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Research Paper

Spatial and Temporal Variations in the Concentrations of Particulate Matter in Ambient Air from Three Different Locations in River State, Nigeria

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Abstract—This research study was conducted due to growing industrial activities and the associated consequences around the study areas to evaluate the temporal and spatial variations (changes) in the concentrations of particulate matter in ambient air from Eleme,Aluu and Ikoku in Rivers state, Nigeria. The duration of this study lasted from April, 2021through January, 2022 which covered both dry and wet seasons. Particulate matters in ambient air were collected from these three different locations using air sampler (Mini volair sampler) as directed by(APHA). During the dry season, mean concentrations of Eleme was reported to be 40 ±10 µg/m^3 and 60 ±026 µg/m^3 for $PM_{2.5}$ andPM_{10} respectively. Ikoku was reported to be 30 ±01 µg/m_3 and 64 ± 024 µg/m^3. While Aluuhad mean concentrations of 50 ±10 µg/m3 and 60 ±116 µg/m3. The result showed thatIkoku had the highest mean concentration of particulate matter. During the raining (wet) season, Eleme had a mean concentration of 27 ±16 µg/m^3 and 37 ±30 µg/m3 for $PM_{2.5}$ and PM_{10}respectively. The mean concentrations of Ikoku were reported to be 23 ±08 µg/m^3 and 35±14 µg/m^3. Aluu was reported to be 13 ± 06 µg/m^3 and 13 ± 06 µg/m3. Analyzed results clearly showed that the particulate matter concentration in the atmospheric region of the studied locations during the wet season, are above the WHO permissible limit for $PM_{2.5}$ (12 µg/m^3)and below the WHO permissible limit for PM_{10} (45 µg/m^3 for PM_{10}). The results of this research are clear indication that the ambient air within the study areas is quite polluted. Judging from the concentrations of PM recorded, it is recommended that the industries operating within the studied areas should be adequately monitored and control by established regulatory agencies to curtail and minimize further emission of these substances into the atmosphere, in order to make Port Harcourt a livable city for people.

Keywords— Particulate matter, Eleme, Ikoku, Aluu, Samples, WHO.

1. Introduction

The term "particulate matter" refers to any potentially harmful gas, liquids or solids that are in suspension in the air [1]. Smoke, soot, pollen, liquid droplet, dust, aerosol, fumes, dirt, and ashes are just few of the inorganic and organic particles that make up this brew[2]. The origins, materials, and sizes of these objects are quite diverse. Particulate matter in the atmosphere may be released either directly (as when fuel is burned and dust is blown about by the wind) or indirectly (through the action of other processes)[3]. Whether or whether these particles are eliminated from the air depends on their aerodynamic properties [4]. Their ability to enter the airways of human respiratory organs is also attributable to their aerodynamic features [5].

One of the most pressing issues in environmental science right now is particle pollution. Particulate matter in the atmosphere causes air pollution, which has serious ramifications for materials and the health of animals and people worldwide[6]. Particulate matter in the atmosphere often carries nitrates, sulfates, furans, dioxins, polycyclic aromatic hydrocarbons, and heavy metals [7],[8]. Particulate matter in the atmosphere is a collective term for solid-liquid particles that float about in the air on their own. In most cases, it is being released by a diverse set of sources that may modify its size distribution, chemical composition, and physical attributes (density, surface area, and size) [9],[10].Particulate matter contributes significantly to both climate change and the toxicity of indoor air. Particulate matter in the high atmosphere acts as a reaction center (reservoir) for air pollutants, influences cloud patterns, and modifies the Earth's radiation budget [11]. Particles in the atmosphere's lower levels are modifying and changing visibility. Particulate matter in the lower 9 atmosphere also affects meteorology and biogeochemical cycles [12],

[13].Major sources of atmospheric particulate matter include carbon compounds, sulphur compounds, the combustion of biomass, and nitrogen compounds [14]. Particles less than 2.5 m in diameter are always emitted when biomass is burned. In this way, the primary feature of particulate matter is totally dependent on the meteorological conditions of that geographical location, the origin, and the sources [15]. Distinctive sources of particulate matter often create 14 particles that have varied emission factors but with specific properties [16]. Biomass combustion releases particulate matter, the majority of which is made up of inorganic elements and compounds of carbon (i.e Volatile organic compounds, black carbon polycyclic aromatic hydrocarbons).

Exactly 50.1% to 70.1% of all PM emissions are made up of mainly organic carbon and black carbon. The ratio of organic carbon to black carbon in biomass burning varies from 12:1 to 8:1; this, of course, is highly dependent on the burning stage [17]. Calcium, chloride, and potassium are examples of inorganic elements that account for around 10.1% of the particulate matter emission [18], [19], [20].Particulate matter is majorly of four basic classifications, which are; Total Suspended Particulates (TSPs), Particulate matter (10) (PM10), Ultrafine Particulate matter (UPM) and Particulate matter (2.5) (PM2.5) [21], [22].The Total suspended particulates (TSPs) is the first classification of particulate matter and they constitute an aerodynamic diameter of less than 30 microns (µm) [23].The Particulate matter (10) (PM10),particles in this category are less than 10 m. The Particles are in the range of 2.5 m to 10 m in size are found in this coarse fraction [24].They are created when huge solid particles are mechanically broken up and may be inhaled by people [25]. Coarse particles include debris from plants and insects, mold spores and pollen grains, and dust from mining, exposed soil, agricultural activities, and highways [26]. Evaporation from the sea spray may also create bigger particles that can be found in coastal areas [27], [28]. Particulate matter (2.5) (PM2.5), for this category, the aerodynamic diameter is smaller than 2.5 m. It has been hypothesized that these particles are quite small [29]. Particles less than 2.5 m in size are found in this tiny particle fraction [30]. It has been suggested that these particles may be inhale [30. Atmospheric gases are a common source for the formation of fine particles [31]. Particles in the air typically range in size from 0.1 m to 2.5 m, with the majority being made of the smaller particles [32], [33].Ultrafine particulate matters (UPM),there are a subset of particles whose aerodynamic diameter is smaller than 0.1 microns [34]. Although ultrafine particles make up over 90.1% of the particle counts, they still account for a small percentage of the overall particulate matter mass [35].Particulate matter discharged into the atmosphere often has physical qualities that are impacted by the diversity of their sources. Mass, volume, and area are the three characteristics in question. Particles may be broken down into two categories based on how they were created: secondary particles and primary particles. First, there is primary particulate matter, which consists of particles that are released directly into the air, and secondary particulate matter, which consists of particles created following chemical transformation of the original gaseous molecule discharged into the environment [36].
Particles may range in size from nanometers to micrometers. Three distinct modes of typical particle size (Figure 1) exist, each with its own unique generational processes. The following are some of them: Nucleation mode, accumulation mode and coarse mode [37]. Particles with equivalent diameters typically below 0.1 m are involved in the nucleation mode, also called the ultrafine particle mode. These particles are generated both by the homogeneous nucleation of the precursor gas and by combustion processes [38]. Particle coagulation in the nucleation mode and gaseous species condensation on the surfaces of already-formed particles both contribute to the accumulation mode, which consists of particles with sizes between 1.0 and 0.1 m. [39]. Particles generated by mechanical processes, such as earth and ocean surface erosion, belong to the coarse mode (sea spray).

Typically, particles with a coarse mode have a higher mass density than those with an ultrafine mode. Although primary particles tend to dominate the coarse mode, secondary particles created by gas chemical modification (possessing crustal particles or marine origin) may also be detected in this mode [40].

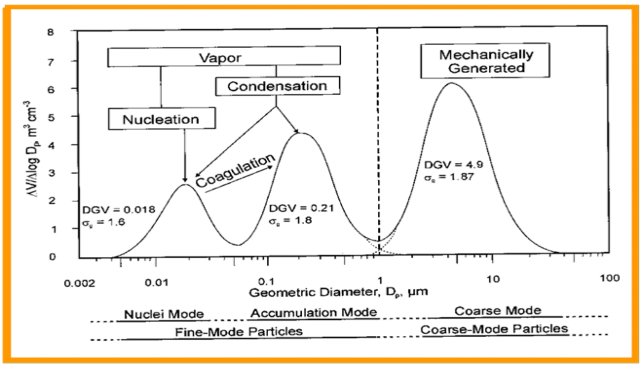

Figure 1. Typical size distribution of atmospheric particles

The two most common origins of PM are human activities and the natural environment. Fragments of animals and plants, fungi spores, bacteria, pollens, dust from deserts and grasslands on fire, sea spray, and ash from volcanoes are all common sources of naturally occurring particulate matter [41]. Industrial processes, power plant use, home heating, fossil fuel consumption in vehicles, household fuels, fugitive dust, unprocessed biomass fuel (such as wood), smokes, animal husbandry, and bush fires are all examples of human activities that can contribute to the formation of anthropogenic particles [42].Particulate matter, also known as atmospheric aerosol particles, may originate from either natural or manmade sources, and can be either directly discharged into the atmosphere (that is, as primary particles) or generated in the atmosphere (that is, as secondary particles) via a variety of different processes (that is, by transformation of emitted precursor gases) [43].Particulate matter is made up of tiny liquid and solid droplets that may offer significant health risks if inhaled. Inhaling particles with a diameter of less than 10 m may have serious effect/consequences for human health, including lung damage and even death. Asthma, lung illnesses, and cardiovascular problems may be brought on by exposure to fine particulate matter, which is especially dangerous for young children and the elderly [44]. Damages to plants, corrosion, poor sight, disruption of atmospheric chemistry, radiation balance distortion due to absorption and scattering of solar radiation, and so on are all possible outcomes of particulate matter. Negative effects on aquatic creatures may also result from changes in cloud droplet production, sulphuric acid depositions, soil acidifications, increased nitrates deposition, and enhanced eutrophication [45].

From my findings, many of the above said research on particulate matter were not carried out in this study area. As a result it is very important and necessary to carry out a thorough research using a well known develop, efficient, simpler and friendly method for this study to evaluate all these PM, and also find solution to all these problems. In this article, the goal of this study was to investigate the spatial and temporal variations in the concentrations of particulate matter (PM) in ambient air in Eleme, Aluu and Ikoku in Rivers State, Nigeria and probably offered solutions to those problems.

2. Related Work

Over the years, many researchers have made significant efforts to evaluate the effects of particulate matter in air. Air-borne Particulate Matter and Human Health were examined by [46]. According to the findings, there is a large temporal and spatial variability in the composition and size of PM. They revealed that, despite the variation in particulate matter properties that are thought to impact human health risks, certain observed relative health risk estimations per unit PM mass fell within a small range of values. Climate, air quality, and particle pollution were all investigated by [47]. According to their findings, the number of articles published each year on particulate matter ,PM, and/or atmospheric aerosol has climbed dramatically over the last 20 years, and is presently between 1500 and 2000.The Particulate Matter Emission Factors of Common Pyrotechnic Articles were calculated by [48]. Emissions of TSP, PM10, and PM2.5 from pyrotechnic items were discussed, along with methods for measuring them.

3. Experimental Method

3.1. Study Areas

The primary emphasis of this investigation was on three distinct regions. Eleme, Ikoku, and Aluu were all notable for their respective sets of economic and industrial pursuits.Elemeis famous across Rivers State, Nigeria, Eleme is one of the state capital's local governments. It's one of the municipalities where several firms are mentioned. There are 138 square kilometers of land there. Eleme may be found at coordinates 4.7994° N and 7.1198° E [49]. Two of Nigeria's refineries and a petrochemical business (INDORAMA) are located at Eleme. Besides being very politically active in Rivers State, the people of Eleme are well-known for their agricultural prowess. Ikokuis One of the neighborhoods in the city of Port Harcourt. The coordinates of this location are 4.7996° N and 6.9926°E. In addition, Ikoku is home to a number of excellent auto repair businesses. Auto repair shops and spare-parts vendors thrive there [50].For Aluu. There are many people residing in Aluu, another city in Rivers State. About 141 square kilometers may be found there. The coordinates for Aluu are 4.9331° N and 6.9316°E.The map showing the different sampling locations and areas is shown in figure 2.

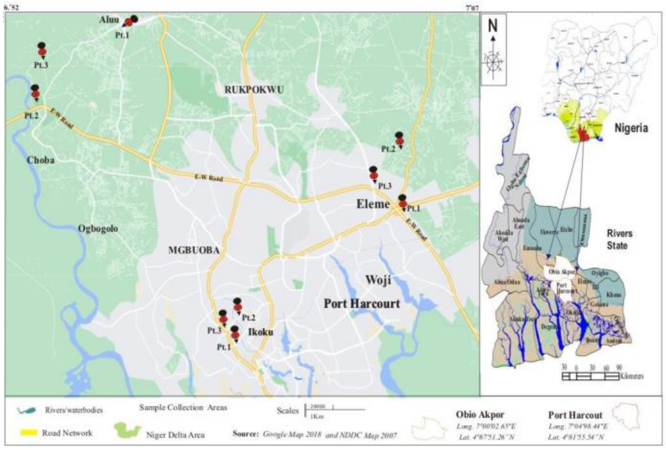

Figure 2. A map showing the different sampling areas and locations

3.2. Sample Collection

A random sampling technique was employed in collecting samples of air [51]. Samples were only collected in ambient air around markets, industries and motor parks. Smoke from cigarette and exhaust from moving vehicles and industries has proven to be main source of particulate matter. For each sampling location, three points were randomly selected. Sampling was carried out once in a month in the three locations for both dry (Nov -March, 2021) and Wet (April -Oct). For each sampling location three different points were selected which included schools, industries and markets. The equipment used for sampling was set up and operated as directed by USEPA . Particles of PM2.5(particulate matter with an aerodynamic diameter of 2.5 and below) and PM10(PM with aerodynamic diameter between 2.5-10um) were trapped with the aid of a glass micro fibre filter placed in the impact or path of a high volume pump to trapped P.M of different sizes, each of these micro fibres were renewed after three hours and the actual weight of the particulate matter deposited for both PM2.5 and PM10 was determined by subtracting the weight of the preweighed filters (Wbs) from the weight of filters after trapping samples (WTs), thereafter the weight were expressed in ug/m3 by multiplying the weight in gram by 10raised to power of 6(1000000) divided by 1000.

4. Results and Discussion

The analyzed results for the research from the three districts areas, that is, Eleme, Ikoku, and Aluu for dry and rainy seasons are presented in table 1 and figure 3.

Table 1. Mean concentratiosn of $PM_{2.5}$ and PM_{10}in the different location for dry and wet seasons

	$PM_{2.5}$		PM_{10}	
Location	Dry season **(μg/m^3)**	Wet season **(μg/m^3)**	Dry season **(μg/m^3)**	Wet season **(μg/m^3)**
Eleme	40±10^a	27±16^a	60±026^a	037±30^a
Ikoku	30±01^a	23±08^a	64±024^a	035±14^a
Aluu	50±10^b	13±06^a	60±116^a	013±06^a

Superscript letter 'a' mean not significantly different (p>0.05) in each location while different superscript letter 'b' means significantly different (p<0.05).

The mean results were obtained after the analysis that were carried out during the dry season and wet season. The three different locations under study are Eleme, Ikoku and Aluu. The three different locations all have their mean values to range from 13 ±06 μg/m3 to 60 ± 116 μg/m3. A difference was observed in the two different types of glass filter paper (2.5 μm and 10 μm) that were used for the analysis at the study location.

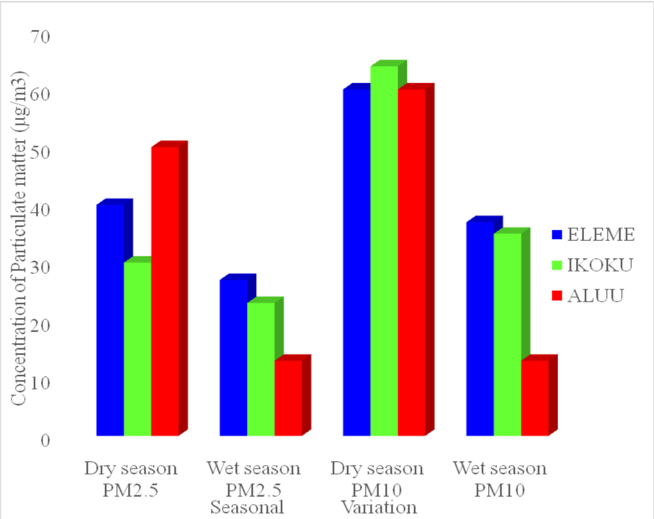

Figure 3. The graphical representation of the mean concentration of $PM_{2.5}$ and PM_{10} in the different location for dry and wet seasons

Particulate Matter Discussion for Dry Season

The results of the particulate matter for dry season are presented in table 1. The mean results were obtained after the analysis that were carried out during the dry season. The three different locations under study are Eleme, Ikoku and Aluu. The three different locations all have their mean values to range from 13 ±06 μg/m3 to 60 ± 116 μg/m3. A difference was observed in the two different types of glass filter paper (2.5 μm and 10 μm) that were used for the analysis at the study location.

Eleme location had mean concentration values of 40 ±10 μg/m3 and 60 ±026 μg/m3 for PM2.5 and PM10 respectively. The mean concentrations of Ikoku were found to be 30 ±01 μg/m3 and 64 ± 024 μg/m3 for PM2.5 and PM10 respectively. Aluu had mean concentrations of 50 ±10 μg/m3 and 60 ±116 μg/m3 for PM2.5 and PM10 respectively. The result showed that Aluu had the highest mean concentration of particulate matter for PM2.5. The results in figure 3 clearly showed that the particulate matter concentration in the atmospheric region at the Eleme location, Ikoku location and Aluu location which were analysed and reported during the dry season, are slightly above the hourly mean WHO limit of 15ug/m3 and 45ug/m3 for PM2.5 and PM10 respectively. The values obtained in table 1 are quite indications that particulate matter poses a little or no risk to humans dwelling in that region as the values are only above the hourly mean of WHO permissible limit (15 μg/m3 for PM2.5 and 45 μg/m3 for PM10). This observation could be attributed to the industrial processes and activities being carried out in in the study area. The vehicular movement, construction processes and other commercial activities been carried out in these locations are basically responsible for the introduction of several particulate matter into the atmosphere of those geographical locations.

It was also observed that concentration of PM10 were higher than PM2.5. This shows that the particulate matter in the air are of both smaller and larger particles which are detrimental to human health. Similar observations were reported by [51]. Table 1 showed that during the dry season that PM2.5 was significantly higher in Aluu than Eleme and Ikoku (p<.05) while in wet season, PM2.5 was not significantly difference between the three locations (p>0.05). For both dry and wet season, there were no significant difference in PM10 between Eleme, Ikoku and Aluu (p>0.05).

Figure 3, shows that the concentrations of particulate matter (PM2.5) obtained from Eleme, Ikoku, and Aluu, which range from 30 ±01 μg/m3 to 50 ± 10 μg/m3, are much lower and also disagree with the values of PM2.5 concentrations reported by [52] which were obtained from Omuanwa, Eleme, Oginigba and RumuOlumeni, which range from 143.8 μg/m3 – 156.7 μg/m3 , 149.9 μg/m3 – 182.3 μg/m3, 148.8 μg/m3 – 300.3 μg/m3 and 181.3 μg/m3 – 245.6 μg/m3 respectively. The concentrations values of this study are also in disagreement with the valuesobtained by Gupta et al. (2016) from India, Hong Kong, Australia, USA and Switzerland, which are 16.20 μg/m3, 22. 50 μg/m3 and 15.20 μg/m3.

The concentrations of particulate matter (PM10) obtained from Eleme, Ikoku, and Aluu, which range from 60 ±026 μg/m3 to 64 ± 024 μg/m3, are also lower and in complete disagreement with the values of the PM10 concentration reported by Akinfolarin et al. (2017) which were obtained from Omuanwa, Eleme, Oginigba and Rumu Olumeni, which range from 177.8 μg/m3 – 855.6 μg/m3 , 960.2 μg/m3 – 1154.4 μg/m3, 940.2 μg/m3 – 1399.8 μg/m3 and 236.0 μg/m3 – 1926.3 μg/m3 respectively. The values of the concentrations obtained from this study, are as well higher and in disagreement with the concentration values reported by [53], which were obtained from Arizona, Califorbia and Los Angeles, which are 39.70 µg/m3, 37.4 µg/m3 and 46.0 µg/m3 respectively.

Particulate Matter for Wet Season

The results of the particulate matter for wet season are presented in table 1 and figure 3. The mean results were obtained after the analysis that was carried out during the wet season. The three different locations under study are Eleme, Ikoku and Aluu. The three different location all have their mean values to range from 13 ± 06 µg/m3 to 37 ± 30 µg/m3. A difference was observed in the two different types of glass filter paper (2.5 µm and 10 µm) that were used for the analysis at the study location. Eleme location had mean concentration values of 27 ± 16 µg/m3 and 37 ± 30 µg/m3 for PM2.5 and PM10 respectively. The mean concentrations of Ikoku location was reported to be 23 ±08 µg/m3 and 35 ±14 µg/m3 for PM2.5 and PM10 respectively. Aluu had mean concentrations of 13 ± 06 µg/m3 and 13 ± 06 µg/m3 for PM2.5 and PM10 respectively. The results in figure 3 showed that Eleme had the highest mean concentration of particulate matter.

The results in table 1, clearly showed that the particulate matter concentration in the atmospheric region at the Eleme location, Ikoku location and Aluu location which were analysed and reported during the wet season, are above the hourly mean of WHO permissible limit for PM2.5 (15 µg/m3) and (45 µg/m3 for PM10). This observation could be attributed to the industrial processes and activities being carried out in in the study area. The vehicular movements, construction processes and other commercial activities been carried out in these locations are basically responsible for the introduction of several particulate matter into the atmosphere of those geographical locations.

The values obtained are quite indications that particulate matter is less dominant in the air during the wet season. It was also observed that concentration of PM10 were greater than PM2.5. This shows that the particulate matter in the air are of both smaller and larger particles which are detrimental to human health, as reported by World Health Organisation [WHO, 2021]

The figure 3 revealed that the spatial distribution of PM2.5 can be grouped into 2 distinct clusters with Eleme and Ikoku in cluster 1 and Aluu in cluster 2 which implies that Eleme and Ikoku have similar spatial distribution of PM2.5.

The concentrations of particulate matter (PM2.5) obtained from Eleme, Ikoku, and Aluu, which range from 13 ± 06 µg/m3 to 27 ± 16 µg/m3, are, are much lower and also disagree with the values of PM2.5 concentrations reported by [54] which were obtained from Omuanwa, Eleme, Oginigba and RumuOlumeni, which range from 143.8 µg/m^3 – 156.7 µg/m^3 , 149.9 µg/m^3 – 182.3 µg/m^3, 148.8 µg/m^3 – 300.3 µg/m^3 and 181.3 µg/m^3 – 245.6 µg/m3 respectively. In figure 3, the concentrations of particulate matter (PM10) obtained from Eleme, Ikoku, and Aluu, which range from 13 ± 06 µg/m^3 to 37 ± 30 µg/m^3, are also lower and in complete disagreement with the values of the PM10 concentration reported by [54] which were obtained from Omuanwa, Eleme, Oginigba and Rumuolumeni, which range from177.8 µg/m^3 – 855.6 µg/m^3 , 960.2 µg/m^3-1154.4 µg/m3, 940.2 µg/m^3 - 1399.8 µg/m^3 , and 236.0 µg/m3 -1926.3 µg/m^3 respectively.

5. Conclusion and Future Scope

This research focused primarily on the concentrations of particulate matter in air samples from three different locations (Eleme, Aluu and Ikoku) in Port Harcourt city, Rivers state, Nigeria. The results revealed that the particulate matter from the three different locations are all above the WHO permissible limit except for PM10 observed during wet season, which are below the WHO permissible limit for (50 µg/m3 for PM10). It was also observed that PM10 were greater in the atmosphere than PM2.5 in all the locations. This shows that the air filled with both smaller and larger particles, which are detrimental to human health. Judging from the concentrations of PM recorded, it is recommended that the industries operating within the studied areas should be adequately monitored and control by established regulatory agencies to curtail and minimize further emission of these substances into the atmosphere, in order to make Port Harcourt a livable city for people.

Conflict of Interest

There was no conflict of interest throughout the research period.

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Authors' Contributions

Authors are required to include a statement of responsibility in the manuscript that specifies the contribution of every author. The level of detail varies; some disciplines produce manuscripts that comprise discrete efforts readily articulated in detail, whereas other fields operate as group efforts at all stages.

For Example- Author-1 researched literature and conceived the study. Author-2 involved in protocol development, gaining ethical approval, patient recruitment, and data analysis. Author-3 wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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