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# Chemical and morphological characteristics of heavy and hazardous metals in settled dust associated with different functional areas of Karachi, Pakistan

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**Key words:** Heavy Traffic, Industry, SEM, SEM-EDX, WD-XRF

**Abstract**

The heavy and hazardous metals have high impact on health of living organism mostly on human beings. Settled dust has great impact on natural environment and human health as it may contain heavy and hazardous metals contributed from anthropogenic activities. Four functional areas of Karachi city, were selected for this study that are named as industrial area (Port Qasim), Traffic area (National Highway from Malir Halt to Port Qasim), Urban Area (Gulshan-e-Iqbal), Rural Area (Saadi Town). 36 samples of settled dust were drawn from all these areas and analyzed on WD-XRF spectrometer. Chromium, Copper, Iron, Manganese, Nickel, Lead, Titanium, and Zinc were studied and their average results were 384, 664, 61699, 1379,167, 427, 4656 and 5909mg $Kg^{-1}$. The average results of all metallic concentration of all four functional areas show that iron, Zinc, Titanium and Manganese are enriched in concentration while Nickel has the lowest concentration in settle dust. Morphological examination was carried out with SEM in which particles size, shape and particle composition was determined. SEM-EDX was used to analyze the particle's chemical composition, and Carbon was also quantify with metals and has high concentration in all samples than heavy metals. The study aided valuable data related with heavy and hazardous metals for the city of Karachi

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## Introduction

Peoples living in polluted areas are exposed to heavy and hazardous metals that are present in air which can be life threatening if exposed for a long period of time. Karachi is the largest and the most polluted city of Pakistan so it essential to study of heavy and hazardous metals contaminations present in settled dust. Heavy metals and hazardous metals are associated with the air pollution and it can causes number of diseases to not only the human being but all living organisms as well. In air these types of metals are present in a very low quantity but can have a great effect on living things due to which it should not present or should be in very low quantity in air dust. When dust blow due to any reason either it blow by traffic movement, air blowing or swimming, and due to industrial process etc. then dust mix with other pollutants emitted from different sources like traffic smoke emission, industrial process emission, different process wastes or effluents etc. and then it settled down on different places ((Wan *et al.*, 2016; Godt *et al.*, 2006; Tchounwou *et al.*, 2012).

There are various studies which have been reported the deposition of harmful metals in the soils of Karachi (e.g. Karim *et al.,* 2015; Khan MN and Sarwar Anila, 2014. Mashiatullah *et al.*, 2013). All these studies assessed the inhabitant's health risk linked with Fe, Cu, Pb, Cr and Zn in urban soils of Karachi. Nevertheless, these studies did not consider the deposition of harmful metals in settled dust with no morphological study. The present work shows chemical composition of hazardous metals and morphological characteristics of settled dust of various functional areas of Karachi.

## Materials and methods

*Area Selection for Study*

Karachi; known as city of lights, is the largest city of Pakistan having an area of 3530 square of kilometers, it covers few costal area of Arabian Sea. It has the coordinates 24°51′36″N 67°0′36″E. Karachi is most polluted city (Khan and Sarwar, 2014) as compared to all other cities of Pakistan so it is chosen for this study.

*Sampling*

In this study, total thirty six samples, nine samples from each of four functional areas were collected. Most of samples for urban area, rural area were collected from residential sites like not cleaned window glasses, flat roofs of outdoor, plants leaves of parks etc. whereas for industrial and heavy traffic area the samples were collected from road sides, (Verma, 2015), (Duong and Lee, 2011) poles, bridges, pipelines, places nearest to industries such as steel mills, (Omran and Fabritius, 2017) old scrapped parts like cars etc. for the collection of samples a small brush was used and samples were collected and stored in polythene bags.

Analysis

*Wavelength Dispersive X-Ray fluorescence spectrometer (WD-XRF)*

*Sample Preparation for WD-XRF*

Settled dust samples were pulverized by mixing with wax to get the homogenization by using mini ball mill, in which zirconium based balls were used. Machine was set at 240 rpm speed and the sample was rotated 2 min clockwise and 2 min anti-clockwise. Then press pellets were prepared to get the hard, flat and smooth surface with the help of Herzog press pellet machine by applying 25 KN force (Wolff, 2006). Binder (Boric Acid) was used to prevent the breaking or dispersion of sample during bombarding of high intensity X-Rays.

*Sample Preparation for SEM*

Samples of settled dust were bombarded with gold particles with the help ion sputter coater machine to make the sample electrical conductor and avoid the building up charges during SEM analysis, which is necessary to analyze the sample with more sensitivity on SEM so that clear images should receive. Ion sputter coater machine is used to deposit metal coating that has thickness of few nanometers, which is very thin layer. In this study ion sputtering of Gold metal (Au) is used but we can also use platinum (Pt), Alloy of Gold and Palladium (Au-Pd) and Alloy of Platinum and Palladium (Pt-Pd) as well.

## Results and discussion

*Results of heavy metallic elements in settled dust of industrial area (Port Qasim) Karachi*

Table 1 shows heavy metallic elemental composition by WD-XRF spectrometer of Chromium, Copper, Iron, Manganese, Nickel, Lead, Titanium, and Zinc in settled dust of industrial area (Port Qasim), Karachi, and the concentrations are 346, 1924, 91929, 1522, 181, 566, 5520, and 18297mg.$Kg^{-1}$ (ppm) respectively. The highest to lowest concentration of heavy metals are as Fe > Zn > Ti > Cu > Mn > Pb > Cr > Ni. Fig. 2 shows the particles of settled dust of industrial area (Port Qasim), Karachi at 100 x magnification power with SEM, which when further magnified at 750 x shows the largest particle (fig. 9A), and it is analyzed with SEM-EDX spectrometer of which graph is shown in fig. 9B and chemical composition of particle is stated in table 6, where the decreasing trend of metallic compositions are as Al > C > Zn > Fe > Ni > Cr > Pb and their concentrations are 232220, 226410, 17637, 9585, 1200, 637, 36.39mg.$Kg^{-1}$ (ppm) respectively. In fig. 4 the large particle is seen which is rectangular shaped and its dimension is determined as $D_1$ 49491.97 x $D_2$ 34969.74$nm^2$ with SEM.

**Table 1.** Heavy Metallic Elemental Composition in settled dust from Industrial Area (Port Qasim), Karachi City, Analyzed on WD-XRF Analyzer (Axios Model).

| S. No. | Sample ID | Cr (ppm) | Cu (ppm) | Fe (ppm) | Mn (ppm) | Ni (ppm) | Pb (ppm) | Ti (ppm) | Zn (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | I.A*-1 | 320 | 230 | 86510 | 1540 | 200 | 680 | 4420 | 41340 |
| 2 | I.A-2 | 320 | 270 | 87480 | 1360 | 180 | 680 | 4280 | 41500 |
| 3 | I.A-3 | 330 | 200 | 86770 | 1520 | 170 | 690 | 4660 | 41680 |
| 4 | I.A-4 | 370 | 1660 | 97230 | 1550 | 210 | 450 | 6110 | 1290 |
| 5 | I.A-5 | 370 | 1900 | 98180 | 1470 | 200 | 520 | 6260 | 1300 |
| 6 | I.A-6 | 400 | 1650 | 98010 | 1540 | 100 | 470 | 6420 | 1190 |
| 7 | I.A-7 | 320 | 3780 | 91720 | 1510 | 220 | 540 | 5800 | 12010 |
| 8 | I.A-8 | 390 | 3750 | 90940 | 1770 | 180 | 520 | 5760 | 12250 |
| 9 | I.A-9 | 290 | 3880 | 90520 | 1440 | 170 | 540 | 5970 | 12110 |
| Mean | | 346 | 1924 | 91929 | 1522 | 181 | 566 | 5520 | 18297 |
| Min | | 290 | 200 | 86510 | 1360 | 100 | 450 | 4280 | 1190 |
| Max | | 400 | 3880 | 98180 | 1770 | 220 | 690 | 6420 | 41680 |
| Median | | 330 | 1660 | 90940 | 1520 | 180 | 540 | 5800 | 12110 |
| Standard Deviation | | 38 | 1554 | 4782 | 111 | 35 | 93 | 832 | 18032 |

* I.A stand for Industrial Area and the value represent the number of sample.

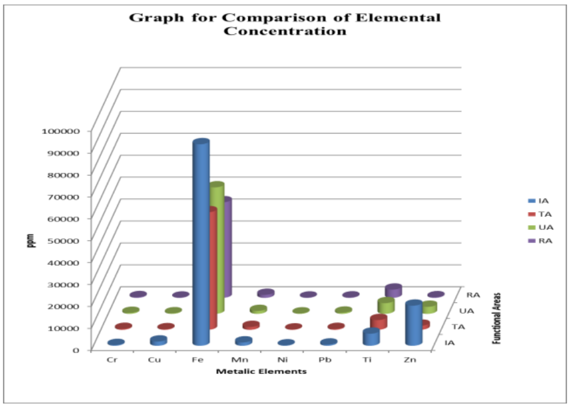


**Fig. 1.** Graph for comparison of metallic elemental concentration in settled dust samples analyzed by WD-XRF Spectrometer of the specified functional areas of Karachi, Pakistan. [IA stands for Industrail Area (Port Qasim), TA stands for Traffic Area (National Highway from malir halt to Port Qasim), UA stands for Urban Area (Gulshan-e-Iqbal), and RA stands for Rural Area (Saadi Town)].

3.2 Results of Scanning Electron Microscope (SEM) analysis of settled dust.

3.2.1 Industrial Area (Port Qasim)

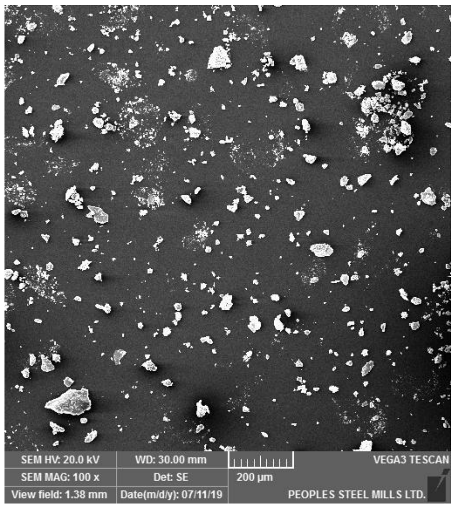


**Fig. 2.** Scanning Electron Microscopic fig. of settled dust particles of industrial area (Port Qasim), Karachi.

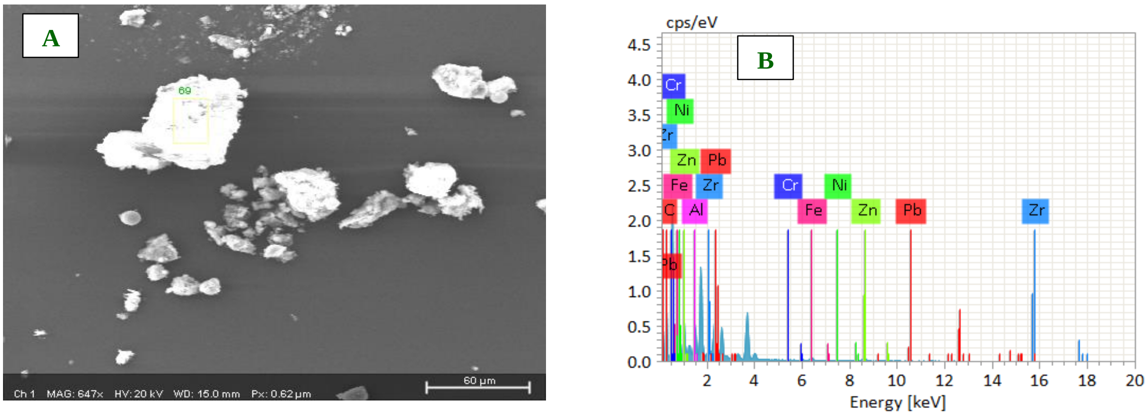


**Fig. 3.** A- Scanning Electron Microscopic [SEM] fig. of Particles of settled dust of industrial area (Port Qasim), Karachi. B- Graph of SEM-EDX (Energy Dispersive X-Rays) Analysis of elements of selected particle in fig. A.

*Results of heavy metallic elements in settled dust of traffic area (National Highway from Malir Halt to Port Qasim) Karachi*

Table 2 shows heavy metallic elemental composition by WD-XRF spectrometer of Chromium, Copper, Iron, Manganese, Nickel, Lead, Titanium, and Zinc in settled dust of traffic area (National Highway from Malir halt to Port Qasim), Karachi, and the concentrations are 421, 271, 53606, 1308, 164, 391, 4449, 1851mg.Kg$^{-1}$ (ppm) respectively. The highest to lowest concentration of heavy metals are as Fe > Ti > Zn > Mn > Cr > Pb > Cu > Ni.

Fig. 5 shows the particles of settled dust of traffic area (National Highway from Malir Halt to Port Qasim), Karachi at 100 x magnification power with SEM, which when further magnified at 750 x shows the largest particles (fig. 6A), and it is analyzed with SEM-EDX spectrometer of which graph is shown in fig. 12B and chemical composition of particle is stated in table 7, where the decreasing trend of metallic compositions are as Si > C > Al > Fe > Zn > Ti > Pb and their concentrations are 151580, 149479, 75364, 45200, 2193, 1797, 529mg.Kg$^{-1}$ (ppm) respectively.

In fig. 7 the two large particles are seen which are rectangular shaped and their dimensions are determined as $D_1$ 41940.63 x $D_2$ 31246.16nm$^2$ for one particle and $D_3$ 43655.05 x $D_4$ 47234.55nm$^2$ with SEM.

**Table 2.** Heavy Metallic Elemental Composition in settled dust from Traffic Area (National highway Malir Halt to Port Qasim), Karachi City, Analyzed on WD-XRF Analyzer (Axios Model).

| S. No. | Sample ID | Cr (ppm) | Cu (ppm) | Fe (ppm) | Mn (ppm) | Ni (ppm) | Pb (ppm) | Ti (ppm) | Zn (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | T.A*-1 | 380 | 160 | 51940 | 1570 | 170 | 370 | 4250 | 630 |
| 2 | T.A-2 | 450 | 120 | 51610 | 1280 | 120 | 290 | 4010 | 620 |
| 3 | T.A-3 | 420 | 180 | 50910 | 1340 | 150 | 290 | 4330 | 620 |
| 4 | T.A-4 | 400 | 290 | 56450 | 1400 | 180 | 520 | 4580 | 3110 |
| 5 | T.A-5 | 400 | 320 | 56880 | 1200 | 230 | 450 | 4650 | 3060 |
| 6 | T.A-6 | 350 | 300 | 57310 | 1160 | 210 | 530 | 4760 | 3080 |
| 7 | T.A-7 | 390 | 300 | 52800 | 1260 | 150 | 370 | 4580 | 1880 |
| 8 | T.A-8 | 390 | 350 | 52070 | 1270 | 120 | 370 | 4550 | 1830 |
| 9 | T.A-9 | 610 | 420 | 52480 | 1290 | 150 | 330 | 4330 | 1830 |
| Mean | | 421 | 271 | 53606 | 1308 | 164 | 391 | 4449 | 1851 |
| Min | | 350 | 120 | 50910 | 1160 | 120 | 290 | 4010 | 620 |
| Max | | 610 | 420 | 57310 | 1570 | 230 | 530 | 4760 | 3110 |
| Median | | 400 | 300 | 52480 | 1280 | 150 | 370 | 4550 | 1830 |
| Standard Deviation | | 76 | 98 | 2521 | 121 | 37 | 90 | 235 | 1065 |

* T.A stand for Traffic Area and the value represent the number of sample.

*Results of heavy metallic elements in settled dust of urban area (Gulshan-e-Iqbal) Karachi*

Table 3 shows heavy metallic elemental composition by WD-XRF spectrometer of Chromium, Copper, Iron, Manganese, Nickel, Lead, Titanium, and Zinc in settled dust of urban area (Gulshan-e-Iqbal), Karachi, and the concentrations are 442, 247, 57681, 1303, 183, 553, 4883, 3208mg.Kg$^{-1}$ (ppm) respectively. The highest to lowest concentration of heavy metals are as Fe > Ti > Zn > Mn > Pb > Cr > Cu > Ni.

Fig. 8 shows the particles of settled dust of urban area (Gulshan-e-Iqbal), Karachi at 100 x magnification power with SEM, which when further magnified at 750 x shows the largest particles (fig. 8A), and it is analyzed with SEM-EDX spectrometer of which graph is shown in fig. 15B and chemical composition of particle is stated in table 8, where the decreasing trend of metallic compositions are as C > Al > Fe > Pb > Zn > Cr > Ti > Ni and their concentrations are 121868, 50662, 8978, 3287, 1738, 1167, 971, 146mg.Kg$^{-1}$ (ppm) respectively.

As Pb is very high in concentration at 1$^{st}$ particle due to which second particle is also selected (fig. 9A) and analyzed with SEM-EDX spectrometer and its graph is shown in fig. 9B, whereas chemical composition is stated in table 9, that shows the decreasing trend of chemical composition of metal elements as C > Al > Fe > Zn > Ti > Ni and their chemical composition are 399715, 41961, 20828, 8644, 1971, 71.5, in the second particle Cr and Pb are not detected.

In fig. 8 the two large particles are seen one is rectangular shaped and the other is round shaped and their dimensions are determined as $D_1$ 12390.01 x $D_2$ 26909.02nm$^2$ for rectangular shaped particle and radius 5319.25nm or diameter 10638.50nm for round shaped particle with SEM.

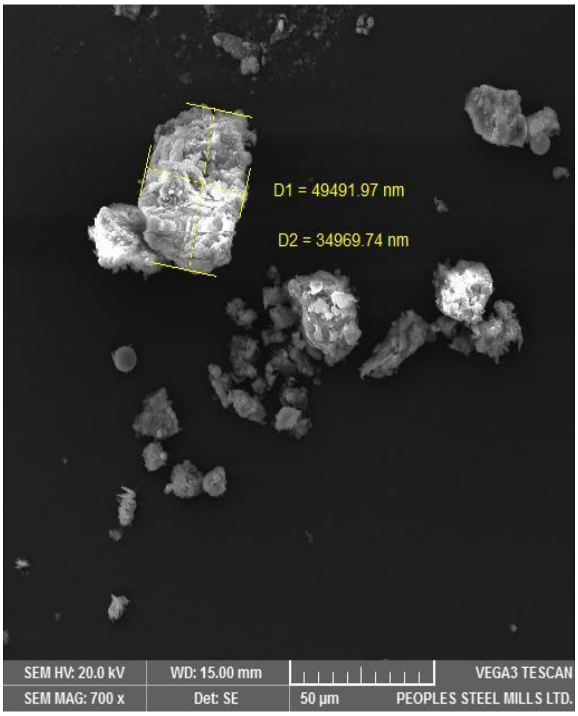


**Fig. 4.** Fig. of settled dust particle of industrial area (Port Qasim), Karachi using Scanning Electron Microscope.

3.2.2 Traffic Area (National Highway from Malir Halt to Port Qasim)

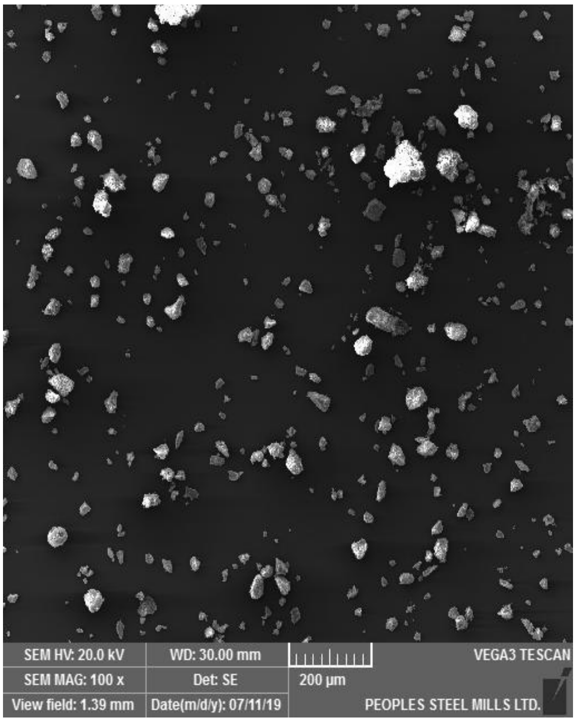


**Fig. 5.** Scanning Electron Microscopic fig. of settled dust particles of traffic area (National Highway from Malir Halt to Port Qasim), Karachi.

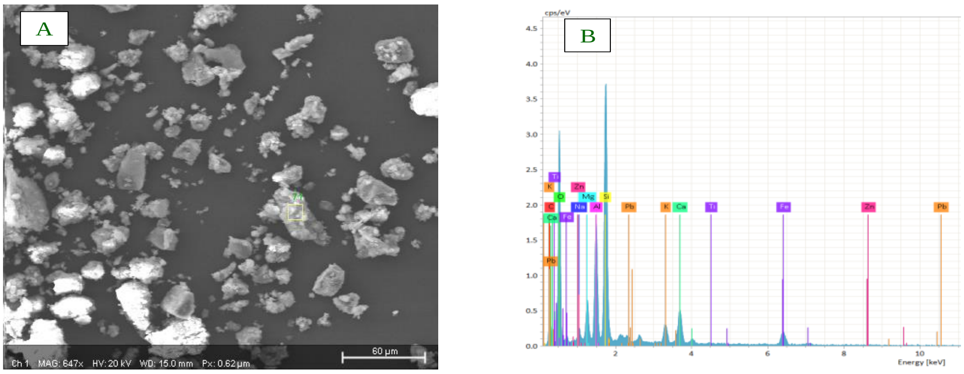


**Fig. 6.** A- Scanning Electron Microscopic [SEM] fig. of Particles of settled dust of traffic area (National Highway from Malir Halt to Port Qasim), Karachi. B- Graph of SEM-EDX (Energy Dispersive X-Rays) Analysis of elements of selected particle in fig. A.

**Table 3.** Heavy Metallic Elemental Composition in settled dust from Urban Area (Gulshan-e-Iqbal), Karachi City, Analyzed on WD-XRF Analyzer (Axios Model).

| S. No. | Sample ID | Cr (ppm) | Cu (ppm) | Fe (ppm) | Mn (ppm) | Ni (ppm) | Pb (ppm) | Ti (ppm) | Zn (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | U.A*-1 | 310 | 250 | 56010 | 1330 | 220 | 570 | 4440 | 800 |
| 2 | U.A-2 | 380 | 260 | 55970 | 1180 | 160 | 470 | 4650 | 830 |
| 3 | U.A-3 | 290 | 250 | 56440 | 1130 | 130 | 440 | 4420 | 720 |
| 4 | U.A-4 | 600 | 280 | 54890 | 1220 | 280 | 670 | 5400 | 7960 |
| 5 | U.A-5 | 580 | 240 | 55140 | 1380 | 230 | 640 | 5370 | 7980 |
| 6 | U.A-6 | 590 | 190 | 56180 | 1350 | 110 | 610 | 5180 | 7960 |
| 7 | U.A-7 | 350 | 280 | 61150 | 1410 | 160 | 570 | 4920 | 840 |
| 8 | U.A-8 | 540 | 230 | 61680 | 1330 | 220 | 500 | 4900 | 930 |
| 9 | U.A-9 | 340 | 240 | 61670 | 1400 | 140 | 510 | 4670 | 850 |
| Mean | | 442 | 247 | 57681 | 1303 | 183 | 553 | 4883 | 3208 |
| Min | | 290 | 190 | 54890 | 1130 | 110 | 440 | 4420 | 720 |
| Max | | 600 | 280 | 61680 | 1410 | 280 | 670 | 5400 | 7980 |
| Median | | 380 | 250 | 56180 | 1330 | 160 | 570 | 4900 | 850 |
| Standard Deviation | | 132 | 27 | 2909 | 101 | 56 | 79 | 372 | 3570 |

* U.A stand for Urban Area and the value represent the number of sample.

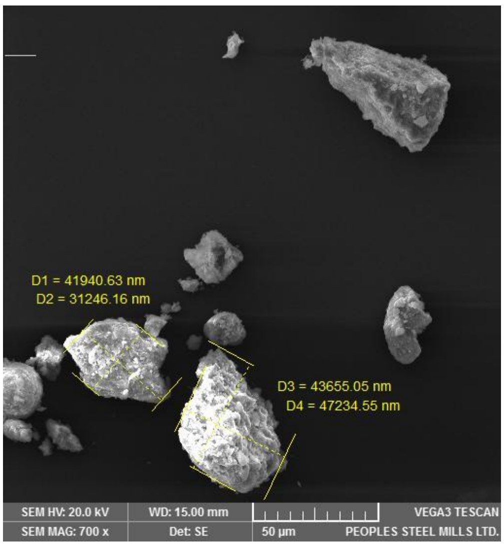


**Fig. 7.** Fig. of settled dust particle of traffic area (National Highway from Malir Halt to Port Qasim), Karachi using Scanning Electron Microscope.

3.2.3 Urban Area (Gulshan-e-Iqbal)

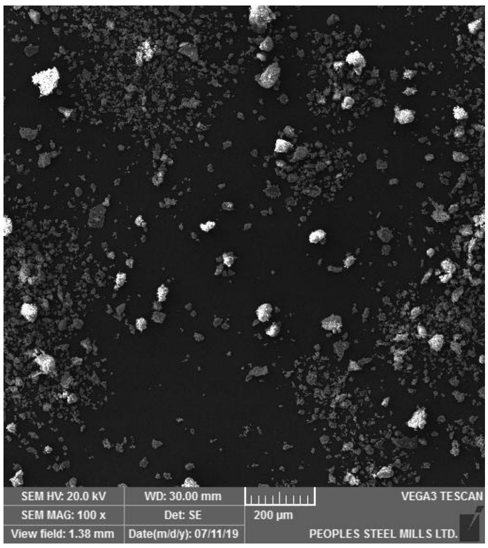


**Fig. 8.** Scanning Electron Microscopic fig. of settled dust particles of urban area (Gulshan-e-Iqbal), Karachi.

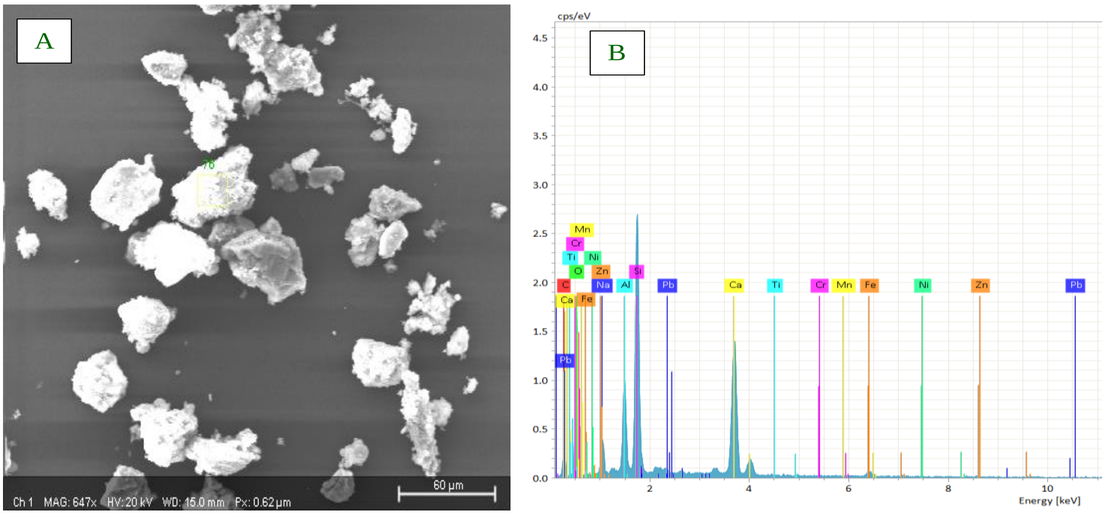


**Fig. 9.** A- Scanning Electron Microscopic [SEM] fig. of Particles of settled dust of urban area (Gulshan-e-Iqbal), Karachi. B- Graph of SEM-EDX (Energy Dispersive X-Rays) Analysis of elements of selected particle in fig. A.

*Results of heavy metallic elements in settled dust of rural area (Saadi Town) Karachi*

Table 4 shows heavy metallic elemental composition by WD-XRF spectrometer of Chromium, Copper, Iron, Manganese, Nickel, Lead, Titanium, and Zinc in settled dust of rural area (Saadi Town), Karachi, and the concentrations are 328, 135, 43579, 1384, 139, 198, 3772, 279mg.Kg$^{-1}$ (ppm) respectively. The highest to lowest concentration of heavy metals are as Fe > Ti > Mn > Cr > Zn > Pb > Ni > Cu.

Fig. 9 shows the particles of settled dust of rural area (Saadi Town), Karachi at 100 x magnification power with SEM, which when further magnified at 750 x shows the largest particles (fig. 10A), and it is analyzed with SEM-EDX spectrometer of which graph is shown in fig. 19B and chemical composition of particle is stated in table 10, where the decreasing trend of metallic compositions are as C > Al > Fe > Cu > Zn > Pb > Cr > Ni > Ti and their concentrations are 156377, 13322, 7168, 1134, 1022, 884, 846, 832, 470mg.Kg$^{-1}$ (ppm) respectively. In fig. 14 the two large particles are seen one is rectangular shaped and the other is round shaped and their dimensions are determined as $D_1$ 23246.83 x $D_2$ 28034.02nm$^2$ for rectangular shaped particle and radius 10990.75nm or diameter 21981.50nm for round shaped particle with SEM.

**Table 4.** Heavy Metallic Elemental Composition in settled dust from Rural Area (Saadi Town), Karachi City, Analyzed on WD-XRF Analyzer (Axios Model).

| S. No. | Sample ID | Cr (ppm) | Cu (ppm) | Fe (ppm) | Mn (ppm) | Ni (ppm) | Pb (ppm) | Ti (ppm) | Zn (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | R.A*-1 | 520 | 110 | 56480 | 1440 | 220 | 360 | 5470 | 430 |
| 2 | R.A-2 | 220 | ND* | 38100 | 1490 | ND | ND | 2830 | 180 |
| 3 | R.A-3 | 480 | 140 | 58010 | 1320 | 130 | 300 | 5580 | 550 |
| 4 | R.A-4 | 250 | 160 | 37650 | 1450 | 100 | 160 | 2950 | 160 |
| 5 | R.A-5 | 510 | 160 | 58010 | 1340 | 190 | 350 | 5330 | 440 |
| 6 | R.A-6 | 260 | ND | 36180 | 1240 | ND | 130 | 3080 | 250 |
| 7 | R.A-7 | 150 | 150 | 35930 | 1460 | 90 | 110 | 2920 | 180 |
| 8 | R.A-8 | ND | 90 | 36470 | 1330 | 120 | 80 | 2870 | 140 |
| 9 | R.A-9 | 230 | ND | 35380 | 1390 | 120 | 90 | 2920 | 180 |
| Mean | | 328 | 135 | 43579 | 1384 | 139 | 198 | 3772 | 279 |
| Min | | 150 | 90 | 35380 | 1240 | 90 | 80 | 2830 | 140 |
| Max | | 520 | 160 | 58010 | 1490 | 220 | 360 | 5580 | 550 |
| Median | | 255 | 145 | 37650 | 1390 | 120 | 145 | 2950 | 180 |
| Standard Deviation | | 150 | 29 | 10483 | 82 | 48 | 119 | 1269 | 152 |

* R.A stand for Rural Area and the value represent the number of sample whereas ND stands for Not Detected.

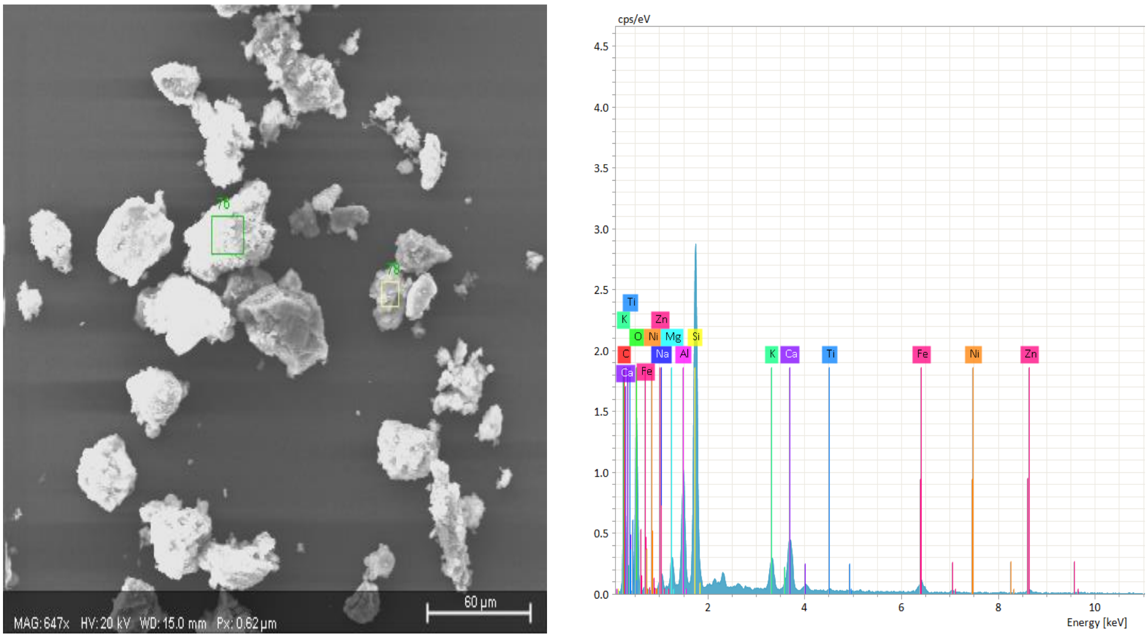


**Fig. 10.** Scanning Electron Microscopic [SEM] fig. of Particles of settled dust of urban area (Gulshan-e-Iqbal), Karachi. B- Graph of SEM-EDX (Energy Dispersive X-Rays) Analysis of elements of selected particle in fig. A.

*Comparison of results of heavy metallic elemental composition in settled dust from different functional areas of Karachi city*

Four functional areas of Karachi city, were selected for this study that are named as industrial area (Port Qasim), Traffic area (National Highway from Malir Halt to Port Qasim) where high heavy traffic is seen 24 hours a day, Urban Area (Gulshan-e-Iqbal) where high traffic, shopping malls and small units are seen, Rural Area (Saadi Town) which is far away from industrial area and low traffic is seen. 36 samples of settled dust was drawn from all these areas and analyzed on WD-XRF spectrometer, the average results of each functional area are stated in table 5 for comparison.The average results of all metallic concentration of all four functional areas shows that iron has the highest concentration while Nickel has the lowest concentration in settle dust.

**Table 5.** Comparison of Heavy Metallic Elemental Concentration in settled dust samples from different functional Areas of Karachi City, analyzed on WD-XRF Analyzer (Axios Model).

| S. No. | Sample ID | Cr (ppm) | Cu (ppm) | Fe (ppm) | Mn (ppm) | Ni (ppm) | Pb (ppm) | Ti (ppm) | Zn (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | I.A* | 346 | 1924 | 91929 | 1522 | 181 | 566 | 5520 | 18297 |
| 2 | T.A* | 421 | 271 | 53606 | 1308 | 164 | 391 | 4449 | 1851 |
| 3 | U.A* | 442 | 247 | 57681 | 1303 | 183 | 553 | 4883 | 3208 |
| 4 | R.A* | 328 | 135 | 43579 | 1384 | 139 | 198 | 3772 | 279 |
| Mean | | 384 | 644 | 61699 | 1379 | 167 | 427 | 4656 | 5909 |
| Min | | 328 | 135 | 43579 | 1303 | 139 | 198 | 3772 | 279 |
| Max | | 442 | 1924 | 91929 | 1522 | 183 | 566 | 5520 | 18297 |
| Median | | 384 | 259 | 55644 | 1346 | 173 | 472 | 4666 | 2530 |
| Standard Deviation | | 56 | 855 | 21007 | 102 | 20 | 172 | 735 | 8345 |

* I.A stands for Industrial Area, T.A stands for Traffic Area, and U.A stands for Urban Area, R.A stands for Rural Area.

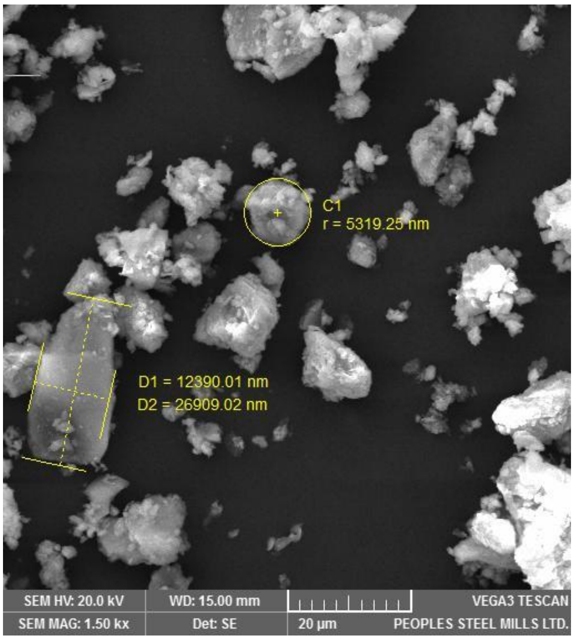


**Fig. 11.** Fig. of settled dust particle of urban area (Gulshan-e-Iqbal), Karachi using Scanning Electron Microscope.

### 3.2.4 Rural Area (Saadi Town)

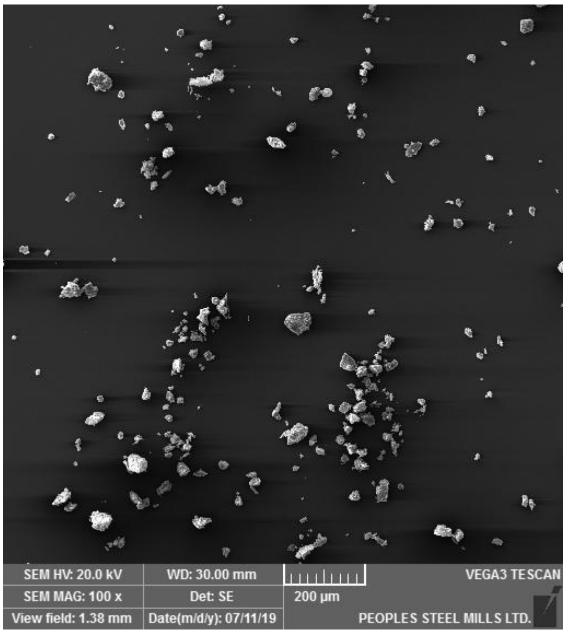


**Fig. 12.** Scanning Electron Microscopic fig. of settled dust particles of rural area (Saadi Town), Karachi.

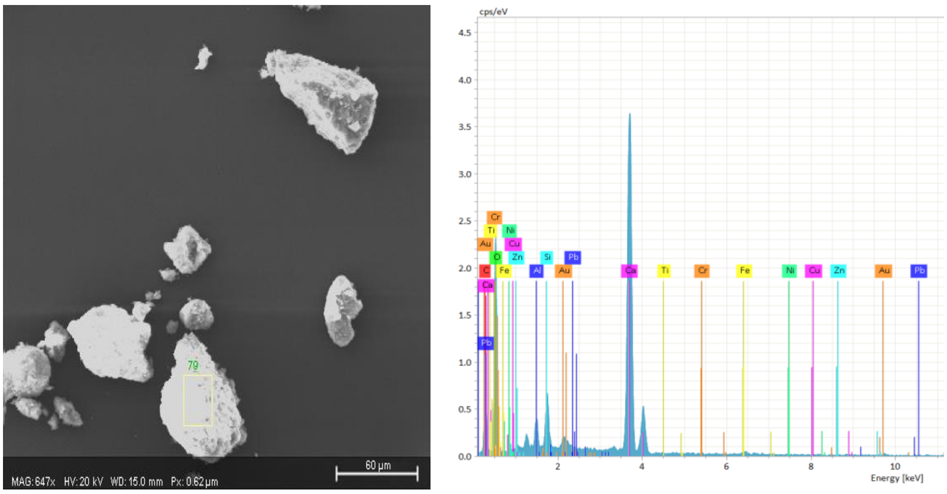


**Fig. 13.** Scanning Electron Microscopic [SEM] fig. of Particles of settled dust of rural area (Saadi Town), Karachi. B- Graph of SEM-EDX (Energy Dispersive X-Rays) Analysis of elements of selected particle in fig. A.

**Table 6.** Chemical concentration of elements present in selected particle of fig. 8.A of industrial area (Port Qasim), Karachi by SEM-EDX.

| Elements | C (ppm) | Al (ppm) | Cr (ppm) | Fe (ppm) | Ni (ppm) | Zn (ppm) | Pb (ppm) |
|---|---|---|---|---|---|---|---|
| Concentration | 226410 | 232220 | 637 | 9585 | 1200 | 17637 | 36.39 |

**Table 7.** Chemical concentration of elements present in selected particle of fig. 12.A of traffic area (National Highway from Malir Halt to Port Qasim), Karachi by SEM-EDX.

| Elements | C (ppm) | Al (ppm) | Si (ppm) | Fe (ppm) | Ti (ppm) | Zn (ppm) | Pb (ppm) |
|---|---|---|---|---|---|---|---|
| Concentration | 149479 | 75364 | 151580 | 45200 | 1797 | 2193 | 529 |

**Table 8.** Chemical concentration of elements present in selected particle of fig. 15.A of urban area (Gulshan-e-Iqbal), Karachi by SEM-EDX.

| Elements | C (ppm) | Al (ppm) | Cr (ppm) | Ni (ppm) | Fe (ppm) | Ti (ppm) | Zn (ppm) | Pb (ppm) |
|---|---|---|---|---|---|---|---|---|
| Concentration | 121868 | 50662 | 1167 | 146 | 8978 | 971 | 1738 | 3287 |

**Table 9.** Chemical concentration of elements present in selected particle of fig. 16.A of urban area (Gulshan-e-Iqbal), Karachi by SEM-EDX.

| Elements | C (ppm) | Al (ppm) | Cr (ppm) | Ni (ppm) | Fe (ppm) | Ti (ppm) | Zn (ppm) | Pb (ppm) |
|---|---|---|---|---|---|---|---|---|
| Concentration | 399715 | 41961 | - | 71.5 | 20828 | 1971 | 8644 | - |

**Table 10.** Chemical concentration of elements present in selected particle of fig. 19.A of rural area (Saadi Town), Karachi by SEM-EDX.

| Elements | C (ppm) | Al (ppm) | Cr (ppm) | Cu (ppm) | Ni (ppm) | Fe (ppm) | Ti (ppm) | Zn (ppm) | Pb (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| Concentration | 156377 | 13322 | 846 | 1134 | 832 | 7168 | 470 | 1022 | 884 |

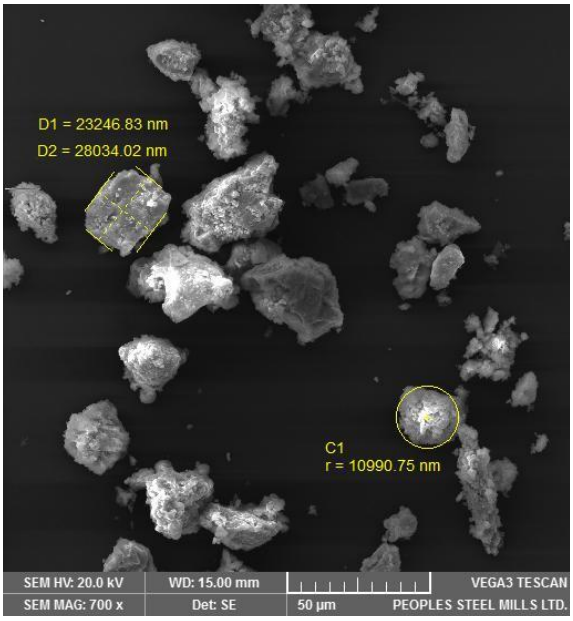


**Fig. 14.** Fig. of settled dust particle of rural area (Saadi Town), Karachi using Scanning Electron Microscope.

*Chromium*

Chromium has highest to lowest trend according to the selected four functional areas of Karachi as Urban Area (Gulshan-e-Iqbal) > Traffic Area (National Highway from Malir Halt to Port Qasim) > Industrial Area (Port Qasim) > Rural Area (Saadi Town) with the values 442 > 421 > 346 > 328 respectively (Table 5), (Fig. 1). In the urban area there are more traffic and small industrial units like power plant etc. that are responsible for the metallic pollution, whereas in rural area (Saadi Town) no industrial units as well as it is far away from industries and highly traffic areas so, it has low pollution level. Chromium concentration in soil is 100-150$mg.Kg^{-1}$ (Arshad *et al.*, 2014), its mean more than 150$mg.Kg^{-1}$ of chromium concentration found in this study is not come from soil only but also from other anthropogenic activities as well.

*Copper*

Copper has highest to lowest trend according to the selected four functional areas of Karachi as Industrial Area (Port Qasim) > Traffic Area (National Highway from Malir Halt to Port Qasim) > Urban Area (Gulshan-e-Iqbal) > Rural Area (Saadi Town) with the values 1924 > 271 > 247 > 135 respectively (Table 5), (Fig. 1). In the industrial area there are large industrial units which are responsible for the high concentration of copper. Whereas in other areas the difference in copper concentration is not significant as compare to Industrial Area [I.A]. Copper concentration in soil at different regions in Pakistan is reported as 6 to 412$mg.Kg^{-1}$ and I Karachi it is reported 272$mg.Kg^{-1}$ ( Siddique *et al.*, 2009; Arshad *et al.*, 2014) according to these results copper in concentration in this study of all functional areas except Industrial Area (Port Qasim) is come from soil only, but in Industrial Area (Port Qasim) the copper concentration i.e. 1924$mg.Kg^{-1}$ is very high that mean in this area copper comes from other anthropogenic activities instead of only soil.

*Iron*

Iron has highest to lowest trend according to the selected four functional areas of Karachi as Industrial Area (Port Qasim) > Urban Area (Gulshan-e-Iqbal) > Traffic Area (National Highway from Malir Halt to Port Qasim) > Rural Area (Saadi Town) with the values 91929 > 57681 > 53606 > 43579 respectively (Table 5), (Fig. 1). Iron [Fe] is reported in soil 35080 to 26960mg.Kg$^{-1}$ in Kohistan region of Pakistan (Arshad *et al.*, 2014) if it is compared with concentration of iron in this study then all the selected functional areas of Karachi has been polluted with some anthropogenic activities which is causing high iron pollution. In industrial area (Port Qasim) there are steel mills which are spreading iron content due to which it shows highest value in industrial region.

*Manganese*

Manganese has highest to lowest trend according to the selected four functional areas of Karachi as Industrial Area (Port Qasim) > Rural Area (Saadi Town) > Traffic Area (National Highway from Malir Halt to Port Qasim) > Urban Area (Gulshan-e-Iqbal) with the values 1522 > 1384 > 1308 > 1303 respectively (Table 5), (Fig. 1). Manganese was reported 117.6 to 309mg.Kg$^{-1}$ in roadside soil of national Highway N-5 Karachi (Khan *et al.*, 2011), in this study all the functional areas have high concentration of manganese its mean it's not come from soil only, but there is involvement of other human activities as well.

*Nickel [Ni]*

Nickel has highest to lowest trend according to the selected four functional areas of Karachi as Urban Area (Gulshan-e-Iqbal) > Industrial Area (Port Qasim) > Traffic Area (National Highway from Malir Halt to Port Qasim) > Rural Area (Saadi Town) with the values 183 > 181 > 164 > 139 respectively (Table 5), (Fig. 1). Nickel has been reported as 5.96 to 13.23mg/Kg in soil of Karachi region (Khan *et al.*, 2011). Nickel has high concentration in settled dust (Table 5) as compared to nickel concentration in soil which means there are other factors involved in contamination of settled dust with nickel.

*Lead*

Lead has highest to lowest trend according to the selected four functional areas of Karachi as Industrial Area (Port Qasim) > Urban Area (Gulshan-e-Iqbal) > Traffic Area (National Highway from Malir Halt to Port Qasim) > Rural Area (Saadi Town) with the values 566 > 553 > 391 > 198 respectively (Table 5), (Fig. 1). As lead contaminated fuel is used in Pakistan and reported as 24.80 µg g$^{-1}$ i.e. equal to 24.80mg Kg$^{-1}$ (Khan *et al.*, 2011). Lead is reported 121mg Kg$^{-1}$ in Pakistan's coastal region of Karachi (Siddique *et al.*, 2009; Arshad *et al.*, 2014) and in Lyari river Karachi sediments has 49.5mg.Kg$^{-1}$ Lead (Mashiatullah *et al.*, 2013). It is also reported in soil of national highway N-5 Karachi with the highest concentration of 176mg.Kg$^{-1}$ (Khan *et al.*, 2011). As the results of lead [Pb] in this study show higher concentration as compared to lead in soil so, its mean there are other anthropogenic activities that causes the lead contamination in settled dust.

*Titanium*

Titanium has highest to lowest trend according to the selected four functional areas of Karachi as Industrial Area (Port Qasim) > Urban Area (Gulshan-e-Iqbal) > Traffic Area (National Highway from Malir Halt to Port Qasim) > Rural Area (Saadi Town) with the values 5520 > 4883 > 4449 > 3772 respectively (Table 5), (Fig. 1).

*Zinc*

Zinc has highest to lowest trend according to the selected four functional areas of Karachi as Industrial Area (Port Qasim) > Urban Area (Gulshan-e-Iqbal) > Traffic Area (National Highway from Malir Halt to Port Qasim) > Rural Area (Saadi Town) with the values 18297 > 3208 > 1852 > 279 respectively (Table 5), (Fig. 1). Zinc metal 37.16mg.Kg$^{-1}$ has been reported in soil sample along the national highway Karachi N-5 (Khan *et al.*, 2011), in Pakistan's soil highest concentration of zinc is reported 29755mg.Kg$^{-1}$ (Muhammad *et al.*, 2011).

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