Assessment of PM_{10} in Colombo, Sri Lanka and Its Potential Source Regions

Thrividya Rathnayake, *Lovleen* Gupta

Department of Environmental Engineering, Delhi Technological University, Shahbad Daulatpur, Main Bawana Road, 110042 Delhi, India

rathnayakemudiyanselag_2k22ene06@dtu.ac.in, lgupta@dce.ac.in

Abstract. Air pollution, specifically the presence of particulate matter (PM_{10}) is a growing concern in many parts of the world, including Sri Lanka because of their ability to cause series health risks, destructive environmental damage and their negative effects on the nation's economy. Since Colombo is the commercial capital of Sri Lanka, this study analyzed the PM_{10} concentrations in Colombo over one-year period; impact of meteorological parameters on the PM_{10} levels and potential source regions. To accomplish this, data on 24-hour average PM_{10} concentrations and meteorological parameters were collected at Colombo from Jan to Dec 2022. Colombo experienced 40.5 ± 26.6μgm^{-3} average PM_{10} concentrations in 2022 which is about 3 times higher than WHO guidelines (15μgm^{-3}). Seasonally, Northeast monsoon season experienced the highest average PM_{10} concentration (~56.8 μgm^{-3}) in Colombo that may be attributed to low rainfall (~3.8mm) and low wind speed (~12.1mph). Conversely, minimum average PM_{10} level (~24.2 μgm^{-3}) occur during Southwest monsoon which may be caused by higher rainfall (~8.4mm) and wind speed (~17.9mph). CBPF was used to evaluate the potential source regions for high PM_{10} levels in Colombo, indicating potential sources could be vehicular emission, thermal power plant, waste combustion and industrial emissions. The results of this study assist policy makers in charting the control strategies in the region.

Keywords: PM_{10}, Health Risks, Colombo, Potential Source Regions, Policy Makers

1 INTRODUCTION

Air pollution is one of the most complicated environmental issues that must be addressed as it has been linked to various health issues leading to mortality [1]. Of all the air pollutants, Particulate Matter (PM) pollution, which consists of particles floating in the air is responsible for ~8.7 million deaths globally [2]. PM_{10} leads to reduced visibility and have the ability to cause bronchial irritation, inflammation, and an increase in respiratory system

reactivity, wheezing, asthmatic flare-ups, respiratory infections, chronic bronchitis, and chronic obstructive pulmonary disease may all be triggered by these effects [3].
Sri Lanka lies in the Indian Ocean, in the southwest of the Bay of Bengal and is categorized as a tropical country [4]. Colombo, Sri Lanka's capital city serves as the country's economic, cultural, and political hub and is located on the island's western coast. While statistics from 2018 indicate that 13% of Sri Lanka's population lives in Colombo, air pollution problem is getting worse due to the city's fast urbanization, accumulation of businesses, commercial sectors, and rising living standards, etc.[5] (S.Nandasena & Premasiri, 2021). Vehicular emissions, burning of organic waste, agricultural byproducts, industrial emissions (particularly from thermal power plants), petroleum refining, and trans-boundary movement of air pollutants from the Asian continent all have an impact on air quality of Colombo [6]. Sri Lanka has historically made significant policy interventions in reducing air pollution through the establishment of necessary legal and regulatory mechanisms, institutional strengthening, and carrying out necessary capacity development activities [7]. The World Health Organization (WHO) air quality guidelines were published in 2005, updated in 2021 and Sri Lanka's air quality standards, including the standards for PM_{10}, were amended and published in August 2008 [8].
In Sri Lanka, regular monitoring of air pollution with automatic air quality stations began in 1997 with two monitoring stations in Colombo [9]. Since then there have been number of air quality studies with limited datasets in different parts of Sri Lanka. A study in Colombo found that the ratio of suspended particulate matter ($TSP:PM_{10}:PM_{2.5}$) is 4:3:2, with PM_{10} accounting for 70% of total particles [10]. Cooking with biomass, car exhaust, and road dust contribute to particle chemical composition [11]. In 2020, a literature review has been conducted and this showed the wellsprings of air contamination can be classified into three essential groups: transport, industry (counting power generation) and homegrown use [9]. There was another study in 2021 which investigated the potential impacts of ambient particulate matter (PM) on respiratory disease hospitalization in Kandy in Sri Lanka for 2019 [12].
This study presents the variation in PM_{10} over Colombo throughout the year from January – December 2022, analysis the impact of meteorological parameters on PM_{10} and explores the potential source regions responsible for high PM10 concentration.

2 METHODOLOGY

2.1 Study Area

The Palk Strait divides Sri Lanka, an island in the Indian Ocean, from peninsular India. Its latitude and longitude are 5°55′ and 9°51′ N and 79°41′ and 81°53′ E, respectively. Its maximum length and width are 268 miles (432 km) and 139 miles (224 km), respectively. Colombo is the commercial capital city of Sri Lanka which is located on the western coast of Sri Lanka, along the Indian Ocean. The coastline extends from north to south, providing access to important ports like the Colombo Port and the newer Port City development. Particularly during the monsoon season, the topographical features in this area have a significant effect on the spatial patterns of winds, seasonal rainfall, temperature, relative humidity, and other climatic aspects. First Inter-monsoon Season (March – April), Southwest Monsoon Season (May – September), Second Inter-monsoon Season (October – November), and Northeast Monsoon Season (December – February) are the four climate seasons that can be used to describe the climate in Sri Lanka over a 12-month period [4].

Fig. 1. Study Area [13]

2.2 Data Collection

24-hour average PM_{10} data of Colombo were monitored and gathered by National Building Research Organization (NBRO) which is a government organization in Sri Lanka for one-year period (2022). There are some blank days for monitoring PM_{10} concentrations due to the power failures and other unavoidable situations. If continuously more than 75% 24-hr data was not available, monthly average value is not calculated. Data was screened any negative values or $PM_{2.5}/PM_{10}$ is more than 1, those data have been eliminated. For this study, annual average Air Quality standards were considered as $50 \mu gm^{-3}$ for PM_{10} which were amended and gazette in 2008 [8].
CSV file of 24 hours daily mean values of meteorological parameters such as rainfall, mean temperature and wind speed in Colombo are freely available at https://www.kaggle.com/datasets/rasulmah/sri-lanka-weather-dataset?resource=download.

3 RESULTS AND DISCUSSION

3.1 Daily, Monthly and Annual PM_{10} Variation

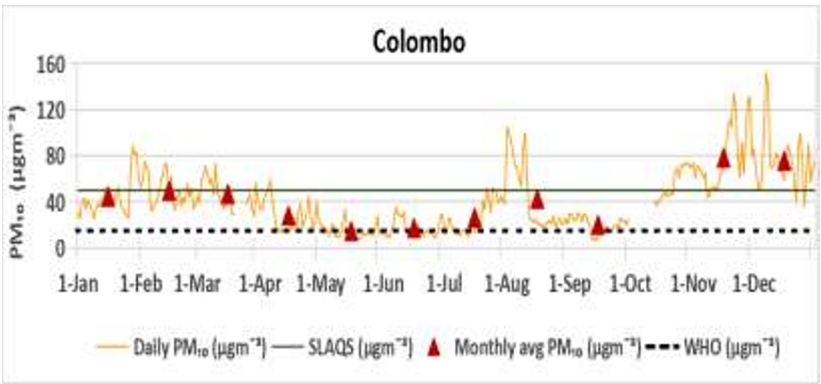

Figure 2. Daily and monthly average variation of PM_{10} concentrations in Colombo

Table 1. Annual summary of PM_{10} data in Colombo (N stands for the number of available data per year and Min (Minimum), Max (Maximum), Median, Mean, Q1 (first quartile), Q3, and SD (Standard Deviation) values are mentioned in μgm^{-3}).

	N	Min	Max	Median	Mean	Q1	Q2	Q3	SD
Colombo	360	6.5	152.0	33.9	40.5	19.3	33.9	56.4	26.6
SLAQS = 50 μgm^{-3} WHO Guidelines = 15 μgm^{-3}									

Colombo, Sri Lanka's capital city serves as the country's economic, cultural, and political hub and is located on the island's western coast. During Jan PM10 concentrations are varying below the SLAQS ($50\mu gm^{-3}$), while pollution concentration during some days of both Feb and March exceeding the permissible limit. From Apr to Jul pollutant level is less than $50\mu gm^{-3}$ and again during Aug there is a sudden increase. PM_{10} amount during Sept and Oct are not crossing the standard limits. Nov and Dec months are experiencing the highest PM_{10} concentrations throughout the study period. Colombo marks the maximum PM_{10} concentration as $152\mu gm^{-3}$ during Dec. According to the summary of PM_{10} data in Colombo the average concentration in 2022 is $40.5\mu gm^{-3}$ which is not higher than SLAQ standards.

3.2 Seasonal Variation

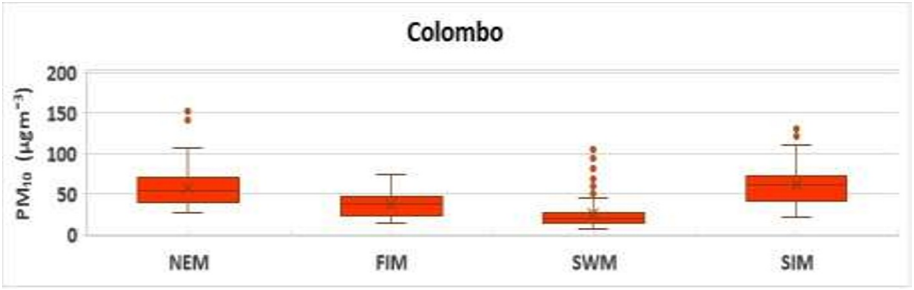

Fig. 4. Seasonal variation of PM_{10} concentrations in Colombo in 2022 (NEM – Northeast monsoon, FIM – First inter-monsoon, SWM – Southwest monsoon, SIM – Second inter-monsoon)

Fig. 4 provides a clear picture of variation of PM_{10} during 4 different climate seasons in Sri Lanka. Northeast monsoon (Dec – Feb) is experiencing the maximum pollutant concentrations while Southwest monsoon (May – Sep) is having the minimum pollution level.

3.3 Effects of Meteorological Parameters

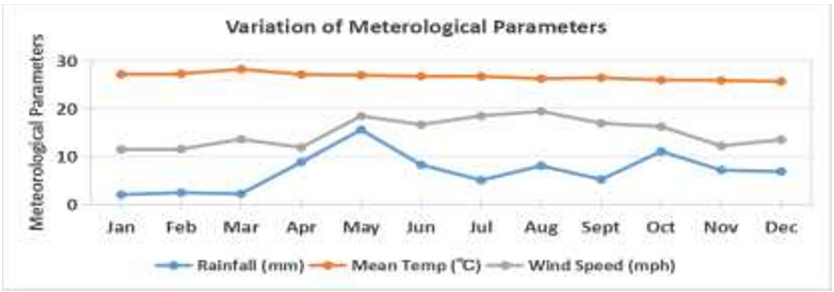

Figure 5. Monthly average rainfall, temperature and wind speed in Colombo in 2022

Behavior of PM_{10} concentrations in Colombo over 2022 can be explained by analyzing meteorological parameters such as rainfall, temperature and wind speed. From Jan to March, Colombo is experiencing low rainfall and low wind speed. From Jan to March mean temperature is slightly increasing and again from March to Dec temperature is decreasing. During the whole year mean temperature is fluctuating between 18 - 30ºC. May is having highest rainfall and highest wind speed which is resulting lower pollutant concentrations. Nov and Dec are facing low rainfall, low winds peed and low temperature that leads to maximum PM_{10} levels in Colombo.

3.4 Role of Local Wind Speed and Wind Direction

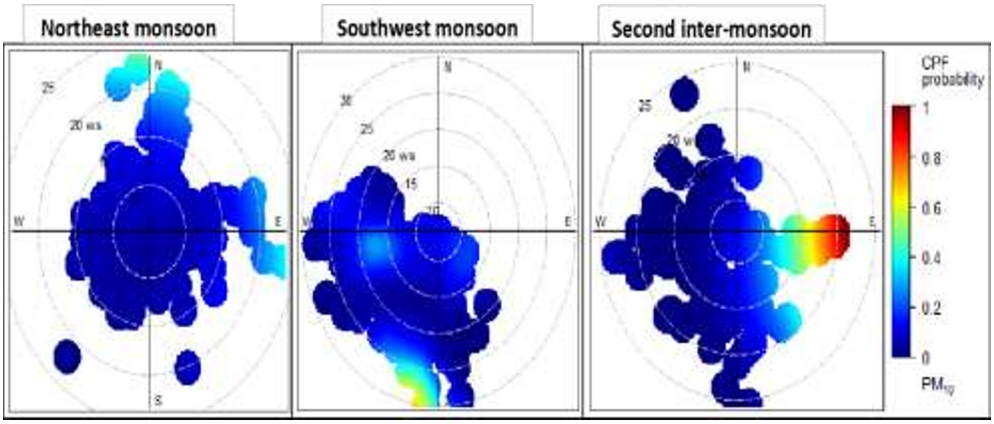

Figure 6: PM_{10} CBPF plots at Colombo for three seasons

During northeast monsoon, high PM_{10} concentrations occur at high wind speed (20-25 mph) from N and SE directions. Likewise, during southwest monsoon high PM_{10} level occur at 30 mph high wind speed from S and SW, while in second inter-monsoon high pollution level is experiencing at 20mph wind speed from E. These plots reveal that cross boundary pollution or stack emissions are present rather than the non-buoyant ground-level sources in Colombo. Potential sources in this area

could be vehicular emission, thermal power plant, waste combustion and industrial emissions.

4 Conclusion

Behavior of PM_{10} over Colombo throughout the year from January –December 2022, impact of meteorological parameters on PM_{10} and the potential source regions responsible for high PM_{10} concentration are analyzed in this study. Daily, monthly and seasonal variations reveal that high PM_{10} level is experiencing during Jan, Nov and Dec months (Northeast monsoon). From May – July (Southwest monsoon), Colombo is experiencing the lowest PM_{10} concentrations. This seasonal trend could be caused by the meteorological parameters as during northeast monsoon Colombo is facing low rainfall, low temperature and low wind speed while Colombo is experiencing highest rainfall, wind speed and temperature during southwest monsoon. CBPF plots indicate that cross boundary or stack emissions are happening in Colombo rather than ground level emissions. Vehicular emission, thermal power plant, waste combustion and industrial emissions could be the potential sources in the study area. This evidence from the study can be utilized for further air quality and exposure measurement for serving as a platform for further researches, eventually leading to environmental policy, health plan review, and population welfare plans not only in Colombo but also in all over Sri Lanka.

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