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STREET DUST CONTAMINATION BY HEAVY METALS IN BABYLON GOVERNORATE, IRAQ

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Abstract

Due to the rapid population growth, advanced technology and continued urbanization worldwide, heavy metals are emitted into the ecosystem and cause negative impacts on health. This study represents the determination of street dust heavy metals copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), nickel (Ni) and chromium (Cr) in thirty sites in Babylon governorate, Iraq and investigates the possible sources of the pollution. The analysis was carried out by using flame atomic absorption spectrophotometer after the digestion process. The average concentration of Cu, Pb, Zn, Cd, Ni and Cr in the street dust were found to be 130.9, 201.4, 253.3, 2.2, 49.1 and 69.1 mg/kg, respectively. After performing a comparison with the mean of worldwide scale and values for uncontaminated soil, the findings indicated that there were high heavy metals concentrations in all sites. The main cause is the increased traffic across all areas which makes the vehicles disposed of different elements in the street dust. Moreover, the absence of regulation and lack of basic sewer and rain networks play a significant role to increase the heavy metals concentrations in the city. This research promotes a baseline data for heavy metals pollution in Babylon street dust which could afford to policymakers in order to adopt urgent environmental management strategies such as increasing green area and implementing new technologies to reduce environmental risks.

Keywords: Babylon, Concentration, Heavy metals, Pollution, Pollution Index, Street dust.

1. Introduction

Heavy metals (HMs) are considered to be toxic compounds and can accumulate in the soil with influencing the environment nearby [1; 2] as well as contributing to the pollution of industrial and agricultural sectors [3-5]. Studies have widely investigated heavy metals due to their effects on health and the environment [6-8]. Anthropogenic activities such as mineral fertilizer, sewage sludge and industrial activities [8-11] along with landfills [12-14] are possible sources for HMs accumulation in the topsoil [15-18]. Moreover, vehicles emission and non-exhaust emissions are the common sources of HMs in street dust [19]. Several studies stated that the elevated HMs concentrations in the street dust were due to traffic flow densities, which included disposed of metals from tires, suspended dust, as well as brakes linings, wears. On the other hand, climate change atmospheric activities such as wind and runoff are playing an important role in transporting of pollutant, such as heavy metals [20-27]. Thus, the content of street dust is a variety of pollutants that came from different sources whether anthropogenic or atmospheric activities [28].

Over the past few decades, there have been intensive studies regarding developing heavy metals removal from aqueous media. These studies employed different mitigation techniques such as adsorption [29-32], electrochemical methods [33-39], filtration [40-44], biological reactors [45; 46] as well as hybrid technologies [47-49]. Also recycling of polluted materials is an option to remove heavy metals [50-53]. Adsorption is widely adapted by researchers between all these techniques it is easy to conduct and inexpensive. The conventional adsorbents for heavy metals mitigation included a wide variety of techniques such as layered double hydroxides, activated carbons, clays, graphene oxides, zeolites and carbon nanotubes [42-44]. Nevertheless, conventional adsorbents are suffering from fragile binding affinity, low HMs adsorption capacity and low selectivity. Moreover, in the case of adsorbents modification, there are still suffering from tedious preparation as well as high-cost consumptions [40-42]. Another widely employed technologies for heavy metals elimination especially with the influence of runoff that can end up HMs in water bodies is water sensitive urban design such as bioretention and permeable paving [54]. That could potentially reduce the pollutants headed to the water bodies during runoff. Moreover, applying these technologies with increasing plantation could be a suitable solution for developing countries to alleviate heavy metals concentration especially in the areas where there is a lack in the infrastructure.

In Iraq and in addition to anthropogenic effects, the dust storm has a significant impact on the topsoil surface as during spring and summer seasons, the wind speed records 19.7 km/h [55] which can transport different sizes of materials including the heavy metals from several sources. The accumulation of these metals on the topsoil for a long period has negative impacts on health and environment for the urban city [56]. Therefore, the concentration of six heavy metals copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), nickel (Ni) and chromium (Cr) have been determined in Babylon street dust in thirty sites included a vital location which is ancient ruins of Babylon, a heritage site. Furthermore, it assesses the pollution level and evaluates the environmental quality of sites for the six heavy metals by employing the Geo Accumulation Index (GAI) and Pollution Index (PI) methods. Such a study that takes into account different area size which provides an informative benchmark for heavy metals pollution in Babylon street dust.

2. Methodology

2.1. Area description

The present study was conducted in Babylon governorate which located 100 km south of Baghdad governorate, capital of Iraq. Babylon governorate total area is 5315 km2 which represents between longitudes (44o2'43"E and 45o12'11"E) and latitudes (32o5'41"N and 33o7'36 "N) [57; 58]. Al-Mahawil, Al-Musayiab, Al-Hillah, Al-Qasim and Al-Hashimiyah are the main cities in Babylon governorate. Furthermore, the total population in the Babylon governorate in 2016 was about 2.15 million. A world heritage site named as Ancient Ruins of Babylon was also included in the Sampling locations [57; 58]. The selected streets are mainly surrounded by residential, farmland, industrial, petrol station as well as commercial activities.

2.2. Sample collection and preparation

A total of 30 street dust samples were collected in this study from different sites in Babylon governorate as it is illustrated in Table 1. The sampling process occurred when the street dust was dry which was in July 2019, the summer season in Iraq. In order to analyse the samples by the flame atomic absorption spectrophotometer (Shimadzu AAS, model AA-6200, Japan), 100 g of a soil sample from the sites collected by using polyethylene brush and tray. They were sieved through 2.00 mm mesh to remove all debris, including hair, leaves, plastic pieces as well as woods. Then, they were stored in labelled polyethylene bags and transported to the laboratory. Several literatures worldwide have examined HMs concentrations in the soil. Therefore, the experimental procedures were followed the steps reported previously [59]. The samples were dried at 105 ºC for 5 hours and sieved after cooling with a 2.00 mm mesh stainless-steel sieve. A proportion of street dust sample (~ 1 g) was subjected to a temperature of 350 ºC for 30 min following by refluxing the samples with 25 ml of 25% HNO3 for about 15 min [60]. After the samples being left at room temperature to cool down, they were passed through Whatman filter paper (42) with a further dilution of 1% HNO3 till the sign. The analysis was carried out by using Flame atomic absorption spectrophotometry. Eight standard solutions with various concentrations in a 2 M HNO3 for each element (Cu, Pb, Zn, Cd, Ni and Cr) were prepared. Moreover, setting minimum detection limits for (Cu, Pb, Zn, Cd, Ni and Cr) was 0.02, 2.00, 0.5, 0.3, 1.00, 0.5 µg/L respectively. An average of four replicates readings of each element measurement was taken after checking with the standard solutions and blanks samples. The allowable standard deviation range for the results was between 4 to 8 % and the standard solution precision was better than 4 %. Prior to the experiments and in order to remove any impurities, tools were prewashed with distilled water and Nitric acid.

3. Results and Discussion

The concentrations of Cu, Pb, Zn, Cd, Ni and Cr in the street dust in Babylon governorate illustrated in Fig. 1. Each heavy metal presents a various range of values. The concentrations of Cu, Pb, Zn, Cd, Ni and Cr in street dust were ranged from 110.0 to 158.5, 155.5 to 300.9, 184.0 to 385.5, 0.9 to 4.8, 33.0 to 73.5 and 23.7 to 126.4 mg/kg with average concentrations of 130.9, 201.4, 253.3, 2.2, 49.1 and 69.1 mg/kg respectively. Due to increased runoff in the city during winter and the lack of basic rain networks, there might be an increase and/or decrease in the concentrations of heavy metals in these sites.

Table 1. Site's Demographic information of Babylon Governorate, Iraq.

Locations	Site No.	Latitude	Longitude	Description
Road Al-Hillah-Najaf	1	32°13'37.2"N	44°23'02.2"E	Main Road, near Al-Kefel, Heavy Traffic Densities
Garage Al-Mouhad	2	32°27'33.7"N	44°24'35.0"E	Vehicles station
Al-Muhandessen Suburb	3	32°27'00.4"N	44°24'02.0"E	Residential area
Nader Suburb	4	32°26'51.9"N	44°25'40.4"E	Residential area
Al-Askan Suburb	5	32°28'02.6"N	44°25'16.5"E	Residential area (near Electricity generation)
Al-Akrameen Suburb	6	32°27'43.6"N	44°23'56.0"E	Residential area
Al-Tohmaziaa Suburb	7	32°27'49.0"N	44°22'34.8"E	Residential area
Nader Bridge	8	32°26'43.5"N	44°25'08.5"E	Heavy Traffic Densities
Al-Thowra Bridge	9	32°29'50.7"N	44°25'12.4"E	Commercial markets nearby, Heavy Traffic Densities
Betta Bridge	10	32°31'00.0"N	44°25'53.5"E	Heavy traffic Bridge
Al-Shawi Street	11	32°28'11.2"N	44°26'02.6"E	Minor Road, Commercial activities, Heavy Traffic Densities
30 Street	12	32°26'11.3"N	44°24'13.0"E	Minor Road
80 Street	13	32°30'04.8"N	44°24'22.0"E	Main Street, Commercial activities
Abo Gharaq	14	32°32'15.1"N	44°20'08.6"E	Semi-urban Area
Ancient Ruins of Babylon	15	32°32'28.8"N	44°25'26.1"E	Heritage site
Al-Jamhori Suburb	16	32°39'42.2"N	44°24'01.0"E	Residential area
Al-Zahraa Suburb	17	32°38'55.2"N	44°25'09.2"E	Residential area
Al-khather Mosque	18	32°41'27.1"N	44°25'40.0"E	Holly place, Farmland
Sadda Road	19	32°41'04.7"N	44°23'15.2"E	Heavy traffic, Farmland
Al-Mowathafeen Suburb	20	32°45'11.0"N	44°16'34.8"E	Residential area
Saddat Al-Hindiyah	21	32°42'44.2"N	44°16'36.7"E	Bridge
Albu Hamdan Suburb	22	32°47'01.4"N	44°16'46.9"E	Residential area
Al-Mashroaa Road	23	32°47'54.7"N	44°24'32.0"E	Heavy density street, near residential area
Al-Amana Suburb	24	32°22'14.4"N	44°39'21.3"E	Residential area
Al-Dabla	25	32°23'01.2"N	44°32'07.9"E	Farmland, Residential area
Al-Ihsaen	26	32°23'34.1"N	44°32'15.2"E	Residential area, Farmland
Al-Mazedia Village	27	32°22'46.2"N	44°37'50.2"E	Residential area, Farmland
Al-shomali	28	32°19'38.2"N	44°55'08.6"E	Residential area
Al-Qasim	29	32°18'11.5"N	44°41'04.3"E	Residential area
Green University of Al Qasim	30	32°18'20.0"N	44°40'38.3"E	University

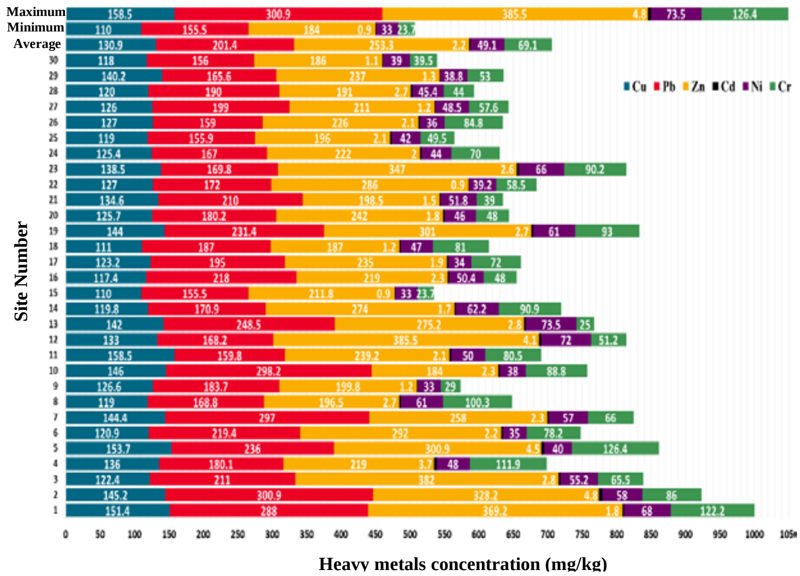

Fig. 1. Effect of forebody shape on the aerodynamic characteristics.

4.1. Copper

Copper is a heavy metal that used widely in various application due to its physical characteristics and low toxicity to health [61]. It is associated with fabricated metal producers, leather factories and landfills [14; 61]. Copper concentrations in Babylon governorate sites were between 110.0 to 158.5 mg/kg with an average of 130.9.

4.2. Lead

It is well known that lead presents in small proportion in the earth's crust and it can be founded in water, soil as well as the plant. Pb also used in agriculture sector particularly in fertilizers and pesticides as well as its application in enhancing the octane rating of gasoline in vehicles [62]. Anthropogenic activities such as burning fossil fuel, factories emission as well as mining increase the metal content in the soil as it is associated with approximately 900 industries. Regarding acute exposure to lead, the increased level can result in many issues such as fatigue, arthritis, vertigo, renal dysfunction and hallucinations while chronic exposure to this metal can cause for example birth defects, autism, brain and kidney damage, psychosis, dyslexia and intellectual disability. The calculated Pb range in all sites was between 155.5 to 300.9 mg/kg with an average value of 201.4 mg/kg. Furthermore, the standard Pb value in uncontaminated soil in an average world scale is 44 mg/kg. Moreover, as indicated in Fig. 2, the average value is higher than the concentrations reported elsewhere Kuwait, Turkey, Saudi and Iran [63; 64]. The maximum Pb value was detected at the Garage Al-Mouhad (300.9 mg/kg) as it is represented main vehicles station for the city with frequent departure to most of the Iraqi provinces. Moreover, other locations (namely 1, 3, 5, 6, 7, 10, 13, 16, 19 and 21) had high Pb values with above 200 mg/kg. The increased content of lead in the street dust is associated with the fact that Iraqi vehicular traffic system is still using lead to improve the octane rate of gasoline. In addition, approximately 75% of this added lead finds its way to the atmosphere as it is disposed of by vehicles exhaust.

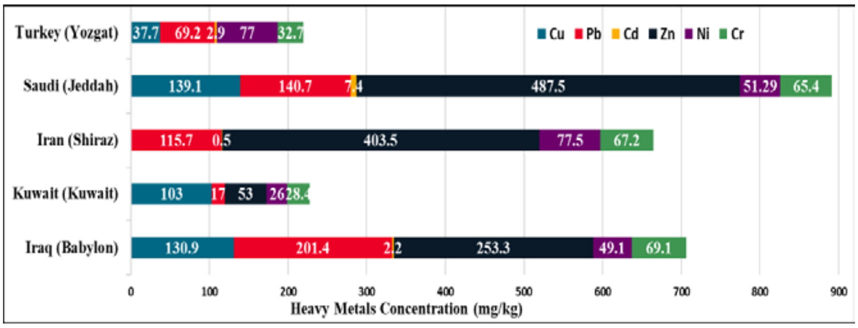

Fig. 2. Average heavy metals concentration (mg/kg) in street dust for Turkey, Saudi, Iran, Kuwait, and Iraq.

4.3. Zinc

The exceed zinc concentration in the soil is mainly due to anthropogenic activities such as industries related to fertilizers and pesticides, liquid manure as well as composted materials [62]. Zn is also used in the production of brass alloy in the vehicles, which come from different parts such as brake linings, oil leak sumps as well as cylinder head gaskets [44]. The typical world range for total Zn in the soil is between 10 – 300 mg/kg [38]. However, it was stated that the uncontaminated Zn concentration in the soil is 100 mg/kg. The Zn concentrations range in all sites was between 184.0 to 385.5mg/kg with an average of 253.3 mg/kg. The highest Zn value was found in 30 Street (site number 12) with a concentration of 385.5 mg/kg as this location near an automobile repair shops. In addition, sill other sites (1, 2, 3, 5, 19 and 23) has Zn concentration above 300 mg/kg. Moreover, as indicated in Fig. 2, the average value of Zn is lower than the concentrations reported elsewhere Iran and Saudi and it is higher than the concentration reported in Kuwait and no recorded concentration for Turkish area [63; 64]. Zn high-level consternation in some sites is due to brake lining wear, carburettors and lubricating oils and motor vehicle tires that can be clearly observed in all sites because of heavy traffic.

4.4. Cadmium

Cd considers a mobile and toxic metal that can accumulate in the body over a while with causing chronic effects [62]. Furthermore, it has been used widely in plastic stabilizer, paint, pigments as well as electroplating. Anthropogenic activities can increase the amount of Cd in the environment via wastewater irrigation, sludge, fertilizer as well as solid waste from different industries [62]. Cadmium has been determined by several researchers through analytical surveys to obtain the worldwide mean. It was founded to be 0.53 mg/kg for uncontaminated soil; therefore, any concentration above this value could have negative impacts on health. Moreover, urbanization, as well as agriculture activities, could elevate the level of Cd in the area nearby. The Cd detected value in the selected locations was varied from 0.9 to 4.8 mg/kg and the average concentration was 2.2 mg/kg and observed to be higher than the worldwide mean in all sites. Location 2 recorded nine-fold the worldwide mean followed by site number 5 with 4.5 mg/kg and location number 12 with a value of 4.1 mg/kg. Furthermore, Fig. 2 shows that the average value of Cd is higher than the concentration reported in Iran and it is lower than the concentration reported in Saudi and Turkey [63; 64] with no value recorded in Kuwait. It is well known that the accumulation of Cd in the soil is due to agricultural amendments, sludge as well as atmospheric deposition. Thus, it is noticed that raising Cd concentration is most Babylon governorate streets are either unpaved or paved with a rough surface, which increases Cd emission form tries degradation via lubrication.

4.5. Nickel

There are many natural resources for Ni such as windblown soil, vegetation, forest fires, sea salt, meteoric dust and volcanoes. Ni compounds are usually released to the environment by the combustion of coal-burning stages and oil residual. Moreover, it is fundamental metal in several industries including battery manufactures, stainless steel operation, electroplating, nickel alloys manufacturing as well as nickel primary production [62]. Furthermore, its toxicity remains not very high but under the exceeded limit can cause respiratory diseases. However, certain nickel compounds listed as carcinogenic metals. Ni concentration range in this work was varying between 33 to 73.5 mg/kg with an average of 49.1 mg/kg. The determined world mean for Ni in uncontaminated soil is 34 mg/kg which if compared with the detected Ni values in all sites, only two sites (9 and 15) were below the world mean value. However, other sites were slightly higher than the world record. Furthermore, Fig. 2 represents that the average value of Ni in this study is lower than the values that reported elsewhere Iran, Saudi and Turkey and higher than the one reported in Kuwait [63; 64]. The high level of Ni is mainly because of the corrosion of the nickel-containing part in the vehicles.

4.6. Chromium

Chromium is considered a low mobility heavy metal particularly when it is under a moderate oxidizing and reducing conditions as well as under natural pH. This element enters into the ecosystem from various natural and anthropogenic sources with a great proportion emitted from industrial sectors [62]. These are chromate production, pigments, textile, ceramics, dyes, tannery facilities, metals processing, glues as well as wood preserving. Besides, chromium used in a cooking system as anticorrosive material. The released Chromium for anthropogenic activities is a hexavalent form Cr (VI) that is toxic, carcinogenic industrial metal. The Cr concentrations in this work were varying from 23.7 to 126.4 mg/kg with an average of 69.1 mg/kg. The Cr findings indicated that about 33% of the sites recorded values more than the average global value (84 mg/kg) and higher than the world scale for uncontaminated soil (83 mg/kg). Furthermore, Fig. 2 shows that the average concentration of Cr is higher than the values that reported elsewhere Kuwait, Iran, Saudi and Turkey [63; 64].

4.7. Pollution Index (*PI*)

This index is used to evaluate the environment quality of the soil, which is also known as Single Element Pollution Index (SEPI). It is defined as the ratio of the metal in the soil to permissible level of metal. The equation used for this index as followed

$$PI = \frac{\text{metal content in soil}}{\text{permissible level of metal}} \quad (1)$$

Classification of this index is either low contamination ($PI \leq 1$), moderate contamination ($1<PI\leq3$) or high contamination $PI>3$ [59]. Figure 3 illustrates the sites pollution index and it is divided into three coloured areas. The results (Fig. 3) showed that both Cu and Pb exhibited the highest values in all locations with ranging between 4.6 to 6.6 and 3.5 to 6.8 for Cu and Pb respectively. According to pollution index classification, they are located in high contamination zone as all values are more than 3. On the other hand, Zn pollution index vales showed both moderate and high contamination. PI for sites number 1, 2, 3, 12 and 23 represent high contamination as their value more than 3 while others are located in classification with moderate pollution. PI values for Cd also varied from high to moderate contamination. About 73% of PI values, precisely sites 1 to 8, 10 to 14, 16, 17, 19, 20, 23 to 26 and 28 recorded the highest index with high contamination while the rest sites exhibited in calcification with moderate pollution. Moreover, regarding Ni values, all sites are within the moderate pollution. Finally, pollution index results regarding Cr showed that the values are located in two zones; low and moderate contamination. Eight sites, namely 1, 4, 5, 8, 10, 14, 19, and 23 are classified as moderate pollution, while the rest of sites are classified as low pollution.

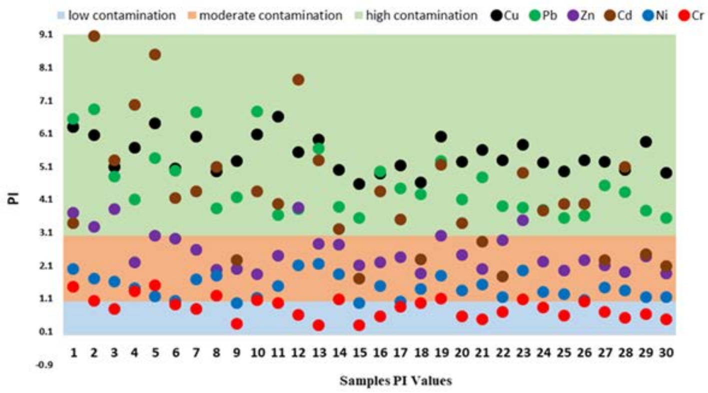

Fig. 3. Single element pollution index for the samples.

4.8. Geo Accumulation Index (GAI)

This index assesses the pollution by comparing the level of the heavy metals to their background values, which was used by past literatures [65; 66] to assess the Igeo of road soil contamination. It is expressed in the following equation

$$\text{Geo Accumulation Index } = Ln\left(\frac{Cm}{1.5\ Bm}\right) \tag{2}$$

where: *Cm*: the mean concentration of heavy metal in the soil, and *Bm*: Background value of the heavy metals. In the equation above, it was used the worldwide average concentration for the selected heavy metals by adopting from the literature [63; 64] as there have not reported yet any background values for the selected province. The results presented in Fig. 4 are taken into consideration two classification regions in Geo Accumulation Index (GAI) as the calculated values for the selected heavy metals are only located in these two areas. Cu recoded moderately contaminated (M) in all site with minimum value of 1.1 and maximum value of 1.5. Furthermore, most sites of Pb (sites 1, 2, 3, 5, 7, 10, 13, 16, 17, 19 and 21) were moderately polluted sites while the rest were uncontaminated to moderately contaminate (U-M). Zn Geo Accumulation Index values in all sites were uncontaminated to moderately contaminate. Cd and Ni were varied between classification numbers 1 to 2 and 0 to 1, respectively. Finally, Cr in all sites was classified as class 0, practically uncontaminated.

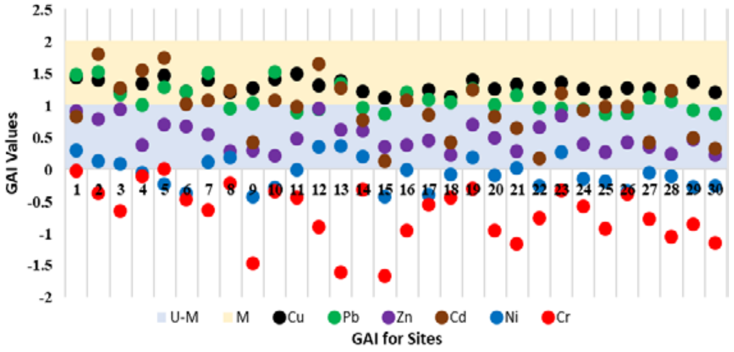

Fig. 4. Geo Accumulation Index (GAI) for samples.

4.9. Geo Accumulation Index (GAI)

In the equation above, it was used the worldwide average concentration for the selected heavy metals by adopting from the literature [63; 64] as there have not reported yet any background values for the selected province. The results presented in Fig. 4 are taken into consideration two classification regions in Geo Accumulation Index (GAI) as the calculated values for the selected heavy metals are only located in these two areas. Cu recoded moderately contaminated (M) in all site with minimum value of 1.1 and maximum value of 1.5. Furthermore, most sites of Pb (sites 1, 2, 3, 5, 7, 10, 13, 16, 17, 19 and 21) were moderately polluted sites while the rest were uncontaminated to moderately contaminate (U-M). Zn Geo Accumulation Index values in all sites were uncontaminated to moderately contaminate. Cd and Ni were varied between classification numbers 1 to 2 and 0 to 1, respectively. Cr in all sites was classified as class 0, practically uncontaminated. Finally, sensing technology, which has recently witnessed substantial developments [67-70], could be used to monitor heavy metals concentration near to the roads.

4. Conclusions

This study was carried out at Babylon governorate, Iraq on thirty street dust samples from which indicated a clear accumulation of metals (Cu, Pb, Zn, Cd, Ni and Cr). The results of this study indicated:

- The increase concentrations are most likely due to heavy traffic emissions in the sites to the atmosphere, some anthropogenic activities as well as lack of regulations and some basic infrastructure such as unpaved streets.
- The average concentrations of the selected heavy metals were as follows: Zn>Pb>Cu>Cr>Ni>Cd.
- From the results of the current study and to reduce the heavy metals concentration in street dust, regulation should be activated in Babylon governorate
- In addition, increasing the plant coverage can play vital roles to reduce the amount of heavy metals in the soil with regular monitoring for the concentrations of heavy metals.

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