

Determination of the best interpolation method in estimating the concentration of environmental air pollutants in Tehran city in 2015

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ARTICLE INFORMATION

Article Chronology:

Received 25 October 2018

Revised 5 November 2018

Accepted 10 December 2018

Published 30 December 2018

Keywords:

Air pollution; Tehran; Interpolation; Zoning; Cross-evaluation

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ABSTRACT:

Introduction: Air pollution is one of the important issues in developing countries, due to increased population and industrialization. In this research, the spatial distribution of ambient air concentration such as CO, NO₂, SO₂, PM_{2.5}, PM₁₀, O₃ and Air quality Index (AQI) in Tehran city in 2015 were evaluated using different deterministic (inverse distance weighted, local polynomial, global polynomial, radial basis functions) and geostatistical (Kriging, Cokriging) methods.

Materials and methods: Root Mean Square Error (RMSE) and Mean Error (ME) using cross-evaluation methods were used to control the accuracy of the interpolation. To find the secondary variables in the cokriging method, the Pearson coefficient of each pollutant was calculated with another pollutant.

Results: The Kolmogorov-Smirnov test showed that all data followed normal distribution. Also the results indicated that in most cases, geostatistical methods were the best methods to estimate ambient air concentration. Finally, after selecting the best interpolation method, the zoning map of the pollutant was drawn with ArcGIS.

Conclusion: The results of 71 methods showed that in most cases, the geostatistical method is better than the deterministic method.

Introduction

Environmental pollution is one of the serious problems in industrialized and developing countries around the world [1]. Among various sources of environmental pollution, air pollution causes the greatest damage to health and loss of well-being from environmental factors in Asian countries [2]. The average person will receive typically around 15 kg/day of air through breathing compared with 2-2.5 kg of water and 1-1.5 kg of food which indicates the importance of healthy

air in human life [3]. Air pollution is the presence of one or more air pollutants above the desirable level which reduces the quality of human health or welfare [4]. The World Health Organization (WHO) predicted that around 7 million people in 2012 died from air pollution exposure, which is about one-eighth of the total deaths [5]. It is also estimated that air pollution in cities will become the leading cause of premature mortality worldwide by 2050 [6]. According to WHO guidelines, air pollution is one of the ten cases

that cause major damage to humans [7]. The main contaminants that cause health hazards include particulate matter, ozone, nitrogen dioxide, and sulfur dioxide [8]. The main sources of air pollution in urban areas are vehicular emissions, which account for 90% of air pollution in cities [9]. The health effects of air pollution include: pulmonary disease, acute lower respiratory illness, cerebrovascular disease, coronary artery disease [10], decline in sperm count and ejaculate volume [11, 12], endothelial dysfunction, thrombosis, arrhythmia, blood pressure, metabolism disorders [13], heart disease, lung cancer, acute respiratory infections in children, chronic bronchitis in adults, aggravating preexisting heart and lung disease, or asthmatic attacks [14]. Tehran is one of the most polluted cities in Iran, whose main reasons are the rapid population growth, industrialization, increase personal vehicle density, and limited public transportation options [15]. 75 percent of Tehran's air pollution is due to vehicles [16]. Each year more than 40 % of the days are unhealthy and unhealthy for sensitive groups [17]. It is estimated that 27 people die every day due to air pollution in Tehran [16]. The economic burden of diseases due to air pollution in Iranian urban areas is more than 8 billion dollars a year [15]. The main sources of air pollution in Tehran are CO, SO₂, HC, O₃, NO_x and PM [18].

One of the useful tools used and effective methods in air quality assessment is Geographic Information System (GIS) and interpolation techniques respectively [19]. Interpolation is a method or mathematical function that predicts an unknown quantity between two known quantities [20]. There are two main types of interpolation techniques: deterministic and geostatistical methods. Deterministic interpolation methods (inverse distance weighted, local polynomial, global polynomial, radial basis functions), based on the degree of similarity and degree of smoothing create the

levels of measurement points and use mathematical functions for interpolation, but geostatistical interpolation (Kriging, cokriging) methods are based on both statistical and mathematical methods and are used for advanced modeling of prediction levels [21].

Many studies have been carried out on air quality assessment using interpolation methods. For example, a group of researchers compared three interpolation methods including Inverse Distance Weighting (IDW) method, Ordinary kriging (OK) method and Universal Kriging (UK) method for predicting air pollution conditions (PM₁₀) in the center of Thailand. According to the results of this study, the IDW method was the best interpolation method to predict the air pollution conditions [22]. Another group of researchers studied spatial variability of Suspended Particulate Matter (SPM), Sulphur Dioxide (SO₂) and Nitrogen Dioxide (NO₂), using kriging and IDW methods in Indian air. They found that IDW in all pollutants had a smaller error than Kriging and was the best interpolation method in Indian air quality [23].

Mexican researchers compares IDW, OK and nearest monitor interpolation methods for NO₂, SO₂, CO, O₃, PM₁₀ and PM_{2.5} in Mexico City air. They found that OK was the best method of interpolation compared to the other methods [24]. Iranian researchers studied spatial interpolation methods including IDW, Global Polynomial Interpolation (GPI), Local Polynomial Interpolation (LPI), Radial Basis Functions (RBF), Simple Kriging (SK), OK and Universal Kriging (UK) to evaluate the spatial distribution of AQI in the air of Tehran, Iran. According to their results, OK was the most accurate method for modeling AQI distribution because of its minimum RMSE [25]. The aim of this research is to compare various deterministic and geostatistical interpolation methods, including inverse distance weighted,

local polynomial, global polynomial, radial basis functions and types of Kriging and Cokriging for estimating ambient air concentration such as CO, NO₂, SO₂, PM_{2.5}, PM₁₀, O₃ and AQI in Tehran city in 2015.

Materials and methods

Study area

Tehran, as the capital of Iran, the world's 19th largest city with a population of more than 8.5 million in 2011 and total surface area of 730 km² is located 35° 34' to 35° 50''N and 51° 8' to 51° 37'E. Tehran has more than 17,000 industrial units (26 % of the total units in Iran) with more than 4 million people working in it. The annual mean daily temperature is 17 °C although highest and lowest recorded temperature was 39 °C and -6 °C respectively. The annual mean precipitation is about 230 mm with the maximum in March (39 mm) and the minimum in September (1 mm). The average elevation is 1200 m above sea level [15, 25-29].

Data collection

This study was conducted in 2015. 18 out of 21 monitoring stations with sufficient and valid data were evaluated. The stations belonged to the Air Quality Control Company (AQCC). The evaluated parameters were included CO, NO₂, SO₂, PM_{2.5}, PM₁₀, O₃ and AQI. All parameters were divided into 6 categories from 0 to 500 according to their breaking point (as AQI). The geographic location of this stations is shown in Fig. 1. In the next step, the SPSS and the Kolmogorov-Smirnov test were used for statistical analysis of the data. Then for each air pollutant concentration, using deterministic (inverse distance weighted, local polynomial, global polynomial, radial basis functions) and geostatistical (Kriging and Cokriging) methods (according to the variability of powers and methods), overall with 71 methods, the RMSE value was obtained using cross-validation. Then, with the lowest RMSE value, the best interpolation method was selected and zoned by GIS9.3.



Fig. 1. Geographic location of studying area

Deterministic methods

Inverse Distance Weighting method (IDW)

The IDW model is one of the most common interpolating methods based on the hypothesis that the effect of a parameter on the surrounding points is not the same. As the distance from the origin increases, the effect and weight assigned to it will be reduced. In this method, unknown values are computed by a linear combination of values at known points. The usual expression of IDW is using Eq. (1) [30]:

$$z_j = \frac{\sum_i \frac{z_i}{d_{ij}^n}}{\sum_i \frac{1}{d_{ij}^n}} \quad (1)$$

Where

Z_j is estimated value for the unknown point at location j

d_{ij} is distance between known point i and unknown point j

Z_i is value at known point i

n is user-defined exponent for weighting

Radial Basis Function method (RBF)

The radial base function method (known as splines) is one of the interpolation methods in which the level of observation passes through observational values. This method is an artificial neural network. Another feature of this method is that the values are greater than the maximum observed values or less than the minimum observed values at the estimation level. In the IDW method, the level of estimation will pass through the observation values, but never estimates more than the maximum and minimum of the minimum observational data. There are 5 types of RBF which include: Completely Regularized Spline (RBF-CRS), Spline With Tension (RBF-SWT), Thin Plate Spline (RBF-TPS), Multiquadric (RBF-M), Inverse Multiquadric (RBF-IM) [31].

Global Polynomial Interpolation (GPI)

GPI uses a polynomial formula to fit a smooth surface to the input sample points. GPI interpolation is used to estimate the unknown points from the data of all measured points. The level changes in GPI are gradual and the effects of sudden changes in data are reduced. In fact, the GPI goal is to minimize errors [32].

Local Polynomial Interpolation method (LPI)

This method, like the GPI, uses a polynomial function for interpolation, and the only difference is that a large number of polynomials are fitted on limited data in a given neighborhoods. In fact, in the LPI model, data from all points is not used to estimate the amount of unknown points [33].

Geostatistical methods

Kriging

Kriging is one of the most important tools in the geostatistical techniques. This method produces less bias in predictions, so that they are known as best linear unbiased estimator (BLUE). Similar to IDW, Kriging uses a linear combination of measured weight values to generate estimates for unknown points. However, the weights in kriging, not only depends on the distance between the predicted points and the measured points, but also on the spatial correlation (i.e., semi-variogram) of the measured points [34].

Cokriging

Cokriging is developed form of kriging but there are secondary variables or covariates that can be used to improve the interpolation. In fact Cokriging can be effective for data with significant inter-variable correlation [35].

Validation of interpolation method

The Cross-Validation technique has been used to compare the interpolation methods and select the most appropriate method. This method initially

temporarily removes one observation from the data set, and then the value of the deleted data is estimated using any interpolation method. In the next step, the original value returns to its location, and this is done for all data in the same way. In this study, the Root Mean Squared Error (RMSE) was used to evaluate interpolation. If RMSE is equal, the Mean Error (ME) used for evaluation. Any method that has the smallest RMSE is known as the most appropriate interpolation method. The RMSE can be calculated using Eq. (2) [36].

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (Z(x_i) - Z^*(x_i))^2} \quad (2)$$

Where $Z^*(x_i)$ is observed value at point x_i , $Z^*(x_i)$ is predicted value at point x_i , N is number of samples.

Results and discussion

In order to investigate the spatial changes that were the main objectives of this research, a Normality Test was initially performed by SPSS using the Kolmogorov–Smirnov test. Because one of the important conditions in the statistical

method is the normalization of the data. By analyzing the data, it was found that the air pollutant data was normal, so a change to normalize the data was not performed.

The annual air quality concentration (as AQI) obtained from average daily concentrations of pollutants is tabulated in Table 1. In total, it can be said that each pollutant passed at least once a year from about 100 number.

After the analysis of normality, we obtained RMSE for each pollutant in each season according to deterministic and geostatistical methods (Tables 2 and 3).

As shown in Tables 2 and 3, the value of RMSE is the same for some pollutants. In this case, other error estimation methods were used such as the Mean Error (ME). Finally, by checking RMSE and ME (the lower the better), the best interpolation method is obtained, which is shown in Table 4.

In the Kriging method, a secondary variable is used to improve interpolation. Pearson coefficient was used to select the secondary variable. Each pollutant that had the highest Pearson coefficient with another pollutant was selected as a secondary variable, as shown in Table 5.

Table 1. Annual Descriptive Statistics as AQI

Pollutant	N	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
CO	3877	8.00	188.00	39	0.28033	17.45485	304.672
O ₃	2790	5.00	154.00	39	0.38671	20.42603	417.223
SO ₂	3127	3.00	101.00	26	0.20192	11.29102	127.487
NO ₂	3689	7.00	178.00	66	0.52714	32.01684	1025.078
PM ₁₀	3315	6.00	500.00	57	0.50942	29.33031	860.267
PM _{2.5}	3338	10.00	244.00	79	0.54496	31.48508	991.310
AQI	5361	7.00	500.00	73	0.44786	32.79163	1075.291

Table 2. Annual RMSE results of deterministic methods interpolation assessment

Types and power			CO	O ₃	NO ₂	SO ₂	PM ₁₀	PM _{2.5}	AQI
			RMSE						
IDW	Standard	1	7.33	11.7	25.5	7.38	15.46	11.17	11.41
		2	7	11.84	24.32	8.12	16.52	11.92	12.3
		3	7.29	12.69	23.47	8.95	17.76	12.79	13.3
		4	7.77	13.49	23.05	9.68	18.93	13.55	14.2
	Smoth	1	6.89	12.14	25.66	8.21	17.11	12.11	12.57
		2	7.15	12.7	24.05	8.84	17.93	12.46	13.18
		3	7.55	13.31	23.08	9.46	18.82	13.28	13.88
		4	7.96	13.89	22.71	10	19.64	13.87	14.56
GPI		1	7.98	11.45	27.64	7.5	15.28	11.49	11.89
		2	8.44	14.96	40.28	10.24	18.64	19.48	18.36
		3	11.44	19.21	87.61	16.01	40.08	15.92	14.23
LPI	Standard	1	7.47	11.59	25.25	7.58	15.44	11.59	12.04
		2	7.76	14.86	39.81	10.39	19.45	19.24	18.11
		3	11.92	19.87	107.4	16.16	42.14	16.06	14.66
	Smoth	1	7.48	11.59	28.69	7.58	15.44	11.59	12.04
		2	8.27	14.86	50.4	10.39	19.45	19.24	18.11
		3	13.33	19.87	71.17	16.16	42.14	16.06	14.66
RBF	Standard	CRS	6.58	12.09	12.43	8.27	16.8	12.17	12.56
		SWT	6.59	11.87	16.89	8.02	16.44	11.88	12.56
		M	6.84	13.65	15.25	9.85	19.25	13.79	14.47
		IM	6.68	10.87	12.89	6.92	14.79	10.63	10.77
		TPS	8.43	16.56	19.68	13.66	27.28	18.04	18.84
	Smoth	IM	7.16	11.81	16.16	7.99	17.12	12.04	12.31

Table 3. Annual RMSE results of geostatistical methods interpolation assessment

Types and power			CO	O ₃	NO ₂	SO ₂	PM ₁₀	PM _{2.5}	AQI	
			RMSE							
Kriging	Standard	OK	CIR	6.69	11.69	21.61	6.9	15.03	11.24	10.68
			SPH	6.62	11.73	21.98	6.92	14.98	11.24	10.68
			EXP	6.75	11.73	24.63	6.92	14.98	10.68	10.68
			GAUS	6.56	11.69	24.88	6.92	14.98	10.68	10.68
		SK	CIR	6.58	11.58	17.69	6.54	14.1	10.09	10.13
			SPH	6.56	11.59	17.82	6.54	14.1	10.09	10.13
			EXP	6.96	11.59	21.25	6.54	14.1	10.09	10.13
			GAUS	6.59	11.57	19.91	6.54	14.1	10.09	10.13
		UK	CIR	6.64	11.7	21.44	6.92	14.98	10.68	10.68
			SPH	6.62	11.73	21.98	6.92	14.98	10.68	10.68
			EXP	6.75	11.73	24.63	6.92	14.98	10.68	10.68
			GAUS	6.56	11.69	24.88	6.92	14.98	10.68	10.68
	Smoth	OK	CIR	6.66	11.74	20.48	6.93	14.81	10.65	10.68
			SPH	6.63	11.76	20.8	6.93	14.81	10.65	10.68
			EXP	6.73	11.76	22.56	6.93	14.81	10.65	10.68
			GAUS	6.57	11.72	22.74	6.93	14.81	10.65	10.68
		SK	CIR	6.56	11.58	18.58	6.54	14.1	10.09	10.13
			SPH	6.55	11.59	18.78	6.54	14.1	10.09	10.13
			EXP	6.95	11.6	20.94	6.54	14.1	10.09	10.13
			GAUS	6.56	11.57	20.06	6.54	14.1	10.09	10.13
		UK	CIR	6.66	11.74	20.48	6.93	14.81	10.65	10.68
			SPH	6.63	11.76	20.8	6.93	14.81	10.65	10.68
			EXP	6.73	11.76	22.56	6.93	14.81	10.65	10.68
			GAUS	6.57	11.72	22.74	6.93	14.81	10.65	10.68
Cokriging	Standard	OK	CIR	6.67	11.58	30.09	7.38	14.89	11.2	11.44
			SPH	6.61	11.57	30.09	7.38	14.43	10.65	10.7
			EXP	6.73	11.45	30.09	7.38	14.45	10.53	10.61
			GAUS	6.53	11.63	30.09	7.38	14.44	10.68	10.7
		SK	CIR	6.56	10.93	17.81	6.53	14.1	10.46	10.54
			SPH	6.54	9.44	18.16	6.53	14.1	10.6	10.65
			EXP	6.73	9.67	21.41	6.53	14.2	7.19	7.65
			GAUS	6.57	10.98	20.29	6.53	14.2	10.51	10.66
		UK	CIR	6.62	11.58	28.1	8.52	14.43	10.66	10.7
			SPH	6.61	11.57	28.1	8.52	14.43	10.65	10.7
			EXP	6.73	11.45	28.1	8.52	14.45	10.53	10.61
			GAUS	6.53	11.63	28.1	8.52	14.44	10.68	10.7
	OK	CIR	6.64	11.62	28.32	7.33	14.96	10.63	10.69	
		SPH	6.63	11.6	28.32	7.33	14.96	10.62	10.68	
		EXP	6.72	11.48	28.32	7.33	14.97	10.49	10.6	
		GAUS	6.54	11.66	28.32	7.33	14.96	10.65	10.68	

Table 3. Annual RMSE results of geostatistical methods interpolation assessment

Types and power			CO	O ₃	NO ₂	SO ₂	PM ₁₀	PM _{2.5}	AQI	
			RMSE							
Cokriging	Smoth	SK	CIR	6.55	10.93	18.1	6.53	14.1	10.44	10.54
			SPH	6.52	9.43	18.4	6.53	14.1	10.5	10.65
			EXP	6.72	9.67	21.09	6.53	14.2	7.17	7.64
			GAUS	6.53	10.98	20.12	6.53	14.12	10.49	10.66
		UK	CIR	6.64	11.62	27.21	8.96	14.96	10.63	10.69
			SPH	6.63	11.6	27.21	8.96	14.96	10.62	10.68
			EXP	6.72	11.48	27.21	8.96	14.97	10.49	10.6
			GAUS	6.54	11.66	27.21	8.96	14.96	10.65	10.68

Table 4. Best interpolation method for each pollutant by checking RMSE and ME

Season	CO	O ₃	NO ₂	SO ₂	PM ₁₀	PM _{2.5}	AQI
Spring	Kriging (SK-CIR-standard)	Cokriging (SK-EXP-smoth)	RBF (IM-standard)	Cokriging (SK-EXP-standard) cokriging(SK-EXP-smoth)	Kriging (SK-EXP-smoth)	Cokriging (SK-EXP-smoth)	Cokriging (SK-EXP-smoth)
Summer	Cokriging (SK-CIR-standard)	Cokriging (SK-GAUS-smoth)	Kriging (SK-CIR-smoth)	Cokriging (SK-CIR-standard) Cokriging (SK-CIR-smoth)	cokriging(SK-GAUS-smoth) Cokriging (SK-GAUS-standard)	Cokriging (SK-EXP-smoth)	Cokriging (SK-EXP-standard)
Autumn	LPI (type 1-smoth)	Cokriging (SK-EXP-standard)	RBF (CRS-standard)	Kriging (SK-SPH-smoth) Kriging (SK-SPH-standard)	Kriging (SK-SPH-standard)	Cokriging (SK-GAUS-smoth)	Cokriging (SK-EXP-smoth)
Winter	Cokriging (SK-EXP-standard)	Kriging (SK-GAUS-standard)	Kriging (SK-GAUS-standard)	Cokriging (OK-EXP-standard) Cokriging (UK-EXP-standard)	Cokriging (SK-SPH-standard)	Cokriging (SK-EXP-smoth)	Cokriging (OK-GAUS-standard)
Annual	Cokriging (SK-SPH-smoth)	Cokriging (SK-SPH-smoth)	RBF (CRS-standard)	Cokriging (SK-EXP-smoth) Cokriging (SK-EXP-standard)	Kriging (SK-all of 4 models-standard) Kriging (SK-all of 4 models-smoth)	Cokriging (SK-EXP-smoth)	Cokriging (SK-EXP-smoth)

Table 5. Summary of the results of the Pearson coefficient

Main pollutant	CO	O ₃	SO ₂	NO ₂	PM ₁₀	PM _{2.5}	AQI	
Secondary variables	Spring	SO ₂	PM ₁₀	AQI	CO	AQI	PM _{2.5}	
	Summer	PM _{2.5}	AQI	NO ₂	SO ₂	AQI	PM _{2.5}	
	Autumn	AQI	SO ₂	NO ₂	SO ₂	AQI	PM _{2.5}	
	Winter	PM _{2.5}	SO ₂	CO	CO	PM _{2.5}	AQI	PM _{2.5}
	Annual	PM _{2.5}	PM ₁₀	NO ₂	SO ₂	AQI	AQI	PM _{2.5}

After identifying the best interpolation method for each pollutant, the zoning map of each pollutant was made using Arc Gis9.3 (Fig. 2). The best interpolation method for CO except for the autumn season has been the geostatistical method. The zoning map showed that in areas 10, 11 and 19, CO concentrations are higher than other points, which is probably due to high traffic loads. In the autumn and winter seasons, concentration of CO was slightly higher than the other seasons due to the opening of the schools and increased air inversion. Since 2011, changes in CO concentration have been decreased due to reducing carburetor vehicles, and improving fuel and vehicle quality. The best interpolation method for SO₂ was the geostatistical method. It is known that areas 10, 16 and 19 have a higher concentration, which is probably due to heavy vehicles. It should be noted that the concentration of SO₂ is lower than that of other pollutants due to lower sulfur content in gasoil [37]. The best interpolation method for NO₂ in the spring, autumn and annual was a deterministic method and for the summer and winter was a geostatistical method. The zoning map shows that in regions 2 and 11, concentrations of NO₂ are high and in the central regions is less. The best interpolation method for O₃ was the geostatistical method. The interpolation map showed that ozone concentrations were higher in the eastern border of the city due to the distance from the city and the intensity of more sunlight [37]. In central locations, ozone is used because of increased traffic load and presence to atmospheric reactions. In warm months, ozone concentrations are also higher compared to cold months due to higher radiation exposure. The best interpolation method for PM₁₀ and PM_{2.5} was the geostatistical method. In area 13 and especially

in area 9, PM₁₀ concentrations are higher than other areas. In the north and east areas, PM_{2.5} concentrations are less than other parts. Also, in the summer, PM_{2.5} concentration has increased compared to other seasons because of the dust phenomenon. In the spring, the concentration of PM_{2.5} was low due to the new year holiday, reduced traffic and atmospheric conditions.

In general, it can be said that the concentration of PM_{2.5} is in a worse situation compared to other pollutants and is currently the most important pollutant in Tehran. The best interpolation method for AQI was the geostatistical method. It is observed that the AQI index is higher in winter than the other seasons due to inversion and atmospheric stability. In general, One-way ANOVA showed that the average of CO, NO₂, SO₂, PM_{2.5}, PM₁₀, O₃ and AQI (each separately) varies in different stations and seasons.

Conclusion

One of the important methods in the environmental assessment is the use of the GIS and geostatistical and deterministic interpolation methods. So the aim of this study was to determine the best interpolation for providing CO, NO₂, SO₂, PM_{2.5}, PM₁₀, O₃ and AQI maps in air of Tehran city. In order to compare the interpolation evaluation, RMSE and ME were used. The evaluation showed that the most important pollutant in Tehran is PM_{2.5}. The results of 71 methods showed that in most cases, the geostatistical method is better than the deterministic method. Also in most seasons, Cokriging and RBF were the best geostatistical and deterministic interpolation methods respectively. After selecting the best interpolation method, the air quality maps of the area were drawn with ArcGIS.

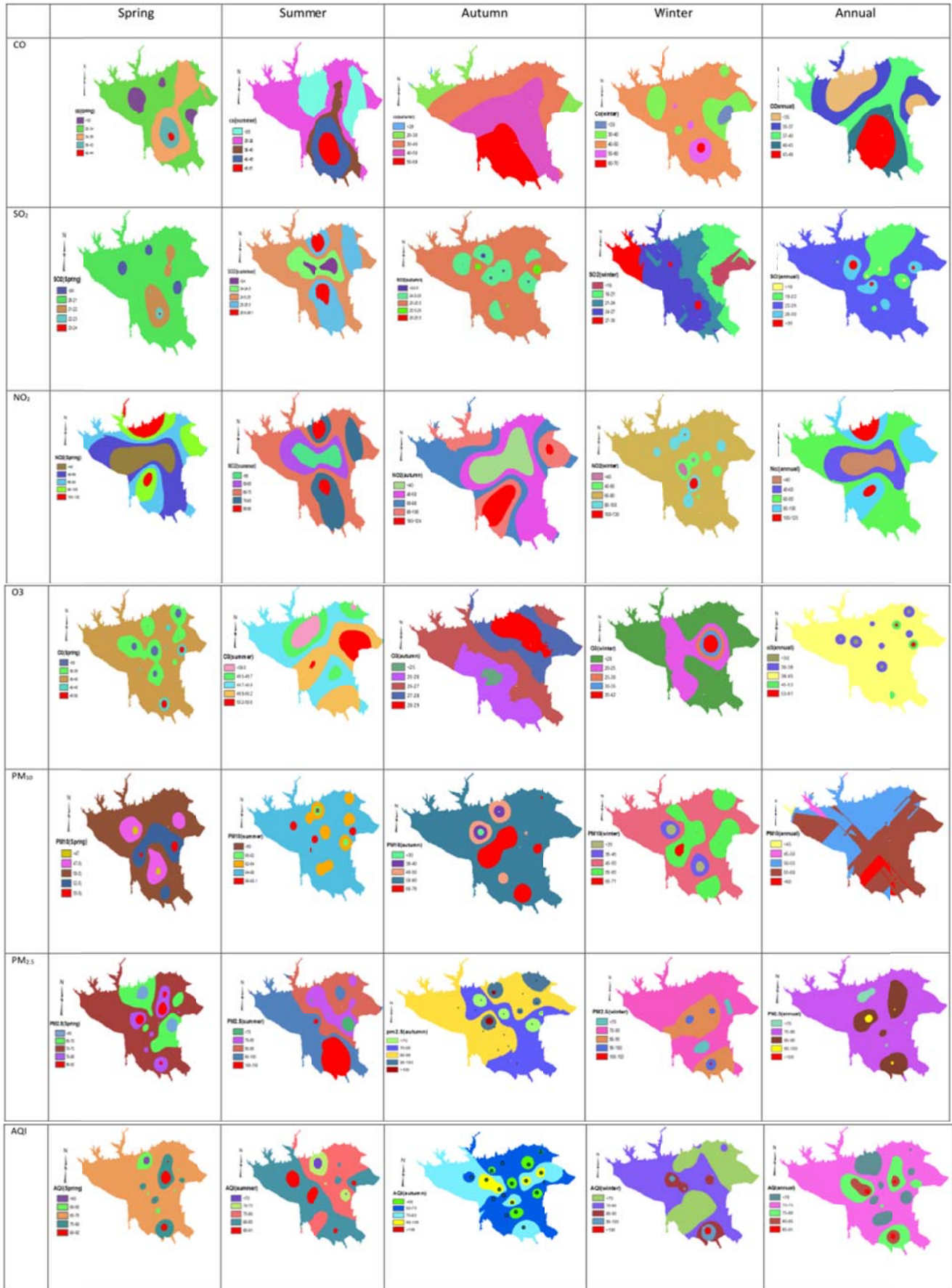


Fig. 2. Zoning of each pollutant with respect to the best interpolation method

List of abbreviations

IDW	Inverse Distance Weighting
GPI	Global Polynomial Interpolation
LPI	Local Polynomial Interpolation
RBF	Radial Basis Function
OK	Ordinary kriging
SK	Simple Kriging
UK	Universal Kriging
RMSE	Root Mean Square Error
ME	Mean error
CIR	Circular
SPH	Spherical
EXP	Exponential
GAUS	Gaussian
CRS	Completely Regularized Spline
SWT	<i>Spline With Tension</i>
<i>M</i>	Multiquadric
<i>IM</i>	<i>Inverse Multiquadric</i>
<i>TPS</i>	<i>Thin Plate Spline</i>

Financial supports

This study was financially supported by the Student Research Committee of Shahid Beheshti University of Medical Sciences.

Competing interests

The authors declare that there are no competing interests.

Acknowledgements

The authors would like to express their thanks to the Department of Environmental Health Engineering and Student Research Committee of School of Health and Safety for the financial support of this study.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission,

redundancy, etc.) have been completely observed by the authors.

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