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Assessment of health benefits using BenMAP-CE in Myanmar

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Abstract: This study was conducted to assess the health benefits from $PM_{2.5}$ reductions in Yangon, the most populous city of Myanmar, during 2019 by using the Environmental Benefits Mapping and Analysis Program-Community Edition model (BenMAP-CE). An associated economic valuation of the health impacts was also performed. The causes of death classified in this study were all-cause (non-accidental), ischemic heart disease and lung cancer. The results of this study showed that daily $PM_{2.5}$ concentrations exceeded the WHO guideline throughout the year, most particularly during the hot and cool seasons. Also, it was found that the use of concentration response coefficients (beta values) from BenMAP-CE that are characteristics of a U.S. population lead to an overestimation of the number of deaths, i.e. all-cause (non-accidental) mortality, ischemic heart disease and lung cancer, compared to values reported in the literature for Thailand. This translated in an overestimation of corresponding costs, which in any case, remained below 1% of the country's GDP as observed in neighboring countries such as China. From a public health perspective, the findings of these investigations suggest that Myanmar should first establish a less stringent National Ambient Air Quality Standard prior to moving toward achieving the WHO guideline. Overall, the findings of this research highlight the importance of addressing the potential risk that $PM_{2.5}$ poses on public health and the economy of the country at large.

Keywords: $PM_{2.5}$, health benefits, Yangon, BenMAP-CE.

1. Introduction

Air pollution has been identified by World Health Organization (WHO) in 2019 as a key environmental risk factor impacting human health. This assessment is based on estimates of air pollution related deaths and disability-adjusted life years derived from the Global Burden of Disease initiative [1]. In recent years, the health problems associated with particulate matter equal to or less than 2.5 microns in aerodynamic diameter ($PM_{2.5}$) have received increasing attention as a major cause of premature mortality and morbidity around the world. [2].

In 2016, 91% of the world's population did not breathe clean air, and more than half of the urban population were exposed to outdoor air pollution levels at least 2.5 times above the safety standard set by WHO. In 2016, it has been estimated that outdoor air pollution, especially related to exposure to fine particulate matter, in both cities and rural areas caused 4.2 million deaths worldwide [3]. In Myanmar, in 2016, annual mean levels of $PM_{2.5}$ in urban areas amounted to 34.6μg/m^3, the fifth largest level out of the 11 countries in the South East Asia Region (SEAR). In terms of age-standardized mortality rate attributed to household and ambient air pollution, Myanmar stands in the top fourth position in SEAR with 156.4 per 100,000; Thailand is tenth, with 62.5 per 100,000 and South Korea is first, with 207.2 per 100,000 [4].

Particulate matter (PM) consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. While particles with a diameter of 10 microns or less, ($\leq PM_{10}$) can penetrate and lodge deep inside the lungs, the even more health-damaging particles are those with a diameter of 2.5 microns or less, ($\leq PM_{2.5}$). $PM_{2.5}$ can penetrate the lung barrier and enter the blood system. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer [3]. This study will focus on $PM_{2.5}$, which are 100 times smaller than the diameter of human hair, are mainly emitted from combustion, with mobile sources being one of the largest contributors to $PM_{2.5}$. Other sources include heating (burning of wood and coal), cigarette smoking, chemical reactions of fumes emitted by power plants, biomass open burning and chemical reactions in the atmosphere. As $PM_{2.5}$ particles are smaller than the coarse fraction of PM_{10} particles, they can stay in the air longer and penetrate deep into the lungs. For this reason, $PM_{2.5}$ particles are generally considered more dangerous than coarse fraction of PM_{10} particles [5].

Early studies by Dockery et al. [6] and Pope et al. [7] investigated the relationship between air pollution and mortality in U.S cities. A Cox proportional-hazards regression model was used to estimate the impact of long-term exposure to fine particulate ($PM_{2.5}$). In the study by Pope et al. [7], data were collected from 116 metropolitan areas in the USA over the period 1979-1983 and 1999-2000. The results revealed an association between $PM_{2.5}$ and all-cause deaths, cardiopulmonary mortality and lung-cancer mortality. Average relative risk values were identified for each health impact endpoints, i.e. 1.06, 1.09 and 1.14 for all-cause, cardiopulmonary and lung cancer mortalities, respectively (for a 10 μg/m^3 change in fine particulate matter).

Over the past 16 years, the USEPA has introduced a new Window-based program called the Environmental Benefits Mapping and Analysis Program (BenMAP) to estimate the number and economic value of adverse health outcomes [2]. In March 2015, the new version of the tool was publicly available and relabeled as the Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE). This software was designed for flexibility to perform a broad array of analyses at the local, regional, national and global scale [8]. In this study, health impacts caused by $PM_{2.5}$ in Yangon were estimated using BenMAP-CE. The Heath benefits associated to a reduction in $PM_{2.5}$ levels to some threshold values, including the WHO annual guideline, were also assessed in monetary terms. To date no studies of this kind have been perform on the S.E. Asian population of Myanmar and our result can be placed in the context of other such studies in Asia and the West.

2. Methodology

2.1 Study Area

The Yangon Region, located in the heart of lower Myanmar, is dominated by its former capital city of Yangon, the largest city in the country. There are four districts and 46 townships in Yangon Region [9-10]. The monitoring station operated by the Department of Metrology and Hydrology (Yangon Office) is located in the Mayangone Township in the West District of the Yangon Region as shown in Figure 1. As information on air quality in Yangon is limited, the air quality data collected from the Yangon Office was assumed to be representative of the 4 districts included in the Yangon Region.

With regard to climate, Yangon (Rangoon) is characterized by a tropical monsoon climate with very wet summers due to the southwest monsoon, which starts from mid-May and lasts until mid-October. From mid-October, the amount of precipitation decreases significantly. The temperature can rise considerably during winter to an average of almost 37° Celsius (98° Fahrenheit) in the hottest month April [11].

2.2 Collection of $PM_{2.5}$ Monitoring Data

The hourly $PM_{2.5}$ monitoring data (2019) were collected from the Department of Meteorology and Hydrology (Yangon) where the location is 16° 51' 55.4076" N and 96° 9' 14.9868" E. The type of $PM_{2.5}$ monitoring equipment installed is MP101M. This equipment is a particle measuring device using Beta gauge technology and it can also be used to monitor sampled air continuously for possible natural radioactivity, with programmed alarm in the event of a threshold event [13].

Due to limited data availability, the period with available monitoring data spans from April 2018 to December 2019. Based on the requirement of the GB3095-2012 standard [14] regarding the suitability of $PM_{2.5}$ data, quality control was conducted based on the following steps: (1) 1-hour average concentration values less than and equal to zero, as well as missing data were ignored; (2) 24-hour average concentration values involving missing data for six hours or more were ignored; (3) 1-hour average concentration values that exceeded 900 μg/m^3 were ignored. [14] Following the above steps, only data for the year 2019 could be analyzed (355 days of data available in that year) since there were insufficient data for the year 2018 (128 days of missing data in that year).

As shown in Table 1, it was observed that the highest concentrations of $PM_{2.5}$ occurred during the hot season, from March to May, with monthly average concentrations in the range 23.2-37.8 μg/m^3. The lowest concentrations of $PM_{2.5}$ were observed during the rainy season, from June to October, with monthly average concentrations in the range 10.0-18.5 μg/m^3. Based on the results of this study, 95 percent of the days during the hot season, the rainy season, and the cool season were found to have $PM_{2.5}$ concentration levels not exceeding 48.4 μg/ m^3, 22.6 μg/m^3 and 54.4 μg/m^3, respectively. As indicated in the Myanmar Climate Report [15], most of the days in a year fall during the cool season with 42% while 25% and 33% of the days occur during the hot season and rainy season, respectively. From the analysis of the data, it was observed that in 2019, 73% of the days during the hot season and 45% of the days during the cool season exceeded the WHO daily guideline. However, it was found that only 5% of the days during the rainy season exceeded the WHO daily guideline.

Table 1. $PM_{2.5}$ concentration levels in different seasons in Yangon in 2019.

	Hot Season (Mar.-May.)	**Rainy Season (Jun.-Sep.)**	**Cool Season (Oct.-Feb.)**
Seasonal average (μg/m^3)	31.5	12.3	30.5
Seasonal daily maximum (μg/m^3)	55.5	62.9	71.9
Seasonal daily minimum (μg/m^3)	9.8	5.3	9.8
95 percentile (μg/m^3)	48.4	22.6	54.4
Number of days exceeding WHO daily standard/Number of days per season	67/92	6/122	68/151
Proportion of days exceeding WHO daily standard (%)	72.83	4.92	45.03

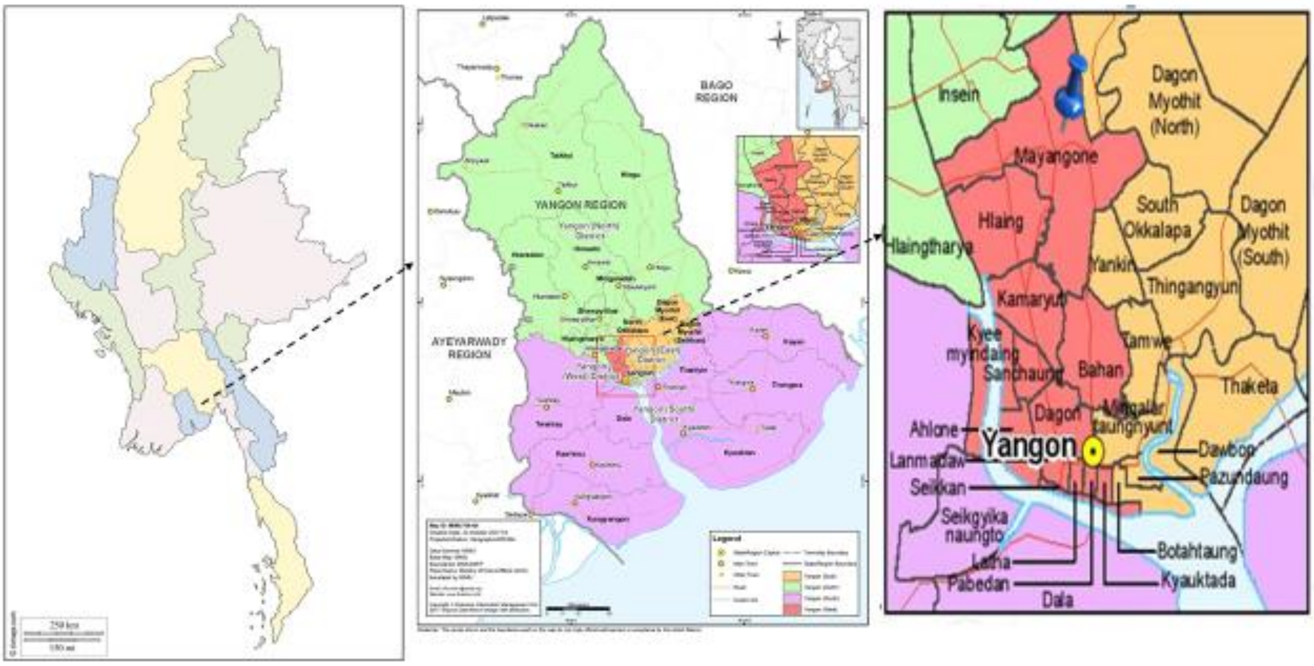

Figure 1. Location of Study Area (Note: The blue pin shows the location of monitoring station).
Source: Based on MIMU [12]

Table 2. Seasonal variance in meteorological indicators and $PM_{2.5}$ concentrations in Yangon.

Season	Month	Average $PM_{2.5}$ (μg/m^3)	Monthly cumulative rainfall (mm)	Average (%) Relative Humidity	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Average Temperature (°C)
Cool	January	42	15	61	33	18	26
Cool	February	50	10	61	34	20	27
Hot	March	38	20	65	36	22	29
Hot	April	35	25	70	37	24	31
Hot	May	28	300	80	33	25	29
Rainy	June	10	500	85	31	24	28
Rainy	July	10	500	90	29	24	27
Rainy	August	10	600	90	29	24	27
Rainy	September	20	360	85	31	24	28
Cool	October	20	220	80	32	24	28
Cool	November	22	70	78	33	22	28
Cool	December	22	20	70	32	20	26

2.3 Estimation of Correlation between $PM_{2.5}$ and Meteorological Conditions

Yang et al. [16] indicated that seasonal changes in $PM_{2.5}$ concentration levels are influenced by meteorological factors. In order to estimate the correlation between $PM_{2.5}$ and meteorological conditions in Yangon during the year 2019, the data was firstly divided into three seasons, i.e. cool season during October to February; hot season during March to May; and rainy season during June to September. Meteorological data for Yangon were retrieved from the Worldwide Weather Forecasts and Climate Information [11]. Table 2 indicates the monthly averages of meteorological occurrences and associated $PM_{2.5}$ concentrations. In the months of the hot season, the average temperature is highest ranging between 29-31°C, and the average monthly $PM_{2.5}$ concentration is 34 μg/m^3. During rainy season, from June to August, the rainfall is highest ranging between 500 mm and 600 mm, and the $PM_{2.5}$ concentration reaches its lowest with a monthly average concentration of about 10 μg/m^3. In February, the relative humidity and average temperature are low, with 61% and 27% respectively, reaching its highest concentration with a monthly average concentration of 50 μg/m^3.

2.4 Health Data Analysis in Yangon

The population of Yangon in 2019 was 7,360,703 (0 to 99 years) with 53% of the population being under the age of 30. Population data were collected from the Department of Population (Yangon). Mortality data, including age range, sex and causes of deaths were downloaded from the GBD Results Tool of Global Health Data Exchange (GHDx) for the most recent year of availability, i.e. 2017. Mortality data were limited to an age range of 30-99 years since the specific concentration-response values selected from Krewski et al. [17] in BenMPA-CE are valid for this age range. The age range 30-99 years was found to account for 65% of the total annual number of deaths in Yangon, with approximately 46,505 deaths. The mean age was 67 years with a median age of 68 years, and first and third quartiles of 55 years and 80 years, respectively (IQR = 25 years).

The fractions of ischemic heart disease and lung cancer to all-cause mortality are 9.21% and 2.27%, respectively. Regarding ischemic heart disease mortality, ages in the range 30-99 years were found to represent 99.16% of the total number of deaths in this category; the range 0-30 years accounts for the remaining 0.83%. For the age range 30-99 years, the mean age is 71 years with a median of 72 years, and first and third quartiles of 60 years and 82 years, respectively (IQR = 22 years). For lung cancer mortality, the age range 30-99 years represents 98.42% of the total number of deaths in this category; the age range 0-30 years accounts for the remaining 1.58%. For the age range 30-99 years, the mean age is 64 years which is same with the median age, and first and third quartiles of 55 years and 73 years, respectively (IQR = 18 years).

2.5 Estimation of Health Impact Using BenMAP-CE

BenMAP-CE is a Geographic Information System (GIS)-based tool that estimates the health effects of changes in air pollution levels, analyzing the links between $PM_{2.5}$ concentrations and mortality. The software utilizes a health impact function that incorporates monitored air-quality data, population data, baseline incidence rates, and an effect estimate to calculate health impacts. To estimate the health effects investigated in this research (i.e. all cause (non-accidental), ischemic heart disease and lung cancer), the following equation is used:

$$\Delta Y = \left(1 - e^{-\beta * \Delta AQ}\right) * Yo * Pop \quad [1]$$

where:

ΔY = the estimated health impact attributed to air pollution
β = the beta coefficient (risk coefficient) from an epidemiologic study
ΔAQ = defined change in air quality
Yo = baseline rate (i.e., incidence) for the health effect of interest
Pop = population exposed to air pollution

As stated earlier, the year 2019 was selected for the health burden and benefit analysis using the data detailed in previous sections. In order to estimate the health impact of a potential policy option, the changes (deltas) in a population's cumulative exposure were created for two different situations: (1) a rollback to the WHO annual guideline and (2) a 50 percent rollback. The difference in these two population exposure surfaces between the two different rollbacks provides an estimated change in human health impacts based on the concentration-response function used. [18-19]

Firstly, the Health Impact Function (HIF) of Krewski et al. [17] available in BenMAP-CE was selected as it provides β values for all-cause (non-accidental) mortality, ischemic heart disease and lung cancer. Secondly, for comparison purposes and in the absence of specific values for Myanmar, beta values estimated by Fold et al. [20] for a population exposed to $PM_{2.5}$ in Bangkok were used as input in BenMAP-CE. In Fold et al. [20], HIFs were determined for all-cause (non-accidental) mortality, cardiopulmonary disease and lung cancer. According to the International Classification of Diseases (ICD-10) [21], cardiovascular disease (I00-I99) is the term used for all types of diseases affecting the heart or blood vessels, including ischemic heart disease (I20-I25). Therefore, the β value estimated for cardiopulmonary disease in Fold et al. [20] was assumed as representative of the β value for ischemic heart disease in this study. The selection of HIFs from Fold et al. [20] is based on the assumption that Bangkok and Yangon populations share greater similarities than when compared with western populations.

Regarding the above health endpoints, as also indicated earlier, the death rates of Myanmar related to the year 2017 were downloaded from the Global Burden of Disease (GBD) Results Tool [22] and used for the assessment since mortality data for Yangon could not be obtained.

2.6 Valuation of Health Impacts

In benefit-cost analyses, the U.S. Environmental Protection Agency (EPA) uses a value of statistical life (VSL) to calculate the benefits of mortality risk reductions in monetary terms [23]. According to Braathen et al. [24], the value of statistical life (VSL) is the rate at which people are prepared to trade off income for a reduction in their risk of dying. For this study, the "Value of Mortality Risk" was used, which relates to VSL, since the EPA is proposing to use VMR in order to reduce the misunderstandings that are sometimes caused by the VSL terminology [25]. The VMR can be estimated as shown in Equation (2).

$$VMR_{c,n} = VMR_{OECD} * \left(\frac{Y_{c,n}}{Y_{OECD}}\right)^{\varepsilon} \quad [2]$$

Where, $VMR_{c,n}$ is the VMR value for country c in year n; VMR_{OECD} is the base OECD VMR; $Y_{c,n}$ is the GDP per capita for country c in year n; Y_{OECD} is the average GDP per capita for the sample of OECD country chosen for the analysis; and ε refers to income elasticity.

According to OECD [26], the income elasticity of the VSL "ε" measures the percentage increase in VSL for a percentage increase in income. The authors mentioned that the meta-analysis in OECD [27] revealed that an elasticity of 0.8 should be used for high-income countries, 0.9 for middle-income countries and 1 for low-income countries.

In order to adjust for price inflation at PPP rates, Equation (2) is modified to include a ratio of the CPIs from a base year to the year analyzed and an adjustment factor for the PPP in the form of multiplication [28]. The equation (3) used in this study which is based on the equation provided in BenMAP-CE, is as follows:

$$VMR_{MMR,2019} = VMR_{Thailand,2005} * \left(\frac{Y_{MMR,2005}}{Y_{Thailand,2005}}\right)^{\varepsilon} * PPP_{MMR,2005} * \frac{CPI_{MMR,2019}}{CPI_{MMR,2005}} \quad [3]$$

In equation (3), the VMR for Thailand was used as the base VMR to estimate that of Myanmar. This was done since the $VMR_{Thailand}$ was found to be available in OECD [27] and it is expected Thailand shares greater similarity with Myanmar than an OECD country, providing therefore a better approximation of the VMR for Myanmar.

3. Results and Discussion

3.1 Time Series Analysis of $PM_{2.5}$ in Yangon in 2019

Based on the $PM_{2.5}$ monitoring data collected from the Department of Meteorology and Hydrology (Yangon Office), Figure 2 was produced. It was found that the $PM_{2.5}$ concentration varied largely between seasons with the highest value observed during the cool season with 71.9 μg/m^3 (mean value is 32.8 μg/m^3) and the lowest during the rainy season with 5.3 μg/m^3 (mean value is 13.4 μg/m^3). As indicated earlier, it was found that $PM_{2.5}$ concentrations did not exceed 48 μg/m^3 during the hot season, 23 μg/m^3 during the rainy season and 54 μg/m^3 during the cool season for 95 per cent of the days in each season. The variation observed in Figure 2 is due to changes in meteorological conditions. In Yangon, the rainy season starts in June and ends in September. It is associated with a daily average $PM_{2.5}$ concentration in the range 5.3-62.9 μg/m^3 which is mostly below the WHO daily guideline (i.e., 25 μg/m^3). $PM_{2.5}$ concentrations were generally observed to exceed the WHO guideline during the cool season in January and February (56% exceedance) as well as during the hot season from March to May (73% exceedance).

Relationships between $PM_{2.5}$ and meteorological parameters, including, rain, temperature, and relative humidity in Yangon were investigated based on a correlation matrix. The results in Table 3 show that $PM_{2.5}$ is positively correlated with temperature, with a correlation coefficient value of 0.778 while $PM_{2.5}$ is negatively correlated with rain and relative humidity, with a correlation coefficient of -0.819 and -0.927, respectively. These results show that there is a strong relationship between $PM_{2.5}$ and these meteorological parameters supporting the seasonality patterns expressed by the data reported in Table 3.

Table 3. Correlation matrix between $PM_{2.5}$ and meteorological factors.

	$PM_{2.5}$	**Rain**	**Relative Humidity**	**Temp max**
$PM_{2.5}$	**1.000**			
Rain	-0.819	**1.000**		
RH	-0.927	0.912	**1.000**	
Temp (max)	0.778	-0.812	-0.764	**1.000**

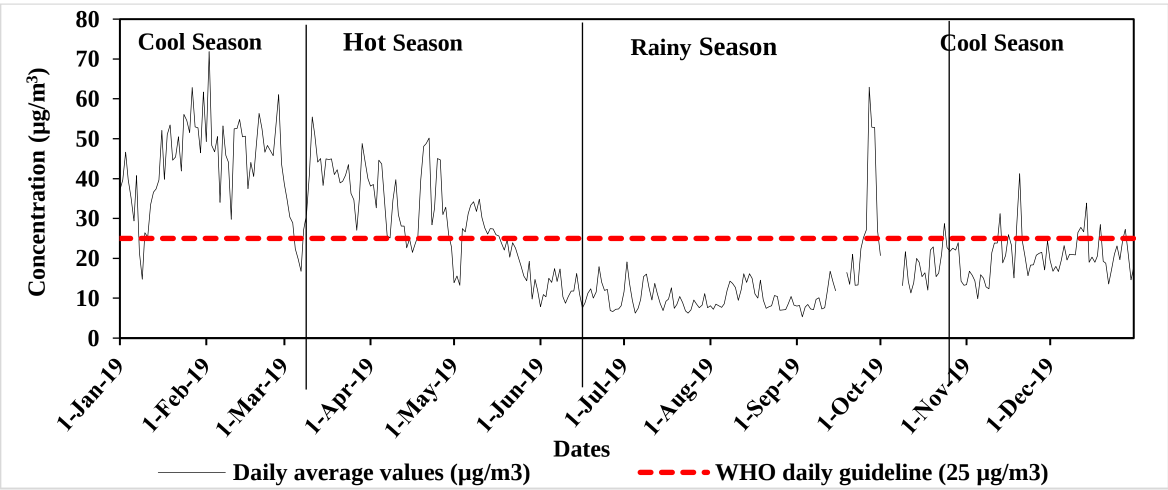

Figure 2. Daily Average $PM_{2.5}$ Concentration in Yangon (2019).

3.2 Assessment of Health Impacts in Yangon Using BenMAP-CE

Table 4 presents the avoided mortalities for all-cause (non-accidental), ischemic heart disease and lung cancer based on (1) a rollback to the WHO annual guideline and (2) a 50 percent rollback. The results show that a roll back to the WHO guideline enable to achieve greater reduction in premature deaths as a 50% rollback does not represent a completely safe level. The fractions of ischemic heart disease and lung cancer to all-cause mortality are about 30% and 5% respectively based on either of the rollback scenarios. These results show that reducing $PM_{2.5}$ concentration to the WHO guideline compared to a 50% rollback would enable avoiding an additional 588 cases of premature deaths (non-accidental), 160 cases of ischemic heart disease, and 28 cases of lung cancer. (See Table. 4).

Based on the same rollback scenarios as above, beta values identified by Fold et al. [20] for a Bangkok population exposed to $PM_{2.5}$, were used for Yangon since both populations are expected to share greater similarities as south-east Asian populations. The results in Table 5 indicate that the number of avoided deaths were three- (non-accidental), eight- (ischemic heart disease), and four-times (lung cancer) lower compared to those obtained based on values from Krewski et al. [17] (see Table 4). These results show that using BenMAP default values from the USA are likely to overestimate health impacts from $PM_{2.5}$ by at least a factor of 3.

3.3 Valuation of Health impacts

To` estimate the economic benefit of mortality reduction, data related to the GDP per capita, purchasing power parity (PPP), and consumer price index (CPI) were downloaded from the World Bank (World Development Indicators) [29]. In order to monetize mortality risk in benefit-cost analysis, the estimation of two critical inputs were also required: a base VMR and an adequate income elasticity value. For this study, a base VMR of $ 659,955 (year 2007) was adopted from Thailand [27]. With regard to elasticity, two values were used; the first one is the default value provided in BenMAP-CE of 0.4 while the second value is an income elasticity of 1 for low income countries as indicated by Viscusi and Masterman [30]. Using Equation (3), the valuation of various health endpoints was performed for (1) a rollback to the WHO annual guideline and (2) a 50 percent rollback. The assessment was performed based on the health impact assessment results obtained in BenMAP-CE using the HIFs from Krewski et al. [17] and Fold et al. [20]. The results are shown in Table 6 and Table 7 respectively.

In 2019, the total GDP of Myanmar amounted to 278 billion USD [29]. Based on the income elasticity value provided in BenMAP (i.e., $\varepsilon = 0.4$), the estimated economic benefit associated to a rollback to the WHO annual guideline was found to account for 0.15% (USA β values) and 0.04 % (Thailand β values) of the total GDP of Myanmar. Based on an income elasticity of 1, it was estimated to account for 0.06% (USA β values) and 0.017 % (Thailand β values) of the total GDP of Myanmar (see Table 6). These results confirm the influence of the beta values on the valuation of health impacts and the necessity of selecting adequate values.

Table 4. Avoided deaths in Yangon in 2019 based on beta values from the USA.

Health Endpoints	**β Values (Standard Deviation)***	**Rollback to WHO Guideline**	**50 Percent Rollback**
All Cause (Non-accidental)	0.005826 (±0.0009628)	3,936 (CI 95%: 2,695-5,139)	3,348 (CI 95%: 2,287-4,379)
Ischemic heart disease	0.021511 (±0.0020584)	1,186 (CI 95%: 991-1,370)	1,026 (CI 95%: 853-1,190)
Lung Cancer	0.013103 (±0.0037945)	195 (CI 95%: 89-290)	167 (CI 95%: 75-251)

*Krewski et al. [17]

Table 5. Avoided deaths in Yangon in 2019 based on beta values from Thailand.

Health Endpoints	**β Values***	**Rollback to WHO Guideline**	**50 Percent Rollback**
All-Cause (Non-accidental)	0.001743	1,200	1,002
Cardiopulmonary disease	0.002284	144**	120**
Lung Cancer	0.003134	48	41

*Fold et al [20]; **this assessment is based on betas values for on cardiopulmonary disease.

Table 6. Valuation of Health Effects Associated to $PM_{2.5}$ in Yangon in 2019 based on a Rollback to WHO Annual Guideline.

	Based on United states β values		**Based on Thailand β values**	
Mortality Effect	**Valuation ($\varepsilon = 0.4$)**	**Valuation ($\varepsilon = 1.0$)**	**Valuation ($\varepsilon = 0.4$)**	**Valuation ($\varepsilon = 1.0$)**
All Cause (non-accidental)	4.07E+08 USD (6.29E+11 MMK)	1.55E+08 USD (2.40E+11 MMK)	1.24E+08 USD (1.92E+11 MMK)	4.73E+07 USD (7.31E+10 MMK)
Ischemic Heart Disease	1.23E+08 USD (1.90E+11 MMK)	4.68E+07 USD (7.23E+10 MMK)	1.49E+07 USD* (2.30+10 MMK)*	5.68E+06 USD* (8.78E+09 MMK)*
Lung Cancer	2.02E+07 USD (3.12E+10 MMK)	7.70E+06 USD (1.19E+10 MMK)	4.96E+06 USD (7.67E+09 MMK)	1.89E+06 USD (2.93E+09 MMK)

Note: Exchange rate: 1 USD = 1,546 MMK as of 1st January 2019 (Source: Central Bank of Myanmar [31]); *these values are based on beta values for cardiopulmonary disease.

Table 7. Valuation of Health Effects Associated to $PM_{2.5}$ in Yangon in 2019 based on a 50 Percent Rollback.

	Based on United states β values		Based on Thailand β values	
Mortality Effect	**Valuation (ε = 0.4)**	**Valuation (ε = 1.0)**	**Valuation (ε = 0.4)**	**Valuation (ε = 1.0)**
All Cause (non-accidental)	3.46E+08 USD (5.35E+11 MMK)	1.32E+08 USD (2.04E+11 MMK)	1.04E+08 USD (1.60E+11 MMK)	3.95E+07 USD (6.11E+10 MMK)
Ischemic Heart Disease	1.06E+08 USD (1.64E+11 MMK)	4.05E+07 USD (6.25E+10 MMK)	1.24E+07 USD* (1.92E+10 MMK)*	4.73E+06 USD* (7.31E+09 MMK)*
Lung Cancer	1.73E+07 USD (2.67E+10 MMK)	6.60E+06 USD (1.02E+10 MMK)	4.24E+06 USD (6.55E+09 MMK)	1.62E+06 USD (2.50E+09 MMK)

Note: Exchange rate: 1 USD = 1,546 MMK as of 1st January 2019 (Source: Central Bank of Myanmar [31]);
*these values are based on beta values for cardiopulmonary disease.

For a 50 percent rollback, based on an income elasticity of 0.4, the estimated economic benefit was found to account for 0.12% (USA β values) and 0.05% (Thailand β values) of the total GDP of Myanmar. Based on an income elasticity of 1, it was estimated to account for 0.05% and 0.014% of the total GDP of Myanmar (See Table 7).

Differences in the economic benefits in Yangon related to avoided health impacts from $PM_{2.5}$ pollution were observed depending on the elasticity values used. The estimated economic benefits calculated using the BenMAP default value (i.e., ε = 0.4) were found to be almost three-times higher than when using an income elasticity of 1 for low income countries as indicated by Viscusi and Masterman [30]. Studies attempting to monetize mortality associated to long-term exposure to $PM_{2.5}$ are scarce. However, one notable example is that of a study by Chen et al. [14] for China for the year 2014. The investigations revealed that the economic benefits related to a rollback of $PM_{2.5}$ to the National Ambient Air Quality Standard (35 μg/m^3, annual average value) would be in the range 0.11 to 0.40% of the country's GDP for cardiovascular disease, respiratory disease and lung cancer combined. These results are in line with those of Yangon with contributions to GDP being less than 1%.

Overall, the valuation of health impacts in Yangon revealed that reaching the WHO annual guideline would enable achieving greater benefits than a 50 percent reduction in $PM_{2.5}$ level (i.e. an additional 23 million USD). However, these relate to marginal benefits in terms of avoided mortality cases as indicated by the results in Table 4. Hence, achieving a less stringent $PM_{2.5}$ concentration target than that provided by the WHO guideline is likely a better option from an economic perspective. In this regard, Myanmar could follow the example of neighboring countries such as China or Thailand which has set national ambient air quality standards ($PM_{2.5}$ annual average concentration) that are 2.5 to 3.5 times less stringent than the WHO guideline.

4. Conclusions

In this research, $PM_{2.5}$ concentration levels were investigated in Yangon for the year 2019. Looking at the air quality situation in Yangon, it was found that the annual average concentration of $PM_{2.5}$ in 2019 was 24.6 μg/m^3, exceeding the WHO annual guideline (10 μg/m^3). From the time-series analysis of the $PM_{2.5}$ concentration in Yangon and correlation with meteorological parameters, a strong positive correlation was observed between $PM_{2.5}$ and temperature and a strong negative correlation between $PM_{2.5}$ and precipitation. By reducing the $PM_{2.5}$ concentration in the year 2019 to the WHO annual guidelin), about 3,936 cases of deaths for all-cause (non-accidental) could be avoided, including 1,026 cases of ischemic heart disease and 195 cases of and lung cancer. The economic benefits were estimated to be in the range 155-407 million USD. The findings of this research indicated that using the HIFs provided in BenMAP-CE for a western population may lead to an overestimation of health impacts compared to using HIFs characteristics of Asian populations. Also, from a cost-perspective consideration, to optimize health benefits, the results of these investigations revealed that prior to attempting achieving the WHO guideline, Myanmar should first consider establishing a less stringent standard for $PM_{2.5}$ as is the case in some neighboring countries.

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