GEOSTATISTICAL ASSESSMENT OF CARBON MONOXIDE LEVELS IN KARACHI

SYEDA KANEEZ FATIMA, YAMNA LIAQUAT, IMRAN AHMED KHAN, SHEEBA AFSAAR, YASMIN ANEES, NAZIA RAFIQUE KEHAR AND SYEDA MUQADAS BATOOL
Department of Geography, University of Karachi, Karachi 75270, Pakistan.
Corresponding author's e-mail: imranak32@uok.edu.pk

خلاصہ

کراچی پاکستان کا سب سے بڑا شہر ہے، جس میں ایک گنجان آباد میٹروپولیٹن کی تمام خصوصیات موجود ہیں۔ شہر کے اہم مسائل میں سے ایک ہوا کا معیار ہے، جس کا تعلق شہری ماحول اور آلودگی سے ہے۔ اس مطالعے کا مقصد یہ بتانا ہے کہ جیو گرافک انفارمیشن سسٹم (GIS) کس طرح کراچی میں نمائش، خطرے کی تشخیص، اور اخراج کی پیشن گوئی میں مدد کر سکتا ہے۔ مطالعہ کا بڑا مقصد ایک GIS ماڈل تیار کرنا ہے جو پورے شہر میں آلودگی کی سطح کے طور پر کاربن مونو آکسائیڈ (CO) کی سطح کا تجزیہ، پیشین گوئی اور تجزیہ کر سکے۔ اس مقصد اور مقصد کو حاصل کرنے کے لیے، Field Data ڈیٹا اکٹھا کیا گیا ہے، اس پر تجزیہ کیا گیا ہے، اور مطالعہ کے علاقے میں کاربن مونو آکسائیڈ کی سطح کا ایک متحرک GIS ماڈل تیار کیا گیا ہے اور تجزیہ کرنے کے لیے، GIS IDW interpolation جغرافیائی شماریاتی (انٹرپولیشن) ماڈلز کا استعمال انٹرایکٹو اور ڈائنامک CO آلودگی کے ماڈلز کا تجزیہ کیا گیا ہے۔ CO کی تشخیص کے لیے، زونل اعداد و شمار Zonal Statistics کو ضلع وار کم از کم Minimum، زیادہ سے زیادہ، حد Maximum، اوسط Mean اور معیاری انحراف standard deviation کی قدروں کے طور پر استعمال کیا گیا ہے ۔اضلاع کی اوسط قدریں نقشہ سازی کے ڈسپلے کے لیے استعمال کی گئیں ہیں۔ اضلاع کی اوسط قدریں نقشہ سازی کے ڈسپلے کے لیے استعمال ہوئی ہیں۔ فیلڈ میں جمع کردہ ڈیٹا اور انکوائری کے دوران تجزیہ کیا گیا کہ (CO) کے اخراج قابل قبول ہوا کے معیار کی ضروریات اور حدود کے اندر تھے۔ تاہم، کاربن مونو آکسائیڈ (CO) کی سطح مرکزی شہر کے کاروباری علاقوں اور تجارتی بازاروں میں زیادہ ہے، اس علاقے میں سانس کے مسائل پیدا ہونے کا زیادہ امکان ہے۔

Abstract

Karachi is Pakistan's largest city, with all the features of a densely populated metropolitan. One of the city's significant issues is air quality, which is linked to the urban environment and pollution. The goal of this study is to show how Geographic Information Systems (GIS) can help with exposure, risk assessment, and emission predicting in Karachi. The study's major goal is to develop a GIS model that can analyze, predict, and analyze carbon monoxide (CO) levels throughout the city as pollution surface. To achieve this objective and aim, sample data have been collected, processed, and managed to generate a dynamic GIS model of Carbon monoxide levels of the study area. To better visualization and analysis, GIS and geostatistical (interpolation) models are used to develop interactive and dynamic CO pollution models. Inverse distance weighted (IDW) interpolation was used to create a surface from CO survey data. For the evaluation of CO, zonal statistics were used as districts wise Minimum, Maximum, Range, Mean and Standard Deviation values. The mean values of later districts were used for mapping displays. Data collected in the field and analyzed during the inquiry found that (CO) emissions were within acceptable ambient air quality requirements and limits. However, carbon monoxide (CO) levels are higher in business zones and commercial marketplaces in the central city, this area is more likely to cause respiratory problems.

Keywords: GIS Mapping**,** Carbon monoxide (CO), Respiratory risk, IDW, Air pollution in Karachi

Introduction

Respiratory diseases and health issues are emerging day by day due to air pollution. This incurable disease is now common around the world. According to WHO, more than 300 million people has been diagnosed by this disease (Khan *et al*, 2020). Since last two decades this tract of respiratory disease has been doubled. It has been become a public issues in almost every country whether it is poor or rich. However, in low income middle countries, the ratio of asthma deaths are around 80%. The reason of rising of this infection is urbanization of developing countries. All of this has been effected the life of an individual a lot. More people moving from village to city as they need to come for job and better facilities.

Due to this it has been resulting in closed apartments, air pollution, traffic jams, noise pollution and other social issues. It has not only effected human's life. But due to industrialization some harmful chemical has been also introduced into the air. These harmful chemical had effected the air quality a lot and made the environment contaminated. Such harmful chemical also results in climate change which indirectly effect human's day to day life. Recent studies has been showed that the major cause of this bad quality of air is smoke emitting from vehicles. All these smoke consist of harmful gases such as CO and NOx, VOCx and SOx especially in urban areas. The pattern shift of urbanization has been given rise to respiratory disease mostly in developed countries. All these changes are effecting health of humans a lot. Urbanization in developing countries is nothing but the closed apartments, traffic, noise and air pollution and other rising issues of environment. All these harmful particles are when added into atmosphere make it worst to breath. These chemicals in such quantities then leads to destructive ecology (Khan *et al*, 2011).

Karachi has been listed as one of the most polluted cities in the world. The four main dominating human induced pollution are vehicular traffic, industrial manufacturing unit, open air garbage burning and rubber tire burning. All these are human induced pollution. These burning materials emits tons of toxic gases which pollute the air of Karachi (Khan *et al.*, 2020). The biggest concern of this metropolitan city is the rising air pollution. GIS has been recognized as an important took it to analyze diseases. This software gather data of concern issue and then represent it in the form of map (Skarková *et al.*, 2015, Shakeel *et al.*, 2015). This GIS and related spatial studies has been used by many other researchers. These mapping helps in pointed out diseases and making plan to handle the situation. High environmental risk has been also mapped recently.

Geographical Information System (GIS) and Geostatistical Approaches

Geostatistics is a statistical approach for predicting and quantifying values related to spatial, temporal, and geographic processes. The most of geostatistical methods are used to explain spatial patterns and interpolate values for areas where no samples were taken. GIS can be helpful in assessing water quality and identifying solutions to urban and environmental issues. Geostatistics is a common class of statistical approaches for estimating or forecasting the value of a continuous spatial process at unobserved sites based on its value at a collection of known locations (Balaji *et al.*, 2022). This type of spatial prediction is usually done using the kriging method, which produces estimates that are maximized over a class of predictors that are a linear combination of the process observed values. The interpolation-based surfaces are readily available as measurements of uncertainty in forecasts, in addition to providing point estimates of the process at unobserved points (Mohammed *et al.*, 2019; Jumaah *et al.*, 2019).

Inverse Distance Weighted (IDW) Interpolation

Inverse distance weighted (IDW) is a method for calculating interpolation using a known set of dispersed points. The values at unknown points are computed using a weighted average of the values available at examined points. IDW interpolation assumes that items that are near together are more similar than those that are far apart. IDW forecasts values at an unknown location by using nearby computed values. Predicted values have a stronger impact on measured values in close proximity than those further away. IDW is built on the concept that all measured points have a local influence that decreases with distance. The term inverse distance weighted comes from the fact that it provides more weight to points that are close to the projected location and less weight to points that are farther away. The IDW technique is a fundamental method that considers all places on the Earth's surface to be interdependent on the basis of distance (Kumar *et al.*, 2016; Tella & Balogun, 2021).

IDW theoretical background with ARCGIS framework

Inverse Distance Weighting (IDW) operates on the principle that the value (z) of an attribute at any unsampled location is an average that is weighted by the distance to sampled points within a defined neighborhood around that location. This approach utilizes a weighted moving average, as illustrated in Equation 1. The weights (λi) are calculated using a weighting function, typically represented as d−p, where:

$$\hat{z}(x_0) = \frac{\sum_{i=1}^{n} z(x_i) \cdot d_{ij}^{-P}}{\sum_{i=1}^{n} d_{ij}^{-P}}$$ ……….. Equation 1.

Z value at location (i,j) is f of Z value at known point (x, y) times the inverse distance raised to a power P. Z value field: numeric attribute to be interpolated; Power: determines relationship of weighting and distance; where p= 0, no decrease in influence with distance; as p increases distant points becoming less influential in interpolating Z value at a given pixel (Figure 1).

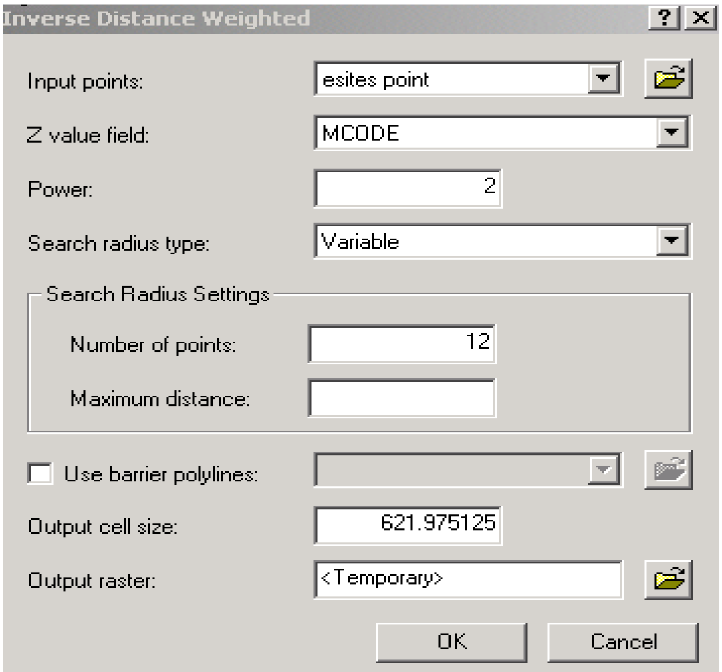

Fig. 1: ArcGIS setting for IDW interpolation.

IDW methods to choose and to limit.

In the context of IDW methods, there are different choices for selecting and constraining the interpolation process. The radius, which can be either variable or fixed, is a key factor influencing how the interpolation is performed:

***Variable Radius (Nearest Neighbor)*:** This option allows users to specify the number of neighboring points that will affect the value of each cell. The radius adjusts based on the density of points, ensuring that a specified number of points are always included in the interpolation.

***Fixed Radius*:** Users can define a specific radius within which each point contributes to the calculation of the cell's value. This method maintains a constant distance for all points influencing the interpolation, regardless of the number of points within that distance.

***Shapefile as Barrier*:** This feature allows the use of a shapefile as a barrier, restricting the interpolation to the area within the shapefile's boundaries. This can enhance the accuracy of the interpolation by confining the interpolated surface to a specific region of interest. These methods provide flexibility in controlling the interpolation process to suit specific needs and datasets.

Materials and Methods

***Base Mapping*:** For developing the digital map, we used Landsat 8 imagery which is downloaded from USGS Earth Explorer for the study area on 1:750.000 scale using ArcGIS 10.6. Base map was digitized by using the polygon tool of ArcGIS 10.6 (figure2).

***Field Survey*:** A thorough field survey was undertaken to evaluate air quality in various locations within the city of Karachi. The data collection process included measuring pollutant concentrations at specified points, capturing fluctuations in atmospheric conditions. The survey was strategically designed to collect precise information on key air quality parameters, focusing particularly on potential and high-traffic locations to ensure accurate measurements of carbon monoxide (CO). This meticulous data collection lays the foundation for a detailed analysis, with the ultimate goal of creating risk maps based on the observed air quality variations.

Point Shapefile Creation

Using ARCGIS, the diligently gathered field data underwent a systematic organization and meticulous transformation into a point shapefile (Figure 3a). This conversion plays a crucial role in enabling a spatial representation of pollution hotspots and variations within the geographical landscape. Each individual data point captured in the shapefile signifies a precise geographical location where comprehensive air quality measurements were carefully recorded during the survey, offering a detailed insight into the nuanced context of pollution. This spatial dataset has now become the keystone, establishing the basis for subsequent detailed spatial analyses and assessments, which are indispensable for understanding the complexities of pollution patterns and their consequential implications.

Carbon Monoxide Concentration Monitoring

Fossil fuel combustion, particularly in the busy traffic on roads, generates carbon monoxide as a by-product. High levels of this pollutant cause health issues in central city areas where traffic jams occur. CO emissions from automobiles and other sources have an indirect impact on climate change, as well as poor health consequences for people who are exposed (Arsalan, 2004). Previous indigenous CO and traffic evaluations are given in a few classic cases that provide a CO sample criterion, such as where CO potential exists at road crossings (Arsalan *et al*, 2020). CO concentrations were measured using a carbon monoxide meter at 57 places throughout Karachi where severe traffic pollution was detected (Table 1) by using CO analyzer (figure3b).

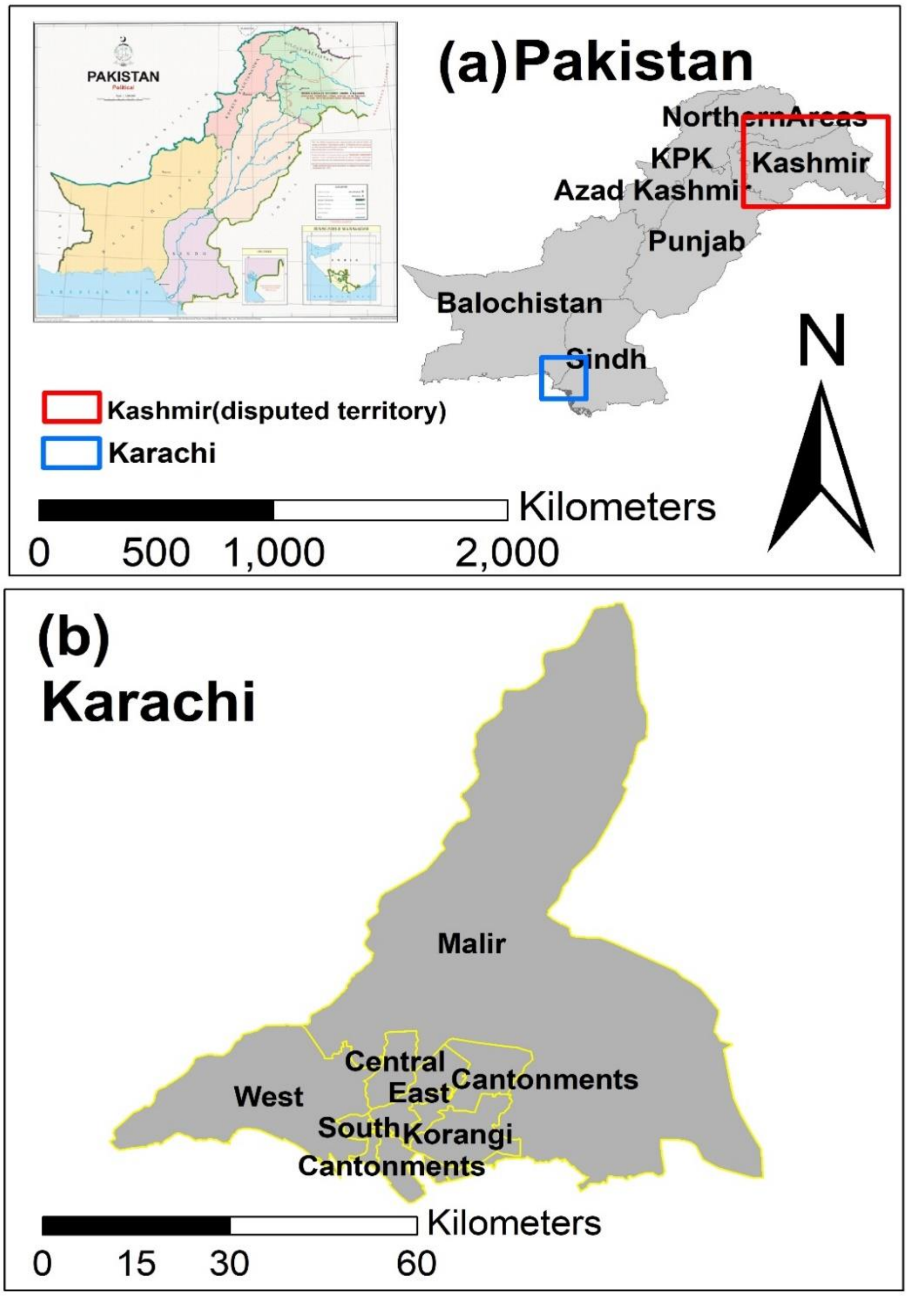

Fig. 2: (a) Pakistan (Indian illegally occupied Jammu & Kashmir. disputed territory final status to be decided in line with relevant unsc resolutions).
(b) Disctricts boundaries Karachi

Interpolation Techniques and Geostatistics through Interpolation in GIS

We applied interpolation techniques using ArcGIS 10.6, specifically employing the Inverse Distance Weighting (IDW) method, to create a continuous surface illustrating pollutant concentrations across the study area (figure 4). The IDW approach, a form of deterministic interpolation, utilizes observed values in proximity to a location, assigning values based on mathematical techniques that define the smoothness of the resulting surface. This process facilitates a comprehensive visualization of pollution trends between surveyed points, providing a detailed understanding of the spatial distribution of pollutants (Masroor et al, 2020; Dwivedi et al, 2024). The visual representation generated enhances our ability to discern patterns and variations in pollutant concentrations, aiding in informed assessments and decisions related to environmental quality and potential risks.

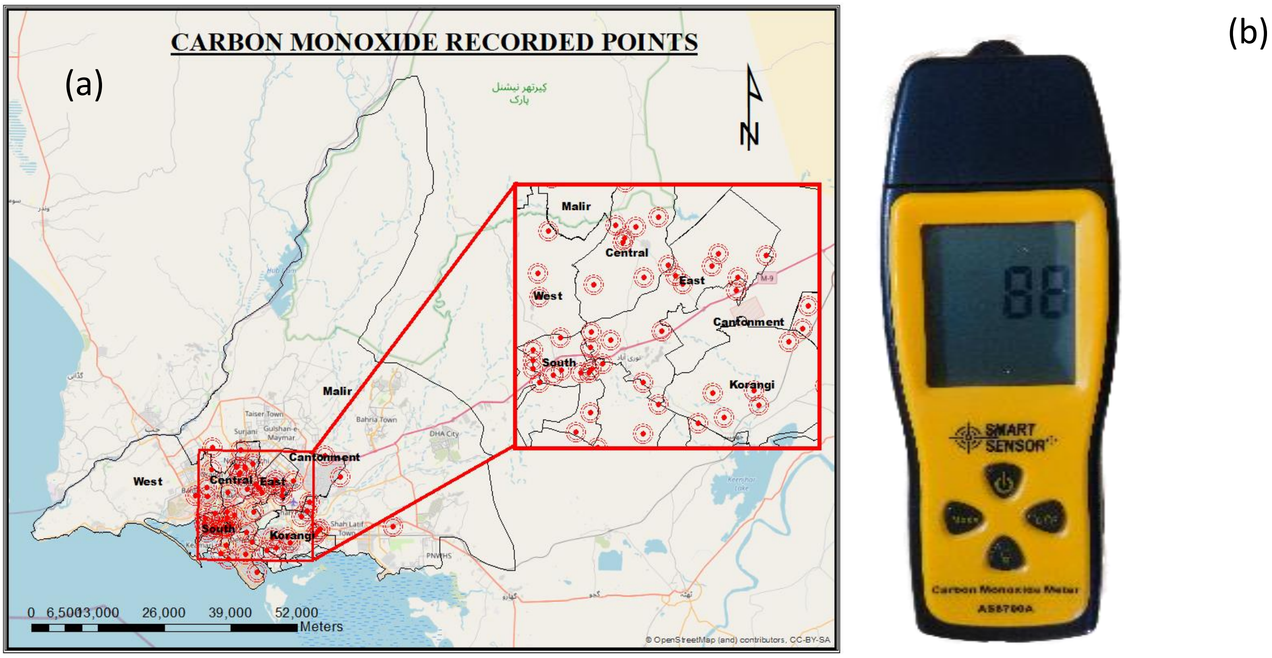

Fig. 3: (a) Survey points (b) CO analyzer.

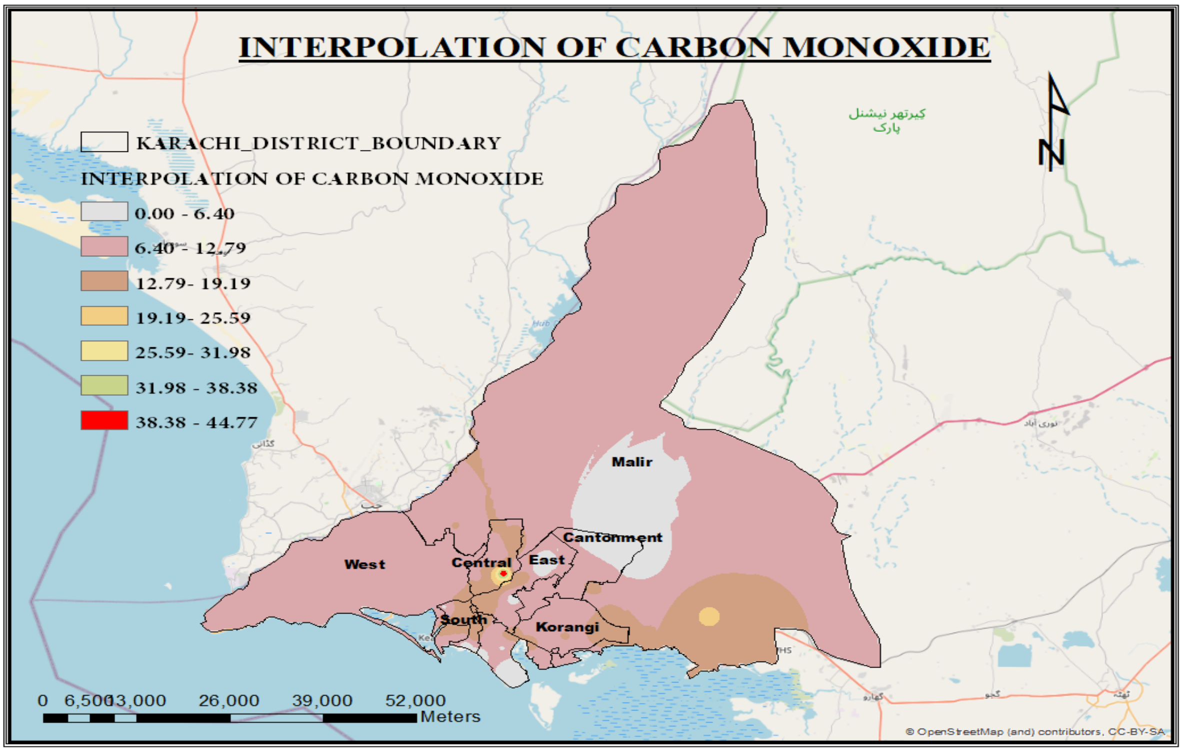

Fig. 4: IDW interpolation surface of CO (ppm) through GIS.

Table 1: Survey Locations

1	APS Saddar	30	Farooq-e-Azam Mosque
2	KPT Interchange		
3	Kamran Chowrangi	31	Nusrat Bhutto Colony
4	Geography Dpt. KU	32	Shadman Town
5	Kala Board Malir	33	Pakistan Quarter
6	Daud Chowrangi	34	Jamshed Quarter
7	Landhi No. 4	35	Garden East
8	Indus Hospital	36	Soldier Bazaar
9	Atrium Mall	37	Civic Centre
10	Governor House	38	Mehmodabad
11	Sindh Assembly	39	Nasir Colony
12	KMC Building	40	Zaman Town
13	Bolton Market	41	Korangi
14	Jinnah Flyover	42	Al Falah Society
15	Wazir Mansion Railway Station	43	Gulshan-e-Hadid
16	Mauripur Road	44	Quidabad
17	Shadman No. 2	45	Model Colony
18	LuckyOne	46	Gadap Town
19	Gulshan Chowrangi	47	Yousuf Goth
20	NIPA Chowrangi	48	Behar Colony
21	KU Silver Jubilee	49	Allama Iqbal Colony
22	DHA College	50	Saddar
23	McDonalds Seaview	51	Clifton
24	Creek Vista Aptmnts	52	Saeedabad
25	Sahil Promenade	53	Mominabad
26	Azizabad	54	Bilal Colony
27	Abbasi Shaheed	55	Jahanabad
28	Godhra	56	Metrovile
29	Khuwaja Ameer Nagri	57	Burmi Colony

Results and Discussions

Through IDW surface of CO in the study area we estimate min, max, range, mean and std. deviation values with GIS framework with spatial analyst tool that is Zonal Statistics. We utilized district shape file and IDW surface for zonal estimation as table 2. Later averages of CO (Mean values) has been used for overall risk assessment (figure5). The districts of Central and South are more affected regions. Since, max Carbon monoxide values are observed. Some conceivable reason may be the area have less green covers and more urbanized area, traffic jam and smoke releasing machineries, which are badly affecting our environmental health which is directly proportional to human health. The district Korangi is also in observant zone, because of industrial area in Korangi, which throwing out different types of acidic gasses in air because of its industrial site, which are harmful for all the living species.

Air pollution poses a significant threat to both the environment and human health, as emphasized by Li et al. (2018). The escalation of rapid urbanization, metropolitan events, population growth, modernization of activities, increased reliance on non-renewable energy sources, a deficient public transportation system, and the use of substandard fuels have collectively contributed to a substantial volume of contamination, surpassing conventional levels and persistently occurring in the background. In this scenario, transportation emerges as a major contributor to air pollution, presenting numerous challenges for individuals, as highlighted by Nuvolone et al. (2011). The primary culprit is the combustion of oil products within the transportation sector, a pivotal factor in the aging of pollutants (Prez-Martinez et al., 2014).

Urban areas with dense populations often grapple with elevated air pollution levels, leading to an increase in respiratory diseases. This study aims to establish a foundational assessment of air pollution and its patterns within the city. Karachi, specifically, contends with air pollution stemming from various sources such as vehicle emissions, particularly from rickshaws and buses, industrial discharges, open waste burning, house fires, and other particulate matter. Despite these concerning levels of pollution, governmental and environmental organizations appear to lack a sense of urgency or timely responsiveness to address the issue. The findings of this study could serve as a basis for health and environmental laws and regulations, prompting further in-depth analysis. Numerous spatial locations and hotspots have been identified, indicating specific areas of concern. However, it is emphasized that a continuous environmental survey, coupled with effective time and spatial extent-based management, would yield optimal results using a similar approach. As a recommendation, the establishment of larger green covers within the city is imperative for fostering a healthier environment and more favorable living conditions, free from the detrimental effects of air pollution.

Table 2: Districts wise CO values (ppm) by Geo-statistics assessment.

District	Min	Max	Range	Mean	Std. Dev.
West	7.05	17.90	10.85	10.61	0.97
South	2.24	18.25	16.00	12.30	3.72
East	0.03	24.40	24.36	9.60	3.93
Korangi	7.84	17.08	9.243	11.45	1.65
Central	6.22	44.77	38.55	14.75	5.60
Malir	0.00	19.98	19.98	9.08	2.93
Cantonment	0.02	17.27	17.25	7.65	3.40

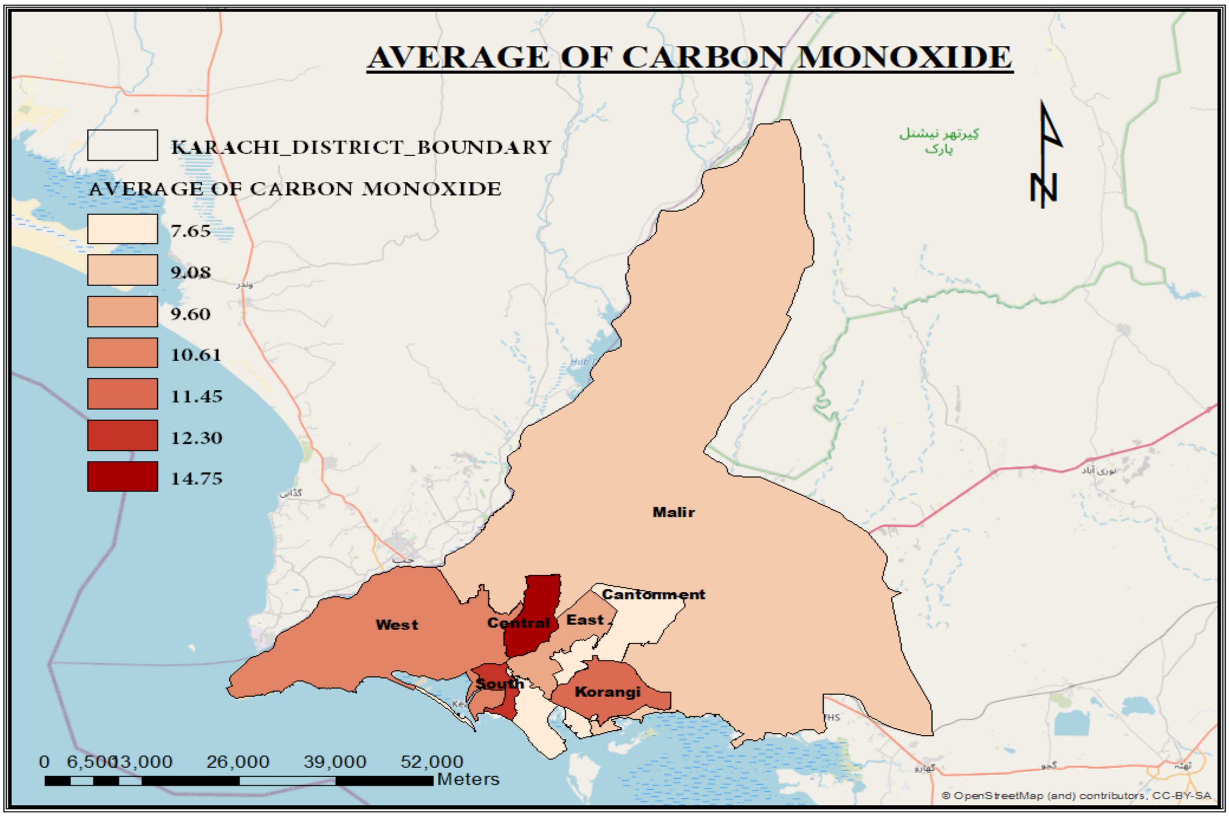

Fig. 5: Mean higher values in Karachi Districts.

The assessment of air quality in proximity to industrial zones reveals a noteworthy impact on respiratory health, indicating a correlation between elevated pollution levels and adverse health outcomes. The combination of industrial emissions and high traffic numbers exacerbates the challenges, emphasizing the need for a comprehensive understanding of the interplay between these factors (Zhou et al, 2023). The results highlight that industrial activities significantly contribute to the degradation of air quality. Emissions from manufacturing processes release various pollutants, including particulate matter and volatile organic compounds. These findings underscore the role of industrial zones as major sources of air pollution, directly influencing the overall atmospheric quality (Khan et al, 2019).

Numerous studies establish a clear connection between industrial emissions and respiratory health issues (Idrees et al, 2023). People residing or working in industrial zones are at higher risk of developing respiratory disorders, including asthma and bronchitis (Moyebi et al, 2023). Those with pre-existing respiratory conditions are particularly vulnerable to severe effects. The examination of air quality further indicates that areas characterized by both industrial activities and high traffic numbers experience a compounded effect (Panunzi et al, 2023). Traffic-related pollutants, such as nitrogen dioxide and carbon monoxide, augment the overall pollution load. This combination underscores the complex nature of urban pollution, where industrial and traffic emissions synergistically contribute to diminished air quality (Sannoh et al, 2024). The cumulative impact of industrial emissions and traffic-related pollution poses a significant challenge to public health. Individuals exposed to both sources face an elevated risk of respiratory problems. The synergistic effects of pollutants emphasize the importance of addressing not only specific industrial emissions but also considering the broader context of urban air quality management (Dondi et al, 2023; Tariq et al, 2023).

The World Health Organization (WHO) sets a permissible limit for carbon monoxide at 9 ppm. In the Cantonment district, the levels are below this limit. Districts East and Malir also fall within the acceptable range. However, the concentrations in other districts, namely West, South, Korangi, and Central, surpass the recommended limit, indicating elevated values in these areas. These results underscore the urgency of implementing mitigation strategies. Stringent emission standards for industries, adoption of cleaner technologies, and improvements in public transportation are imperative. Urban planning should be strategic in mitigating the impact of industrial zones on air quality. Additionally, fostering public awareness and advocating for sustainable practices are essential components of a comprehensive approach to create a healthier living environment in areas affected by industrial and traffic-related air pollution (Ribeiro et al, 2019; Liao et al, 2023).

The study emphasizes the intricate relationship between industrial activities, traffic emissions, and their collective impact on air quality and respiratory health. Addressing these challenges requires a holistic and collaborative effort from policymakers, industries, and the public to ensure a sustainable and healthy living environment.

Conclusion

Karachi, Pakistan's largest city deals with severe air quality issues due to its dense population and urban setting. This study demonstrates vital role of GIS in assessing exposure, analyzing risks, and predicting air pollution emissions. The IDW interpolation GIS techniques is used to make a dynamic GIS model was crafted to forecast carbon monoxide (CO) levels in Karachi, revealing generally acceptable emissions. Hazardous and risky heightened CO concentrations were pinpointed in central business zones, particularly in the Central and South districts, posing heightened risks of respiratory ailments. Many factors contributing to these elevated levels encompassed limited green coverage, escalating urbanization, traffic congestion, and emissions from various machinery. Furthermore, the industrial enclave of Korangi exhibited increased CO levels due to emissions of assorted acidic gases from its industrial activities. Recognizing the critical importance of air pollution assessment for public health, GIS technologies offer precise exposure evaluations and mapping capabilities, thereby assisting city planners and administrators in fostering cleaner environments and enhancing urban management. The GIS-based air pollution assessment in Karachi stands as a testament, providing a template for similar urban centers in underdeveloped countries to effectively combat air pollution challenges.

Future Implications

The study results unveil Mean CO values and pinpoint areas with elevated concentrations through mapping. This investigation underscores the significance of continuous environmental monitoring and management, considering both spatial and temporal aspects. A crucial suggestion is to introduce larger green spaces within urban areas as a measure to alleviate the adverse effects of air pollution. The extensive dataset and its spatial representation can provide a basis for formulating health and environmental policies, fostering a proactive approach in tackling air quality concerns. The GIS-based methodology employed in this study holds potential for application in similar urban centers, especially in underdeveloped countries facing comparable challenges. Integrating technology with epidemiological research, this approach provides a sturdy framework for continual evaluations of air pollution and informed urban planning. The results could become a valuable asset for urban management, contributing to efforts aimed at creating cleaner environments and promoting healthier living conditions.

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