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Determination of Particulate Matter (PM) Concentration Levels Generated During Sporting Activities in Bare and Grass Fields, and the Effects of Some Atmospheric Parameters

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Abstract
This study focused on the determination of concentration levels of particulate matter (PM) generated during sporting activities in bare and grass fields, and the effects of wind, relative humidity, and temperature on emission of particulate matter. Ten bare fields (F_B) and ten grass fields (F_G) were selected for the study. The study utilized particulate matter monitor, digital anemometer, geographical positioning system (GPS) and measuring tape to determine PM concentration, atmospheric variables (wind speed, relative humidity, temperature), geographical coordinates, and breathable height respectively of the selected fields on a daily basis for a period of three weeks. The findings revealed that the PM concentrations were significantly higher in bare fields, with $PM_{1.0}$ ranging from 2.8 to 7.2 µg/m³, $PM_{2.5}$ from 7.2 to 49.1 µg/m³, and PM_{10} from 29.3 to 158.7 µg/m³. In contrast, grass fields showed lower PM levels with $PM_{1.0}$ ranging from 1.1 to 4.1 µg/m³, $PM_{2.5}$ from 3.1 to 24.1 µg/m³, and PM_{10} from 10.8 to 74.8 µg/m³, suggesting that grass acts as a natural barrier to the escape of PM. Correlation analysis indicated strong interrelationships among PM fractions but weak correlations with atmospheric variables such as wind speed, temperature, and relative humidity. PM concentration of the selected bare fields namely, FB_5 and FB_7 exceeded the World Health Organisation (WHO) air quality guidelines of 25 µg/m³ for $PM_{2.5}$ and 50 µg/m³ for PM_{10} for the period under study, which are capable of aggravating serious health problems such as asthmatic attack, chronic bronchitis, ischemia, heart diseases, and other respiratory issues. Hence, the need for grass cover implementation and routine PM monitoring, especially during sporting activities.

Keywords: *Particulate Matter (PM), Concentration Levels, Atmospheric Parameters*

Introduction

Air pollution is a serious environmental problem as it poses serious danger to human health worldwide, especially in metropolitan regions where human activities have a substantial effect on air quality. Within the city of Port Harcourt, the rising population density and diverse human activities are factors that lead to the decline of air quality, thereby presenting significant health hazards to the inhabitants of the city. A substantial proportion of atmospheric particulate matter consists of carbonaceous particles, which encompass a diverse array of chemicals. Depending on the source, the carbonaceous component is expected to contribute 20-50% of the $PM_{2.5}$ mass fraction in urban and rural regions, and 70% of the PM mass fraction (Querol et al., 2009).

An often disregarded cause of particulate matter (PM) contamination is the dust produced during football games on unpaved athletic grounds. According to Koren & Bisesi (2003), the National Centre for Environmental Health (NCEH) (2016), and Tiwary & Colls (2010), particulate matter (PM) or aerosol pollutants can be solid or liquid droplets and are most often observed as dust, dirt, soot, smoke, or liquid drops. These tiny particles can be profoundly inhaled into the lungs, resulting in respiratory and cardiovascular damage. Considering the widespread popularity of football as a sport and the regular usage of fields by people of all age groups, this omission is worrisome as it may expose a significant number of people to detrimental amounts of particulate matter (PM). Insufficient grass cover on bare fields worsens this problem, as there is no vegetation to collect the dust and particles produced during intense sporting activities. Thus, both players and spectators have an increased likelihood of breathing these contaminants, which can result in both immediate and long-term health consequences. According to WHO (2005), optimal air quality is an essential prerequisite for the physical and mental well-being of humans. Research has demonstrated that particulate matter, particularly $PM_{2.5}$ and PM_{10}, is a health hazard and can trigger a higher rate of hospital admissions (Cifuentes et al., 2001; Giri et al., 2006; Hopke 2009).

The particulate matter (PM) load in a given region comprises both direct emissions from natural and human activities, as well as indirect emissions from secondary PM sources, such as those generated from gaseous precursors (Ngele & Onwu, 2014). The concentration and makeup of particulate matter (PM) differ depending on the geographical location, human and natural activities, terrain, climatic conditions, and atmospheric properties of the area (Weli & Kobah, 2014). The presence of heavy metals, dioxins, and similar substances has a harmful impact as they accumulate in tissue and disrupt the normal cellular function (Thakur & Pathania, 2020). Presence of PM diminishes vision, impacts precipitation, leads to fog formation, impairs the beauty of buildings and sculptures, and lowers agricultural output by blocking stomata openings (Enotoriuwa et al., 2016). Shindell and Faluvegi (2009), also posited black carbon particle deposition has worsened Arctic warming and added to feedback loops that make the climate system there even more unstable. Song et al. (2017), opined that particulate matter pollution, namely $PM_{2.5}$, is one of the leading causes of premature deaths and disability-adjusted life years (DALYs) on a worldwide scale. One example is China, where 1.3 billion people are subjected to $PM_{2.5}$ levels that are above the Air Quality Guidelines (AQG) set by the World Health Organization (Song et al., 2017). Results of a study conducted by Robert et al. (2023) showed that data from hospitals before and during construction activities revealed that $PM_{2.5}$ and PM_{10} emitted from construction sites have substantial effects on human health, specifically in terms of the number of hospital admissions related to respiratory diseases during the study period. The World Health organization (WHO) estimates that outdoor air pollution causes 3.7 million premature deaths per year, surpassing the combined mortality rates of Human Immunodeficiency Virus (HIV), malaria, and Tuberculosis (TB) (WHO, 2015). Inhaling particulate matter (PM) at high levels is harmful to humans because it can build up in the lungs and some particle compositions have been defined as carcinogenic (Enotoriuwa et al., 2016). The health risks associated with particulate matter have prompted several nations to establish ambient air quality baselines and contextual regulatory levels (Wu et al., 2017; Tong et al., 2019). Because of the health hazards it poses to putative receptors, $PM_{2.5}$ is given considerable attention, especially in locations where industrial activities, such as gas flaring, are significant. One example is the correlation between respiratory problems and air pollution; studies have shown that these underlying conditions make people more susceptible to the devastating coronavirus (COVID-19) (AlBarrak et al., 2012; Munster et al., 2020; Maduka & Tobin-West, 2017). According to Revich & Shaposhnikov (2010), Hamad et al. (2015), Kakooei & Kakooei (2007), and Talbi et al. (2018), countries like Russia, Nigeria, Iran, Iraq, and Saudi Arabia that are at the top of the gas-flaring chart must take adequate measures to protect their citizens from exposure to all types of particulate matter.

Influence of Atmospheric Variables on Air Pollution

Oyem and Igbafe (2010) posited that understanding the physical processes that cause pollutants to gather at a certain spot is a useful skill for figuring out how pollutants at the ground level are spreading at any given time. For example, Ede (2007) noted that the direction of the wind decides the path that the pollution will take across the land. How fast the wind blows affects both the rise in emissions and the rate of dilution. Most of the time, the most important factor that affects how much air pollution is diluted is how turbulent the air is (Davis & Cornwell, 1998). Air near the earth's surface moves around because of turbulence in the atmosphere, which is a random change in wind speed (Azeez, 2002).The wind speed as reported by Edokpa (2018), in the lower atmosphere over Port Harcourt's top layer is modest, with most of it being between 0 and 3m/s.

Relative Humidity

Elevated relative humidity can result in hygroscopic growth, a process in which particles absorb moisture and undergo size extension. These processes can influence the concentration, content, and health effects of particulate matter (Kakavas & Pandis, 2021). Higher relative humidity has been identified as a contributory factor to the size of $PM_{2.5}$ and as well, resulting in their fallout and subsequently reducing their concentration levels in the air (Wang & Ogawa, 2015). Cheng et al. (2008) pointed out that elevated humidity levels can result in the generation of secondary organic aerosols (SOAs), which in turn contribute to elevated $PM_{2.5}$ concentrations. During the monsoon season in South Asia, the combination of high humidity levels and higher emissions from human activities can result in widespread outbreaks of severe air pollution (Gautam et al., 2020). The combination of relative humidity (RH) and temperature can have a synergistic impact on particulate matter (PM) levels. Research conducted by Li et al. (2016) emphasizes the significance of using both environmental parameters in air quality models to precisely forecast particulate matter levels and their effects on human health. Studies have extensively established the health consequences of exposure to particulate matter (PM), establishing a strong correlation between elevated PM levels and respiratory and cardiovascular disorders (Pope & Dockery, 2006). The toxicity and health effects of PM can be influenced by relative ambient dampness. Specifically, elevated levels of humidity can result in the production of secondary contaminants, such as sulphates and nitrates, which can intensify the detrimental impacts of particulate matter (Seinfeld & Pandis, 2016). Given the usually high relative humidity in Port Harcourt City, the combined impact of particulate matter (PM) and secondary pollutants can provide substantial health hazards to people, especially those participating in outdoor activities on football fields. Abulude et al. (2021) study in Lagos, Nigeria, offers more understanding of the correlation between particulate matter (PM), relative humidity, and health hazards.

Temperature and Particulate Matter

The dynamics of particulate matter are extensively influenced by temperature. Elevated temperatures can accelerate the evolution of secondary organic aerosols (SOAs) derived from volatile organic compounds (VOCs), and thus leading to elevated levels of particulate matter (PM) (Zhang et al., 2019). Seiyaboh et al. (2019) study of particulate matter concentration at several football fields in Port Harcourt Metropolis, the results of the study showed substantial disparities in particulate matter (PM) levels among the selected locations, with PM_{10} values varying from 65.48 to 90.82 µg/m³, and the control station consistently recorded the lowest PM values, indicating the impact of local activities and environmental variables, such as temperature. Seinfeld and Pandis (2016), also revealed that elevated temperatures can accelerate the process of semi-volatile chemicals evaporating off the surfaces of particles, thereby modifying the content and health effects of particulate matter. Given Port Harcourt's tropical environment, which often leads to quite high temperatures, this phenomenon can greatly impact the amounts of particulate matter (PM) at outdoor areas like football fields.

Materials and Method

Area of Study

Port Harcourt is one of the coastal cities in Nigeria's Niger Delta Region and has geographical coordinates of 4°46' 430'' N, 7°1' 20'' E. It is the state capital of Rivers State. Port Harcourt is located 16 meters above sea level. The City's topography is generally flat and extends over 369 kilometers per square (km^2). The city's annual mean temperature and rainfall are 26.0 ^oC and 2708 2708 mm respectively. The driest month is January with 36 mm rainfall, while the coldest and warmest months are August, and February with mean temperatures of 25.2 °C and 27.6 °C respectively (Climate–Data.org). Port Harcourt is host to Oil and gas companies and other manufacturing establishments (Ngene et al., 2015).

The latest population projection of Port Harcourt in 2024 by the UN World Urbanization Prospects is 3,636,547 (https://worldpopulationreview.com/ cities/nigeria/port-harcourt#).

Materials

The following materials were employed in the study; Particulate matter monitor with digital thermometer and hydrometer, Digital anemometer, Global Positioning System (GPS), and Measuring Tape.

Method

This was carried out in some selected football fields within Port Harcourt Metropolis. This study was conducted in some selected football fields within Port Harcourt metropolis.

Ten (10) grass and ten (10) bare fields were selected for the study. The sampling locations include: Rumuola, Rumuokoro, Rumuosi, Rumuigbo, Rumuodara, Iwofe, Eliozu, Nkpor village, Woji, Nkpolu-Oroworukwo, Uzoba, and Choba. At each of these locations, a calibrated PM monitor was positioned at breathable height (1.5m) with the help of measuring tape above each of the selected fields to determine the concentration levels of $PM_{1.0}$, $PM_{2.5}$, PM_{10} respectively. Atmospheric variables (wind speed, relative humidity and temperature) of the selected fields were also determined. The geographical positions of the sampling locations were recorded using GPS. This was done for a period of three (3) weeks.

The PM monitor was placed at a breathable weight of 1.5m above each of the chosen fields at each of these sites. Furthermore, the atmospheric parameters (namely wind speed, relative humidity, and temperature) of the chosen fields were also determined. The geographical positions of the sampling locations were recorded using a GPS instrument.

Results and Discussion

Results

Table 1: Geographical Coordinate of the Selected Bare fields

Bare Football Field	
F_{B1}	Government Girls Secondary School, Rumuola 4º 50' 21.3"N 6º 59' 02.7"E
F_{B2}	Rukpokwu – Maga Field 4º 54'10.4724"N 6º 0' 4.5468"E
F_{B3}	Elechi Amadi Polytechnic, Rumuola 4º 50' 12.6"N 6º 59'43.8"E
F_{B4}	UPTH 4º 53'58"N 6º 55' 43" E
F_{B5}	FGC, Port Harcourt 4º 86' 21" N, 6º.99'04" E
F_{B6}	RSU, Nkoplu 4º 47'47.6"N, 6º 58' 42.1"E
F_{B7}	IAUE, Rumuolumeni 4º 48'18.8"N, 6º 55'52.0"E
F_{B8}	Rumuosi 4º 53'5"N, 6º 55'36"E
F_{B9}	RSU 4º 48'18.50"N, 6º 58'39.12"E
F_{B10}	Uniport 4º 54'24.8"N, 6º 54'53.3"E

Table 2: Geographical Coordinate of the Selected Grass fields

Grass Football Field	
F_{G1}	Holy Cross International, Iwofe 4º 48' 61" N, 6º 02' 16.08" E
F_{G2}	ABC Bus Park, Eliozu 4º 51' 35.64" N, 6º 01' 18.12" E
F_{G3}	Kina Education Centre 4º 49' 5.88" N, 6º 03' 23.76" E
F_{G4}	Chiovin Int'l School 4º 48' 33.84" N, 6º 95' 6.00" E
F_{G5}	Regeneration school, Rukpoku 4º 53' 38.04" N, 6º 00' 23.40" E
F_{G6}	Funtouch Kiddies Int'l School 4º 52' 28.92" N, 6º 00'13.32" E

F_{G7}	Rumuodara 4^{o} 51' 48.24" N, 6^{o} 00' 11.52" E
F_{G8}	The Citadel School 4^{o} 53' 38.04" N, 6^{o} 00' 3.60" E
F_{G9}	Haruk Group of Schools 4^{o} 51'18.00" N, 6^{o} 59' 7.44" E
F_{G10}	Ever glittering star school, NTA 4^{o} 51' 33.84" N, 6^{o} 58' 3.00" E

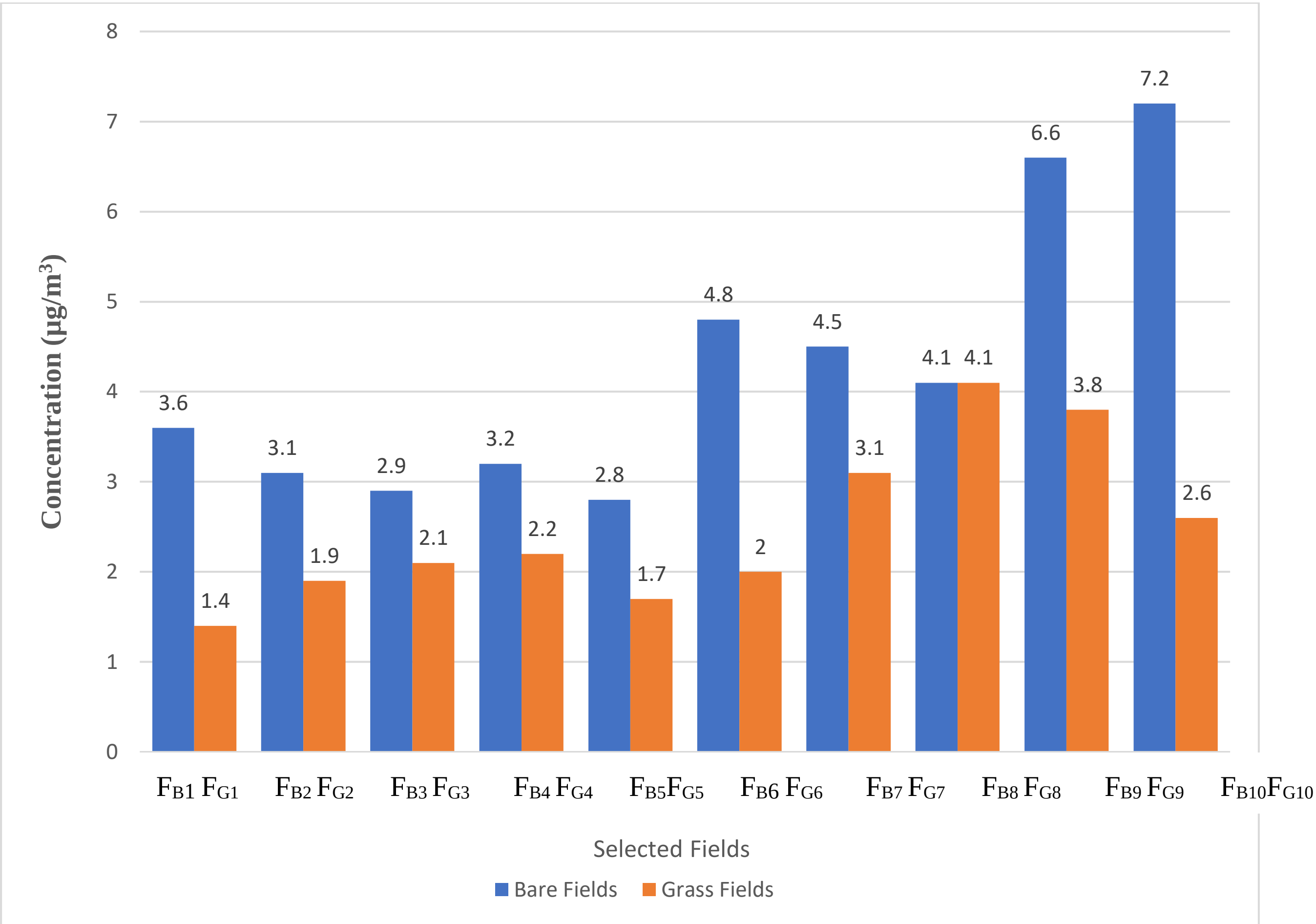

Figure 1: Concentrations of $PM_{1.0}$ in the Selected Bare and Grass Football Fields

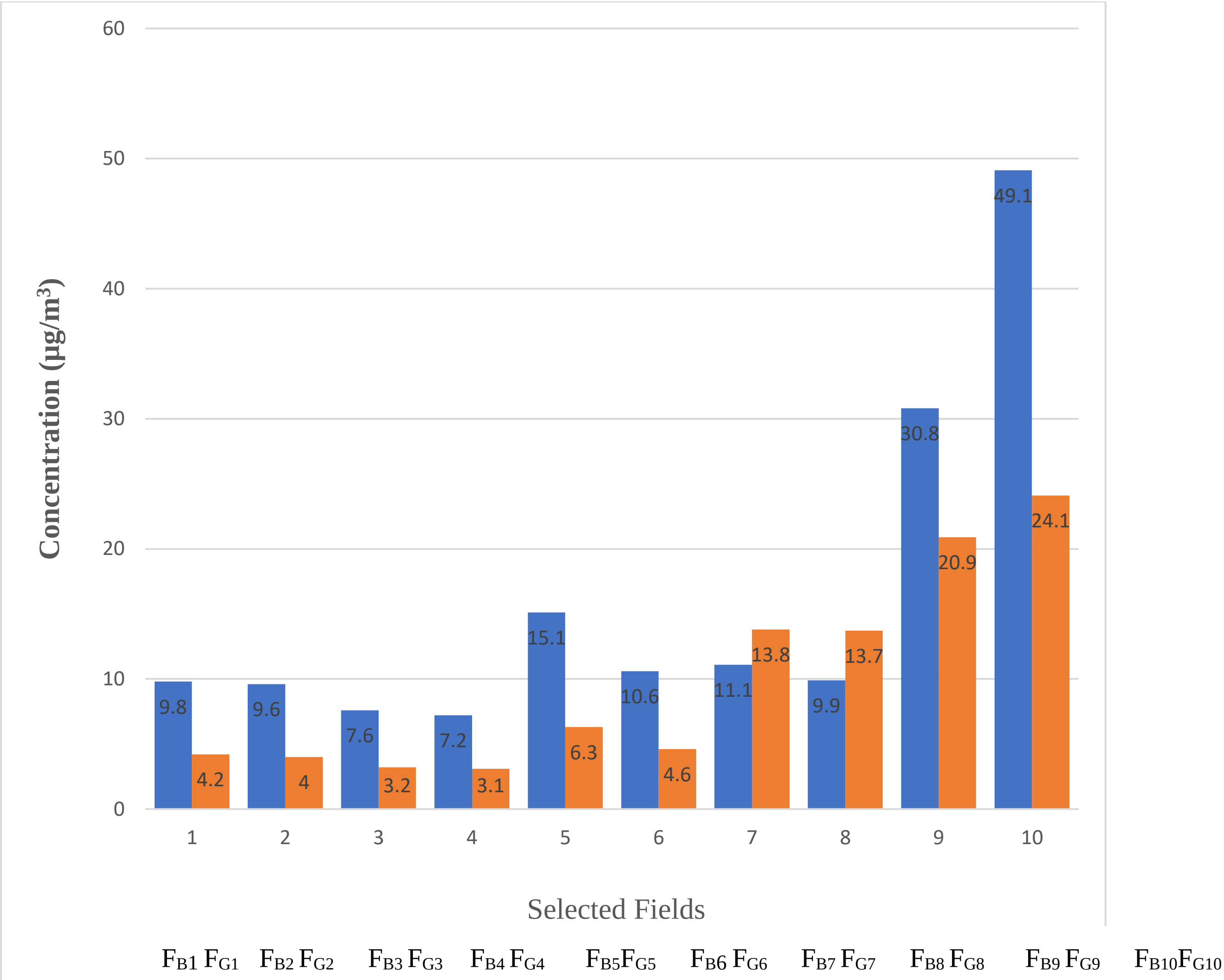

Figure 2: Concentrations $PM_{2.5}$ in the Selected Bare and Grass Football Fields

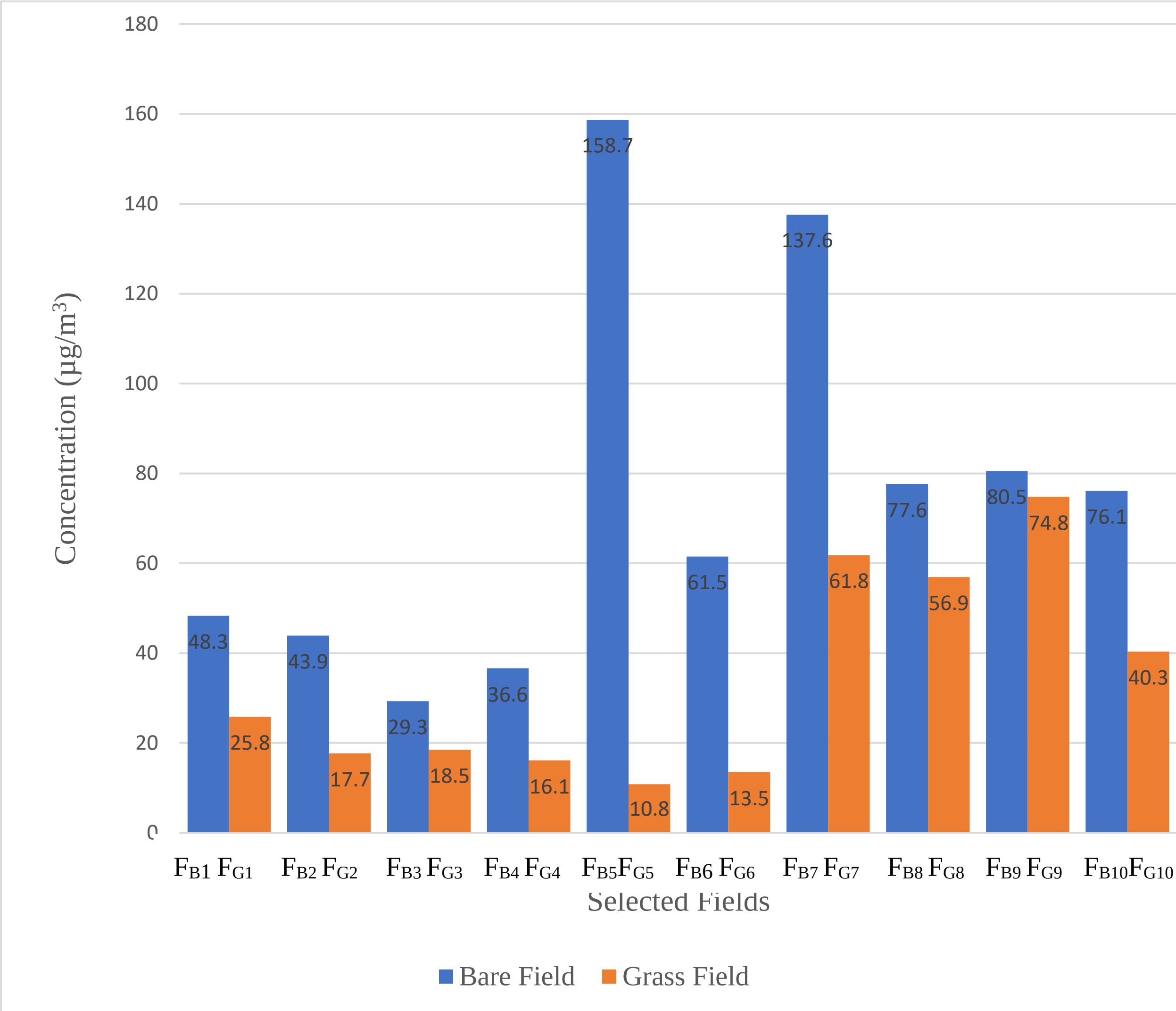

Figure 3: Concentrations of PM_{10} in the Selected Bare and Grass Football Fields

Discussion

Analysis of the data shows notable variations in particulate matter (PM) levels between bare and grass football fields. Concentrations of $PM_{1.0}$ in the bare fields vary between 2.8 and 7.2 µg/m³, $PM_{2.5}$ between 7.2 and 49.1 µg/m³, and PM_{10} between 29.3 and 158.7 µg/m³. These values indicate a wide variability in particulate matter levels, with some fields showing remarkably high concentrations. For example, FB_{10} has a $PM_{2.5}$ value of 49.1 µg/m³, which is notably high, and thus raises serious concerns for air quality. The increased levels of particulate matter (PM) in plain fields can be attributed to the absence of vegetation, which allows dust and other particulate matter to be easily stirred up and remained airborne, particularly during sporting activities.

By comparison, the grass fields exhibit much reduced levels of particulate matter (PM) concentrations: $PM_{1.0}$ varies between 1.4 and 4.1 µg/m³, $PM_{2.5}$ varies between 3.1 and 24.1 µg/m³, and PM_{10} varies between 10.8 and 74.8 µg/m³. The reduced levels of particulate matter in areas with grass provide evidence that grass cover functions as an inherent filter, effectively capturing dust and particles, therefore diminishing their concentration in the atmosphere. This disparity emphasises the efficacy of grass in reducing air pollution and spotlights the possible health advantages of preserving football pitches covered with grass. Although certain grassed fields, such as FG_{10} with a $PM_{2.5}$ level of 24.1µg/m³, come close to the World Health Organization's 24-hour mean recommendation, they often stay within safer thresholds compared to the bare fields.

Atmospheric Variables

The study also documents wind speed, temperature, and relative humidity statistics for each field, therefore offering a framework for comprehending the dynamics of particulate matter. The wind velocities in both types of fields are somewhat comparable, falling between 0.5 and 0.9 m/s. The temperature exhibits a very modest fluctuation, spanning from 28.1°C to 35.0°C, while the relative humidity varies between 57.0% and 84.7%.

Notwithstanding these atmospheric considerations, the main determinant of PM levels seems to be the existence or nonexistence of vegetation. The limited association between concentrations of particulate matter and meteorological parameters such as wind speed, temperature, and humidity implies that the influence of local ground cover (grass) on PM levels is more substantial than these atmospheric variables.

$PM_{1.0}$ Correlations: The Spearman correlation analysis indicates that there are substantial associations between $PM_{1.0}$ values and other component fractions of particulate matter. Specifically, there is a significant positive association between $PM_{1.0}$ and $PM_{2.5}$ ($\rho = 0.710$, $p < 0.01$) as well as PM_{10} ($\rho = 0.785$, $p < 0.01$). This observation suggests that there is a constant correlation between increased concentrations of $PM_{1.0}$ and greater levels of both finer ($PM_{2.5}$) and coarser (PM_{10}) fractionate matter. Nevertheless, the associations between $PM_{1.0}$ and environmental variables such as wind speed, temperature, and relative humidity are minimal and lack statistical significance. This implies that although $PM_{1.0}$ is strongly connected to other fractions of particulate matter, its connection with these atmospheric conditions on the football fields is minimal.

$PM_{2.5}$ Correlations: The investigation reveals significant correlations between $PM_{2.5}$ levels and other atmospheric indices. $PM_{2.5}$ has significant positive associations with $PM_{1.0}$ ($\rho = 0.710$, $p < 0.01$) and PM_{10} ($\rho = 0.811$, $p < 0.01$), suggesting that higher levels of $PM_{2.5}$ are followed by simultaneous increases in both finer and denser particles. Furthermore, there is a modest positive association between $PM_{2.5}$ and wind speed ($\rho = 0.551$, $p < 0.05$), indicating that increased wind speeds might influence the dispersion or increase of $PM_{2.5}$ levels. Nevertheless, the associations between $PM_{2.5}$ and temperature or relative humidity are feeble and lack statistical significance, suggesting that these climatic factors have relatively little influence on $PM_{2.5}$ levels in the football pitch setting.

PM_{10} Correlations: The Spearman correlation statistical analysis reveals statistically significant relationships between PM_{10} levels and certain atmospheric parameters. PM_{10} has significant positive associations with both $PM_{1.0}$ ($\rho = 0.785$, $p < 0.01$) and $PM_{2.5}$ ($\rho = 0.811$, p

< 0.01), indicating that higher levels of PM_{10} are followed by simultaneous increases in proportions of finer particulate matter. Moreover, there is a modest significant positive relationship between PM_{10} and wind speed ($\rho = 0.417$, $p > 0.05$), suggesting that wind may affect the distribution of PM_{10}. Nevertheless, like the other fractions of particulate matter, the associations between PM_{10} and temperature or relative humidity are feeble and devoid of statistical significance. This highlights the restricted impact of these meteorological factors on PM_{10} levels in the football pitch setting. In the selected football fields, the Spearman correlation analysis shows robust interrelationships among the various fractions of particulate matter ($PM_{1.0}$, $PM_{2.5}$, and PM_{10}). This suggests that increases in one form of particulate matter are linked to increases in the others. Nevertheless, the established relationships between levels of particulate matter and meteorological factors such as wind speed, temperature, and relative humidity are generally weak and lack statistical significance. This observation implies that although there is a strong correlation between levels of particulate matter, they are less influenced by measured atmospheric conditions in this specific environment.

Conclusion

The selected grass football fields have markedly reduced the levels of particulate matter (PM) concentration in comparison to the bare fields. The increased levels of $PM_{1.0}$, $PM_{2.5}$, and PM_{10} in the selected bare fields are mostly caused by lack of grass cover, which facilitates the easy agitation and airborne dispersion of dust and other particles, particularly during football activities. Comparing the observed PM levels with the WHO air quality guidelines highlights several areas of concern. The WHO's 24-hour mean guideline for $PM_{2.5}$ is 25 µg/m³ and for PM_{10} is 50 µg/m³. Many bare fields exceeded these guidelines. These results reveal the intricate nature of particulate matter dynamics and emphasise the importance of implementing specific approaches to control air quality in such environments.

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