Household air pollution impacts on mortality and disease burden in East Africa and Nile Basin African countries

Awoke Misganaw[1,2*], Alemnesh Hailemariam[1], Tezera Moshago Berheto[1], Yihunie Lakew[1], Sisay Derso Mengesha[1], Mesfin Agachew[1], Ally Walker[2], Asrat Arja[1], Wendwosen Teklemariam[1], Ababi Zergaw[1], Fentabil Getnet[1], Ebba Abate[1], Michael Brauer[2] , Mohsen Naghavi[2], Lia Tadesse[3]

Abstract

Background: Clean household energy access is a major public health challenge across East Africa and the Nile Basin African countries.

Objectives: This is to quantify exposure and health impacts of household air pollution from using solid fuels for cooking from 1990 to 2019 to inform policy and practice.

Methods: In all 18 countries across East Africa and the Nile Basin Africa region, we estimated exposure to household air pollution from solid fuels (defined as the percentage of households using solid cooking fuels and the corresponding exposure to particulate matter 2.5 ($PM_{2.5}$). We applied the methods of the Global Burden of Diseases, Injuries, and Risk Factor Study 2019 to estimate deaths, premature mortality, and disability-adjusted life years attributable to household air pollution from solid fuels with 95% Uncertainty Intervals (UI).

Results: There was a high prevalence of household air pollution from using solid fuels for cooking, ranging from 78% in Somalia to 0.02% in Egypt in 2019. In total, there were 346,600 deaths attributable to household air pollution from using solid fuels for cooking in ENB countries in 2019. The highest number of all-cause household air pollution-attributable deaths was in Ethiopia, 67,830 (95% UI: 52,710-82,420), DR. Congo, 58,040 (95% UI: 41,170-77,460), Tanzania 39,170 (95% UI: 29,180-49,860) and Somalia 27,550 (95%% UI: 19,570-38,960), and the lowest deaths were in Comoros 550 (95% UI: 410-710), Djibouti 20 (95% UI: 90-360) and Egypt 70 (95% UI: 30-170). Almost all deaths were due to respiratory infection, neonatal diseases and conditions, cardiovascular diseases, chronic respiratory disease, and diabetes across all countries. Premature mortality and disability attributable to household air pollution from solid fuels were highly prevalent in Somalia, DR. Congo, Ethiopia, Tanzania, and Uganda compared to Egypt. Though the trend of death rate per 100,000 populations attributable to household air pollution showed a decline in Ethiopia and all countries between 1990 and 2019, it was unacceptably high in Somalia (272 deaths), Burundi (186 deaths), DR. Congo (157 deaths), Eritrea (140 deaths), South Sudan (133 deaths) and Ethiopia (130 deaths) compared to Egypt (0 deaths).

Conclusion: Household air pollution is highly prevalent and a major public health concern across East Africa and the Nile Basin Africa countries except Egypt. The prevalence and impact vary between countries. Governments need to address Household air pollution in their disease prevention and control strategies for lower respiratory infection, neonatal, diabetes, chronic respiratory diseases, and cardiovascular diseases. To provide affordable and clean energy for their population and achieve Sustainable Development Goal 7, partnership on different energy sources, including building dams for electrification, such as the Grand Ethiopian Renaissance Dam, could be important. [*Ethiop. J. Health Dev.* 2023;37 (SI-2)]

Keywords. Household air pollution, Solid Fuels, risk factors, burden of diseases, Ethiopia, East Africa countries, Nile Basin Countries.

Introduction

Household air pollution (HAP) from solid fuels is among the most important environmental health risks in low- and middle-income countries (1). Cooking and heating with polluting fuels and technologies produce high levels of household air pollution, including a range of health-damaging pollutants such as fine particles and carbon monoxide (2). Solid fuels are smoky, often used in an open fire or simple stove with incomplete combustion, and result large amount of household air pollution (3). An estimated three billion people worldwide are exposed to cooking-related HAP caused by solid fuel combustion (4).

In sub-Saharan Africa, 85% of the population uses solid fuels such as wood, animal dung, charcoal, crop wastes, and coal burnt in inefficient, highly polluting stoves for cooking and heating (5). Household air pollution is inextricably linked to poverty and population growth and is common in rural and poor urban population who uses solid fuels and inefficient stoves. Both global and local interventions on poverty reduction, use of clean and more efficient energy technology, and behavioral change efforts are expected to address its health and socioeconomic impacts (6). However, there is limited evidence on the impacts of these interventions, and high exposure to household air pollutants from cooking fuels is still leading to a wide range of adverse health outcomes in children, the elderly, and women, who spend most of their time in the indoor environment (7).

[1]National Data Management and Analytic Center (NDMC), Ethiopian Public Health Institute, Ethiopia;
[2] Institute for Health Metrics and Evaluation, University of Washington, USA;
[3.] Ministry of Health, Ethiopia
[*]Corresponding Author Email: awoket@uw.edu or asterawoke2007@gmail.com

Studies showed that household air pollution increases the risk of respiratory infections, chronic obstructive pulmonary disease, lung cancer, stroke, and ischemic heart disease (8). It is also associated with low birth weight, increased infant and perinatal mortality, pulmonary tuberculosis, nasopharyngeal and laryngeal cancer, and cataracts. Overall, it is causing 3.8 million attributable deaths each year, mainly from respiratory illness, cardiovascular diseases, and cancer, as well as serious injuries from scalding, burns, and poisoning (3,9–11). Members of households that rely on polluting fuels and devices also suffer a higher risk of burns, poisoning, musculoskeletal injuries, and accidents (12). This study presentss Global Burden of Disease (GBD) 2019 results on household air pollution and its mortality and disease burden impacts to inform East Africa and Nile Basin (ENB) African countries for their evidence-informed decisions at different levels.

Methods

This analysis is part of the GBD 2019 study to estimate disease burden attributable to household air pollution from solid fuels for East African countries, according to GBD classification (13), and Nile basin African countries named in this paper as East and Nile Basin (ENB) African countries. This paper has included 18 countries with a total population of 560 million, encompassing Burundi, Comoros, Djibouti, DR. Congo, Egypt, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, Somalia, South Sudan, Sudan, Tanzania, Uganda, Zambia. Abay Basin or Nile Basin covers Tanzania, Uganda, Rwanda, Burundi, Kenya, Ethiopia, Eritrea, South Sudan, Sudan, Egypt, and DR. Congo. In this region, Ethiopia, Egypt, Tanzania, Kenya, Uganda, and Sudan are highly populous countries (14).

GBD 2019 study used Comparative Risk Assessment (CRA) framework developed for previous iterations of GBD to estimate levels and trends in exposure, attributable deaths, attributable Years of Life Lost (YLLs), attributable Years of Life with Disability (YLDs), and attributable disability-adjusted life years (DALYs), by age group, sex, year, and geographic location for behavioral, environmental and occupational, and metabolic risks or groups of risks from 1990 to 2019. Years of life lost (YLLs) are calculated as a measure of premature mortality by summing up the life expectancy for people dying attributable to HAP in each age group. Years lived with a disability is measured by taking the prevalence of HAP-attributable diseases multiplied by the disability weight for that disease. Disability-adjusted life-years (DALYs) are the sum of YLLs and YLDs for a given cause (15). Exposure to HAP from solid fuels in GBD analysis was defined as the proportion of households using solid cooking fuels. The definition of solid fuel in this analysis includes coal, wood, charcoal, dung, and agricultural residues (16). The household exposure to solid fuels was converted to average $PM_{2.5}$ exposures from solid fuel use for different household members based on studies measuring 24-hour kitchen and living area $PM_{2.5}$ concentrations in households estimating this for men, women, and children (17). Summary Exposure Value (SEV) is a single, interpretable measure which captures risk-weighted exposure for a population or risk-weighted prevalence of exposure. The scale for SEV spans 0% to 100%, such that a SEV of 0% reflects no HAP risk exposure in a population, and 100% indicates that an entire population has the maximum possible risk. A decline in SEV indicates reduced exposure to HAP risk factors, whereas an increase in SEV indicates increased exposure (18).

Global Burden of Diseases uses statistical models to pool data, adjust for bias, and incorporate covariates. The GBD used a counterfactual scenario of theoretical minimum risk exposure level (TMREL), and GBD estimated the portion of deaths and DALYs that could be attributed to household air pollution. We reported the relationship between development and household air pollution from the GBD 2019 study. GBD modeled the relationship between the Socio-demographic Index (SDI) and risk-weighted exposure prevalence and estimated expected levels of exposure and risk-attributable burden by SDI. A Socio-demographic Index (SDI) is a summary measure that identifies where countries or other geographic areas sit on the development spectrum. Expressed on a scale of 0 to 1, the rankings of the incomes per capital, average educational attainment, and fertility rates of all areas in the GBD study (13). We classified the socio-demographic status of the countries into five categories based on their values: low SDI (<20), low, middle SDI (20-29), Middle SDI (30-39), high Middle SDI (40-49) and High SDI (>50). Estimates of the proportion of the population exposed to household air pollution from solid fuel use were modeled using spatiotemporal regression and Gaussian process regression techniques on population-based data. GBD 2019 analyses were completed with Python version 3.6.2, Stata version 13, and R version 3.5.0. Statistical code used for GBD estimation is publicly available online: http://ghdx.healthdata.org/gbd2019/code.

Ethical Statement

The study follows GBD protocol publicly available online and complies with the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) recommendations: (https://www.healthdata.org/gbd/about/protocol).

GATHER defines best practices for documenting studies that synthesize evidence from multiple sources to describe past and current population health and its determinants quantitatively. These practices include documenting and sharing data inputs, analyses, methods, and results. Documenting the input data on which estimates are based and the methods by which estimates are derived is essential for the accurate interpretation and use of results (19).

Results

Socio-demographic Index for ENB Africa countries

This paper has classified Socio-demographic Index (SDI) quantiles into low SDI, low, middle SDI, middle SDI, high middle SDI, and high SDI. Thus, Egypt and Sudan were classified as *high SDI* countries. Comoros, Djibouti, Kenya, Madagascar, Rwanda, Uganda, Tanzania, and Zambia *were under high-middle SDI* countries. Ethiopia, DR. Congo, Eritrea, Malawi, Mozambique, South Sudan were *middle SDI countries*,Burundi was low *middle* SDI category, and Somalia was a *low* SDI country (Table 1) (Appendix 1B).

Appendix 1B: **Socio-demographic Index values for all estimated GBD 2019 locations, 1990-2019**

Location	SDI_2019	Classification
Sub-Saharan Africa	44.5	High Middle SDI
Eastern SSA	40·2	High Middle SDI
Burundi	28·7	Low Middle SDI
Comoros	45·2	High Middle SDI
DR. Congo	37·9	Middle SDI
Djibouti	46·9	High Middle SDI
Egypt	63·1	High SDI
Eritrea	39·5	Middle SDI
Ethiopia	33·8	Middle SDI
Kenya	49·8	High Middle SDI
Madagascar	40·1	High Middle SDI
Malawi	36·4	Middle SDI
Mozambique	31·4	Middle SDI
Rwanda	42·5	High Middle SDI
Somalia	8·49	Low SDI
South Sudan	37·6	Middle SDI
Sudan	51·1	High SDI
Uganda	40·0	High Middle SDI
Tanzania	41·9	High Middle SDI
Zambia	49·8	High Middle SDI

Household air pollution exposure among ENB Africa countries

In 2019, the risk-weighted prevalence of household air pollution (HAP) from solid fuels across East Africa and the Nile basin (ENB) Africa countries was highest among low and middle SDI countries, Somali 77.73%, (95%UI; 54.42-87.11), Burundi, 60.04% (95% UI; 36.15-80.13) and Ethiopia 53.94% (95% UI: 33.01-72.41)); and it was lowest in high SDI countries, in Egypt (0.02) and Sudan (12%) (Table 1 and Figure 1).

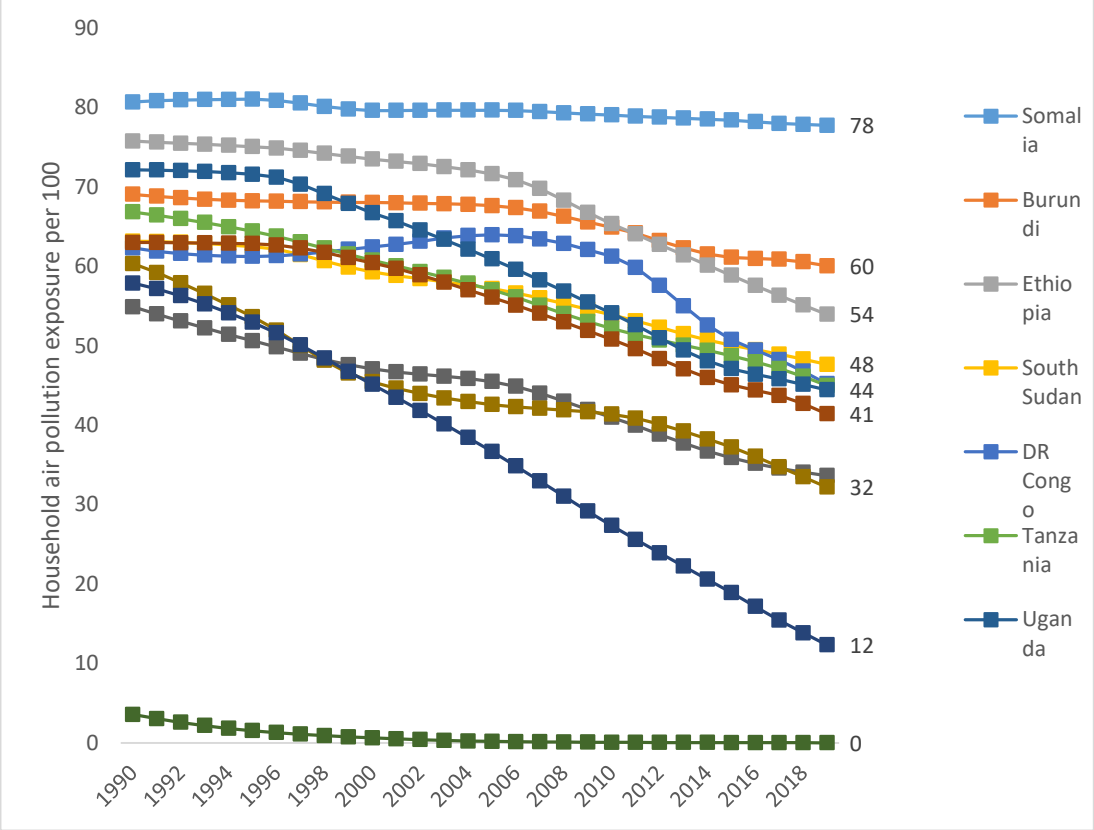

Figure 1. **Trends of the age-standardized risk-weighted prevalence of household air pollution from solid fuel exposure per 100 people across East and Nile Basin African countries, 1990-2019**

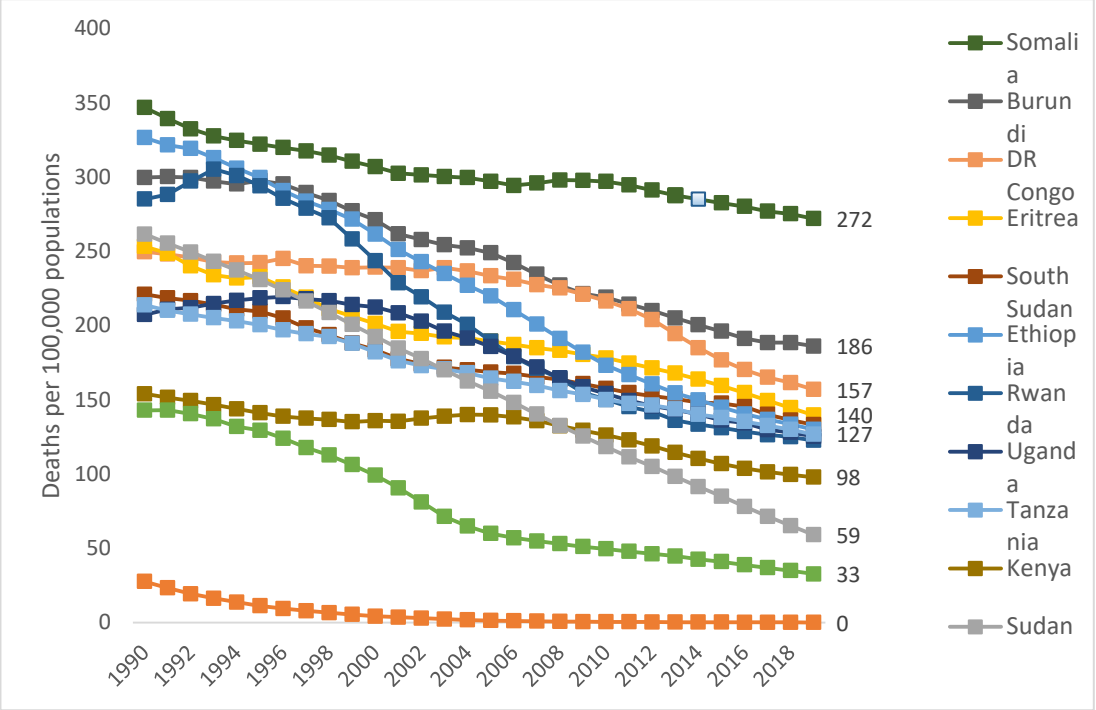

Figure 2. **Trends of all causes age-standardized death rate per 100,000 attributable to household air pollution from solid fuel in East and Nile Basin African countries, 1990 -2019**

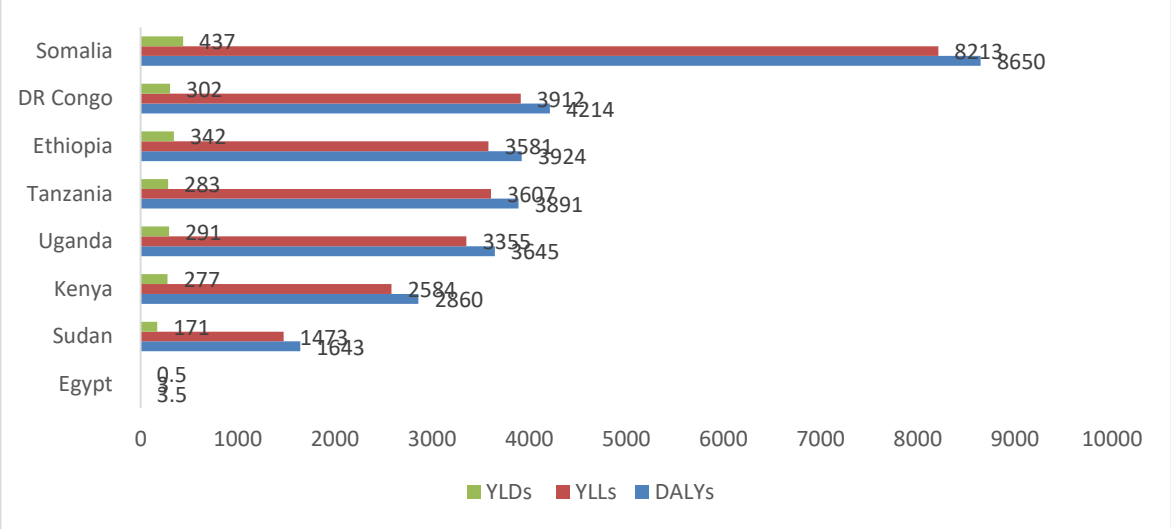

Figure 3. **All-cause age-standardized YLLs, YLDs, and DALYs rates per 100,000 populations by countries in 2019. (YLDs= years lived with disability, YLLs=years of life lost, DALYs= Disability Adjusted Life Years)**

Table 1: **Age-standardized risk-weighted prevalence of household air pollution from solid fuel exposure per 100 people across East and Nile Basin Africa countries, 1990-2019, with mean percentage change**

	Male			Female			Both sex		
Countries	**1990**	**2019**	**% change, 1990-2019**	**1990**	**2019**	**% change, 1990-2019**	**1990**	**2019**	**% change, 1990-2019**
Burundi	68.38 (42.09-86)	59.34 (35.21-79.91)	-13.23	69.66 (44.52-86.62)	60.78 (37.03-81)	-12.74	69.06 (43.03-86.18)	60.04 (36.15-80.13)	-13.06
Comoros	62.85 (39.92-81.58)	34.38 (21.35-52.87)	-45.3	63.58 (40.97-81.91)	36.22 (23.41-54.08)	-43.03	63.23 (40.62-81.54)	35.32 (22.43-53.25)	-44.14
DR. Congo	61.52 (35.51-81.5)	44.1 (24.48-65.02)	-28.33	63.01 (38.27-82.27)	46.27 (27.51-65.89)	-26.57	62.31 (36.74-81.98)	45.21 (26.26-65.33)	-27.44
Djibouti	37 (20.87-54.05)	6.57 (2.89-12.92)	-82.24	38.57 (23.49-55.05)	7.84 (3.63-14.95)	-79.66	37.74 (22.09-54.25)	7.18 (3.23-13.9)	-80.98
Egypt	3.2 (1.31-6.59)	0.02 (0.01-0.04)	-99.46	3.96 (1.72-7.82)	0.02 (0.01-0.05)	-99.44	3.58 (1.53-7.26)	0.02 (0.01-0.05)	-99.45
Eritrea	59.48 (35.22-77.99)	30.97 (16.89-48.35)	-47.94	61.07 (37.98-79.41)	33.31 (19.22-50.35)	-45.46	60.34(36.81-78.62)	32.19 (18.33-49.36)	-46.65
Ethiopia	75.38 (51.8-85.28)	53.34 (31.65-72.96)	-29.24	76.11 (53.46-85.5)	54.54 (33.71-72.74)	-28.34	75.75(52.96-85.27)	53.94 (33.01-72.41)	-28.79
Kenya	53.35 (33.43-69.85)	32.68 (20-49.05)	-38.75	56.39 (36.92-73)	34.56 (22.01-51.05)	-34.56	54.89(35.46-71.32)	33.65 (21.17-50.09)	-38.7
Madagascar	66.9 (43.01-85.03)	49.3 (29.77-71.04)	-26.31	67.53 (44.4-85.16)	50.92 (32.58-73.1)	-24.6	67.22(43.65-85.17)	50.12 (31.13-72.12)	-25.43
Malawi	71.2 (46.3-86.56)	51.8 (31.48-72.26)	-27.24	72.09 (48.07-86.9)	53.35 (33.69-73.52)	-26	71.66(47.49-86.56)	52.62 (32.45-72.51)	-26.57
Mozambique	77.27 (53.86-87.71)	58.25 (35.94-77.61)	-24.61	77.96 (54.57-88.05)	59.33(37.95-77.76)	-23.89	77.64(54.03-87.7)	58.83 (36.9-77.66)	-24.23
Rwanda	62.23 (36.7-82.14)	40.07 (22.51-62.18)	-35.61	63.65 (39.57-82.9)	42.56(24.54-63.63)	-33.13	62.99 (38.41-82.61)	41.41 (23.67-62.96)	-34.25
Somalia	80.38 (59.4-88.34)	77.33 (54.24-86.98)	-3.79	80.93 (60.37-88.85)	78.1 (55.32-87.39)	-3.5	80.66 (59.52-88.47)	77.73 (54.42-87.11)	-3.64
South Sudan	62.5 (37.12-83.06)	46.5 (26.53-67.92)	-25.6	63.95 (40.56-82.95)	48.73 (29.38-69.66)	-23.79	63.16 (38.68-82.94)	47.65 (28.21-68.47)	-24.55
Sudan	56.99 (32.49-76.59)	11.38 (5.63-20.5)	-80.03	58.73 (35.57-78.47)	13.29 (7.02-23.15)	-77.36	57.86 (34.3-77.35)	12.33 (6.41-21.24)	-78.69
Uganda	71.56 (45.67-86.24)	43.18 (24.97-64.77)	-39.66	72.68 (47.78-86.51)	45.54 (27.89-66.43)	-37.35	72.14 (46.96-85.94)	44.45 (26.97-65.96)	-38.38
Tanzania	66.36 (41.51-84.34)	43.86 (26.17-64.83)	-33.9	67.25 (43.35-85.25)	45.99 (28.47-66.55)	-31.62	66.83 (42.71-84.57)	44.98 (27.68-65.87)	-32.69
Zambia	55.26 (33.62-73.79)	27.19 (15.9-43.75)	-50.79	56.46 (35.8-74.41)	29.69 (18.77-46.16)	-47.42	55.87 (35.09-73.88)	28.46 (17.5-45.2)	-49.07

Age-standardized HAP prevalence for both sexes decreased in 2019 compared to the reference year, 1990. Based on this, HAP decreased in Somalia by only 3.64% from 80.66 (59.52-88.47) to 77.73 (54.42-87.11), in Burundi by 13%, from 69.06 (43.03-86.18) to 60.04 (36.15-80.13), in DR. Congo by 27.44% from 62.31 (36.74-81.98) to 45.21 (26.26-65.33) in Ethiopia by 28.79%, from 75.75 (52.96-85.27) to 53.94 (33.01-72.41), in Madagascar by 25.43% from 67.22 (43.65-85.17) to 50.12 (31.13-72.12), in Malawi by 26.57% from 71.66 (47.49-86.56) to 52.62 (32.45-72.51) and Mozambique by 24.23%, from 77.64 (54.03-87.7) to 58.83 (36.9-77.66) from 1990 to 2019. However, the differences were not statistically significant.

In Sudan, age-standardized weighted prevalence for both sexes decreased by 78.69% from 57.86 (34.3-77.35) in 1990 to 12.33 (6.41-21.24) in 2019 and Djibouti decreased by 80.98%, from 37.74 (22.09-54.25) in 1990 to 7.18 (3.23-13.9); while Egypt decreased by 99.45 % from 3.58 (1.53-7.26) in 1990 to 0.02 (0.01-0.05) in 2019 (Table 1) and the difference were statically significant.

All-cause mortality attributable to household air pollution in ENB Africa countries

The total deaths attributable to HAP in ENB countries in 2019 for both sexes combined was 9% (346,590.23) of the total deaths (Table 2 and Appendix 1A). The highest number of all-cause HAP attributable death was in DR. Congo, 58,040 (41,170-77,460), Ethiopia 67,830 (52,710-82,420), Somalia 27,550 (19,570-38,960), and Tanzania 39,170 (29,180-49,860); and the lowest deaths were in Egypt 70 (30-170), Djibouti 20 (90-360) and Comoros 550 (410-710).

All-cause, the age-standardized death rate per 100,000 attributable to HAP was highest among low and Middle SDI countries, in Somalia, 272.02 (192.33-376.19) deaths per 100,000, Burundi, 186.15 (133.65-241.47), Mozambique, 185.46 (139.11-240.47), Madagascar, 181.01(133.83-238.45), DR. Congo, 156.92 (111.01-210.43); while it was lowest in Djibouti 32.75 (15.59-58.39) and Egypt, 0.13 (0.05-0.3) deaths per 100,000. During the same period, age-standardized HAP-attributable death rates in Ethiopia and Sudan were 129.95 (98.18-162.42) and 59.14 (34.81-90.67) per 100,000, respectively (Table 3).

Appendix 1A. **All-cause attributable percent of total death from household air pollution for all age-standardized rate per 100,000, both sexes in ENB countries,2019**

Location	% of total death	Rank
Sub-Saharan Africa	9(7-12)	2
Eastern Sub-Saharan Africa	12(9-15)	2
Burundi	14(11-18)	2
Comoros	11(9-14)	2
Djibouti	3(1-5)	12
DR.Congo	13(10-16)	2
Egypt	0(0-0)	48
Eritrea	10(7-14)	2
Ethiopia	13(10-16)	1
Kenya	9(6-11)	3
Madagascar	15(12-18)	2
Malawi	12(9-14)	2
Mozambique	12(9-14)	3
Rwanda	12(9-15)	2
Somalia	17(13-22)	1
South Sudan	11(8-14)	2
Sudan	6(4-10)	9
Uganda	11(8-14)	2
Tanzania	12(9-15)	2
Zambia	8(6-11)	4

Table 2: **The numbers of deaths, years of life lost (YLL), years lived with disability (YLD), disability-adjusted life years (DALYs) attributable to household air pollution across East and Nile Basin Africa countries, 1990-2019**

Countries	1990 deaths (thousands)	2019 deaths (thousands)	1990 YLLs (thousands)	2019 YLLs (thousands)	1990 YLDs (thousands)	2019 YLDs (thousands)	1990 DALYs (thousands)	2019 DALYs (thousands)
Burundi	10.65 (8.13-13.18)	10 (7.24-13.01)	597.29 (442.74-757.26)	488.67 (358.18-646.24)	10.6 (7.56-14.02)	17.42 (12.05-23.39)	607.89 (451.52-769.63)	506.09 (371.42-665.75)
Comoros	0.81 (0.56-1.02)	0.55 (0.41-0.71)	48.46 (34.5-61.97)	20.4 (15.11-26.55)	0.95 (0.69-1.22)	1.34 (0.94-1.81)	49.41 (35.37-62.79)	21.75 (16.23-27.96)
Djibouti	0.37 (0.25-0.51)	0.2 (0.09-0.36)	24.84 (16.43-34.52)	9.3 (4.19-16.97)	0.5 (0.33-0.7)	0.57 (0.29-0.97)	25.34 (16.93-35.19)	9.87 (4.53-17.84)
Egypt	9.55 (4.29-17.89)	0.07 (0.03-0.17)	456.83 (207.18-874.56)	2.1 (0.75-4.87)	14.46 (6.9-26.32)	0.31 (0.12-0.65)	471.29 (215.26-898.91)	2.42 (0.96-5.46)
Eritrea	4.61 (3.23-6.19)	3.94 (2.55-5.7)	303.99 (208.41-420.48)	179.63 (111.96-266.37)	4.71 (3.28-6.29)	8.19 (5.51-11.53)	308.7 (212.55-425.13)	187.83 (118.46-276.27)
Ethiopia	121.04 (96.1-154.76)	67.83 (52.71-82.42)	7984.59 (6322.26-10353.21)	3411.33 (2585.49-4309.15)	112.52 (80.58-152.37)	160.37 (112.19-214.67)	8097.12 (6429.12-10491.27)	3571.7 (2738.71-4488.49)
Kenya	21.43 (17.11-26.23)	22.11 (16.14-28.47)	1325.13 (1037.92-1658.92)	960.01 (723.98-1204.9)	35.81 (25.91-46.74)	67.1 (46.99-89.52)	1360.95 (1070.27-1696.89)	1027.12 (785.44-1275.49)
Madagascar	20.48 (16.41-24.33)	21.46 (15.76-27.89)	1216.36 (969.88-1464.02)	981.14 (716.14-1280.61)	23.87 (17.3-30.65)	46.54 (33.73-60.55)	1240.23 (990.69-1492.95)	1027.68 (760.94-1321.67)
Malawi	16.35 (13.03-20.27)	12.38 (9.31-15.52)	1069.11 (837.35-1347.91)	599.91 (443.16-792.52)	17.07 (12.2-22.66)	27.49 (19.5-36.34)	1086.18(852.54-1372.06)	627.4(463.96-822.5)
Mozambique	25.46 (19.64-33.58)	25.02 (18.77-32)	1652.03(1225.15-2293.83)	1223.09(907.49-1588.34)	26.6(19.1-35.51)	48.13(34.73-62.68)	1678.63(1248.67-2327.32)	1271.22(950.79-1637.98)
Rwanda	13.1 (9.77-16.76)	7.47 (5.34-9.81)	782.53(565.72-1020.3)	318.57(219.49-432.23)	12.53(8.89-16.47)	16.92(11.69-22.99)	795.06(577.15-1034.7)	335.49(234.01-450.34)
Somalia	16.06 (11.73-22.42)	27.55 (19.57-38.96)	1067.01(752.77-1538.85)	1664.92(1154.55-2426.36)	13.7(9.76-18.47)	35.02(24.37-49.58)	1080.71(765.6-1552.58)	1699.94(1184.63-2460.26)
South Sudan	10 (7.38-13.01)	7.68 (5.49-10.27)	664.86(475-901.53)	461.8(322.79-620.86)	11.5(8.25-15.21)	15.65(11.02-20.94)	676.36(484.99-911.37)	477.45(334.96-639.39)
Sudan	34.04 (25.51-43.96)	11.31 (6.57-17.28)	1812.37(1301.03-2469.7)	407(228.75-624.57)	37.81(25.87-51.52)	34.77(21.22-52.54)	1850.18(1336.01-2508.02)	441.77(250.45-670.57)
Uganda	22.96 (17.68-29.07)	23 (16.91-29.32)	1414.52(1064.21-1832.29)	1192.84(863.75-1575.56)	27.45(19.44-37.03)	47.58(33.24-64.33)	1441.97(1090.1-1864.94)	1240.42(907.71-1634.28)
Tanzania	42.13 (32.56-52.05)	39.17 (29.18-49.86)	2754.73(2075.57-3494.89)	1953.73(1373.06-2610.87)	38.03(27.75-49.34)	77.72(55.03-103.63)	2792.76(2108.85-3524.13)	2031.45(1438.94-2696.85)
Zambia	12.02 (9.07-15.06)	8.82 (6.09-11.89)	805.25(584.54-1032.02)	424.24(283.29-602.82)	10.98(7.9-14.4)	18.26(12.58-24.72)	816.23(595.49-1044.5)	442.5(296.65-620.29)

Table 3. **All-cause attributable death, YLL, YLDs, DALYs to household air pollution for all age-standardized rates per 100,000 in East and Nile basin African countries.**

Countries	Age-standardized deaths rate		Age-standardized YLLs rate		Age-standardized YLDs rate		Age-standardized DALYs rate	
	1990	2019	1990	2019	1990	2019	1990	2019
Sub-Saharan Africa	212.92 (161.07-267.21)	113.14 (85.84-142.12)	7805.18(5985.6-9747.47)	3509.84 (2643.96-4429.49)	361.71 (258.74-480.32)	260.45 (182.71-352.8)	8166.89 (6308-10132.66)	3770.29 (2876.41-4720.23)
Eastern SSA	252.99 (195.82-317.27)	138.53 (107.09-170.36)	8892.53(7081.46-10987.6)	3894.39 (3025.66-4777.31)	412.55 (296.22-551.49)	318.21 (227.04-423.28)	9305.08 (7437.51-11455.79)	4212.6 (3308.18-5149.58)
Burundi	299.65 (222.65-381.63)	186.15 (133.65-241.47)	9485.01(7197.57-11813.6)	4927.85 (3574.22-6448.67)	399.63(284.19-533.44)	322.61(224.83-432.07)	9884.64 (7518.54-12262.92)	5250.46 (3829.23-6795.29)
Comoros	227.14 (160.45-288.04)	113.36 (84.95-145.98)	8041.18(5351.23-10294.65)	3306.25 (2466.95-4282.73)	394.07 (285.42-514.2)	261.73(183.54-354.89)	8435.24 (5764.98-10696.16)	3567.98 (2691.86-4556.48)
DR. Congo	249.66 (183.08-320.04)	156.92 (111.01-210.43)	7668.24(5698.35-9779.01)	3911.96 (2767.66-5232.9)	323.18 (224.33-442.22)	301.81(205.79-409.18)	7991.42 (5940.39-10163.12)	4213.77 (3011.19-5583.31)
Djibouti	142.95 (98.4-197.09)	32.75 (15.59-58.39)	4536.14(3110.02-6149.23)	921.47 (424.44-1655.6)	285.63 (190.06-397.92)	83.15(41.78-139.57)	4821.77 (3330.61-6487.91)	1004.62 (479.07-1798.07)
Egypt	27.67 (12.36-52.07)	0.13 (0.05-0.3)	855.66(383.57-1608.27)	2.96 (1.08-6.87)	47.53 (22.86-85.46)	0.5(0.2-1.01)	903.19 (409.63-1683.98)	3.46 (1.38-7.85)
Eritrea	253.26 (174.83-350.3)	139.67 (89.52-201.48)	9021.04(6343.11-12077.15)	3741.75 (2432.29-5405.41)	390.44 (273.87-522.76)	260.88(178.2-366.14)	9411.48 (6697.75-12509.06)	4002.62 (2631.53-5723.31)
Ethiopia	326.51 (248.52-415.01)	129.95 (98.18-162.42)	11925.07 (9359.82-15174.03)	3581.43 (2779.66-4352.38)	506.27 (360.33-686.05)	342.25(238.88-462.4)	12431.34 (9821.59-15740.37)	3923.68 (3087.09-4716.27)
Kenya	153.99 (119.41-192.9)	97.87 (69.03-130.41)	4819.35(3868.29-5921.48)	2583.58 (1893.97-3307.68)	394.05 (286.46-515.34)	276.73(194.35-369.61)	5213.4 (4223.03-6370.5)	2860.31 (2142.78-3618.96)
Madagascar	252.65 (198.98-305.47)	181.01 (133.83-238.45)	8589.31(6879.68-10188.66)	4881.71(3591.62-6348.97)	410.88(299.78-530.48)	361.47(262.82-468.77)	9000.19 (7229.8-10655.92)	5243.18 (3884.13-6706.67)
Malawi	236.69 (184.73-	141.9 (107.43-176.59)	8306.5(6578.83-10296.45	4053.67(3047.7-5111.12)	394.58(280.71-526.7)	332.03(236.5-441.47)	8701.08 (6890.74-10766.84)	4385.7 (3351.73-5473.33)

	295.86)		)					
Mozambique	251.02 (190.61-327.13)	185.46 (139.11-240.47)	9248.12(7093.06-12252.41)	5061.33(3768.25-6488.33)	402.87(285.91-551.25)	383.43(275.7-499.61)	9650.99 (7472.11-12739.3)	5444.76 (4109.69-6898.68)
Rwanda	285.17 (213.59-357.67)	122.67 (86.98-160.22)	9518.32(7153.65-12097.14)	3236.93(2327.19-4249.51)	375.84(267.25-496.91)	248.33(172.67-338.52)	9894.16 (7474.63-12525.69)	3485.27 (2510.61-4545.66)
Somalia	346.73 (251.79-467.88)	272.02 (192.33-376.19)	12394.63 (9092.3-17175.53)	8212.63(5862.67-11410.25)	449.14(318.95-619.44)	436.9(304.64-622.37)	12843.77 (9443.6-17678.11)	8649.53 (6200.81-11867.54)
South Sudan	221.05 (160.07-282.38)	133.28 (94.04-176.35)	8503.67(6252.75-11027.79)	4368.43(3112.83-5858.97)	449.19(321.15-596.75)	377.96(266.48-505.9)	8952.87 (6668.45-11497.18)	4746.39 (3410.14-6257.56)
Sudan	261.51 (195.81-341.8)	59.14 (34.81-90.67)	8032.95(6025.5-10299.84)	1472.83(848.62-2252.83)	379.93(261.83-518.07)	170.65(105.87-255.01)	8412.88 (6302.62-10760.28)	1643.48 (968.34-2465.26)
Uganda	207.4(153.75--266.1)	125.34 (91.98-160.12)	6288.66(4814.79-7992.85)	3354.81(2473.47-4282.67)	375.79(265.19-511.22)	290.68(203.73-394.18)	6664.45 (5140.96-8440.12)	3645.48 (2722.16-4639.68)
Tanzania	213.84 (166.79-262.38)	126.79 (95.47-158.01)	7711.6(6003.62-9491.62)	3607.5(2683.5-4601.04)	316.37(230.02-409.92)	283.05(200.52-377.71)	8027.97 (6279.3-9835.6)	3890.55 (2938.38-4902.28)
Zambia	214.93 (163.61-266.34)	111.11 (75.72-149.36)	7654.79(5825.46-9559.35)	3017.82(2068.36-4080.28)	336.97(242.65-442.05)	236.71(163.34-321.04)	7991.75 (6110.46-9947.1)	3254.54 (2271.91-4341.69)

Table 4. **All-cause age-standardized death and YLL rates attributable to household air pollution per 100,000 in sub-Saharan Africa region, East and Nile Basin African countries**

Countries	1990 deaths rate	2019 deaths rate	% change, 1990-2019	1990 YLLs rate	2019 YLLs rate	% change, 1990-2019
Sub-Saharan Africa	212.92(161.07-267.21)	113.14(85.84-142.12)	-46.87	8892.53(7081.46-10987.6)	3894.39(3025.66-4777.31)	-55.03
Eastern SSA	252.99(195.82-317.27)	138.53(107.09-170.36)	-45.24	7805.18(5985.6-9747.47)	3509.84(2643.96-4429.49)	-56.21
Burundi	299.65(222.65-381.63)	186.15(133.65-241.47)	-37.88	9485.01(7197.57-11813.6)	4927.85(3574.22-6448.67)	-48.05
Comoros	227.14(160.45-288.04)	113.36(84.95-145.98)	-50.09	8041.18(5351.23-10294.65)	3306.25(2466.95-4282.73)	-58.88
Djibouti	142.95(98.4-197.09)	32.75(15.59-58.39)	-77.09	4536.14(3110.02-6149.23)	921.47(424.44-1655.6)	-79.69
DR. Congo	249.66(183.08-320.04)	156.92(111.01-210.43)	-37.15	7668.24(5698.35-9779.01)	3911.96(2767.66-5232.9)	-48.98
Egypt	27.67(12.36-52.07)	0.13(0.05-0.3)	-99.54	855.66(383.57-1608.27)	2.96(1.08-6.87)	-99.65
Eritrea	253.26(174.83-350.3)	139.67(89.52-201.48)	-44.35	9021.04(6343.11-12077.15)	3741.75(2432.29-5405.41)	-58.52
Ethiopia	326.51(248.52-415.01)	129.95(98.18-162.42)	-60.2	11925.07(9359.82-15174.03)	3581.43(2779.66-4352.38)	-69.97
Kenya	153.99(119.41-192.9)	97.87(69.03-130.41)	-36.44	4819.35(3868.29-5921.48)	2583.58(1893.97-3307.68)	-46.39
Madagascar	252.65(198.98-305.47)	181.01(133.83-238.45)	-28.36	8589.31(6879.68-10188.66)	4881.71(3591.62-6348.97)	-43.17
Malawi	236.69(184.73-295.86)	141.9(107.43-176.59)	-40.05	8306.5(6578.83-10296.45)	4053.67(3047.7-5111.12)	-51.2
Mozambique	251.02(190.61-327.13)	185.46(139.11-240.47)	-26.12	9248.12(7093.06-12252.41)	5061.33(3768.25-6488.33)	-45.27
Rwanda	285.17(213.59-357.67)	122.67(86.98-160.22)	-56.99	9518.32(7153.65-12097.14)	3236.93(2327.19-4249.51)	-65.99
Somalia	346.73(251.79-467.88)	272.02(192.33-376.19)	-21.55	12394.63(9092.3-17175.53)	8212.63(5862.67-11410.25)	-33.74
South Sudan	221.05(160.07-282.38)	133.28(94.04-176.35)	-39.71	8503.67(6252.75-11027.79)	4368.43(3112.83-5858.97)	-48.63
Sudan	261.51(195.81-341.8)	59.14(34.81-90.67)	-77.38	8032.95(6025.5-10299.84)	1472.83(848.62-2252.83)	-81.67
Uganda	207.4(153.75-266.1)	125.34(91.98-160.12)	-59.57	6288.66(4814.79-7992.85)	3354.81(2473.47-4282.67)	-46.65
Tanzania	213.84(166.79-262.38)	126.79(95.47-158.01)	-40.71	7711.6(6003.62-9491.62)	3607.5(2683.5-4601.04)	-53.22
Zambia	214.93(163.61-266.34)	111.11(75.72-149.36)	-48.31	7654.79(5825.46-9559.35)	3017.82(2068.36-4080.28)	-60.58

Table 5: **Cause-specific deaths attributable to household air pollution across East and Nile Basin African countries, 1990-2019**

	Lower respiratory infections		**Neonatal disorders**		**Diabetes Mellitus**		**Chronic respiratory diseases**		**Cardiovascular diseases**		**Neoplasms**	
Countries	Number of deaths	Death rate per 100,000	Number of deaths	Death rate per 100,000	Number of deaths	Death rate per 100,000	Number of deaths	Death rate per 100,000	Number of deaths	Death rate per 100,000	Number of deaths	Death rate per 100,000
Sub-Saharan Africa	256280.26 (175346.3-351307.24)	34.92 (24.18-46.44)	144452.19 (113602.14-183110.11)	8.26 (6.49-10.47)	24418.96 (15960.92-36760.4)	6.36 (4.12-9.58)	41116.04 (26195.29-57617.1)	11.52 (7.33-16.17)	201045.8 (153340.37-256575.99)	49.55 (37.82-63.36)	8961.54 (6057.19-12600.19)	2.09 (1.42-2.92)
Eastern SSA	92675.61 (64379.4-124535.44)	40.88 (28.47-53.37)	58599.21 (45273.26-75755.2)	8.69 (6.72-11.24)	10713.4 (7012.97-16555.11)	8.01 (5.31-12.28)	18845.34(12419.98-25746.06)	15.11(10.1-20.43)	90367.53(69081.59-113398.85)	63.21(48.05-79.99)	3279.64(2243.83-4753.33)	2.19(1.51-3.13)
Burundi	3273.84(2122.08-4717.33)	55.51(37.53-75.5)	1975.77(1392.14-2728.59)	8.87(6.25-12.24)	326.99(196.95-584.39)	8.85(5.43-15.79)	916.22(562.17-1320.14)	27.18(16.92-38.42)	3246.57(2280.34-4480.53)	82.52(57.95-114.41)	106.6(62.84-171.29)	2.53(1.51-4.02)
Comoros	150.57(90.52-220.17)	30.62(18.53-44.98)	72.97(48.98-101.35)	9.23(6.19-12.82)	30.08(20.05-42.89)	6.94(4.65-9.86)	42.65(25.09-64.47)	10.23(6.09-15.44)	243.62(175.8-326.93)	53.99(39.42-72.24)	9.49(6.04-13.92)	2.02(1.27-2.93)
Djibouti	47.62(20.12-93.76)	7.35(3.09-14.06)	40.07(14.14-80.22)	2.42(0.85-4.85)	13.08(5.55-24.41)	2.89(1.26-5.3)	8.08(3.13-17.36)	2.02(0.79-4.21)	86.41(39.85-154.5)	17.18(8.23-30.25)	4.55(1.85-9.21)	0.83(0.35-1.64)
DR. Congo	18837.42(11508.81-27784.93)	47.09(28.43-71.46)	8262.886(4818.155-12170.51)	5.91(3.45-8.71)	2193.16(1358.02-3489.32)	7.4(4.63-11.64)	6072.56(3287.81-10160.64)	24.26(13.1-42.44)	20915.8(14551.71-28111.15)	68.31(47.61-92.58)	1220.94(572.58-2567.32)	3.56(1.65-7.28)
Egypt	5.14(1.77-12.3)	0.01(0-0.02)	0.98(0.28-2.52)	0(0-0)	3.89(1.21-10.1)	0.01(0-0.02)	3.82(1.32-8.74)	0.01(0-0.02)	57.63(20.64-132.45)	0.1(0.04-0.23)	1.35(0.45-3.27)	0(0-0.01)
Eritrea	1456.86(740.79-2616.74)	49.29(24.74-92.44)	565.85(344.29-865.09)	5.94(3.61-9.08)	175.13(103.88-275.98)	8.27(4.98-12.79)	251.77(132.19-386.87)	13.33(7.06-20.24)	1401.32(940.85-1977.45)	60.44(41.07-83.05)	52.62(31.32-79.84)	2.06(1.24-3.08)
Ethiopia	22082.11(15274.76-29173.67)	40.38(28.47-51.72)	16943.53(12754.62-22232.51)	9.69(7.3-12.71)	2686.01(1734.7-4458.3)	7.85(5.09-13.05)	5325.89(3480.93-7349.71)	16.41(10.65-22.54)	19250.48(13611.34-25612.01)	53.29(37.79-72.03)	692.19(402.94-1110.85)	1.84(1.07-2.97)
Kenya	6854.38(4388.31-9866.19)	29.42(17.83-43.48)	3576.45(2799.32-4489.19)	5.56(4.35-6.98)	990.64(655.62-1410.97)	5.63(3.75-7.93)	1760.38(1039.46-2799.23)	10.83(6.37-17.4)	8250.05(5734.25-10993.84)	44.4(31.09-58.94)	284.34(190.94-404.18)	1.42(0.97-2)
Madagascar	6014.76(3861.97-8353.3)	43.31(28.32-60.57)	2961.8(2046.37-4088.44)	7.23(5-9.98)	594.12(379.07-921.68)	6.89(4.42-10.6)	1662.88(1019.06-2494.72)	22.05(13.52-32.4)	9683.08(6933.94-12985.97)	98.62(70.43-131.36)	213.26(135.8-319.42)	2.11(1.37-3.09)
Malawi	4244.4(2822.77-5793.14)	43.7(30-57.05)	2437.81(1696.38-3392.03)	9.29(6.46-12.93)	526.45(345.84-805.58)	8.62(5.66-13.18)	788.07(499.8-1102.71)	13.7(8.62-19.18)	4153.07(3119.36-5343.92)	64.23(48.36-82.63)	134.68(91.15-191.67)	1.99(1.35-2.79)
Mozambique	7727.72(5025.47-10627.71)	49.5(34.23-66.76)	5072.07(3402.44-7033.48)	9.44(6.33-13.09)	1031.7(652.61-1710.18)	11.15(7.14-18.61)	1314.33(810.9-1935.06)	15.71(9.87-22.4)	9477.71(7000.25-12509.5)	96.52(72-127.32)	296.12(185.72-438.55)	2.97(1.89-4.34)
Rwanda	2209.72(1417.47-3191.39)	33.64(21.47-48.44)	1203.7(728.99-1760.1)	7.13(4.32-10.42)	359.63(215.78-561.3)	7.49(4.46-11.47)	732.73(448.76-1099.14)	16.36(9.75-24.15)	2788.84(1853.06-3838.02)	55.4(36.83-75.69)	133.93(78.52-215.53)	2.42(1.43-3.87)
Somalia	12485.2(7940.83-19724.75)	87.07(58.51-132)	5419.7(3604.25-7771.81)	13.05(8.68-18.7)	725.43(367.01-1696.26)	13.55(6.92-31.91)	1624.9(954.94-2692.29)	33.63(20.29-55.91)	6761.33(4506.17-9708.89)	121.36(79.62-177.02)	154.33(68.54-328.5)	2.44(1.09-5.12)
South Sudan	3392.65(2123.59-4952.08)	45.81(29.47-64.45)	1734.48(1196.01-2366.05)	10.05(6.93-13.7)	225.07(133.08-350.18)	7.28(4.35-11.24)	376.78(215.87-574.2)	13.44(7.76-20.35)	1743.24(1093.55-2462.82)	53.27(34.27-74.25)	96.94(55.14-153.47)	2.8(1.62-4.4)
Sudan	985.87(488.6-1726.55)	4.03(2.05-7.04)	1365.31(593.89-2454.48)	2.43(1.06-4.37)	247.56(121.56-433.47)	1.52(0.75-2.62)	684.63(324.5-1249.44)	4.58(2.18-8.25)	7785.43(4465.16-12239.74)	45.47(26.64-70.34)	175.29(83.11-327.36)	0.99(0.46-1.86)
Uganda	6847.83(4335.61-9647.06)	36.08(22.77-50.13)	6403.99(4384.98-8969.15)	8.49(5.81-11.89)	969.04(600.57-1466.76)	8.41(5.32-12.76)	1571.02(903.74-2367.18)	14.6(8.53-21.76)	6731.93(4856.06-8772.03)	55.27(39.51-71.37)	294.84(198.43-405.82)	2.24(1.51-3.06)
Tanzania	13542.59(8451.56-19258.94)	37.52(24.58-51.85)	8252.88(5197.95-11778.33)	8.37(5.27-11.94)	1642.34(1059.19-2386.94)	7.91(5.12-11.51)	1991.33(1256.3-2803.97)	10.16(6.45-14.22)	12925.17(9465.75-16792.3)	59.86(44.39-76.96)	643.46(400.2-1016.83)	2.8(1.78-4.34)
Zambia	2271.27(1269.72-3455.57)	25.15(14.44-37.37)	1891.29(1125.06-2874.26)	6.44(3.83-9.79)	409.14(257.03-591.9)	7.46(4.84-10.62)	463.25(261.86-702.18)	9.29(5.29-13.98)	3552.49(2430.37-4871.87)	59.95(41.83-80.61)	159.66(93.5-240.82)	2.56(1.52-3.85)

In 2019, HAP attributable death was 14 (11-18) percent of the total deaths in Burundi, 13% (10-16) in Ethiopia, 15% (12-18) in Madagascar, 17% (13-22) in Somalia, and it was 3% (1-5) in Djibouti and 0 % (0-0) in Egypt. In sub-Saharan Africa, 9 (7-12) percent of the total deaths were attributable to HAP, and 12 (9-15) percent were in East Africa. In 2019, HAP was the 1st leading risk factor for all-cause death in Ethiopia and Somalia, it was 2nd leading risk factor in Burundi and Madagascar, and 12th and 48th ranked in Djibouti and Egypt, respectively. The HAP was the second leading risk factor of death in the Sub-Saharan African and Eastern Sub-Saharan Africa sub-region (Appendix 1A).

Between 1990 and 2019, overall HAP-attributable all-cause age-standardized death rates for both sexes showed a 46.87% decline in Sub-Saharan Africa from 212.92 (161.07-267.21) in 1990 to 113.14 (85.84-142.12) per 100,000 in 2019; and 45.24% in Eastern Sub-Saharan Africa from 252.99 (195.82-317.27) in 1990 to 138.53 (107.09-170.36) in 2019 (Table 4). During the same period, HAP attributable all-cause age-standardized death rates for both sexes showed a higher decline in Djibouti 77.09% (from 142.95 (98.4-197.09) in 1990 to 32.75 (15.59-58.39) in 2019), in Egypt 99.54% (from 27.67(12.36-52.07) in 1990 to 0.13(0.05-0.3) in 2019), and Sudan 77.38% (from 261.51(195.81-341.8) in 1990 to 59.14(34.81-90.67) in 2019. During the same period, HAP-attributable death for both sexes showed a lower decline in all-cause age-standardized rates in Somalia 21.55% (from 346.73(251.79-467.88) in 1990 to 272.02(192.33-376.19) in 2019), in Mozambique 26.12 (from 251.02(190.61-327.13) in 1990 to 185.46 (139.11-240.47) in 2019), in Madagascar 28.36 (from 252.65(198.98-305.47) in 1990 to 181.01(133.83-238.45) in 2019 (Table 4). In Ethiopia, the HAP all-cause age-standardized death rates declined by 60.2%, from 326.51 (248.52-415.01) in 1990 to 129.95 (98.18-162.42) deaths per 100,000 in 2019. In 2019, the leading causes of age-standardized death rates attributable to household air pollution from solid fuels across ENB countries were lower respiratory infection, neonatal conditions, cardiovascular diseases, chronic respiratory disease, diabetes mellitus, and neoplasm (Table 5).

All-cause premature mortality attributable to household air pollution in ENB countries

In 2019, all-cause age-standardized HAP attributable mortality rate per 100,000, measured in YLLs, for both sexes combined was highest in Somalia, 12394.63 (9092.3-17175.53), Ethiopia, 11925.07 (9359.82-15174.03), Rwanda, 9518.32(7153.65-12097.14), Burundi, 9485.01(7197.57-11813.6), Mozambique, 9248.12(7093.06-12252.41) and Eritrea, 9021.04(6343.11-12077.15); the lowest was in Egypt, 855.66(383.57-1608.27). All-cause premature mortality and disability attributable to household air pollution from solid fuels is highly prevalent in Somalia, DR. Congo, Ethiopia, Tanzania, and Uganda compared to Egypt (Figure 4). In Ethiopia, household air pollution from solid fuel is the first leading risk factor attributing to premature mortality and the second leading risk factor for disability in 2019.

All-cause- disability-adjusted life years attributable to household air pollution

In 2019, age-standardized HAP years lived with disability per 100,000, measured in YLDs, for both sexes combined was highest in Ethiopia, 506.27 (360.33-686.05), Somalia, 449.14 (318.95-619.44), South Sudan, 449.19 (321.15-596.75), Madagascar 410.88 (299.78-530.48) and Mozambique, 402.87 (285.91-551.25); the lowest was in Egypt, 0.5 (0.2-1.01). In 2019, Household Air Pollution (HAP) was the first leading health risk factor in Eastern and Nile Basin (ENB) African countries. HAP ranked 1st to 3rd from all risk factors to attribute age-standardized DALYs. It was the first leading risk factor in Burundi, Ethiopia, Rwanda, Somalia, and Tanzania, and was 15th leading in Djibouti and 55th in Egypt. During the same year, age-standardized HAP disability-adjusted life years per 100,000, measured in DALYs, for both sexes combined was highest in Somalia, 8649.53 (6200.81-11867.54), Mozambique, 5444.76 (4109.69-6898.68), Burundi, 5250.46 (3829.23-6795.29), Madagascar, 5243.18 (3884.13-6706.67), South Sudan, 377.96 (266.48-505.9); the lowest was in Sudan 1643.48 (968.34-2465.26), Djibouti 1004.62 (479.07-1798.07) and Egypt, 3.46 (1.38-7.85). Ethiopia, 4002.62 (2631.53-5723.31) DALYs per 100,000 populations.

Neonatal conditions and lower respiratory mortality and disease burden

Lower respiratory infection (LRI) age-standardized death rate attributable to HAP was 34.92 (24.18-46.44) per 100,000 for the sub-Saharan Africa region and 40.88 (28.47-53.37) for the Eastern sub-Saharan Africa subregion. The LRIage–standardized death rate per 100,000 was highest in low and low middle SDI countries, Burundi, 55.51 (37.53-75.5), Somalia 87.07(58.51-132), DR. Congo 47.09(28.43-71.46), Eritrea, 49.29(24.74-92.44), Ethiopia, 40.38(28.47-51.72), Malawi, 43.7(30-57.05), Mozambique, 49.5(34.23-66.76), South Sudan 45.81(29.47-64.45). It was lowest in high SDI countries Sudan 4.03 (2.05-7.04) and Egypt 0.01(0-0.02) per 100,000.

Neonatal condition age-standardized death rate attributable to HAP was 8.26 (6.49-10.47) per 100,000 in the sub-Saharan Africa region and 8.69 (6.72-11.24) in the Eastern sub-Saharan Africa sub-region. Neonatal conditions death rate per 100,000 was generally higher in low and middle SDI countries, in Somalia 13.05 (8.68-18.7), South Sudan 10.05 (6.93-13.7), Ethiopia 9.69 (7.3-12.71), Malawi 9.29 (6.46-12.93), Mozambique 9.44 (6.33-13.09), and Burundi, 8.87(6.25-12.24). In contrast, the neonatal conditions death rate was lowest among high SDI countries Egypt (0) and Sudan 2.43(1.06-4.37).

Non-communicable diseases mortality and disease burden

Cardiovascular age-standardized death rate point values per 100,000 attributable to HAP were highest among low and middle SDI countries, in Somalia, 121.36 (79.62-177.02), Mozambique 96.52 (72-127.32), Burundi 82.52(57.95-114.41) and Dr. Congo 68.31(47.61-92.58). It was also higher in Madagascar, 98.62 (70.43-131.36), a high middle SDI country. It was lowest among some high SDI countries, Egypt 0.1 (0.04-0.23), Djibouti 17.18(8.23-30.25), and Sudan 45.47(26.64-70.34). It was also lower in Kenya at 44.4 (31.09-58.94), a high middle SDI country. The death rate difference between high and low/middle SDI countries was statistically insignificant.

Diabetes Mellitus age-standardized death rate per 100,000 attributable to HAP was highest in low SDI countries, Somalia, 13.55 (6.92-31.91), Mozambique 11.15 (7.14-18.61), Burundi 8.85(5.43-15.79), Malawi 8.62(5.66-13.18), Eritrea, 8.27(4.98-12.79), and it was lowest in high SDI countries Sudan,1.52 (0.75-2.62), Djibouti 2.89(1.26-5.3) and Egypt 0.01(0-0.02).

Chronic respiratory diseases age-standardized death rate per 100,000 attributable to HAP was highest in Somalia 33.63 (20.29-55.91), Burundi 27.18 (16.92-38.42) and DR. Congo, 24.26(13.1-42.44). The COPD death rate was also high in Madagascar, 22.05(13.52-32.4), a high middle SDI country. The COPD death rate was lowest in high SDI countries, Sudan, Djibouti, and Egypt. Cancer age-standardized death rate was high in DR. Congo and lowest among high SDI countries.

Discussion

This analysis helps monitor household air pollution's impact and the progress of global commitments to address household energy as indicated in SDG-7 (20). Sub-Saharan Africann countries cover 13% of the global population (21), but 42% of the global DALYs are attributable to household air pollution. Specific to East African countries, the burden of diseases attributable to HAP is 16% of the global DALYs attributed to household air pollution. In 2019, HAP was a leading risk factor in sub-Saharan African countries and contributed more than 10% of the total volume of death or disease burden in the region, and the majority of the deaths occurred in DR. Congo, Ethiopia, Somalia and, Tanzania,, and fewer deaths occurred in Djibouti and Egypt. Within East Africa and the Nile Basin, age-standardized deaths attributable to HAP were highest in Somalia, Burundi, Mozambique, Madagascar, and DR. Congo.

Household air pollution is a major public health concern in East Africa and Nile basin countries (ENB), especially in the region's low and middle SDI countries. Household use of biomass fuels is one of the largest sources of HAP in sub-Saharan Africa, using wood, charcoal, dung, and crop residue as their domestic cooking fuel (22). Since much of the cooking is carried out in an environment that lacks proper ventilation, and pollutants emitted by the incomplete combustion of solid fuels or kerosene for cooking, heating, and lighting are associated with serious health risks. For example, in Ethiopia, the main cooking fuel is predominantly wood (84% in 2005, 86% in 2011, and 76% in 2016) (23–26).

While it is clear that HAP is a major contributor to disease burden in the region, this analysis has some important limitations that need to be considered. When evaluating the disease burden attributable to household air pollution, we only included household solid fuel use for cooking but not for heating. Previous studies have reported that heating and cooking could contribute to premature deaths, and the absence of estimates on household solid fuel use for heating might bias our results (23–26). The diseases linked to the different exposures might under-represent the overall effect of these exposures because emerging research might indicate that additional diseases are associated with these risk factors.

The HAP prevalence and attributable death rates from lower respiratory infections, neonatal conditions, non-communicable diseases, and all causes varied between countries. These diseases are primarily caused by high levels of fine particulate matter released by burning solid fuels such as wood, coal, animal dung, crop waste, and charcoal in inefficient stoves, space heaters, or lamps (1). However, the prevalence was highest in Somalia, Burundi, and Ethiopia, and lowest in Sudan and Egypt, ranging from 0.02% in Egypt to 78% in Somalia. These countries could benefit from improved access to and use of cleaner home energy sources such as liquefied petroleum gas, biogas, natural gas, ethanol, or electricity. Smokeless energy is one of the vital and cross-cutting elements to achieve sustainable development goals by 2030. However, 1.1 billion people are globally without access to it, and of whom 602 million live in Sub-Saharan Africa, many of them in rural areas (27). Even though the Nile countries are gifted with substantial energy resources with an estimated amount of 140,000 MW as hydroelectric power, most countries except Egypt have limited access to sustainable electricity services (28). According to the World Bank 2018 report, 78% of the population in Somalia, 60% of the population in Burundi, 54% of Ethiopia's population, and 40% of Sudan’s population have no electricity (29). Similarly, South Sudan, Kenya, Tanzania, Uganda, Rwanda, Burundi, DR. Congo, and Eritrea have low electricity coverage compared to Egypt (100% electricity coverage) (29). This low level of access to clean energy will force a community to use alternative means of energy, particularly biomass fuels, for their domestic use, but such types of energy sources cause indoor air pollution (30,31).

It is useful to note that although air pollution is commonly thought to be associated with lung disease, a substantial proportion of the disease burden due to household air pollution in ENB Africa countries is from neonatal conditions, cardiovascular disease, diabetes, and cancer. Another notable aspect of air pollution in ENB Africa countries is its contribution to the disease burden from ischemic heart disease, stroke, chronic obstructive pulmonary disease, and lung cancer, commonly associated with smoking. In East Africa, lower respiratory infection, neonatal disorder, diabetes mellitus, chronic respiratory diseases, and cardiovascular diseases were the leading causes of death in 2019 (32). Household air pollution was a major risk factor in the region, and its attributable death rates were high in 2019.

Strategies that target to reduce HAP from solid fuels will significantly decreasing the disease burden of infectious and non-communicable diseases across East and Nile Basin African countries. The effect of household air pollution varies by country in the region; HAP attributed lower respiratory infection death rate was higher in Somali and Burundi; neonatal disorder was higher in Ethiopia, Malawi, Mozambique, Somalia, South Sudan; diabetes mellitus was higher in Somalia and Mozambique, chronic respiratory disease was higher in Burundi, Somalia; cardiovascular disease was higher Somalia, Mozambique, Madagascar. Given a high high-risk weighted prevalence rate of HAP among countries, this high mortality rate may show a lack of quality healthcare access and affordability for early diagnosis and treatment of victims. Respective countries need to address HAP in their economy and developmental strategies, health sector strategies, environment, and climate strategies and strengthen regional partnerships to reduce the impacts of HAP through existing East Africa platforms of the Intergovernmental Authority on Development (IGAD), East Africa Community and others.

During the study period, countries such as Sudan and Djibouti have shown more than 75% progress in reducing HAP between 1990 and 2019. However, the progress against HAP was only 3.6% in Somalia, and less than 30% in Burundi, DR. Congo, Ethiopia, Madagascar, Malawi, and Mozambique. This progress can be explained by economic development and urbanization over the years. However, slow decline in Somalia and other countries can also be explained by countries' slow progress on universal electricity access and clean cooking access to the population (29). This indicates that countries face challenges in achieving SDG 7 on affordable and clean energy use (33). Countries could benefit from using renewable energy sources like sun, wind, and water to help reduce household air pollution and the occurrence of diseases and to decrease the mortality rate. The use of renewable energy sources is serving to lessen emissions of carbon dioxide and other climate warming agents, as well as harmful air pollutants, which can ultimately decrease the mortality rate and extend the life expectancy in Sub-Saharan Africa (34).

There is an urgent need for efficient strategies to educate populations on the health issues associated with the health hazards related to HAP, provide affordable clean cooking energy for poor people, and to promote improved household ventilation. ENB countries can develop and implement national and regional household air pollution action plans, including targets to reduce air pollution and monitoring mechanisms. Outdoor air pollution could outweigh for few countries, such as Egypt, to develop national strategies (35). Moreover, ; most of the population across sub-Saharan African countries lives below WHO air quality standard, mainly from household air pollution (36). Regional policies could consider the huge hydropower potential of the region and under-development projects, such as one of the largest hydropower projects in the world (the GERD, Ethiopia), one of the largest planned geothermal projects in Africa (Corbetti, Ethiopia), and the largest onshore wind development in Africa (Lake Turkana, Kenya) to address HAP attributable disease burden in the future (37).

Policy and research implications

Household air pollution is a major public health concern in most countries with predominantly rural populations having poor access to electricity and/or clean energy for cooking. East and Nile basin countries could have averted thousands of deaths attributable to household air pollution from solid fuel in 2019, significant mortalities, and disability through addressing universal electricity access. East and Nile basin countries must collaborate on renewable energy sources and electricity access, such as hydropower, including the Grand Ethiopian Renaissance Dam (GERD), to avail universal electric access. As interim solutions, regional and country strategies need to prioritize e interventions to improve the use of cleaner fuels (such as liquefied petroleum gas, natural gas) and fuel-efficient stoves keeping pace with the region's population growth (38). Countries need to collaborate to generate continuous strong research evidence on the public health impact of hydropower sources to facilitate evidence-informed decisions to improve maternal and child mortality and adult mortality and progress on SDG and health-related indicators.

Conclusions

Household air pollution is highly prevalent and a major public health concern across ENB African countries. The prevalence and impact vary between countries. There is an important indication to benefit from the regional partnership: Egypt could share best practices and interventions to reduce HAP in the region. The findings also indicate ENB Africa countries are facing challenges to achieve SDG 7 to provide affordable and clean energy for their population. Countries need to address HAP in their disease prevention and control

strategies for lower respiratory infection, neonatal, diabetes, chronic respiratory diseases, and cardiovascular diseases.

Conflict of interest

The authors assert that they do not possess any competing or potential conflicts of interest..

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Acronyms

COPD – Chronic Obstructive Pulmonary Diseases
CRA - Comparative Risk Assessment Framework
DALYs – Disability Adjusted Life Years

ENB – East and/or Nile Basin African countries
GATHER - Guidelines for Accurate and Transparent Health Estimates Reporting ()
GBD – Global Burden of Diseases
GERD - Grand Ethiopian Renaissance Dam
HAP – Household Air Pollution
IGAD - Intergovernmental Authority on Development
LRI - Lower Respiratory Infection
SDI – Socio-demographic Index
SDG – Sustainable Development Goals
SEV - Summary Exposure Value
TMREL- Theoretical minimum risk exposure level
WHO – World Health Organization
YLDs – Years Lived with Disability
YLLs – Years of Life Lost

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