

## CHAPTER 5

### Characterization of Particulate Matter with reference to Composition

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*This chapter emphasizes the importance of elemental composition of particulate matters. A sequential extraction procedure was applied for the speciation of water-soluble inorganic ions, major and trace elements (Ag, Al, As, Br, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Na, Ni, Pb, Se, Si, Sr, Th, U, V, Zn, C, H, N, S, Br<sup>-</sup>, Cl<sup>-</sup>, F<sup>-</sup>, NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>, PO<sub>4</sub><sup>3-</sup>, SO<sub>4</sub><sup>2-</sup>, Ca<sup>2+</sup>, K<sup>+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup>, and NH<sub>4</sub><sup>+</sup>) in airborne particulate matters of different sizes. The standard available techniques were used for the determination of the water-soluble inorganic ions, major, and trace element concentrations. The reliability and applicability of the method were checked by using the National Institute of Standards and Technology (NIST). The NIST standard reference materials were used as discussed in the previously (Chapter 3). In the study area, water-soluble inorganic ions and major & trace elements concentrations have been investigated and discussed.*

*The details analysis was done with expectation that almost all toxic metals will be included in future guidelines. However, the concentration of Pb, Ni, and As in particulate matter was compare with exiting standard. The enrichment factor and correlation studies have also been discussed.*

## 5.1 Introduction

The elemental particulate matter composition is important and unique because it can potentially impact the chemical composition and physical properties [60,168]. It originates from both natural sources (wind erosion, the friction of surfaces, suspension of soil minerals and resuspension, volcanic eruptions, dust storms) and industrial sources (traffic sources crushing and grading of ores, coal, rocks, and coal combustion) [9,169]. The composition of particulate matter, concentration, and toxicity are important factors that significantly affect human health [71,170]. It is, particularly, the fine and ultrafine particulate matter with the associated trace metals. A enhances the ability to outsource natural defense functions within our respiratory system that affected as compare to coarse particulate matter associated elements [171,172].

The particulate matters of different sizes appear to have a carrying capacity for associated elements. The fine and ultrafine particulate matters with their associated elements ability have to enter the blood, carrying with them the components that enable them to produce all kinds of systemic effects. Among these constituents, metals (As, Cd, Cr, and Ni) have toxicological and carcinogenic effects [135,173].

The loadings and sources of ions in the air have great spatial variability over different locations, which is mainly caused by different meteorological conditions (prevailing wind directions and type, frequency, temperature, relative humidity and amount of precipitation) and the emission patterns of pollutants (emission sources, distance from emission sources and the sampling locations). Keeping the above aspect, a detailed investigation of elemental composition has been conducted in this study area. The major pollutants are released in the atmosphere by huge-scale coal mining and coal-based power plants in the area.

The present study was conducted during the two consecutive years (2016 & 2017) to determine particulate matter composition. The composition has been described as major &

trace elements, and water-soluble inorganic ions in the particulate matters are subsequent paragraphs.

## **5.2 Composition of major and trace elements of airborne dust**

The composition of particulate matter decides the virulency. Hence, the composition of airborne dust has been discussed under the following headings in details:

- 1) The concentration of major & trace elements in particulate matter
- 2) Percentage distribution of major & trace elements in particulate matter
- 3) Seasonal variation of major & trace elements in particulate matter

A brief of each is discussed below in subsequent paragraphs.

### **5.2.1 Concentration of major & trace elements in particulate matter**

The particulate matters of different sizes collected on filter paper were digested and analyzed by available advanced techniques. Twenty-nine important elements (Ag, Al, As, Br, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Na, Ni, Pb, Se, Si, Sr, Th, U, V, Zn, C, H, N, S) in particulate matters (PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM) were analyzed. The results are summarized in **Tables 5.1–5.6** with their range, average values, and standard deviation of concentration.

The major elements are those in which concentration is more than one percent. Out of twenty-nine analyzed elements, C is in higher concentration with an average value of  $5.97 \pm 0.84 \mu\text{g m}^{-3}$  followed by H ( $5.92 \pm 0.45 \mu\text{g m}^{-3}$ ), Mg ( $5.10 \pm 1.10 \mu\text{g m}^{-3}$ ), N, Na, Fe, K, S, Ca, Al, Si, Pb, Zn, Mn, Se, Cu, Cr, Ni, Sr, Co, Cd, As, V, Hg, Br, Li, Ag, Th ( $0.06 \pm 0.02 \text{ ng m}^{-3}$ ) and U ( $0.01 \pm 0.001 \text{ ng m}^{-3}$ ), in the PM<sub>2.5</sub> samples during the two consecutive years (January 2016 to December 2017) (**Table 5.1**) in AQMS-01.

From **Table 5.1**, It may be observed that the important elements like Fe, K, Mg, Ca, Al, Na and Zn in PM<sub>10</sub> samples was found to be in the range of 1.08–25.42  $\mu\text{g m}^{-3}$ , 1.26–18.92  $\mu\text{g m}^{-3}$ , 0.17–10.57  $\mu\text{g m}^{-3}$ , 0.96–19.25  $\mu\text{g m}^{-3}$ , 0.34–14.97  $\mu\text{g m}^{-3}$ , 0.47–17.48  $\mu\text{g m}^{-3}$  and 7.76–898.45  $\text{ng m}^{-3}$ , respectively.

It may be observed from the **Table 5.1**, that C was the most abundant element in SPM samples in AQMS–01 with an annual average concentration of  $26.07 \pm 1.80$  (2.74–44.13)  $\mu\text{g m}^{-3}$  followed by  $\text{Na} < \text{Ca} < \text{H} < \text{K} < \text{Fe} < \text{Al} < \text{N} < \text{Mg} < \text{S} < \text{Si} < \text{Pb} < \text{Zn} < \text{Mn} < \text{Se} < \text{Cu} < \text{Cr} < \text{Ni} < \text{Sr} < \text{Co} < \text{Cd} < \text{Hg} < \text{V} < \text{As} < \text{Br} < \text{Li} < \text{Ag} < \text{Th} < \text{U}$ . The detailed concentrations of other monitoring stations installed in the Singrauli coalfield have been given in the **Tables 5.2–5.6**. Perrino et al. [174] have reported similar range of concentration of major and trace elements.

The annual average concentration results are summarized in **Tables 5.7–5.18** with their range, average values, standard deviation, and enrichment factor of particulate matters of different sizes of their associated elements.

The annual concentration of trace metals i.e., As, Br, Hg, Pb, Cr, Ni, Th, U and Cd in PM<sub>2.5</sub> samples was found to be in the range of 0.72–10.52 ( $4.06 \pm 1.08$ )  $\mu\text{g m}^{-3}$ , 0.92–5.39 ( $1.62 \pm 0.39$ )  $\mu\text{g m}^{-3}$ , 0.005–7.46 ( $3.47 \pm 1.12$ )  $\mu\text{g m}^{-3}$ , 10.40–1061.42 ( $314.67 \pm 19.76$ )  $\mu\text{g m}^{-3}$ , 0.66–99.13 ( $19.92 \pm 4.33$ )  $\mu\text{g m}^{-3}$ , 0.03–18.75 ( $13.96 \pm 2.63$ )  $\mu\text{g m}^{-3}$ , 0.001–0.103 ( $0.061 \pm 0.024$ )  $\mu\text{g m}^{-3}$ , 0.0003–0.0194 ( $0.011 \pm 0.001$ )  $\mu\text{g m}^{-3}$  and 0.56–79.63 ( $7.29 \pm 2.46$ )  $\text{ng m}^{-3}$  respectively in the AQMS–03 in the year 2016 (**Table 5.13**).

It may be observed from **Table 5.13** that the annual concentration of As, Ni, and Pb have been well within the prescribed permissible limit (As=6 $\text{ng m}^{-3}$ ; Ni=20 $\text{ng m}^{-3}$ ; Pb=0.50  $\mu\text{g m}^{-3}$ ) of the NAAQS [101].

**Table 5.1:** Concentration of various elements in particulate matter during two consecutive years (2016 & 2017) at AQMS-01

Elements	Unit	PM <sub>2.5</sub>		PM <sub>10</sub>		SPM	
		Range	Average	Range	Average	Range	Average
Ag	ng m <sup>-3</sup>	0.11–1.20	1.00±0.21	0.10–1.34	1.10±0.20	0.11–1.68	1.32±0.23
Al	µg m <sup>-3</sup>	0.13–4.93	2.14±1.02	0.34–14.97	9.82±1.63	0.39–28.48	18.68±1.83
As	ng m <sup>-3</sup>	0.69–9.52	4.01±1.03	1.56–11.29	4.02±1.02	1.76–14.11	5.05±1.15
Br	ng m <sup>-3</sup>	0.81–4.51	1.45±0.34	0.09–7.29	2.13±0.98	0.10–9.11	2.56±1.11
Ca	µg m <sup>-3</sup>	0.49–6.71	2.73±1.08	0.96–19.25	12.01±1.45	1.08–36.62	22.85±1.64
Cd	ng m <sup>-3</sup>	0.52–78.54	7.22±1.93	1.04–90.31	10.88±0.07	1.17–112.89	13.11±0.08
Co	ng m <sup>-3</sup>	0.52–12.88	8.92±2.45	0.55–15.16	11.01±1.26	0.62–18.95	13.27±1.42
Cr	ng m <sup>-3</sup>	0.49–101.56	21.21±5.45	0.49–115.56	33.56±15.49	0.55–144.45	40.44±17.43
Cu	ng m <sup>-3</sup>	0.74–237.76	30.06±15.83	0.75–348.49	54.03±24.68	0.84–435.61	65.11±27.77
Fe	µg m <sup>-3</sup>	0.14–6.46	3.98±0.88	1.08–25.42	10.23±1.31	1.22–48.36	19.46±1.47
Hg	ng m <sup>-3</sup>	0.002–7.40	2.82±0.96	0.004–10.00	5.45±1.36	0.004–12.50	6.57±1.52
K	µg m <sup>-3</sup>	0.74–10.43	3.94±0.74	1.26–18.92	10.93±1.81	1.42–35.99	20.79±2.03
Li	ng m <sup>-3</sup>	0.02–3.01	1.21±0.31	0.04–5.12	1.66±0.60	0.04–6.40	2.00±0.68
Mg	µg m <sup>-3</sup>	0.14–9.67	5.10±1.10	0.17–10.57	7.17±1.14	0.20–20.11	13.64±1.28
Mn	ng m <sup>-3</sup>	0.54–364.06	101.39±44.61	5.28–540.65	308.95±40.16	5.94–675.81	372.29±45.18
Na	µg m <sup>-3</sup>	0.09–10.68	4.61±1.98	0.47–17.48	12.21±1.18	0.53–33.25	23.24±1.33
Ni	ng m <sup>-3</sup>	0.02–18.68	14.85±1.99	0.04–27.69	17.94±5.76	0.04–34.61	21.62±6.48
Pb	ng m <sup>-3</sup>	5.86–1070.31	304.72±18.71	12.01–1201.56	395.55±40.54	13.51–1501.95	497.14±152.61
Se	ng m <sup>-3</sup>	0.07–66.52	45.16±7.18	0.17–80.71	61.58±7.84	0.19–100.88	74.21±8.82
Si	µg m <sup>-3</sup>	0.12–2.48	1.50±0.52	0.23–3.53	2.46±0.51	0.25–6.71	4.68±0.58
Sr	ng m <sup>-3</sup>	0.13–305.16	10.38±8.64	0.28–351.42	17.18±8.51	0.32–439.28	20.71±9.58
Th	ng m <sup>-3</sup>	0.001–0.104	0.0602±0.0215	0.001–0.1235	0.0781±0.03	0.001–0.1544	0.0941±0.034
U	ng m <sup>-3</sup>	0.0003–0.0204	0.0101±0.001	0.0005–0.0284	0.0118±0.003	0.0006–0.036	0.0142±0.003
V	ng m <sup>-3</sup>	0.21–30.54	3.69±1.08	0.41–43.01	5.18±1.01	0.46–53.77	6.24±1.14
Zn	ng m <sup>-3</sup>	2.34–718.41	245.19±40.19	7.76–898.45	326.79±47.58	8.73–1123.06	393.78±53.53
C	µg m <sup>-3</sup>	1.36–18.54	5.97±0.84	2.44–23.19	13.70±1.60	2.74–44.13	26.07±1.80
H	µg m <sup>-3</sup>	0.70–15.04	5.92±0.45	1.04–19.02	11.36±1.41	1.17–36.18	21.61±1.58
N	µg m <sup>-3</sup>	0.03–10.34	4.72±0.29	0.07–11.45	7.47±1.23	0.08–21.77	14.22±1.39
S	µg m <sup>-3</sup>	0.39–7.19	3.02±0.83	0.79–8.57	4.01±1.35	0.89–16.30	7.64±1.52
Br <sup>-</sup>	ng m <sup>-3</sup>	0.0051–0.2001	0.1024±0.003	0.01–0.21	0.13±0.001	0.01–0.26	0.15±0.01
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.49–4.40	2.02±0.61	0.55–6.56	3.31±1.31	0.62–12.49	6.31±1.47
F <sup>-</sup>	µg m <sup>-3</sup>	0.05–4.68	1.84±0.71	0.06–5.42	2.02±0.45	0.07–10.32	3.85±0.50
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.02–1.01	0.41±0.21	0.03–1.23	0.56±0.34	0.04–2.35	1.06±0.39
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.13–18.00	3.10±1.00	0.24–21.00	6.23±1.10	0.27–39.96	11.85±1.24
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.13–4.43	3.45±1.02	0.17–5.72	4.85±1.71	0.20–10.87	9.22±1.92
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	0.90–20.09	6.01±2.08	1.06–27.21	9.81±2.72	1.19–51.77	18.67±3.06
Ca <sup>2+</sup>	ng m <sup>-3</sup>	0.98–13.43	5.45±2.17	1.92–38.50	24.02±2.91	2.16–73.25	45.71±3.27
K <sup>+</sup>	ng m <sup>-3</sup>	1.48–20.85	7.89±1.47	2.52–37.83	21.85±3.61	2.84–71.98	41.58±4.07
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.27–19.33	10.19±2.19	0.35–21.15	14.34±2.28	0.39–40.23	27.28±2.56
Na <sup>+</sup>	ng m <sup>-3</sup>	0.17–21.37	9.22±3.96	0.95–34.95	24.42±2.36	1.07–66.50	46.47±2.65
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.00–23.73	10.94±3.07	1.73–31.02	15.90±5.18	1.94–38.78	19.16±5.82

± Standard deviation

**Table 5.2:** Concentration of various elements in particulate matter during two consecutive years (2016 & 2017) at AQMS-02

Elements	Unit	PM <sub>2.5</sub>		PM <sub>10</sub>		SPM	
		Range	Average	Range	Average	Range	Average
Ag	ng m <sup>-3</sup>	0.10–1.21	1.01±0.20	0.11–1.38	1.18±0.20	0.12–1.73	1.42±0.23
Al	µg m <sup>-3</sup>	0.22–5.01	2.34±1.23	0.46–15.82	10.02±2.55	0.52–30.10	19.07±2.87
As	ng m <sup>-3</sup>	0.71–10.76	4.14±1.12	1.61–11.45	4.35±1.32	1.81–14.32	5.45±1.49
Br	ng m <sup>-3</sup>	0.92–5.51	1.65±0.41	0.10–7.51	2.25±1.41	0.11–9.39	2.71±1.59
Ca	µg m <sup>-3</sup>	1.73–7.63	3.80±1.21	1.23–20.27	13.67±2.20	1.38–38.56	26.01±2.47
Cd	ng m <sup>-3</sup>	0.56–79.61	7.43±2.56	1.24–86.29	10.72±2.21	1.39–107.86	12.92±2.49
Co	ng m <sup>-3</sup>	0.56–13.67	9.15±2.64	0.56–16.67	11.15±2.60	0.63–20.83	13.44±2.93
Cr	ng m <sup>-3</sup>	0.66–101.32	20.28±4.51	0.42–115.49	34.20±8.23	0.47–144.36	41.21±9.26
Cu	ng m <sup>-3</sup>	0.75–212.13	35.13±15.88	0.80–350.39	54.05±28.29	0.90–437.99	65.13±31.83
Fe	µg m <sup>-3</sup>	0.98–8.73	3.18±1.62	1.23–25.72	10.55±1.78	1.38–48.94	20.07±2.00
Hg	ng m <sup>-3</sup>	0.01–7.62	3.53±1.17	0.01–10.90	5.91±2.92	0.01–13.63	7.12±3.29
K	µg m <sup>-3</sup>	0.94–10.20	3.78±1.12	1.10–19.13	11.46±2.74	1.24–36.40	21.81±3.09
Li	ng m <sup>-3</sup>	0.03–3.14	1.07±0.42	0.03–5.14	1.70±0.60	0.04–6.42	2.05±0.68
Mg	µg m <sup>-3</sup>	0.10–6.90	4.06±1.84	0.18–11.26	7.32±1.59	0.20–21.42	13.92±1.79
Mn	ng m <sup>-3</sup>	0.85–396.78	115.46±50.53	5.52–540.49	146.25±47.17	6.21–675.62	176.23±53.07
Na	µg m <sup>-3</sup>	0.11–10.01	4.08±1.08	0.56–18.88	12.52±3.90	0.63–35.92	23.82±4.39
Ni	ng m <sup>-3</sup>	0.03–18.75	14.21±2.74	0.03–29.65	18.06±5.61	0.03–37.07	21.76±6.31
Pb	ng m <sup>-3</sup>	10.32–1084.89	306.15±20.58	12.40–1211.29	396.64±69.94	13.95–1514.12	498.45±103.68
Se	ng m <sup>-3</sup>	0.07–68.50	45.25±7.81	0.18–81.73	63.99±8.48	0.20–102.17	77.11±9.54
Si	µg m <sup>-3</sup>	0.12–2.45	1.52±0.63	0.25–3.54	2.57±0.53	0.28–6.74	4.90±0.60
Sr	ng m <sup>-3</sup>	0.13–305.56	10.37±10.65	0.30–356.15	17.83±10.51	0.34–445.19	21.49±11.83
Th	ng m <sup>-3</sup>	0.001–0.1050	0.0620±0.0252	0.001–0.135	0.081±0.0312	0.0011–0.1687	0.0976±0.0351
U	ng m <sup>-3</sup>	0.0003–0.0198	0.0104±0.001	0.0005–0.029	0.0121±0.003	0.0006–0.0363	0.0146±0.003
V	ng m <sup>-3</sup>	0.21–32.53	3.87±1.76	0.41–44.01	5.22±1.01	0.46–55.02	6.29±1.14
Zn	ng m <sup>-3</sup>	5.08–786.45	259.72±44.02	8.44–957.49	327.36±58.81	9.49–1196.86	394.47±66.16
C	µg m <sup>-3</sup>	1.39–18.94	6.07±1.84	2.84–23.29	13.99±1.98	3.19–44.31	26.61±2.23
H	µg m <sup>-3</sup>	0.70–15.70	6.19±1.45	1.04–19.17	11.59±1.45	1.17–36.46	22.06±1.63
N	µg m <sup>-3</sup>	0.03–10.34	4.72±1.29	0.07–11.45	7.72±1.33	0.08–21.79	14.68±1.49
S	µg m <sup>-3</sup>	0.39–7.86	3.19±0.83	0.88–8.65	4.14±1.53	0.99–16.46	7.88±1.72
Br <sup>-</sup>	ng m <sup>-3</sup>	0.0052–0.2021	0.1042±0.03	0.0056–0.2161	0.1265±0.005	0.0063–0.271	0.1524±0.006
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.51–4.46	2.05±0.69	0.55–6.64	3.35±1.37	0.62–12.64	6.37±1.54
F <sup>-</sup>	µg m <sup>-3</sup>	0.05–4.84	1.87±0.76	0.06–5.44	2.03±0.48	0.07–10.36	3.86±0.54
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.02–1.02	0.47±0.26	0.03–1.24	0.56±0.35	0.04–2.35	1.07±0.39
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.13–18.01	3.20±1.01	0.25–21.04	6.29±1.14	0.28–40.03	11.97±1.28
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.14–4.61	3.52±1.15	0.17–5.71	4.85±1.78	0.20–10.87	9.23±2.00
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	0.91–20.91	6.08±2.77	1.06–27.22	9.83±2.77	1.19–51.79	18.71±3.11
Ca <sup>2+</sup>	ng m <sup>-3</sup>	3.46–15.27	7.59±2.42	2.46–40.53	27.34±4.40	2.76–77.11	52.02±4.95
K <sup>+</sup>	ng m <sup>-3</sup>	1.88–20.39	7.55±2.24	2.21–38.26	22.92±5.49	2.48–72.79	43.61±6.17
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.21–13.81	8.11±3.68	0.35–22.52	14.64±3.17	0.40–42.84	27.85±3.57
Na <sup>+</sup>	ng m <sup>-3</sup>	0.22–20.02	8.16±2.16	1.12–37.76	25.04±7.80	1.27–71.84	47.64±8.77
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.03–24.29	11.43±3.66	1.73–31.22	15.94±5.77	1.94–39.03	19.21±6.49

± Standard deviation

**Table 5.3:** Concentration of various elements in particulate matter during two consecutive years (2016 & 2017) at AQMS-03

Elements	Unit	PM <sub>2.5</sub>		PM <sub>10</sub>		SPM	
		Range	Average	Range	Average	Range	Average
Ag	ng m <sup>-3</sup>	0.10–1.22	1.02±0.21	0.11–1.42	1.22±0.21	0.12–1.78	1.47±0.24
Al	µg m <sup>-3</sup>	0.22–5.02	2.34±1.23	0.46–15.83	10.03±2.55	0.52–30.11	19.08±2.87
As	ng m <sup>-3</sup>	0.71–10.76	4.14±1.12	1.61–11.45	4.35±1.32	1.81–14.31	5.45±1.49
Br	ng m <sup>-3</sup>	0.92–5.51	1.65±0.41	0.10–7.51	2.25±1.41	0.11–9.39	2.71±1.59
Ca	µg m <sup>-3</sup>	1.73–7.64	3.80±1.21	1.23–20.27	13.67±2.20	1.38–38.57	26.01±2.47
Cd	ng m <sup>-3</sup>	0.56–79.63	7.43±2.56	1.24–86.31	10.73±2.21	1.40–107.89	12.93±2.49
Co	ng m <sup>-3</sup>	0.56–13.67	9.16±2.64	0.56–16.67	11.16±2.60	0.63–20.84	13.44±2.93
Cr	ng m <sup>-3</sup>	0.66–101.35	20.29±4.51	0.42–115.52	34.20±8.23	0.47–144.40	41.22±9.26
Cu	ng m <sup>-3</sup>	0.75–212.18	35.14±15.88	0.80–350.48	54.07±28.29	0.90–438.10	65.15±31.83
Fe	µg m <sup>-3</sup>	0.98–8.73	3.18±1.62	1.23–25.73	10.55±1.78	1.38–48.95	20.08±2.00
Hg	ng m <sup>-3</sup>	0.01–7.62	3.53±1.17	0.01–10.90	5.91±2.92	0.01–13.62	7.12±3.29
K	µg m <sup>-3</sup>	0.94–10.20	3.78±1.12	1.10–19.14	11.46±2.74	1.24–36.41	21.81±3.09
Li	ng m <sup>-3</sup>	0.03–3.14	1.07±0.42	0.04–5.14	1.70±0.60	0.04–6.42	2.05±0.68
Mg	µg m <sup>-3</sup>	0.10–6.91	4.06±1.84	0.18–11.26	7.32±1.59	0.20–21.42	13.93±1.79
Mn	ng m <sup>-3</sup>	0.85–396.88	115.49±50.53	5.52–540.63	146.29±47.17	6.21–675.79	176.27±53.07
Na	µg m <sup>-3</sup>	0.11–10.01	4.08±1.08	0.56–18.89	12.52±3.90	0.63–35.93	23.83±4.39
Ni	ng m <sup>-3</sup>	0.03–18.75	14.22±2.74	0.03–29.66	18.06±5.61	0.03–37.08	21.76±6.31
Pb	ng m <sup>-3</sup>	10.32–1085.16	306.25±20.58	12.40–1211.72	396.76±69.94	13.95–1514.65	498.60±103.68
Se	ng m <sup>-3</sup>	0.07–68.52	45.26±7.81	0.18–81.75	64.01±8.48	0.20–102.19	77.13±9.54
Si	µg m <sup>-3</sup>	0.12–2.45	1.52±0.63	0.25–3.54	2.57±0.53	0.28–6.74	4.90±0.60
Sr	ng m <sup>-3</sup>	0.13–305.64	10.37±10.65	0.30–356.24	17.84±10.51	0.34–445.30	21.49±11.83
Th	ng m <sup>-3</sup>	0.001–0.105	0.062±0.025	0.001–0.135	0.081±0.031	0.0011–0.1688	0.0976±0.0351
U	ng m <sup>-3</sup>	0.0003–0.0198	0.0104±0.001	0.0005–0.029	0.0121±0.003	0.0006–0.0363	0.0146±0.0034
V	ng m <sup>-3</sup>	0.21–32.54	3.87±1.76	0.41–44.02	5.22±1.01	0.46–55.03	6.29±1.14
Zn	ng m <sup>-3</sup>	5.08–786.65	259.78±44.02	8.44–957.73	327.44±58.81	9.50–1197.16	394.57±66.16
C	µg m <sup>-3</sup>	1.39–18.94	6.07±1.84	2.84–23.29	13.99±1.98	3.19–44.32	26.62±2.23
H	µg m <sup>-3</sup>	0.70–15.70	6.19±1.45	1.04–19.17	11.60±1.45	1.17–36.47	22.07±1.63
N	µg m <sup>-3</sup>	0.03–10.34	4.72±1.29	0.07–11.45	7.72±1.33	0.08–21.79	14.69±1.49
S	µg m <sup>-3</sup>	0.39–7.86	3.19±0.83	0.88–8.65	4.14±1.53	0.99–16.46	7.88±1.72
Br <sup>-</sup>	ng m <sup>-3</sup>	0.0052–0.202	0.1042±0.0303	0.0056–0.216	0.1264±0.005	0.0063–0.27	0.1523±0.0057
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.51–4.46	2.05±0.69	0.55–6.65	3.35±1.37	0.62–12.64	6.37±1.54
F <sup>-</sup>	µg m <sup>-3</sup>	0.05–4.84	1.88±0.76	0.06–5.44	2.03±0.48	0.07–10.36	3.86±0.54
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.02–1.02	0.47±0.26	0.03–1.24	0.56±0.35	0.04–2.35	1.07±0.39
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.14–18.02	3.20±1.01	0.25–21.05	6.29±1.14	0.28–40.04	11.97±1.28
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.14–4.62	3.52±1.15	0.17–5.72	4.85±1.78	0.20–10.87	9.23±2.00
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	0.91–20.92	6.08±2.77	1.06–27.23	9.84±2.77	1.19–51.80	18.72±3.11
Ca <sup>2+</sup>	ng m <sup>-3</sup>	3.46–15.27	7.59±2.42	2.46–40.54	27.34±4.40	2.77–77.13	52.03±4.95
K <sup>+</sup>	ng m <sup>-3</sup>	1.88–20.40	7.56±2.24	2.21–38.27	22.93±5.49	2.48–72.81	43.62±6.17
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.21–13.81	8.11±3.68	0.35–22.52	14.64±3.17	0.40–42.85	27.85±3.57
Na <sup>+</sup>	ng m <sup>-3</sup>	0.22–20.02	8.17±2.16	1.13–37.77	25.05±7.80	1.27–71.86	47.66±8.77
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.03–24.29	11.43±3.66	1.73–31.23	15.94±5.77	1.94–39.04	19.21±6.49

± Standard deviation

**Table 5.4:** Concentration of various elements in particulate matter during two consecutive years (2016 & 2017) at AQMS-04

Elements	Unit	PM <sub>2.5</sub>		PM <sub>10</sub>		SPM	
		Range	Average	Range	Average	Range	Average
Ag	ng m <sup>-3</sup>	0.10–1.24	0.95±0.19	0.11–1.42	1.02±0.21	0.11–1.55	1.15±0.22
Al	µg m <sup>-3</sup>	0.12–4.93	2.14±1.02	0.34–14.97	9.81±1.63	0.39–28.47	18.67±1.83
As	ng m <sup>-3</sup>	0.69–9.52	4.01±0.93	1.56–5.29	5.03±1.32	1.76–6.61	5.26±1.49
Br	ng m <sup>-3</sup>	0.81–4.51	1.45±0.34	0.09–7.28	2.12±0.98	0.10–9.10	2.56±1.11
Ca	µg m <sup>-3</sup>	0.49–6.71	2.73±1.08	0.96–19.25	12.01±1.45	1.08–36.61	22.85±1.64
Cd	ng m <sup>-3</sup>	0.52–78.52	7.22±1.93	1.04–90.29	10.88±0.07	1.17–112.86	13.11±0.08
Co	ng m <sup>-3</sup>	0.52–12.88	8.92±2.45	0.55–15.16	11.01±1.26	0.62–18.95	13.27±1.42
Cr	ng m <sup>-3</sup>	0.49–101.53	21.20±5.45	0.49–115.53	33.55±15.49	0.55–144.41	40.43±17.43
Cu	ng m <sup>-3</sup>	0.74–237.70	30.05±15.83	0.75–348.40	54.02±24.68	0.84–435.50	65.09±27.77
Fe	µg m <sup>-3</sup>	0.14–6.46	3.98±0.88	1.08–25.41	10.23±1.31	1.22–48.34	19.46±1.47
Hg	ng m <sup>-3</sup>	0.002–7.40	2.82±0.96	0.0039–10.01	5.45±1.36	0.0044–12.51	6.57±1.52
K	µg m <sup>-3</sup>	0.74–10.42	3.94±0.74	1.26–18.91	10.92±1.81	1.42–35.98	20.79±2.03
Li	ng m <sup>-3</sup>	0.02–3.01	1.21±0.31	0.03–5.12	1.66±0.60	0.04–6.40	2.00±0.68
Mg	µg m <sup>-3</sup>	0.14–9.66	5.09±1.10	0.17–10.57	7.17±1.14	0.20–20.11	13.64±1.28
Mn	ng m <sup>-3</sup>	0.54–363.97	101.36±44.61	5.28–540.51	308.88±40.16	5.94–675.64	372.20±45.18
Na	µg m <sup>-3</sup>	0.09–10.68	4.61±1.98	0.47–17.47	12.21±1.18	0.53–33.24	23.23±1.33
Ni	ng m <sup>-3</sup>	0.02–18.67	14.85±1.99	0.04–27.68	17.94±5.76	0.04–34.60	21.61±6.48
Pb	ng m <sup>-3</sup>	5.86–1070.04	304.62±18.71	12.01–1201.11	390.42±40.54	13.51–1501.39	490.96±152.61
Se	ng m <sup>-3</sup>	0.07–66.50	45.15±7.18	0.17–80.69	61.57±7.84	0.19–100.86	74.19±8.82
Si	µg m <sup>-3</sup>	0.12–2.48	1.50±0.52	0.22–3.52	2.46±0.51	0.25–6.71	4.67±0.58
Sr	ng m <sup>-3</sup>	0.13–305.08	10.38±8.64	0.28–351.34	17.18±8.51	0.32–439.17	20.70±9.58
Th	ng m <sup>-3</sup>	0.001–0.104	0.0602±0.0215	0.001–0.1235	0.0781±0.0301	0.0011–0.154	0.094±0.034
U	ng m <sup>-3</sup>	0.0003–0.021	0.0101±0.001	0.0005–0.0284	0.0118±0.0027	0.0006–0.036	0.014±0.003
V	ng m <sup>-3</sup>	0.21–30.53	3.69±1.08	0.41–43.00	5.18±1.01	0.46–53.75	6.24±1.14
Zn	ng m <sup>-3</sup>	2.34–718.23	245.13±40.19	7.76–898.23	326.71±47.58	8.73–1122.78	393.68±53.53
C	µg m <sup>-3</sup>	1.36–18.54	5.97±0.84	2.44–23.19	13.70±1.60	2.74–44.12	26.06±1.80
H	µg m <sup>-3</sup>	0.70–15.04	5.92±0.45	1.04–19.01	11.36±1.41	1.17–36.17	21.61±1.58
N	µg m <sup>-3</sup>	0.03–10.34	4.72±0.29	0.07–11.44	7.47±1.23	0.08–21.77	14.21±1.39
S	µg m <sup>-3</sup>	0.39–7.18	3.02±0.83	0.79–8.56	4.01±1.35	0.89–16.29	7.64±1.52
Br <sup>-</sup>	ng m <sup>-3</sup>	0.0051–0.201	0.1024±0.003	0.01–0.21	0.13±0.001	0.01–0.26	0.15±0.01
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.49–4.40	2.02±0.61	0.55–6.56	3.31±1.31	0.62–12.49	6.31±1.47
F <sup>-</sup>	µg m <sup>-3</sup>	0.05–4.68	1.84±0.71	0.06–5.42	2.02±0.45	0.07–10.32	3.85±0.50
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.02–1.01	0.41±0.21	0.03–1.23	0.56±0.34	0.04–2.35	1.06±0.39
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.13–18.00	3.10±1.00	0.24–21.00	6.23±1.10	0.27–39.95	11.85±1.24
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.13–4.43	3.45±1.02	0.17–5.71	4.84±1.71	0.20–10.87	9.22±1.92
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	0.90–20.09	6.01±2.08	1.06–27.21	9.81±2.72	1.19–51.76	18.67±3.06
Ca <sup>2+</sup>	ng m <sup>-3</sup>	0.98–13.42	5.45±2.17	1.92–38.49	24.02±2.91	2.16–73.23	45.70±3.27
K <sup>+</sup>	ng m <sup>-3</sup>	1.48–20.85	7.88±1.47	2.52–37.82	21.85±3.61	2.84–71.96	41.57±4.07
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.27–19.33	10.19±2.19	0.35–21.14	14.34±2.28	0.39–40.22	27.28±2.56
Na <sup>+</sup>	ng m <sup>-3</sup>	0.17–21.36	9.22±3.96	0.95–34.94	24.42±2.36	1.07–66.48	46.46±2.65
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.00–23.72	10.94±3.07	1.73–31.02	15.90±5.18	1.94–38.77	19.16±5.82

± Standard deviation

**Table 5.5:** Concentration of various elements in particulate matter during March, April and May 2016 at AQMS-05

Elements	Unit	PM <sub>2.5</sub>		PM <sub>10</sub>		SPM	
		Range	Average	Range	Average	Range	Average
Ag	ng m <sup>-3</sup>	0.10–1.27	0.98±0.19	0.11–1.45	1.05±0.21	0.11–1.58	1.18±0.22
Al	µg m <sup>-3</sup>	0.13–5.03	2.19±1.02	0.35–15.27	10.04±1.63	0.39–29.05	19.11±1.83
As	ng m <sup>-3</sup>	0.70–9.71	4.13±0.93	1.59–11.51	4.16±1.32	1.79–14.39	5.22±1.49
Br	ng m <sup>-3</sup>	0.83–4.60	1.48±0.34	0.09–7.43	2.17±0.98	0.10–9.29	2.62±1.11
Ca	µg m <sup>-3</sup>	0.50–6.85	2.79±1.08	0.98–19.64	12.29±1.45	1.10–37.36	23.38±1.64
Cd	ng m <sup>-3</sup>	0.53–80.12	7.39±1.93	1.06–92.13	11.13±0.07	1.19–115.16	13.41±0.08
Co	ng m <sup>-3</sup>	0.53–13.14	9.13±2.45	0.56–15.46	11.27±1.26	0.63–19.33	13.58±1.42
Cr	ng m <sup>-3</sup>	0.50–103.60	21.70±5.45	0.50–117.88	34.34±15.49	0.57–147.35	41.38±17.43
Cu	ng m <sup>-3</sup>	0.76–242.54	30.76±15.83	0.76–355.49	55.28±24.68	0.86–444.37	66.61±27.77
Fe	µg m <sup>-3</sup>	0.14–6.59	4.07±0.88	1.11–25.93	10.46±1.31	1.24–49.33	19.91±1.47
Hg	ng m <sup>-3</sup>	0.002–7.55	2.88±0.96	0.004–10.20	5.57±1.36	0.004–12.75	6.72±1.52
K	µg m <sup>-3</sup>	0.75–10.64	4.03±0.74	1.29–19.30	11.18±1.81	1.45–36.71	21.27±2.03
Li	ng m <sup>-3</sup>	0.02–3.07	1.23±0.31	0.04–5.23	1.70±0.60	0.04–6.53	2.04±0.68
Mg	µg m <sup>-3</sup>	0.14–9.86	5.21±1.10	0.18–10.79	7.34±1.14	0.20–20.52	13.96±1.28
Mn	ng m <sup>-3</sup>	0.55–371.38	103.74±44.61	5.39–551.52	316.10±40.16	6.06–689.40	380.90±45.18
Na	µg m <sup>-3</sup>	0.09–10.90	4.72±1.98	0.48–17.83	12.49±1.18	0.54–33.92	23.77±1.33
Ni	ng m <sup>-3</sup>	0.02–19.05	15.19±1.99	0.04–28.25	18.35±5.76	0.05–35.31	22.12±6.48
Pb	ng m <sup>-3</sup>	5.98–1091.82	314.08±18.71	12.25–1137.77	350.13±40.54	13.78–1422.21	442.41±152.61
Se	ng m <sup>-3</sup>	0.07–67.86	46.20±7.18	0.17–82.33	63.01±7.84	0.19–102.91	75.93±8.82
Si	µg m <sup>-3</sup>	0.12–2.53	1.54±0.52	0.23–3.60	2.51±0.51	0.26–6.84	4.78±0.58
Sr	ng m <sup>-3</sup>	0.13–311.29	10.62±8.64	0.29–358.49	17.58±8.51	0.32–448.11	21.19±9.58
Th	ng m <sup>-3</sup>	0.001–0.1061	0.0616±0.0215	0.001–0.13	0.08±0.03	0.001–0.16	0.10±0.03
U	ng m <sup>-3</sup>	0.0003–0.0208	0.0103±0.001	0.001–0.03	0.01±0.003	0.001–0.04	0.01±0.003
V	ng m <sup>-3</sup>	0.21–31.16	3.771.08±	0.42–43.88	5.30±1.01	0.47–54.85	6.39±1.14
Zn	ng m <sup>-3</sup>	2.39–732.85	250.86±40.19	7.92–916.51	334.35±47.58	8.91–1145.64	402.89±53.53
C	µg m <sup>-3</sup>	1.38–18.92	6.11±0.84	2.49–23.66	14.02±1.60	2.80–45.01	26.67±1.80
H	µg m <sup>-3</sup>	0.71–15.34	6.06±0.45	1.06–19.40	11.62±1.41	1.19–36.91	22.11±1.58
N	µg m <sup>-3</sup>	0.03–10.55	4.83±0.29	0.07–11.68	7.64±1.23	0.08–22.21	14.55±1.39
S	µg m <sup>-3</sup>	0.40–7.33	3.09±0.83	0.80–8.74	4.11±1.35	0.90–16.62	7.82±1.52
Br <sup>-</sup>	ng m <sup>-3</sup>	0.0052–0.2041	0.1048±0.003	0.01–0.22	0.13±0.001	0.01–0.27	0.15±0.01
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.50–4.49	2.07±0.61	0.56–6.70	3.39±1.31	0.63–12.74	6.45±1.47
F <sup>-</sup>	µg m <sup>-3</sup>	0.05–4.77	1.88±0.71	0.06–5.53	2.07±0.45	0.07–10.53	3.94±0.50
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.02–1.03	0.42±0.21	0.04–1.26	0.57±0.34	0.04–2.39	1.08±0.39
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.13–18.36	3.17±1.00	0.25–21.43	6.37±1.10	0.28–40.76	12.13±1.24
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.13–4.52	3.53±1.02	0.18–5.83	4.96±1.71	0.20–11.09	9.43±1.92
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	0.92–20.50	6.15±2.08	1.08–27.76	10.04±2.72	1.21–52.81	19.10±3.06
Ca <sup>2+</sup>	ng m <sup>-3</sup>	1.00–13.69	5.58±2.17	1.96–39.27	24.58±2.91	2.20–74.72	46.77±3.27
K <sup>+</sup>	ng m <sup>-3</sup>	1.51–21.27	8.07±1.47	2.57–38.59	22.36±3.61	2.89–73.42	42.54±4.07
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.28–19.72	10.43±2.19	0.35–21.57	14.67±2.28	0.40–41.04	27.92±2.56
Na <sup>+</sup>	ng m <sup>-3</sup>	0.17–21.80	9.44±3.96	0.97–35.65	24.99±2.36	1.09–67.83	47.55±2.65
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.00–23.73	10.94±3.07	1.73–31.02	15.90±5.18	1.94–38.78	19.16±5.82

± Standard deviation

**Table 5.6:** Concentration of various elements in particulate matter during March, April and May 2016 at AQMS-05

Elements	Unit	PM <sub>2.5</sub>		PM <sub>10</sub>		SPM	
		Range	Average	Range	Average	Range	Average
Ag	ng m <sup>-3</sup>	0.10–0.43	0.16±0.10	0.11–1.45	1.05±0.21	0.12–1.81	1.26±0.24
Al	µg m <sup>-3</sup>	0.22–5.07	2.37±1.23	0.47–16.14	10.26±2.55	0.53–30.71	19.52±2.87
As	ng m <sup>-3</sup>	0.72–10.87	4.20±1.12	1.64–11.68	4.50±1.32	1.85–14.60	5.63±1.49
Br	ng m <sup>-3</sup>	0.93–5.57	1.67±0.41	0.10–7.66	2.30±1.41	0.11–9.58	2.77±1.59
Ca	µg m <sup>-3</sup>	1.75–7.71	3.84±1.21	1.25–20.68	13.99±2.20	1.41–39.34	26.62±2.47
Cd	ng m <sup>-3</sup>	0.57–80.43	7.52±2.56	1.26–88.04	10.98±2.21	1.42–110.06	13.23±2.49
Co	ng m <sup>-3</sup>	0.57–13.81	9.26±2.64	0.57–17.01	11.41±2.60	0.64–21.26	13.75±2.93
Cr	ng m <sup>-3</sup>	0.67–102.36	20.52±4.51	0.43–117.84	35.00±8.23	0.48–147.30	42.17±9.26
Cu	ng m <sup>-3</sup>	0.76–214.30	35.54±15.88	0.82–357.52	55.32±28.29	0.92–446.91	66.66±31.83
Fe	µg m <sup>-3</sup>	0.99–8.82	3.22±1.62	1.25–26.25	10.80±1.78	1.41–49.93	20.54±2.00
Hg	ng m <sup>-3</sup>	0.004–7.70	3.57±1.17	0.01–11.12	6.04±2.92	0.01–13.90	7.28±3.29
K	µg m <sup>-3</sup>	0.95–10.30	3.82±1.12	1.13–19.52	11.73±2.74	1.27–37.14	22.32±3.09
Li	ng m <sup>-3</sup>	0.03–3.17	1.08±0.42	0.04–5.24	1.74±0.60	0.04–6.55	2.10±0.68
Mg	µg m <sup>-3</sup>	0.11–6.98	4.10±1.84	0.18–11.49	7.49±1.59	0.20–21.85	14.25±1.79
Mn	ng m <sup>-3</sup>	0.86–400.85	116.82±50.53	5.63–551.50	149.67±47.17	6.33–689.37	180.35±53.07
Na	µg m <sup>-3</sup>	0.11–10.11	4.13±1.08	0.57–19.27	12.81±3.90	0.65–36.65	24.38±4.39
Ni	ng m <sup>-3</sup>	0.03–18.94	14.38±2.74	0.03–30.26	18.48±5.61	0.03–37.82	22.27±6.31
Pb	ng m <sup>-3</sup>	10.42–1096.01	310.92±20.58	12.65–1146.13	350.25±51.94	14.23–1432.66	442.55±183.43
Se	ng m <sup>-3</sup>	0.07–69.21	45.78±7.81	0.18–83.40	65.49±8.48	0.21–104.25	78.91±9.54
Si	µg m <sup>-3</sup>	0.12–2.48	1.54±0.63	0.26–3.61	2.63±0.53	0.29–6.88	5.01±0.60
Sr	ng m <sup>-3</sup>	0.13–308.70	10.49±10.65	0.31–363.40	18.25±10.51	0.34–454.25	21.99±11.83
Th	ng m <sup>-3</sup>	0.001–0.1061	0.0627±0.025	0.001–0.1377	0.0829±0.032	0.0011–0.1721	0.0999±0.035
U	ng m <sup>-3</sup>	0.0003–0.02	0.0105±0.001	0.0005–0.0296	0.0124±0.003	0.0006–0.037	0.0149±0.003
V	ng m <sup>-3</sup>	0.22–32.87	3.91±1.76	0.42–44.91	5.34±1.01	0.47–56.14	6.43±1.14
Zn	ng m <sup>-3</sup>	5.13–794.52	262.77±44.02	8.61–976.98	335.01±58.81	9.69–1221.23	403.69±66.16
C	µg m <sup>-3</sup>	1.40–19.13	6.14±1.84	2.90–23.76	14.31±1.98	3.26–45.21	27.24±2.23
H	µg m <sup>-3</sup>	0.70–15.86	6.26±1.45	1.06–19.56	11.87±1.45	1.19–37.20	22.58±1.63
N	µg m <sup>-3</sup>	0.03–10.45	4.77±1.29	0.07–11.68	7.90±1.33	0.08–22.23	15.03±1.49
S	µg m <sup>-3</sup>	0.39–7.94	3.22±0.83	0.90–8.83	4.24±1.53	1.01–16.79	8.07±1.72
Br <sup>-</sup>	ng m <sup>-3</sup>	0.0052–0.204	0.1054±0.03	0.0057–0.2203	0.1293±0.005	0.0064–0.2754	0.1559±0.006
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.52–4.50	2.07±0.69	0.56–6.78	3.43±1.37	0.63–12.90	6.52±1.54
F <sup>-</sup>	µg m <sup>-3</sup>	0.05–4.89	1.90±0.76	0.06–5.55	2.07±0.48	0.07–10.57	3.95±0.54
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.02–1.03	0.48±0.26	0.04–1.26	0.58±0.35	0.04–2.40	1.10±0.39
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.14–18.20	3.24±1.01	0.26–21.47	6.44±1.14	0.29–40.85	12.25±1.28
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.14–4.66	3.56±1.15	0.18–5.83	4.96±1.78	0.20–11.09	9.45±2.00
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	0.91–21.13	6.15±2.77	1.08–27.78	10.06±2.77	1.21–52.84	19.15±3.11
Ca <sup>2+</sup>	ng m <sup>-3</sup>	3.49–15.42	7.68±2.42	2.51–41.36	27.98±4.40	2.82–78.68	53.23±4.95
K <sup>+</sup>	ng m <sup>-3</sup>	1.90–20.60	7.64±2.24	2.25–39.04	23.46±5.49	2.53–74.27	44.63±6.17
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.21–13.95	8.21±3.68	0.36–22.97	14.98±3.17	0.41–43.71	28.50±3.57
Na <sup>+</sup>	ng m <sup>-3</sup>	0.23–20.22	8.26±2.16	1.15–38.53	25.63±7.80	1.29–73.30	48.76±8.77
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.03–24.29	11.43±3.66	1.73–31.23	15.94±5.77	1.94–39.04	19.21±6.49

± Standard deviation

The annual average concentration of elements (Al, Mg, Si, Ca, Fe, K, and Na) had a total level of  $22.5 \pm 8.3 \mu\text{g m}^{-3}$  and  $23.2 \pm 8.3 \mu\text{g m}^{-3}$  in the year 2016 and year 2017, respectively at AQMS-03, occupying 28.64 % and 28.21 % of  $\text{PM}_{2.5}$  mass, while the concentration of all analyzed trace elements was  $839 \pm 160 \text{ ng m}^{-3}$  and  $846 \pm 160 \text{ ng m}^{-3}$  with a  $\text{PM}_{2.5}$  fraction of 1.07 % and 1.03 % in the year 2016 and year 2017, respectively at AQMS-03.

It notices that the trace elements, Pb was the most severe heavy metal and approximately 60 % of the permissible limit value made by the National Ambient Air Quality Standards in India ( $500 \text{ ng m}^{-3}$ ; [101]). The annual mean concentration of As was  $4.06 \pm 1.08 \text{ ng m}^{-3}$  and  $4.25 \pm 1.08 \text{ ng m}^{-3}$ , which is well within the permissible limit of NAAQS ( $6 \text{ ng m}^{-3}$ ) [101]. The Ni was analyzed beyond the permissible limit of NAAQS ( $20 \text{ ng m}^{-3}$ ) [101]. It may be concluded that the pollution from trace elements associated with  $\text{PM}_{2.5}$  monitored at AQMS-03 was relatively better than in other areas. The observation of other monitoring stations is summarized in **Tables 5.7, 5.10, & 5.16**.

The same investigation has been carried out for  $\text{PM}_{10}$  samples. The annual concentration of  $\text{PM}_{10}$  associated major and trace elements is given in **Table 5.14** at sampling station AQMS-03 for two consecutive years (2016 & 2017). From the **Table**, the annual concentration of trace elements i.e., As, Br, Hg, Pb, Cr, Ni, Th, U, and Cd in  $\text{PM}_{10}$  samples were found to be in the average value of  $4.23 \pm 1.2$  &  $4.60 \pm 1.2 \text{ ng m}^{-3}$ ,  $2.19 \pm 1.3$  &  $2.38 \pm 1.3 \text{ ng m}^{-3}$ ,  $5.74 \pm 2.8$  &  $6.25 \pm 2.8 \text{ ng m}^{-3}$ ,  $419 \pm 68$  &  $385 \pm 68 \text{ ng m}^{-3}$ ,  $33.2 \pm 8$  &  $36.1 \pm 8 \text{ ng m}^{-3}$ ,  $17.5 \pm 5$  &  $19.1 \pm 5 \text{ ng m}^{-3}$ ,  $0.079 \pm 0.03$  &  $0.086 \pm 0.03 \text{ ng m}^{-3}$ ,  $0.0128 \pm 0.002$  &  $0.0117 \pm 0.002 \text{ ng m}^{-3}$  and  $10.4 \pm 2$  &  $11.3 \pm 2 \text{ ng m}^{-3}$ , respectively in the year 2016 & year 2017 (**Table 5.14**).

It is concluded that all analyzed trace elements are slightly different annual average during the monitoring period of the year 2016 and the year 2017 (**Table 5.14**). The annual concentration of As, Ni, and Pb have been well with the prescribed permissible limit of the

NAAQS [101]. The yearly total level of elements (Al, Mg, Si, Ca, Fe, K, and Na) were found to be the  $67.4 \pm 14.8 \mu\text{g m}^{-3}$  and  $70.8 \pm 14.8 \mu\text{g m}^{-3}$  in the year 2016 and year 2017, respectively at AQMS-03, occupying 36.22 % and 35.02 % of  $\text{PM}_{10}$  mass, while the concentration of all analyzed trace elements was  $1.11 \pm 0.24 \mu\text{g m}^{-3}$  and  $1.13 \pm 0.24 \mu\text{g m}^{-3}$  with a  $\text{PM}_{10}$  fraction of 0.60 % and 0.56 % in the year 2016 and year 2017, respectively at AQMS-03. It may notice that the trace elements, Pb was the most severe heavy metal and approximately 80 % of the permissible limit value made by the National Ambient Air Quality Standards, New Delhi, India ( $500 \text{ ng m}^{-3}$ ; [101]).

The annual average concentration of As was  $4.23 \pm 1.2 \text{ ng m}^{-3}$  and  $4.60 \pm 1.2 \text{ ng m}^{-3}$ , which is well within the permissible limit of National Ambient Air Quality Standards, New Delhi, India [ $6 \text{ ng m}^{-3}$ ; [101]].

Besides, only 20% of As, Ni, and Pb have been analyzed in particulate matter ( $\text{PM}_{10}$ ) samples beyond the permissible limit value of NAAQS, New Delhi, India [( $20 \text{ ng m}^{-3}$  for Ni;  $6 \text{ ng m}^{-3}$  for As; and  $500 \text{ ng m}^{-3}$  for Pb [101]). It may be concluded that the pollution from trace elements associated with  $\text{PM}_{10}$  monitoring at AQMS-03 was relatively similar to other analyzed areas.

In AQMS-03, the average value of Si/Al was 0.26, which is the same in two consecutive years (2016 & 2017), varying inconspicuously with the annual, implying that local dust dominated through the whole year. Si and Al's ratio was used to evaluate the local and transported dust because Si was depleted after the long-distance transportation [175]. The observations of other monitoring station's results are summarized in **Tables 5.8, 5.11, 5.17**. For suspended particulate matter (SPM), the annual average concentrations of SPM samples associated with analyzed major and trace elements collected at AQMS-03 is given in **Table 5.15**.

The major analyzed elements (Al, Ca, Fe, K, Mg, Na, Si) contribute about 34 % of the total fraction of the mass concentration of SPM. Similar levels of annual mean concentration have been measured and reported by the researcher in their studies [115,176] and are related to dust storms and anthropogenic fugitive dust. The annual concentration levels of trace elements (U, Th, Ag, Li, Br, As, V, Hg, Cd, Co, Sr, Ni, Cr, Cu, and Se) is ranging between 0.01 and 78.04 ng m<sup>-3</sup>. The researchers also reported that the Al, Ca, Fe, K, Mg, Na, and Si elements mainly originated from re-suspension, and rainfall can reduce the re-suspension [61,115].

**Table 5.15** summarizes the average and standard deviation of the trace-element concentrations associated with suspended particulate matter. The average levels of the trace elements follow the order as follows: Al > Fe > Mg > Zn > Cr > Ni > Co in the SPM samples, while almost the same observations were seen in the PM<sub>10</sub> and PM<sub>2.5</sub> samples (**Tables 5.13 and 5.14**).

The other remaining trace elements, mostly the toxic trace elements, are observed the low concentrations (<1 µg m<sup>-3</sup>) due to industrial emissions and coal combustion at AQMS-03, providing dust-free harmful to human health [173,177]. The heavy metals As, Cd, Cr, and Ni have potential carcinogenic risk [105,135,178].

In different circumstances, the elements, i.e., Al, Ca, Fe, Mg, Na, are not investigated harmful for human health. Afterward, some epidemiological researchers indicate very little association between these elements and mortality [179].

Although alternative particles, especially combustion-related particles, can be acted as surfaces in pursuance of the depiction. The results of other monitoring stations of the study area are given in **Tables 5.9, 5.12, 5.18**.

**Table 5.7:** Annual average concentration of major, trace elements and water-soluble ions and enrichment factor in PM<sub>2.5</sub> at AQMS-01

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.11–1.14	0.98±0.21	188.97±179.97	0.11–1.20	1.02±0.21	188.97±179.97
Al	µg m <sup>-3</sup>	0.13–4.93	2.10±1.01	0.37±0.79	0.13–4.69	2.19±1.01	0.37±0.79
As	ng m <sup>-3</sup>	0.69–9.05	3.94±1.01	31.53±36.59	0.69–9.52	4.10±1.01	31.53±36.59
Br	ng m <sup>-3</sup>	0.81–4.29	1.42±0.34	8.54±9.08	0.81–4.51	1.48±0.34	8.54±9.08
Ca	µg m <sup>-3</sup>	0.49–6.38	2.78±1.07	0.97±1.67	0.49–6.71	2.68±1.07	0.89±1.67
Cd	ng m <sup>-3</sup>	0.52–78.54	7.09±1.90	680.70±825.06	0.52–74.65	7.37±1.90	680.70±825.06
Co	ng m <sup>-3</sup>	0.52–12.24	8.75±2.42	5.05±6.28	0.52–12.88	9.11±2.42	5.05±6.28
Cr	ng m <sup>-3</sup>	0.49–96.53	20.82±5.37	2.94±3.43	0.49–101.56	21.65±5.37	2.94±3.43
Cu	ng m <sup>-3</sup>	0.74–237.76	30.69±15.61	7.37±16.92	0.74–225.98	29.50±15.61	6.81±16.92
Fe	µg m <sup>-3</sup>	0.14–6.14	3.91±0.87	1.00±1.00	0.14–6.46	4.06±0.87	1.00±1.00
Hg	ng m <sup>-3</sup>	0.002–7.030	2.764±0.951	468.60±727.69	0.002–7.396	2.875±0.951	468.60±727.69
K	µg m <sup>-3</sup>	0.74–9.91	3.87±0.73	2.67±2.26	0.74–10.43	4.03±0.73	2.672.26±
Li	ng m <sup>-3</sup>	0.02–3.01	1.18±0.31	0.85±1.00	0.02–2.86	1.23±0.31	0.85±1.00
Mg	µg m <sup>-3</sup>	0.14–9.19	5.00±1.08	3.09±3.02	0.14–9.67	5.20±1.08	3.09±3.02
Mn	ng m <sup>-3</sup>	0.54–346.02	99.50±44.00	1.51±3.01	0.54–364.06	103.51±44.00	1.51±3.01
Na	µg m <sup>-3</sup>	0.09–10.15	4.53±1.95	2.76±5.38	0.09–10.68	4.71±1.95	2.76±5.38
Ni	ng m <sup>-3</sup>	0.02–18.68	14.57±1.96	2.50±1.52	0.02–18.68	15.16±1.96	2.50±1.52
Pb	ng m <sup>-3</sup>	5.87–1017.27	311.09±18.45	320.21±85.70	5.86–1070.31	299.05±18.45	295.89±85.70
Se	ng m <sup>-3</sup>	0.07–63.22	44.32±7.08	12773.0±9210.0	0.07–66.52	46.10±7.08	12773.0±9210.0
Si	µg m <sup>-3</sup>	0.12–2.36	1.47±0.51	0.08±0.12	0.12–2.48	1.53±0.51	0.08±0.12
Sr	ng m <sup>-3</sup>	0.13–305.16	10.19±8.52	0.40±1.50	0.13–290.04	10.60±8.52	0.40±1.50
Th	ng m <sup>-3</sup>	0.001–0.099	0.059±0.021	0.09±0.14	0.001–0.104	0.0615±0.02	0.09±0.14
U	ng m <sup>-3</sup>	0.0003–0.019	0.0103±0.001	0.06±0.02	0.0003–0.0204	0.010±0.001	0.05±0.02
V	ng m <sup>-3</sup>	0.21–29.03	3.62±1.06	0.43±0.57	0.21–30.54	3.76±1.06	0.43±0.57
Zn	ng m <sup>-3</sup>	2.34–682.81	240.62±39.64	49.54±36.82	2.34–718.41	250.32±39.64	49.54±36.82
C	µg m <sup>-3</sup>	1.36–18.54	5.86±0.83	422.00±269.32	1.36–17.62	6.09±0.83	422.00±269.32
H	µg m <sup>-3</sup>	0.70–14.29	5.81±0.45	59.83±20.71	0.70–15.04	6.05±0.45	59.83±20.71
N	µg m <sup>-3</sup>	0.03–9.83	4.63±0.28	3511.7±971.9	0.03–10.34	4.82±0.28	3511.7±971.9
S	µg m <sup>-3</sup>	0.39–7.19	3.08±0.82	126.89±152.43	0.39–6.83	2.96±0.82	117.25±152.43
Br <sup>-</sup>	ng m <sup>-3</sup>	0.005–0.19	0.1005±0.003	————	0.005–0.20	0.1046±0.003	————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.49–4.18	1.99±0.60	————	0.49–4.40	2.07±0.60	————
F <sup>-</sup>	µg m <sup>-3</sup>	0.05–4.45	1.80±0.70	————	0.05–4.68	1.87±0.70	————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.02–1.01	0.42±0.20	————	0.02–0.96	0.40±0.20	————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.13–17.11	3.04±0.99	————	0.13–18.00	3.17±0.99	————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.13–4.43	3.52±1.00	————	0.13–4.43	3.39±1.00	————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	0.90–19.10	5.90±2.05	————	0.90–20.09	6.13±2.05	————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	0.98–12.76	5.57±2.14	————	0.98–13.43	5.35±2.14	————
K <sup>+</sup>	ng m <sup>-3</sup>	1.48–19.82	7.74±1.45	————	1.48–20.85	8.05±1.45	————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.27–18.38	10.00±2.16	————	0.27–19.33	10.40±2.16	————
Na <sup>+</sup>	ng m <sup>-3</sup>	0.17–20.31	9.05±3.91	————	0.17–21.37	9.42±3.91	————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.00–22.55	10.74±2.76	————	1.00–23.73	11.17±2.70	————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.8:** Annual average concentration of major, trace elementals and water-soluble ions and enrichment factor in PM<sub>10</sub> at AQMS-01

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.10–1.29	1.05±0.19	80.40±115.99	0.10–1.34	1.15±0.19	80.40±115.99
Al	µg m <sup>-3</sup>	0.35–14.97	9.44±1.53	0.66±0.85	0.34–14.40	10.26±1.53	0.66±0.85
As	ng m <sup>-3</sup>	1.57–10.85	3.87±0.96	12.30±24.45	1.56–11.29	4.21±0.96	12.30±24.45
Br	ng m <sup>-3</sup>	0.09–7.01	2.04±0.93	4.87±17.67	0.09–7.29	2.22±0.93	4.87±17.67
Ca	µg m <sup>-3</sup>	0.96–18.51	12.56±1.37	1.73±1.51	0.96–19.25	11.55±1.37	1.47±1.51
Cd	ng m <sup>-3</sup>	1.04–90.31	10.46±0.07	399.28±20.11	1.04–86.85	11.37±0.07	399.28±20.11
Co	ng m <sup>-3</sup>	0.55–14.58	10.59±1.19	2.42±2.17	0.55–15.16	11.51±1.19	2.42±2.17
Cr	ng m <sup>-3</sup>	0.49–111.14	32.27±14.58	1.81±6.54	0.49–115.56	35.08±14.58	1.81±6.54
Cu	ng m <sup>-3</sup>	0.75–348.49	56.48±23.22	5.39±17.72	0.75–335.15	51.95±23.22	4.56±17.72
Fe	µg m <sup>-3</sup>	1.08–24.44	9.83±1.23	1.00±1.00	1.11–25.42	10.69±1.23	1.00±1.00
Hg	ng m <sup>-3</sup>	0.004–9.62	5.24±1.28	352.86±686.93	0.004–10.002	5.70±1.27	352.86±686.93
K	µg m <sup>-3</sup>	1.26–18.19	10.51±1.70	2.88±3.73	1.26–18.92	11.42±1.70	2.88±3.73
Li	ng m <sup>-3</sup>	0.04–5.12	1.59±0.56	0.46±1.29	0.04–4.93	1.73±0.56	0.46±1.29
Mg	µg m <sup>-3</sup>	0.17–10.17	6.89±1.07	1.69±2.11	0.17–10.57	7.50±1.07	1.69±2.11
Mn	ng m <sup>-3</sup>	5.28–519.96	297.04±37.79	1.79±1.82	5.42–540.65	322.97±37.79	1.79±1.82
Na	µg m <sup>-3</sup>	0.47–16.81	11.74±1.11	2.85±2.15	0.49–17.48	12.77±1.11	2.85±2.15
Ni	ng m <sup>-3</sup>	0.04–27.69	17.25±5.42	1.18±2.95	0.04–27.69	18.75±5.42	1.18±2.95
Pb	ng m <sup>-3</sup>	12.08–1155.58	413.50±38.15	169.11±124.76	12.01–1201.56	380.29±38.15	143.04±124.76
Se	ng m <sup>-3</sup>	0.17–77.62	59.21±7.38	6780.1±6756.9	0.17–80.71	64.38±7.38	6780.1±6756.9
Si	µg m <sup>-3</sup>	0.23–3.39	2.36±0.48	0.05±0.08	0.23–3.53	2.57±0.48	0.05±0.08
Sr	ng m <sup>-3</sup>	0.28–351.42	16.52±8.01	0.26±0.99	0.28–337.98	17.96±8.01	0.26±0.99
Th	ng m <sup>-3</sup>	0.001–0.119	0.075±0.03	0.04±0.14	0.001–0.124	0.082±0.02	0.04±0.14
U	ng m <sup>-3</sup>	0.0005–0.0273	0.0124±0.002	0.03±0.04	0.0005–0.028	0.0114±0.002	0.02±0.04
V	ng m <sup>-3</sup>	0.41–41.37	4.98±0.95	0.24±0.36	0.41–43.01	5.42±0.95	0.24±0.36
Zn	ng m <sup>-3</sup>	7.80–864.07	314.19±44.77	25.70±29.28	7.76–898.45	341.62±44.77	25.70±29.28
C	µg m <sup>-3</sup>	2.44–23.19	13.17±1.50	377.05±344.32	2.44–22.31	14.32±1.50	377.05±344.32
H	µg m <sup>-3</sup>	1.04–18.29	10.92±1.32	44.67±43.24	1.06–19.02	11.88±1.32	44.67±43.24
N	µg m <sup>-3</sup>	0.07–11.01	7.18±1.16	2164.7±2795.5	0.07–11.45	7.81±1.16	2164.7±2795.5
S	µg m <sup>-3</sup>	0.79–8.57	4.20±1.27	68.65±166.57	0.79–8.24	3.86±1.27	58.07±166.57
Br <sup>-</sup>	ng m <sup>-3</sup>	0.005–0.204	0.121±0.01	—————	0.005–0.212	0.131±0.004	—————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.55–6.31	3.19±1.23	—————	0.55–6.56	3.47±1.23	—————
F <sup>-</sup>	µg m <sup>-3</sup>	0.06–5.22	1.94±0.42	—————	0.06–5.42	2.11±0.42	—————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.03–1.23	0.58±0.32	—————	0.03–1.19	0.54±0.32	—————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.24–20.20	5.99±1.04	—————	0.24–21.00	6.51±1.04	—————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.17–5.72	5.07±1.61	—————	0.17–5.72	4.66±1.61	—————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	1.06–26.17	9.44±2.56	—————	1.06–27.21	10.26±2.56	—————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	1.92–37.03	25.11±2.74	—————	1.92–38.50	23.10±2.74	—————
K <sup>+</sup>	ng m <sup>-3</sup>	2.52–36.39	21.01±3.40	—————	2.52–37.83	22.85±3.40	—————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.35–20.34	13.79±2.14	—————	0.35–21.15	14.99±2.14	—————
Na <sup>+</sup>	ng m <sup>-3</sup>	0.95–33.61	23.48±2.22	—————	0.97–34.95	25.53±2.22	—————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.73–29.84	15.29±4.66	—————	1.77–31.02	16.63±4.56	—————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.9:** Annual average concentration of major, trace elements and water-soluble ions and enrichment factor in SPM at AQMS-01

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.11–1.53	1.30±0.21	50.92±115.99	0.11–1.68	1.34±0.21	50.92±115.99
Al	µg m <sup>-3</sup>	0.41–28.48	18.38±1.72	0.66±0.85	0.39–25.92	18.97±1.72	0.66±0.85
As	ng m <sup>-3</sup>	1.88–12.84	4.97±1.08	8.12±24.45	1.76–14.11	5.13±1.08	8.12±24.45
Br	ng m <sup>-3</sup>	0.10–8.29	2.52±1.04	3.09±17.67	0.10–9.11	2.60±1.04	3.09±17.67
Ca	µg m <sup>-3</sup>	1.08–33.33	23.21±1.54	1.64±1.51	1.08–36.62	22.49±1.54	1.54±1.51
Cd	ng m <sup>-3</sup>	1.17–112.89	12.90±0.07	252.86±20.11	1.17–102.75	13.31±0.07	252.86±20.11
Co	ng m <sup>-3</sup>	0.62–17.25	13.06±1.33	1.54±2.17	0.62–18.95	13.47±1.33	1.54±2.17
Cr	ng m <sup>-3</sup>	0.55–131.48	39.80±16.41	1.15±6.54	0.55–144.45	41.07±16.41	1.15±6.54
Cu	ng m <sup>-3</sup>	0.84–435.61	66.11±26.14	3.24±17.72	0.84–396.49	64.07±26.14	3.04±17.72
Fe	µg m <sup>-3</sup>	1.22–44.01	19.15±1.38	1.00±1.00	1.25–48.36	19.76±1.38	1.00±1.00
Hg	ng m <sup>-3</sup>	0.005–11.38	6.46±1.45	223.47±686.93	0.004–12.502	6.67±1.44	223.47±686.93
K	µg m <sup>-3</sup>	1.42–32.76	20.46±1.91	2.88±3.73	1.42–35.99	21.11±1.91	2.88±3.73
Li	ng m <sup>-3</sup>	0.04–6.40	1.96±0.64	0.29±1.29	0.04–5.83	2.03±0.64	0.29±1.29
Mg	µg m <sup>-3</sup>	0.20–18.31	13.43±1.21	1.69±2.11	0.20–20.11	13.85±1.21	1.69±2.11
Mn	ng m <sup>-3</sup>	5.94–615.12	366.38±42.54	1.13±1.82	6.09–675.81	378.05±42.54	1.13±1.82
Na	µg m <sup>-3</sup>	0.53–30.26	22.87±1.25	2.85±2.15	0.55–33.25	23.60±1.25	2.85±2.15
Ni	ng m <sup>-3</sup>	0.05–34.61	21.27±6.10	0.74±2.95	0.04–34.61	21.95±6.10	0.74±2.95
Pb	ng m <sup>-3</sup>	14.46–1367.06	504.83±143.70	106.00±417.44	13.51–1501.95	489.25±143.70	99.56±417.44
Se	ng m <sup>-3</sup>	0.19–91.82	73.03±8.31	4293.8±6756.9	0.19–100.88	75.36±8.31	4293.8±6756.9
Si	µg m <sup>-3</sup>	0.25–6.10	4.60±0.54	0.05±0.08	0.25–6.71	4.75±0.54	0.05±0.08
Sr	ng m <sup>-3</sup>	0.32–439.28	20.38±9.02	0.16±0.99	0.32–399.83	21.03±9.02	0.16±0.99
Th	ng m <sup>-3</sup>	0.001–0.141	0.093±0.03	0.03±0.14	0.0012–0.1544	0.096±0.031	0.03±0.14
U	ng m <sup>-3</sup>	0.0006–0.0323	0.015±0.002	0.02±0.04	0.0006–0.035	0.014±0.002	0.01±0.04
V	ng m <sup>-3</sup>	0.49–48.94	6.15±1.07	0.15±0.36	0.46–53.77	6.34±1.07	0.15±0.36
Zn	ng m <sup>-3</sup>	9.34–1022.20	387.53±50.40	16.27±29.28	8.73–1123.06	399.88±50.40	16.27±29.28
C	µg m <sup>-3</sup>	2.74–44.13	25.65±1.69	377.05±344.32	2.74–40.16	26.47±1.69	377.05±344.32
H	µg m <sup>-3</sup>	1.17–32.93	21.27±1.49	44.67±43.24	1.20–36.18	21.95±1.49	44.67±43.24
N	µg m <sup>-3</sup>	0.08–19.82	13.99±1.31	2164.7±2795.5	0.08–21.77	14.44±1.31	2164.7±2795.5
S	µg m <sup>-3</sup>	0.89–16.30	7.76±1.43	65.15±166.57	0.89–14.83	7.52±1.43	61.19±166.57
Br <sup>-</sup>	ng m <sup>-3</sup>	0.006–0.241	0.149±0.005	—————	0.006–0.265	0.154±0.005	—————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.62–11.37	6.21±1.38	—————	0.62–12.49	6.41±1.38	—————
F <sup>-</sup>	µg m <sup>-3</sup>	0.07–9.39	3.79±0.47	—————	0.07–10.32	3.91±0.47	—————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.04–2.35	1.08±0.37	—————	0.04–2.14	1.04±0.37	—————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.27–36.37	11.66±1.17	—————	0.27–39.96	12.04±1.17	—————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.20–10.87	9.36±1.81	—————	0.20–10.87	9.07±1.81	—————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	1.19–47.12	18.38±2.88	—————	1.19–51.77	18.96±2.88	—————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	2.16–66.67	46.42±3.08	—————	2.16–73.25	44.98±3.08	—————
K <sup>+</sup>	ng m <sup>-3</sup>	2.84–65.51	40.92±3.83	—————	2.84–71.98	42.23±3.83	—————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.39–36.62	26.85±2.41	—————	0.39–40.23	27.71±2.41	—————
Na <sup>+</sup>	ng m <sup>-3</sup>	1.07–60.52	45.74±2.50	—————	1.09–66.50	47.19±2.50	—————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.94–35.30	18.86±5.24	—————	1.99–38.78	19.46±5.12	—————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.10:** Annual average concentration of major, trace elementals and water-soluble ions and enrichment factor in PM<sub>2.5</sub> at AQMS-02

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.10-1.14	0.98±0.20	238.50±92.94	0.10-1.21	1.04±0.20	238.50±92.94
Al	µg m <sup>-3</sup>	0.22-5.01	2.28±1.21	0.50±0.52	0.22-4.73	2.42±1.21	0.50±0.52
As	ng m <sup>-3</sup>	0.72-10.16	4.03±1.11	40.71±21.66	0.71-10.76	4.27±1.11	40.71±21.66
Br	ng m <sup>-3</sup>	0.92-5.20	1.61±0.41	12.17±5.92	0.92-5.51	1.70±0.41	12.17±5.92
Ca	µg m <sup>-3</sup>	1.73-7.20	3.92±1.20	1.72±1.01	1.73-7.63	3.69±1.20	1.53±1.01
Cd	ng m <sup>-3</sup>	0.56-79.61	7.23±2.53	876.96±591.73	0.56-75.14	7.66±2.53	876.96±591.73
Co	ng m <sup>-3</sup>	0.56-12.90	8.91±2.61	6.48±3.66	0.56-13.67	9.44±2.61	6.48±3.66
Cr	ng m <sup>-3</sup>	0.66-95.63	19.75±4.46	3.52±1.53	0.66-101.32	20.92±4.46	3.52±1.53
Cu	ng m <sup>-3</sup>	0.75-212.13	36.24±15.71	10.99±9.18	0.75-200.21	34.20±15.71	9.78±9.18
Fe	µg m <sup>-3</sup>	0.98-8.24	3.09±1.61	1.00±1.00	0.98-8.73	3.28±1.61	1.00±1.00
Hg	ng m <sup>-3</sup>	0.0055-7.1956	3.44±1.15	735.44±475.25	0.0054-7.6238	3.64±1.15	735.44±475.25
K	µg m <sup>-3</sup>	0.94-9.62	3.68±1.11	3.20±1.86	0.94-10.20	3.90±1.11	3.20±1.86
Li	ng m <sup>-3</sup>	0.03-3.14	1.04±0.42	0.95±0.73	0.03-2.96	1.10±0.42	0.95±0.73
Mg	µg m <sup>-3</sup>	0.10-6.52	3.95±1.82	3.08±2.74	0.10-6.90	4.18±1.82	3.08±2.74
Mn	ng m <sup>-3</sup>	0.85-374.50	112.39±49.98	2.15±1.84	0.85-396.78	119.10±49.98	2.15±1.84
Na	µg m <sup>-3</sup>	0.11-9.45	3.97±1.07	3.06±1.58	0.11-10.01	4.21±1.07	3.06±1.58
Ni	ng m <sup>-3</sup>	0.03-18.75	13.83±2.71	3.00±1.13	0.03-18.75	14.66±2.71	3.00±1.13
Pb	ng m <sup>-3</sup>	10.42-1023.96	315.80±20.36	410.38±50.97	10.32-1084.89	298.00±20.36	365.43±50.97
Se	ng m <sup>-3</sup>	0.07-64.66	44.04±7.73	16026.0±5418.9	0.07-68.50	46.68±7.73	16026.0±5418.9
Si	µg m <sup>-3</sup>	0.12-2.32	1.48±0.62	0.10±0.08	0.12-2.45	1.57±0.62	0.10±0.08
Sr	ng m <sup>-3</sup>	0.13-305.56	10.09±10.53	0.50±1.00	0.13-288.40	10.69±10.53	0.50±1.00
Th	ng m <sup>-3</sup>	0.0010-0.0991	0.061±0.02	0.11±0.09	0.001-0.1050	0.064±0.024	0.11±0.09
U	ng m <sup>-3</sup>	0.0003-0.0187	0.011±0.001	0.07±0.01	0.0003-0.0198	0.011±0.001	0.06±0.01
V	ng m <sup>-3</sup>	0.22-30.71	3.77±1.74	0.57±0.51	0.21-32.53	3.99±1.74	0.57±0.51
Zn	ng m <sup>-3</sup>	5.13-742.28	252.80±43.54	65.70±21.80	5.08-786.45	267.90±43.54	65.70±21.80
C	µg m <sup>-3</sup>	1.39-18.94	5.91±1.82	537.15±318.98	1.39-17.87	6.26±1.82	537.15±318.98
H	µg m <sup>-3</sup>	0.70-14.82	6.03±1.44	78.32±35.96	0.70-15.70	6.39±1.44	78.32±35.96
N	µg m <sup>-3</sup>	0.03-9.76	4.59±1.27	4396.3±2350.3	0.03-10.34	4.87±1.27	4396.3±2350.3
S	µg m <sup>-3</sup>	0.39-7.86	3.29±0.82	170.89±82.42	0.39-7.42	3.10±0.82	152.17±82.42
Br <sup>-</sup>	ng m <sup>-3</sup>	0.0052-0.1907	0.102±0.03	—————	0.0052-0.2021	0.108±0.03	—————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.51-4.21	1.99±0.68	—————	0.51-4.46	2.11±0.68	—————
F <sup>-</sup>	µg m <sup>-3</sup>	0.05-4.57	1.82±0.75	—————	0.05-4.84	1.93±0.75	—————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.02-1.02	0.49±0.26	—————	0.02-0.96	0.46±0.26	—————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.13-17.00	3.12±1.00	—————	0.13-18.01	3.30±1.00	—————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.14-4.61	3.63±1.14	—————	0.14-4.61	3.43±1.14	—————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	0.91-19.74	5.92±2.74	—————	0.91-20.91	6.27±2.74	—————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	3.46-14.41	7.83±2.39	—————	3.46-15.27	7.39±2.39	—————
K <sup>+</sup>	ng m <sup>-3</sup>	1.88-19.25	7.35±2.22	—————	1.88-20.39	7.79±2.22	—————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.21-13.03	7.90±3.64	—————	0.21-13.81	8.37±3.64	—————
Na <sup>+</sup>	ng m <sup>-3</sup>	0.22-18.89	7.95±2.13	—————	0.22-20.02	8.42±2.13	—————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.03-22.92	11.12±3.29	—————	1.03-24.29	11.79±3.22	—————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.11:** Annual average concentration of major, trace elementals and water-soluble ions and enrichment factor in PM<sub>10</sub> at AQMS-02

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.11–1.26	1.13±0.19	83.99±84.97	0.11–1.38	1.24±0.19	83.99±84.97
Al	µg m <sup>-3</sup>	0.46–15.82	9.64±2.40	0.65±0.98	0.46–14.40	10.53±2.40	0.65±0.98
As	ng m <sup>-3</sup>	1.62–10.42	4.19±1.24	12.91±23.27	1.61–11.45	4.57±1.24	12.91±23.27
Br	ng m <sup>-3</sup>	0.10–6.83	2.16±1.33	5.00±18.62	0.10–7.51	2.36±1.33	5.00±18.62
Ca	µg m <sup>-3</sup>	1.23–18.45	14.36±2.07	1.92±1.68	1.23–20.27	13.14±2.07	1.61±1.68
Cd	ng m <sup>-3</sup>	1.24–86.29	10.31±2.08	381.59±467.00	1.24–78.54	11.26±2.08	381.59±467.00
Co	ng m <sup>-3</sup>	0.56–15.17	10.72±2.45	2.38±3.30	0.56–16.67	11.71±2.45	2.38±3.30
Cr	ng m <sup>-3</sup>	0.42–105.12	32.88±7.75	1.79±2.56	0.42–115.49	35.92±7.75	1.79±2.56
Cu	ng m <sup>-3</sup>	0.80–350.39	56.77±26.64	5.25±14.95	0.80–318.92	51.97±26.64	4.40±14.95
Fe	µg m <sup>-3</sup>	1.23–23.41	10.14±1.67	1.00±1.00	1.25–25.72	11.08±1.67	1.00±1.00
Hg	ng m <sup>-3</sup>	0.006–9.92	5.68±2.75	371.01±1090.5	0.006–10.90	6.21±2.73	371.01±1090.5
K	µg m <sup>-3</sup>	1.10–17.41	11.02±2.58	2.93±4.16	1.10–19.13	12.04±2.58	2.93±4.16
Li	ng m <sup>-3</sup>	0.03–5.14	1.63±0.56	0.45±0.95	0.03–4.68	1.79±0.56	0.45±0.95
Mg	µg m <sup>-3</sup>	0.18–10.25	7.04±1.49	1.68±2.16	0.18–11.26	7.69±1.49	1.68±2.16
Mn	ng m <sup>-3</sup>	5.52–491.95	140.61±44.42	0.82±1.57	5.62–540.49	153.61±44.42	0.82±1.57
Na	µg m <sup>-3</sup>	0.56–17.18	12.04±3.67	2.83±5.24	0.57–18.88	13.15±3.67	2.83±5.24
Ni	ng m <sup>-3</sup>	0.03–29.65	17.36±5.28	1.15±2.12	0.03–29.65	18.96±5.28	1.15±2.12
Pb	ng m <sup>-3</sup>	12.47–1102.50	416.60±65.86	165.20±158.35	12.40–1211.29	381.33±65.86	138.41±158.35
Se	ng m <sup>-3</sup>	0.18–74.39	61.52±7.99	6830.8±5376.9	0.18–81.73	67.21±7.99	6830.8±5376.9
Si	µg m <sup>-3</sup>	0.25–3.22	2.47±0.50	0.05±0.06	0.25–3.54	2.70±0.50	0.05±0.06
Sr	ng m <sup>-3</sup>	0.30–356.15	17.14±9.90	0.26±0.90	0.30–324.17	18.73±9.90	0.26±0.90
Th	ng m <sup>-3</sup>	0.001–0.123	0.08±0.02	0.05±0.10	0.001–0.135	0.09±0.02	0.05±0.10
U	ng m <sup>-3</sup>	0.0005–0.0264	0.013±0.002	0.03±0.04	0.0005–0.029	0.012±0.002	0.02±0.04
V	ng m <sup>-3</sup>	0.41–40.06	5.01±0.95	0.23±0.27	0.41–44.01	5.48±0.95	0.23±0.27
Zn	ng m <sup>-3</sup>	8.49–871.50	314.73±55.38	24.96±26.63	8.44–957.49	343.84±55.38	24.96±26.63
C	µg m <sup>-3</sup>	2.84–23.29	13.45±1.87	373.26±314.43	2.84–21.20	14.69±1.87	373.26±314.43
H	µg m <sup>-3</sup>	1.04–17.44	11.15±1.37	44.20±32.88	1.06–19.17	12.18±1.37	44.20±32.88
N	µg m <sup>-3</sup>	0.07–10.42	7.42±1.25	2167.5±2216.7	0.07–11.45	8.10±1.25	2167.5±2216.78
S	µg m <sup>-3</sup>	0.88–8.65	4.35±1.44	69.02±138.74	0.88–7.87	3.98±1.44	57.83±138.74
Br <sup>-</sup>	ng m <sup>-3</sup>	0.0056–0.1966	0.122±0.004	—————	0.0056–0.2161	0.133±0.004	—————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.55–6.05	3.22±1.29	—————	0.55–6.64	3.52±1.29	—————
F <sup>-</sup>	µg m <sup>-3</sup>	0.06–4.95	1.95±0.45	—————	0.06–5.44	2.13±0.45	—————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.03–1.24	0.59±0.33	—————	0.03–1.12	0.54±0.33	—————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.25–19.15	6.05±1.07	—————	0.25–21.04	6.61±1.07	—————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.17–5.71	5.10±1.67	—————	0.17–5.71	4.66±1.67	—————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	1.06–24.78	9.46±2.60	—————	1.06–27.22	10.33±2.60	—————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	2.46–36.89	28.71±4.14	—————	2.46–40.53	26.28±4.14	—————
K <sup>+</sup>	ng m <sup>-3</sup>	2.21–34.82	22.04±5.17	—————	2.21–38.26	24.07±5.17	—————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.35–20.49	14.07±2.99	—————	0.35–22.52	15.37±2.99	—————
Na <sup>+</sup>	ng m <sup>-3</sup>	1.12–34.37	24.07±7.34	—————	1.15–37.76	26.30±7.34	—————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.73–28.42	15.32±5.19	—————	1.76–31.22	16.74±5.07	—————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.12:** Annual average concentration of major, trace elementals and water-soluble ions and enrichment factor in SPM at AQMS-02

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.12–1.69	1.40±0.21	53.19±84.97	0.12–1.73	1.46±0.21	53.19±84.97
Al	µg m <sup>-3</sup>	0.53–30.10	18.72±2.70	0.65±0.98	0.52–29.50	19.52±2.70	0.65±0.98
As	ng m <sup>-3</sup>	1.85–14.03	5.35±1.40	8.49±23.27	1.81–14.32	5.58±1.40	8.49±23.27
Br	ng m <sup>-3</sup>	0.11–9.20	2.66±1.49	3.17±18.62	0.11–9.39	2.77±1.49	3.17±18.62
Ca	µg m <sup>-3</sup>	1.38–37.79	26.62±2.33	1.83±1.68	1.38–38.56	25.53±2.33	1.69±1.68
Cd	ng m <sup>-3</sup>	1.39–107.86	12.69±2.34	241.66±467.00	1.39–105.71	13.23±2.34	241.66±467.00
Co	ng m <sup>-3</sup>	0.63–20.42	13.19±2.75	1.51±3.30	0.63–20.83	13.75±2.75	1.51±3.30
Cr	ng m <sup>-3</sup>	0.47–141.48	40.45±8.72	1.13±2.56	0.47–144.36	42.17±8.72	1.13±2.56
Cu	ng m <sup>-3</sup>	0.90–437.99	66.66±29.97	3.17±14.95	0.90–429.25	63.94±29.97	2.92±14.95
Fe	µg m <sup>-3</sup>	1.38–47.96	19.70±1.88	1.00±1.00	1.38–48.94	20.54±1.88	1.00±1.00
Hg	ng m <sup>-3</sup>	0.007–13.354	6.99±3.09	234.96±1090.5	0.007–13.626	7.287±3.098	234.96±1090.5
K	µg m <sup>-3</sup>	1.24–35.67	21.41±2.91	2.93±4.16	1.24–36.40	22.32±2.91	2.93±4.16
Li	ng m <sup>-3</sup>	0.04–6.42	2.01±0.64	0.29±0.95	0.04–6.29	2.10±0.64	0.29±0.95
Mg	µg m <sup>-3</sup>	0.20–20.99	13.67±1.68	1.68±2.16	0.20–21.42	14.25±1.68	1.68±2.16
Mn	ng m <sup>-3</sup>	6.21–662.13	173.00±49.97	0.52±1.57	6.21–675.62	180.37±49.97	0.52±1.57
Na	µg m <sup>-3</sup>	0.63–35.20	23.39±4.13	2.83±5.24	0.63–35.92	24.38±4.13	2.83±5.24
Ni	ng m <sup>-3</sup>	0.03–37.07	21.36±5.94	0.73±2.12	0.03–37.07	22.27±5.94	0.73±2.12
Pb	ng m <sup>-3</sup>	14.28–1483.89	510.17±97.63	104.12±208.66	13.95–1514.12	489.32±97.63	95.79±208.66
Se	ng m <sup>-3</sup>	0.20–100.13	75.70±8.99	4325.9±5376.9	0.20–102.17	78.92±8.99	4325.9±5376.9
Si	µg m <sup>-3</sup>	0.28–6.60	4.81±0.56	0.05±0.06	0.28–6.74	5.01±0.56	0.05±0.06
Sr	ng m <sup>-3</sup>	0.34–445.19	21.09±11.14	0.16±0.90	0.34–436.30	21.99±11.14	0.16±0.90
Th	ng m <sup>-3</sup>	0.0011–0.1653	0.096±0.033	0.03±0.10	0.0011–0.1687	0.10±0.03	0.03±0.10
U	ng m <sup>-3</sup>	0.0006–0.0355	0.015±0.003	0.02±0.04	0.0006–0.0363	0.014±0.003	0.01±0.04
V	ng m <sup>-3</sup>	0.47–53.92	6.17±1.07	0.15±0.27	0.46–55.02	6.43±1.07	0.15±0.27
Zn	ng m <sup>-3</sup>	9.72–1172.97	387.25±62.30	15.81±26.63	9.49–1196.86	403.74±62.30	15.81±26.63
C	µg m <sup>-3</sup>	3.19–44.31	26.13±2.10	373.26±314.43	3.19–43.42	27.24±2.10	373.26±314.43
H	µg m <sup>-3</sup>	1.17–35.73	21.66±1.54	44.20±32.88	1.17–36.46	22.58±1.54	44.20±32.88
N	µg m <sup>-3</sup>	0.08–21.35	14.41±1.41	2167.5±2216.7	0.08–21.79	15.03±1.41	2167.5±2216.7
S	µg m <sup>-3</sup>	0.99–16.46	8.07±1.62	65.87±138.74	0.99–16.13	7.74±1.62	60.59±138.74
Br <sup>-</sup>	ng m <sup>-3</sup>	0.0063–0.2647	0.147±0.005	—————	0.0063–0.2701	0.156±0.005	—————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.62–12.39	6.25±1.45	—————	0.62–12.64	6.52±1.45	—————
F <sup>-</sup>	µg m <sup>-3</sup>	0.07–10.15	3.79±0.50	—————	0.07–10.36	3.95±0.50	—————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.04–2.35	1.10±0.37	—————	0.04–2.30	1.05±0.37	—————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.28–39.24	11.75±1.21	—————	0.28–40.03	12.25±1.21	—————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.20–10.87	9.45±1.88	—————	0.20–10.87	9.06±1.88	—————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	1.19–50.76	18.37±2.93	—————	1.19–51.79	19.15±2.93	—————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	2.76–75.57	53.24±4.66	—————	2.76–77.11	51.06±4.66	—————
K <sup>+</sup>	ng m <sup>-3</sup>	2.48–71.34	42.81±5.81	—————	2.48–72.79	44.64±5.81	—————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.40–41.98	27.34±3.36	—————	0.40–42.84	28.50±3.36	—————
Na <sup>+</sup>	ng m <sup>-3</sup>	1.27–70.41	46.77±8.26	—————	1.27–71.84	48.76±8.26	—————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.94–38.25	18.85±5.84	—————	1.94–39.03	19.66±5.71	—————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.13:** Annual average concentration of major, trace elements and water-soluble ions and enrichment factor in PM<sub>2.5</sub> at AQMS-03

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.11–1.19	1.00±0.20	241.25±97.31	0.11–1.22	1.05±0.20	241.25±97.31
Al	µg m <sup>-3</sup>	0.22–5.02	2.30±1.18	0.50±0.52	0.22–4.91	2.41±1.18	0.50±0.52
As	ng m <sup>-3</sup>	0.72–10.52	4.06±1.08	40.69±21.66	0.71–10.76	4.25±1.08	40.69±21.66
Br	ng m <sup>-3</sup>	0.92–5.39	1.62±0.39	12.17±5.92	0.92–5.51	1.70±0.39	12.17±5.92
Ca	µg m <sup>-3</sup>	1.73–7.47	3.90±1.16	1.70±1.01	1.73–7.64	3.73±1.16	1.55±1.01
Cd	ng m <sup>-3</sup>	0.56–79.63	7.29±2.46	876.96±591.73	0.56–77.89	7.63±2.46	876.96±591.73
Co	ng m <sup>-3</sup>	0.56–13.37	8.99±2.53	6.48±3.66	0.56–13.67	9.41±2.53	6.48±3.66
Cr	ng m <sup>-3</sup>	0.66–99.13	19.92±4.33	3.52±1.53	0.66–101.35	20.85±4.33	3.52±1.53
Cu	ng m <sup>-3</sup>	0.75–212.18	36.11±15.25	10.85±9.18	0.75–207.54	34.50±15.25	9.91±9.18
Fe	µg m <sup>-3</sup>	0.98–8.54	3.12±1.56	1.00±1.00	0.99–8.73	3.27±1.56	1.00±1.00
Hg	ng m <sup>-3</sup>	0.005–7.46	3.47±1.12	735.07±475.25	0.005–7.62	3.65±1.11	735.07±475.25
K	µg m <sup>-3</sup>	0.94–9.97	3.71±1.08	3.20±1.86	0.94–10.20	3.88±1.08	3.20±1.86
Li	ng m <sup>-3</sup>	0.03–3.14	1.05±0.40	0.95±0.73	0.03–3.07	1.10±0.40	0.95±0.73
Mg	µg m <sup>-3</sup>	0.10–6.76	3.98±1.77	3.08±2.74	0.10–6.91	4.17±1.77	3.08±2.74
Mn	ng m <sup>-3</sup>	0.85–388.20	113.38±48.52	2.15±1.84	0.86–396.88	118.67±48.52	2.15±1.84
Na	µg m <sup>-3</sup>	0.11–9.79	4.01±1.04	3.06±1.58	0.11–10.01	4.20±1.04	3.06±1.58
Ni	ng m <sup>-3</sup>	0.03–18.75	13.96±2.63	3.00±1.13	0.03–18.75	14.61±2.63	3.00±1.13
Pb	ng m <sup>-3</sup>	10.40–1061.42	314.69±19.76	405.34±50.97	10.32–1085.16	300.67±19.76	370.03±50.97
Se	ng m <sup>-3</sup>	0.07–67.02	44.43±7.50	16026.0±5418.9	0.07–68.52	46.51±7.50	16026.0±5418.9
Si	µg m <sup>-3</sup>	0.12–2.40	1.50±0.60	0.10±0.08	0.12–2.45	1.56±0.60	0.10±0.08
Sr	ng m <sup>-3</sup>	0.13–305.64	10.18±10.23	0.50±1.00	0.13–298.95	10.66±10.23	0.50±1.00
Th	ng m <sup>-3</sup>	0.001–0.103	0.061±0.024	0.11±0.09	0.001–0.105	0.064±0.024	0.11±0.09
U	ng m <sup>-3</sup>	0.0003–0.0194	0.011±0.001	0.07±0.01	0.0003–0.0198	0.010±0.001	0.07±0.01
V	ng m <sup>-3</sup>	0.22–31.83	3.80±1.69	0.57±0.51	0.21–32.54	3.98±1.69	0.57±0.51
Zn	ng m <sup>-3</sup>	5.12–769.44	255.04±42.27	65.70±21.80	5.08–786.65	266.94±42.27	65.70±21.80
C	µg m <sup>-3</sup>	1.39–18.94	5.96±1.77	537.15±318.98	1.39–18.53	6.24±1.77	537.15±318.98
H	µg m <sup>-3</sup>	0.70–15.36	6.08±1.39	78.32±35.96	0.70–15.70	6.36±1.39	78.32±35.96
N	µg m <sup>-3</sup>	0.03–10.12	4.63±1.24	4396.3±2350.3	0.03–10.34	4.85±1.24	4396.3±2350.3
S	µg m <sup>-3</sup>	0.39–7.86	3.28±0.80	168.78±82.42	0.39–7.69	3.13±0.80	154.08±82.42
Br <sup>-</sup>	ng m <sup>-3</sup>	0.005–0.198	0.102±0.029	————	0.005–0.202	0.107±0.029	————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.51–4.36	2.01±0.66	————	0.51–4.46	2.11±0.66	————
F <sup>-</sup>	µg m <sup>-3</sup>	0.05–4.74	1.84±0.73	————	0.05–4.84	1.93±0.73	————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.02–1.02	0.49±0.25	————	0.02–1.00	0.47±0.25	————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.14–17.62	3.15±0.97	————	0.14–18.02	3.29±0.97	————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.14–4.62	3.62±1.11	————	0.14–4.62	3.46±1.11	————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	0.91–20.46	5.97±2.66	————	0.91–20.92	6.25±2.66	————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	3.46–14.94	7.80±2.32	————	3.46–15.27	7.46±2.32	————
K <sup>+</sup>	ng m <sup>-3</sup>	1.88–19.95	7.42±2.16	————	1.88–20.40	7.76±2.16	————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.21–13.51	7.97±3.53	————	0.21–13.81	8.34±3.53	————
Na <sup>+</sup>	ng m <sup>-3</sup>	0.22–19.58	8.02±2.07	————	0.23–20.02	8.39±2.07	————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.03–23.76	11.22±3.29	————	1.04–24.29	11.74±3.22	————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.14:** Annual average concentration of major, trace elementals and water-soluble ions and enrichment factor in PM<sub>10</sub> at AQMS-03

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.11-1.41	1.19±0.20	86.85±88.96	0.11-1.42	1.29±0.20	86.85±88.96
Al	µg m <sup>-3</sup>	0.46-15.83	9.75±2.48	0.65±0.98	0.46-15.66	10.60±2.48	0.65±0.98
As	ng m <sup>-3</sup>	1.62-11.33	4.23±1.29	12.90±23.27	1.61-11.45	4.60±1.29	12.90±23.27
Br	ng m <sup>-3</sup>	0.10-7.43	2.19±1.37	5.00±18.62	0.10-7.51	2.38±1.37	5.00±18.62
Ca	µg m <sup>-3</sup>	1.23-20.06	14.46±2.14	1.91±1.68	1.23-20.27	13.29±2.14	1.62±1.68
Cd	ng m <sup>-3</sup>	1.24-86.31	10.43±2.15	381.59±467.00	1.24-85.40	11.34±2.15	381.59±467.00
Co	ng m <sup>-3</sup>	0.56-16.49	10.85±2.53	2.38±3.30	0.56-16.67	11.80±2.53	2.38±3.30
Cr	ng m <sup>-3</sup>	0.42-114.30	33.26±8.00	1.79±2.56	0.42-115.52	36.17±8.00	1.79±2.56
Cu	ng m <sup>-3</sup>	0.80-350.48	57.18±27.51	5.23±14.95	0.80-346.79	52.57±27.51	4.42±14.95
Fe	µg m <sup>-3</sup>	1.23-25.46	10.26±1.73	1.00±1.00	1.23-25.73	11.16±1.73	1.00±1.00
Hg	ng m <sup>-3</sup>	0.006-10.784	5.74±2.84	370.82±1090.5	0.006-10.899	6.25±2.84	370.82±1090.5
K	µg m <sup>-3</sup>	1.10-18.93	11.15±2.67	2.93±4.16	1.10-19.14	12.12±2.67	2.93±4.16
Li	ng m <sup>-3</sup>	0.04-5.14	1.65±0.58	0.45±0.95	0.04-5.08	1.80±0.58	0.45±0.95
Mg	µg m <sup>-3</sup>	0.18-11.14	7.12±1.54	1.68±2.16	0.18-11.26	7.74±1.54	1.68±2.16
Mn	ng m <sup>-3</sup>	5.52-534.94	142.23±45.87	0.82±1.57	5.52-540.63	154.71±45.87	0.82±1.57
Na	µg m <sup>-3</sup>	0.56-18.69	12.18±3.79	2.83±5.24	0.56-18.89	13.24±3.79	2.83±5.24
Ni	ng m <sup>-3</sup>	0.03-29.66	17.56±5.46	1.15±2.12	0.03-29.66	19.10±5.46	1.15±2.12
Pb	ng m <sup>-3</sup>	12.45-1198.97	419.61±68.02	164.49±158.35	12.40-1211.72	385.76±68.02	139.02±158.35
Se	ng m <sup>-3</sup>	0.18-80.89	62.23±8.25	6830.8±5376.9	0.18-81.75	67.69±8.25	6830.8±5376.9
Si	µg m <sup>-3</sup>	0.25-3.51	2.50±0.52	0.05±0.06	0.25-3.54	2.72±0.52	0.05±0.06
Sr	ng m <sup>-3</sup>	0.30-356.24	17.34±10.22	0.26±0.90	0.30-352.49	18.86±10.22	0.26±0.90
Th	ng m <sup>-3</sup>	0.001-0.1336	0.079±0.030	0.05±0.10	0.001-0.135	0.086±0.030	0.05±0.10
U	ng m <sup>-3</sup>	0.0005-0.0287	0.0128±0.002	0.03±0.04	0.0005-0.029	0.0117±0.002	0.02±0.04
V	ng m <sup>-3</sup>	0.41-43.56	5.07±0.99	0.23±0.27	0.41-44.02	5.52±0.99	0.23±0.27
Zn	ng m <sup>-3</sup>	8.47-947.65	318.36±57.19	24.96±26.63	8.44-957.73	346.29±57.19	24.96±26.63
C	µg m <sup>-3</sup>	2.84-23.29	13.60±1.93	373.26±314.43	2.84-23.05	14.80±1.93	373.26±314.43
H	µg m <sup>-3</sup>	1.04-18.97	11.28±1.41	44.20±32.88	1.04-19.17	12.27±1.41	44.20±32.88
N	µg m <sup>-3</sup>	0.07-11.33	7.50±1.29	2167.5±2216.7	0.07-11.45	8.16±1.29	2167.5±2216.7
S	µg m <sup>-3</sup>	0.88-8.65	4.38±1.49	68.72±138.74	0.88-8.56	4.03±1.49	58.08±138.74
Br <sup>-</sup>	ng m <sup>-3</sup>	0.005-0.214	0.123±0.004	————	0.005-0.216	0.134±0.004	————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.55-6.58	3.26±1.33	————	0.55-6.65	3.54±1.33	————
F <sup>-</sup>	µg m <sup>-3</sup>	0.06-5.39	1.97±0.46	————	0.06-5.44	2.14±0.46	————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.03-1.24	0.60±0.34	————	0.03-1.22	0.55±0.34	————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.25-20.83	6.12±1.11	————	0.25-21.05	6.65±1.11	————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.17-5.72	5.13±1.73	————	0.17-5.72	4.72±1.73	————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	1.06-26.94	9.56±2.69	————	1.06-27.23	10.40±2.69	————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	2.46-40.11	28.92±4.28	————	2.46-40.54	26.59±4.28	————
K <sup>+</sup>	ng m <sup>-3</sup>	2.21-37.87	22.29±5.34	————	2.21-38.27	24.25±5.34	————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.35-22.28	14.23±3.09	————	0.35-22.52	15.48±3.09	————
Na <sup>+</sup>	ng m <sup>-3</sup>	1.13-37.37	24.35±7.58	————	1.13-37.77	26.49±7.58	————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.73-30.90	15.50±5.19	————	1.73-31.23	16.86±5.07	————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.15:** Annual average concentration of major, trace elementals and water-soluble ions and enrichment factor in SPM at AQMS-03

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.12–1.76	1.45±0.24	55.00±88.96	0.12–1.78	1.49±0.24	55.00±88.96
Al	µg m <sup>-3</sup>	0.53–30.11	18.81±2.85	0.65±0.98	0.52–29.89	19.30±2.85	0.65±0.98
As	ng m <sup>-3</sup>	1.85–14.21	5.37±1.48	8.49±23.27	1.81–14.31	5.51±1.48	8.49±23.27
Br	ng m <sup>-3</sup>	0.11–9.32	2.67±1.58	3.17±18.62	0.11–9.39	2.74±1.58	3.17±18.62
Ca	µg m <sup>-3</sup>	1.38–38.29	26.32±2.46	1.80±1.68	1.38–38.57	25.65±2.46	1.71±1.68
Cd	ng m <sup>-3</sup>	1.40–107.89	12.74±2.47	241.66±467.00	1.40–107.11	13.08±2.47	241.66±467.00
Co	ng m <sup>-3</sup>	0.63–20.69	13.25±2.91	1.51±3.30	0.63–20.84	13.60±2.91	1.51±3.30
Cr	ng m <sup>-3</sup>	0.47–143.37	40.64±9.20	1.13±2.56	0.47–144.40	41.70±9.20	1.13±2.56
Cu	ng m <sup>-3</sup>	0.90–438.10	65.92±31.62	3.12±14.95	0.90–434.96	64.23±31.62	2.97±14.95
Fe	µg m <sup>-3</sup>	1.38–48.60	19.79±1.99	1.00±1.00	1.38–48.95	20.31±1.99	1.00±1.00
Hg	ng m <sup>-3</sup>	0.007–13.53	7.02±3.26	234.84±1090.5	0.007–13.62	7.20±3.27	234.84±1090.58
K	µg m <sup>-3</sup>	1.24–36.14	21.50±3.07	2.93±4.16	1.24–36.41	22.07±3.07	2.93±4.16
Li	ng m <sup>-3</sup>	0.04–6.42	2.02±0.67	0.29±0.95	0.04–6.38	2.07±0.67	0.29±0.95
Mg	µg m <sup>-3</sup>	0.20–21.27	13.73±1.77	1.68±2.16	0.20–21.42	14.09±1.77	1.68±2.16
Mn	ng m <sup>-3</sup>	6.21–670.95	173.79±52.72	0.52±1.57	6.21–675.79	178.35±52.72	0.52±1.57
Na	µg m <sup>-3</sup>	0.63–35.67	23.49±4.36	2.83±5.24	0.63–35.93	24.11±4.36	2.83±5.24
Ni	ng m <sup>-3</sup>	0.03–37.08	21.46±6.27	0.73±2.12	0.03–37.08	22.02±6.27	0.73±2.12
Pb	ng m <sup>-3</sup>	14.28–1503.80	504.48±103.02	102.49±208.66	13.95–1514.65	491.57±103.02	97.32±208.66
Se	ng m <sup>-3</sup>	0.20–101.46	76.04±9.48	4325.9±5376.9	0.20–102.19	78.04±9.48	4325.9±5376.93
Si	µg m <sup>-3</sup>	0.28–6.69	4.83±0.59	0.05±0.06	0.28–6.74	4.96±0.59	0.05±0.06
Sr	ng m <sup>-3</sup>	0.34–445.30	21.19±11.75	0.16±0.90	0.34–442.11	21.75±11.75	0.16±0.90
Th	ng m <sup>-3</sup>	0.001–0.1675	0.096±0.034	0.03±0.10	0.001–0.1688	0.100±0.034	0.03±0.10
U	ng m <sup>-3</sup>	0.0006–0.036	0.015±0.003	0.02±0.04	0.0006–0.0363	0.014±0.003	0.01±0.04
V	ng m <sup>-3</sup>	0.47–54.64	6.20±1.13	0.15±0.27	0.46–55.03	6.36±1.13	0.15±0.27
Zn	ng m <sup>-3</sup>	9.72–1188.59	389.01±65.74	15.81±26.63	9.50–1197.16	399.22±65.74	15.81±26.63
C	µg m <sup>-3</sup>	3.19–44.32	26.25±2.22	373.26±314.43	3.19–44.00	26.93±2.22	373.26±314.43
H	µg m <sup>-3</sup>	1.17–36.21	21.76±1.62	44.20±32.88	1.17–36.47	22.33±1.62	44.20±32.88
N	µg m <sup>-3</sup>	0.08–21.64	14.48±1.49	2167.5±2216.7	0.08–21.79	14.86±1.49	2167.5±2216.78
S	µg m <sup>-3</sup>	0.99–16.46	7.98±1.71	64.83±138.74	0.99–16.34	7.77±1.71	61.56±138.74
Br <sup>-</sup>	ng m <sup>-3</sup>	0.006–0.268	0.150±0.005	—————	0.006–0.270	0.154±0.005	—————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.62–12.55	6.28±1.53	—————	0.62–12.64	6.45±1.53	—————
F <sup>-</sup>	µg m <sup>-3</sup>	0.07–10.28	3.80±0.53	—————	0.07–10.36	3.90±0.53	—————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.04–2.35	1.09±0.39	—————	0.04–2.33	1.06±0.39	—————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.28–39.76	11.80±1.27	—————	0.28–40.04	12.11±1.27	—————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.20–10.87	9.34±1.98	—————	0.20–10.87	9.10±1.98	—————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	1.19–51.43	18.45±3.09	—————	1.19–51.80	18.94±3.09	—————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	2.77–76.58	52.64±4.92	—————	2.77–77.13	51.30±4.92	—————
K <sup>+</sup>	ng m <sup>-3</sup>	2.48–72.29	43.01±6.13	—————	2.48–72.81	44.14±6.13	—————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.40–42.54	27.46±3.55	—————	0.40–42.85	28.18±3.55	—————
Na <sup>+</sup>	ng m <sup>-3</sup>	1.27–71.34	46.98±8.71	—————	1.27–71.86	48.22±8.71	—————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.94–38.76	18.94±5.84	—————	1.94–39.04	19.44±5.71	—————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.16:** Annual average concentration of major, trace elementals and water-soluble ions and enrichment factor in PM<sub>2.5</sub> at AQMS-04

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.10–1.21	0.93±0.18	179.92±163.73	0.10–1.24	0.99±0.18	179.92±163.73
Al	µg m <sup>-3</sup>	0.13–4.93	2.08±0.95	0.37±0.79	0.12–4.80	2.22±0.95	0.37±0.79
As	ng m <sup>-3</sup>	0.70–9.27	3.90±0.87	31.55±33.02	0.69–9.52	4.15±0.87	31.55±33.02
Br	ng m <sup>-3</sup>	0.81–4.39	1.41±0.32	8.54±9.08	0.81–4.51	1.50±0.32	8.54±9.08
Ca	µg m <sup>-3</sup>	0.49–6.53	2.82±1.01	0.99±1.67	0.49–6.71	2.65±1.01	0.87±1.67
Cd	ng m <sup>-3</sup>	0.52–78.52	7.01±1.80	680.70±825.06	0.52–76.44	7.46±1.80	680.70±825.06
Co	ng m <sup>-3</sup>	0.52–12.54	8.67±2.29	5.05±6.28	0.52–12.88	9.22±2.29	5.05±6.28
Cr	ng m <sup>-3</sup>	0.49–98.84	20.61±5.09	2.94±3.43	0.49–101.53	21.93±5.09	2.94±3.43
Cu	ng m <sup>-3</sup>	0.74–237.70	31.08±14.78	7.54±16.92	0.74–231.40	29.20±14.78	6.66±16.92
Fe	µg m <sup>-3</sup>	0.14–6.29	3.87±0.82	1.00±1.00	0.14–6.46	4.12±0.82	1.00±1.00
Hg	ng m <sup>-3</sup>	0.002–7.202	2.74±0.90	468.84±727.69	0.002–7.398	2.91±0.88	468.84±727.69
K	µg m <sup>-3</sup>	0.74–10.15	3.83±0.69	2.67±2.26	0.74–10.42	4.08±0.69	2.67±2.26
Li	ng m <sup>-3</sup>	0.02–3.01	1.17±0.29	0.85±1.00	0.02–2.93	1.25±0.29	0.85±1.00
Mg	µg m <sup>-3</sup>	0.14–9.41	4.95±1.02	3.09±3.02	0.14–9.66	5.27±1.02	3.09±3.02
Mn	ng m <sup>-3</sup>	0.54–354.33	98.50±41.65	1.51±3.01	0.54–363.97	104.83±41.65	1.51±3.01
Na	µg m <sup>-3</sup>	0.09–10.40	4.48±1.85	2.76±5.38	0.09–10.68	4.77±1.85	2.76±5.38
Ni	ng m <sup>-3</sup>	0.02–18.67	14.43±1.86	2.50±1.52	0.02–18.67	15.35±1.86	2.50±1.52
Pb	ng m <sup>-3</sup>	5.93–1041.69	315.02±17.47	327.55±85.70	5.86–1070.04	296.01±17.47	289.21±85.70
Se	ng m <sup>-3</sup>	0.07–64.74	43.87±6.71	12773.0±9210.0	0.07–66.50	46.69±6.71	12773.0±9210.0
Si	µg m <sup>-3</sup>	0.12–2.42	1.46±0.49	0.08±0.12	0.12–2.48	1.55±0.49	0.08±0.12
Sr	ng m <sup>-3</sup>	0.13–305.08	10.08±8.07	0.40±1.50	0.13–297.00	10.73±8.07	0.40±1.50
Th	ng m <sup>-3</sup>	0.001–0.101	0.059±0.02	0.09±0.14	0.001–0.104	0.062±0.020	0.09±0.14
U	ng m <sup>-3</sup>	0.0003–0.0201	0.010±0.001	0.06±0.02	0.0003–0.0204	0.010±0.001	0.05±0.02
V	ng m <sup>-3</sup>	0.21–29.72	3.58±1.00	0.43±0.57	0.21–30.53	3.81±1.00	0.43±0.57
Zn	ng m <sup>-3</sup>	2.36–699.20	238.20±37.53	49.54±36.82	2.34–718.23	253.50±37.53	49.54±36.82
C	µg m <sup>-3</sup>	1.36–18.54	5.80±0.78	422.00±269.32	1.36–18.05	6.17±0.78	422.00±269.32
H	µg m <sup>-3</sup>	0.70–14.64	5.75±0.42	59.83±20.71	0.70–15.04	6.12±0.42	59.83±20.71
N	µg m <sup>-3</sup>	0.03–10.07	4.58±0.27	3511.7±971.98	0.03–10.34	4.88±0.27	3511.7±971.9
S	µg m <sup>-3</sup>	0.39–7.18	3.12±0.78	129.81±152.43	0.39–6.99	2.93±0.78	114.62±152.43
Br <sup>-</sup>	ng m <sup>-3</sup>	0.005–0.195	0.100±0.002	—————	0.005–0.200	0.106±0.002	—————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.49–4.28	1.97±0.57	—————	0.49–4.40	2.09±0.57	—————
F <sup>-</sup>	µg m <sup>-3</sup>	0.05–4.55	1.78±0.67	—————	0.05–4.68	1.90±0.67	—————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.02–1.01	0.42±0.19	—————	0.02–0.99	0.40±0.19	—————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.13–17.52	3.01±0.94	—————	0.13–18.00	3.21±0.94	—————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.13–4.43	3.57±0.95	—————	0.13–4.43	3.35±0.95	—————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	0.90–19.55	5.84±1.94	—————	0.90–20.09	6.21±1.94	—————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	0.98–13.07	5.64±2.02	—————	0.98–13.42	5.30±2.02	—————
K <sup>+</sup>	ng m <sup>-3</sup>	1.48–20.30	7.66±1.38	—————	1.48–20.85	8.15±1.38	—————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.27–18.82	9.90±2.05	—————	0.27–19.33	10.54±2.05	—————
Na <sup>+</sup>	ng m <sup>-3</sup>	0.17–20.80	8.96±3.70	—————	0.17–21.36	9.54±3.70	—————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.00–23.09	10.63±2.76	—————	1.01–23.72	11.31±2.70	—————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.17:** Annual average concentration of major, trace elementals and water-soluble ions and enrichment factor in PM<sub>10</sub> at AQMS-04

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.11-1.37	0.98±0.21	75.01±120.92	0.11-1.42	1.08±0.21	75.01±120.92
Al	µg m <sup>-3</sup>	0.35-14.97	9.42±1.60	0.66±0.85	0.34-14.44	10.33±1.60	0.66±0.85
As	ng m <sup>-3</sup>	1.57-5.10	4.83±1.30	15.37±31.63	1.56-5.29	5.29±1.30	15.37±31.63
Br	ng m <sup>-3</sup>	0.09-7.03	2.04±0.97	4.87±17.67	0.09-7.28	2.24±0.97	4.87±17.67
Ca	µg m <sup>-3</sup>	0.96-18.57	12.64±1.43	1.75±1.51	0.96-19.25	11.53±1.43	1.45±1.51
Cd	ng m <sup>-3</sup>	1.04-90.29	10.45±0.07	399.28±20.11	1.04-87.10	11.45±0.07	399.28±20.11
Co	ng m <sup>-3</sup>	0.55-14.62	10.57±1.24	2.42±2.17	0.55-15.16	11.58±1.24	2.42±2.17
Cr	ng m <sup>-3</sup>	0.49-111.45	32.22±15.19	1.81±6.54	0.49-115.53	35.30±15.19	1.81±6.54
Cu	ng m <sup>-3</sup>	0.75-348.40	56.84±24.20	5.43±17.72	0.75-336.11	51.87±24.20	4.52±17.72
Fe	µg m <sup>-3</sup>	1.08-24.51	9.82±1.28	1.00±1.00	1.08-25.41	10.76±1.28	1.00±1.00
Hg	ng m <sup>-3</sup>	0.004-9.65	5.23±1.32	353.04±686.93	0.004-10.00	5.74±1.32	353.04±686.93
K	µg m <sup>-3</sup>	1.26-18.24	10.49±1.77	2.88±3.73	1.26-18.91	11.50±1.77	2.88±3.73
Li	ng m <sup>-3</sup>	0.03-5.12	1.59±0.59	0.46±1.29	0.03-4.94	1.74±0.59	0.46±1.29
Mg	µg m <sup>-3</sup>	0.17-10.20	6.88±1.12	1.69±2.11	0.17-10.57	7.54±1.12	1.69±2.11
Mn	ng m <sup>-3</sup>	5.28-521.44	296.61±39.38	1.79±1.82	5.28-540.51	325.01±39.38	1.79±1.82
Na	µg m <sup>-3</sup>	0.47-16.86	11.72±1.16	2.85±2.15	0.47-17.47	12.85±1.16	2.85±2.15
Ni	ng m <sup>-3</sup>	0.04-27.68	17.22±5.65	1.18±2.95	0.04-27.68	18.87±5.65	1.18±2.95
Pb	ng m <sup>-3</sup>	12.08-1158.72	410.82±39.75	168.25±124.76	12.01-1201.11	374.92±39.75	140.13±124.76
Se	ng m <sup>-3</sup>	0.17-77.84	59.12±7.69	6780.1±6756.9	0.17-80.69	64.79±7.69	6780.1±6756.9
Si	µg m <sup>-3</sup>	0.22-3.40	2.36±0.50	0.05±0.08	0.22-3.52	2.59±0.50	0.05±0.08
Sr	ng m <sup>-3</sup>	0.28-351.34	16.50±8.35	0.26±0.99	0.28-338.94	18.08±8.35	0.26±0.99
Th	ng m <sup>-3</sup>	0.001-0.119	0.075±0.029	0.04±0.14	0.001-0.124	0.082±0.029	0.04±0.14
U	ng m <sup>-3</sup>	0.0005-0.027	0.012±0.002	0.03±0.04	0.0005-0.028	0.011±0.002	0.02±0.04
V	ng m <sup>-3</sup>	0.41-41.48	4.98±0.99	0.24±0.36	0.41-43.00	5.45±0.99	0.24±0.36
Zn	ng m <sup>-3</sup>	7.81-866.53	313.74±46.66	25.70±29.28	7.76-898.23	343.78±46.66	25.70±29.28
C	µg m <sup>-3</sup>	2.44-23.19	13.15±1.57	377.05±344.32	2.44-22.37	14.41±1.57	377.05±344.32
H	µg m <sup>-3</sup>	1.04-18.34	10.91±1.38	44.67±43.24	1.04-19.01	11.95±1.38	44.67±43.24
N	µg m <sup>-3</sup>	0.07-11.04	7.17±1.21	2164.7±2795.5	0.07-11.44	7.86±1.21	2164.7±2795.5
S	µg m <sup>-3</sup>	0.79-8.56	4.22±1.33	69.18±166.57	0.79-8.26	3.85±1.33	57.62±166.57
Br <sup>-</sup>	ng m <sup>-3</sup>	0.005-0.204	0.121±0.004	————	0.005-0.212	0.132±0.004	————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.55-6.33	3.18±1.28	————	0.55-6.56	3.49±1.28	————
F <sup>-</sup>	µg m <sup>-3</sup>	0.06-5.23	1.94±0.44	————	0.06-5.42	2.13±0.44	————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.03-1.23	0.59±0.34	————	0.03-1.19	0.53±0.34	————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.24-20.26	5.98±1.08	————	0.24-21.00	6.55±1.08	————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.17-5.71	5.10±1.67	————	0.17-5.71	4.65±1.67	————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	1.06-26.25	9.42±2.66	————	1.06-27.21	10.32±2.66	————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	1.92-37.13	25.27±2.85	————	1.92-38.49	23.06±2.85	————
K <sup>+</sup>	ng m <sup>-3</sup>	2.52-36.49	20.98±3.54	————	2.52-37.82	22.99±3.54	————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.35-20.39	13.77±2.23	————	0.35-21.14	15.09±2.23	————
Na <sup>+</sup>	ng m <sup>-3</sup>	0.95-33.71	23.45±2.31	————	0.95-34.94	25.69±2.31	————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.73-29.92	15.27±4.66	————	1.73-31.02	16.73±4.56	————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

**Table 5.18:** Annual average concentration of major, trace elementals and water-soluble ions and enrichment factor in SPM at AQMS-04

Elements	Unit	Year-2016			Year-2017		
		Range	Average	Enrichment Factor	Range	Average	Enrichment Factor
Ag	ng m <sup>-3</sup>	0.11–1.50	1.13±0.21	44.35±110.00	0.11–1.55	1.18±0.21	44.35±110.00
Al	µg m <sup>-3</sup>	0.40–28.47	18.42±1.80	0.66±0.85	0.39–27.54	19.17±1.80	0.66±0.85
As	ng m <sup>-3</sup>	1.80–6.39	5.19±1.46	8.46±31.63	1.76–6.61	5.40±1.46	8.46±31.63
Br	ng m <sup>-3</sup>	0.10–8.81	2.53±1.09	3.09±17.67	0.10–9.10	2.63±1.09	3.09±17.67
Ca	µg m <sup>-3</sup>	1.08–35.41	23.46±1.60	1.66±1.51	1.08–36.61	22.54±1.60	1.53±1.51
Cd	ng m <sup>-3</sup>	1.17–112.86	12.93±0.08	252.86±20.11	1.17–109.16	13.46±0.08	252.86±20.11
Co	ng m <sup>-3</sup>	0.62–18.32	13.09±1.39	1.54±2.17	0.62–18.95	13.62±1.39	1.54±2.17
Cr	ng m <sup>-3</sup>	0.55–139.68	39.88±17.10	1.15±6.54	0.55–144.41	41.51±17.10	1.15±6.54
Cu	ng m <sup>-3</sup>	0.84–435.50	66.84±27.24	3.27±17.72	0.84–421.23	64.20±27.24	3.02±17.72
Fe	µg m <sup>-3</sup>	1.22–46.76	19.19±1.44	1.00±1.00	1.22–48.34	19.98±1.44	1.00±1.00
Hg	ng m <sup>-3</sup>	0.004–12.10	6.48±1.49	223.58±686.93	0.004–12.50	6.74±1.50	223.58±686.93
K	µg m <sup>-3</sup>	1.42–34.80	20.50±1.99	2.88±3.73	1.42–35.98	21.34±1.99	2.88±3.73
Li	ng m <sup>-3</sup>	0.04–6.40	1.97±0.66	0.29±1.29	0.04–6.19	2.05±0.66	0.29±1.29
Mg	µg m <sup>-3</sup>	0.20–19.45	13.45±1.26	1.69±2.11	0.20–20.11	14.01±1.26	1.69±2.11
Mn	ng m <sup>-3</sup>	5.94–653.50	367.12±44.33	1.13±1.82	5.94–675.64	382.18±44.33	1.13±1.82
Na	µg m <sup>-3</sup>	0.53–32.15	22.91±1.30	2.85±2.15	0.53–33.24	23.85±1.30	2.85±2.15
Ni	ng m <sup>-3</sup>	0.05–34.60	21.32±6.36	0.74±2.95	0.04–34.60	22.19±6.36	0.74±2.95
Pb	ng m <sup>-3</sup>	13.84–1452.18	504.13±149.74	105.64±417.44	13.51–1501.39	484.26±149.74	97.48±417.44
Se	ng m <sup>-3</sup>	0.19–97.55	73.18±8.66	4293.8±6756.9	0.19–100.86	76.18±8.66	4293.8±6756.9
Si	µg m <sup>-3</sup>	0.25–6.49	4.61±0.57	0.05±0.08	0.25–6.71	4.80±0.57	0.05±0.08
Sr	ng m <sup>-3</sup>	0.32–439.17	20.42±9.40	0.16±0.99	0.32–424.78	21.26±9.40	0.16±0.99
Th	ng m <sup>-3</sup>	0.001–0.149	0.093±0.033	0.03±0.14	0.001–0.154	0.097±0.032	0.03±0.14
U	ng m <sup>-3</sup>	0.0006–0.0343	0.0146±0.003	0.02±0.04	0.0006–0.0355	0.0141±0.003	0.01±0.04
V	ng m <sup>-3</sup>	0.47–51.99	6.16±1.12	0.15±0.36	0.46–53.75	6.41±1.12	0.15±0.36
Zn	ng m <sup>-3</sup>	8.94–1085.99	388.31±52.52	16.27±29.28	8.73–1122.78	404.25±52.52	16.27±29.28
C	µg m <sup>-3</sup>	2.74–44.12	25.70±1.76	377.05±344.32	2.74–42.67	26.76±1.76	377.05±344.32
H	µg m <sup>-3</sup>	1.17–34.99	21.31±1.55	44.67±43.24	1.17–36.17	22.19±1.55	44.67±43.24
N	µg m <sup>-3</sup>	0.08–21.06	14.02±1.36	2164.7±2795.5	0.08–21.77	14.59±1.36	2164.7±2795.5
S	µg m <sup>-3</sup>	0.89–16.29	7.84±1.49	65.73±166.57	0.89–15.76	7.53±1.49	60.65±166.57
Br <sup>-</sup>	ng m <sup>-3</sup>	0.006–0.256	0.150±0.005	—————	0.006–0.265	0.155±0.005	—————
Cl <sup>-</sup>	µg m <sup>-3</sup>	0.62–12.08	6.22±1.44	—————	0.62–12.49	6.48±1.44	—————
F <sup>-</sup>	µg m <sup>-3</sup>	0.07–9.98	3.80±0.49	—————	0.07–10.32	3.95±0.49	—————
NO <sub>2</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.04–2.35	1.09±0.38	—————	0.04–2.27	1.04±0.38	—————
NO <sub>3</sub> <sup>-</sup>	µg m <sup>-3</sup>	0.27–38.64	11.69±1.22	—————	0.27–39.95	12.17±1.22	—————
PO <sub>4</sub> <sup>3-</sup>	µg m <sup>-3</sup>	0.20–10.87	9.46±1.88	—————	0.20–10.87	9.09±1.88	—————
SO <sub>4</sub> <sup>2-</sup>	µg m <sup>-3</sup>	1.19–50.06	18.41±3.00	—————	1.19–51.76	19.17±3.00	—————
Ca <sup>2+</sup>	ng m <sup>-3</sup>	2.16–70.83	46.92±3.21	—————	2.16–73.23	45.07±3.21	—————
K <sup>+</sup>	ng m <sup>-3</sup>	2.84–69.60	41.01±3.99	—————	2.84–71.96	42.69±3.99	—————
Mg <sup>2+</sup>	ng m <sup>-3</sup>	0.39–38.90	26.91±2.51	—————	0.39–40.22	28.01±2.51	—————
Na <sup>+</sup>	ng m <sup>-3</sup>	1.07–64.30	45.83±2.60	—————	1.07–66.48	47.71±2.60	—————
NH <sub>4</sub> <sup>+</sup>	µg m <sup>-3</sup>	1.94–37.50	18.90±5.24	—————	1.94–38.77	19.67±5.12	—————

± Standard deviation

Annual permissible limit: As=6ng m<sup>-3</sup>; Ni=20ng m<sup>-3</sup>; Pb=0.50 µg m<sup>-3</sup> [101]

### 5.2.2 Percentage distribution of major & trace elements in particulate matter

Out of the twenty–nine elements, the eleven elements Na, Mg, H, C, N, Ca, K, S, Fe, Al, and Si contribute more than 95 % of the total weight of the elements in PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM samples. In the Bina industrial cum–residential area (AQMS–01), the weight percentage of the elements based on analyzed of twenty–nine associated with SPM showed that, Ca (11.8 %), Na (12.0 %), C (13.41 %), H (11.12 %), K (10.69 %) constituted the dominant fraction followed by Fe (10.01 %), Al (9.61 %), N (7.31 %), Mg (7.02 %), S (3.93 %), Si (2.41 %) and the remaining eighteen elements constitute (0.79 %), given in **Fig. 5.1**. Out of this, the remaining eighteen elements, Pb, Zn, and Mn, contribute approximately 0.65 % and all the toxic metals viz. Se, Cu, Cr, Ni, Sr, Co, Cd, Hg, V, As, Br, Li, Ag, Th, and U contribute only 0.14 % of the total weight. Whereas in the PM<sub>10</sub> samples, in the Bina industrial cum–residential area (AQMS–01), the average weight percentage of the elements were found to be C (13.35 %), Na (11.90 %), Ca (11.70 %), H (11.07 %), K (10.65 %), Fe (9.97 %), Al (9.56 %), N (7.28 %), Mg (6.99 %), S (3.91 %), Si (2.39 %) and the remaining eighteen elements i.e., Pb, Zn, Mn, Se, Cu, Cr, Ni, Sr, Co, Cd, Hg, V, As, Br, Li, Ag, Th, and U (1.22 %) (**Fig. 5.1**).

The weight percentage of elements in both SPM and PM<sub>10</sub> samples, the eleven elements, i.e., C, Na, Ca, H, K, Fe, Al, N, Mg, S, and Si in the Bina industrial cum–residential area (AQMS–01) contribute more than 98%, there were of crust origin, and all the remaining toxic metals contribute only > 2%. Out of this > 2%, Pb, Zn, and Mn contribute a significant fraction as compared to toxic metals i.e., Se, Cu, Cr, Ni, Sr, Co, Cd, Hg, V, As, Br, Li, Ag, Th, and U. As for as PM<sub>2.5</sub> is concerned, C, H, Mg, N, Na, Fe, and K constituted the dominant fraction followed by S, Ca, Al, Si elements contributed more than 98 %, and the remaining eighteen elements constitute > 1.81 %, respectively (**Fig. 5.1**). Out of this, the other remaining eighteen elements, Pb, Zn, and Mn, contribute 1.47 % and all the toxic

metals viz. Se, Cu, Cr, Ni, Sr, Co, Cd, As, V, Hg, Br, Li, Ag, Th, and U contribute only 0.34 % of the total weight of measured elements in the PM<sub>2.5</sub> samples, respectively.

In the Industrial cum–residential area of Dudhichua (AQMS–03), the weight percentage of them based on analyzed the twenty–nine elements associated with the PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM revealed that the H (12.4, 11.2, and 11.1 %), C (12.1, 12.5, and 12.8 %), N (11.3, 7.4, and 7.3 %), Na (9.8, 11.1, and 11.5 %), and Mg (9.7, 7.1, and 7.0 %), respectively, constituted the dominant fraction followed by Ca (9.1, 12.2, and 12.6 %), K (9.0, 11.0, and 11.0 %), S (7.6, 4.0, and 4.0 %), Fe (7.6, 10.1, and 10.1 %), Al (5.6, 9.6, and 9.6 %), Si (3.6, 4.0, and 4.0 %), respectively, and the remaining eighteen elements constitute (2.0, 1.1, and 0.7 %), respectively (**Fig. 5.3**). Out of this, the remaining eighteen elements, Pb, Zn, and Mn, contribute 1.63, 0.84, and 0.54 % and all the toxic metals viz. Se, Cu, Cr, Ni, Sr, Co, Cd, As, V, Hg, Br, Li, Ag, Th, and U contribute only 0.38 %, 0.22 %, and 0.14 % of the total weight of measured elements in the PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM samples during the study for two consecutive years, respectively.

Whereas, in the PM<sub>2.5</sub> samples, in the mining area of Dudhichua (AQMS–06), the average weight percentage of the elements was found to be H (11.14 %), C (10.81 %), N (9.86 %), Na (10.79%), Mg (8.11 %), Ca (10.04 %), K (9.98 %), S (8.43 %), Fe (8.40 %), Al (6.19 %), Si (4.03%) and the remaining eighteen elements i.e., Pb, Zn, Mn, Se, Cu, Cr, Ni, Sr, Co, Cd, As, V, Hg, Br, Li, Ag, Th, and U (2.22 %), given in **Fig. 5.6**.

In the mining area of Dudhichua (AQMS–6), Mg contributes 7.0 % in PM<sub>10</sub> as compared to SPM as same, and Fe contribution in PM<sub>10</sub> was marginally lower than that observed in SPM (**Fig. 5.6**). It is maybe inferred that naturally occurring Fe and Mn in particulate forms were of smaller particle size due to natural weathering processes [**180,181**].

The weight percentage of almost all elements based on analyzed twenty–nine elements associated with PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM samples in the other area was comparable. The other

monitoring stations, a detailed analyzed element percentage, have been given in **Figs. 5.2, 5.4, and 5.5**. Similar studies by researchers have been reported [15,121].

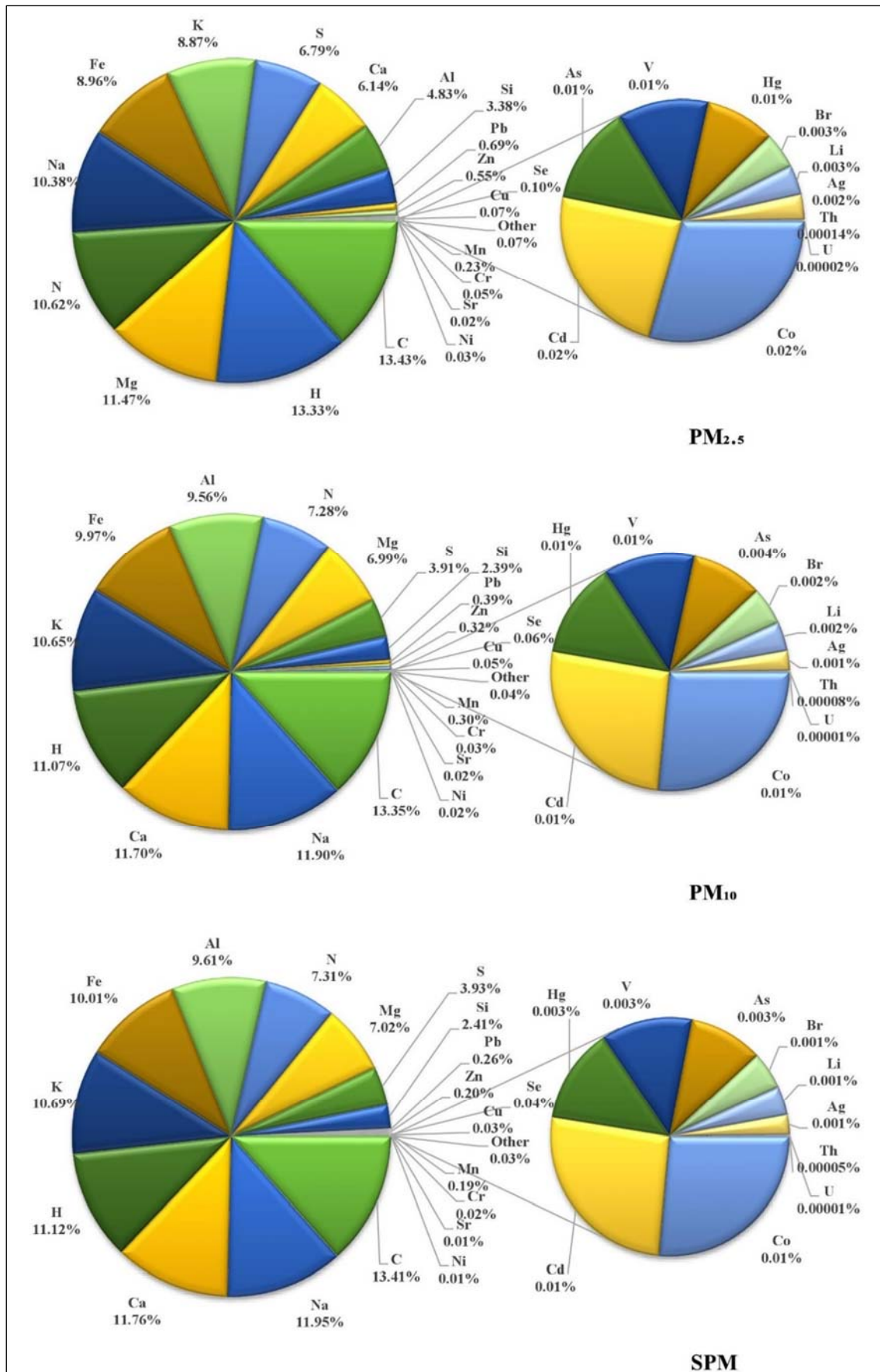
### **5.2.3 Seasonal variation of major & trace elements in particulate matter**

In this study, the seasonal variation in chemical composition of particulate matter has been illustrated as percent abundance in **Figs. 5.7, 5.8, 5.9, and 5.10**. The composition of particulate matter shows that the meteorological factors may influence pollutants' source strength and the physicochemical transformations occurring in the environment [61,156].

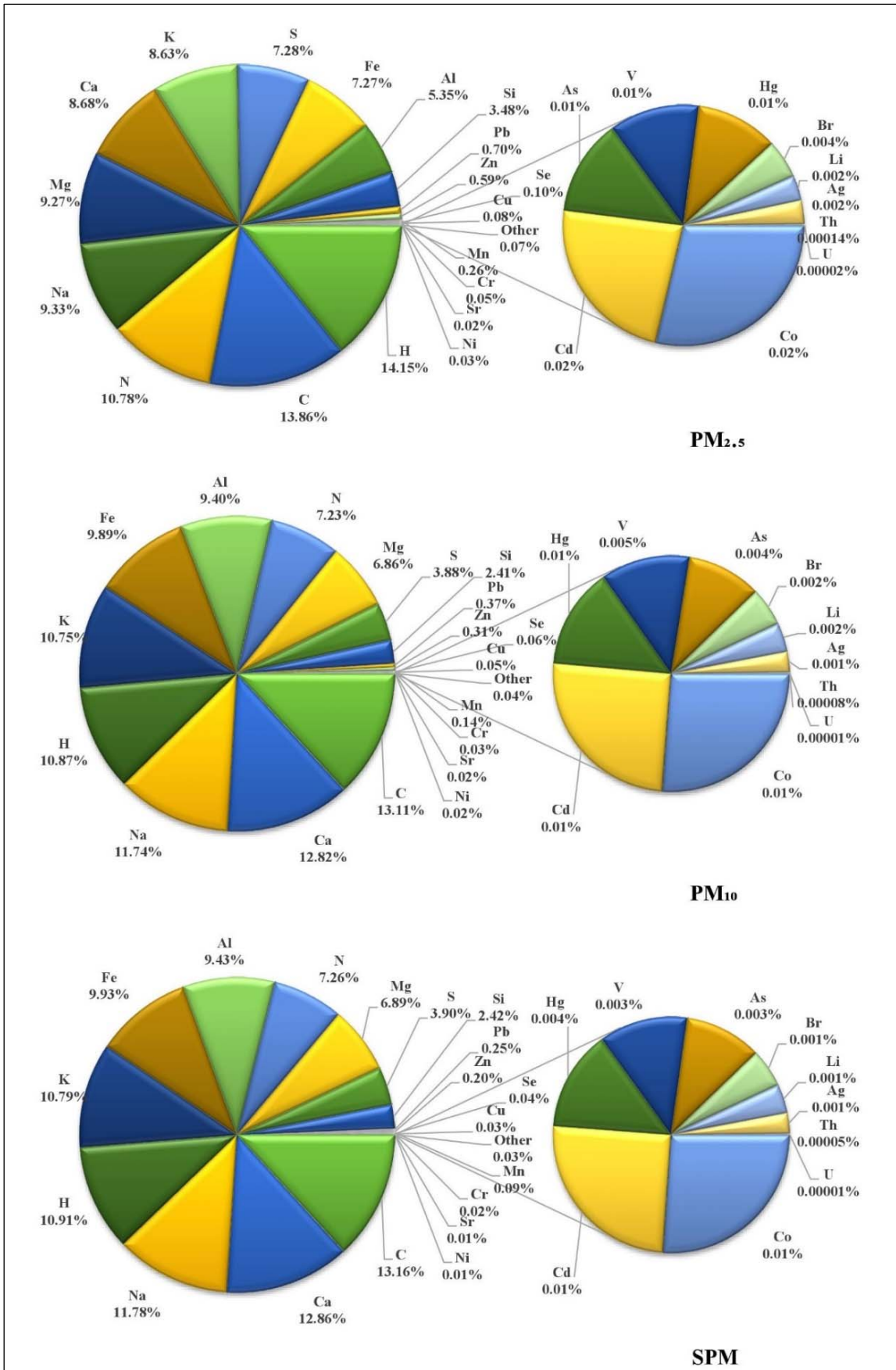
It may be observed from these **Figs. 5.7, 5.8, 5.9, and 5.10** are seasonal variations of measured elements. Most of the analyzed elements associated with different particulate matter samples were presented higher concentrations in winter than those in summer and rainy. The sum-up of Al, Ca, Fe, K, Mg, Na, Si, C, H, N, and S, which are typically crust elements, accounted for 36.2 %, 33.8 %, and 30.0 % in PM<sub>2.5</sub> samples in winter, summer, and rainy, respectively in Dudhichua industrial cum-residential area (AQMS-03) and shown in **Fig. 5.9**.

The PM<sub>10</sub> samples contribute in the crust elements of Al, Ca, Fe, K, Mg, Na, Si, C, H, N, and S are 37.1 %, 32.0 %, and 31.0 % in winter, summer, and rainy, respectively in AQMS-03 (**Fig. 5.9**). As for SPM samples, the sum-up of Al, Ca, Fe, K, Mg, Na, Si, C, H, N, and S, which are typically crust elements, accounted for 37.6 %, 32.0%, and 30.4 % in winter, summer, and rainy, respectively in AQMS-03 (**Fig. 5.9**).

The excess of higher crust elements during winter can be caused by low temperatures and low wind speeds, leading to air convection re-suspension dust from local and regions. Mineral dust can significantly affect particles' concentration in areas affected by dust reclamation [182].



**Fig. 5.1:** Percentage distribution of elements in the particulate matter at AQMS–01 during two consecutive years (2016 and 2017)



**Fig. 5.2:** Percentage distribution of elements in the particulate matter at AQMS–02 during two consecutive years (2016 and 2017)

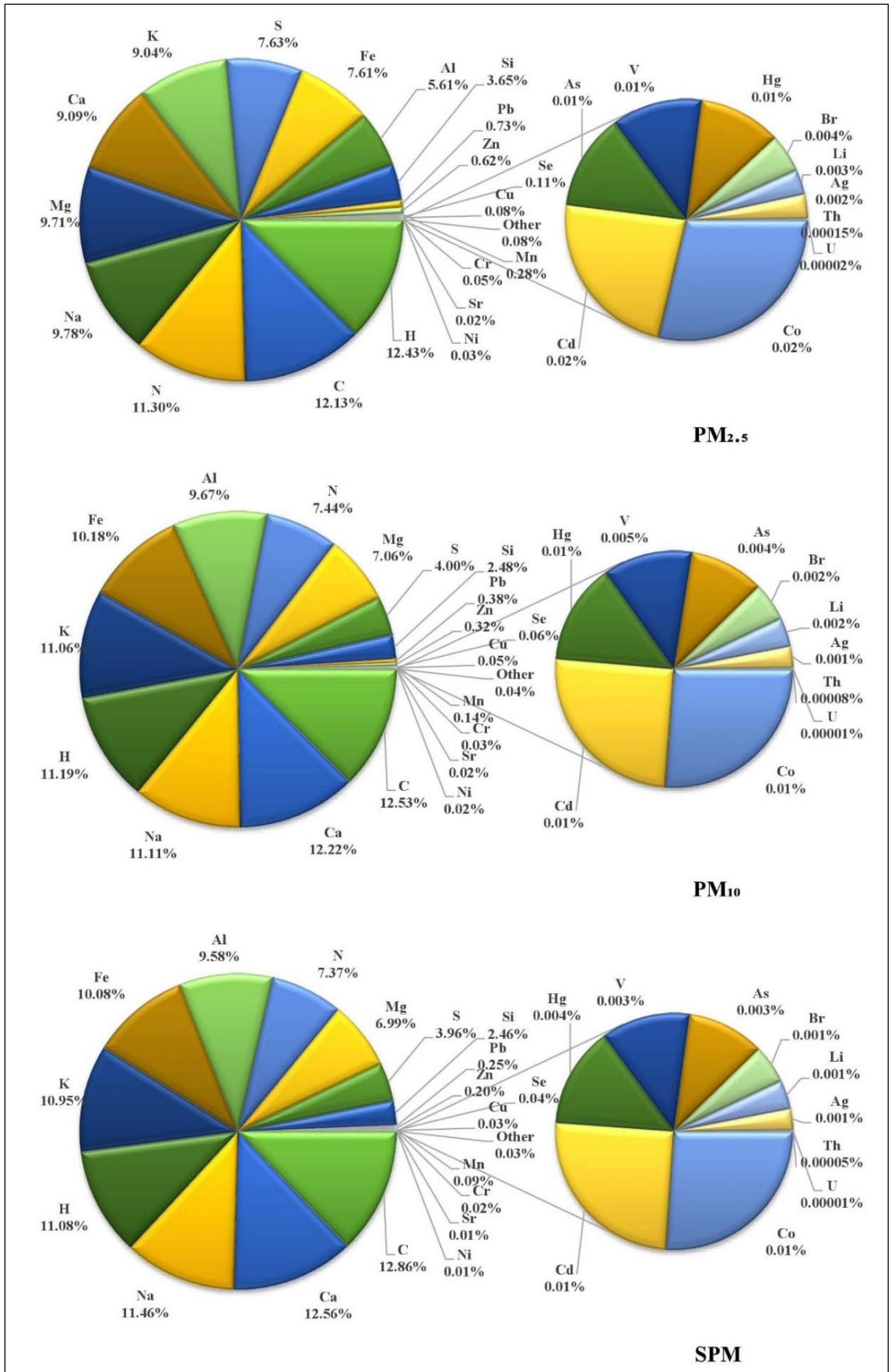
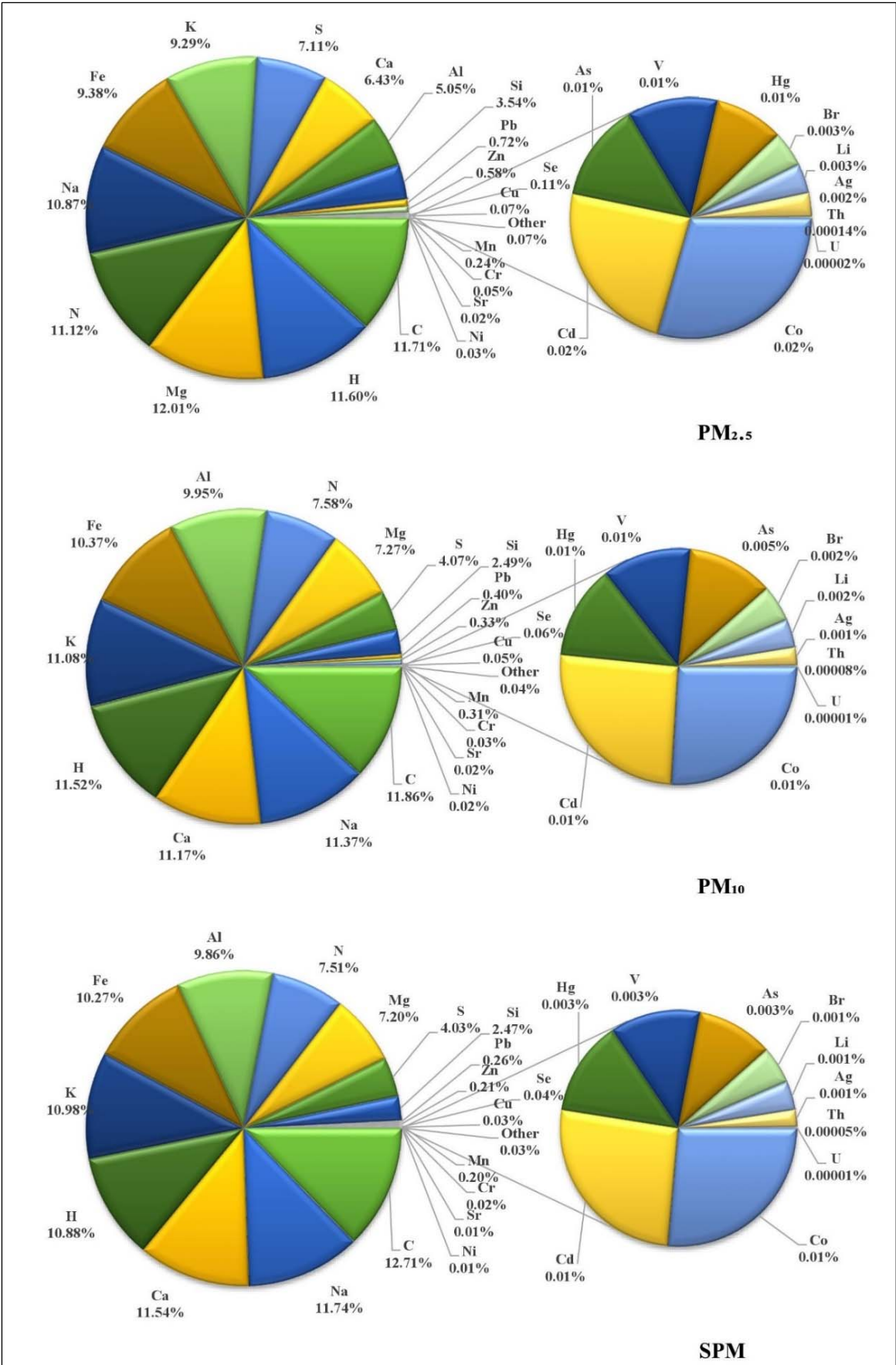


Fig. 5.3: Percentage distribution of elements in the particulate matter at AQMS-03 during two consecutive years (2016 and 2017)



**Fig. 5.4:** Percentage distribution of elements in the particulate matter at AQMS-04 during two consecutive years (2016 and 2017)

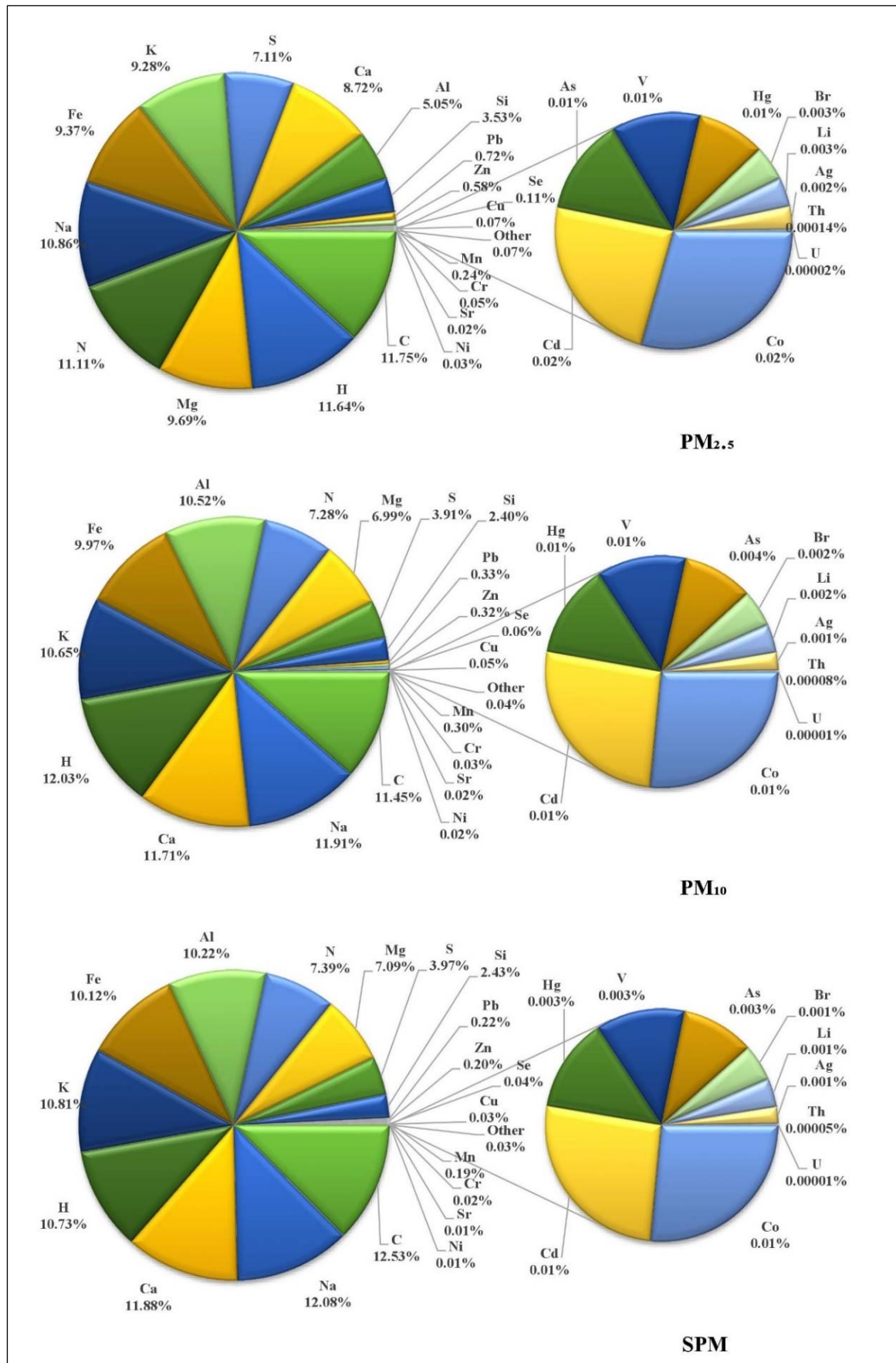


Fig. 5.5: Percentage distribution of elements in the particulate matter at AQMS-05 during March, April, and May 2016

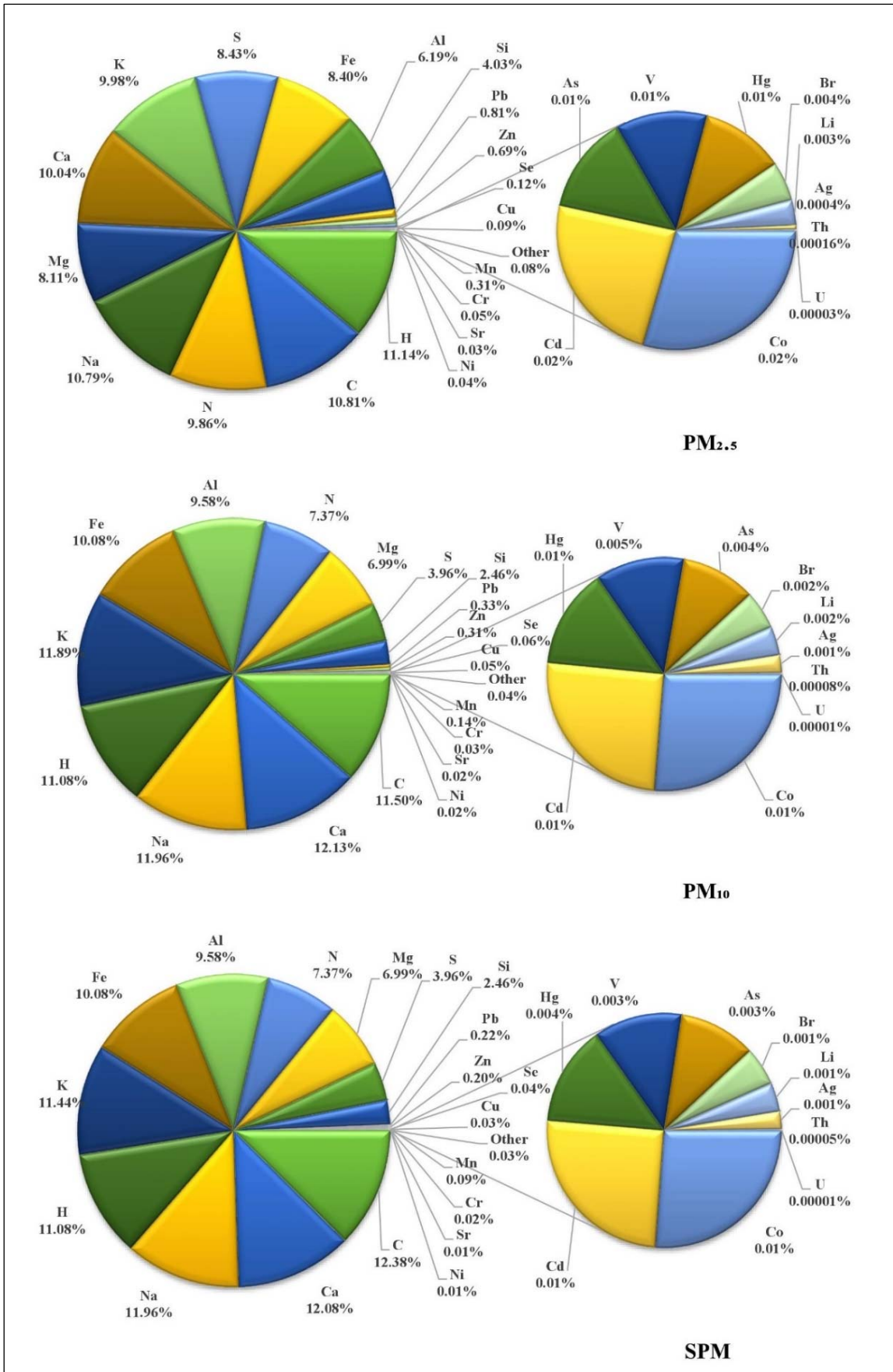
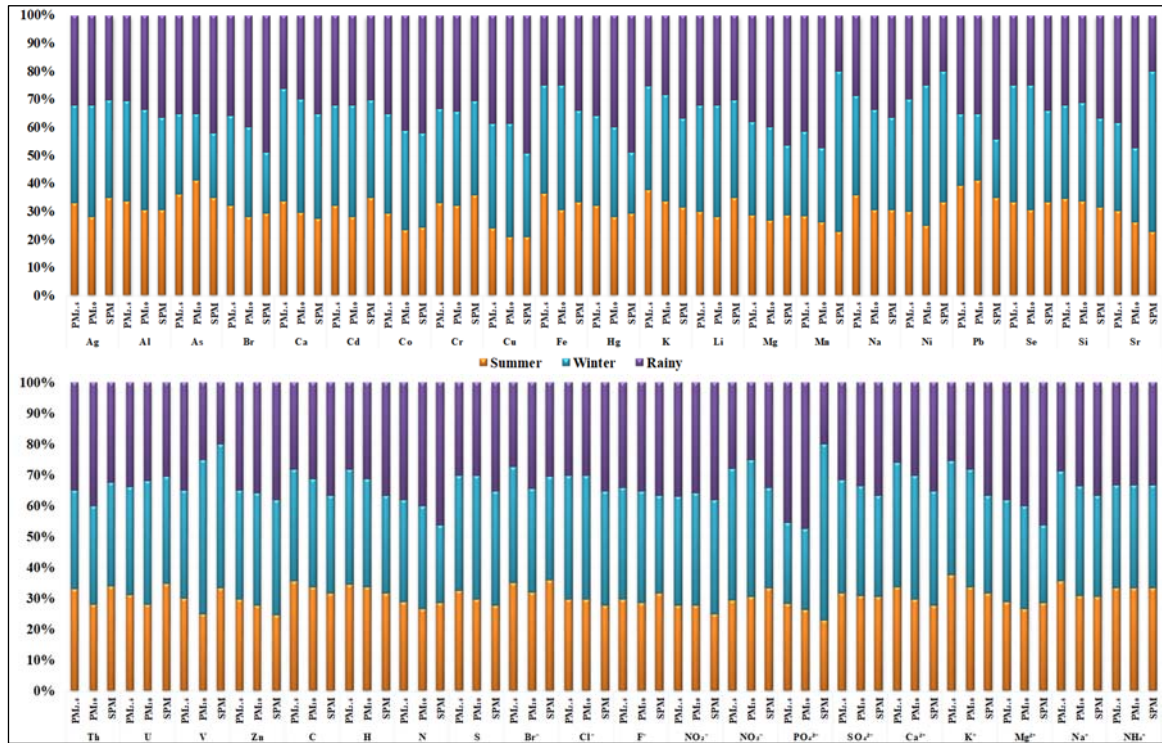
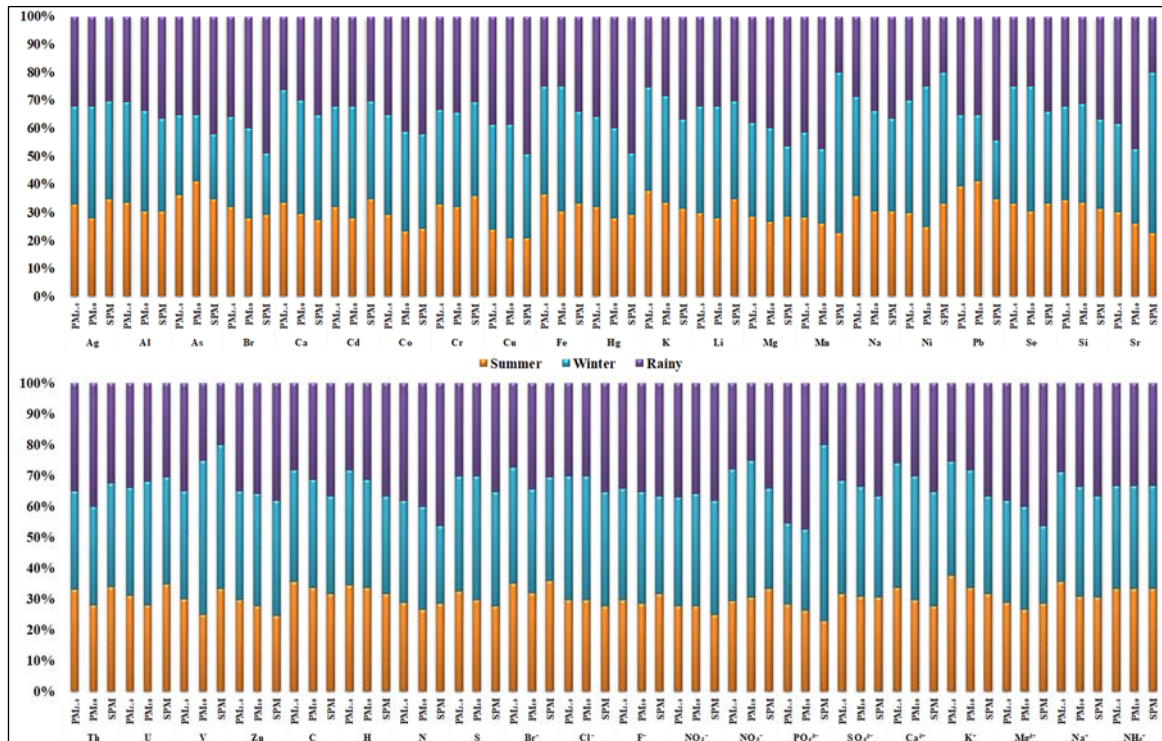


Fig. 5.6: Percentage distribution of elements in the particulate matter at AQMS-06 during March, April, and May 2016



**Fig. 5.7:** Average seasonal variation of particulate matter associated species at AQMS–01



**Fig. 5.8:** Average seasonal variation of particulate matter associated species at AQMS–02

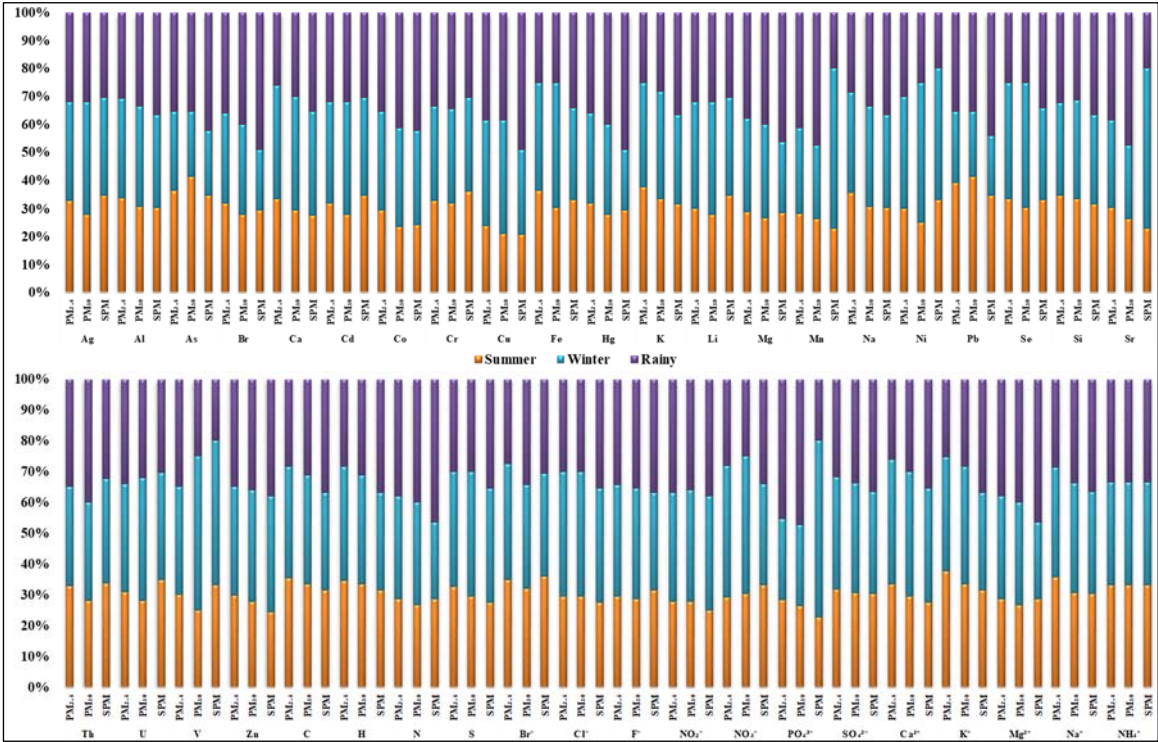


Fig. 5.9: Average seasonal variation of particulate matter associated species at AQMS-03

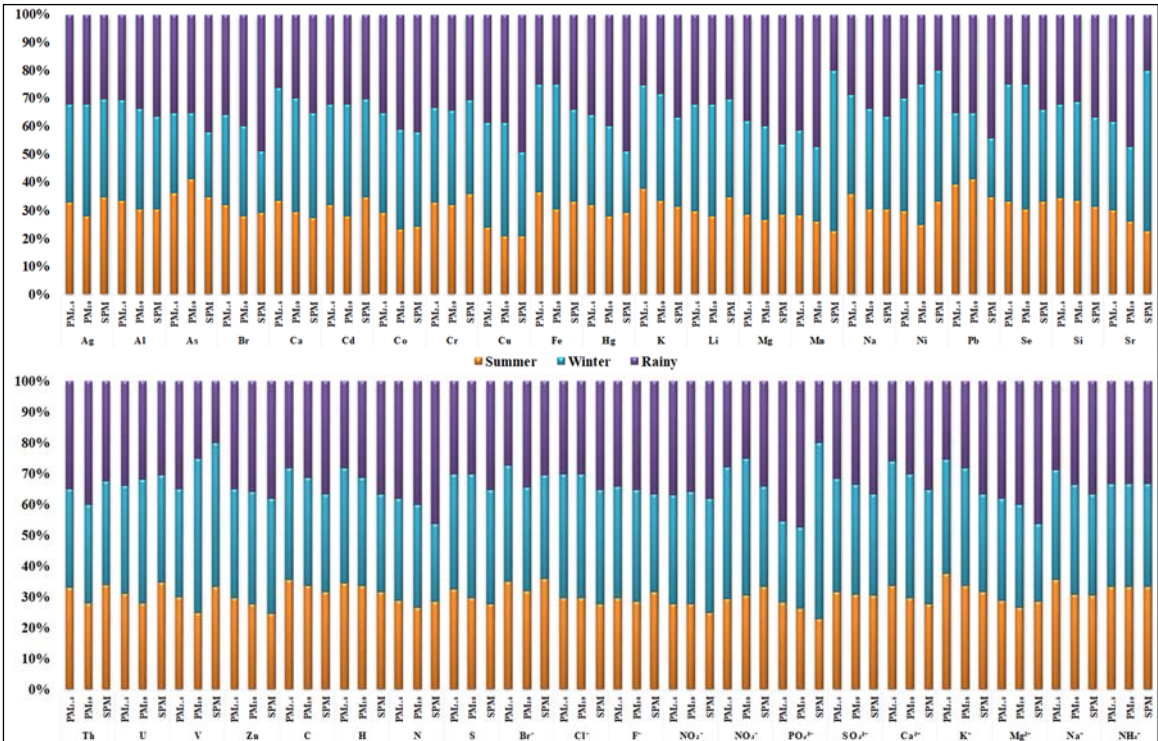


Fig. 5.10: Average seasonal variation of particulate matter associated species at AQMS-04

The observation of other monitoring stations is also shown in the **Figs. 5.7, 5.8, and 5.10**. The S, Cl, As, Se and Pb are in higher proportions in PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM in winter than those in other seasons, indicating other sources, e.g., coal combustion for heating the season, had a significant contribution. The ratio of S/Se in different particulate matter sizes was varying from 75 to 105 during the winter seasons in the area. Seasonal variations do not appear to have any effect on some heavy metals, i.e., As, Cd, Cr, and Ni, which are well-known carcinogenic heavy metals registered in the United States Agency for Toxic Substances and Disease Registry and other researcher have been reported similar trends [15,177].

### **5.3 Concentration of water-soluble ions in particulate matter**

The composition of water-soluble ions in particulate matter decides the virulence. Hence, the composition of airborne dust has been discussed under the following headings in details:

- 1) Annual variation of water-soluble ions in particulate matter
- 2) Percentage distribution and seasonal variation of water-soluble ions in particulate matter

A brief of each is discussed below in subsequent paragraphs.

#### **5.3.1 Annual variation of water-soluble ions in particulate matter**

Particulate matters are of great importance in influencing atmospheric radiation, cloud formation, atmospheric photochemical reactions and light extinction affecting global weather changes. Important features of particulate matter particles are their water-soluble components, i.e., magnesium, sodium, potassium, calcium, ammonium, nitrate, sulphate, and chloride [121,183]. The average and standard deviation of water-soluble ions in PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM are summarized in **Tables 5.1–5.18**.

The  $\text{NH}_4^+$ ,  $\text{SO}_4^{2-}$ ,  $\text{PO}_4^{3-}$ ,  $\text{NO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{F}^-$  were the most abundant ion among all samples in  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM, particularly, followed by  $\text{NO}_2^-$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ , and  $\text{Br}^-$  accounted for 36.42 %, 22.00 %, and 18.40 % in the  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM mass, respectively in AQMS–01 and given in **Table 5.1**. The observations of other monitoring results are summarized, and the detailed analysis of water–soluble ions has been given in **Tables 5.2, 5.4, and 5.5**.

The  $\text{K}^+/\text{K}$  and  $\text{Ca}^{2+}/\text{Ca}$  ratios were calculated to detect K and Ca's phase states. In general,  $\text{K}^+/\text{K}$  and  $\text{Ca}^{2+}/\text{Ca}$  ratios were slightly varying between  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM samples. However, the  $\text{K}^+/\text{K}$  and  $\text{Ca}^{2+}/\text{Ca}$  ratios have low values in  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM samples. It's revealed that the potential contribution of  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM to water–soluble K is insignificant and further demonstrates that  $\text{K}^+$  can be considered a marker for biomass burning emission [184].

The annual average concentration of the total water–soluble ions in  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM in Dudhichua industrial cum–residential area (AQMS–03) were  $28.8 \pm 9.6$ ,  $43.6 \pm 12.8$ , and  $70.5 \pm 14.6 \mu\text{g m}^{-3}$  and constitutes almost 35.8 %, 22.5 %, and 18.0 % of the  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM mass, respectively (**Tables 5.13, 5.14, and 5.15**). The major water–soluble ions of  $\text{Cl}^-$ ,  $\text{F}^-$ ,  $\text{NO}_3^-$ ,  $\text{PO}_4^{3-}$ ,  $\text{SO}_4^{2-}$ , and  $\text{NH}_4^+$  in  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM samples concentration were varied from  $0.47$ – $11.74 \mu\text{g m}^{-3}$ ,  $0.55$ – $16.86 \mu\text{g m}^{-3}$ , and  $1.06$ – $19.44 \mu\text{g m}^{-3}$  with annual average concentrations of  $4.11 \pm 1.38 \mu\text{g m}^{-3}$ ,  $6.21 \pm 1.83 \mu\text{g m}^{-3}$ , and  $10.05 \pm 2.08 \mu\text{g m}^{-3}$ , respectively. The trend for the average concentration of water–soluble ions were as ( $\text{NH}_4^+ > \text{SO}_4^{2-} > \text{PO}_4^{3-} > \text{NO}_3^- > \text{Cl}^- > \text{F}^- > \text{NO}_2^-$ ), ( $\text{NH}_4^+ > \text{SO}_4^{2-} > \text{NO}_3^- > \text{PO}_4^{3-} > \text{Cl}^- > \text{F}^- > \text{NO}_2^-$ ), and ( $\text{NH}_4^+ > \text{SO}_4^{2-} > \text{NO}_3^- > \text{PO}_4^{3-} > \text{Cl}^- > \text{F}^- > \text{NO}_2^-$ ) in  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM samples, respectively. The other observed water–soluble ions in  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM samples of  $\text{Na}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{K}^+$ , and  $\text{Br}^-$  concentration were varied from  $0.10$ – $8.39 \text{ ng m}^{-3}$ ,  $0.12$ – $28.91 \text{ ng m}^{-3}$ , and  $0.15$ – $52.64 \text{ ng m}^{-3}$  with annual average concentrations of

6.34±2.02 ng m<sup>-3</sup>, 18.29±4.05 ng m<sup>-3</sup>, and 34.22±4.66 ng m<sup>-3</sup>, respectively. The trend for the average concentration of water-soluble ions were as (Na<sup>+</sup> > Mg<sup>2+</sup> > Ca<sup>2+</sup> > K<sup>+</sup> > Br<sup>-</sup>), (Ca<sup>2+</sup> > Na<sup>+</sup> > K<sup>+</sup> > Mg<sup>2+</sup> > Br<sup>-</sup>), and (Ca<sup>2+</sup> > Na<sup>+</sup> > K<sup>+</sup> > Mg<sup>2+</sup> > Br<sup>-</sup>) in PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM samples, respectively (Tables 5.13, 5.14, & 5.15). The observations of other sampling station results of water-soluble ions have summarized and given in Tables 5.7–5.12, & 5.16–5.18.

### 5.3.2 Percentage distribution and seasonal variation of water-soluble ions in particulate matter

Out of the twelve ions, the ion NH<sub>4</sub><sup>+</sup> contributes more than 39 %, 37 %, and 27 % of the total weight of the measured ions in PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM, respectively, in Dudhichua industrial cum-residential area (AQMS-03) in the study area.

In the Industrial cum-residential area of Dudhichua (AQMS-03), the weight percentage of the based on analyzed twelve water soluble ions in PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM samples revealed that NH<sub>4</sub><sup>+</sup> (39.87 %, 37.12 %, and 27.21 %), SO<sub>4</sub><sup>2-</sup> (21.22 %, 22.90 %, and 26.51 %), PO<sub>4</sub><sup>3-</sup> (12.28 %, 11.30 %, and 13.08 %), NO<sub>3</sub><sup>-</sup> (11.18 %, 14.65 %, and 16.96 %), Cl<sup>-</sup> (7.15 %, 7.80 %, and 9.02 %), F<sup>-</sup> (6.54 %, 4.72 %, and 5.46 %), NO<sub>2</sub><sup>-</sup> (1.65 %, 1.31 %, and 1.52 %) constituted the dominant fraction followed by Na<sup>+</sup> (0.028 %, 0.058 %, and 0.067 %), Mg<sup>2+</sup> (0.028 %, 0.034 %, and 0.039 %), Ca<sup>2+</sup> (0.026 %, 0.064 %, and 0.074 %), K<sup>+</sup> (0.026 %, 0.053 %, and 0.062 %), and Br<sup>-</sup> (0.0004 %, 0.0003 %, and 0.0002 %), respectively.

The annual average of water-soluble ion concentrations of Cl<sup>-</sup> was 2.06±0.7 µg m<sup>-3</sup>, 3.40±1.3 µg m<sup>-3</sup>, and 6.37±1.5 µg m<sup>-3</sup>, occupying 7.15%, 7.80%, and 9.02 % of PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM samples mass, respectively.

Compared with other seasons,  $\text{Cl}^-$  has more concentration in the winter seasons. Thus, it was possibly related to coal combustion, considering additional coal consumption for burning in the winter in the area [185].

The  $\text{K}^+$  was an important component in water-soluble ions with the highest concentration in winter than summer followed by the rainy season in  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM, respectively, in Dudhichua industrial cum-residential area (AQMS-03) (Fig. 5.9). The  $\text{K}^+$  is an indicator of biomass burning and according to the relationships between  $\text{K}^+$ ,  $\text{Ca}^{2+}$ , and  $\text{Na}^+$  in soil and biomass burning emission in the area [185].

The annual average concentration of  $\text{K}^+$  from biomass burning was estimated to be  $7.56 \pm 2.24 \text{ ng m}^{-3}$ ,  $22.93 \pm 5.49 \text{ ng m}^{-3}$ , and  $43.62 \pm 6.17 \text{ ng m}^{-3}$  in  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and SPM samples, respectively, at AQMS-03, accounting for 0.03 %, 0.05 %, and 0.06 % in total measured ions in particulate matter mass. The fraction was higher in winter, indicating that the relatively high  $\text{K}^+$  concentration in winter was probably related to more coal and biomass burning in the area [120]. In the observation of other locations, the results of water-soluble ions were analyzed and shown in Figs. 5.7, 5.8, and 5.10.

In this study, the average ratio of  $\text{NO}_3^-/\text{SO}_4^{2-}$  varying from 0.53 to 0.64 in different particulate matter sizes. The annual average ratio of  $\text{NO}_3^-/\text{SO}_4^{2-}$  was  $0.6 \pm 0.1$  in  $\text{PM}_{2.5}$  samples, which is lower than that in cities with heavy traffic density, such as Guangzhou (0.79) [186], but higher than that in coal-dominated cities, such as Guiyang (0.14) and Qingdao (0.35) [187].

However, it may reveal that strong effects come from stationary pollution emission sources, such as coal combustion, but could not ignore the traffic-related-emission.

## 5.4 Enrichment factor of elements in particulate matter

The enrichment factor is an impact parameter to see the variation in the composition of particulate matter. The enrichment factors were calculated in the particulate matter sample to investigate whether the elemental origin was a natural source or an anthropogenic emission. One way to estimate the possible sources of the particulate matter elements can be carried out by calculating the enrichment factor established by Taylor [188]. The calculation considers each element's average abundances in geologic material and adopted from Lide [117].

In this analysis, the enrichment factors were calculated using Fe as the reference element because there are no known anthropogenic sources in the study area. The way to estimate the enrichment factor is:

$$\text{Enrichment factor}_{\text{Crust},X} = \frac{(X/Y)_{\text{air}}}{(X/Y)_{\text{Crust}}} \quad \text{--- 5.1}$$

where,

X is the element of interest, while  $(X/Y)_{\text{air}}$  and  $(X/Y)_{\text{Crust}}$  refer to the ratio between the concentrations of the element of interest (X) concerning enrichment factor (Y) in the air and geological material, respectively. If the estimated value for enrichment factor is approximate to the unit, soil and geological materials are the dominant fine particles' sources. On the other hand, if the enrichment factor is greater than 5, the element of interest is originated from anthropogenic emission sources [61,92].

The details of the calculated enrichment factor in particulate matters are tabulated in **Tables 5.7–5.18**. An attempt has been made to separate anthropogenic processes from natural processes. It is also approximated by the above **equation number 5.1**.

The enrichment factor of the various concentration of element (Ag, Al, As, Br, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Na, Ni, Pb, Se, Si, Sr, Th, U, V, Zn, C, H, N, and S) of PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM samples collected at the study area have been estimated and summarized in **Tables 5.7–5.18**. At site AQMS–03, the Ca, Mn, Ni, Na, Mg, K, and Cr of PM<sub>2.5</sub> have a low enrichment factor value ranging from <1 to 5 in the average enrichment factor indicates that elements mostly derived from the soil. The average enrichment factor values of Co, Cu, Br, As, Zn, and H have ranged from 5 to 150, indicating that they are likely to be affected by originated from anthropogenic emission sources. The higher enrichment factor of N and Se of PM<sub>2.5</sub> mass were also attributed to industrial sources as the coal industry, and coal storage is located near the sampling location (**Table 5.13**).

In the PM<sub>10</sub>, **Table 5.14** shows the enrichment factor values; elements such as U, Th, Si, V, Sr, Li, Al, Mn, Ni, Ca, Mg, Cr, Co, Na, K, Cu, and Br were lower than 10, which indicated that these elements originated mostly from natural origin. In contrast, the enrichment factor values for As, Zn, H, S, Ag, Pb, Hg, C, Cd, N, and Se were more than ten, which suggested that they were mostly from anthropogenic sources [61]. For instance, high enrichment factor values of Se, Pb, As, Hg and Cd were associated with coal combustion, high levels of Pb and Zn have been demonstrated a link to traffic-related emission and abundant Na, Fe, and V originated from earth crust [61,177].

In SPM samples, trace elements, including Cd, Hg, C, N, and Se, have the highest enrichment factor values (241, 234, 373, 2167, and 4325). This is probably due to coal combustion and mining activities (**Table 5.15**). Thus, it might have originated from mixing the local anthropogenic particulate matter with the transported soil dust. Hence, these elements in PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM samples in AQMS–03 were related to anthropogenic activities (coal combustion, vehicle emission, biomass burning) and were also impacted by dust particles transported from the surrounding opencast mining. Generally, Cd, As, Pb,

Cu, Zn, S, Fe, Al, Ca, Mg, Mn, Fe, K, Na, and Se are used as a tracer for India's industrial area [177,189,190].

## 5.5 Correlation studies among analyzed elements in particulate matter

The correlation analysis was performed to explore the correlation between all the measured species and to get a general profile of the sources adding to PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM.

A correlation study was carried out with the forty-one analyzed elements in PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM samples of Singrauli Coalfield. A high correlation coefficient reveals a possibility of common sources in the area [115]. The analyzed elements strongly correlated at a receptor point indicate a likelihood of similar originating source or transporting agencies from source to receptor location. The correlation coefficient  $r \geq \pm 0.60$  is a strong identity of the species' common sources [191]. The correlation among the elements in PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM of the Singrauli Coalfield area is given in **Tables 5.19–5.21**.

The correlation analysis results revealed a high and significant correlation between the elements concentrations in particulate matter and their exposure concentration. The level of elements in PM<sub>2.5</sub>, PM<sub>10</sub>, and SPM directly affects the exposure concentration of the same elements in the air [192].

**Table 5.19** outlines the Pearson correlation matrix for various elements, where R values  $> \pm 0.60$  are significant at  $p=0.0001$ . From the **Table 5.19**, it may be clear that Al is significantly correlated with Arsenic (0.68), Ca (0.62), Fe (0.74), Hg (0.68), K (0.67), Li (0.64), Mg (0.63), Se (0.65), Si (0.67), Cl<sup>-</sup> (0.64), and SO<sub>4</sub><sup>2-</sup> (0.61) which may be from the same origin and Ca is significantly correlated with Fe (0.75), Li (0.63), Na (0.83), Si (0.66), and SO<sub>4</sub><sup>2-</sup> (0.67), thus indicating a common source i.e. crustal origin, coal combustion residue, coal mining activities & transportation. Pb has positive correlation with Cd (0.67), Co (0.69), Cr (0.60), Cu (0.64), Mn (0.68), Ni (0.61) and PM<sub>2.5</sub> (0.68), thus indicating road

traffic as a common source of these elements [193]. Cu is positively correlated with Cr (0.66) and Cd (0.65), which may be due to industries, and it is positively correlated with As (0.63), Mn (0.61), Sr (0.69) and C (0.62) also, indicating a common source, i.e., of crustal origin. Cr is positively correlated with Mn (0.63), Ni (0.62), and PM<sub>2.5</sub> (0.67), maybe come from the traffic-related emission or metals industry. The interspecies correlations between the particulate matter constituents are given in **Table 5.20**.

The mass concentrations of PM<sub>10</sub> showed significant correlations among major water-soluble ions (Cl<sup>-</sup>, F<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, Ca<sup>2+</sup>, K<sup>+</sup>, Na<sup>+</sup>, and NH<sub>4</sub><sup>+</sup>), trace elements (Cr, Pb, As, Mn). Significant correlations of these species with PM<sub>10</sub> are indicative of the fact that these variables contributed to a major fraction of PM<sub>10</sub> loading. Major water-soluble ions showed a significant correlation among each other, and some other analyzed elements in PM<sub>10</sub>, suggesting their similar sources and processes have undergone in the atmosphere. K<sup>+</sup>, a tracer for biomass burning and coal combustion, showed significant correlations with PM<sub>10</sub> and the carbon fractions. It could explain biomass burning's contribution to the PM<sub>10</sub> load and abundance of carbon in the PM<sub>10</sub>. Also, Al showed significant positive correlations with other crustal metals Ca, Fe, Hg, K, Li, Na, Pb, Se, Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, Ca<sup>2+</sup>, K<sup>+</sup>, Mg<sup>2+</sup>, NH<sub>4</sub><sup>+</sup>, and arsenic.

All samples of analyzed elements in the suspended particulate matter have listed in the matrix in **Table 5.21**. A strong correlation ( $r = 0.81-0.94$ ,  $p < 0.0001$ ) was observed in Singrauli coalfield between Al, Si, K, Na, and SO<sub>4</sub><sup>2-</sup>, meaning that they have the same sources can be considered as specifically particulate matter trace elements. The correlation coefficients between Ca and Al, Na, and SPM were from 0.71 to 0.87 ( $p < 0.0001$ ). Such strong positive correlations illustrate that the emission sources of Ca and typical particulate matter trace elements should be the abundance crust of Ca be linked with a crustal origin. From **Table 5.21**, it is clear that Ca is significantly correlated with K (0.63,  $p < 0.0001$ ) and

Na (0.82,  $p < 0.0001$ ), thus indicating a common source of these elements as also manifested by positive correlations of K and Na (0.95,  $p < 0.0001$ ), while significant negative correlations are observed with Pb–SPM ( $-0.73$ ,  $p < 0.0001$ ). Also, there was a high correlation between  $\text{Ca}^{2+}$  and  $\text{K}^+$  that may come from soil or road dust, especially in the area (**Tables 5.19, 5.20, and 5.21**).

In  $\text{PM}_{2.5}$  samples, the  $\text{K}^+$  was positively correlated with particulate matter of  $2.5\mu\text{m}$  size, and it comes from biomass burning in the study area (**Table 5.21**). But  $\text{K}^+$  was in the  $\text{PM}_{10}$  and SPM in this case; therefore, the soil may be a source of  $\text{K}^+$ . Road dust contributes to  $\text{PM}_{10}$  and SPM; the chemical constituents of road dust include  $\text{Ca}^{2+}$  and  $\text{K}^+$ , includes  $\text{K}^+$ . However,  $\text{K}^+$  is the main element in soil and crustal, and it is also found in biomass burning and coal combustion [**183**].

There is a high correlation between  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  in the study area (**Table 5.21**). The high correlation of  $\text{NO}_3^-$  with the  $\text{Cl}^-$ ,  $\text{F}^-$ ,  $\text{NO}_2^-$ ,  $\text{SO}_4^{2-}$ , and  $\text{Mg}^{2+}$  indicates that they may be emitted from the same source, and crust origin contains and biomass burning of these ionic species [**183**].

Hence, it may be concluded that the trace elements have been highly correlated to  $\text{PM}_{2.5}$  samples in comparison to the  $\text{PM}_{10}$  and followed by SPM.

**Table 5.19:** Correlation coefficient among the concentration value of analyze species in the PM<sub>2.5</sub> at the study area

	Ag	Al	As	Br	Ca	Cl	Co	Cr	Cu	Fe	Hg	K	Li	Mg	Mn	Na	Ni	Pb	Se	Si	Sr	
Ag	1.00																					
Al	0.34	1.00																				
As	0.15	0.68	1.00																			
Br	-0.01	0.40	0.58	1.00																		
Ca	0.13	0.62	0.49	0.56	1.00																	
Cd	-0.02	0.33	0.64	0.71	0.54	1.00																
Co	0.43	0.37	0.37	0.22	0.25	0.37	1.00															
Cr	0.08	0.33	0.54	0.63	0.43	0.63	0.48	1.00														
Cu	0.11	0.26	0.63	0.58	0.57	0.65	0.49	0.66	1.00													
Fe	0.18	0.74	0.70	-0.38	0.75	0.53	0.26	0.51	0.53	1.00												
Hg	0.43	0.68	0.64	0.37	0.38	0.61	0.38	0.37	0.38	-0.31	1.00											
K	0.14	0.67	0.54	-0.49	0.50	0.53	0.39	0.51	-0.46	0.86	0.61	1.00										
Li	0.30	0.64	0.47	0.41	0.63	0.46	0.30	-0.43	0.53	0.68	0.65	0.62	1.00									
Mg	0.35	0.63	-0.35	0.23	0.26	0.22	0.33	-0.26	0.29	0.62	0.64	0.77	0.58	1.00								
Mn	0.21	0.52	0.47	0.53	0.52	0.66	0.61	0.63	0.61	0.52	0.36	0.50	0.48	0.30	1.00							
Na	0.29	0.71	0.48	0.47	0.83	0.46	0.34	0.53	0.54	0.84	0.44	0.84	0.61	0.56	0.51	1.00						
Ni	0.49	0.60	0.47	0.12	0.49	0.53	0.58	0.62	0.19	0.19	0.48	0.28	0.50	0.44	0.62	0.30	1.00					
Pb	0.20	0.41	0.58	0.48	0.53	0.67	0.69	0.60	0.64	0.61	-0.46	0.56	0.64	0.60	0.68	0.49	0.61	1.00				
Se	0.55	0.65	0.63	0.08	0.23	0.33	0.42	-0.23	0.27	0.36	0.47	-0.22	-0.37	0.46	-0.19	0.27	0.51	0.53	1.00			
Si	0.42	0.67	-0.21	0.21	0.66	0.36	0.39	0.20	0.25	-0.33	0.34	0.64	0.68	-0.42	-0.32	0.66	0.48	0.65	0.46	1.00		
Sr	-0.05	0.31	0.42	0.71	0.54	0.63	-0.15	0.68	0.69	0.56	-0.32	0.54	-0.38	0.19	0.21	0.47	-0.03	0.63	0.03	0.46	1.00	
Th	0.36	0.22	0.24	0.23	0.26	0.23	0.21	0.25	-0.24	0.25	0.28	0.33	0.34	0.16	0.24	0.25	0.15	0.25	0.28	0.15	0.18	1.00
U	0.32	0.38	0.25	0.21	0.37	0.38	0.23	0.28	0.32	0.34	0.37	0.29	0.35	0.31	0.35	0.27	0.13	0.21	0.36	0.16	0.26	0.26
V	0.03	0.36	-0.41	0.57	-0.56	0.40	-0.18	0.63	0.62	0.49	0.37	0.56	0.46	0.26	0.57	0.54	0.53	-0.23	-0.08	0.12	0.68	0.68
Zn	0.21	0.40	0.49	0.54	0.49	0.59	0.52	0.60	0.55	0.45	0.67	0.63	0.43	0.40	0.64	0.45	0.32	0.69	0.69	0.29	0.64	0.64
C	0.15	0.43	0.55	0.50	0.55	0.60	0.27	0.15	0.62	0.55	0.42	0.52	0.44	0.31	0.51	0.50	0.31	0.56	0.26	0.33	0.60	0.60
H	0.20	0.38	0.49	0.58	0.51	0.63	0.33	0.54	0.52	0.51	-0.37	0.59	0.43	0.30	0.53	0.54	-0.29	0.48	0.27	0.31	0.58	0.58
N	0.33	0.34	0.48	0.50	0.40	0.51	0.45	0.45	0.44	0.39	0.48	0.48	0.46	0.36	0.41	0.43	0.45	0.52	0.35	0.38	0.41	0.41
S	0.27	0.33	0.45	0.49	0.53	0.59	0.35	0.49	0.51	0.44	0.54	0.53	0.51	0.37	0.48	0.47	0.28	0.48	0.34	0.34	0.50	0.50
Br <sup>-</sup>	0.26	0.25	-0.43	0.74	-0.13	0.42	0.43	0.42	0.41	0.37	0.46	0.43	0.44	-0.37	-0.36	0.41	0.46	-0.43	0.44	0.39	0.36	0.36
Cl <sup>-</sup>	0.26	0.64	0.71	0.48	0.45	-0.50	0.30	0.44	0.53	0.44	0.48	0.44	0.43	0.34	0.49	0.45	0.34	0.50	0.28	0.37	0.42	0.42
F <sup>-</sup>	0.29	-0.33	-0.48	-0.46	0.49	0.54	-0.38	0.61	0.57	0.47	-0.42	0.38	0.55	-0.32	0.49	-0.49	0.32	0.45	0.33	0.32	0.47	0.47
NO <sub>2</sub> <sup>-</sup>	0.33	0.31	0.34	0.26	0.40	0.37	-0.43	0.37	-0.37	0.39	0.40	0.64	0.35	0.31	0.37	0.34	0.30	0.40	0.37	0.29	0.36	0.36
NO <sub>3</sub> <sup>-</sup>	0.07	0.21	0.77	0.70	0.58	0.66	-0.19	0.68	-0.60	0.53	0.36	0.61	0.42	0.27	0.52	0.56	0.11	0.59	0.32	0.15	0.66	0.66
PO <sub>4</sub> <sup>3-</sup>	0.49	0.39	0.15	0.06	-0.16	0.00	0.64	-0.09	0.11	-0.15	0.37	0.18	0.29	0.34	0.15	0.24	0.51	0.10	0.43	0.38	-0.23	-0.23
SO <sub>4</sub> <sup>2-</sup>	0.16	0.75	0.55	0.51	0.67	0.48	0.68	0.60	0.54	0.50	0.37	0.67	0.41	0.28	-0.52	0.44	0.21	0.54	0.25	0.31	0.57	0.57
Ca <sup>2+</sup>	0.30	0.46	0.46	0.41	0.96	0.45	0.32	0.52	0.52	0.43	0.34	0.43	0.33	0.68	0.43	0.47	0.26	0.48	0.34	0.61	0.43	0.43
K <sup>+</sup>	0.17	0.38	0.50	0.45	0.50	0.46	0.32	0.48	0.54	0.49	0.42	0.98	0.32	0.50	0.53	0.46	0.19	0.47	0.25	0.67	0.59	0.59
Mg <sup>2+</sup>	0.44	0.35	0.26	0.35	0.28	0.38	0.40	0.26	0.27	0.28	0.40	0.31	-0.35	0.94	0.30	0.27	0.40	0.29	0.40	0.79	0.39	0.39
Na <sup>+</sup>	0.28	0.21	0.44	0.47	0.42	0.43	0.43	0.35	-0.44	0.49	0.39	0.56	0.50	0.67	0.48	0.96	0.38	0.52	0.38	0.59	0.43	0.43
NH <sub>4</sub> <sup>+</sup>	0.30	0.42	0.45	0.36	0.39	0.42	0.38	0.39	0.45	0.35	0.43	0.47	-0.44	0.38	-0.48	0.67	0.39	0.40	0.34	0.61	0.35	0.35
PM <sub>2.5</sub>	0.45	0.58	0.88	-0.13	0.63	0.53	0.41	0.67	0.42	0.56	0.63	0.61	0.64	0.70	0.64	0.62	0.68	0.61	0.64	0.57	0.39	0.39

Continued.....

	Th	U	V	Zn	C	H	N	S	Br <sup>-</sup>	Cl <sup>-</sup>	F <sup>-</sup>	NO <sub>2</sub> <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	PO <sub>4</sub> <sup>3-</sup>	SO <sub>4</sub> <sup>2-</sup>	Ca <sup>2+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	NH <sub>4</sub> <sup>+</sup>	PM <sub>2.5</sub>		
Ag																							
Al																							
As																							
Br																							
Ca																							
Cd																							
Co																							
Cr																							
Cu																							
Fe																							
Hg																							
K																							
Li																							
Mg																							
Mn																							
Na																							
Ni																							
Pb																							
Se																							
Si																							
Sr																							
Th	1.00																						
U	0.51	1.00																					
V	0.26	0.31	1.00																				
Zn	0.30	0.33	0.64	1.00																			
C	0.20	0.48	0.57	0.51	1.00																		
H	0.11	0.34	0.56	0.48	0.62	1.00																	
N	0.25	0.38	0.46	0.56	0.69	0.66	1.00																
S	0.20	0.24	0.48	0.51	0.66	0.62	0.63	1.00															
Br <sup>-</sup>	0.14	0.24	0.33	0.45	0.44	0.51	-0.45	0.43	1.00														
Cl <sup>-</sup>	-0.29	0.11	0.43	0.56	0.48	0.51	-0.48	0.53	0.54	1.00													
F <sup>-</sup>	0.26	0.26	0.43	0.44	0.54	0.47	-0.46	0.58	0.44	0.61	1.00												
NO <sub>2</sub> <sup>-</sup>	-0.28	0.34	0.39	0.36	-0.42	0.43	0.35	0.37	0.42	0.29	0.49	1.00											
NO <sub>3</sub> <sup>-</sup>	-0.25	0.27	0.51	0.61	-0.52	0.55	0.45	0.46	0.48	0.60	0.42	0.65	1.00										
PO <sub>4</sub> <sup>3-</sup>	0.18	0.44	0.24	0.24	-0																		

**Table 5.20:** Correlation coefficient among the concentration value of analyze species in the PM<sub>10</sub> at the study area

	Ag	Al	As	Br	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Li	Mg	Mn	Na	Ni	Pb	Se	Si	Sr	
Ag	1.00																					
Al	0.25	1.00																				
As	0.34	0.62	1.00																			
Br	-0.28	-0.07	0.24	1.00																		
Ca	0.07	0.84	0.49	-0.13	1.00																	
Cd	0.45	0.17	0.25	0.37	-0.28	1.00																
Co	0.18	0.07	0.66	0.26	0.04	0.33	1.00															
Cr	0.23	-0.04	0.12	0.17	0.15	0.27	0.32	1.00														
Cu	0.29	0.43	0.61	0.25	0.48	0.48	0.29	0.29	1.00													
Fe	-0.21	0.79	0.62	-0.01	0.81	0.45	0.34	0.31	0.19	1.00												
Hg	0.56	0.65	0.43	0.04	0.62	0.20	0.35	0.27	0.36	0.64	1.00											
K	0.10	0.63	0.52	0.04	0.73	0.46	0.46	0.52	0.40	0.82	0.64	1.00										
Li	-0.28	0.68	0.51	0.19	0.67	0.33	0.45	0.32	0.33	0.69	0.62	0.68	1.00									
Mg	0.14	0.71	0.62	0.18	0.62	0.46	0.38	-0.16	0.23	0.66	0.63	0.62	0.66	1.00								
Mn	0.32	0.52	0.42	0.22	0.23	0.24	0.14	0.33	0.27	0.68	0.13	0.46	0.64	0.26	1.00							
Na	0.24	0.75	0.53	0.21	0.67	0.41	0.41	0.47	0.57	0.72	0.76	0.77	0.52	0.62	0.49	1.00						
Ni	0.26	0.49	0.63	0.14	0.42	-0.20	0.67	0.67	0.63	0.19	-0.14	0.15	0.62	0.16	0.35	0.13	1.00					
Pb	-0.38	0.68	0.66	0.19	0.54	0.35	0.46	0.43	0.62	0.47	0.37	0.52	0.15	-0.46	0.53	0.25	0.68	1.00				
Se	0.41	0.62	0.69	0.21	0.64	0.44	0.18	-0.12	-0.31	0.62	0.53	0.64	0.56	0.54	0.38	0.42	0.11	0.30	1.00			
Si	0.37	0.71	0.25	-0.16	0.56	-0.28	0.16	0.13	0.20	0.58	0.47	0.62	0.60	0.23	0.46	0.55	0.19	0.31	0.34	1.00		
Sr	-0.48	-0.11	0.30	0.27	-0.18	0.51	-0.16	0.38	0.43	0.25	0.03	-0.19	0.38	-0.23	0.25	-0.32	0.32	0.37	0.38	-0.38	1.00	
Th	0.15	0.18	0.07	0.13	0.02	0.31	0.01	0.29	-0.08	0.23	0.07	0.29	0.07	0.34	0.18	0.16	0.25	0.06	0.08	0.26	0.19	
U	0.09	0.08	0.09	0.14	0.01	0.19	0.04	0.13	0.07	0.18	0.12	0.13	0.13	0.30	0.14	0.17	0.10	0.03	-0.14	0.15	0.10	
V	0.55	-0.18	0.37	0.38	-0.13	0.43	-0.20	0.34	0.37	0.26	0.47	0.28	0.24	-0.25	0.25	0.18	0.37	0.34	0.42	0.23	0.51	
Zn	0.21	0.63	0.18	0.07	0.57	0.44	0.40	0.29	0.43	0.53	0.27	0.57	0.46	0.49	0.43	0.67	0.49	0.45	0.68	0.45	0.33	
C	0.06	0.59	0.61	0.22	0.56	0.24	0.14	0.01	0.18	0.63	0.11	0.58	0.45	0.29	0.35	0.22	0.21	0.21	0.21	0.39	0.27	
H	0.18	0.58	0.15	0.20	0.41	0.25	0.19	0.12	0.13	0.52	0.17	0.36	0.41	0.33	0.22	0.34	0.23	0.23	0.30	0.46	-0.22	
N	0.34	0.54	0.63	0.51	0.62	0.20	0.13	0.17	0.28	0.54	0.26	0.44	0.35	0.30	0.49	0.26	0.18	0.28	0.33	0.38	0.25	
S	0.16	0.52	0.57	0.30	0.57	0.22	0.13	0.04	0.14	0.64	0.39	0.52	0.46	0.25	0.37	0.43	0.32	0.24	0.27	0.35	0.56	
Br <sup>-</sup>	0.14	0.49	0.33	0.62	0.22	-0.20	0.07	-0.18	-0.25	0.10	-0.23	0.25	-0.37	0.13	0.21	0.14	0.13	0.21	0.17	0.14	-0.32	
Cl <sup>-</sup>	0.03	0.62	0.37	0.35	-0.11	0.18	0.19	0.15	0.14	0.36	0.10	0.01	0.18	0.25	0.10	0.12	0.09	0.13	0.23	0.15	0.27	
F <sup>-</sup>	0.20	0.15	0.21	0.16	-0.06	0.27	0.11	0.17	0.21	0.12	0.17	-0.10	0.20	-0.11	0.14	0.22	0.17	0.16	0.11	0.31	0.13	
NO <sub>2</sub> <sup>-</sup>	0.28	0.09	0.56	0.19	0.27	0.13	-0.08	0.25	0.08	0.47	-0.08	0.46	0.43	0.35	0.28	0.12	0.47	0.18	0.19	0.37	0.16	
NO <sub>3</sub> <sup>-</sup>	0.36	0.18	0.87	0.12	0.32	0.24	-0.13	0.27	0.32	0.35	-0.16	0.36	0.26	0.30	0.12	0.23	0.41	0.25	0.35	0.20	0.27	
PO <sub>4</sub> <sup>3-</sup>	0.31	0.15	-0.24	-0.21	0.18	-0.35	0.19	0.13	-0.24	-0.11	0.10	0.37	-0.21	0.14	-0.19	0.11	0.20	0.16	0.30	0.21	0.29	
SO <sub>4</sub> <sup>2-</sup>	-0.23	0.72	0.48	0.08	0.54	0.29	0.21	0.14	0.31	0.37	0.57	0.79	0.48	0.44	0.39	0.59	-0.27	0.33	0.59	0.34	0.24	
Ca <sup>2+</sup>	0.12	0.64	0.48	0.22	0.91	0.14	0.14	0.14	0.16	0.64	0.35	0.44	0.34	0.61	0.16	0.63	0.12	0.15	0.47	0.42	0.28	
K <sup>+</sup>	0.08	0.69	0.42	0.47	0.63	0.17	0.17	0.07	0.05	0.73	0.43	0.94	0.42	0.55	0.44	0.72	0.23	0.26	0.32	0.51	0.28	
Mg <sup>2+</sup>	0.29	0.72	0.43	0.45	0.54	0.23	0.11	0.20	0.22	0.58	0.29	0.51	0.40	0.93	-0.49	0.64	0.30	0.42	0.28	0.47	0.31	
Na <sup>+</sup>	0.27	0.59	0.46	0.33	0.68	0.24	0.16	0.10	0.32	0.67	0.45	0.42	0.53	0.67	0.32	0.87	0.17	0.44	0.53	0.53	0.22	
NH <sub>4</sub> <sup>+</sup>	0.25	0.62	0.57	0.32	0.45	0.27	0.19	0.14	0.34	0.49	0.42	0.54	0.47	0.52	0.33	0.59	0.24	0.46	0.46	0.48	0.44	
PM <sub>10</sub>	0.40	0.67	0.81	-0.09	0.65	0.49	0.38	0.60	0.40	0.58	0.57	0.64	0.67	0.68	0.63	0.65	0.46	0.62	0.57	0.51	0.35	

Continued.....

	Th	U	V	Zn	C	H	N	S	Br <sup>-</sup>	Cl <sup>-</sup>	F <sup>-</sup>	NO <sub>2</sub> <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	PO <sub>4</sub> <sup>3-</sup>	SO <sub>4</sub> <sup>2-</sup>	Ca <sup>2+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	NH <sub>4</sub> <sup>+</sup>	PM <sub>10</sub>		
Ag																							
Al																							
As																							
Br																							
Ca																							
Cd																							
Co																							
Cr																							
Cu																							
Fe																							
Hg																							
K																							
Li																							
Mg																							
Mn																							
Na																							
Ni																							
Pb																							
Se																							
Si																							
Sr																							
Th	1.00																						
U	0.47	1.00																					
V	0.18	0.14	1.00																				
Zn	0.13	0.19	0.33	1.00																			
C	0.13	0.29	0.23	0.23	1.00																		
H	0.15	0.28	0.21	0.21	0.63	1.00																	
N	0.09	0.14	0.25	-0.14	0.48	0.60	1.00																
S	0.19	0.15	0.14	0.28	0.62	0.67	0.68	1.00															
Br <sup>-</sup>	0.10	0.16	-0.14	-0.24	0.69	0.21	0.14	0.27	1.00														
Cl <sup>-</sup>	0.17	0.13	0.28	0.33	0.22	0.14	0.27	0.25	0.25	1.00													
F <sup>-</sup>	-0.16	0.15	0.25	0.15	0.25	0.16	-0.24	0.31	0.30	0.60	1.00												
NO <sub>2</sub> <sup>-</sup>	0.19	0.13	0.20	0.17	0.32	0.23	0.38	0.18	0.33	0.65	0.59	1.00											
NO <sub>3</sub> <sup>-</sup>	0.26	0.12	0.36	0.24	0.23	0.46	0.32	0.26	0.32	0.69	0.43	0.63	1.00										
PO <sub>4</sub> <sup>3-</sup>	-0.01	-0.13	-0.30	-0.19	0.52	0.20	0.27	0.38	0.29	0.51	-0.18	0.45	0.41	1.00									

**Table 5.21:** Correlation coefficient among the concentration value of analyze species in the SPM at the study area

	<i>Ag</i>	<i>Al</i>	<i>As</i>	<i>Br</i>	<i>Cu</i>	<i>Cd</i>	<i>Co</i>	<i>Cr</i>	<i>Cu</i>	<i>Fe</i>	<i>Hg</i>	<i>K</i>	<i>Li</i>	<i>Mg</i>	<i>Mn</i>	<i>Na</i>	<i>Ni</i>	<i>Pb</i>	<i>Se</i>	<i>Si</i>	<i>Sr</i>	
<i>Ag</i>	1.00																					
<i>Al</i>	0.19	1.00																				
<i>As</i>	0.23	0.60	1.00																			
<i>Br</i>	0.19	-0.18	0.31	1.00																		
<i>Ca</i>	0.26	0.71	0.56	-0.17	1.00																	
<i>Cd</i>	0.36	0.42	0.46	0.40	0.34	1.00																
<i>Co</i>	0.42	0.23	0.29	-0.15	0.28	0.45	1.00															
<i>Cr</i>	-0.19	0.32	0.49	0.29	0.36	0.38	-0.43	1.00														
<i>Cu</i>	0.66	-0.43	0.31	0.32	0.20	0.66	-0.30	0.28	1.00													
<i>Fe</i>	0.53	0.83	0.48	0.10	0.87	0.30	0.53	0.13	0.18	1.00												
<i>Hg</i>	0.48	0.63	0.53	-0.11	0.67	-0.37	0.47	-0.36	-0.45	0.53	1.00											
<i>K</i>	0.53	0.90	0.58	0.14	0.63	-0.26	0.40	-0.16	0.38	0.80	0.67	1.00										
<i>Li</i>	0.47	0.67	0.62	0.21	0.69	0.37	-0.47	0.43	0.47	0.61	0.54	0.68	1.00									
<i>Mg</i>	0.33	0.55	0.51	-0.21	0.60	0.36	0.32	0.22	0.29	0.85	0.68	0.76	0.60	1.00								
<i>Mn</i>	0.28	0.49	0.32	0.40	0.25	0.59	0.37	0.38	0.36	0.45	-0.46	0.38	0.46	0.27	1.00							
<i>Na</i>	0.41	0.86	0.63	0.31	0.82	0.37	0.41	0.26	-0.17	0.72	0.41	0.95	0.63	0.67	0.27	1.00						
<i>Ni</i>	0.35	0.43	0.45	-0.24	0.43	-0.27	0.32	-0.36	-0.24	0.46	0.41	0.54	0.56	0.49	0.38	0.63	1.00					
<i>Pb</i>	0.26	0.58	0.49	0.31	0.55	0.44	0.61	0.23	0.63	0.58	0.45	0.49	0.48	0.46	0.32	0.48	0.64	1.00				
<i>Se</i>	0.28	0.62	0.48	0.11	0.46	-0.35	0.43	-0.45	0.35	0.73	0.67	0.68	0.56	0.53	0.37	0.79	0.42	0.59	1.00			
<i>Si</i>	0.29	0.82	0.51	-0.20	0.62	0.28	0.17	0.21	0.36	-0.14	0.56	0.69	0.59	0.49	-0.27	0.61	0.44	0.32	0.69	1.00		
<i>Sr</i>	-0.41	-0.44	0.44	0.37	-0.26	0.44	-0.20	0.46	0.54	0.16	-0.14	-0.17	0.32	-0.23	0.40	-0.32	-0.39	0.26	0.32	0.34	1.00	
<i>Th</i>	0.15	0.15	0.14	0.13	0.12	0.12	0.10	0.19	0.08	0.14	-0.22	0.15	0.27	0.28	0.14	0.12	0.11	0.15	0.19	0.18	0.16	
<i>U</i>	0.16	0.21	0.12	0.07	0.10	0.17	-0.11	0.16	0.27	0.18	-0.24	0.14	0.21	0.28	0.15	0.13	0.14	0.29	0.21	0.13	0.20	
<i>V</i>	-0.43	-0.21	0.28	0.17	0.21	0.40	0.02	0.33	0.54	0.03	-0.19	-0.11	0.26	-0.27	0.33	0.42	-0.25	0.38	-0.34	-0.27	0.57	
<i>Zn</i>	0.21	0.41	0.67	0.42	0.12	0.17	0.48	0.43	0.55	0.52	-0.39	0.17	0.25	-0.22	0.14	0.48	-0.13	0.62	0.31	0.40	0.51	
<i>C</i>	0.18	0.50	0.48	-0.26	0.67	0.36	0.16	0.14	0.14	-0.55	0.42	0.39	0.42	0.57	0.40	0.23	0.41	0.37	0.31	0.36	0.46	
<i>H</i>	0.25	0.53	0.44	0.28	0.51	0.41	0.14	0.12	0.29	-0.44	0.43	0.49	0.45	0.31	0.37	0.28	0.33	0.38	0.33	0.40	0.42	
<i>N</i>	0.20	0.55	0.58	0.19	0.50	0.34	0.18	0.31	0.32	0.70	0.49	0.35	0.50	0.43	0.14	0.23	0.33	0.36	0.35	0.46	0.42	
<i>S</i>	0.13	0.57	0.43	0.23	0.62	0.38	0.10	0.16	0.49	0.72	0.40	0.38	0.52	0.56	0.25	0.20	0.28	0.33	0.37	0.39	0.44	
<i>Br<sup>-</sup></i>	0.26	0.31	-0.28	0.24	0.17	0.17	-0.26	-0.16	-0.15	0.12	0.11	-0.27	0.15	-0.31	0.38	0.13	0.14	-0.18	0.43	0.17	-0.23	
<i>Cl<sup>-</sup></i>	0.33	0.23	-0.31	-0.33	0.18	0.16	0.24	0.18	-0.16	0.16	-0.17	0.38	0.33	-0.21	0.43	0.19	0.14	0.16	0.44	0.15	-0.29	
<i>F<sup>-</sup></i>	0.38	0.35	0.30	0.12	-0.15	0.36	0.29	0.18	0.25	0.10	-0.14	0.26	0.29	0.43	0.22	0.19	0.17	0.28	-0.32	-0.19	0.08	
<i>NO<sub>2</sub><sup>-</sup></i>	0.32	0.49	0.41	0.15	-0.25	0.35	-0.23	0.26	0.26	0.19	0.19	0.32	0.37	0.45	0.29	0.13	-0.41	0.32	0.46	-0.17	0.07	
<i>NO<sub>3</sub><sup>-</sup></i>	-0.48	0.47	0.42	0.14	-0.23	0.33	-0.22	0.27	0.30	0.16	0.29	0.24	0.47	0.39	0.33	0.17	-0.44	0.37	0.48	0.34	0.30	
<i>PO<sub>4</sub><sup>3-</sup></i>	0.43	0.28	-0.39	-0.28	0.29	-0.52	0.13	-0.35	-0.50	0.32	0.24	0.14	-0.20	-0.43	0.36	0.23	0.31	0.26	0.50	0.35	0.53	
<i>SO<sub>4</sub><sup>2-</sup></i>	-0.34	0.81	0.68	0.23	0.51	0.43	0.40	0.47	0.33	-0.43	0.46	0.67	0.24	0.55	0.40	0.24	0.36	0.43	0.58	0.46	0.55	
<i>Ca<sup>2+</sup></i>	0.30	0.50	0.61	0.24	0.88	0.29	0.31	0.47	0.25	0.61	0.56	0.81	0.57	0.62	0.54	0.32	0.31	0.29	0.39	0.22	0.38	
<i>K<sup>+</sup></i>	0.35	0.62	0.58	0.23	0.67	0.19	0.38	0.39	0.22	0.66	0.65	0.94	0.51	0.63	0.57	0.37	0.25	0.25	0.35	0.24	0.36	
<i>Mg<sup>2+</sup></i>	0.44	0.64	0.48	0.11	0.52	0.12	0.39	0.31	0.23	0.87	0.52	0.62	0.54	0.98	0.49	0.40	0.36	0.28	0.36	0.28	0.38	
<i>Na<sup>+</sup></i>	0.48	0.51	0.50	0.19	0.64	0.33	0.32	0.31	0.26	0.78	0.47	0.74	0.60	0.73	0.32	0.96	0.30	0.24	0.38	0.22	0.23	
<i>NH<sub>4</sub><sup>+</sup></i>	0.51	0.56	0.68	0.23	0.52	0.42	0.33	0.34	0.38	0.57	0.68	0.54	0.56	0.62	0.45	0.44	0.41	0.29	0.38	0.41	0.33	
<i>SPM</i>	0.38	0.74	0.61	-0.08	0.71	0.47	0.39	0.56	0.42	0.62	0.51	0.71	0.65	0.63	0.62	0.82	0.47	-0.73	0.61	0.74	0.32	

Continued.....

	<i>Th</i>	<i>U</i>	<i>V</i>	<i>Zn</i>	<i>C</i>	<i>H</i>	<i>N</i>	<i>S</i>	<i>Br<sup>-</sup></i>	<i>Cl<sup>-</sup></i>	<i>F<sup>-</sup></i>	<i>NO<sub>2</sub><sup>-</sup></i>	<i>NO<sub>3</sub><sup>-</sup></i>	<i>PO<sub>4</sub><sup>3-</sup></i>	<i>SO<sub>4</sub><sup>2-</sup></i>	<i>Ca<sup>2+</sup></i>	<i>K<sup>+</sup></i>	<i>Mg<sup>2+</sup></i>	<i>Na<sup>+</sup></i>	<i>NH<sub>4</sub><sup>+</sup></i>	<i>SPM</i>	
<i>Ag</i>																						
<i>Al</i>																						
<i>As</i>																						
<i>Br</i>																						
<i>Ca</i>																						
<i>Cd</i>																						
<i>Co</i>																						
<i>Cr</i>																						
<i>Cu</i>																						
<i>Fe</i>																						
<i>Hg</i>																						
<i>K</i>																						
<i>Li</i>																						
<i>Mg</i>																						
<i>Mn</i>																						
<i>Na</i>																						
<i>Ni</i>																						
<i>Pb</i>																						
<i>Se</i>																						
<i>Si</i>																						
<i>Sr</i>																						
<i>Th</i>	1.00																					
<i>U</i>	0.21	1.00																				
<i>V</i>	0.14	0.33	1.00																			
<i>Zn</i>	0.23	0.43	0.18	1.00																		
<i>C</i>	0.31	0.48	0.13	0.56	1.00																	
<i>H</i>	0.39	0.35	0.18	0.51	0.68	1.00																
<i>N</i>	0.36	0.41	0.21	0.56	0.66	0.58	1.00															
<i>S</i>	0.34	0.44	0.17	0.52	0.83	0.49	0.62	1.00														
<i>Br<sup>-</sup></i>	0.11	-0.22	-0.08	0.23	0.19	0.65	0.31	0.31	1.00													
<i>Cl<sup>-</sup></i>	0.29	-0.18	-0.02	-0.11	-0.24	0.16	0.21	0.29	0.26	1.00												
<i>F<sup>-</sup></i>	0.31	-0.17	0.15	0.32	0.31	-0.19	0.24	0.24	0.16	0.68	1.00											
<i>NO<sub>2</sub><sup>-</sup></i>	0.28	0.29	0.12	-0.16	-0.27	0.12	-0.33	0.19	0.28	0.42	0.57	1.00										
<i>NO<sub>3</sub><sup>-</sup></i>																						

## 5.6 Conclusion

The elemental characterization of elements in different sizes of particulate matters in the Singrauli coalfield were investigated. The major elements of Fe, K, Mg, Ca, Al, Na and Zn in PM<sub>10</sub> samples were found in the range 1.08–25.42  $\mu\text{g m}^{-3}$ , 1.26–18.92  $\mu\text{g m}^{-3}$ , 0.17–10.57  $\mu\text{g m}^{-3}$ , 0.96–19.25  $\mu\text{g m}^{-3}$ , 0.34–14.97  $\mu\text{g m}^{-3}$ , 0.47–17.48  $\mu\text{g m}^{-3}$  and 7.76–898.45  $\text{ng m}^{-3}$ , respectively, at AQMS–01. Most of the crust elements of different particulate matter sizes were observed at high levels, mainly in the winter season.

The annual concentration of As, Ni, and Pb in different particulate matter samples has been well within the permissible limits of the National Ambient Air Quality Standard.

The enrichment factors and elemental composition profiles of the PM<sub>2.5</sub> were used to suggest the emission sources. The study area's enrichment factors were high–value arsenic, lead, cadmium, cobalt, chromium, copper, mercury, nickel, selenium, and zinc. The enrichment factor suggests an anthropogenic origin. The other elements (Ca, Mn, Na, Mg, K) have seen that lower than five enrichment factors are due to concentration in a geological material, possibly due to the suspension of particles in the atmosphere.

Higher concentrations of most ions have been observed during the winter season, which is a combined effect of biomass burning and weather conditions (low temperatures, low wind speeds, and low mixing heights). The lower value in the rainy season is perhaps due to scavenging of aerosol particles by rainfall.

It may be concluded that the major sources of water–soluble ions in the Singrauli coalfield are possibly biomass combustion and local soil.

