Geostatistical Modeling of Carbon Monoxide Levels in Khartoum State-GIS Based Study

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ABSTRACT

The objective of this study was to develop a digital GIS model that is able to evaluate, predict, and visualize Carbon monoxide (CO) levels in Khartoum State. To achieve this objective, sample data have been collected, processed, and managed to generate a dynamic GIS model of Carbon monoxide levels of the study area.

GIS and geostatistical models were found to be valuable tools for creating interactive and dynamic models to enhance the visualization and analysis of Carbon monoxide (CO) emissions in Khartoum state. Parametric data collected from the field and analysis carried throughout this study showed that CO emissions were much lower than the allowable ambient air quality standards released by National Environment Protection Council (NEPC) for 1998. However, this pilot study has found CO emissions to be unevenly distributed geographically as well as temporally; with Omdurman city exhibiting highest levels. This pilot study showed that GIS and geostatistical modeling can be used as a powerful tool to produce maps of exposure to enhance exposure assessment in environmental studies for Khartoum State.

INTRODUCTION

- A large number of chemicals are used on a regular basis in modern societies (Jarup L., 2004).

- Rapid assessment of the risk associated with the use of these chemicals is essential to protect people from exposure to potentially harmful substances (Dunn, 2010).

- Exposures to chemicals (and physical agents) are typically unevenly distributed geographically as well as temporally (Jarup, 2004).

- Exposure mapping using advanced GIS modeling may enhance exposure assessment and reveal spatial variations in risk and trends related to distance from sources of pollution in environmental studies (Croner et al., 1996).

- Motor vehicles are the main source of carbon monoxide pollution in urban areas. Cars' emissions contain carbon monoxide from incomplete burning of fuel in the engine (Mayer, 1999).
- Like many other major cities of the world, air pollution from motor vehicles is one of the rapidly growing problems in Khartoum State, the capital of Sudan (Duria, 2002).
- The problem has further been complicated with the noticeable concentration of large numbers of vehicles and comparatively high motor vehicles to population ratios in this city, where 500.000 vehicles have been recorded in General Transportation Administration in Khartoum State for the year 2002 with an annual increase of 5.4% for the period extending from 1995-2000 (Duria, 2002).
- Carbon monoxide have serious economic and health impacts on humans and animals.

OBJECTIVE

The main objective of this scientific work was to build a digital dynamic GIS model that can evaluate and visualize Carbon monoxide levels in Khartoum State.

Methods

❑ Study area

- Khartoum State is located between 15° 35' 17" North, 32° 32' 3" East. Its one of the 18 states of federal governance system of Sudan (Fig.1). It has an area of 22,122 km2 and an estimated population of approximately 7,152,102 (Eltayeb, 2003).
- Khartoum state, consists of three major cities:

  - Khartoum (Administrative city)
  - Omdurman (Historical and legislative city)
  - Khartoum North (Industrial city)

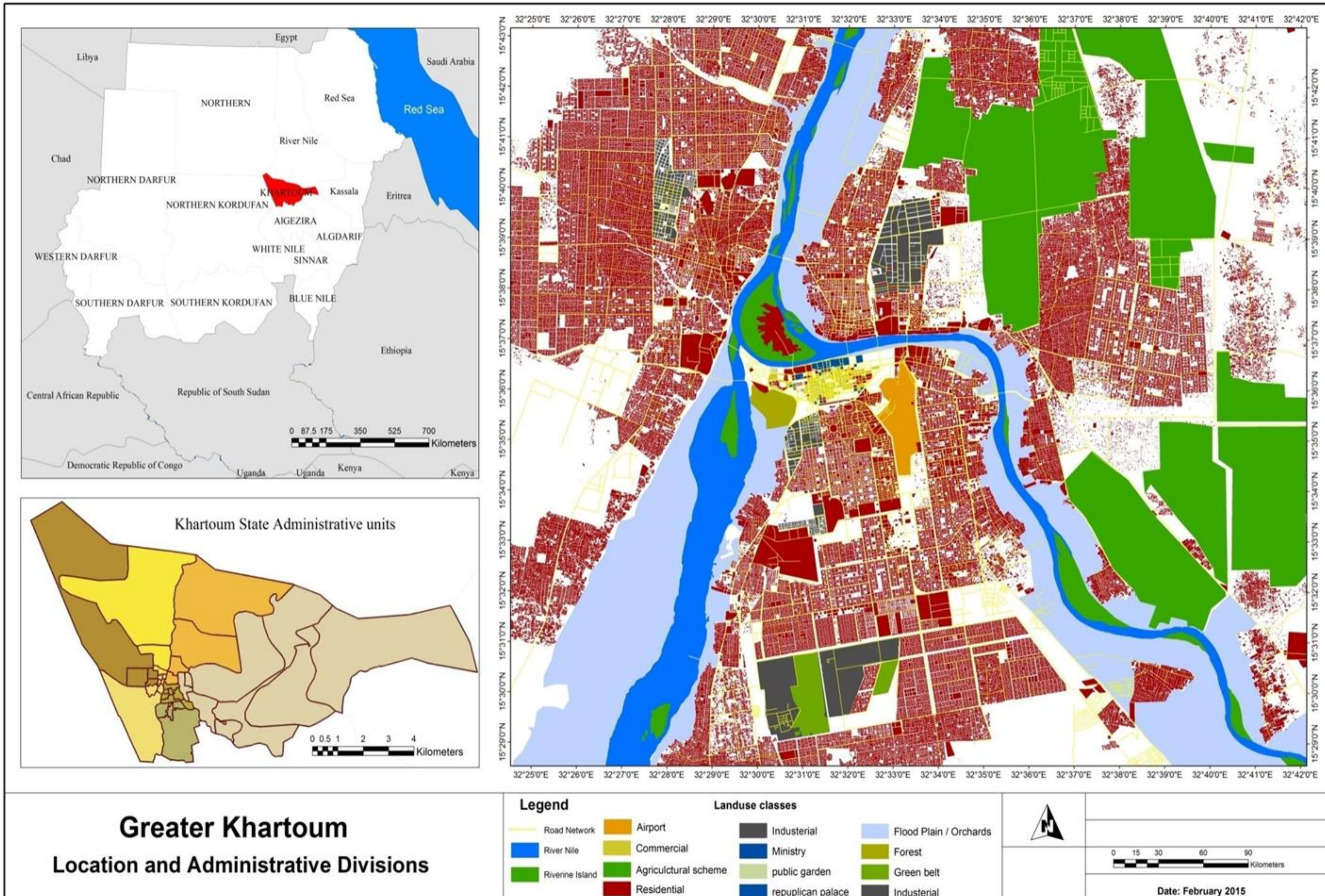
  Make Greater Khartoum

Administratively, Khartoum State is divided into seven localities:

- Al-Khartoum Locality.
- Al-Khartoum Bahri Locality.
- Omdurman Locality.
- Jabal Awliya Locality.
- Sharq an-Nil Locality.
- Ombadda Locality.
- Karari Locality.

Each locality is divided into administration units

Fig. 1 STUDY AREA, CONURBATION AREA , ROADS, & ADMISTRATIVE DIVISIONS

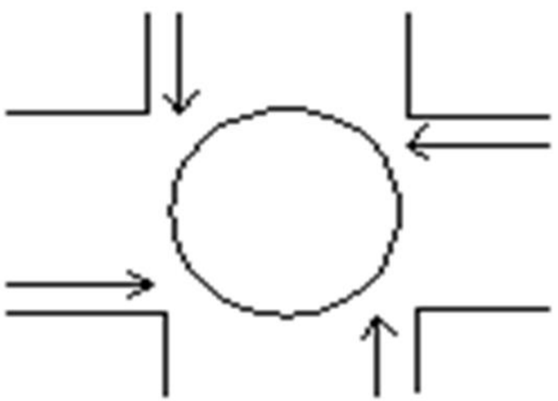


❑ Test data

- To achieve the aforementioned objective, 31 traffic roundabouts randomly were selected around the major towns that compose Khartoum State (Fig.2) to measure CO levels using digital gas tester (Fig. 3a, 3b) at three different times during a day: morning, mid-day, and night.

- The readings of the CO concentrations during three daily periods were taken in intervals with three hours latency time between each period of measurement to overcome the problems of insufficient field kits (Tab.1).

FIGURE 2. GPS COORDINATES & GAS TESTING SITES



FIGURES 3. GAS TESTER & GPS USED in MEASUREMENTS

Fig. 3a. Garmin GPS

Fig.3b. Gas Tester BW/Defender II

TABLE 1. THE EXAMPLES OF CO MEASUREMENT POINTS

Location Description	**Morning Measurements 8:00-12:00 AM**			**Midday Measurements 1:00-4:00 noon**			**Night Measurements 5:00-9:00 PM**			**Coordinates**		
	(H_2S) PPm	**(CO) PPm**	**(O_2) %**	**(H_2S) PPm**	**(CO) PPm**	**(O_2) %**	**(H_2S) PPm**	**(CO) PPm**	**(O_2) %**	**X**	**Y**	**E Meter**
S.markazi Br.	0.000	0.004	20.9	0.000	0.000	20.9	0.000	0.006	20.9	449682	1729898	389
Alsamrab	0.000	0.005	20.9	0.000	0.000	20.9	0.000	0.010	20.9	452301	1735948	388
Kouper	0.000	0.006	20.9	0.000	0.015	20.9	0.009	0.007	20.9	452318	11727222	402
Almaygoma	0.000	0.006	20.9	0.000	0.004	20.9	0.000	0.010	20.9	456116	1726665	391
Alshelikha	0.000	.0010	20.9	0.000	0.000	20.9	0.000	0.005	20.9	457411	1726929	391
Alsikahadeed	0.000	0.011	20.9	0.000	0.030	20.9	0.000	0.004	20.9	450822	1727066	394

❑ Generation of the digital GIS model of the study area

- The GIS model of study area consists of four thematic views. Each view describes a specific spatial aspect.
  - The first and second views are a general frame that show the location of Sudan, location Khartoum State, and its all residential areas and paved roads (Fig.1).
  - The third view represents the gauge points of CO emitted from vehicles and its attributed statistics.
  - Fourth view represents prediction process carried out in this study. The main database file is associated with CO emission layer. This database consists of 13 columns and 31 rows describing the parametric readings acquired from the field.

❑ Analysis

- A raster map displaying the spatial distribution of CO has been generated using geostatistical modeling and subsequently converted to a GIS coverage.

- The analysis was carried out using simple Kriging interpolation. Kriging interpolation is a moderately quick interpolator that can be exact or smoothed depending on the measurement error model. Kriging uses statistical models that allow a variety of map outputs including predictions, prediction standard errors, probability, etc… depending on equation 1 (Shigidi, Garcia, 2003).

- In simple Kriging wizard, nugget has been selected equal to zero, lag size was 0.0076 and numbers of lags were 12 – 15 and five neighbors' points have been sited

KRIGING INTERPOLATION EQUATION

$$Z_k(x) = \sum_{i=1}^{n} \omega_i \, .Z(x_i) \ldots\ldots\ldots$$

Where ω_i are estimated weights.

RESULTS

- The results reveal that *Sharg Elniel* (Khartoum Bahari) represents a hot spot of CO emissions during the morning period (Fig. 4a).

- *Omdurman* city exhibited the highest levels of Carbon monoxide during mid day and night (Fig. 4b, 4c).

- Most of gauge points exhibited a remarkable high readings of CO during mid-day and evening times, with a noticeable concentration of CO during mid-day within the Central Business District (CBD) of Khartoum (Fig. 5).

FIG.4. (CO) LEVELS IN THREE TIMES OF THE DAY AS PREDICTED USING KRIGING INTERPOLATOR

Fig. 4a (CO) level at morning Period

Fig. 4b (CO) level at mid day Period

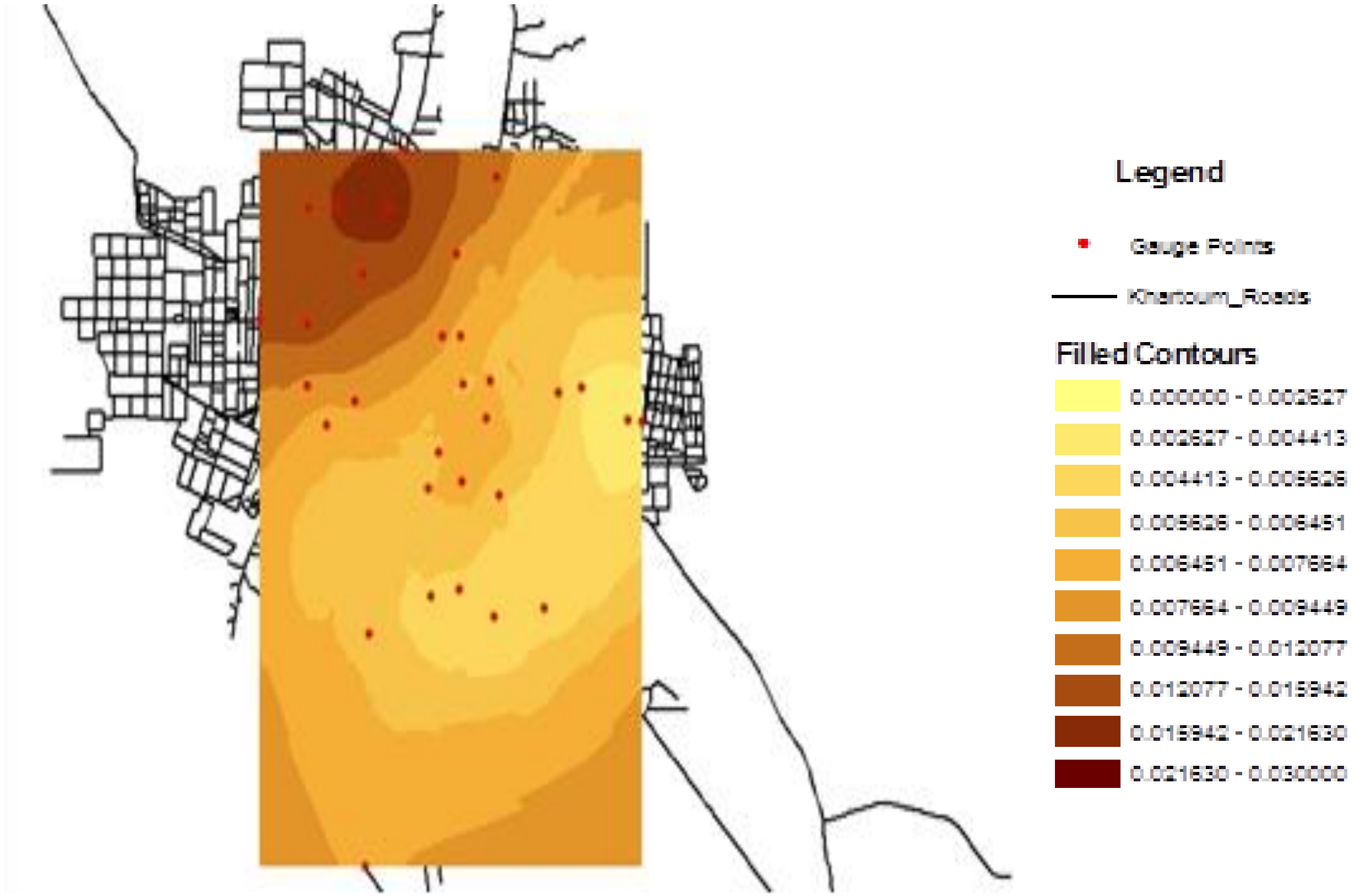


Fig. 4c (CO) level at night Period

FIG. 5 PERCENTAGE OF (CO) LEVEL PER EACH GAUGE-POINT DURING THE DAY

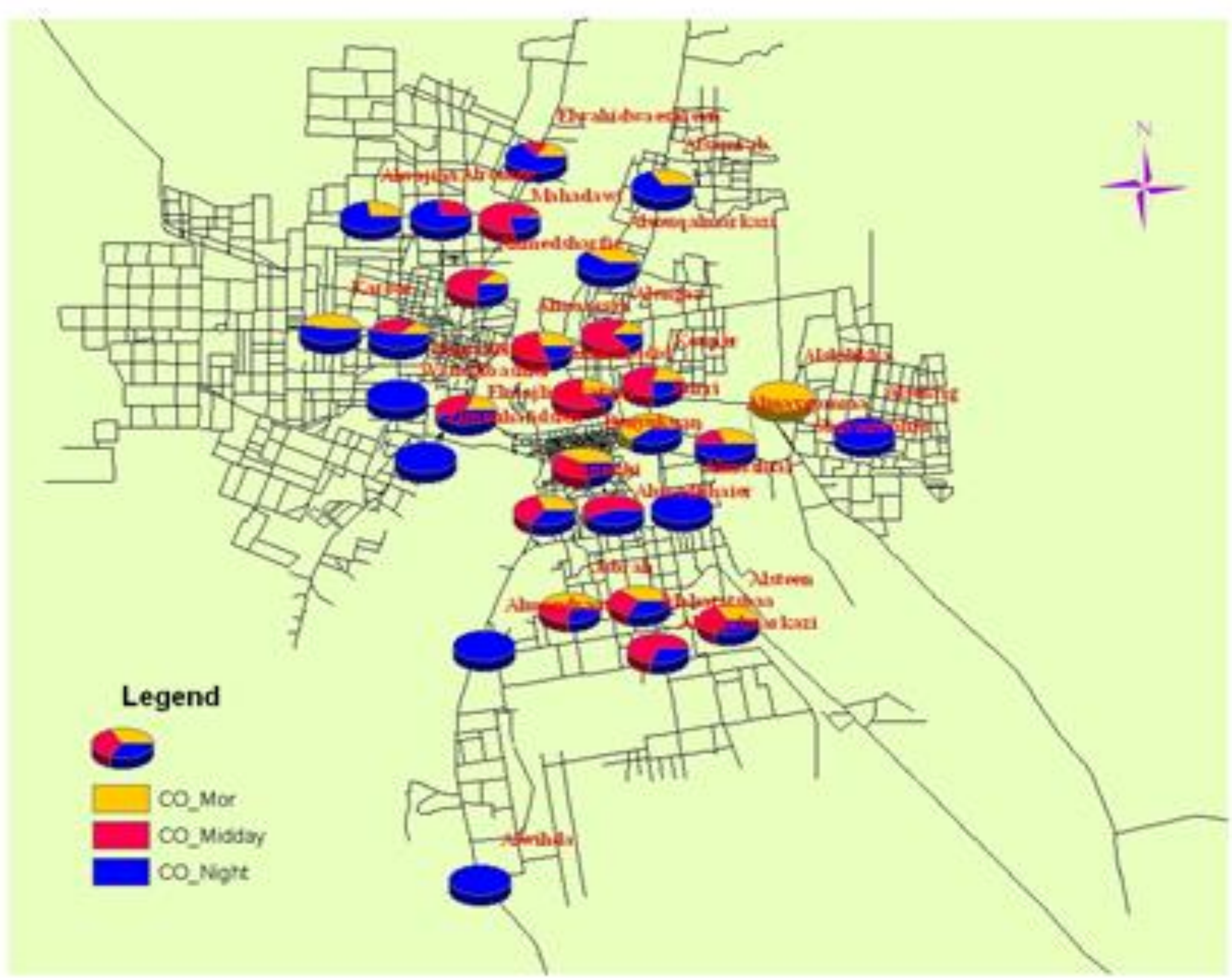


Fig. 5

DISCUSSION

- The National Environment Protection Measure for Ambient Air Quality (NEPM) was released in June 1998 by the National Environment Protection Council (NEPC-USA). The desired environmental outcome of the Air NEPM is ambient air quality is for the protection of human health and well-being. It sets air quality standards for six pollutants, together with the maximum exceedance levels of each standard and a goal for these standards to be met within ten years from the commencement of the Air NEPM. The Air NEPM standards (Tab.2).

TABLE 2. AMBIENT AIR STANDARDS ACCORDING TO NEPC-USA 1998

Pollutant	Air NEPM Standards	Averaging Time
Ozone	0.10 ppm 0.08 ppm	1 hour * 4 hour *
Nitrogen dioxide	0.12 ppm 0.03 ppm	1 hour * 1 year
Sulfur dioxide	0.20 ppm 0.08 ppm 0.02 ppm	1 hour * 24 hour * 1 year
Carbon monoxide	9.0 ppm	8 hour *
PM10	50 µg/m3	24 hour **
Lead	0.50 µg/m3	1 year

ppm: parts per million;
µg/m3: micrograms per cubic meter
* not to be exceeded more than one day per year
** not to be exceeded more than five days per year

- Comparing data acquired from the field shown in table 1 with that referred to Ambient Air Standards sited by NEPC-USA 1998 (shown in table 2), its obvious that CO levels as detected in this study are much lower than the international standards.

- Car congestions during different times of the day and microclimate conditions of each gauge point might be responsible for the disparities in the measurements of the CO in the study area. However, the GIS model of the study area offered solutions for various questions related to CO levels in the study area, and the methodology applied found to be useful and applicable in the case of Khartoum State.

MODEL LIMITATIONS

Due to financial constraints, related to the provision of proper and abundant gauge tool kits, the model of the study area suffers from a number of limitations that may limit the credibility of its results; these limitations are:

- The gas tester used to obtain the results of the study is designed to gauge indoor ambient air quality.
- The model didn’t include the wind velocity and direction which may affect the CO level concentration during measurements.

Nevertheless, GIS itself was found to be a powerful tool for the interpolation of emissions at unmonitored locations, and the current study can be considered as a pilot study and offer an opportunity for future interdisciplinary environmental research work.

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Thank you

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