Environmental risks and life expectancy reduction in East Africa

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Abstract. This study aims to evaluate the influence of environmental and behavioural risk factors on life expectancy in East Africa. Applying the standard life table functions, our estimates revealed that the potential environmental reducers of life expectancy are air pollution-related deaths, followed by poor hygienic facilities and practices, and tobacco use. If it was possible to fully eliminate death coming from household air pollution, ambient particulate matter and ground-level ozone pollution, the increment in life expectancy at birth should respectively be 3.15 years; 2.84 years; 2.20 years; 2.06 years; 1.59 years in Burundi, Rwanda, Tanzania, Uganda, and Kenya. The simultaneous and complete elimination of all environmental and behavioural risks making the objects of this study shall increase the life expectancy at birth by 7.62 years in Rwanda, 7.12 years in Tanzania, 6.40 years in Uganda, 5.77 years in Kenya and 8.43 years in Burundi. Although the complete elimination of some causes of death appears to be an improbable scenario, these results recommend resource allocation and program evaluation regarding environmental monitoring and assessment and goal-setting in the health domain for the long and healthy living population of East Africa.

1 Introduction

The degradation of the environment has a significant impact on the rise in serious public health issues that affect longevity and general human health. Environmental risk factors are linked to over 100 diseases and injuries [1]. In the year 2019, air pollution alone was anticipated to be the origin of the 6.7 million fatalities globally [2]. Life Expectancy (LE) at birth is often used as an indicator of overall population health. Thus, knowledge of the factors that affect a country's life expectancy is essential for economic growth since a prosperous country must have a healthy population [3]. The convenience of basic healthcare services, improvements in fertility, the health of mothers, newborns, and children, as well as advancements in the fight against infectious illnesses, have all contributed to the extension of healthy life expectancy in African nations [4,5]. Despite efforts to decrease maternal and infant mortality, and other potential causes of death, the life expectancy at birth is still lower in sub-Saharan Africa [6]. While the East Africa region is experiencing accelerated socio-economic growth accompanied by the deterioration of the environment [7,8], few studies

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assessed the consequences of environmental hazards on human health in the region. This study aimed to evaluate the decline in life expectancy caused by environmental stressors in East Africa. Focusing on the countries of Burundi, Kenya, Rwanda, Uganda, and the United Republic of Tanzania (here denoted as Tanzania), we compared the decline in life expectancy resulting from environmental factors with other occupational and behavioural risks such as drug, alcohol, and tobacco use. Our findings will be crucial in helping the countries to develop efficient environmental and public health strategies.

2 Material and methods

2.1 Life table functions

To compute the life table, data on births and deaths are compulsory. However, this information is missing in most African countries [9]. We used data from the Institute for Health Metrics and Evaluation (IHME) and the Global Burden of Disease (GBD) 2019 report [10] to get age-resolved estimates of death rates in the concerned countries. We adopted the standard life table methodology [11,12] and calculated abridged life tables with age intervals of 0 to 1, 1 to 4, and then intervals of 5 years (from 5 to 100 years). For each age interval, we estimated the probability of dying during the age interval of duration n years between age x and $x + n$ using Equation (1).

$$ {}_nq_x = \frac{{}_nm_x \times n}{1 + (1 - \alpha_x) \times {}_nm_x \times n} \tag{1} $$

where ${}_nm_x$ denotes the mortality incident rate for age internal x and $x + n$; and α_i is the fraction of the age interval duration that the average dying cohort member survives at age x. We assumed that the takes place at the midpoint of each age interval $\alpha_x = 0.5$).

The number of surviving l_x from the original life table cohort of 100,000 live births to the beginning of each age interval was computed using Equation (2).

$$ l_x = \begin{cases} 100{,}000\,; & for\ x = 0 \\ l_{x-1}(1 - {}_nq_x)\,; & for\ x > 0 \end{cases} \tag{2} $$

The relation expressed in Equation (2) implies that the population who is still alive at the beginning of the age interval x depends on the number of individuals that were alive at the outset of the previous age interval $(x - n)$ and the fraction of members who survived the proceeding age interval. The number of person-years lived by life table cohort with an age interval x to $x + n$, is given by Equation (3). These are the total years lived between two indicated birthdays by all persons reaching the earlier birthday.

$$ {}_nL_x = \frac{{}_nd_x}{{}_nm_x} \tag{3} $$

where ${}_nd_x$ is the number of deaths occurring between ages x and $x + n$.

Finally, the life expectancy at a given age interval was estimated by dividing the total person-years that would be lived above age x by the number of people who survived to that age interval (Equation (4)).

$$e_x = \frac{\sum {}_nL_x}{l_x} \tag{4}$$

2.2 Life tables eliminating specified causes of death

To compute the life tables eliminating specific causes of death, we first estimated the probabilities of survival with i^{th} cause eliminated using Equation (5),

$${}_np_x^i = {}_np_x^{(1-\pi_i \cdot {}_nr_x)} \tag{5}$$

where π_i is the improvement factor ($o \leq \pi_i \leq 1$), and ${}_nr_x$ is the ratio of the death rate of the i^{th} risk factor of interest to the death rate from all factors, mathematically expressed in Equation (6) below.

$${}_nr_x = \frac{{}_nd_x^i}{{}_nd_x} \tag{6}$$

The improvement factor allowed us to estimate the partial ($\pi_i < 1$) or total ($\pi_i = 1$) cause-elimination of risk factors [12]. Once the probability of dying between the age interval x to $x + n$ was estimated, we used the methodology proposed by Arias et al. (2013) to compute the cause-eliminated life tables and all other related functions. Using this approach, we assessed the effect of environmental stressors on the reduction of human longevity in each country. The gain in life expectancy was calculated by making the difference between the all-cause life table and the life table after excluding a specific cause of death.

3 Results

The life expectancy at birth without cause-deletion, in 2019, is estimated to be 68.58 years in Rwanda, 67.03 years in Tanzania, 66.50 years in Kenya, 66.08 years in Uganda, and 63.76 years in Burundi. These results are, on average, 99.8% consistent with the IMHE estimates [10], although different approaches were utilized. Table 1 presents the life expectancy at birth and years gained by the whole population after the total elimination of individual environmental and behavioural stressors.

Table 1. Increment in life expectancy from environmental and behavioural risks (years)

Risk Factors	Burundi		Kenya		Rwanda		Tanzania		Uganda	
	e^i_o	ΔLE	e^i_o	ΔLE	e^i_o	ΔLE	e^i_o	ΔLE	e^i_o	ΔLE
Air pollution	66.90	3.15	68.09	1.59	71.42	2.84	69.23	2.20	68.13	2.06
Poor hygiene	65.40	1.65	67.70	1.20	69.64	1.07	68.06	1.03	67.05	0.98
Other environmental risks	63.96	0.10	66.58	0.08	68.69	0.11	67.15	0.12	66.18	0.10
Occupational risks	64.18	0.25	66.70	0.20	68.84	0.27	67.25	0.22	66.32	0.25
Tobacco use	64.90	1.24	67.21	0.71	69.93	1.36	68.24	1.20	67.31	1.24
Alcohol use	65.63	1.16	67.43	0.93	69.83	1.26	68.14	1.11	67.24	1.16
Drug use	63.78	0.02	66.81	0.31	68.59	0.02	67.15	0.11	66.09	0.02

The potential gains in life expectancy among all countries come from the complete elimination of air pollution-related deaths (ambient particulate matter, ambient ozone, and household air pollution); followed by poor hygiene (unsafe water sources, unsafe sanitation, and no access to handwashing facilities) and tobacco use. If it was possible to fully eliminate death coming from air household air pollution, ambient particulate matter and ozone, the increment in life expectancy at birth should be 3.15 years; 2.84 years; 2.20 years; 2.06 years; 1.59 years in Burundi, Rwanda, Tanzania, Uganda, and Kenya, respectively. The full elimination of drug use projected the increase in life expectancy at birth from about 7 days in Burundi, Rwanda, and Uganda to 115 days in Kenya. Since it is unlikely that any cause of mortality will be fully identified and eradicated, these numbers are extremely implausible.

To be more rational, we assumed the scenario where there is a 25% and 50% elimination of considered risks. Table 2 presents the gains in expectation of life at birth after 25% and 50% elimination of the considered causes of death, respectively. The results revealed that there may be gains of 0.58 years (i.e., 212 days) in Burundi, 0.52 years (190 days) in Rwanda and Tanzania, 0.49 years (179 days) in Uganda, and 0.38 years (139 days) in Kenya after 25% elimination of air pollution-related deaths. Furthermore, there was a minimal gain of 84 days for 25% elimination of poor hygienic risks in Uganda, and a minimal 7-day gain in Kenya for other environmental risks (radon and lead exposure), and a gain of 18 days for occupation risks (asthmagen, air pollutants, and occupation injuries) in Kenya and Tanzania. Furthermore, a 25% reduction in Tobacco, alcohol, and drug use showed a respective minimal gain of 62 days in Kenya and Uganda, 84 days in Kenya, and 1.8 days in Burundi, Rwanda, and Uganda. Individual elimination of all these causes at 50% shall increase these gains by a factor of two, respectively.

Table 2. Increment in life expectancy from different environmental and behavioural risks (25% and 50% elimination of risks)

Risk Factors	**Burundi**		**Kenya**		**Rwanda**		**Tanzania**		**Uganda**	
	25%	50%	25%	50%	25%	50%	25%	50%	25%	50%
Air pollution	0.58	1.18	0.38	0.77	0.52	1.07	0.52	1.06	0.49	0.99
Poor hygiene	0.47	0.95	0.29	0.59	0.26	0.52	0.25	0.51	0.23	0.46
Other Environmental risks	0.03	0.06	0.02	0.04	0.03	0.06	0.03	0.06	0.03	0.06
Occupational risks	0.08	0.16	0.05	0.10	0.07	0.13	0.05	0.11	0.06	0.11
Tobacco use	0.20	0.39	0.17	0.35	0.32	0.65	0.29	0.59	0.17	0.34
Alcohol use	0.33	0.67	0.23	0.46	0.31	0.62	0.27	0.54	0.34	0.69
Drug use	0.00	0.01	0.08	0.16	0.00	0.01	0.03	0.06	0.00	0.01

Finally, we assumed an extreme scenario where all risk factors are progressively and simultaneously eliminated. Results for the progressive and simultaneous elimination of death causes are presented in Figure 1. Figure 1.a shows that life expectation at birth would respectively increase from 68.58 to 76.19 years, 67.03 to 74.16 years, 66.08 to 72.47, 66.50 to 72.27 years and from 63.76 to 72.19 years in Rwanda, Tanzania, Uganda, Kenya, and Burundi. These quantities reflect the gains of 8.43 years in Burundi, 7.62 years in Rwanda, 7.12 years in Tanzania, 6.40 years in Uganda, and 5.77 years in Kenya as presented in Figure 1.b. These results reflect that the higher the increment, the more stress is caused by the environmental or behavioural risk.

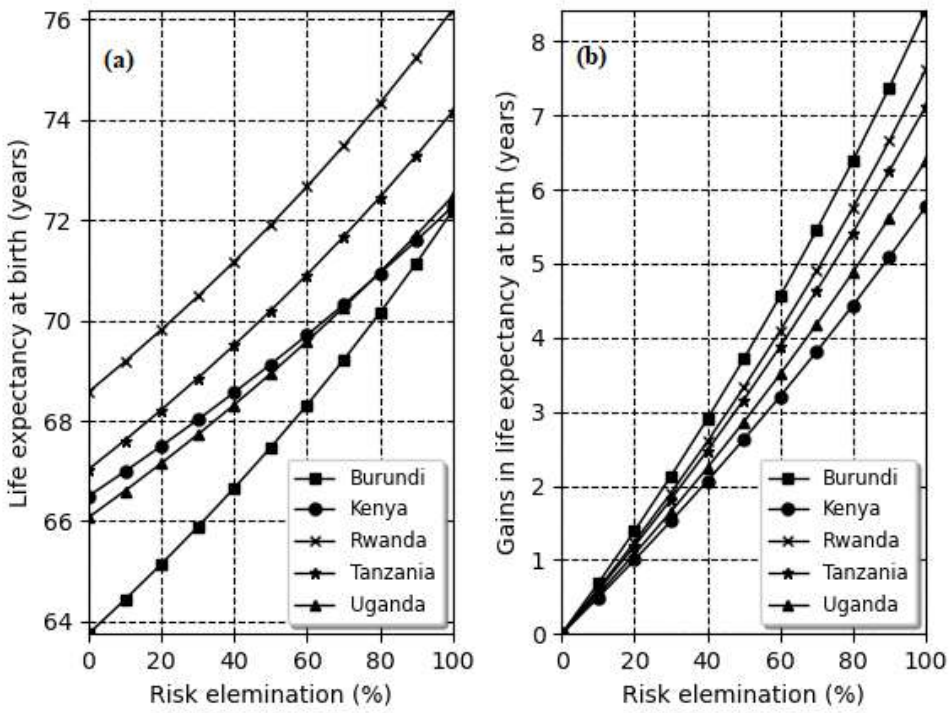

Fig. 1. The relationship progresses risk eliminations and life expectancy at birth.

4 Discussion

Through this study, we showed that air pollution potentially reduces the expectation of life at birth, followed by unsafe hygienic facilities and practices. Various studies showed that people in developed countries expect to live longer than those in middle- and low-income countries [13]. The contamination of the environment, risky behaviour and the lack of adequate hygienic facilities increase unhygienic-related and non-communicable diseases in low-income countries. Exposure to air pollution is linked with various harms leading to morbidity and mortality [14]. Air pollution has a great influence on the death rate in the whole studied countries, but few studies estimated the degree of the reduction of life expectancy from air environmental pollution. This study agrees with previous studies in revealing the role of air pollution in reducing life expectancy [15,16]. Limited resources and infrastructures for environmental monitoring and assessment in low-income countries complicate actions aimed at raising awareness about the danger caused by poor air quality.

Moreover, inadequate hygienic and sanitation facilities increase health incidences associated with poor hygienic behaviour [17,18]. In principle, access to safe drinking water is a basic human right, but access to clean and affordable water remains a real challenge for many people in East Africa [19]. In addition, sanitation facilities are also lacking in those countries [18]. Although all countries in the region are concerned, countries with high gains in life expectancy at birth from the elimination of poor hygienic-related causes should put much effort into building capacities and infrastructures for potable water resources and public awareness of good hygienic practices such as frequent handwashing and other sanitation systems. While air pollution is a transboundary risk that sometimes needs cooperative

programmes of all actors in the region, access to clean water and practices of hygienic behaviour, are facts that require the enforcement of local policies and regulations.

Furthermore, this study revealed that risk behaviours such as excessive alcohol consumption, and tobacco use are also significant contributors to the lower life expectancy in the East African region. Cigarette smoking and other tobacco use are known to have medical consequences including cancer, heart and lung diseases [20] causing an excessive number of deaths yearly [21]. Various studies showed that poor people [22] and those with low educational attainment [23] are more likely to smoke than those in the general population. Public education and policies should be enacted to reduce tobacco use, especially in the young population which is a growing behaviour in sub-Saharan Africa [24]. The reduction of alcohol consumption and tobacco use not only contributes to a healthy population but also increases its productivity.

This study presents some limitations. The estimated results were the best fits since it is challenging to accurately determine the life expectancy linked with specific risk factors due to a variety of causal relationships and competing risk variables associated with the health outcomes. Besides the mortality linked with these risks, they are also sources of morbidity often converted to life years lost that have not been the object of the current study. Nonetheless, these results recommend resource allocation and program evaluation regarding environmental monitoring and assessment, and goal-setting in the health domain for the long and healthy living population of East Africa

5 Conclusion

This study assessed the contribution of environmental risks to the reduction of the expectancy of life in East African countries. The life expectancy at birth, in 2019, was estimated to vary between 68.56 years in Rwanda to 63.76 years in Burundi. Poor air quality, tobacco use, and the inadequacy of hygienic infrastructures were identified as the main causes of the decline in life expectancy at birth. Although quantifying changes in life expectancy attributable to individual risk factors is challenging due to multi-causality and competing risk issues, this study revealed that efforts to simultaneously eliminate all relevant environmental risks may lead to a minimal increase in Kenya by at least 2.63 years for a 50% cause-elimination and 5.77 years for a 100% cause-elimination. These results recommend resource allocation and program evaluation regarding environmental monitoring and assessment and goal-setting in the health domain. One of the effective methods of evaluating the impact of initiatives on population health is to examine the decline in mortality resulting from different environmental hazards and raise awareness of dangerous behaviours and practices.

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