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Modeling the Contamination of Soil Adjacent to Mohammed AL-Qassim Highway in Baghdad

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Abstract
The aim of this paper is to estimate the concentrations of some heavy metals in Mohammed AL-Qassim Highway in Baghdad city for different distances by using the polynomial interpolation method for functions passing from the data, which is proposed by using the MATLAB software. The sample soil in this paper was taken from the surface layer (0-25 cm depth) at the two sides of the road with four distances (1.5, 10, 25 and 60 m) in each side of the road. Using this method, we can find the concentrations of heavy metals in the soil at any depth and time without using the laboratory, so this method reduces the time, effort and costs of conducting laboratory analyzes.

Keywords: Contamination, Heavy metals, Polynomial, Interpolation method.

نمذجة لتلوث التربة المجاورة لطريق محمد القاسم السريع ببغداد

فرح فيصل غازي
قسم الرياضيات ، كلية التربية للعلوم الصرفة ابن الهيثم ، جامعة بغداد ، بغداد ، العراق

الخلاصه
الهدف من هذه الورقة هو تقدير تركيز بعض المعادن الثقيلة في طريق محمد القاسم السريع في مدينة بغداد لمسافة مختلفة باستخدام طريقة الاستيفاء متعدد الحدود للدالة التي تمر من البيانات المقترحة باستخدام برنامج MATLAB. تم أخذ عينة التربة في هذه الورقة من عمق الطبقة السطحية (0−25) سم على جانبي الطريق بأربعة مسافات (1.5 و 10 و 25 و 60) متر من كل جانب من جوانب الطرق. باستخدام هذه الطريقة يمكننا إيجاد تراكيز المعادن الثقيلة في التربة بأي عمق ووقت بدون استخدام المختبر ، لذا فإن هذه الطريقة تقلل من الوقت والجهد والتكاليف لإجراء التحليلات المختبرية.

1. Introduction

Since 2003, the number of vehicles imported to Iraq has been increased. These vehicles are considered to be one of the most important sources of elements of contamination, which leads to contamination of the environment.

Heavy metals in the soil are one of the most dangerous contaminants because of their direct impact on the environment. Such impacts take place through increasing toxic metals dissemination and gradual accumulation in the surrounding plants, animals, and humans, possibly causing death in some cases [1]. Many researchers studied the contamination in soil by heavy metals by using different methods [2-14].

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Therefore, we suggest here a mathematical model to estimate the levels of heavy metals in soil. The estimation method is designed to find the function of the mathematical model that describes the data. By this method, we could obtain an estimate, for different distances, of the concentrations of Nickel (Ni), Cadmium (Cd), Lead (Pb) and Zinc (Zn) without the need for laboratory to analyze soil samples.

This paper was carried out on the soil of the road sides of Mohammed AL-Qassim highway in Baghdad city.

2. Materials and Methods

2.1. Study area

Mohammed AL-Qassim is an old and famous highway road that built in 1981 in Baghdad city of Iraq (Figure-1). The climate of Iraq is hot and dry in the summer and cold and rainy in winter; the mean of rainfall rate is about 151.8 mm [15].

The average traffic density for Mohammed AL-Qassim highway was estimated to be 1200 car hour^{-1} passing the sampling sites over a period of 24 hours from 06:00 am to 06:00 pm for 3 days [16].

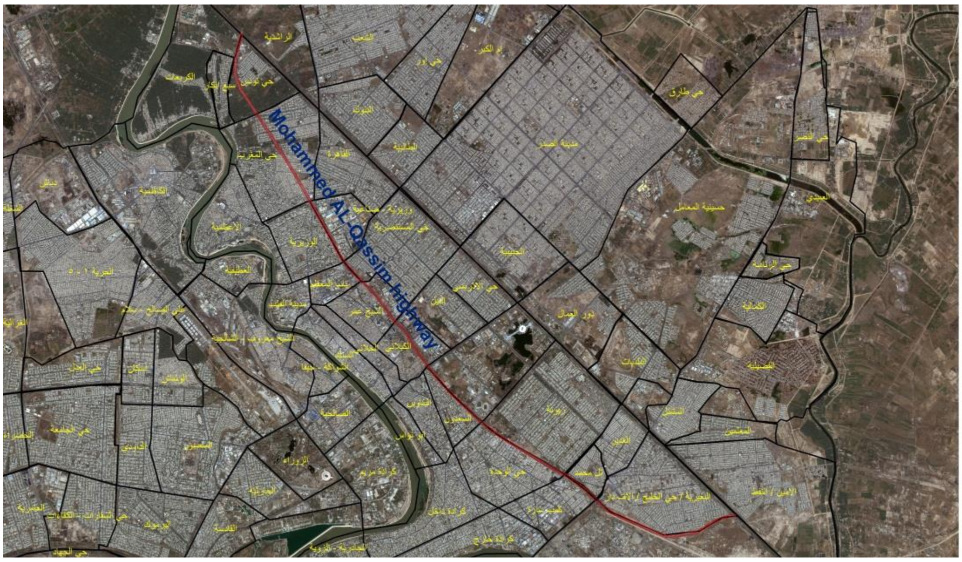
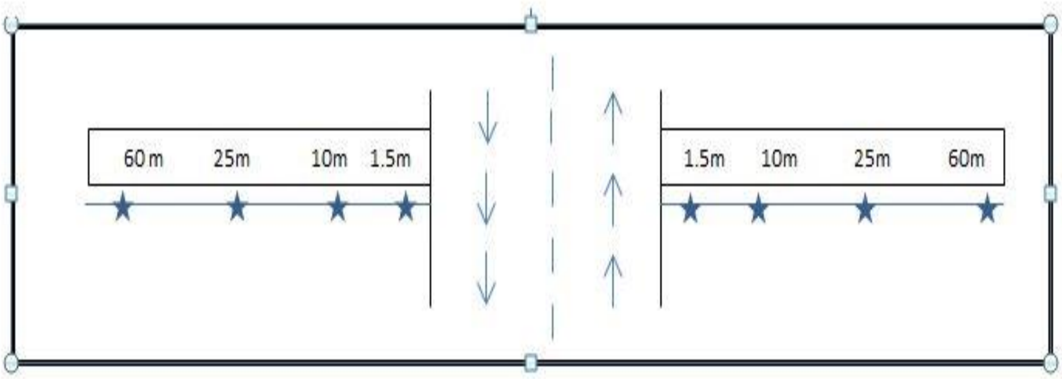


Figure 1- A map of Baghdad city showing Mohammed AL-Qassim highway**.**

2.2. Soil Sampling and Analyses

Nine soil samples were collected in different distance (0, 1.5, 10, 25 and 60 m) from both sides of the road with a depth range of 0-25 cm (Scheme 1).

Scheme1:- Soil samples taken from both sides of highway.



The samples were analyzed in the laboratory by Atomic Absorption Spectrophotometer (AAS) to measure the content of heavy metals and the results are demonstrated in Table-1.

Table 1-Total Cd, Zn, Pb and Ni concentrations ($mg.kg^{-1}$) along Mohammed AL-Qassim roadside soils at depth range of 0-25 cm.

	West road ← Distance from Road (m)				Central	East road → Distance from Road (m)			
HMs	**60**	**25**	**10**	**1.5**	**Zero**	**1.5**	**10**	**25**	**60**
Cd	2.26	2.19	2.51	2.36	1.77	2.18	1.35	1.31	1.06
Pb	85.0	93.0	90.0	102.0	89.0	93.0	102.0	95.0	104.0
Zn	56.0	63.0	148.0	171.0	97.0	124.0	146.0	45.0	103.0
Ni	248.0	213.0	159.0	184.0	164.0	132.0	151.0	143.0	122.0

In general, we observe from the table 1 that the higher concentrations of heavy metals appear in the distance of 1.5 m from the road for some metals. At distances more far away from the road, the concentrations of heavy metals become lower. This can be explained by the effects of vehicles, which are considered as one of the major sources of contamination to the environment.

2.3. Mathematical Method

From Table-1, we observe the descriptive statistics of the heavy metal data. The order of occurrence of concentration heavy metals measured in the studied soils followed the sequences of Cd < Pb < Zn < Ni at the distances of 0, 1.5 and 10 m on both road sides. The other distance values of 25 and 60 m followed the sequence of Cd < Zn < Pb < Ni.

In this paper, we used the interpolation method to find the value between the known data points. For example, this method is applied if we have two known data points, e.g. (D_0,C_0) and (D_1,C_1), and we want to estimate any value of C for a given value of D between these two data points. Fig. 2 shows the interpolated value of D green point, within the range of known data points. To determine the unknown value of C, we first find the function (D) that passes through these known points, which is calculated by using MATLAB Interpolation technique. This function value can be determined for any value of D between the points (D_0,C_0) and(D_1,C_1) .

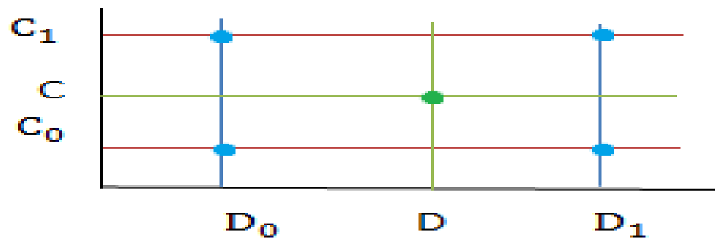


Figure 2-The polynomial interpolation.

In general, when we consider that (D_i, C_j) are given as:

D_i ; $i = 0,1,2 , \dots , m$ and C_j ; $j = 0, 1,2, \dots , n$

We find the function passing through the data for (D_i, $f(D_i) = C_j$) for the concentrations of heavy metals, ∀ i=1, 2, 3, …, 5, by using theorem 2.4.

2.4. Theorem: the fundamental theorem of algebra

For the point $(xi, f(xi)), i = 1, 2, \dots , n$ there is a unique polynomial passing through the given point of degree at most n-1, and the interpolating polynomial is written as:

$$P(x) = f(x) = a_1 + a_2x + a_3x^2 + + \cdots + a_nx^{n-1} \quad (1)$$

Hence, we have a polynomial passing through the data from the west side of the road and another polynomial passing through the data from the east side of the road. Each concentration of heavy metals has one polynomial that is different for the other polynomial for the 4th degree .

$$P(D) = f(D) = C = a_1 + a_2D + a_3D^2 + a_4D^3 + a_5D^4 \quad (2)$$

This polynomial of degree 4 has 5 coefficients and the basic functions are:

$$f_1(D) = C_1 = 1, \ f_2(D) = C_2 = D, f_3(D) = C_3 = D^2, f_4(D) = C_4 = D^3,$$
$$f_5(D) = C_5 = D^4 \quad (3)$$

For data of distances $D_1,\ D_2,\ D_3,\ D_4,\ D_5$ the basis matrix is

$$\begin{bmatrix} 1 & D_1 & {D_1}^2 & {D_1}^3 & {D_1}^4 \\ 1 & D_2 & {D_2}^2 & {D_2}^3 & {D_2}^4 \\ 1 & D_3 & {D_3}^2 & {D_3}^3 & {D_3}^4 \\ 1 & D_4 & {D_4}^2 & {D_4}^3 & {D_4}^4 \\ 1 & D_5 & {D_5}^2 & {D_5}^3 & {D_5}^4 \end{bmatrix} . \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} = \begin{bmatrix} f(D_1) = C_1 \\ f(D_2) = C_2 \\ f(D_3) = C_3 \\ f(D_4) = C_4 \\ f(D_5) = C_5 \end{bmatrix} \quad (4)$$

We used that method to compute the concentrations of heavy metals among the data in that paper to find the function passing through that data by using MATLAB version 18b.

Example 1: We apply that method on the data of the concentration of Cd. Eq. (5) and Figure-3. represent the function passing through the data for Cd from the west side, while Eq. (6) and Figure-4 show the function passing through the data of Cd from the east side.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1.5 & 1.5^2 & 1.5^3 & 1.5^4 \\ 1 & 10 & 10^2 & 10^3 & 10^4 \\ 1 & 25 & 25^2 & 25^3 & 25^4 \\ 1 & 60 & 60^2 & 60^3 & 60^4 \end{bmatrix} . \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} = \begin{bmatrix} 1.77 \\ 2.36 \\ 2.51 \\ 2.19 \\ 2.25 \end{bmatrix} \quad (5)$$

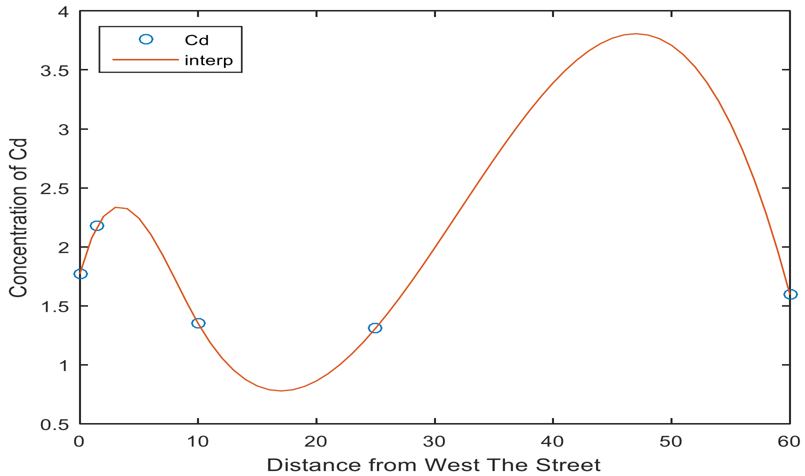


Figure 3-The interpolation function which passes through the data for Cd from the west side of the street.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1.5 & 1.5^2 & 1.5^3 & 1.5^4 \\ 1 & 10 & 10^2 & 10^3 & 10^4 \\ 1 & 25 & 25^2 & 25^3 & 25^4 \\ 1 & 60 & 60^2 & 60^3 & 60^4 \end{bmatrix} . \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} = \begin{bmatrix} 1.77 \\ 2.18 \\ 1.35 \\ 1.31 \\ 1.06 \end{bmatrix} \quad (6)$$

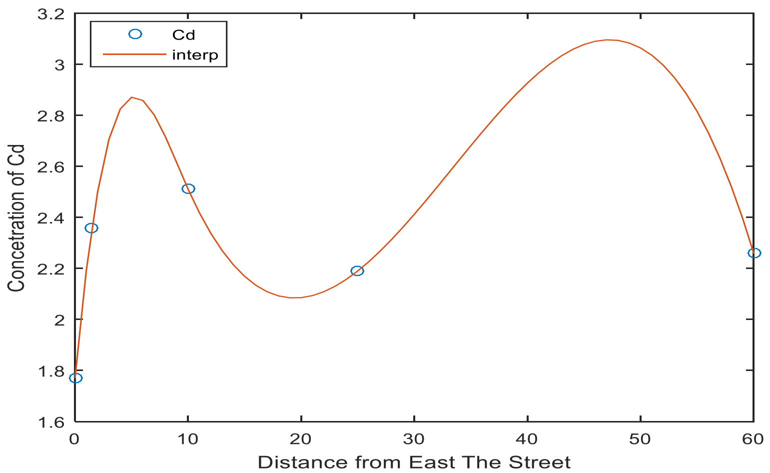


Figure 4- The interpolation function which passes through the data for Cd from the east side of the street.

Example 2:- Now we apply the method on the data of the concentration of Pd Eq. (7) and the Figure-5 represent the function passing through the data for Pb from the west side, while Eq. (8) and Figure-6 show the function passing through the data of Pb from the east side.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1.5 & 1.5^2 & 1.5^3 & 1.5^4 \\ 1 & 10 & 10^2 & 10^3 & 10^4 \\ 1 & 25 & 25^2 & 25^3 & 25^4 \\ 1 & 60 & 60^2 & 60^3 & 60^4 \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} = \begin{bmatrix} 89.0 \\ 102.0 \\ 90.0 \\ 93.0 \\ 85.0 \end{bmatrix} \quad (7)$$

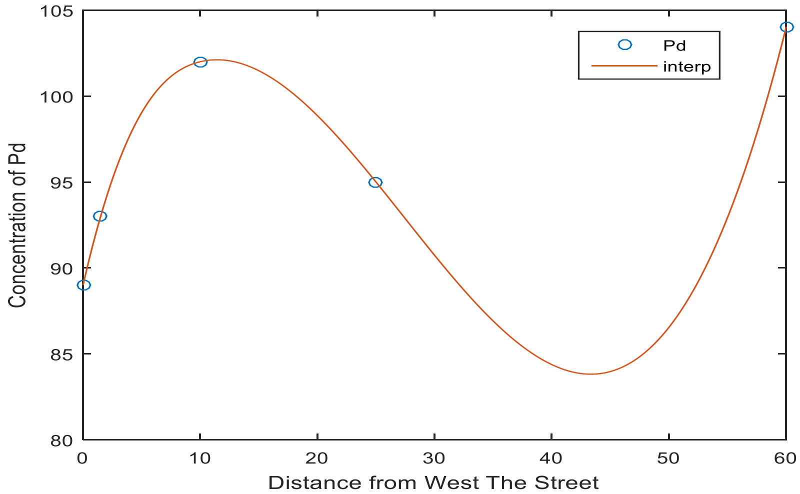


Figure 5- The interpolation function which passes through the data for Pb from the west side of the street.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1.5 & 1.5^2 & 1.5^3 & 1.5^4 \\ 1 & 10 & 10^2 & 10^3 & 10^4 \\ 1 & 25 & 25^2 & 25^3 & 25^4 \\ 1 & 60 & 60^2 & 60^3 & 60^4 \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} = \begin{bmatrix} 89.0 \\ 93.0 \\ 102.0 \\ 95.0 \\ 104.0 \end{bmatrix} \quad (8)$$

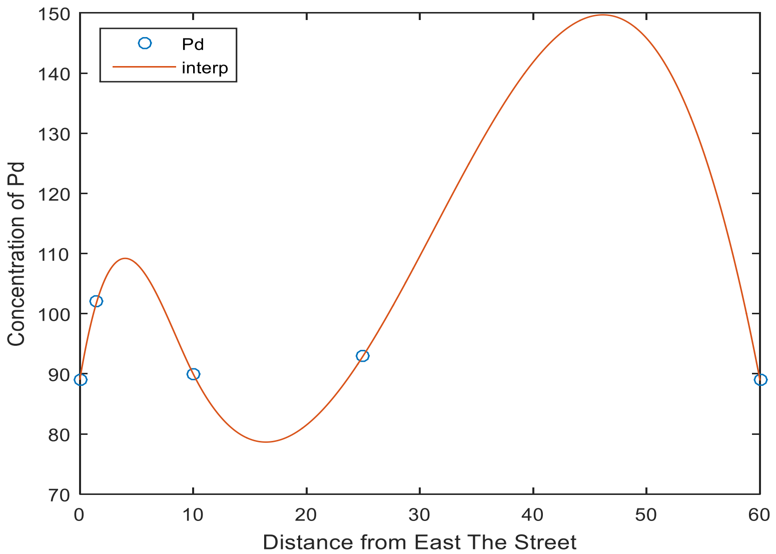


Figure 6-The interpolation function which passes through the data for Pb from the east side of the street.

Example 3: Here we apply the method on the data of the concentration of Zn. Eq. (9) and the Figure-7 represent the function passing through the data for Zn from the west side, while Eq. (10) and Figure-8 show the function passing through the data of Zn from the east side.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1.5 & 1.5^2 & 1.5^3 & 1.5^4 \\ 1 & 10 & 10^2 & 10^3 & 10^4 \\ 1 & 25 & 25^2 & 25^3 & 25^4 \\ 1 & 60 & 60^2 & 60^3 & 60^4 \end{bmatrix} . \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} = \begin{bmatrix} 97.0 \\ 171.0 \\ 148.0 \\ 63.0 \\ 56.0 \end{bmatrix} \qquad (9)$$

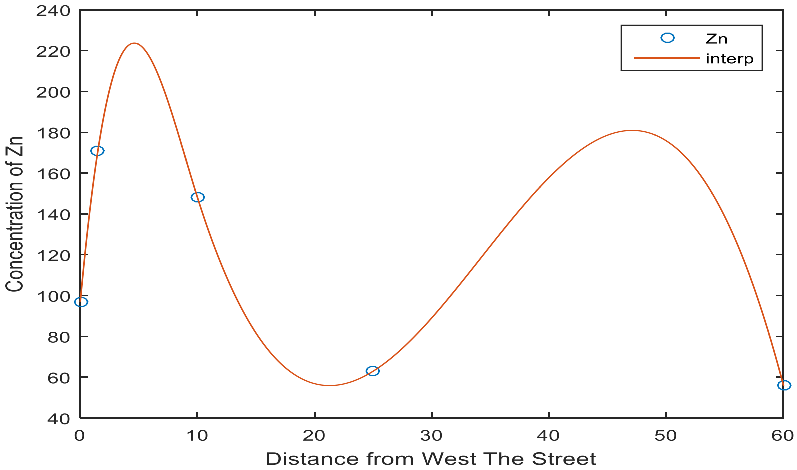


Figure 7-The interpolation function which passes through the data for Zn from the west side of the street.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1.5 & 1.5^2 & 1.5^3 & 1.5^4 \\ 1 & 10 & 10^2 & 10^3 & 10^4 \\ 1 & 25 & 25^2 & 25^3 & 25^4 \\ 1 & 60 & 60^2 & 60^3 & 60^4 \end{bmatrix} . \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} = \begin{bmatrix} 97.0 \\ 124.0 \\ 146.0 \\ 45.0 \\ 103.0 \end{bmatrix} \qquad (10)$$

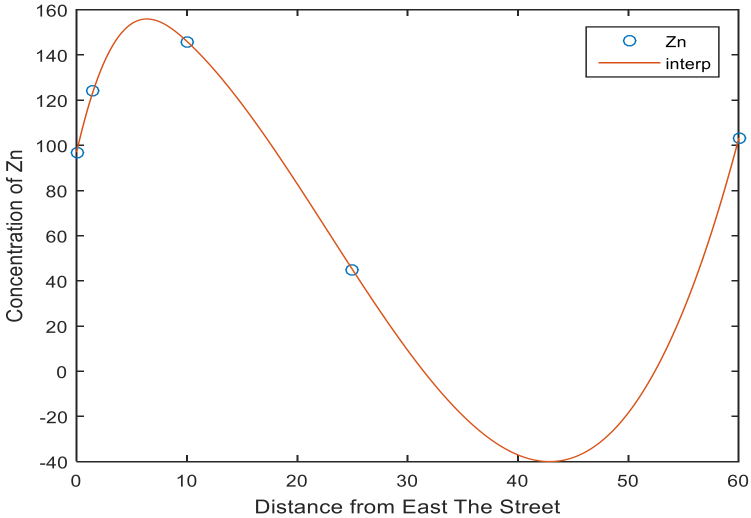


Figure 8-The interpolation function which passes through the data for Zn from the east side of the street.

Example 4: We apply here the method on the data of the concentration of Ni. Eq. (11) and Figure-9 represent the function passing through the data for Ni from the west side, while Eq. (12) and Figure-10 show the function passing through the data of Ni from the east side.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1.5 & 1.5^2 & 1.5^3 & 1.5^4 \\ 1 & 10 & 10^2 & 10^3 & 10^4 \\ 1 & 25 & 25^2 & 25^3 & 25^4 \\ 1 & 60 & 60^2 & 60^3 & 60^4 \end{bmatrix} . \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} = \begin{bmatrix} 164.0 \\ 184.0 \\ 159.0 \\ 213.0 \\ 248.0 \end{bmatrix} \qquad (11)$$

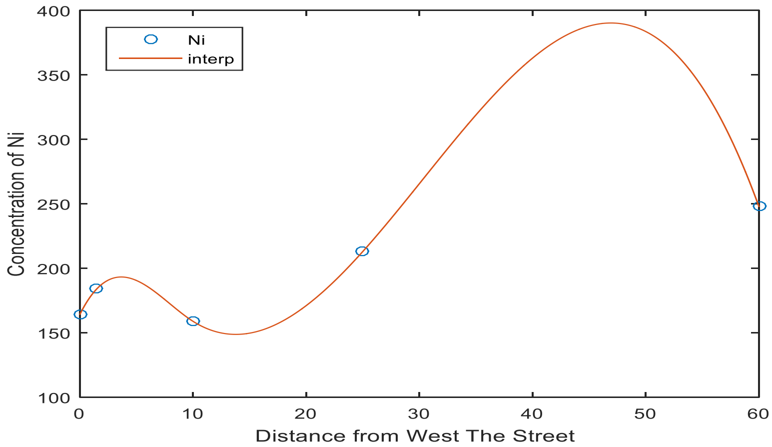


Figure 9-The interpolation function which passes through the data for Ni from the west side of the street.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1.5 & 1.5^2 & 1.5^3 & 1.5^4 \\ 1 & 10 & 10^2 & 10^3 & 10^4 \\ 1 & 25 & 25^2 & 25^3 & 25^4 \\ 1 & 60 & 60^2 & 60^3 & 60^4 \end{bmatrix} . \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} = \begin{bmatrix} 164.0 \\ 132.0 \\ 151.0 \\ 143.0 \\ 122.0 \end{bmatrix} \quad (12)$$

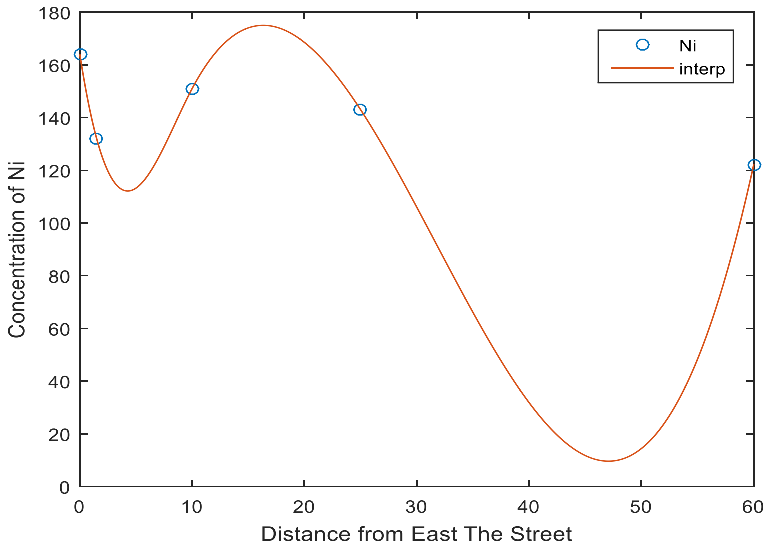


Figure 10- The interpolation function which passes through the data for Ni from the east side of the street.

3. Conclusions

We used the polynomial interpolation method to find the polynomial passing from the data of the concentration of heavy metals in Mohammed AL-Qassim Highway in Baghdad city. From this polynomial, data for concentrations of heavy metals in the soil could be found, just by appointing a point at any distance for which heavy metals content is to be estimated, as calculated by using MATLAB Interpolation technique and without using laboratory.

This method to determine the concentrations of heavy metals in the soil is important because it reduces times, effort and costs. When compared with the laboratory methods, there was a small proportion of error (0.01) as compared to the real data.

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