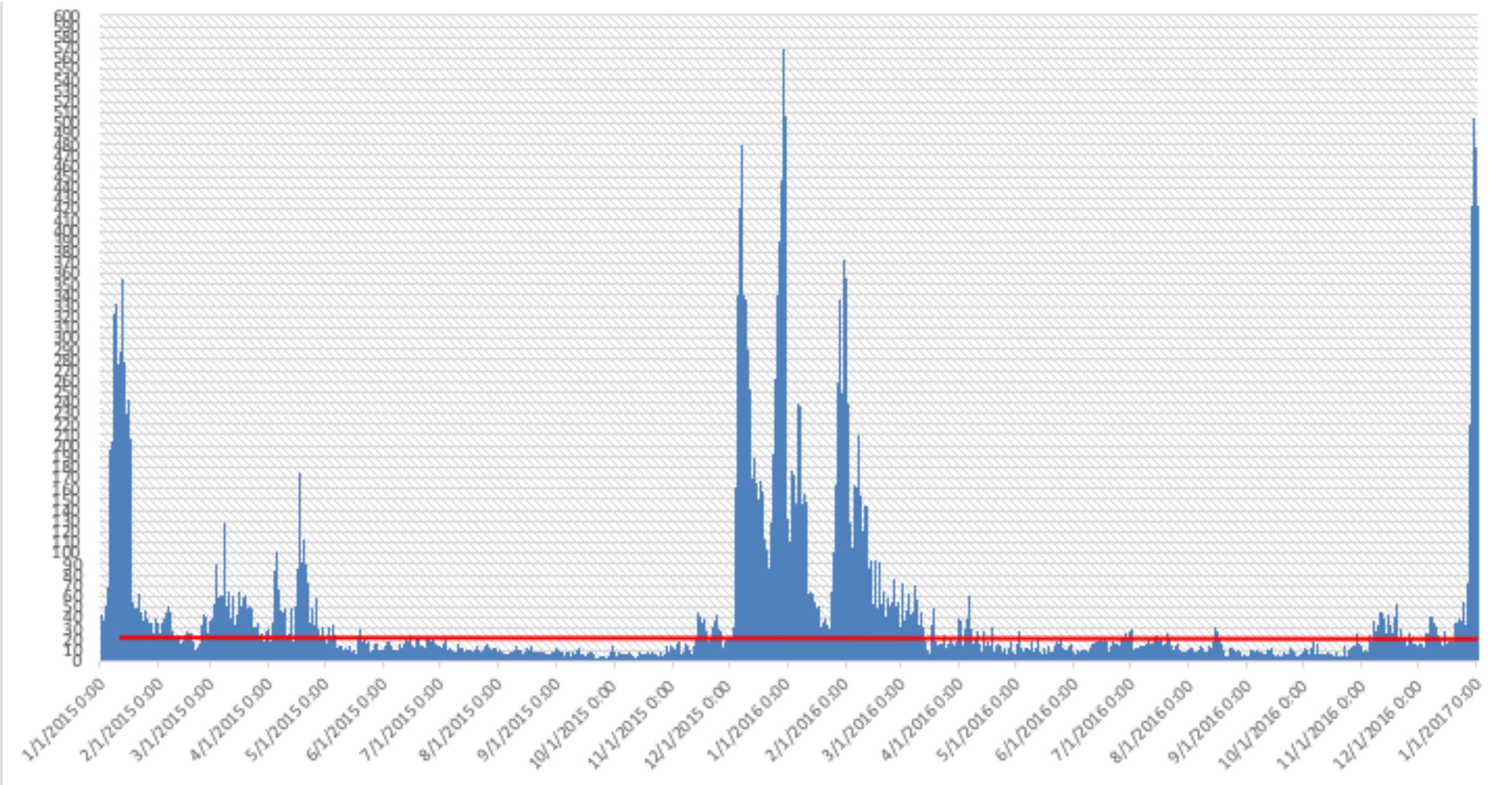
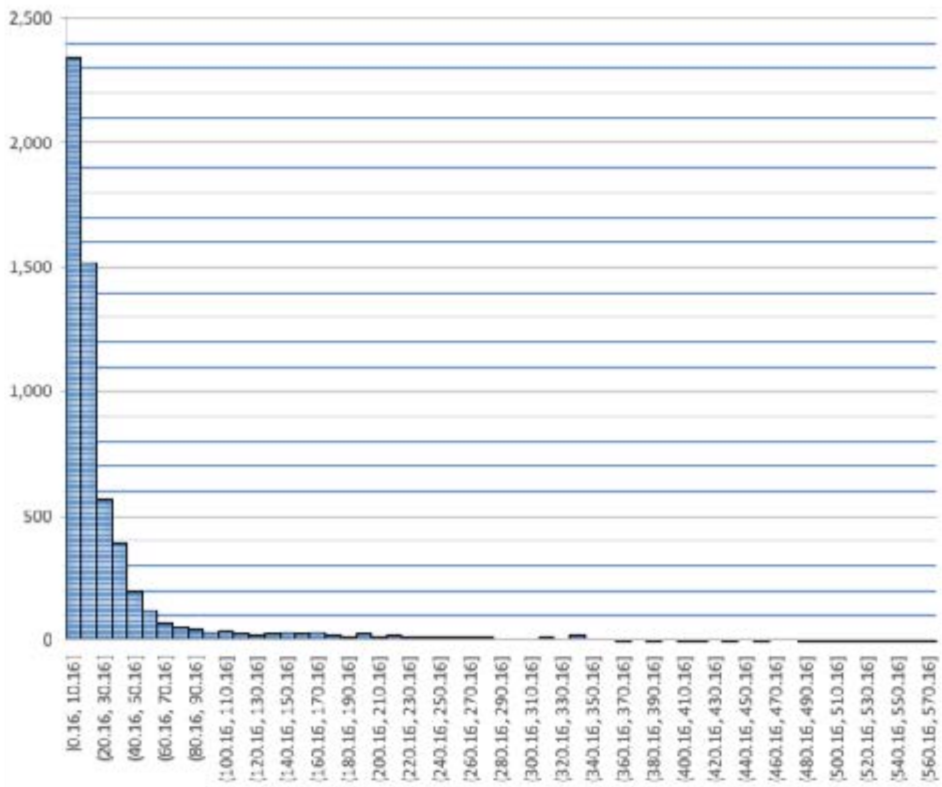
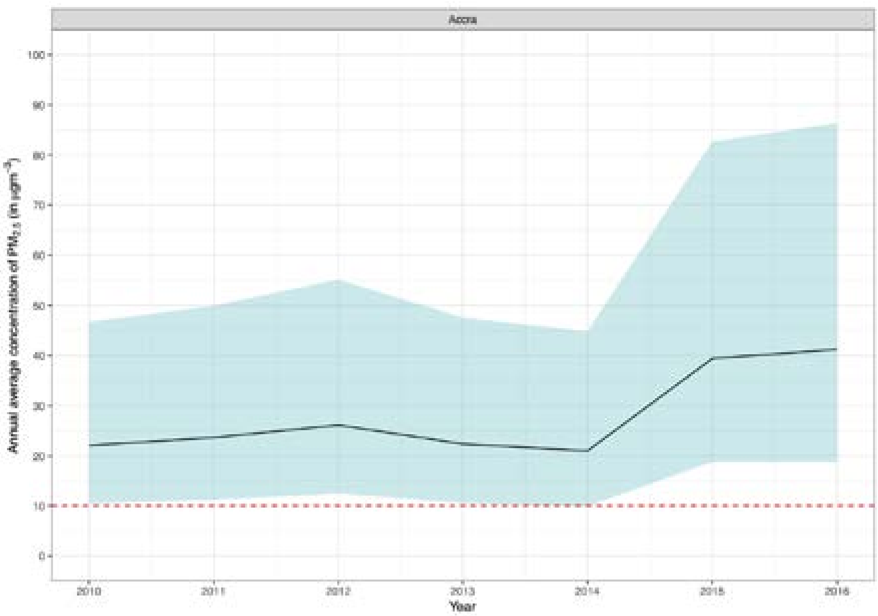


**Fig. 3.5 $PM_{2.5}$ frequency of hourly values, 2015–2016**




Information from the DIMAQ model (Shaddick and Wakefield, 2002) confirms the analysis by WMO regarding $PM_{2.5}$ concentration values – which for central estimates are on average 25–50 µg/m$^3$ (see Fig. 3.6).

**Fig. 3.6 Other sources of data: DIMAQ model $PM_{2.5}$, 2010–2016**

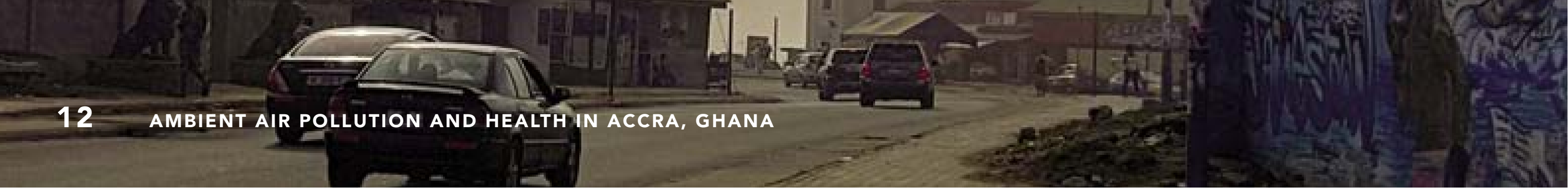



*Source:* G Shaddick (personal communication, February 2019).

Ghana's mountainous topography and the position of Accra are responsible for a slight decrease in air pollution in the Greater Accra region compared with central areas (see Fig. 3.7).

**Fig. 3.7 $PM_{2.5}$ modelled average values in the Accra region, 2016**


*Source:* G Shaddick (personal communication, February 2019).





# 4. SOURCE APPORTIONMENT INFORMATION FOR ACCRA'S AIR POLLUTION

Little information is available on the specific contributions of the most likely sources of air pollution in Accra – vehicular exhaust emissions, industrial emissions, dust, building activities, dumpsites, fires and open burning, domestic heating and cooking. Work is ongoing on source apportionment between EPA-Ghana and US EPA.

In 2012, EPA-Ghana identified the following major sources of air pollution (Fiahagbe, 2012):

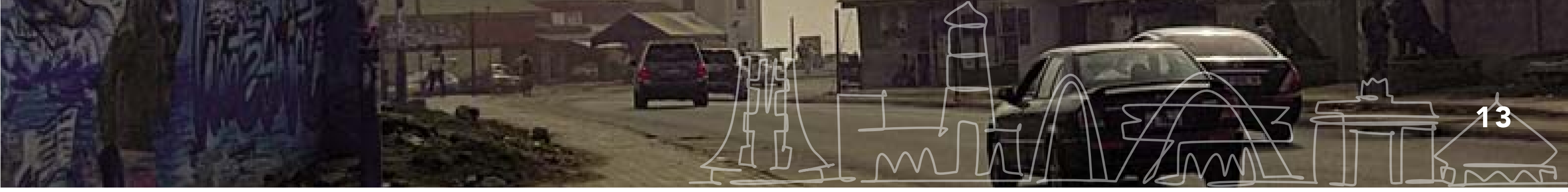
- vehicular exhaust emissions: the largest emitter as a result of old, unmaintained vehicles
- emissions from industrial sources
- open burning of waste and other materials[1]
- road and wind-blown dust
- Harmattan winds.

Emissions from the waste sector accounted for 10% of Ghana's total emissions between 2000 and 2006, and 13.9% by 2010 (UNFCCC, 2015).

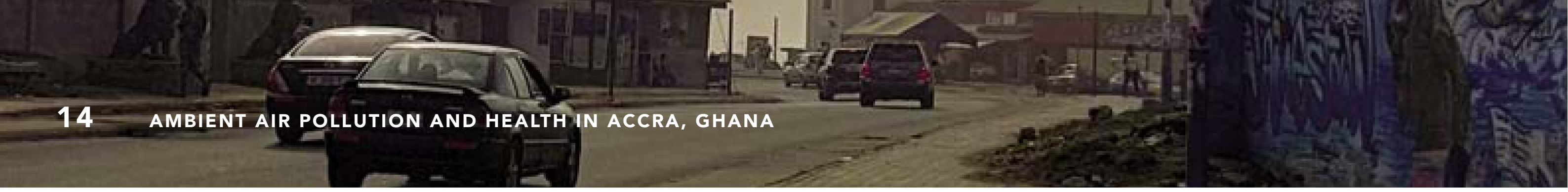
A sampling campaign of ambient air $PM_{2.5}$ mass was carried out in Ashaiman (8 km north of the Tema commercial centre and 30 km east of central Accra), between February and August 2008. Eight sources were identified from the results of the aerosol samples collected: industrial emissions (11.4%), fresh sea salt (15.5%), diesel emissions (18.4%), biomass burning (9.5%), two-stroke engines (5.1%), gasoline emissions (15.8%), aged sea salt (6.2%) and soil dust (17.7%) (Ofosu et al., 2012).

> *"Combustion sources contributed the majority of the ambient $PM_{2.5}$ mass concentrations. Diesel emissions provided the largest single source contributions to ambient air PM values among the eight identified sources. Industrial emissions contributed significantly to air pollution in Ashaiman from the industrial area that lies to the southeast of the sampling location. Biomass burning contributed 9.5% of the average $PM_{2.5}$ mass concentrations and was significant in a suburban community with the ambient air quality primarily influenced by urban heavy vehicular, industrial, and other commercial activities. The soil dust contribution to $PM_{2.5}$ was 18% arising from transported dust as well as re-suspended road and other fugitive dusts. The sea spray contribution was significant as expected for a site located about 10 km from the sea. The relatively high levels of Ca and Zn observed in vehicular emissions have shown the high use of old and less efficient vehicular engines." (Ofosu et al., 2012: 308).*

[1] $CO_2$ emissions from the waste sector accounted for 10% of Ghana's total emissions between 2000 and 2006, and 13.9% by 2010 (UNFCCC, 2015).




"The results highlight that the highest personal $PM_{2.5}$ exposures were for female adult population groups, in households where charcoal was used for cooking. This was followed by female children in those households, and then by male children (…), and finally, male office workers (who were assumed to not take part in cooking)." (Malley et al., 2020). An emissions inventory for Accra is under development by the Stockholm Environment Institute, and it will be modelled with the the Long-range Energy Alternatives Planning – Integrated Benefits Calculator (LEAP-IBC).





# 5. AIR QUALITY AND HEALTH IN ACCRA

If we pose the question: what levels of air pollution are the population of Accra exposed to? We do not have a straightforward answer. Lack of data, discontinuity in measurements, and the absence of an air quality strategy have not helped in the monitoring of air pollution. Nevertheless, the available data and results from surveys indicate without doubt that values exceed WHO AQG, and there are some estimates available which can be used to evaluate the impact of air pollution on health.

## 5.1 Estimated air pollution health impacts in Accra and Ghana – focus on burden

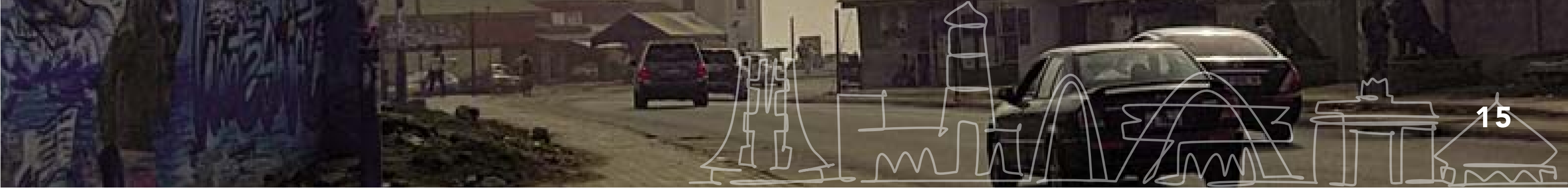
The major urban centres in Ghana are close to the coast, and have a lower contribution from desert dust during the Harmattan season. In fact, the 2016 WHO estimate[1] of the 2012 annual median $PM_{2.5}$ concentration in rural and urban areas is 24 µg/m³, with a slightly lower value in urban (22 µg/m³) than in rural areas. Using the 2012 data, WHO estimated the annual health impacts of ambient air pollution in Ghana (approx. 28 million people) to be 5729 premature deaths, 224 647 years of life lost (YLL) and 229 888 disability-adjusted life years (DALYs) (Table 5.1) (WHO, 2016). However, the assessment was considered to be a "conservative figure", as it does not include the separate impacts of health from other air pollutants, and excludes health impacts where evidence is still limited (e.g. pre-term birth or low birth weight).

**Table 5.1 Ghana: numbers of deaths, YLL and DALYs attributable to $PM_{2.5}$ ambient air pollution, 2012**

| Cause of death | Number of deaths | | | | YLL | | | | DALYs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | F | M | CI | Total | F | M | CI | Total | F | M | CI |
| ALRI | 968 | 450 | 517 | n.a. | 87 880 | 40 887 | 46 994 | n.a. | 88 159 | 41 021 | 47 138 | n.a. |
| COPD | 72 | 33 | 39 | n.a. | 1718 | 747 | 972 | n.a. | 5674 | 2679 | 2995 | n.a. |
| Lung cancer | 75 | 16 | 59 | n.a. | 2304 | 499 | 1805 | n.a. | 2324 | 503 | 1821 | n.a. |
| IHD | 1810 | 853 | 957 | n.a. | 52 610 | 22 515 | 30 095 | n.a. | 53 339 | 22 854 | 30 485 | n.a. |
| Stroke | 2804 | 1676 | 1128 | n.a. | 80 135 | 45 407 | 34 727 | n.a. | 80 391 | 45 531 | 34 860 | n.a. |
| **All** | **5729** | 3028 | 2700 | 3816–7407 | **224 647** | 110 055 | 114 593 | 143 698–295 100 | **229 887** | 112 588 | 117 299 | 146 097–304 536 |

*Notes:* ALRI – acute lower respiratory tract disease; 95% CI – confidence interval; COPD – chronic obstructive pulmonary disease; DALYs – disability–adjusted life years; F – females; IHD – ischaemic heart disease; M – males; n.a. – not available; YLL – years of life lost.

[1] Ambient air pollution: a global assessment of exposure and burden of disease. Geneva: World Health Organization; 2016.





More recent global estimates (not comparable with the 2012 presented above, because of changes in methodology) of the health impacts of ambient air pollution were 11 739 premature deaths, 419 049 YLL and 425 931 DALYs annually. Estimates for specific causes of death are shown in Table 5.2. It has to be considered that these figures are generated using age-standardized population, as well as using the population data from the United Nations World population prospects (WHO, 2016), not the population census source used in the analysis presented in the estimates of health impacts.[1]

The latest WHO estimate (WHO, 2016) of the annual mean $PM_{2.5}$ concentration in the country is 31.9 µg/m$^3$, with a slightly lower mean in urban areas of 31.1 µg/m$^3$ (CI 17.7–64.7) than in rural areas (34.0 µg/m$^3$ CI 20.1–78.0).

**Table 5.2 Ghana: numbers of deaths, YLL and DALYs attributable to ambient air pollution, 2016**

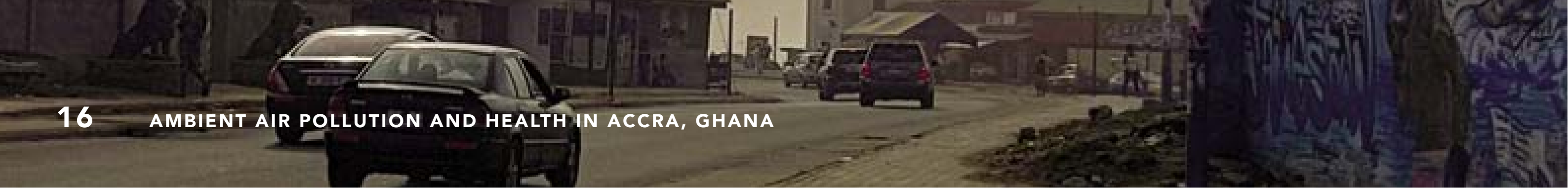
| | 2016 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cause of death | Number of deaths | | | | YLL | | | | DALYs | | | |
| | Total | F | M | CI | Total | F | M | CI | Total | F | M | CI |
| ALRI | 5353 | 2132 | 6411 | 3652–7194 | 251 491 | 103 395 | 148 096 | 171 588–337 991 | 252 019 | 103 617 | 148 401 | 171 948–338 700 |
| COPD | 674 | 345 | 329 | 374–1026 | 15 830 | 8071 | 7758 | 8787–24 118 | 20 040 | 9564 | 10 476 | 11 124–30 532 |
| Lung cancer | 58 | 12 | 46 | 34–84 | 1790 | 378 | 1412 | 1051–2619 | 1814 | 385 | 1428 | 1065–2655 |
| IHD | 3197 | 1970 | 1226 | 2618–3754 | 82 805 | 49 574 | 33 231 | 70 106–95 409 | 83 266 | 49 745 | 33 522 | 70 485–95 925 |
| Stroke | 2458 | 1768 | 690 | 1964–3056 | 67 134 | 46 371 | 20 763 | 56 146–78 817 | 68 793 | 47 440 | 21 352 | 57 529–80 806 |
| **All** | **11 739** | 6227 | 5512 | 9835–13 854 | **419 049** | 207 788 | 211 260 | 330 799–506 372 | **425 931** | 210 751 | 215 180 | 336 844–513 676 |

*Notes:* ALRI – acute lower respiratory tract disease; 95% CI – confidence interval; COPD – chronic obstructive pulmonary disease; DALYs – disability–adjusted life years; F – females; IHD – ischaemic heart disease; M – males; n.a. – not available; YLL – years of life lost.

If Global Burden of Disease (GBD) data are considered, there are some additional points to be made. In the 2010 and 2013 GBD, the counterfactual concentration, that is the concentration level under which no health effects are being calculated in health impact assessment, was selected to be a uniform distribution with lower and upper limits of 5.8–8.8 µg/m$^3$ and 5.9–8.7 µg/m$^3$ respectively; whereas in the 2015 GBD the counterfactual concentration value was selected in the range 2.4–5.9 µg/m$^3$. Note: due to age standardization the national burden estimates for the YLL are overestimated.

In 2016 the mortality rate attributed to household and ambient air pollution for Ghana was estimated by WHO to equal 101 per 100 000 (http://apps.who.int/gho/data/view.main.SDGAIRBOD392v?lang=en). But the completeness of cause-of-death data is a serious challenge for the country. Also, local experts recognize the need to improve epidemiological data collection in relation to air pollution (Amegah and Agyei-Mensah, 2017), given the fact that health endpoints related to air pollution exposure have been rising in the region for many years (Dalal et al., 2011; Codjoe et al., 2014).

[1] *Note:* Due to age standardization, the national burden estimates for YLL are overestimated.





In terms of mortality burden, considering that the population of the Greater Accra region is around 15% of that of the whole country, ambient air pollution burden estimates approximate 1700 deaths annually. In terms of impacts, when considering different counterfactuals levels, the situation is obviously different and though the attributable number of deaths is an indicator of results associated with various scenarios, a life table approach can offer more analytical details.

Tables 5.3–5.5 (mortality due to ambient air pollution, household air pollution, and the joint effect of ambient and household air pollution) summarize the mortality burden estimates in Ghana as of 2016. Again, the figures are generated using age-standardized population as well as using the population data from the United Nations World population prospects (WHO, 2016), not using the population census source used in the analysis presented in the estimates of health impacts. The burden of disease attributable to the joint effects of household and ambient air pollution was estimated based on the calculation of the joint population attributable fractions assuming independently distributed exposures and independent hazards.[1] Estimates for ambient air pollution indicate that the annual burden is approximately 11 739 deaths, that is a rate of 42 per 100 000 population.

**Table 5.3 Ghana: mortality due to ambient air pollution, 2016**

| | 2016 | | | | | |
|---|---|---|---|---|---|---|
| | Ambient air pollution attributable deaths | | | Ambient air pollution attributable death rate (per 100 000 population) | | |
| **Cause** | **Both sexes** | **Male** | **Female** | **Both sexes** | **Male** | **Female** |
| Lower respiratory infections | 5353 (3652–7194) | 3221 (2198–4329) | 2132 (1455–2866) | 19 (13–26) | 23 (16–31) | 15 (10–20) |
| Trachea, bronchus, lung cancers | 58 (34–84) | 46 (27–67) | 12 (7–18) | 0 (0–0) | 0 (0–0) | 0 (0–0) |
| Ischaemic heart disease | 3197 (2618–3754) | 1226 (1013–1436) | 1970 (1594–2323) | 11 (9–13) | 9 (7–10) | 14 (11–16) |
| Stroke | 2458 (1964–3056) | 690 (567–828) | 1768 (1391–2226) | 9 (7–11) | 5 (4–6) | 12 (10–16) |
| Chronic obstructive pulmonary disease | 674 (374–1026) | 329 (183–501) | 345 (1919–525) | 2 (1–4) | 2 (1–4) | 2 (1–4) |
| **Total** | **11 739 (9835–13 354)** | **5512 (4387–6666)** | **6227 (5394–7160)** | **42 (35–49)** | **39 (31–47)** | **44 (38–51)** |

*Source:* WHO, 2016.

Estimates for household air pollution highlight the remarkable information that it is responsible for a burden of 20 988 deaths, corresponding to 74 per 100 000 population (see Annex for an example of calculations of the burden of IHD due to solid fuel use).

[1] WHO (2018). Burden of disease from joint household and ambient air pollution for 2016 (https://www.who.int/airpollution/data/AP_jointeffect_methods_May2018.pdf).

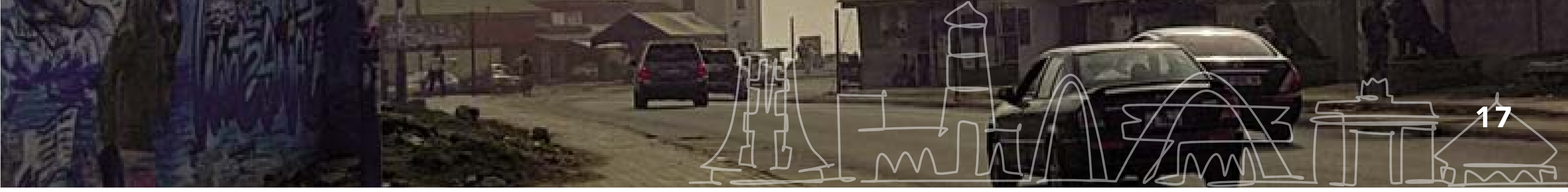




**Table 5.4 Ghana: mortality due to household air pollution, 2016**

| | 2016 | | | | | |
|---|---|---|---|---|---|---|
| | Household air pollution attributable deaths | | | Household air pollution attributable death rate (per 100 000 population) | | |
| Cause | Both sexes | Male | Female | Both sexes | Male | Female |
| Lower respiratory infections | 10 775 (8220–12 977) | 6308 (4789–7731) | 4467 (3443–5296) | 38 (29–46) | 45 (34–55) | 32 (24–37) |
| Trachea, bronchus, lung cancers | 153 (114–187) | 115 (82–144) | 37 (30–44) | 1 (0–1) | 1 (1–1) | 0 (0–0) |
| Ischaemic heart disease | 4581 (3852–5344) | 1644 (1354–1932) | 2937 (2467–3425) | 16 (14–19) | 12 (10–14) | 21 (17–24) |
| Stroke | 4181 (3412–5036) | 1069 (873–1294) | 3112 (2515–3775) | 15 (12–18) | 8 (6–9) | 22 (18–27) |
| Chronic obstructive pulmonary disease | 1298 (842–1677) | 559 (150–887) | 739 (530–902) | 5 (3–6) | 4 (1–6) | 5 (4–6) |
| **Total** | **20 988 (17 758–24 093)** | **9695 (8015–11 397)** | **11 292 (9734–12 781)** | **74 (63–85)** | **69 (57–81)** | **80 (69–90)** |

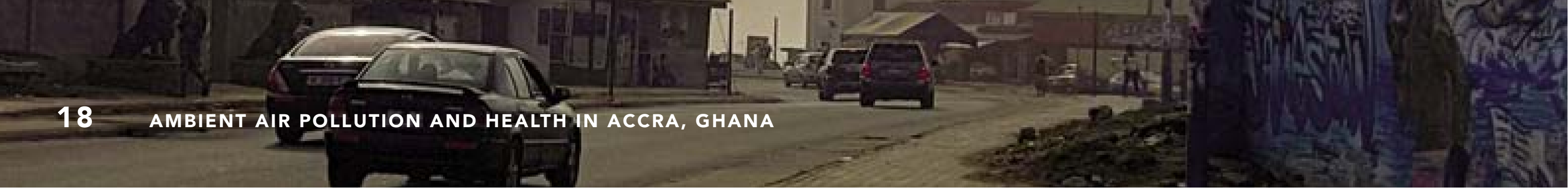
*Source:* WHO, 2016.

**Table 5.5 Ghana: joint effects of ambient and household air pollution, 2016**

| | 2016 | | | | | |
|---|---|---|---|---|---|---|
| | Ambient and household air pollution attributable deaths (per 100 000 population) | | | Ambient and household air pollution attributable death rate (per 100 000 population, age-standardized) | | |
| Cause | Both sexes | Male | Female | Both sexes | Male | Female |
| Lower respiratory infections | 48 (40–55) | 57 (47–66) | 39 (33–44) | 84 (71–96) | 113 (94–130) | 62 (52–70) |
| Trachea, bronchus, lung cancers | 1 (0–1) | 1 (1–1) | 0 (0–0) | 1 (1–2) | 2 (2–3) | 1 (0–1) |
| Ischaemic heart disease | 25 (21–28) | 18 (16–21) | 31 (27–35) | 56 (49–64) | 46 (40–53) | 64 (56–73) |
| Stroke | 21 (18–25) | 11 (10–13) | 31 (27–36) | 48 (41–55) | 27 (23–31) | 64 (54–74) |
| Chronic obstructive pulmonary disease | 6 (4–7) | 5 (3–7) | 6 (5–7) | 14 (11–17) | 15 (8–21) | 14 (11–16) |
| **Total** | **101 (91–112)** | **94 (82–105)** | **109 (99–119)** | **204 (183–225)** | **203 (179–227)** | **204 (184–224)** |

*Source:* WHO, 2016.

The evidence from studies of direct effects of dust events on health suggest an increase of risk for cardiovascular disease (CVD) mortality and for morbidity due to respiratory causes and child-hood asthma (WHO systematic review by IDAEA, unpublished).



# 6. AIRQ+ ESTIMATES OF HEALTH IMPACTS: INPUT DATA

The estimates of air pollution impacts on health have been calculated using the AirQ+ WHO software, available online for download.[1] All the estimates are based on published official data. $PM_{2.5}$ (or $PM_{10}$) is the traditional measure for estimating the health impact of air pollution. For health impact calculations, the average value for $PM_{2.5}$ converted from $PM_{10}$ measurements between 2010 and 2015 was used. An average annual value of outdoor levels of particles is usually recognized as a primary exposure measure.

## 6.1 Air pollution concentration values

Two values, based on the analysis of available collected data, can be considered:

- for the city of Accra: $PM_{10}$ from residential monitoring stations
- for the whole Greater Accra region: $PM_{2.5}$ from satellite data.

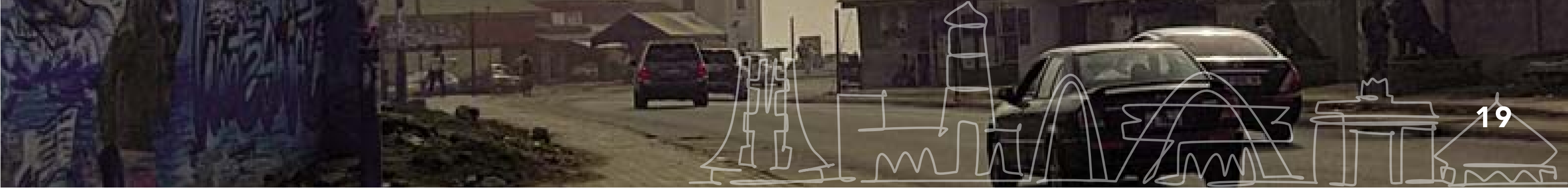
For $PM_{10}$ in 2014–2015 the monitoring stations produced measured values that were on average equal to 81.1 µg/m$^3$.[2] If a conversion factor to $PM_{2.5}$ of 0.61 is applied (Zhou et al., 2013), we have the results of 49.47 µg/m$^3$ mean concentration value. 36.02 µg/m$^3$ is the mean for $PM_{2.5}$ along 2 years of measurements (2014–2015), from the modelled satellite data. For calculations, both values – ground monitoring estimates for Accra and satellite estimates for Greater Accra – were used. The different values produced by ground monitoring stations and satellite data are probably due to an overestimation of the air pollution values by the monitoring stations and underestimation of satellite measures. In Accra, a 6-day monitoring regime that includes the collection of data on Saturdays and Sundays is in force (Table 3.1). This ensures that at least 62 data sets per annum would be generated at a particular monitoring location.

## 6.2 Air pollution exposure

Identifying a value for PM representative for the exposure of the population to air pollution is not an easy task. If we exclude data from roadside monitoring stations, there are not many available data. One monitoring station is located in the residential area of Dansoman and can provide an indication of the exposure of the population in Accra. In 2014 and 2015 the annual mean of $PM_{10}$ (µg/m$^3$) levels from the monitoring station of Dansoman were 67 and 114, respectively. But the number of samples collected was only 31% (21/61) and 15% (9/60) respectively. If we take an average weighted

[1] AirQ+: software tool for health risk assessment of air pollution. In: WHO Regional Office for Europe [website]. Copenhagen: WHO Regional Office for Europe; 2019 (http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/airq-software-tool-for-health-risk-assessment-of-air-pollution).

[2] From EPA-Ghana raw data and Table 3.1 in this report, considering the whole dataset, produces an average for $PM_{10}$ = 172.3 µg/m$^3$.





value of $PM_{10}$ equal to 81.1 μg/m³ and convert it, using 0.61, i.e. the value used by EPA-Ghana and close to the highest value reported for the $PM_{2.5}/PM_{10}$ ratio (Zhou et al., 2013), we obtain 49.47 μg/m³ for $PM_{2.5}$. This average value of $PM_{2.5}$ is higher than the value reported by Arku et al. for $PM_{2.5}$ (40.2 μg/m³) in James Town and in three sites in Nima (22.3, 22.7 and 26.6 μg/m³) (Arku et al., 2008). In this situation of uncertainty regarding $PM_{2.5}$ values we decided to use 49.47 μg/m³, which is also comparable to the upper limit of the $PM_{2.5}$ value estimated for urban Ghana from WHO estimates (WHO, 2016).[1] In 2005–2008, $PM_{10}$ levels in residential areas were 61.0 μg/m³ in the wet season and 150.0 μg/m³ in the dry season (EPA-Ghana).

## 6.3 Population exposed

According to the 2010 census (Table 6.1), the population of the city of Accra was 1 848 614 (531 719 for children 0–14; 1 243 884 for ages 15–64; and 73 011 for age 65+).[2] The population in Greater Accra was 4 010 054 (3 630 955 and 379 099, urban and rural); 0–14: 1 253 632 (1 110 726 and 142 906, urban and rural); 15–64: 2 614 312 (2 393 471 and 220 841 urban and rural); and 65+: 142 110 (126 758 and 15 352 urban and rural).

The age structure shows that the young population, age groups 20–24 and 25–29 years, form the highest proportion. These figures are expected because of the fertility rate and a rather significant presence of migrant workers.

**Table 6.1 Greater Accra region population by metropolitan, municipal and district assemblies, 2010**

| | | Metropolitan, municipal and district assemblies | Population |
|---|---|---|---|
| Greater Accra Region | Greater Accra Metropolitan Area | Accra Metropolitan District | 1 665 086 |
| | | Tema Metropolis | 292 773 |
| | | Adenta | 78 215 |
| | | Ga East | 147 742 |
| | | Ga West | 219 788 |
| | | Ga South | 411 377 |
| | | Ga Central | 117 220 |
| | | La Nkwantang-Madina | 111 926 |
| | | Ledzokuku-Krowor | 227 932 |
| | | Ashaiman | 190 972 |
| | | Kpone-Katamanso | 109 864 |
| | | La dade-Kotopon | 183 528 |
| | | Sub-total | 3 756 423 |
| | | Ningo-Prampram | 70 923 |
| | | Ada West District | 59 124 |
| | | Shai Osudoku | 51 913 |
| | | Ada East | 71 671 |
| | | **Total** | **4 010 054** |

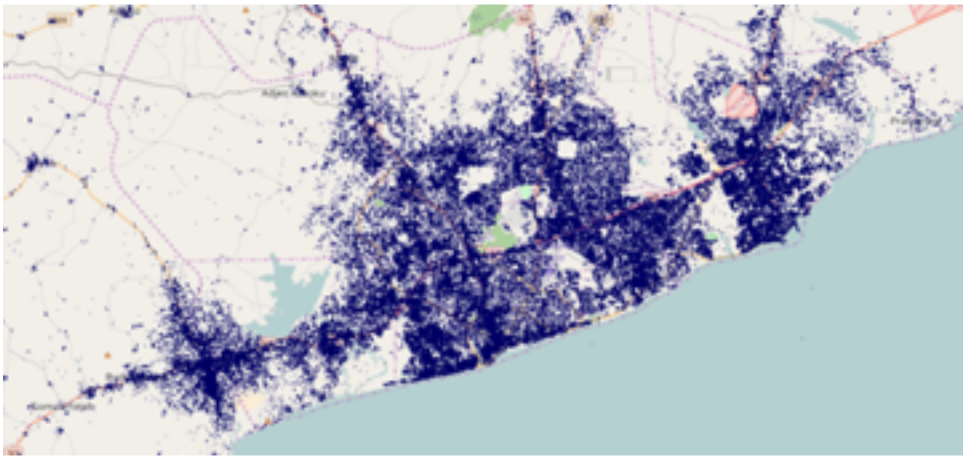
*Source:* Ghana Statistical Services, 2012.

[1] In 2010, for Accra and Greater Accra, the female population was 52.0% and 51.7% of the total population respectively. In Accra the expected lifetime at birth was 67.1 years for males and 68.2 years for females. Recent estimates of life expectancy at birth for Ghana indicates 61.0 years for males, 63.9 years for females and 62.4 for both sexes (WHO, 2017).

[2] WHO (2016). Ambient air pollution: a global assessment of exposure and burden of disease (http://apps.who.int/iris/bitstream/10665/250141/1/9789241511353-eng.pdf?ua=1).

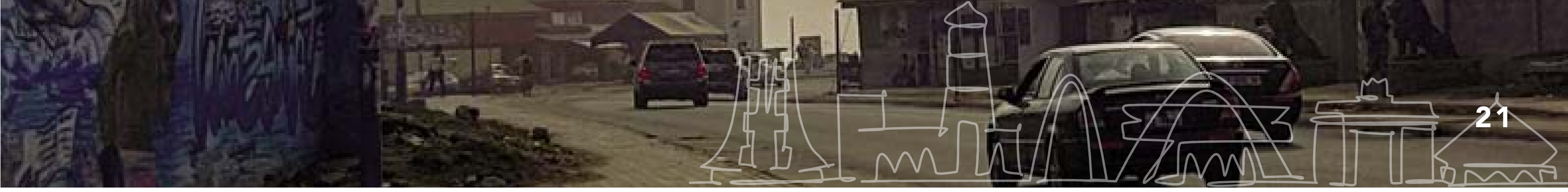
Since the 1980s, Accra has experienced rapid urban sprawl and is now a large conurbation (see Fig. 6.1) that includes Tema (30 km east of Accra city) (Osei et al., 2015).

**Fig. 6.1 Accra built area, 2016**



*Source:* EC, 2016.

The exposed population for Accra and the Greater Accra region has been projected to increase at a rate of 2.3% per annum (see UN-DESA projections and WHO climate and health country profile 2015 – UN-DESA, 2019; WHO and UN, 2015) to 2 071 211 and 4 492 917, respectively, in 2015; 2 320 612 and 5 033 923 in 2020; and 2 913 124 and 6 319 212 in 2030. In health impact calculations, the adult population aged 25+ was considered. This takes into account the fact that in Africa, and specifically in sub-Saharan Africa, the elderly are usually defined as either above 50 or 55 years of age.





Age-structured population data are available for the largest communities of Accra (Table 6.2) (Ghana Statistical Services, 2014a).

**Table 6.2 Population by age group in the 20 largest communities, 2010**

| | | Age group | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Community name** | **All ages** | **0–4** | **5–9** | **10–14** | **15–19** | **20–24** | **25–29** | **30–34** | **35–39** | **40–44** | **45–49** | **50–54** | **55–59** | **60–64** | **65–69** | **70–74** | **75+** |
| Abeka | 85 692 | 9349 | 8119 | 7979 | 8146 | 9985 | 10034 | 8140 | 6396 | 4988 | 3591 | 2857 | 1870 | 1298 | 875 | 830 | 1235 |
| Nima | 80 843 | 8944 | 7249 | 7287 | 8215 | 9824 | 9112 | 6644 | 5179 | 4148 | 3315 | 3006 | 2164 | 1766 | 1070 | 1251 | 1669 |
| Mamobi | 61 724 | 6683 | 5525 | 5600 | 6343 | 7756 | 6959 | 5351 | 4209 | 3221 | 2614 | 2138 | 1598 | 1167 | 790 | 710 | 1060 |
| Darkuman | 61 562 | 6675 | 5906 | 5825 | 6010 | 7128 | 7221 | 5675 | 4538 | 3517 | 2564 | 2023 | 1233 | 1057 | 675 | 630 | 885 |
| Osu | 59 460 | 5755 | 4891 | 4910 | 5551 | 6716 | 6221 | 5112 | 3861 | 3603 | 3076 | 2801 | 2073 | 1569 | 1131 | 868 | 1322 |
| New Town | 58 488 | 5833 | 5165 | 5050 | 5860 | 6973 | 6597 | 5257 | 4076 | 3297 | 2507 | 2383 | 1625 | 1323 | 838 | 715 | 989 |
| Achimota | 57 635 | 6520 | 5463 | 5757 | 5489 | 6743 | 6913 | 5425 | 4125 | 3254 | 2322 | 1760 | 1209 | 866 | 561 | 529 | 699 |
| Dansoman | 56 609 | 5553 | 4774 | 5291 | 5571 | 5897 | 6364 | 5210 | 4043 | 3303 | 2469 | 2104 | 1555 | 1460 | 1083 | 833 | 1099 |
| Russia | 46 912 | 5449 | 4740 | 4681 | 4748 | 5150 | 5146 | 4084 | 3322 | 2699 | 1924 | 1639 | 1051 | 779 | 476 | 394 | 630 |
| Alajo | 44 044 | 4660 | 3889 | 3940 | 4258 | 5768 | 5573 | 4043 | 3046 | 2309 | 1778 | 1521 | 1009 | 784 | 479 | 411 | 576 |
| West Abbossey Okai | 43 642 | 4553 | 4112 | 4213 | 4323 | 5202 | 4794 | 3959 | 3022 | 2563 | 1799 | 1576 | 1007 | 836 | 572 | 449 | 662 |
| Bubuashie | 43 374 | 4559 | 4239 | 4416 | 4283 | 4925 | 4577 | 3693 | 3022 | 2541 | 1936 | 1673 | 1097 | 875 | 514 | 416 | 608 |
| South Odorkor | 41 079 | 4379 | 3659 | 3724 | 3945 | 5031 | 4715 | 3902 | 3072 | 2329 | 1719 | 1469 | 909 | 672 | 507 | 410 | 637 |
| Adedenkpo | 38 999 | 4344 | 2404 | 2198 | 4893 | 8537 | 6733 | 3535 | 1958 | 1297 | 882 | 646 | 436 | 308 | 227 | 238 | 363 |
| Adabraka | 36 510 | 3300 | 2904 | 2943 | 3524 | 4976 | 4204 | 3056 | 2409 | 1958 | 1700 | 1512 | 1157 | 936 | 638 | 503 | 790 |
| Kokomlemle | 35 320 | 3140 | 2672 | 2991 | 3582 | 4309 | 4199 | 3145 | 2427 | 1943 | 1706 | 1412 | 1149 | 859 | 562 | 480 | 744 |
| Lartebiokorshie | 35 183 | 3669 | 3224 | 3207 | 3306 | 3697 | 3750 | 3141 | 2593 | 2191 | 1603 | 1449 | 973 | 794 | 459 | 421 | 706 |
| Sukura | 34 473 | 4039 | 3542 | 3548 | 3274 | 3681 | 3706 | 3050 | 2394 | 2005 | 1504 | 1158 | 770 | 587 | 390 | 332 | 493 |
| Kotobabi | 33 628 | 3636 | 3039 | 3099 | 3126 | 4066 | 3821 | 3014 | 2420 | 1944 | 1406 | 1276 | 924 | 661 | 380 | 335 | 481 |
| Kaneshie | 31 141 | 2965 | 2440 | 2583 | 2868 | 3773 | 3616 | 2707 | 2083 | 1880 | 1550 | 1374 | 945 | 706 | 479 | 402 | 770 |

*Source:* Ghana Statistical Services, 2012.

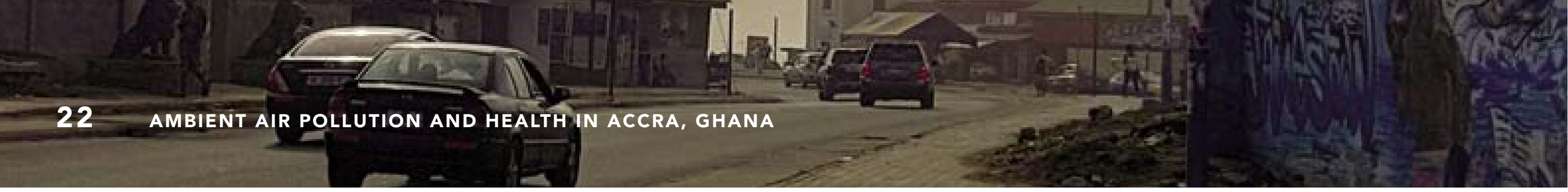




**Fig. 6.2**
**Greater Accra population pyramid, 2010**


*Source:* Elaboration based on census data (Ghana Statistical Services, 2012).

## 6.4 Mortality data from the 2010 census and other sources

"The 2010 PHC data showed remarkable mix in the pattern and distribution of deaths across different geographical areas of Ghana. The age-standardized crude death rate of Ghana was 7.7 deaths per 1000 mid-year population. This was 20% higher than the unadjusted crude death rate, which highlighted the potential influence of young age structure of the Ghana population" (Ghana Statistical Services, 2014b: 2). During the last census year (2010) there were 163 534 deaths in Ghana (see Annex Table A1.4).

"The crude death rate (CDR) directly estimated from the 2010 PHC was 6.6 deaths per 1000 for the total population and 5.4 deaths per 1000 and 7.9 deaths per 1000 mid-year population in urban and rural areas respectively" (Ghana Statistical Services, 2014b: 11). The standardized crude death rate for Ghana was 7.7 deaths per 1000, which is slightly higher than the unadjusted rate of 6.4 deaths per 1000 (Ghana Statistical Services, 2014b: 16).[1] Mortality incidence data for Accra are available from the census. According to the last census, standardized crude death rates (per 1000) in Greater Accra are 5.7 (5.5 urban and 6.9 rural), 6.5 for male and 5.0 for female (Ghana Statistical Services,

[1] The relevant percentage of total deaths due to communicable diseases should be considered. For example, "in 2008 about 53% of total deaths in Ghana were attributed to communicable diseases, maternal, perinatal and nutrition conditions" (Ghana Statistical Services, 2014b: 4). The estimated number of deaths by cause and sex in 2010 produced by WHO (2018a) contains an important warning for estimates such as the ones for Ghana: "Death registration data are unavailable or unusable due to quality issues. Estimates of mortality by cause should be interpreted with caution. Estimates may be used for priority setting, however, they are not likely to be informative for policy evaluation or comparisons among countries." (WHO, 2018a).

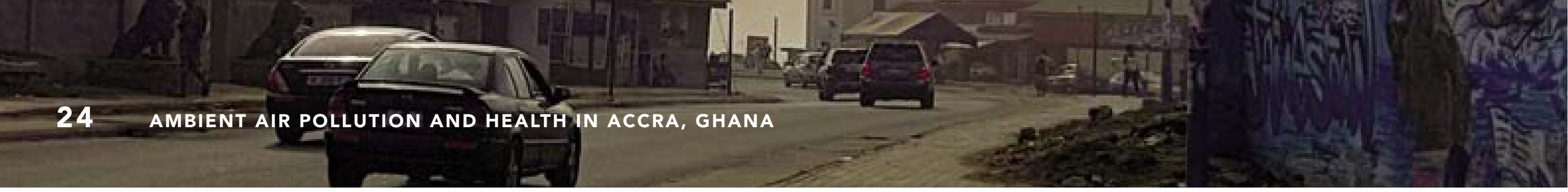
2014b: 16). The general mortality incidence number can be estimated equal to 550 per 100 000 yearly based on the census estimates. In Ghana, using WHO estimated deaths data by age and causes, the natural mortality incidence of adults (25+) can be estimated equal to 1244 per 100 000 (elaboration based on WHO Disease burden and mortality estimates – cause-specific mortality, 2000–2016: Summary tables of mortality estimates by cause, age and sex, globally and by region, 2000–2016: https://www.who.int/healthinfo/global_burden_disease/estimates/en/). This figure is produced when excluding deaths due to accidents, violence and suicide (approximately 8% of all deaths). If we also exclude deaths due to communicable diseases, we have a natural mortality incidence equal to 413 per 100 000.[1] An important factor has to be considered: "it is clear that there is substantial under-reporting of deaths, especially in the adult ages" (Ghana Statistical Services, 2014b: 17). Due to the uncertainty in death estimates and under-reporting of deaths in adult ages, it was decided to use the total mortality incidence and this figure was adopted in calculations both for the city of Accra and the greater Accra region.

Another consideration is that the death registration coverage is low, both for completeness (%) and quality of cause-of-death data. Cause-of-death information is poorly recorded: "Cause-of-death information is not meticulously completed on the forms. Not only is non-institutional death registration generally low, but most of the records do not have accurate information on the cause-of-death and many relatives do not consent to post-mortems being conducted on their dead ones. There is no component for medical officers' training on how to properly complete the medical certification section of the forms and use of the international classification of diseases (ICD-10) (Ghana Statistical Services, 2015: viii)".

In 2012, in Ghana, noncommunicable diseases (NCDs) account for 42% of total deaths, and CVD, cancer and chronic respiratory diseases are estimated at 18%, 5% and 2% respectively (WHO, 2014). The updated figures in 2016 confirm previous estimates, in Ghana: NCDs account for 43% of total deaths, and CVD, cancer and chronic respiratory diseases are estimated at 19%, 5% and 2% respectively (WHO, 2018b). Investigations using the electronic database of the University of Ghana Hospital showed that almost 60% of deaths were caused by NCDs. These figures indicate that attributable deaths produced in impact analysis are likely to produce an overestimation of expected impacts that are based on the use of risks from cohorts in population that suffer higher levels of NCDs. Nevertheless, air quality may contribute to exacerbate communicable disease, for example tuberculosis (Tremblay, 2007; Lai et al., 2016).

A life table was built applying the urban age-specific death rates (ASDR) per 1000 mid-year population (Ghana Health Service, 2012) (see Annex Table A1.4).

[1] Other figures by the Ghana Statistical Services based on the census data for the Accra metropolis (1 665 086) indicate a total number of 7276 deaths, corresponding to a crude rate of 4.4 per 1000 (Ghana Statistical Services, 2014b).



# 7. SCENARIO RESULTS

## 7.1 Health impacts of ambient air pollution

For the impact evaluations, we applied a log-linear model for the calculation of the attributable fraction with RRs, though the values of exposure (> 30 µg/m³) are higher than the ones measured in the cohort studies (Western Europe and North America) that provide data for the meta-analysis usually employed to produce the RRs.

The 1790 "estimated attributable deaths" in Scenario 1 (reaching WHO AQG) can be interpreted in two ways (see Table 7.1). It is the yearly impact on adults' mortality due to measured levels of $PM_{2.5}$ exceeding the WHO AQG in the Greater Accra region, and it is also the annual benefit that could be obtained by reducing the current exposure to the WHO AQG value. Achieving the WHO AQG at the urban level may depend on the impact of natural emissions on total $PM_{2.5}$ mass, and the contribution of anthropogenic sources to the transboundary pollutant transport. For this reason, the alternative scenarios shown are more likely in increasing order from scenario 1 to scenario 5, but the first scenario, that is the most ambitious, should be the final objective of policies that can use intermediate targets.

**Table 7.1 Greater Accra air pollution reduction scenarios, baseline year 2015, $PM_{2.5}$ = 36.02 µg/m³**

| Scenarios | Scenario 1 AQG ($PM_{2.5}$ = 10 µg/m³) | Scenario 2 IT-3 ($PM_{2.5}$ = 15 µg/m³) | Scenario 3 IT-2 ($PM_{2.5}$ = 25 µg/m³) | Scenario 4 IT-1 ($PM_{2.5}$ = 35 µg/m³) | Scenario 5 Reduction by 10% of current $PM_{2.5}$ levels (= 32.42 µg/m³) | Scenario 6 24-hr $PM_{2.5}$ (= 25 µg/m³) |
|---|---|---|---|---|---|---|
| Attributable proportion % (CI 95%) | 14.49 (9.7–18.74) | 11.88 (7.91–15.43) | 6.41 (4.23–8.41) | 0.61 (0.40–0.81) | 1.91 (1.25–2.52) | 2.93 (1.00–5.15) |
| Estimated attributable deaths | 1790 (1199–2315) | 1468 (978–1907) | 792 (523–1039) | 76 (49–100) | 236 (154–311) | 362 (124–636) |
| Number of attributable deaths per 100 000 population at risk (95% CI) | 79.69 (53.36–103.05) | 65.33 (43.52–78487) | 35.28 (23.27–46.26) | 3.36 (2.20–4.45) | 10.49 (6.86–13.86) | 16.13 (5.51–28.30) |

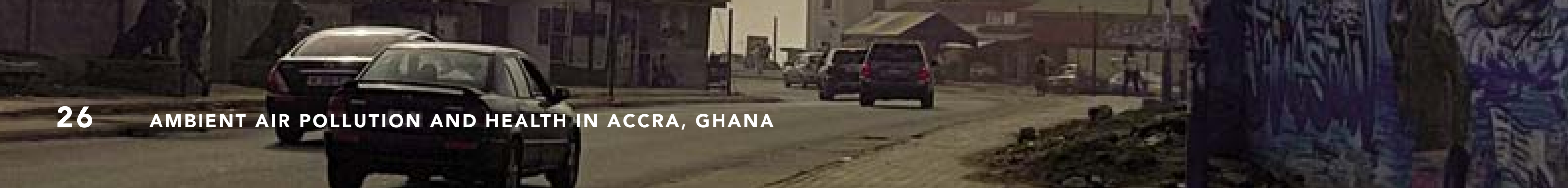
*Notes:* AQG = Air quality guidelines; IT = interim target; Scenarios 1–5 are long term; Scenario 6 is short term.

If a 2.3% increase in the population is assumed, with a distribution proportional to the 2015 age group structure, while maintaining the population mortality rate constant, and at the same time decreasing the ambient air pollution according to the various scenarios, future scenarios can also be assessed.

**Table 7.2 Greater Accra YLL and air pollution reduction scenarios, baseline year 2015, $PM_{2.5}$ = 36.02 μg/m³**

| Scenarios | Scenario 1 AQG ($PM_{2.5}$ = 10 μg/m³) | Scenario 2 IT-3 ($PM_{2.5}$ = 15 μg/m³) | Scenario 3 IT-2 ($PM_{2.5}$ = 25 μg/m³) | Scenario 4 IT-1 ($PM_{2.5}$ = 35 μg/m³) | Scenario 5 Reduction by 10% of current $PM_{2.5}$ levels (= 32.42 μg/m³) |
|---|---|---|---|---|---|
| YLL over 10 years (males + females) | 69 746 (36 475 + 33 271) | 64 478 (33 718 + 30 760) | 41 254 (21 567 + 19 687) | 4450 (2325 + 2125) | 15 141 (7913 + 7228) |

*Note:* The scenario was built projecting the 2015 adult (> 25 years) population until 2030 with a growth rate of 2.3% and an expected yearly reduction of air pollution based on the scenarios.



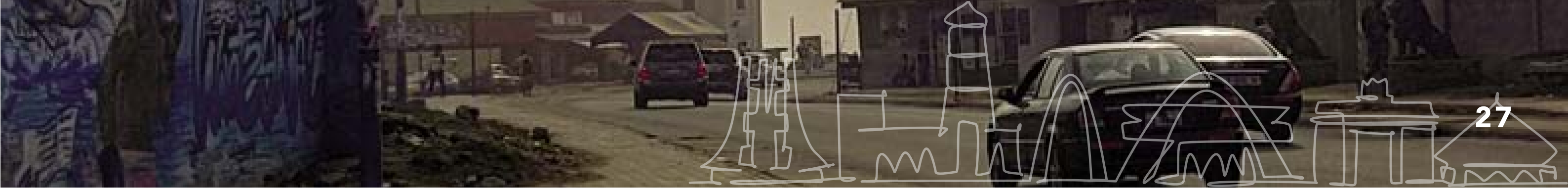


# 8. CONCLUSION

The conclusions are organized in two subsections: a discussion on current estimated health impacts of air pollution and likely impacts based on a projection for 2030; and recommendations on air quality network development and monitoring in GAMA and on collection of background health data for impact assessment. Before considering all the points summarized in the subsections below, given the COVID-19 pandemic, and given that a primary goal in the context of COVID-19 is to reduce impacts on the health care system, an important point to recognize is that air pollution increases diseases (e.g. cardiovascular and respiratory) that increase the risk of COVID-19 death. This is an additional point to consider when promoting air pollution reduction strategies.

## 8.1 Scenario estimates

- There are several data issues, both for air pollution and health data. Mortality data for adults are probably an underestimation. Cause-specific mortality data are not available at city level and estimates are based on assumptions and modelling.
- Levels of air pollution in Accra are significantly high and concentrations of $PM_{2.5}$, on average, after conversion from $PM_{10}$ measurements from ground monitoring stations, are approximately 49.47 µg/m$^3$. But there are serious problems of lack of data. Satellite data are also available for Greater Accra.
- Levels of air pollution in Greater Accra are high and concentrations of $PM_{2.5}$, on average, from satellite modelling, are approximately 36.02 µg/m$^3$.
- According to the last census, in 2010, the population of the city of Accra is nearly 1.85 million and that of the Greater Accra region at 4 million. Projections estimate the population in 2030 at 2.9 million for the city of Accra and 6.4 million for the Greater Accra region.
- In Greater Accra, the 2015 levels of air pollution – in excess of those recommended by the WHO AQG – will be responsible over a period of 10 years (2020–2030) for almost 70 000 years of life lost in the adult (25+) population.
- Various scenarios of air pollution reduction indicate that reaching WHO AQG could potentially prevent 1790 deaths annually in the Greater Accra region, and this corresponds to an estimated economic burden for the city of approximately US$ 247 million (see the UHI report on household air pollution (WHO, 2020)).
- Household air pollution is an issue due to the significant use of solid fuels (see dedicated report on household air pollution (WHO, 2020).





## 8.2 Recommendations

- Do not develop a large network of diverse stations that is very difficult to integrate, but dedicate resources for long-term monitoring and maintenance of a few monitoring stations located in residential areas. Priority should be given to measurements of $PM_{2.5}$.

- Minimize the relocation of monitoring stations, and give preference to monitoring stations located in the same place, ideally in residential areas, for long periods.

- Dedicate resources to the collection of vital statistics, in particular for mortality.

- Improve the health data collection for hospitalization, in particular for cardiovascular and respiratory diseases.

- Provide availability of data on air pollution and health for the public.

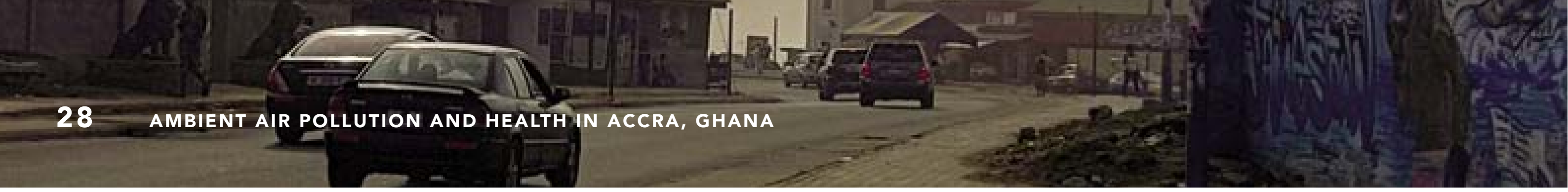
- Any air quality standard that will be enforced should be protective for human health.
  Any air quality master plan developed for Accra and Ghana will be an example for other African cities; it is important to have ambitious (and realistic) objectives. $PM_{10}$ and $PM_{2.5}$ can have interim targets to be achieved in the short to medium term. Other pollutants to be considered in national monitoring with protective levels for health are carbon monoxide, nitrogen dioxide and sulfur dioxide.

- Due to the seasonal variability of air pollution and the effects of dust from sand and desert storms in the Harmattan season, air pollution reduction plans that aim at protecting public health should not allow exceedance of WHO AQG values for PM for 70% of the days in a year in non-Harmattan months. Permitted exceedances should be no more than 30% of the days in a year. Measures should be taken to reduce air pollution, that for 70% of the year is due to anthropogenic sources.

- Measures should be taken to decrease exposure levels during dust events, in particular to reduce local emissions of pollutants that can exacerbate exposure during dust episodes.

- Sectorial interventions are needed, in particular to reduce traffic, waste, industrial and household air pollution.

- Land-use interventions should take into account the particular ecosystem situation of the city, and the lack of green spaces for the population.





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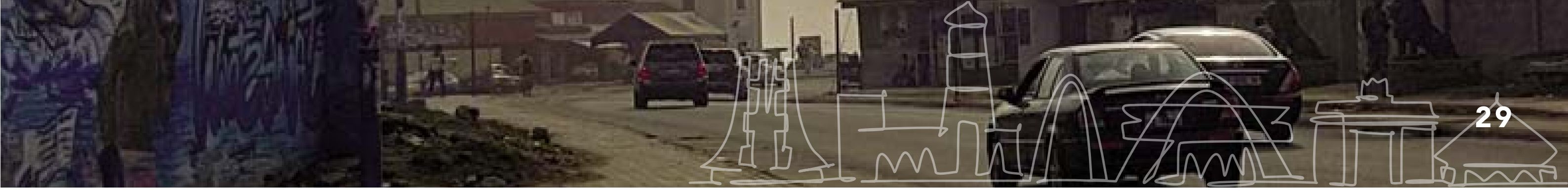




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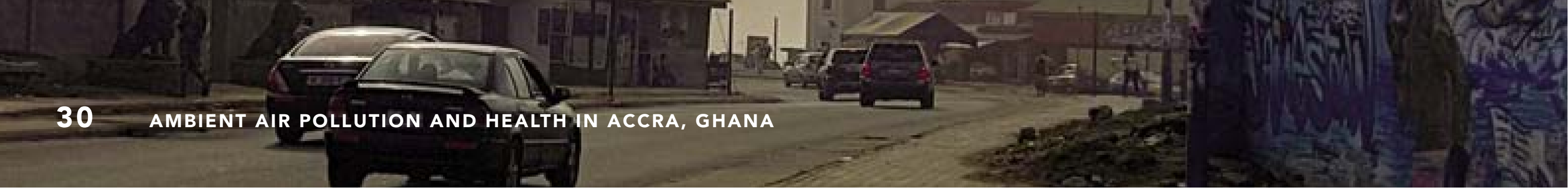




# ANNEX

Accra includes half of the population of the Greater Accra region and it is important to consider the detail of the impact of air pollution using local measurements. Compared with the Greater Accra region, monitoring data for the city of Accra are sparse and incomplete. The calculations done in the report are detailed in Tables A1.1 and A1.2.

**Table A1.1 Accra: air pollution reduction scenarios, baseline year 2015, $PM_{2.5}$ = 49.47 $\mu g/m^3$**

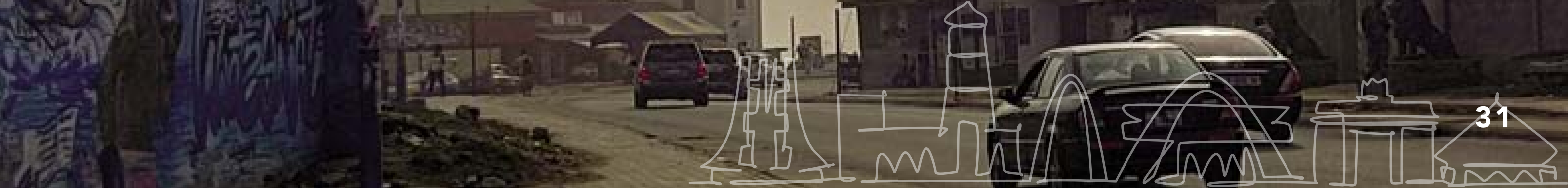
| Scenarios | Scenario 1 AQG ($PM_{2.5}$ = 10 $\mu g/m^3$) | Scenario 2 IT-3 ($PM_{2.5}$ = 15 $\mu g/m^3$) | Scenario 3 IT-2 ($PM_{2.5}$ = 25 $\mu g/m^3$) | Scenario 4 IT-1 ($PM_{2.5}$ = 35 $\mu g/m^3$) | Scenario 5 Reduction by 10% of current $PM_{2.5}$ levels (= 44.52 $\mu g/m^3$) | Scenario 6 24-hr $PM_{2.5}$ (= 25 $\mu g/m^3$) |
|---|---|---|---|---|---|---|
| Attributable proportion (%, range) | 21.13 (14.34–27.00) | 18.73 (12.65–24.03) | 13.69 (9.15–17.73) | 8.34 (.52–10.9) | 2.93 (1.92–3.87) | 2.95 (1.09–4.75) |
| Estimated attributable deaths | 1204 (817–1538) | 1067 (720–1369) | 780 (521–1010) | 475 (314–621) | 351 (230–462) | 168 (62–271) |
| Number of attributable deaths per 100 000 population at risk (CI) | 116.24 (78.88–148.50) | 103.00 (69.55–132.17) | 75.28 (50.33–97.49) | 48.85 (30.34–59.93) | 16.14 (10.57–21.29) | 16.21 (6.01–26.14) |

*Notes:* AQG = Air quality guidelines; IT = interim target; Scenarios 1–5 are long term; Scenario 6 is short term.

In addition to calculating various health benefits of reduced air pollution, we have calculated an estimate of the expected burden of air pollution in Greater Accra assuming a cut-off value for $PM_{2.5}$ of 4.15 $\mu g/m^3$ (i.e. between 2.4 and 5.9 $\mu g/m^3$). In this scenario, in Accra the premature mortality burden is 1359 deaths (928–1727), and for Greater Accra it is 2155 deaths (1452–2773). If we consider 2.4 $\mu g/m^3$ as the cut-off, the results are 1405 deaths (960–1782) for Accra and 2262 (1526–2905) for Greater Accra.[1]

[1] Additional explanation on the calculations leading to these numbers are given with a concise summary of the input data. Calculations for total = all-cause natural mortality were produced using HRAPIE functions that are implemented in AirQ+. Numbers in () are 95% CIs. Details on cut-off concentrations and log-linear functions are given in the documents attached to AirQ+. Concentrations values used are 49.5 $ug/m^3$ for Accra and 36.0 $ug/m^3$ for the Greater Accra region.
In particular, for the first example of this section, the input data are:

**Greater Accra:**
Cut-off = 4.15 $ug/m^3$
Mortality = 550 deaths per 100 000 population
Adult population = 2 246 459 in 2015
Exposure = 36.01 $ug/m^3$





It is interesting to consider an estimate for the burden of air pollution just considering IHD and using the specific 2016 integrated exposure response (IER) with a counterfactual equal to the WHO AQG.

**Table A1.2 Greater Accra ischaemic heart disease burden (counterfactual equal to the WHO AQG)**

| Ischaemic heart disease | Burden vs AQG ($PM_{2.5}$ = 10 µg/m³) |
|---|---|
| Attributable proportion (%, range) | 34.56 (18.32–48.49) |
| Estimated attributable deaths | 939 (498–1318) |
| Number of attributable deaths per 100 000 population at risk (CI) | 41.81 (22.17–58.67) |

The population data used for the analysis is produced in Tables A1.3 and A1.4 below.

**Table A1.3 Population by age and sex in Greater Accra, 2010**

| | Greater Accra | | |
|---|---|---|---|
| Age | Male | Female | Total |
| < 1 | 56 930 | 56 147 | 113 077 |
| 1–4 | 181 283 | 175 491 | 356 774 |
| 5–9 | 198 577 | 198 922 | 397 499 |
| 10–14 | 183 246 | 203 036 | 386 282 |
| 15–19 | 180 173 | 208 230 | 388 403 |
| 20–24 | 215 803 | 242 272 | 458 075 |
| 25–29 | 209 640 | 233 743 | 443 383 |
| 30–34 | 175 564 | 181 506 | 357 070 |
| 35–39 | 139 524 | 142 896 | 282 420 |
| 40–44 | 109 928 | 110 592 | 220 520 |
| 45–49 | 80 923 | 84 599 | 165 522 |
| 50–54 | 65 046 | 71 531 | 136 577 |
| 55–59 | 44 852 | 47 050 | 91 902 |
| 60–64 | 34 067 | 36 373 | 70 440 |
| 65–69 | 21 299 | 23 705 | 45 004 |
| 70–74 | 17 554 | 21 301 | 38 855 |
| 75–79 | 10 264 | 13 221 | 23 485 |
| 80–84 | 6894 | 10 223 | 17 117 |
| 85–89 | 3928 | 6 270 | 10 198 |
| 90–94 | 1806 | 3113 | 4919 |
| 95+ | 924 | 1608 | 2532 |
| Total | 1 938 225 | 2 071 829 | **4 010 054** |

*Source:* Ghana Statistical Services, 2012.

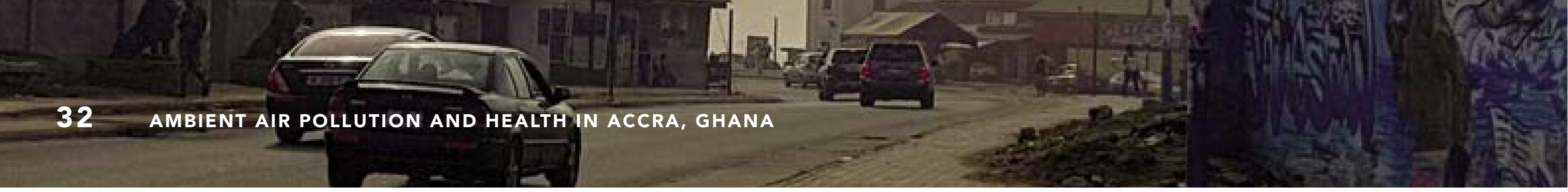




**Table A1.4 Age-sex distribution of mid-year population and deaths in Ghana, 2010**

| | Male | | Female | | Total | |
|---|---|---|---|---|---|---|
| Age group (years) | Mid-year population | Deaths | Mid-year population | Deaths | Mid-year population | Deaths |
| < 1 | 370 320 | 15 807 | 360 881 | 12 261 | 731 201 | 28 068 |
| 1–4 | 1 361 467 | 9424 | 1 312 738 | 8444 | 2 674 205 | 17 868 |
| 5–9 | 1 589 632 | 3437 | 1 539 320 | 2838 | 3 128 952 | 6275 |
| 10–14 | 1 477 525 | 1587 | 1 438 515 | 2054 | 2 916 040 | 3641 |
| 15–19 | 1 311 112 | 1752 | 1 298 877 | 2647 | 2 609 989 | 4399 |
| 20–24 | 1 100 727 | 2117 | 1 222 764 | 3350 | 2 323 491 | 5467 |
| 25–29 | 943 213 | 2516 | 1 106 898 | 3809 | 2 050 111 | 6325 |
| 30–34 | 790 301 | 3397 | 888 508 | 4821 | 1 678 809 | 8218 |
| 35–39 | 676 768 | 3579 | 744 635 | 4636 | 1 421 403 | 8215 |
| 40–44 | 572 620 | 4141 | 613 730 | 4714 | 1 186 350 | 8855 |
| 45–49 | 452 975 | 3715 | 485 123 | 3858 | 938 098 | 7573 |
| 50–54 | 394 600 | 4376 | 438 498 | 4201 | 833 098 | 8577 |
| 55–59 | 258 582 | 3564 | 265 113 | 2092 | 523 695 | 5656 |
| 60–64 | 227 050 | 4418 | 248 799 | 2741 | 475 849 | 7159 |
| 65–69 | 136 244 | 3360 | 157 627 | 2310 | 293 871 | 5670 |
| 70–74 | 149 512 | 5096 | 201 818 | 3347 | 351 330 | 8443 |
| 75–79 | 89 149 | 3599 | 116 804 | 2598 | 205 953 | 6197 |
| 80+ | 123 048 | 8329 | 193 330 | 8599 | 316 378 | 16 928 |
| **Total** | 12 024 845 | 84 214 | 12 633 978 | 79 320 | **24 658 823** | **163 534** |

*Source:* Ghana Statistical Services, 2012.

**Table A1.5 Greater Accra: age structure by broad age group, 1960–2010**

| Age group | 1960 | 1970 | 1984 | 2000 | 2010 |
|---|---|---|---|---|---|
| < 15 | 39.4 | 42.0 | 41.6 | 33.1 | 31.3 |
| 15–24 | 21.3 | 20.8 | 20.3 | 22.7 | 21.1 |
| 25–29 | 35.2 | 33.9 | 33.4 | 38.8 | 42.3 |
| 60+ | 4.1 | 3.3 | 4.7 | 5.5 | 5.3 |

*Source:* Ghana Statistical Services, 2013.

## Health impacts of household air pollution

According to WHO data, in 2013, in Ghana, 82.6% (in 2016 78%) of the population use solid fuel (WHO, Household energy database "Country estimates for access to clean fuels (2000–2016)" 2018 version: https://www.who.int/airpollution/data/en/). Ghana Statistical Services data show almost half of all households in Greater Accra use charcoal (45.4%) or wood (3.5%) as their main cooking fuel (Ghana Statistical Services, 2012).

The calculations for cause-specific mortality impacts and household air pollution are based on the GBD methodology and they include RRs for five diseases: ALRI for children, COPD, lung cancer, IHD and stroke for adults (Burnett et al., 2014; GBD 2015 Risk Factors Collaborators, 2016). Sub-Saharan countries face a growing burden of CVD due to socioeconomic changes. In a study that focused on a 5-year review of autopsy cases carried out at the leading hospital in Ghana (Korle-Bu Teaching Hospital) between 2006 and 2010, CVD accounted for 22.2% of all causes of death (Sanuade et al., 2014). Due to the lack of cause-specific mortality data for the city of Accra, only one hypothetical scenario was run considering IHD to show the potential magnitude of the problem of household air pollution on health. As an hypothesis, considering a 22.2% incidence (Sanuade et al., 2014), we can assume an incidence of IHD mortality of approximately 121 per 100 000).

A rough estimate of the impact of household air pollution indicates significant consequences for the population. In Greater Accra between 160 and 477 premature deaths (female 95–250) (male 65–227) annually related to IHD are expected due to the use of solid fuel. These results indicate 8–22 female and 6–20 male deaths per 100 000 of the at-risk population. And, the burden of household air pollution is expected to be much higher in the rest of Ghana, particularly in rural areas, where solid fuel use is higher than in Accra (WHO, 2018c).

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