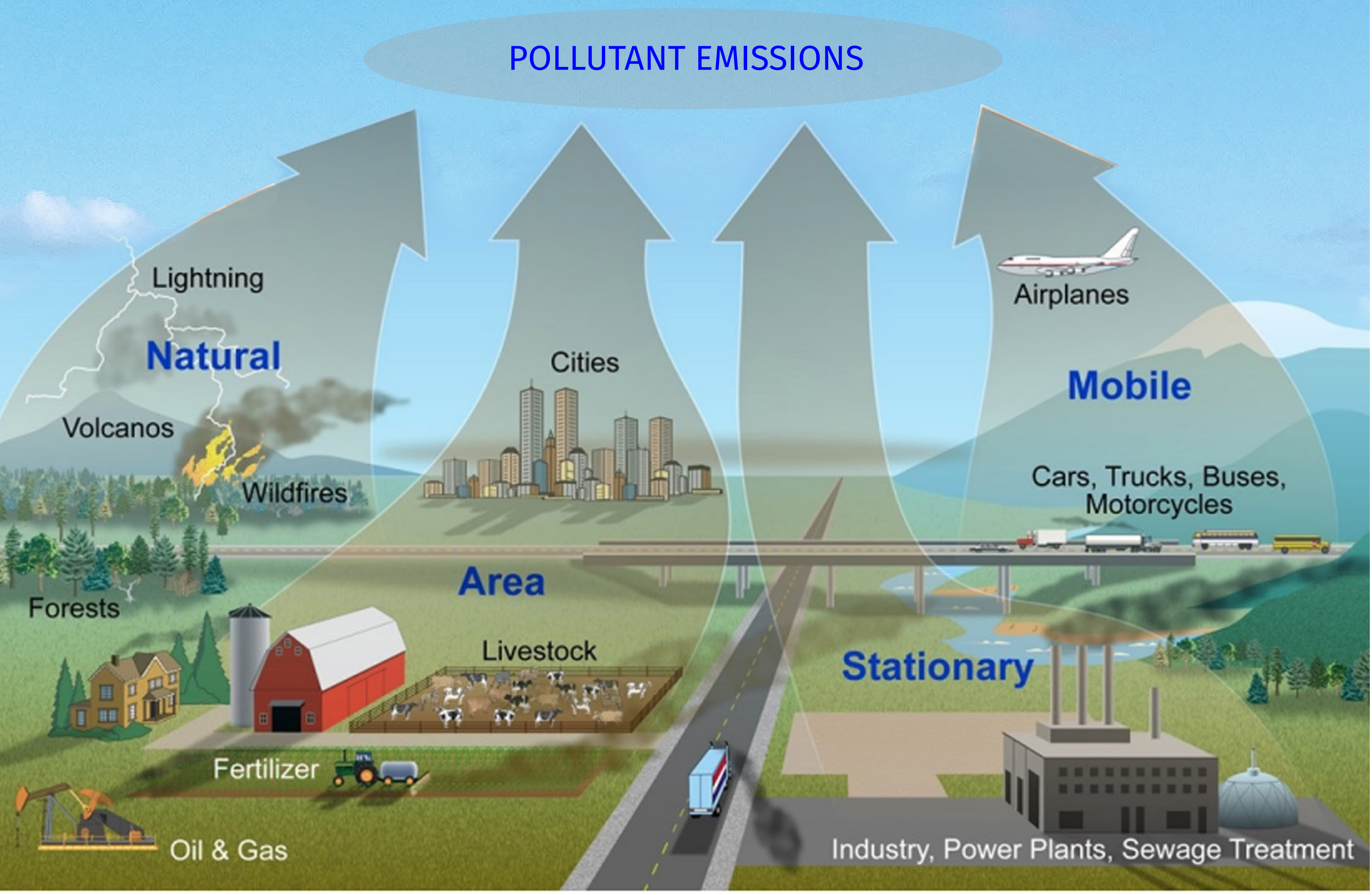
Federal Democratic Republic
of Ethiopia Ministry of Health

Air Quality and Health Guideline

June 2022



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MINISTRY OF HEALTH-ETHIOPIA

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Acronyms and abbreviations

AAEAGDC	Addis Ababa Environmental authority and green development commission
ALRI	Acute lower respiratory Infection
AP-HRA	Health Risk Assessment of Air Pollution
AQ	Air Quality
AQG	Air Quality Guideline
AQHG	Air Quality and Health Guide
AQMS	Air Quality Monitoring System
BAM	Beta attenuation monitoring
CCAC	Climate and Clean Air Coalition
CCT	Controlled Cooking Test
CFC	chlorofluorocarbons
COPD	Chronic Obstructive Pulmonary Disease
CRFs	Cause Response Function
DALYs	disability-adjusted life years
e-CHIS	Electronic community health information system
EDHS	Ethiopian demographic and health survey
EEA	Ethiopia Energy Authority
EFCCC	Environment forest and climate change commission
EIA/ESIA	Environmental impact assessment
EMP	Environmental management plan
EnDev	Energizing Development
ESA	Ethiopia Standard Agency
ESIA	Environment, social impact assessment
FDRE	Federal Democratic Republic of Ethiopia
GACC	Global Alliance for Clean Cookstoves
GBD	Global Burden of Disease
GPS	Ground positioning system
HAP	Household air pollution

HIA	Health Impact Assessment
HMIS	Health monitoring and information system
IAP	indoor air pollution
ICS	Improved Cookstove
IFC	International financial corporation
IHD	ischemic heart disease
IHM	International health metrics
KPT	Kitchen Performance Test
LPG	Liquid Petroleum Gas
LRI	Lower Respiratory Infection
MOH	Ministry of health
MW	Megawatt
N95	A mask type that prevents 95%
NMA	National Meteorology Agency
PAH	poly-aromatic-hydrocarbons
PM	Particulate matter
PM10	Particulate matter size less than 10 micrometer
PM2.5	Particulate Matter size less than 2.5 micrometer
POPs	Persistent organic pollutants
ppm	parts per million
SBCC	social and behavioral change communication
SDG	Sustainable development goal
SE4ALL	Sustainable Energy for All
SLCPs	Short-lived climate pollutants
SuM4All	Sustainable Mobility for All
TVETs	Technical vocational Education and Training
US EPA	United States of America Environment protection authority
VOC	volatile organic compounds
WBT	Water Boiling Test
WHA	World health assembly
WHO	World Health Organization
YLL	years of life lost

Forward

Air pollution is the leading cause of morbidity and mortality worldwide. The most devastating health effect of air pollution comes from household air pollution. The ambient air pollution is also overly critical for cities. Globally, ambient air pollution deprived 3.8 million lives and indoor air pollution causes 4.2 million deaths. Totally 8 million death accounts for air pollution.

In Ethiopia, air pollution is the second leading cause of mortality and morbidity next to malnutrition. Indoor air pollution accounts for more than 67 thousand deaths annually while ambient air pollution accounts for 9 thousand deaths.

The main source of indoor air pollution in Ethiopia is due to biomass burning for cooking, heating, and lighting. Almost 95% of Ethiopians use unclean biomass fuel for cooking. On the other hand, the old vehicles imported, old industries operated, unclean fuel used, unpaved roads in cities, and haphazard burning of wastes are the main problems for the ambient air pollution

Even though attempts are seen on clean cook stove development and distribution, there is still a huge gap. Even in the area where there is access to electricity, people do not use it due to cost, technology access, inefficient technology, and poor awareness.

An integrated program on indoor air pollution has to be developed among stakeholders such as the health sector, TVET, small micro-enterprises, microfinance, standard agency, Ethiopia energy authority, NGOs, and others to address the devastating health impact of indoor pollution.

The ambient air quality has to be monitored for designing interventions. It also demands multi-sectorial interventions. The public is also by large the main contributor as the same time stakeholder for the solution.

Finally, I would like to call all concerned stakeholders for their collaborative effort towards protecting the public health from air pollution and I believe the guideline provides important guidance for future planning.

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Executive Summary

Clean air is one of the basic requirements of human existence, health, and well-being. Air pollution, however, continues to pose a significant threat to the quality of health worldwide. Air pollution is the presence of chemical, physical or biological agents in the indoor or outdoor air we breathe that modifies the natural characteristics of the atmosphere in a way harmful to the health of humans and other living organisms, damage properties, and the atmosphere.

Primary air pollutants include sulfur dioxide, oxides of nitrogen, carbon monoxide, volatile organic compounds, and carbonaceous and non-carbonaceous particles. Secondary air pollutants arise from chemical reactions of primary pollutants in the atmosphere, often involving natural components of the environment such as oxygen and water.

Globally, air pollution is responsible for an estimated 8 million deaths annually, or one in eight premature deaths every year. Of which 4.3 million air pollution-related deaths are due to household air pollution and 3.7 million deaths are due to outdoor air pollution. This makes it the world's largest environmental health risk, and among the largest global health risks. Most air pollution-related deaths are from heart disease and stroke, followed by chronic obstructive pulmonary disease (COPD), acute and chronic respiratory conditions, and cancers.

Ethiopia is characterized by rapid urbanization, economic growth, and densely populated low-income communities relying mainly on biomass and other dirty fuels for domestic cooking and heating.

The main sources of ambient air pollutants in Ethiopia are vehicular, industrial, open waste burning and energy generation sources and for indoor air pollutants is unclean biomass burning for cooking, heating, and lighting.

Household air pollution is the second leading cause of death next to malnutrition accounting for 12.15% of the disease burden attribution exceeding the combined effect of water hygiene and sanitation (WASH) which accounts for 10.66% of the disease burden attribution in Ethiopia.

There is a strong linkage between climate change, air pollution, and human health. Climate change affects air quality through several pathways. Many of the drivers of air pollution (i.e., combustion of fossil fuels) are also sources of high CO_2 emissions. Some air pollutants such as ozone and black carbon are short-lived climate pollutants that greatly contribute to climate change and affect agricultural productivity.

Policies to reduce air pollution, therefore, offer a “win-win” strategy for both climate and health, lowering the burden of disease attributable to air pollution, as well as contributing to the near- and long-term mitigation of climate change. In general, climate change contributes to air pollution and air pollution also is a risk factor for climate change. Improving air quality is part of mitigating climate change by protecting public health.

Ambient air quality monitoring is the systematic, long-term assessment of pollutant levels by measuring the quantity and types of certain pollutants in the surrounding, outdoor air. It helps in evaluating the existing policies and their effective implementation. The objectives of ambient air quality monitoring are to assess the extent of pollution; provide air pollution data to the general public in a timely manner; support the implementation of air quality goals or standards; evaluate the effectiveness of emissions control strategies; provide information on air quality trends; provide data for the evaluation of air quality models, and support research.

Since achieving the maximum air quality level within brief time is impossible, the interim guideline value is set and used as an indicator. The interim guideline values are lower or less stringent than the guideline value with lower protection scope.

The air quality management strategy for this guideline was basically prepared on three areas i.e., policy, legislation, and regulation, technology, and social and behavioral change communication (SBCC). On the policy aspect, both technology and SBCC based interventions will be designed and enabling environment created. Regulatory and legislative actions amended and enacted. The technology-based interventions are more focused on innovations for pollution reduction as primary or secondary interventions. Here sectorial integration, collaboration, and partnership are very vital for the success of air quality management assurance.

CHAPTER ONE

Introduction

1.1 BACKGROUND

Clean air is one of the basic requirements of human existence, health, and well-being. The amount of air required by humans, in general, is constant which 10-20 m3 is. Free access to an acceptable quality of air a fundamental human right for all people

Air pollution, however, continues to pose a significant threat to the quality of health worldwide. It is recognized by the World Health Assembly (WHA) Resolution of May 2015 as being of major public health concern

Air pollution is the presence of chemical, physical or biological agents in the indoor or outdoor air we breathe that modifies the natural characteristics of the atmosphere in a way harmful to the health of humans and other living organisms, damage properties, and the atmosphere.

Air pollutants are substances in the atmosphere-certain gases and aerosols-that have harmful effects. It may be either emitted into the atmosphere (primary air pollutants) or formed within the atmosphere itself (secondary air pollutants). Primary air pollutants include sulfur dioxide, oxides of nitrogen, carbon monoxide, volatile organic compounds, and carbonaceous and non-carbonaceous primary particles. Secondary air pollutants arise from chemical reactions of primary pollutants in the atmosphere, often involving natural components of the environment such as oxygen and water. Prominent secondary pollutants in the air include ozone, oxides of nitrogen, and secondary particulate matter (PM).

Air pollution is associated with a broad spectrum of acute and chronic health effects, the nature of which may vary depending on constituent of the pollutants as well as the group of the population. The pulmonary deposition and absorption of inhaled chemicals can have direct consequences for health. Nevertheless, public health can also be indirectly affected by the deposition of air pollutants in environmental media and uptake by plants and animals, resulting in chemicals entering the food chain or being present in drinking water and thereby constituting additional sources of human exposure.

Most air pollution-related deaths are from heart disease and stroke, followed by chronic obstructive pulmonary disease (COPD), acute and chronic respiratory conditions, and cancers. The air pollutant linked most closely to a high number of deaths and diseases is particulate matter less than 2.5 micrometers in diameter (PM2.5), heavily emitted by both diesel vehicles and the combustion of biomass, coal, and kerosene. Ozone is another pollutant that causes significant respiratory illness, including chronic asthma. There is growing evidence that oxides of nitrogen (NOx), a major contributor to ozone and heavily emitted by diesel vehicles, are also linked to significant health risks. Air pollution can also cause short-term problems such as sneezing and coughing, eye irritation, headaches, and dizziness. Particulate matter smaller than 10 micrometers (which is classified as PM10 and even smaller) poses higher health risks.

Air pollutants cause less direct health effects when they contribute to climate change. Heat waves, extreme weather, food supply disruptions, and other effects related to increased greenhouse gases can have negative impacts on human health.

Globally, air pollution is responsible for an estimated 8 million deaths annually, or one in eight premature deaths every year. Of which 4.3 million air pollution-related deaths are due to household air pollution and 3.7 million deaths are due to outdoor air pollution. This makes it the world's largest environmental health risk, and among the largest global health risks.

Open burning and residential use of biomass fuels for heating and cooking are the main anthropogenic sources of air pollution in Africa and developing countries of Asia and Latin America (Liousse et al., 2010). Additional natural sources of air pollution also include dust from various sources and smoke from human-made and wildfires (Naidja et al., 2018). In Africa, about 10% of communities assessed by the WHO recommended air quality guidelines, which is below the average of 18% globally and well below the 40-80% rates found in high-income countries in Europe and North America (WHO, 2018b).

In Ethiopia, indoor air pollution is the second and ambient air pollution is the 13th risk factor for disease burden as per the Global Burden of Disease (GBD) report, 2019. From all environmental risk factors for disease burden, air pollution is the leading followed of WASH. According, to the recent EDHS 2016 report more than 95% of all households and 75% of the urban residents primarily use solid fuels for cooking. It is estimated that 63% of 36,800 child deaths occurring annually in Ethiopia due to acute lower respiratory infections is attributable to household air pollution. Respiratory illness among children is one of the leading causes of hospital admissions and deaths in Ethiopia, and chronic obstructive lung disease is a growing concern among women, who are most heavily exposed to household pollution due to cooking with biomass fuel. Reduction of exposure during pregnancy and in the first 2 years of life should be a high priority to reduce mortalities and morbidities due to air pollution.

The Constitution of Ethiopia has policy provisions related to air pollution. Under Article 92/1 of the constitution, all persons are granted the right to a clean and healthy environment. The Federal democratic republic of Ethiopia (FDRE) environmental policy lists objectives and measures to address issues related to air quality. Environmental pollution control proclamation (Proclamation No. 300/2002) specifies ambient air quality standards and allowable emissions

However, there is no national guiding document, which shows the air pollution management strategy, stakeholders' responsibility, and implementation arrangement. This guideline provides the basic structure and guidance to plan and coordinate, monitor, and assess, prevent, and control health systems response, communication, and public education in response to air pollution-induced health problems across the country.

1.2 RATIONALE

The prevention and control of the health impact of air pollution is complex and incredibly challenging especially due to industrial development and rapid population growth.

Ethiopia is characterized by rapid urbanization, economic growth, and densely populated low-income communities relying mainly on biomass and other dirty fuels for domestic cooking and heating. Additionally, industrial emissions, forest fires, vehicle emissions from exhausts, unpaved roads, and mine dumps are some of the major contributors to poor ambient air quality in the country.

This problem has been exacerbated by the lack of strong coordination and implementation guidelines and enforcing procedures that translate the available policies and regulations into practice.

There are enough evidence that signal the need for urgent, coordinated actions to reduce both short and long-term health impacts of air pollution to children, the elderly, and the poor and general population, at large. Hence, developing an evidence-based air quality and health guideline is especially important to provide guidance on national air quality standards, management strategies and implementation and coordination arrangements.

1.3 SCOPE OF THE GUIDELINE

The guideline provides the basic structure and guidance to plan, implement, coordinate, and monitor interventions towards prevention and control of the impact of air pollution on public health a. Governmental, non-governmental organizations, private actors, researchers, regulatory bodies, and others can use this guideline.

1.4 OBJECTIVES

General objective

The main objective of this guideline is to protect the public health and the environment. Through providing a framework that serves as a guidance for strengthening stakeholders' participation, designing, implementing, monitoring, and evaluating air quality initiatives

Specific Objectives

- To explicitly show the health impacts of air pollution in Ethiopia
- To indicate the steps in assessing public health impact of air pollution
- To provide guidance on air quality monitoring
- To define interim standards for air quality
- To provide guidance on air quality management strategies
- To define roles and responsibilities of different stakeholders for ensuring air quality
- To enhance cooperation and coordination among relevant stakeholders
- To provide a framework for monitoring and evaluation of Air quality initiatives

CHAPTER TWO

Source and types of air pollutants

It is known that air pollutants are trans-boundary in nature as they travel and affect areas far away from their point of origin. Air pollution and air pollutants can be categorized based on their formation, sources, state, or other characteristics.

2.1 Source-based classification

Sources of air pollution refer to the various locations, activities, or factors that are responsible for the releasing of pollutants into the atmosphere. These sources can be classified into two major categories; Based on their origin air pollutants are classified as natural (stationary and mobile sources) and anthropogenic (human activity).

Based on their presence in the environment they are classified as indoor and ambient/ outdoor air pollutants.

2.1.1 Indoor air pollution

The major sources of indoor air pollution worldwide include indoor combustion of solid fuels, tobacco smoking, emissions from construction materials and furnishings, and improper maintenance of ventilation and air conditioning systems. Although some indoor air pollutants, such as environmental tobacco smoke, are of concern globally, profiles of indoor air pollutants and the resulting health risks are generally quite different in developed and developing countries.

In Ethiopia, the most significant issue for indoor air quality is pollutants released during the combustion of solid fuels including biomass (wood, dung, and crop residues) that are used for cooking, lighting, and heating. Households burning such biomass fuels are generally used open pits or poorly functioning earthen or metal stoves in kitchens that are not well ventilated.

2.1.2 Outdoor/ambient air pollution

Outdoor sources of air pollutants include vehicles, combustion of fossil fuels in stationary sources, such as power generating stations, and a variety of industries. Forest fires and deliberate biomass burning, although intermittent sources of air pollution represent major sources of combustion pollution globally. Nature including volatile organic compounds released from trees, wind-blown soil, dust storms, and sea spray can be an important source of many trace gases and particles within the atmosphere.

The major sources of air pollutants in the country for ambient air pollution are:

i. Emissions from road traffic;

It is estimated that motor vehicles account for up to 80 % of urban air pollution in some cities, especially in developing countries and countries with economies in transition such as Ethiopia.

Ethiopia's total in-use vehicle population currently stands at about 1.2 million with an annual growth rate of 10 % in vehicle registrations. About 48 % of the vehicles are diesel-powered (and more polluting) while 45 % are petrol-powered vehicles and an extremely limited number of eclectic powered vehicles in the country.

According to the Addis Ababa City Transport Authority, about 31 % of the overall vehicle fleet lacks catalytic converters. The high number of aged vehicles mostly imported used vehicles, coupled with poor fuel quality; poor vehicle maintenance as well as poor road infrastructure is responsible for the prominent level of vehicle emissions in Addis Ababa. Estimates of the pollution load from the increasing vehicle numbers in the city point to diesel-powered heavy-duty vehicles (freight and buses) as the biggest contributors to both PM and NOX.

ii. Emissions from industrial sources;

The growth in the industrial sector is mainly driven by the booming construction industry as well as manufacturing, both of which account for the industrial sector emissions in Ethiopia.

Emissions of concern from the industrial sector include particulate matter (PM2.5 and PM10), SO2, and NOX. The particulate matter produced from their energy use, demolition of building in the reconstruction process, and dust in the construction process with poor management are main.

iii. Emissions from open burning of waste.

Open burning of waste is a widespread problem in the country owing to the lack of an efficient integrated waste management system. Agricultural waste burning in rural and other waste burning in urban and semi-urban Ethiopia contributes to air pollution. There is also emission of air pollutants from health facilities due to the absence of incinerators.

iv. Other emission sources: Emissions from power generation

Currently, 97 % of installed electricity generation is from renewable sources (hydropower 89 %; wind 8 %). Thermal sources only account for 3 % of total generation. However, the government is currently diversifying its electricity generation mix as a result of droughts that have severely affected the hydro-dominated systems with other sources such as solar, wind, geothermal, and thermal power plants. The thermal plants may result in some level of increased emissions. For instance, the 50MW Reppie waste to energy plant that is expected to incinerate approximately 1,400 tons of waste per day will result in emission to air. Methane air pollutants from animal waste and other wastes produce significant pollutants. Poor waste incineration from the medical facilities are other sources of air pollution.

Table 1: Major gaseous and toxic air pollutants, their sources, and effects

Pollutant	Sources	Effects
Ozone. A gas that can be found in two places. Near the ground (the troposphere), which is a major part of smog. The harmful ozone in the lower atmosphere should not be confused with the protective layer of ozone in the upper atmosphere (stratosphere), which screens out harmful ultraviolet rays.	Ozone is not created directly but is formed when nitrogen oxides and volatile organic compounds mix in sunlight. That is why ozone is mostly found in the summer. Nitrogen oxides come from burning gasoline, coal, or other fossil fuels. There are many types of volatile organic compounds, and they come from sources ranging from factories to trees.	Ozone near the ground can cause a number of health problems. Ozone can lead to more frequent asthma attacks in people who have asthma and can cause sore throats, coughs, and breathing difficulty. It may even lead to premature death. Ozone can also hurt plants and crops.
Carbon monoxide. A gas that comes from the burning of fossil fuels, mostly in cars. It cannot be seen or smelled.	Carbon monoxide is released when engines burn fossil fuels. Emissions are higher when engines are not tuned properly, and when fuel is not completely burned. Cars emit a lot of the carbon monoxide found outdoors. Furnaces and heaters in the home can emit high concentrations of carbon monoxide, too, if they are not properly maintained. In addition, incomplete burning of wooden charcoal with local stoves at the household level may result in the formation of carbon monoxide.	Carbon monoxide makes it hard for body parts to get the oxygen they need to run correctly. Exposure to carbon monoxide makes people feel dizzy and tired and gives them headaches. In high concentrations it is fatal. Elderly people with heart disease are hospitalized more often when they are exposed to higher amounts of carbon monoxide.

Pollutant	Sources	Effects
Nitrogen dioxide. A reddish-brown gas that comes from the burning of fossil fuels. It has a strong smell at elevated levels.	Nitrogen dioxide mostly comes from power plants and cars. Nitrogen dioxide is formed in two ways-when nitrogen in the fuel is burned, or when nitrogen in the air reacts with oxygen at extremely hot temperatures. Nitrogen dioxide can also react in the atmosphere to form ozone, acid rain, and particles.	Elevated levels of nitrogen dioxide exposure can give people coughs and can make them feel short of breath. People who are exposed to nitrogen dioxide for a long time have a higher chance of getting respiratory infections. Nitrogen dioxide reacts in the atmosphere to form acid rain, which can harm plants and animals.
Particulate matter. Solid or liquid matter that is suspended in the air. To remain in the air, particles usually must be less than 0.1-mm wide and can be as small as 0.00005 mm.	Particulate matter can be divided into two types- coarse particles and fine particles. Coarse particles are formed from sources like road dust, sea spray, and construction. Fine particles are formed when fuel is burned in automobiles and power plants.	Particulate matter that is small enough can enter the lungs and cause health problems. Some of these problems include more frequent asthma attacks, respiratory problems, and premature death.
Sulfur dioxide. A corrosive gas that cannot be seen or smelled at low levels but can have a “rotten egg “smell at elevated levels.	Sulfur dioxide mostly comes from the burning of coal or oil in power plants. It also comes from factories that make chemicals, paper, or fuel. Like nitrogen dioxide, sulfur dioxide reacts in the atmosphere to form acid rain and particles.	Sulfur dioxide exposure can affect people who have asthma or emphysema by making it more difficult for them to breathe. It can also irritate people's eyes, noses, and throats. Sulfur dioxide can harm trees and crops, damage buildings, and make it harder for people to see long distances.

Pollutant	Sources	Effects
Lead. A blue-gray metal that is very toxic and is found in a number of forms and locations.	Outside, lead comes from cars in areas where unleaded gasoline is not used. Lead can also come from power plants and other industrial sources. Inside, lead paint is an important source of lead, especially in houses where paint is peeling. Lead in old pipes can also be a source of lead in drinking water.	Excessive amounts of lead can be dangerous for small children and can lead to lower IQs and kidney problems. For adults, exposure to lead can increase the chance of having heart attacks or strokes.
Toxic Air Pollutants. A large number of chemicals are known or suspected to cause cancer. Some important pollutants in this category include arsenic, asbestos, benzene, and dioxin.	Each toxic air pollutant comes from a slightly different source, but many are created in chemical plants or are emitted when fossil fuels are burned. Some toxic air pollutants, like asbestos and formaldehyde, can be found in building materials and can lead to indoor air problems. Many toxic air pollutants can also enter the food and water supplies.	Toxic air pollutants can cause cancer. Some toxic air pollutants can also cause birth defects. Other effects depend on the pollutant but can include skin and eye irritation and breathing problems.
Stratospheric ozone-depleting chemicals. Chemicals can destroy the ozone in the stratosphere. These chemicals include chlorofluorocarbons (CFCs), halons, and other compounds that include chlorine or bromine.	CFCs are used in air conditioners and refrigerators since they work well as coolants. They can also be found in aerosol cans and fire extinguishers. Other stratospheric ozone depleters are used as solvents in industry.	If the ozone in the stratosphere is destroyed, people are exposed to more radiation from the sun (ultraviolet radiation). This can lead to skin cancer and eye problems. Higher ultraviolet radiation can also harm plants and animals.

Pollutant	Sources	Effects
Greenhouse gases. Gases that stay in the air for a long time and warm up the planet by trapping sunlight. This is called the “greenhouse effect” because the gases act like glass in a greenhouse. Some of the important greenhouse gases are carbon dioxide, methane, and nitrous oxide.	Carbon dioxide is the most important greenhouse gas. It comes from the burning of fossil fuels in cars, power plants, houses, and industry. Methane is released during the processing of fossil fuels, and also comes from natural sources like cows and rice paddies. Nitrous oxide comes from industrial sources and decaying plants.	The greenhouse effect can lead to changes in the climate of the planet. Some of these changes might include more temperature extremes, higher sea levels, changes in forest composition, and damage to land near the coast. Human health might be affected by diseases that are related to temperature or by damage to land and water.
Aldehydes	Thermal decomposition of fats, oil, or glycerol	Irritant nasal and respiratory tract
Ammonia	Chemical processes dye making; explosives; lacquer; fertilizer	Inflame upper respiratory passages
Arsine	Processes involving metals or acids containing arsenic soldering	Break down red cells in the blood, damage kidneys, cause jaundice
Chlorine	Reach cotton and flour; many other chemical processes	Attack entire respiratory tract and mucous membranes of eyes; cause pulmonary edema
Hydrogen	Fumigation; blast furnaces;	Interfere with nerve cells; produce dry throat, indistinct vision, headache

Pollutant	Sources	Effects
Hydrogen fluoride	Petroleum refining glass etching; aluminum and fertilizer production	Irritate and corrode all body passages
Hydrogen sulphide	Refineries and chemical industries; bituminous fuels	Smell like rotten eggs; cause nausea; irritate eyes and throat
Nitrogen oxide.	Motor vehicle exhausts; soft coal	Inhibit cilia action so that soot and dust penetrate far into the lungs
Phosgene (carbonyl) chloride	Chemical and dye manufacturing	Induce coughing, irritation, and sometimes and fatal pulmonary edema
Sulfur dioxide	Coal and oil combustion	Cause chest construction, headache, vomiting, and death from respiratory ailments
Suspended particles (ash, soot, , smog,)	Incinerators; almost any manufacture	Cause emphysema, eye irritants and possibly cancer

Source: Jonathan Levy, Harvard School of Public Health.

CHAPTER THREE

Air quality and health

Air quality is the largest single environmental determinant to health. Pollutants with the strongest evidence for public health concern include particulate matter (PM), ozone (O3), nitrogen dioxide (NO2), carbon monoxide (CO), and sulfur dioxide (SO2).

The health risks associated with particulate matter of less than 10 and 2.5 microns in diameter (PM10 and PM2.5) are especially well documented. PM2.5 iis capable of penetrating deep into lung passageways and entering the bloodstream causing cardiovascular, cerebrovascular, and respiratory impacts. Smaller-diameter particles (PM2.5 or smaller) are generally more dangerous, as they can reach deep into the small airways of the body and deposit on the alveoli – the tiny sacs in the lungs where oxygen exchanges with carbon dioxide in the blood. Ultrafine particles (one micron in diameter or less) can penetrate tissues and organs, posing an even greater risk of systemic health impacts.

Even at relatively low concentrations, particulate matter (PM) can produce adverse effects on health, with no evidence of a safe level of exposure or a threshold below which no adverse health effects occur (World Health Organization, 2016). Nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon mono oxidized (CO) and ozone (O3) also have deleterious health effects.

Deterioration of air quality contributes to acute and chronic myriad health problems and medical conditions including eye/nose/throat irritation, breathing conditions such as asthma, cardiovascular disease, ischemic heart disease, diabetic's type 2, chronic obstructive pulmonary disease (COPD), lung cancer, nervous system disorders, low birth weight, problems of the reproductive system and other chronic and long-term diseases.

In Ethiopia, air pollution accounts for 13.75% of the disease burden. Tackling ambient (outdoor) and household (indoor) air pollution is crucial for achieving the 2030 Sustainable Development Goals (SDGs).

3.1. Indoor Air Quality and Health

Household air pollution (HAP) from inefficient fuel combustion is one of the most important global environmental health risks today. Almost 3 billion people, mainly in low- and middle-income countries, still rely on solid fuels: such as dung, wood, and coal in inefficient stoves or open hearths produces a variety of health-damaging pollutants, including particulate matter (PM), methane, carbon monoxide, poly-aromatic-hydrocarbons (PAH) and volatile organic compounds (VOC) (wood, animal dung, charcoal, crop wastes, and coal) burnt in inefficient, highly polluting stoves for cooking, heating, and lighting. Burning kerosene in simple wick lamps also produces significant emissions of fine particles and other pollutants

Generally, small particulate matter and other pollutants in indoor smoke inflame the airways and lungs, impairing immune response and reducing the oxygen-carrying capacity of the blood. There is also evidence of links between household air pollution and low birth weight, tuberculosis, cataract, nasopharyngeal and laryngeal cancers. Mortality from ischaemic heart disease and stroke are also affected by risk factors such as high blood pressure, unhealthy diet, lack of physical activity, and smoking. Some other risks for childhood pneumonia include suboptimal breastfeeding, underweight and second-hand smoke. For lung cancer and chronic obstructive pulmonary disease, active smoking and second-hand tobacco smoke are also main risk factors.

Exposure to smoke from cooking biomass fuels causes 3.8 million premature deaths each year, mostly in low- and middle-income countries. Household air pollution is the second leading cause of death next to malnutrition accounting for 12.15% of the disease burden attribution exceeding the combined effect of water; sanitation and hygiene (WASH) which accounts for 10.66% of the disease burden attribution in Ethiopia (IHM, 2019,)

Among the 67, 826 (12.15% attribution) deaths annually in Ethiopia, household air pollution attributes as risk factor for COPD 57%, LRI 47.7%, stroke 35.3%, IHD 29.5%, Neonatal death 21.9%, diabetics 20.9%, Meningitis 2.03% and diarrhea 1.16%(IHM, 2019).

Women exposed to elevated levels of indoor smoke are more than two times as likely to suffer from COPD; than women who use cleaner fuels and technologies. Among men (who already have a heightened/sharp risk of COPD due to their higher rates of smoking), exposure to household air pollution nearly doubles the risk of death.

Improvement of indoor air quality to maintain good health is related to many SDGs (Fig.1). For example, Healthy Indoor Environment is related to well-being for all occupants (Goal 3: good health and well-being). It also related to other goals, like, protection of women who are more exposed to indoor pollutants from combustion and cooking (Goal 5: Gender Equality), maintenance of clean water, and sanitation to avoid infection (Goal 6: Clean Water and Sanitation), use of clean energy to reduce the emission of pollutants (Goal 7: Affordable and Clean Energy), buying from green companies with low chemical pollutant emission levels (Goal 8: Decent Work and Economic growth), thinking of innovative materials to reduce pollutant levels (Goal 9; Industry, Innovation, and Infrastructure), keeping the city air clean (Goal 10: Sustainable Cities and communities), development and usage of the building and indoor materials with less emission of hazardous chemicals (Goal 12:Responsible Production and Consumption), and reduction in emissions of CO_2, black carbon, and NO_2 (Goal 13: Climate Action). In conclusion, achieving indoor air quality and clean energy will help to achieve most of the SDGs.

Figure 1: Improvement of indoor air quality to maintain good health is related to many SDGs

3.2. Ambient Air Quality and Health

Ambient (outdoor air pollution) is a major cause of death and disease globally. The health effects range from quality-of-life deterioration to increased risk of premature death. An estimated 3.8 million premature deaths globally are linked to ambient air pollution, mainly from heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, and acute respiratory infections.

In Ethiopia Ambient air pollution as measured by the effects of PM and ozone accounts for 1.73% (9656) of death annually as a risk factor. Ambient air pollution particulate matter (PM) accounts for 8.11% of COPD, 5.88% of LRI, 5.70% of stroke, 5.38% of Tracheal, bronchus, and lung cancer, 4.90% of IHD, 3.48% of diabetics, 0.20% of meningitis and 0.12% of diarrhea. Ozone (O3) accounts for 7.5% of COPD as a risk factor.

Emerging evidence also suggests ambient air pollution may affect diabetes and neurological development in children. Considering the precise death and disability toll from many of the conditions mentioned are not currently quantified in current estimates, with growing evidence, the burden of disease from ambient air pollution is expected to greatly increase.

3.3. Air Quality, Climate Change, and health

There is a strong linkage between air pollution, climate change, and human health. Climate change affects air quality through several pathways. From smog hanging over cities to smoke inside the home, air pollution poses a major threat to health and climate.

Air quality is intricately linked to the earth's climate and ecosystems globally. Many of the drivers of air pollution (i.e., combustion of fossil fuels) are also sources of high CO2 emissions. Short-lived climate pollutants (SLCPs) such as black carbon, methane, and tropospheric ozone are released through inefficient use and burning of biomass and fossil fuels for transport, housing, power production, industry, waste disposal (municipal and agricultural), and forest fires. SLCPs are responsible for a substantial fraction of global warming as well as air-pollution-related deaths and diseases. Since SLCPs persist in the atmosphere for weeks or months while CO2 emissions persist for years, significant reductions of SLCPs emissions could reap/gain immediate health benefits and health cost savings and generate very rapid climate benefits – helping to reduce near-term climate change by as much as 0.5oC before 2050.

In Ethiopia, it is projected that a reduction in SLCPs could prevent 24,800 premature deaths per year from outdoor air pollution (PM2.5 and ozone), from 2030 onwards (Source: Shindell, D., Science, 2012).

Hot temperatures raise the levels of ozone, pollen, aeroallergen levels, and other pollutants in the air. Extreme high air temperatures also contribute directly to deaths from cardiovascular and respiratory disease, particularly among elderly people.

In general, climate change contributes to air pollution; and air pollution is also a risk factor for climate change. Policies to reduce air pollution, therefore, offer a "win-win" strategy for both climate and health, lowering the burden of disease attributable to air pollution, as well as contributing to the near- and long-term mitigation of climate change.

3.4. Air Pollution Health Risk Assessment

A health risk assessment is the scientific evaluation of potential adverse health effects resulting from human exposure to a particular hazard. In the context of this guideline, Air Pollution Health Risk Assessment of (AP-HRA) aims to estimate the risks of past, current, or future exposure to air pollution and of changes in exposure that may result from planned policies or other modifications of air quality. An AP-HRA may be quantitative or qualitative; it generally assesses.

- The amount of air pollution present, i.e., pollutant concentrations,
- The amount of contact (exposure) of the targeted population, and
- How harmful the concentration is for human health, i.e., the resulting health risks to the exposed population (WHO, 2010).

As an analytical tool, an AP-HRA can be used as part of a comprehensive assessment of the health impacts of policies, programs, and projects that affect environmental conditions – health impact assessment (HIA).

3.4.1. Planning and Conducting AP-HRA

3.4.1.1 Definition of the Policy Question

As outlined above, the main purpose of an AP-HRA is to answer policy questions about the likely health impacts of planned policies or modifications of air quality. AP-HRAs are often used to answer the following policy questions (WHO Regional Office for Europe, 2014).

- What is the public health burden associated with current levels of air pollution?

What are the human health benefits associated with changing an air quality policy or applying a more stringent air quality standard?

- What are the human health impacts of emissions from specific sources or selected economic sectors and what are the benefits of policies related to them?
- What are the human health impacts of current policy or implemented action?
- What are the policy implications of the uncertainties of the assessment?

The results of an AP-HRA can be used in an estimation of the economic value of health benefits resulting from a policy change. Some AP-HRA tools incorporate this step. The knowledge gained through an AP-HRA can also be used to improve policies, such as increasing the stringency of air quality standards.

3.4.1.2 Planning the Health Risk Assessment

Planning for AP-HRA includes a careful definition of the policy question, determination of the availability of data and resources, and selection of appropriate methods and tools. Input data are required on, for example:

(1) The level of air pollution,

(2) The exposed population, and

(3) The health outcome affected (concentration-response functions). The selection of the method may depend on data availability or may determine the data requirements. In addition, different tools will entail different workloads and require various levels of expertise. The following factors should be considered concerning data needs and availability, depending on the question to be answered (WHO Regional Office for Europe, 2014)

The policy question and the event or condition of interest will define the data needs with respect to the following:

- Who is affected?
- How are people affected by air pollution?
- Which key pollutant indicators are to be considered to describe the exposure and estimate the health risk for a specific population in a specific situation?
- What is the spatial resolution of the issue or question to be assessed in the AP-HRA?
- What is the temporal resolution of the issue or question to be assessed in the AP-HRA?

The selection of the tool will define the data needs with respect to the following:

- What spatial resolution of the air pollution and population data is needed?
- What temporal resolution of the air pollution data is needed: hourly, daily or annual averages?
- What temporal resolution of the health data is needed: daily mortality or annual mortality?
- Are the data needed for the AP-HRA available?
- Are measurements of air pollution available or modeled data?
- Have previous studies been describing the concentration-response relationship for the health outcomes of interest?
- How many people in the population of interest are affected by a specific health outcome caused by air pollution?

Once the desired data have been identified, the availability of the data has to be assessed. The available, compiled data on exposure to air pollution, health, and population are then used to assess the health impacts associated with exposure to air pollutants with respect to the specific policy question to be answered.

3.4.1.3 Estimating Population Exposure to Air pollution

Data on population exposure to air pollutants generally come from monitoring by local or national institutions. Estimations of population exposure based on measured air pollution data are often limited by the restricted geographical and time coverage. In addition, it may be difficult to reconcile data from various locations since measurements are often made using different procedures and techniques (WHO Regional Office for Europe, 2014). Even the methods used in one location may change with time. Recent progress in combining satellite remote sensing, global chemical transport modeling, land-use regression models, and high-resolution local dispersion models in combination with existing ground-based monitoring has made information on key air pollutant indicators increasingly available, including in some of the most highly polluted and data-poor regions (Brauer et al., 2012; Hoek et al., 2008; Paciorek & Liu, 2012; UNECE, 2010; van Donkelaar et al., 2010).

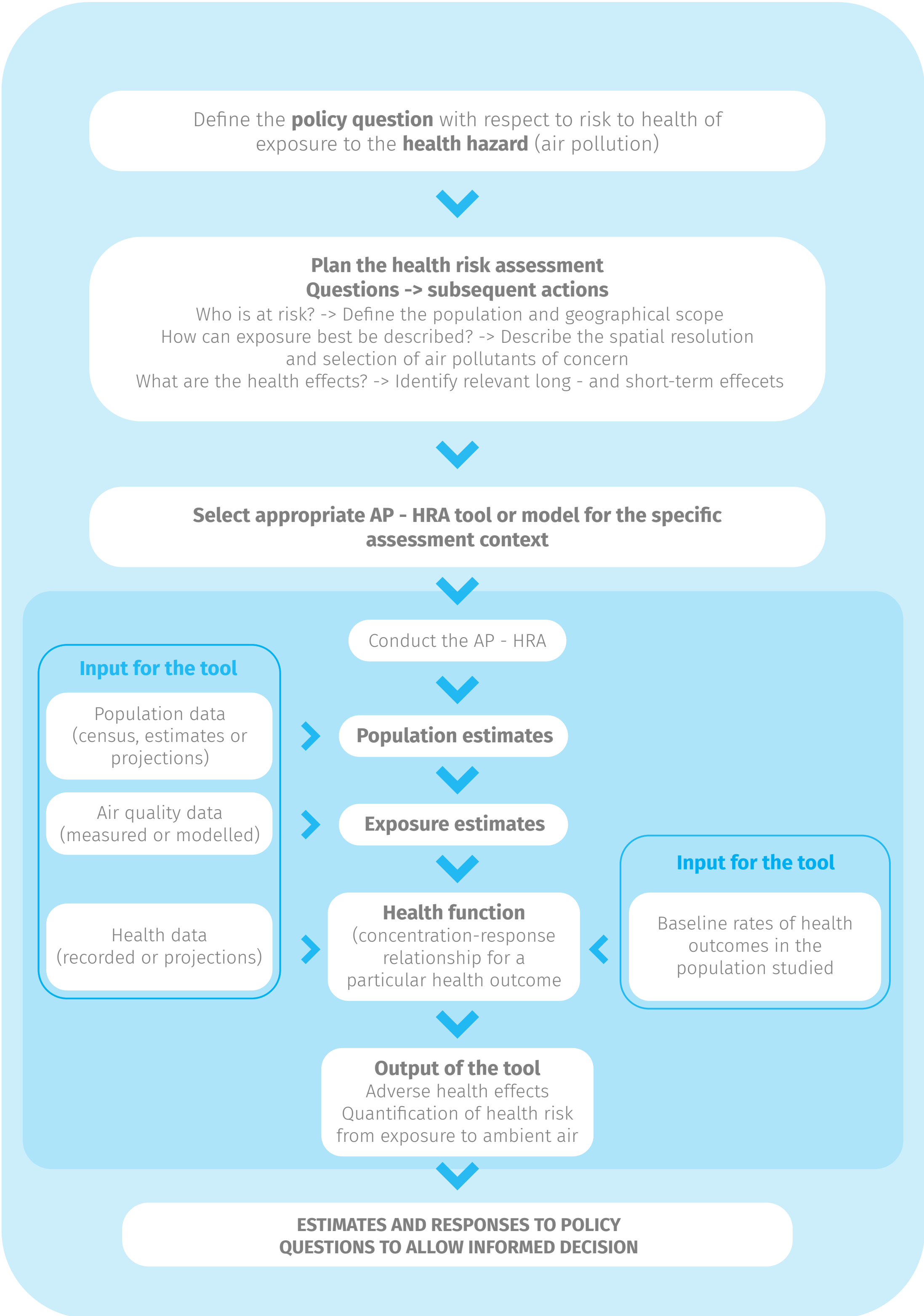

Figure 2: Adopted from WHO Regional Office for Europe, 2014

The cause response function (CRFs) used in AP-HRA tools are typically based on the epidemiological evidence available for a specific health outcome. Some are based on evidence from experiments in which people or animals are deliberately exposed to a pollutant (WHO Regional Office for Europe, 2014). The CRF may therefore be refined as new scientific evidence becomes available. For example, the likely health risks of exposure to ultrafine particles are currently not considered, as there is no reliable CRF available (Hoek et al., 2010). In some cases, CRFs available may not be appropriate for extremely high and exceptionally low concentrations. Finally, it is important to note that most studies have been carried out in Europe and North America. Pollution levels, chemical composition, and health care systems may be quite different in other places, and this may affect the CRF.

All these factors mean that, in certain assessment contexts, the absence of direct epidemiological evidence about the health risk of exposure to air pollution is an important limitation. For regions with limited or no epidemiological evidence, information from studies in other parts of the world may be used to conduct an AP-HRA. However, such extrapolated information may not accurately describe the concentration-response relationship in the region to be assessed, leading to uncertainties in the results (WHO Regional Office for Europe, 2014).

When generating and communicating AP-HRA results for a specific health endpoint, it should be kept in mind that the effects of long-term exposure are much greater than those observed for short-term exposure (WHO Regional Office for Europe, 2013).

3.4.1.4 Quantifying the Health Impact

Results of AP-HRAs are often reported in terms of number of the attributable deaths or cases of the disease, years of life lost (YLL), disability-adjusted life years (DALYs), or change in life expectancy attributable to total exposure to air pollution or a change in exposure (WHO Regional Office for Europe, 2014)). Number of attributable deaths or cases of disease: This is calculated as the difference in number of deaths or cases of diseases between the incidence/rate at the exposure measured. Steps followed in a risk assessment protocol over a specific period and that at baseline exposure, e.g., difference between current disease incidence and historical incidence or projected future incidence, or total health risk (in relation to zero exposure or some assumed threshold value) (WHO Regional Office for Europe, 2014).

CHAPTER FOUR

Air quality monitoring

4.1. Ambient Air Quality Monitoring

Ambient air monitoring is the systematic, long-term assessment of pollutant levels by measuring the quantity and types of certain pollutants in the surrounding, outdoor air. It helps in evaluating the existing policies and their effective implementation. One of the important components of any air quality monitoring program is planning, design, and establishment of a monitoring network based on the air quality objectives.

The Air Quality Monitoring System (AQMS) is a facility to measure the concentration of air pollutants (such as SO2, NOx, CO, O3, etc.), particulate matters, wind speed, direction, other weather parameters, continuously all year round. Mobile AQMS can also be customized to monitor multiple sites via one system.

The objectives of ambient air quality monitoring is to assess the extent of pollution; provide air pollution data to the general public in a timely manner; support the implementation of air quality goals or standards; evaluate the effectiveness of emissions control strategies; provide information on air quality trends; provide data for the evaluation of air quality models; and support research (e.g., long-term studies of the health effects of air pollution).

There are different methods to measure any given pollutant. A developer of a monitoring strategy should examine the options to determine which methods are most appropriate, taking into account the main uses of the data, initial investment costs for equipment, operating costs, reliability of systems, and ease of operation.

The locations for monitoring stations depend on the purpose of the monitoring, pollution level, and coverage area. Most air quality monitoring networks are designed to support human health objectives, and monitoring stations are established in population centers. The locations selected one station for 500,000 populations. They may be near busy roads, in city centers, or at locations of particular concern (e.g., a school, hospital, particular emissions sources). Monitoring stations also may be established to determine background pollution levels, away from urban areas and emissions sources.

Systems are needed to ensure that data are of acceptable quality, to record and store the data, and to analyze the data and present results. Air quality monitoring can be based on Ground-level Monitoring, Satellite Remote Sensing, and air pollution modeling such as WRF- CHIMERE or Visibility as a proxy for air pollution.

4.1.1. Conventional Ground Air Quality Monitoring

Conventional fixed monitoring stations that are acceptable quality for regulatory purposes are those instruments approved by the US EPA or EU Environment Agency as a reference method. Ethiopia is among the few nations in Africa that have real-time air quality monitoring stations, which were installed by the National Meteorology Agency (NMA) in Addis Ababa city, Adama, and Hawassa town. The stations are equipped to monitor nitrogen oxides (NOx), ozone (O3), and carbon monoxide (CO). Particulate matter was not being monitored in Addis Ababa by NMA but is being monitored now by US Embassy and Black lion Hospital Geo-Health Hub and EPHI. The other two monitoring stations in Adama and Hawassa town have a PM10 and PM2.5 monitoring capacity.

4.2.2. Ground air quality monitoring with smart sensors

Air quality sensors are mostly light scattering methods, convert particle count internally into concentrations of the required parameter. It can be used to measure air quality parameters, including the particulate matter of various size cuts (PM0.1, PM1, PM2.5, PM10, TSP), with the most important one being PM2.5, and gaseous pollutants (NO2, SO2, O3, CO). Some monitors are designed to monitor different gases simultaneously, with real-time data logging and transferring capacity to a central server and a webpage.

There are few portable smart sensors in Addis Ababa installed by different organizations. UN Environment installed five smart sensors at various locations in Addis Ababa to develop a predictive model using the satellite data fusion with the ground truth from monitors. Yet, the sensitivity and the accuracy of these smart sensors greatly vary compared to measurements by conventional air quality monitoring stations. Therefore, there is a need to perform calibration and validation through colocation with a conventional fixed monitor (e.g., BAM devices). Hence, such devices are not suitable for decision-making to affirm the attainment of air quality ambient standards, but regulatory purposes to advise industries of their emission reduction.

4.3. Indoor Air Quality Monitoring

As ambient air qualities, indoor air quality is also possible to monitor using wireless low-cost sensor networks in the area where internet connection can be secured. Of course, this can be done in remote area of rural Ethiopia using solar power energy sources for low-cost sensor networks.

Basically, the indoor air quality monitoring will target household energy use, type of cook stove available, and survey-based indoor air quality monitoring. EDHS surveys will help to collect the health and other indoor air pollution-related variables. A continuous data monitoring for household and kitchen condition, ventilation, energy use, and clean cook stove adoption and utilization report through the existing e-CHIS and HMIS is recommended. To conduct a survey of indoor air quality handy air quality measuring devices can be used.

4.4. Stakeholders' collaboration and data sharing

In Ethiopia, the air quality-monitoring task is given to National Meteorology Agency (NMA) with a legal provision. Other stakeholders have the stake from different perspectives.

The Ministry of health is vested with different legal provisions, mandated to formulate policies, strategies, guides, and implementation systems for any health services and health determining environmental and social issues. Therefore, when MoH formulates this guide, it aims to protect the public health from the impacts of air pollution through different interventions in collaboration with all concerned stakeholders

Similarly, other sectors can use air quality monitoring data to plan and design interventions. Therefore, data sharing among different stakeholders such as NMA, EFCCC, Research institutes, and other sectors is especially important and crucial.

CHAPTER FIVE

Interim guideline values of pollutants in Ethiopia

5.1. Criteria air pollutants

The 2005 "WHO Air quality guidelines" offer global guidance on thresholds and limits for key air pollutants that pose health risks. The Guidelines indicate that by reducing particulate matter (PM10) pollution from 70 to 20 micrograms per cubic meter (µg/m3), we can cut air pollution-related deaths by around 15%. The Guidelines apply worldwide and are based on expert evaluation of current scientific evidence for particulate matter (PM); ozone (O3); nitrogen dioxide (NO2), carbon monoxide (CO), Lead (Pb), and sulfur dioxide (SO2), in all WHO regions.

5.1.1. Particulate Matter

PM is a common indicator for air pollution; it affects more people than any other pollutant. The ambient and indoor air qualities are the same on criteria for air pollutants. However, there are suggested emission levels for clean cook stoves of diverse types with different energy sources. The mean annual concentration of PM2.5 in Addis Ababa, perhaps the highest ambient PM2.5 concentration in Ethiopia, found 53.8 (±25.0) µg/m3. So, taking this as a benchmark value, this guideline value suggests an interim air quality level for 15 µg/m3 for PM2.5 i.e., WHO Interim target-3 (IT-3) for PM10 for the next 5 years. We suggest the WHO interim target 3 daily and annually.

5.1.2. Ozone (O3)

Even though the current ozone level of Ethiopia is lower than WHO recommended level on 8 hours basis, from the emission of precursors of ozone formation gases such as NO2 and VOC emission and global temperature increase there might be an increase of ozone in the future. Therefore, this guideline value suggests the WHO guideline value i.e.,100 µg/ m3 on 8 hours average.

5.1.3. Nitrogen Dioxide (NO2)

Longitudinal indoor air pollution study in rural Ethiopia, show the high average NO2 concentration found 97 ppb or 182.40 µg/m3 for indoor and 49 µg/m3 for ambient nitrogen dioxide in Addis Ababa and taking this as the maximum average for the country with limited evidence, this guideline suggests the WHO guideline value 40 µg/m3 annual and 200 µg/m3 for 1 hour for ambient air.

5.1.4. Sulfur Dioxide (SO2)

There is a dearth of evidence for SO2 air concentration in Ethiopia. Some studies were done in Addis Ababa show 20 µg/m3, and assuming that other parts of the country will become lower than this value, this guideline value recommends the WHO guideline value 20 µg/m3 24 hours and 500 µg/ m3 for 10-minute exposure.

5.1.5. Carbon monoxide (CO)

It is a colorless, non-irritant, odorless, and tasteless toxic gas. It is produced by the incomplete combustion of carbonaceous fuels such as wood, petrol, coal, natural gas, and kerosene.

Anthropogenic emissions are responsible for about two thirds of the carbon monoxide in the atmosphere and natural emissions account for the remaining one third. Exposure to low levels of carbon monoxide can occur outdoors near roads, as it is also produced by the exhaust of petrol- and diesel-powered motor vehicles. Parking areas can also be a source of carbon monoxide. The WHO guidelines put (100 mg/m3), for 15 minutes (35 mg/ m3) for 1 hour and (10 mg/ m3) for 8 hours.

5.1.6. Lead (Pb)

Leaded gas oil is banned in Ethiopia since 2011 but studies done in Addis Ababa show the ambient concentration of 2.8 μg/m3. The WHO recommended 0.5 μg/m3 annual mean. This guide adopts the WHO guideline value.

5.2. Indoor air quality interim target

The other especially important guideline value is the indoor air quality and emission concentration of household fuel combustions of any fuel type, the minimum emission acceptable level suggested. Even though any of the suggested biomass fuel household combustion technologies could not achieve the WHO interim target-1 i.e., PM2.5 (35 μg/ m3), household biomass fuel combustion with chimney (vent) highly reduces the indoor air concentration level. The table below puts the minimum emission level from cook stoves under vented (chimney) and not vented kitchen condition to achieve the minimum target-1 value. The ultimate goal is to reach the air quality targets in the indoor environment, and this can be measured using a handy portable air quality-measuring device during and after cooking activities.

Table 2: Emission level of improved cook stoves in vented and unvented households

Pollutant	Concentration	Household conditions
Particulate Matter (PM2.5)	0.23 mgmin-1	Unvented
	0.80 mgmin-1	Vented
Carbon Monoxide (CO)	0.16 gmin-1	Unvented
	0.59 gmin-1	Vented

Source: WHO indoor air quality guidelines: household fuel combustion (2014, p. 101)

The test mechanisms for cook stoves emission will be done in a controlled laboratory or field based. Three common standardized tests are the Water Boiling Test (WBT), the Controlled Cooking Test (CCT), and the Kitchen Performance Test (KPT). The Ethiopian Standard Agency formulates on its ES ISO 19867-1 and ES ISO 21276 the following standards of Emission for cook stove at different tier levels and stove performance levels. It also formulates test methods and protocols for emission levels from cook stove and their durability.

Table 3: Target value for Emission, thermal efficiency, durability, and safety score of improved Cook stove (ESA-2019)

	Tiers[b]	Thermal efficiency	Emissions		Safety (score)[c]	Durability (score)[d]
		%	CO	$PM_{2,5}$ mg/MJ$_d$		
			g/MJ$_d$			
Better	5	≥50	≤3,0	≤5	≥95	<10
Performance	4	≥40	≤4,4	≤62	≥86	<15
	3	≥30	≤7,2	≤218	≥77	<20
	2	≥20	≤11,5	≤481	≥68	<25
	1	≥10	≤18,3	≤1030	≥60	<35
	0	<10	>18,3	>1030	<60	>35

[b]The tier level for each performance metric should be reported separately.

[c]Safety protocols (see ES ISO19867-1) cover solid-fuel stoves only. For gaseous, liquid, and alcohol stoves shall be tested as per ES ISO 23550 and 23551 all parts.

[d]Durability protocols (see ES ISO19867-1) evaluate common material failures in biomass cook stoves. The protocol is not comprehensive of all failures that might be found in the field, nor are the tests found in the durability protocol applicable for all cook stoves. Instead, the durability protocol seeks to cover the most prevalent durability concerns found across a range of cook stove technologies and construction materials.

Source: ESA-2020

Table 4: Minimum Indicators for Emission level for different cook stove types, thermal efficiency, safety, and durability

Type of stove	Thermal[a] efficiency	Emissions[a]		Safety (score)[b]	Durability [a]
	%	CO	$PM_{2.5}$		
		g/MJ_d	mg/MJ_d		
Natural draft solid biomass stove	>20	≤7.2	≤321	≥77	< 20
Forced draft solid biomass stove	>30	≤4.4	<92	≥77	< 20
Charcoal	>30	≤4.4		≥77	< 20
Biogas	40	≤4.4	≤62	x	< 15
Ethanol	40	< 4.4	≤62	x	< 20
LPG	60	< 3.3	< 5	x	< 20
a: The performance test (thermal and emission) and Durability of the clean stove shall be tested in accordance with ES ISO 19867-1.					
b: For safety test ES ISO 19867 – 1 is applicable for solid fuel stoves. For gaseous, liquid, and alcohol fuel stoves ES ISO 23550 and 23551 all parts shall be applicable.					

Source: ESA-2020

5.3. Others air pollutants

Other pollutants of health importance such as black carbon, benzene, Formaldehyde, Naphthalene,Polycyclic aromatichydrocarbons, Radon, Trichloroethylene, Tetrachloroethylene, POPs (dioxin and furans) & VOC are considered in the WHO indoor air quality guide. Even though the main health affecting air pollutant is from indoor air quality, and major criteria pollutants mentioned above, these other pollutants are also a health issue in many ways, and their quality level from the source they produced and in the indoor and outdoor environment will be monitored. Some of the health important pollutants produced from health care facility waste incineration emission. For example, 26% of dioxin and furans are produced from health care facilities in Ethiopia. Ethiopia accepts and signs the Stockholm convention on POPs and will follow that emission reduction targets too.

CHAPTER SIX

Air quality mamagement strategy

6.1. Policy, legislation, and Regulatory Strategies

Enforcement of air quality standards is overly critical to achieve human health and environmental targets stipulated in the guideline through intervening in ambient and household air pollution.

The constitution of the Federal Democratic Republic of Ethiopia (FDRE) is the basis for all development-related policies, legal provisions, and related outcomes within the country. It gives policy provisions regarding air pollution and endorses the 'middle road' approach to development, which emphasizes the importance of environmental protection. This provides a solid foundation for the development of policies, laws, and institutional arrangements that support air quality control.

With consideration to the constitutional provisions, the environmental policy of Ethiopia has grounded itself on the two clear environmental objectives of Ethiopia: i.e. I) clean & healthy environment, and II) sustainable development.

Ethiopia enacted Environmental Pollution Control Proclamation (Proclamation No. 300/2002) in 2009. This proclamation aims to eliminate, and where not possible, mitigate the impacts of pollution as an undesirable consequence of social and economic development activities. It prohibits persons from engaging in any activities that pollute the environment by violating the relevant environmental standards. The Federal EFCCC or the relevant regional environmental agency, e.g., Environmental Authority and Green Development Commission (EAGDC) may take administrative or legal action against a person who violates the law by releasing any pollutant into the environment. Persons engaged in any activity, which is likely to cause environmental pollution is required, upon a decision to that effect by the relevant regional environmental agency, to install appropriate technology that avoids or reduces, the generation and emission of pollutants.

As per the established regulatory framework, regulation, and compliance to air quality standards through regular monitoring of air quality can be undertaken at the national, regional, and city administration level. Regional government and city administration can take enforcement action in their respective authority, while federal government provide supports through technical capacity building and equipment provision to facilitate enforcement on compliance and for monitoring of air quality by city administration or regional government.

6.2. Source-based regulatory measures

The main sources of ambient air pollution in Ethiopia are vehicular emission, industrial emission, waste burning, and power plant sources. Below are suggested source-based regulatory intervention approaches for Ethiopia.

6.2.1. Vehicular emission control strategies

i. Clean fuel standard enforcement

From the clean fuel standard aspect, the main targets are lead and sulfur dioxide. Ethiopia banned leaded fuel and recommended the maximum sulfur dioxide level to be 500 ppm. Therefore, the concerned bodies on this i.e., EFCCC, ministry of transport, Ethiopian petroleum supply enterprises (EPSE), MOH, Ethiopian standard Agency, and Ministry of Mining and petroleum should work to enforce the standard.

ii. Vehicular emission standard and enforcement

There is no vehicular emission standard for Ethiopia. Ministry of transport tried to study how much to be the emission level of pollutant gases per vehicle. The ultimate goal of emission control is to protect the public health and the environment. Of course, the measures will have economic and social benefits. Therefore, the health impact of emission per vehicle must be monitored and followed. The factors determining for high vehicular emissions are old car importation, absence of vehicle service year limit (mileage), poor annual maintenance, poor catalytic converter enforcement, and poor road condition (high traffic jams). The polluter pays principle must be applied on polluting vehicles and it says, "Polluters and users of natural resources should bear the full environmental and social costs of their activities and internalize environmental externalities."

Therefore, the following regulatory initiatives are suggested in this guideline:

- Enforce installation of the catalytic converter during annual licensing and renewal
- Enforce annual maintenance and renewal
- Roadside vehicle emissions tests
- Annual vehicle emissions tests and law enforcement
- Develop a regulation for service year limit (mileage)
- Subsidies tax for non-fuel transport options like bicycles and encourage walking
- Subsidizing public transport
- Traffic jam (congestion) charging

- Heavy-duty track ban in urban centers
- Banning old car importation/high taxation
- Urban Road User Charging and Workplace Parking Levies
- National road pricing
- Improved anti-idling enforcement
- Reduced Vehicle Excise Duty for early purchase of new vehicles
- Promotion of low emission zones
- Fiscal incentives for low emission vehicles
- Pollution car labeling scheme
- Newer buses used for most polluted routes (label based)

6.2.2. Industrial emission control strategy

A subsidiary legislation to the Environmental Pollution Control Proclamation, prevention of Industrial Pollution: Council of Ministers Regulation (Reg. No. 159/2008: Prevention of Industrial Pollution Council of Ministers Regulation) was enacted. The Regulation imposes general obligations on factories subject to:

- Minimize the generation of every pollutant to an amount not exceeding the limit set by the relevant environmental standard and dispose of the same in an environmentally sound manner
- Handle equipment, inputs, and products in a manner that prevents damage to the environment and to human health.
- Measures to increase the number of inspections and enforcement actions
- Providing industries and companies with an incentive or the means to reduce industrial pollution by adopting air pollution prevention and control technologies and to undertake research into the process and product efficiency
- Penalizing polluters for negative environmental impacts at the company/industry level (Follow polluter pays principle)
- Market-based measure for reducing emissions of pollutants through emissions trading

Under industrial emission control, enforcing the laws and regulations developed based on the industrial emission standards. The emission effect on the ambient air quality must be monitored and studied continuously. The mitigation measures enforcement i.e., emission control device installation, undertake Environmental and health impact assessment, and environmental management plan (EMP) preparation and execution based on which the suggested mitigation measures by the authority must be enforced.

6.2.3. Open waste burning (prohibiting by regulation)

The Ethiopian solid waste management proclamation (No. 513/2007) prohibits open waste burning and suggests the emission level of incinerators. Therefore, municipalities and EFCCC should work to enforce this legislation.

6.2.4. Clean cook stove standard Enforcement

Ethiopian clean cookstove standard is prepared by ESA in collaboration with MoH. The technologies in the area of cook stoves such as LPG, biomass-based, and kerosene-fueled cook stoves standard has been tried to be formulated by Ethiopia Standard Agency.

Cleaner household energy use such as electrical stove in areas where electrical access available, must be encouraged through cost reduction from electric charges, appliances, etc.

The manufacturing industries for clean cook stove technologies must be encouraged through facilitating conducive enabling environment. . On the other hand, they must be regulated against emission level standards of cook stove technologies set in this guideline before mass production and distribution.

This regulation must be in laboratory-based monitoring and testing as well as field-based in the actual use situation. For this MOH, ESA and EFCCC must work together at each step.

6.2.5. Regulatory control strategy for other air pollutants

Other air pollutants of public health concern in Ethiopia are black carbon, benzene, Formaldehyde, Naphthalene, Polycyclic aromatic hydrocarbons, Radon, Trichloroethylene, Tetrachloroethylene, POPs (dioxin and furans) & VOC.

Basically, the POPs (dioxin and furans) & VOC are an especially important and significant public health concern. About 26% of dioxin and furans are produced from health care facilities. Therefore, health care facilities must follow an environmentally friendly and sound waste management system.

Ministry of health with Ethiopian standard agency formulated the type of waste treatment options for health care facilities for various levels and the waste incineration technologies for incineration option. Therefore, the incinerator technologies used for private and government health care facilities' minimum temperature, incinerator type, and emission levels must be regulated.

The standard emission level for health care waste incinerators developed in this guideline adapting the World Bank (International financial corporation) standards for different pollutant emission levels.

6.3. Technology-based air quality management strategies

Under this strategy, the hierarchies are prevention of emission, mitigation using technologies, and avoidance of public exposure. The first priority in any action to improve air quality is to consider whether air pollution can be removed or reduced at source – 'Prevention.' For example, implementing interventions which remove or reduce polluting sources such as emissions from cars (e.g., by promotion of public transport, non-motorized transport, use of electric vehicles) or emissions from wood-burners (cleaner fuels, removing old appliances). Importantly, 'Prevention' applies to emissions of pollutants rather than activities. There is no need to stop or reduce activities if they can be carried out in a way that is less polluting.

The air pollution intervention hierarchy recognizes that it is not always possible to prevent emissions of pollutants to the air. If emissions cannot be fully eliminated, then the next step is to consider how environmental pollution could be reduced. Examples are keeping sources of pollution away from people, redesigning spaces to introduce barriers to separate people from pollution, and displacing pollutant emissions outside hotspots and populated areas to reduce population exposure.

Finally, if environmental pollution cannot be reduced or displaced, the last step is to consider how people can avoid exposure: setting out interventions to support exposure reduction (such as using travel plans based on less polluted routes, using personal protective equipment etc.).

Within this air pollution hierarchy, the least preferable interventions when implemented in isolation, at a population, level is exposure reduction (avoidance of pollution); ideally, interventions based on avoidance should be used to supplement, not replace, wider packages of interventions that prevent or mitigate air pollution.

At each level of this hierarchy, interventions need to be appropriately evaluated to ensure they are proportionate and deliver overall benefits to public health.

The technology strategies focus similarly on our sources of pollution for ambient and indoor air pollution sources. All the technologies will be sought to address these sources. As stated above the sources of ambient air pollution in Ethiopia mainly focuses on vehicular, industrial, haphazard waste burning and power plants while the main sources of pollution for indoor air pollution is from biomass use for cooking, lighting, and heating using poor technologies in poorly ventilated houses. Therefore, this guideline will suggest technology interventions towards these sources.

6.3.1. Vehicular source (transport) technology interventions

- Prioritizing rapid urban transit, non-motorized transport in cities as well as rail interurban freight and passenger travel
- Shifting to cleaner heavy-duty diesel vehicles and low-emissions vehicles and fuels, including fuels with reduced sulfur content
- Promoting electric cars and other lower emission vehicles
- Prioritize mass transportation options
- Catalytic converter installation in vehicles
- Vehicle renovation and service for annual maintenance(improve vehicle condition)
- Implementing speed limit and eco-driving
- Installation of vehicular emission reduction technologies
- Improve fuel quality and fuel-efficient technologies in vehicles
- Improve traffic management and routing using GPS technologies to give instantaneous jams
- Improve road condition and making all roads well-paved in cities especially
- Creating green spaces that help remove particulate matter and reduce the heat Island effect

6.3.2. Industrial emission reduction technology strategies

When we say industrial sources, it includes construction, manufacturing, mining, and factories. The emissions may be from fuel use, grinding and crashing, processing burning, etc. In principle, the technology options for industrial emission reduction are recommended to follow the hierarchy for pollution control i.e., prevention, mitigation, and avoidance.

The following measures are suggested according to this guide:

Diffuse dust abatement: Measures to prevent and control diffuse dust emissions from industrial activities

Dust Abatement: Abatement measures to control dust emissions (combustion and process emissions) from industrial activities

Primary NOx/SO2/PM measures: Primary measures to prevent the formation of NOx, SO2, and PM from industrial activities

- Selection of less polluting and green industrial technology options and use less-polluting energy sources, frequent renovation, annual maintenance system of the industry

- Implement the Environmental and health impact assessment of the industry and implement the environmental management plans suggested. Continuous emission monitoring system as an integral part of overall industrial process follow the principle of waste reduction and an environmentally friendly approach

- Install emission control device built-in such as Adsorption, Absorption, condensation, incineration, Flue gas Desulphurization, Flue gas Denitrification, etc. Mitigate the emission by improving stack height improvement to avoid public exposure, afforestation around the industries and on buffering zones of the industries

6.3.3 Open Waste burning emission control strategies

Haphazard waste incineration accounts appreciable contribution to air pollution in both urban, semi-urban, and rural Ethiopia. This guideline recommends integrated waste management to apply at all steps. Promoting waste reduction, waste separation, recycling, and reuse or waste reprocessing. Improving methods of biological waste management such as anaerobic waste digestion to produce biogas are feasible, low-cost alternatives to the open incineration of solid waste. Methane gas capturing from liquid waste in urban areas also must be considered for economic energy recovery and pollution control. Where incineration is unavoidable, then combustion technologies with strict emission controls are critical. In rural places, agricultural waste incineration must be discouraged and rather composting and animal feeding must be used as an option.

6.3.4 Power generation

Power generation from the burning of fossil fuels in Ethiopia is exceptionally low and Ethiopia uses renewable energy sources i.e., hydroelectric, geothermal, and wind. But energy source diversification tried from thermal sources such as waste incineration (Reppi waste-based thermal power) which have appreciable emission contribution for air pollution. Ubiquitous use of diesel generators as backup when power grid electric system interrupted also contributed to air pollution. As an option, this guideline recommends promotion of solar power as a backup system rather than diesel generators both for urban and rural. Solar power system should be built on roofs of buildings as resilient city strategy.

6.3.5 Technology and design-based household air pollution prevention strategy

In Ethiopia, the indoor household air pollution or indoor air quality problem emanates from the use of biomass fuel for cooking, heating, and lighting. Technology options for indoor air pollution reduction must target this problem considering the available energy source, cooking devices, and cooking culture.

As a strategy, even though the ultimate target is clean energy source i.e., electrical, as an intermediate outcome, technologies must be tailored to the needs of our 95% of households' biomass fuel use reality.

Shifting to cleaner cook stoves requires a multi-pronged approach including:

a) The introduction of cleaner technologies and fuels for cooking, heating, and lighting as well as improved housing and ventilation design;

b) Supportive government policies and economic incentives; and

c) Education and awareness raising to support needed changes in cultural habits around cooking and household energy management.

For biomass, fuel based coking technology there are:

Switching to low-emission (improved) biomass cook stoves:

Stoves with specific features, such as secondary combustion, insulated combustion chambers, and/or fans can improve combustion efficiency and significantly lower emissions.

While not all "improved" biomass stoves meet WHO guidelines, low-emission stoves serve as an important transitional technology. Improved cook stove with chimneys is particularly important and are recommended by this guideline for peri-urban and rural communities of Ethiopia.

The production, distribution, and promotion for utilization must be geared with social marketing concepts integrating with sanitation marketing (detail addressed on SBCC & Advocacy section). There is a trial by different institutions and partners such as energy authority and GIZ to distribute some branded cook stoves such as Lakech, Gunzie, Tikikil, enjera Baking Gasifier Stove, etc. These trials are very encouraging solution for biomass-based cook stoves. However, the main limitations with them are:

1) They are energy efficient to some extent but not considering pollutant emission and health oriented. The emissions are released inside the house and

2) Most of them are designed for enjera baking, while not addressing other cooking needs i.e., "wote," coffee, roasting grains, etc. and also as known most of the people in southern Ethiopia depends on food other than enjera, therefore, do not address their cooking needs.

Therefore, improved biomass cookstoves tailored to different cooking and food culture should be designed, produced, and distributed (refer to improved biomass cook stove options in a separate implementation manual).

Phasing out kerosene:

The use of unprocessed or "raw" kerosene has contributed as sources of health-harmful particulate matter in homes even though its use in Ethiopia is lower. Kerosene, previously regarded as a "modern" fuel, also emits exceedingly elevated levels of particulate matter and is a major risk for burns and poisoning, particularly among children. WHO's Guidelines for indoor air quality: household fuel combustion discourage the use of kerosene as a household fuel. Electric lighting from solar lamps and photovoltaic (PV) solar rooftop panels can reduce reliance on kerosene lamps.

Cleaner fuels:

Use of cleaner fuels, such as biogas, ethanol, and liquid petroleum gas (LPGs) are cleaner options that minimize the health risk from household air pollution. Technologies are available using clean fuels for household cooking, heating, and lighting. Improved distribution networks and subsidies are making these cleaner fuels more widely available and used in emerging economies. There is a trail in rural Ethiopia to generate biogas from animal manure, so this should be encouraged and scaled up option.

Solar and wind-based electricity:

In communities lacking reliable grid access but with ample wind or sunlight, micro-grids or home systems using photovoltaic solar, or wind energy can power a household's electrical lights, reducing reliance on dirty kerosene lighting. Such sources also can often power light appliances, such as fans, radios, mobile phones, computer devices, and TVs, reducing reliance on dirty diesel generators that can pollute inside and outside of the home.

Solar hot water & space heating: Rooftop thermal solar panels for water heating are already widely available in the Middle East, parts of Africa, Europe, and Latin America. Access to hot water improves the conditions for bathing/personal hygiene as well as kitchen cleaning purpose.

6.4.Improved ventilation and housing design:

Hooded stoves with chimneys vent pollutants outdoors:

Ventilation can help reduce inhabitants' exposure to smoke indoors. For example, lung cancer incidence in farmers in Xuanwei, China, decreased by more than 40% when they switched from unvented fire pits to stoves with chimneys in their homes. Therefore, ventilation is most effective when paired with a low-emission stoves and fuels. Separation of cooking kitchens from the main house, window and ventilation, chimney venting for both "enjera" and "wote" should be implemented as a package.

Implementing passive design principles:

Passive solar heating and cooling techniques – such as strategic placement of windows, shading, insulated walls, and reflective roofs can reduce demand for space heating and the associated combustion of solid fuels and kerosene in cool climates, as well as reducing heat stress and improving ventilation in warm climates. Care must be taken to maintain adequate introduction of fresh air and ventilation with window openings.

6.5. Advocacy and Social Behavioral Change and Communication

6.5.1 Advocacy

Advocacy communication in this guideline aimed to hinge on the creation of a broad network /linkage or coalition of support. Such networks bring greater attention to decision-makers.

The overall goal of the advocacy is to attain a positive behavior change among stakeholders with respect to acquiring and sustaining positive behaviors towards prevention of air pollution. This will include enhancing knowledge, attitudes, and practices on key thematic areas of prevention of air pollution tailored to sources of pollution mentioned above.

Therefore, the advocacy works focus on the persuasion of the political leaders, industry investors, entrepreneurs, designers, and marketing and promotion leaders to take ambient and indoor air pollution as a priority issue and take measures to prevent and control it.

The advocacy must focus on:

- Allocating sufficient budget for air quality improvement technologies and promotion
- Formulating policies ,regulations, strategies pertaining to air quality improvements by all relevant sectors
- Expanding the knowledge base about impacts of air pollution on health and direct and indirect effect on economy, social and political environs;
- Monitoring and reporting on health trends and progress towards the air pollution-related targets of the Sustainable Development Goals;
- Leveraging the health sector to raise awareness of health benefits from air pollution reduction measures;

- Enhancing the health sector's capacity to work with other sectors and at all levels – local, national, regional, and global – to help address the adverse health effects from air pollution through training, guidelines, and national action plans.

6.5.2 Social and Behavior Change Communication

Social and Behavior Change Communication (SBCC) is an evidence-based, consultative process of addressing knowledge, attitudes, and practices through identifying, analyzing, and segmenting audiences and participants in programs and by providing them with relevant information and motivation through well-defined strategies, using an appropriate mix of interpersonal, group and mass media channels, including participatory methods. The SBCC air quality assurance aspect targets air pollution reduction through targeted behaviors at individual, community, and public levels.

I. SBCC for household air quality improvement

The priority area for SBCC from our country aspect will focus on household air pollution reduction and then on ambient air pollution. Behaviors targeted from household air pollution aspect are:

- Use of improved biomass cook stove use with venting (chimney)
- Use of clean fuel energy sources i.e., LPGs, biogas, ethanol, electric
- Use of induction cook stoves with minimal electric consumption in electrified areas
- Use of solar for lighting in areas where electric access limited
- Housing improvement and ventilation
- Separating of living house from kitchen and animal houses
- Good ventilation of the kitchen room
- Not allowing children to enter the kitchen room while cooking

Determinant factors for adoption of improved cook stove

The promotion for improved cook stoves and clean cooking solutions will be applied tailored to the adoption behaviors of urban and rural communities for improved cook stoves in Ethiopia.

Determining and affecting factors for improved cook stove adoption can be categorized on seven domains:

Domain 1: fuel and technology characteristic

Domain 2: Household and setting characteristic

Domain 3: Knowledge and perception

Domain 4: Financial, subsidy and tax aspects

Domain 5: Market development

Domain 6: regulation, legislation, and standards

Domain 7: programmatic and policy mechanisms

Domain 1 - Fuel and technology characteristic:

Fuel saving, impacts on time, general design requirements, Durability and specific design requirements, Fuel processing requirements determine the adoption.

Domain 2 - Household and setting characteristics:

Socio-economic status, Education, demographics (larger family-less adopt), House ownership and structure (space availability), Multiple fuel and stove use, Geography and climate are determining factors related with household and setting.

Domain 3 - Knowledge and perception:

smoke, health and safety knowledge, Cleanliness and home improvement, total perceived benefit, social influence, tradition and culture determines adoption of improved cook stoves.

Domain 4 - Financial, tax and subsidy aspects:

Stove costs and stove subsidies, payment modalities, program subsidies (Direct or indirect financial support by the government for improved stove programs) determine improved cook stove adoption.

Domain 5 - Market development:

demand creation (stove promoters making contact with individual users and live demonstrations of the innovative technology positively influence the market; while coercion, false promises or misinformation negatively influence demand, "word of mouth"), supply chains, Business and sales approach(stove builders, entrepreneurs and sales approach) affects improved cook stove adoption.

Domain 6 - Regulation, legislation, and standards:

Regulation, certification and standardization, Enforcement mechanisms must be strengthened for accredited, efficient, and lower emission standard fit improved cook stove dissemination.

Domain 7 - Programmatic and policy mechanisms:

Construction and installation (training for business entrepreneurs, institutional arrangement (key stakeholder coordination), community involvement, creation of competition, user training (safety and use –chimney), post-acquisition support (after sales service), Monitoring and quality control will help as program for improved cook stove adoption.

Equity considerations on improved cook stove uptake

Equity is critical in efforts to scale up improved stove interventions because it is generally those with the lowest incomes, those living in rural and more remote areas, and women who experience the greatest health risks, yet these groups are also the least able to access or afford improved stoves. With regard to poverty, some programs have adopted mechanisms to reach families on lower incomes, including:

i. A tiered approach offering different stove models and prices for higher- Vs lower-income households,

ii. Subsidies,

iii. Payments in installments and

iv. Access to credit. The risk of exclusion of more disadvantaged families with market-based dissemination programs was reported in several settings especially in rural areas.

In terms of rural/urban location, perceptions about the opportunity costs of fuel collection and fuel availability both appear to play a part in determining uptake. Poor rural communities – who usually collect firewood and pay for little or nothing for their fuel – can be a difficult group to target. As a consequence, commercial businesses tend to target more urban and other higher population density, and income areas where the business is more feasible and profitable as users often pay for fuel wood or other solid fuels and are more willing to pay for an improved stove.

A gendered approach is critical for adoption and sustained use of improved stoves, and the key message is that while better understanding of women's needs and involvement in technology development and implementation are vitally important, so too is greater involvement of men. This is because men usually exercise more control over the household budget and have more decision-making authority when it comes to changing the structure of the kitchen or installing/ buying an improved cook stove.

Social Marketing approach for improved cook stove distribution

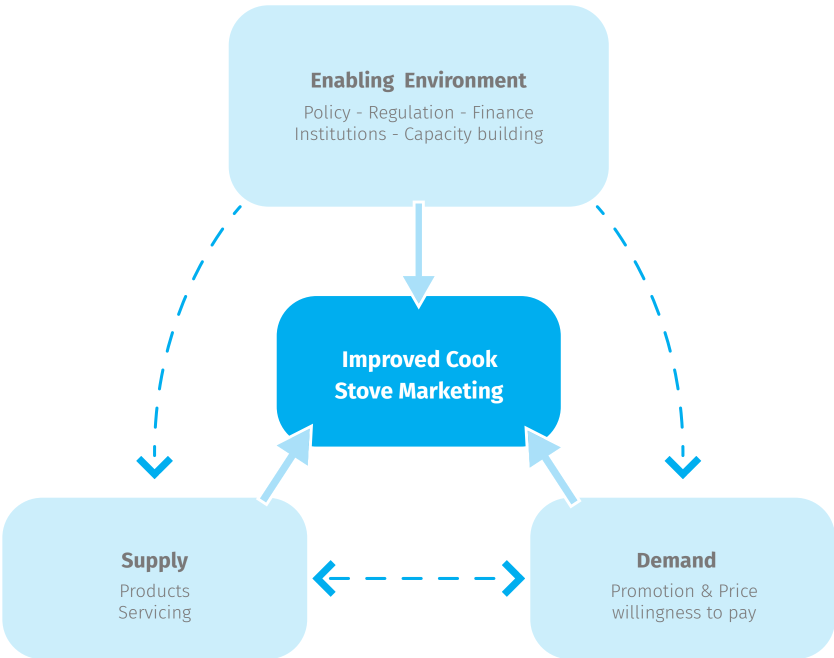

Figure 3: Adopted from social marketing concept (UN Habitat-2006)

The social marketing approach in the health sector well practiced on health commodity distribution such as condom distribution by DKT, Ethiopia, water treatment chemical distribution by PSI, Ethiopia, and market-based sanitation for improved sanitation and hygiene access in Ethiopia by ministry of health Ethiopia. Therefore, using these fertile grounds for the improved cook stove distribution has to be enhanced and scaled up. However,, since it requires its own business structure, regulation and entrepreneurs, collateral program with market-based sanitation system will be established.

The three important structures required in social marketing system is enabling environment, product, and promotion. Enabling environment mean, regulations, policies, standards, subsidies, and tax (duty free systems) will be considered. The supply aspect signifies product and services (installation, maintenance, replacement, etc.) will consider the product quality from thermal efficiency, emission reduction, meet different segment of the community (different culture, socio-economic status, urban/rural etc.) need and expectation. The demand side will consider price and promotion, which focuses on willingness to pay and ability to pay. Generally, the 4Ps of marketing i.e., product, price, place and promotion will be addressed using this framework.

Therefore, to access the rural and urban community for improved cook stove in Ethiopia enabling environment from policy, regulation, finance, and institution, capacity building aspect will be considered. Financial arrangements from small micro finance, revolving fund, tax exemption, loan access with low interest rate will be sought. Capacity building (training) at all levels both for government staffs, entrepreneurs, distributers (sales) and promotes will be given.

In the supply side product quality assurance in collaboration with ESA and energy authority with cook stove tests will be done. The service after installation, maintenance and replacement will be arranged giving technical trainings in collaboration with TVETs and Universities for both rural and urban-based entrepreneurs. In order to ensure supply with low price, transportation costs should be reduced, to do so production centers will be tried to be in center places near to the consumer to access new products as well as spare parts for replacement.

Demand should be promoted by awareness raising, sensitization, advertising, and education. The demand creation activity will be organized centering health extension workers and primary health care unit as main center. The community willingness to pay and ability to pay will be assessed continuously in different segments of the community and price will be fixed negotiating with producers considering every aspect of the market. Subsidies and tax relief will be considered as indirect method of subsidy. Demonstration for improved cook stoves, ventilation with chimney installation and others will be done centering the health posts and health centers.

II. SBCC for Ambient air quality improvement and Exposure reduction

Individual and corporal level targets suggested in this guideline pertaining to Ethiopia are:

Prevention - green technology and green energy dependency, promote active transport (cycling& walking), promote mass transportation, and use green and low emission vehicles;

Mitigation - emission reduction & control device use, conduction EIA/ESIA/HIA and mitigate recommendations based on EMP, plantation around emission sources as buffering, proper and integrated waste management;

Avoidance - prohibition of the settlement of people around industries and locate appropriately, enhance the release of emissions by increasing stake heights appropriately etc. will be applied. Use of face mask (N95) at high pollution time, promoting active transport, choose less polluted travel routes, optimize driving style, moderate physical activity when outdoor air pollution is high, monitor air quality and alarming system, use of household air cleaner, treat respiratory conditions, modify diet and supplement with antioxidants or anti-inflammatory agents will be promoted based on the real-time air quality index and networked information provision system nationally for air quality alarm and health measure suggestion.

Table 5: Behavioral interventions for ambient air pollution

Behavioral Interventions	Description /principles
Prevention	
Promotion of walking and cycling	To encourage a move away from polluting forms of transport
Eco-driver training	Eco-driving is a way of driving that increase fuel efficiency, speed, and safety
No idling campaigns	Idling is when a vehicle’s engine is left running while parked or stationary

Behavioral Interventions	Description /principles
Eco-travel coordination programs	Education to encourage changes in travel behavior including raising awareness of impact and encouragement to use other methods
Mitigation	
Investment in public transport	To increase public transport use
Avoidance	
Air quality messages/alerts/ indices	Information on current or forecast levels of air pollution communicated to the public
Public engagement	To involve the public in understanding the issues, for example citizen science initiatives to measure air
Mixed interventions	
Clean air days	Pollution awareness day
Personal exposure reduction programs	Actions to reduce health risks from personal exposure to air pollutants

Source: (Naima Bradley et al., 2019)

CHAPTER SEVEN

Stakeholder involvement, coordination and partnership

7.1 Implementation of the guideline

The guideline will be used for guidance in the preparation of annual plans of all relevant actors. The health sector will coordinate the planning, implementation, and monitoring and evaluation of proposed interventions at all levels.

7.2 Roles and responsibilities of Stakeholders

Air quality is a public good and it is a public issue, demanding everyone's effort and involvement. The stakeholders for air quality are many but the Ministry of Health, Environment, Forest and Climate Change Commission (EFCCC), National metrology agency, Ethiopian Standard Agency, Ethiopian Energy Authority, and different Research Institutes are the main regulator and acting stakeholder on air quality. Ministry of transport, Ministry of trade and industry, Ministry of mining and petroleum, ministry of construction, housing and urban development, Ministry of Agriculture, and municipalities are stakeholders as polluters.

Therefore, according to this guide, the roles and responsibilities and their engagements must be guided based on these principles. Of course, to some extent regulator sectors may become a source of pollution, but not be main pertaining to Ethiopia. Other sectors such as the Ministry of Science and Innovation, Ministry of trade and industry have also their stakes on air quality assurance.

Table 6: The role and responsibility of government organization to reduce air pollution

S. No	Stakeholders	Roles and responsibility
1	Health Sector	■ Coordinate planning and regular monitoring of air quality interventions with relevant actors ■ Advocates for adequate allocation of resources for air quality interventions ■ Develop necessary guidelines and manuals for air quality and health ■ Develop and implement strategies for advocacy and social and behavior change communications towards indoor and ambient air pollution ■ Engage in demand creation towards using improved technologies with reduced emission of pollutants

S. No	Stakeholders	Roles and responsibility
		■ Promote technology innovations for air quality ■ Promote engagement of private sector in supply chain of clean cook stoves and other clean energy products ■ Establishes and follow a continuous M&E mechanism ■ Conduct different researches in the area of air quality and health ■ Facilitates documentation and sharing of lessons learned for scale up
2	Energy Sector	■ Develop strategies, guidelines and manuals for clean cook stove and clean energy ■ Design and introduce different context specific clean energy products
3	Transport Sector	■ Develop strategies, guidelines, and manuals for vehicular source air pollution ■ Promote appropriate actions for reduction of vehicular source air pollution ■ Enforce vehicular source air pollution rules and regulations
4	Industry sector	■ Ensure implementation of industrial pollution prevention and control measures based on regulations and standards ■ Select and promote technologies that can reduce industrial air pollution and emission.
5	Micro enterprises	■ Establish micro-enterprises and support them to produce eco-friendly products.
6	Environmental protection Sector	■ Regulates the standards on industries, vehicles, and other sources of pollution. ■ Monitoring and controlling of air polluting emitting sectors

S. No	Stakeholders	Roles and responsibility
7	National Metrology agency	■ Monitors the air pollution using ground stations in distinct parts of the country ■ Provide information on air pollution along with other metrology information.
8	Ethiopian Standard Agency	■ Prepare emission standards for the clean cook stove, clean energy fuels, etc.
9	Ministry of Science and innovation	■ Promotes innovations on the clean cook stove and clean energy ■ Provide accreditations for green energy technologies

7.3 Coordination

As air quality is one component of environmental health, existing coordination platforms for Environmental Health will be used for joint monitoring and alignment of efforts.

The hygiene and environmental health technical committee (HEHTC) will incorporate air quality among major agenda. Actors' plan will be aligned on this platform at the beginning of fiscal year. Joint progress monitoring will be conducted at the end of each quarter.

The HEHTC will present progress report biannually for the Hygiene and Environmental health steering committee (HEHSC) for overall direction and guidance.

7.4 Partnership

A coalition of private companies, government agencies and non-profit organizations dedicated to raising awareness of air quality in the country and promoting actions that people and organizations can take to reduce air pollution and protect public health. Through the air quality action program, the partnership disseminates air quality forecasts and advisories to notify the public and media when air pollution levels reach unhealthy levels. The advisories offer suggestions to protect personal health and actions to take to reduce air pollution. The partnership raises awareness of air quality issues through paid and donated advertising, sponsorship of community events and through our partners' outreach to their employees, clients, and stakeholders.

CHAPTER EIGHT

Monitoring and evaluation of air quality managements

The monitoring of air quality (AQ) and evaluation of results is fundamental for assessing the nature of population exposure to air pollution. The aim of an AQ monitoring program is to reduce or eliminate air quality-related diseases and illnesses through the implementation of effective preventative measures to reduce air pollution. Thus, the ultimate goal of AQ monitoring and evaluation (M&E) as part of an AQ management program is to protect the receiving environment and reduce human health risks.

Air Quality Assurance Monitoring and Evaluation Framework

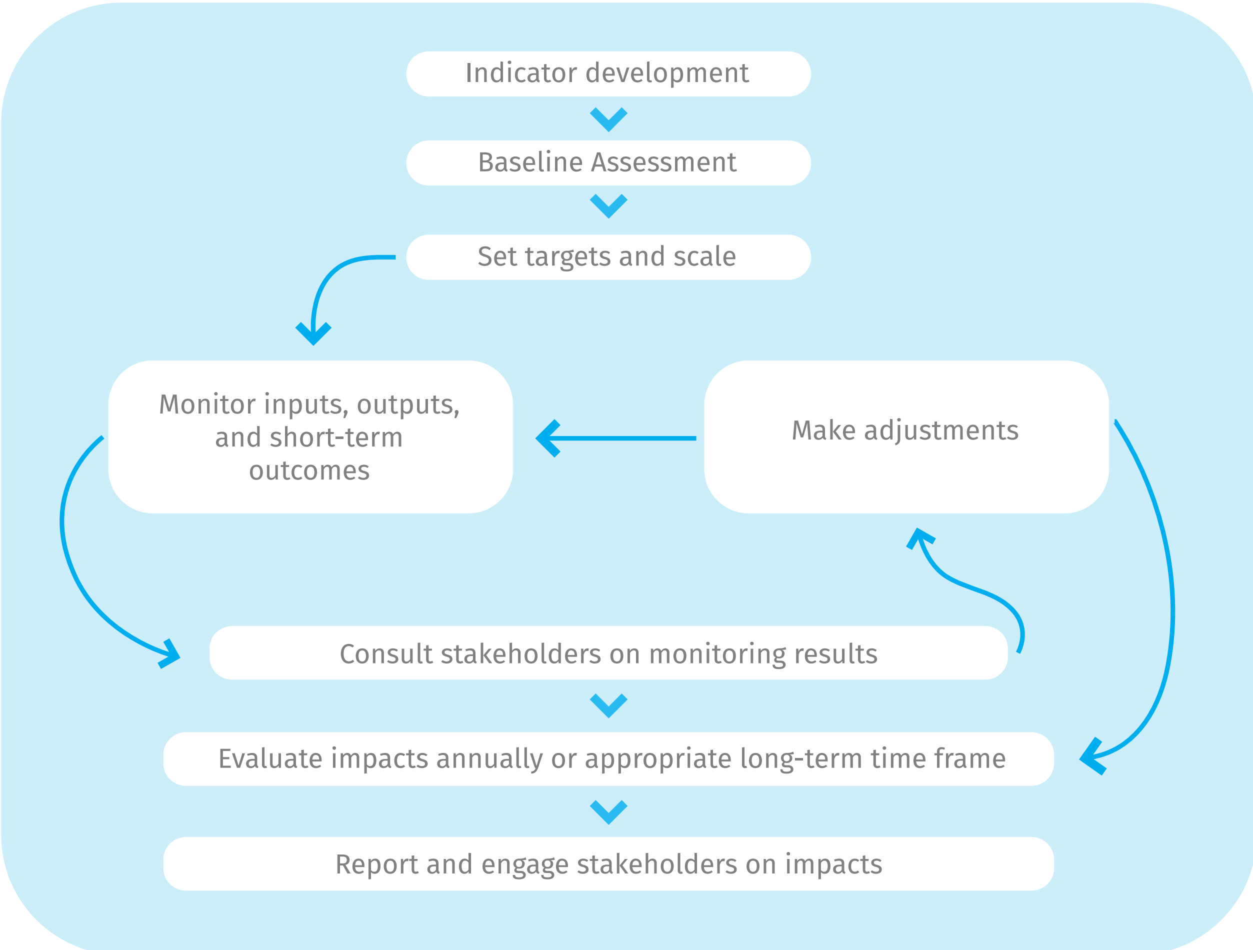

Figure 4: Air quality assurance monitoring and evaluation framework

As shown on the above diagram the monitoring and evaluation program for air quality improvement will start from indicator development. Therefore, the air quality improvement indicators are selected based on goals and targets set in the guideline. The indicators will be input, output, outcome, and impact level indicators... The impact will be evaluated bi-annually and communicated to the community for further actions for air quality improvement.

Table 7: Domain of Air Quality Indicator

Level	Household Air quality improvement	Ambient air quality improvement indicators
Input	▪ Number of ICS business established ▪ Number of trainings given to start ICS business ▪ Improved Cook stove technology (ICS) types identified ▪ Improved cook stove types tested and approved by ESA &MOH ▪ IEC/SBCC materials produced and distributed on IAP ▪ Number of workshops conducted among task force ▪ Amount of subsidy from tax, loan, and others ▪ Amount of Finance allocated to the program	▪ Number of air quality monitoring stations per population ▪ Number of emission monitoring device distributed per region ▪ Number of persons trained on Air pollution (monitoring) ▪ Amount of finance allocated for Ambient AP program ▪ Amount of subsidies, tax reliefs and loans for green technology in transport, industries, and waste management sector

Level	Household Air quality improvement	Ambient air quality improvement indicators
Output	■ Percent of the population have market access for ICS ■ Percentage of population addressed with IEC/SBCC	■ Percentage of Vehicles monitored for emission ■ Percentage of industries monitored for emissions
Outcome	■ Percentage of population with primary reliance on clean fuels and improved biomass cook stove technologies at the household level ■ Percentage of population with primary reliance on clean energy source for lighting	■ Mean levels of exposure to ambient air pollution (population weighted) ■ Annual mean levels of fine particulate matter (i.e., PM2.5) air pollution in cities (population weighted)
Impact	■ Number/percent of deaths and illnesses from indoor air pollution	■ Number/percent of deaths due to ambient air pollution

The indicators for each level will be collected from different sectors using platforms established. Input, output, and outcome data for household air pollution (clean or improved cook stove) access and utilization will be collected through the DHIS. The indoor household level of exposure will be collected using handy portable indoor air quality monitoring devices. Indoor household air quality monitoring network also tried to monitor using low-cost sensors and solar power.

Data for the ambient air quality program will be tracked from different sectors based on data sharing platforms.

The impact level i.e., the percentage of death due to indoor air pollution will be collected through surveys such as EDHS.

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HEALTHIER CITIZENS FOR PROSPEROUS NATION!

Air Quality and Health Guideline

June 2022