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Air Quality Assessment of Faisalabad and Gujranwala Cities of Pakistan: Application of Pollution Indices

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ABSTRACT

Urban air quality of industrial cities of Pakistan, namely Gujranwala and Faisalabad was assessed in terms of pollution level indicators such as pollution load index (PLI), geo-accumulation index (I_{geo}), pollution index (PI) and integrated pollution index (IPI). It was found that both cities have elevated metal concentrations indicating heavy to extreme contamination for most of the sites. Local anthropogenic activities and elevated geo-accumulation indices for different suite of elements were used to indicate possible pollutant sources in these two industrial cities to be traffic derived emissions, suspended soil, road dust, construction materials, fossil fuel and industrial emissions, tanneries, chrome plating units and metal smelters. Comparison of the pollution indices shows that Ba, Br, Ca, Cd, Na, Pb, Sb and Zn have mean PLI, I_{geo}, PI and IPI for both cities which are in the highly polluted category. Cu, La, Sc, V and Zr have pollution indices corresponding to high or extreme levels in Faisalabad only while Cr and Ti are highly polluting only in Gujranwala. In Faisalabad and Gujranwala it was found that 91.43 % and 85.29 % respectively of the PI data occurs in high level of pollution implying that to some extent Faisalabad is more polluted as compared to Gujranwala.

1. Introduction

Anthropogenic sources of heavy metals in air can be generally classified into three categories: mixed origin elements; natural elements and urban elements. Urban elements consist of metal pollutants which have undergone geochemical reaction and their major attributes have changed [1]. In developing countries air quality deterioration is a foremost challenge for environmental scientists and engineers mainly due to lack of control strategies and their ultimate implementation. Emissions from the power sector along with industrial, agricultural, vehicular and domestic sectors and natural disasters increase airborne particulates posing a threat to human health and the environment [2-3]. Moreover, runoff re-suspension, leaching, and weathering of soils and roadside dust also contribute pollutants to the hydrosphere as well as the atmosphere [4]. Furthermore, ingestion of toxic metals through these particulates poses a direct effect on public health as they can easily enter the human bodies by direct inhalation or dermal contact [5]. Numerous studies show that these metals can accumulate in the fatty tissues, subsequently affecting the proper function of organs, and affecting the nervous or endocrine systems [6].

Studies on air pollution have generally focused on elemental concentration, distribution and pollution assessment by the use of different pollution indices [7-10]. For instance the calculated enrichment factors (EF), geo-accumulation index (I_{geo}) and pollution index (PI) all showed that the levels of Pb, Zn and Cu in street dusts collected from Baoji, NW China correspond to high levels of pollution [7] while the integrated pollution index (IPI) of soil samples collected from 30 urban parks of Beijing for Cu, Ni, Pb and Zn ranged from 0.97 to 9.21, with the highest IPI in the densely populated historic center district (HCD) [8].

In the present study elemental data composition of suspended particulate matter (SPM) obtained for two industrially important cities of Pakistan i.e. Faisalabad and Gujranwala have been analyzed to assess the pollution levels using the parameters; pollution load index (PLI), geo-accumulation index (I_{geo}), pollution index (PI) and integrated pollution index (IPI) [11]. The elemental concentrations were obtained using instrumental neutron activation analysis (INAA) and atomic absorption spectroscopy (AAS). The particles were collected on glass fiber filters using Hi-Vol samplers during a comprehensive joint study carried out by the Japan International Cooperation Agency (JICA) and Pakistan Environmental Protection Agency (PAK-EPA) [12]. In the present work the elemental data obtained from previous study [12] has been analyzed to determine whether short term studies can reveal any information about the level of pollution in a city and if possible identify the major polluting elements and sources.

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2. Materials and Methods

2.1 Sampling Sites

Faisalabad and Gujranwala cities of the Punjab province were chosen for the sampling of airborne particulate matter (APM) as they are highly populated with numerous industries. Faisalabad is a densely populated city of nearly 5 million inhabitants and is a leading industrial city of Punjab, famous for its textile and hosiery industy. In Faisalabad there are more than 180 brick kilns, 140 textile dying units, 120 foundries, 80 engineering units etc [12].

Gujranwala is the seventh largest city of Pakistan with a population of over 3.45 million [12]. It is famous for electrical appliances such as manufacturing of fans, motor pumps, washing machines etc. Gujranwala is also the hub of other industries such as steel pipe industries, woolen textiles, poultry feed, soaps, rubber tubing, metal and melamine utensils, cutlery, kitchen ware, ceramics tiles, sanitary products and agriculture equipments. In Gujranwala there are more than 400 aluminum plants, 300 foundries, 200 sanitary fitting manufacturers, 190 engineering units, 120 brick kilns, 110 textile dying units, 80 plastic/ rubber factories, 70 tanneries etc [12]. These cities were chosen for this study as they contribute significantly to the national industry which may affect their air quality. In both cities, sampling sites were selected to obtain a range of pollution levels; from highly polluted to low pollution sites.

2.2. Sampling and Elemental Analysis

Samplers were installed at the sampling sites as listed in Table 1. Hi-Vol air samplers (HV-500F, SIBATA Scientific Technology Ltd., Japan) with glass fiber air filters (8”X10” rectangular) were used. Size separator was not used, so total suspended particles (TSP) were collected. Sampling was carried out from 12-23rd December 2002 when the weather was generally dry. In both cities eighteen hours sampling was carried out with frequent change of filters as per conditions and requirement to avoid clogging of the filter media. Sampling volume of the Hi-Vol sampler is 800 L/min and sampling was stopped when the volume went down to 400 L/min. Sampling started at 700 hours and ended at 2400 hrs with an average of 4 samples collected daily at each site. A 1.5 m high wooden stand was designed for the samplers. The samplers were mounted and placed at few meters distance from the roadside. In order to identify possible sources, soil samples were also collected from each site. These samples were collected directly from the surface using a clean spatula and were analyzed as mentioned in our earlier work [13, 14].

After exposure air particulate loaded filters and soil samples were stored separately in labeled clean plastic bags. The samples were stored at a temperature of 20 ^{o}C. Samples were brought to the Instrumental Neutron Activation Analysis (INAA) Laboratory at the Pakistan Institute of Nuclear Science and Technology (PINSTECH) in Islamabad. Exposed air samples

Table 1: Description of the Sites of Faisalabad and Gujranwala cities

Sr. no.	Site code	Site name	Coordinates	Site Description
FAISALABAD				
1	KCF	Kotwali Chowk	31.4206N 73.0861E	Hospital, garden, commercial area, health and other offices
2	ACF	Abdullah Crossing Junction	31.4223N 73.1007E	Schools, railway station, DHQ hospital, residential area, textile mill, play grounds
3	SCF	Shami Chowk	31.4199N 73.0615E	Densely populated residential area, hospital
4	MHF	Mian Muhammad Trust Hospital	31.4262N 73.0923E	Hospital, markets, offices, hotels, automobile workshops, main bus stop
5	MRF	Maqbool Road	31.4079N 73.0739E	Densely populated residential area, grain and other markets, automobiles workshops and some small industries
GUJRANWALA				
1	PBG	Pindi Bypass	32.2025N 74.1763E	Heavy traffic, residential area with some green area
2	GCG	Gondalwala Chowk	32.1637N 74.1877E	Heavy traffic, residential area, markets
3	BCG	Baghbanpura Chowk	32.1560N 74.1727E	Extremely dense residential area with markets
4	SRG	Sheikhupura Road	32.1369N 74.1847E	Schools, parks, sports complex, metal works units and industries
5	STG	Sialkot Road	32.4766N 74.2019E	Chrome plating units and tanneries, motorcycle market residential colonies

collected on glass fiber filters were handled with Teflon-coated clean forceps in the laboratory. All filter and soil samples were analyzed in accordance with our previously validated methodology using comparative method [9, 10]. The filters were divided into 8 equal parts. Six parts were used for INAA while the remaining two were used to determine Cd, Cu, Ni and Pb using Atomic Absorption Spectroscopy (AAS).

2.3 Instrumental Neutron Activation Analysis (INAA)

Four irradiation schemes were used for INAA. Duplicates of each sample and reference materials (RMs) were individually packed in pre-cleaned polyethylene capsules which were then packed in individual rabbits. The RMs used included synthetic reference materials (RMs) prepared from high purity salts of different elements as well as International Atomic Energy Agency (IAEA) RMs) IAEA-S-7 (Soil) [15] and IAEA-SL-1 (Lake Sediment) [16] which were used for quality assurance (QA) purposes. The synthetic RMs were used for calibration and quantitative analysis purposes. The targets were irradiated, one after the other, for sequential irradiations of two minutes at the Pakistan Atomic Research Reactor 2 (PARR-2), which is a 27 kW, Miniature Neutron Source Reactor (MNSR) with a thermal neutron flux of $1x10^{12}$ n cm^{-2} s^{-1}. After irradiation each sample was transferred from its polythene capsule to a fresh pre-weighed capsule and, after 3 minutes of cooling, was counted for 100 seconds on a HPGe detector to determine the very short-lived elements, such as Al, Mg, Ti, V, etc. In this manner all of the samples were measured with the time interval between irradiation of consecutive samples of 5 minutes. Once the spectra for all samples had been obtained the samples were cooled for a further 30 minutes and counted for 300 seconds to determine the short-lived element Mn, Sm etc.

For intermediate lived elements such as As, Br, K, La, Na etc duplicates of each sample along with RMs were sealed in one rabbit. These were irradiated at PARR-2 for 1 hour, cooled for 2 days and counted for 600 seconds. Similarly for long irradiation, the prepared rabbits were irradiated at PARR-2 for 5 hours, cooled for 2 weeks and counted for 2 hours to determine the long lived elements Ce, Co, Cr, Cs, Fe, Zn etc. In this way ~40 elements were determined. The soil samples were also analyzed in the same way.

RMs were employed for the quantification and validation of the INAA procedure. Moreover, a blank filter was also analyzed to determine the composition of the sampling media. The gamma ray spectrometry system consisted of a HPGe detector (Canberra Model AL-30) connected to a PC-based Intertechnique Multichannel Analyzer (MCA). Intergamma, version 5.03 software was used for analysis of spectra. The system has a resolution of 1.9 keV at 1332.5 keV peak of ^{60}Co and a peak-to-Compton ratio of 40: 1. Elemental compositions of the samples were calculated with the help of peak energy, peak area, area uncertainty etc and an in-house program [17]. Blank correction was applied for each irradiation and error propagation rules were followed to determine elemental concentrations (in ng⁄m^3) along with uncertainties and limits of detection (LODs) [18]. The use of multiple irradiation schemes and gamma peaks made it possible to remove interferences [19, 20]. For example ^{27}Mg and ^{56}Mn have gamma peaks at 843.8 and 846.8 keV respectively. Therefore first ^{27}Mg was determined using the sequential irradiation scheme while ^{56}Mn was determined after a further cooling period of ~30 mins. Moreover ^{82}Br can be determined using the peaks at 554.3 and 776.5 keV. As gamma peaks for ^{76}As and ^{122}Sb also occur at 559.1 and 563.9 keV respectively the results for the 776.5 keV peak are considered more reliable even though it is a less abundant peak.

2.4 Atomic Absorption Spectroscopy (AAS)

The loaded filter samples were digested in 5 ml of purified HNO_3 and heated at 80 °C for 30 minutes. After cooling, 2 ml of $HClO_4$ was added and the solution reheated at 250 °C with occasional shaking till white fumes evolved. The clear solution was transferred to a 25 ml measuring flask. AAS instrument was a Hitachi Z-8000 spectrometer coupled with a microprocessor based data handling facility. Cu and Ni were determined by flame atomic absorption (FAAS) using air acetylene flame while Cd and Pb were measured by graphite furnace (GFAAS) method. Further experimental details are available in our earlier work [14].

2.5 Pollution Indices

The elemental concentrations obtained were used to calculate the pollution indices given below:

2.5.1. Pollution Load Index (PLI)

PLI is used to determine the contamination level of a specific site. This elemental pollution level parameter is estimated by a method based on the assessment of contaminants as PLI of a specific site as discussed by Daud et al. [13] using following equations.

$$CF = \frac{C_{metal}}{C_{background}} \quad (1)$$

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 ..... \times CF_n} \quad (2)$$

where

CF = Contamination factor, n = Number of metals

C_{metal} = Metal concentration in polluted PM

$C_{background}$ = Background concentration of same metal

Four categories of PLI have been distinguished.

PLI < 1 Low level contamination

1 ≤ PLI < 3 Moderate level contamination

3 ≤ PLI < 6 Considerable level contamination

6 ≤ PLI Very high level contamination

PLI values were calculated for each element at a site and reflect its contamination level.

2.5.2 Geo-accumulation Index (I_{geo})

The Geo-accumulation Index was introduced by Muller [21] to assess metal pollution in sediments. This index incorporates a range of degrees of enrichment above the background value ranging from uncontaminated to extremely contaminated sediment quality. I_{geo} values were calculated for each element at a site using the following equation:

$$I_{geo} = \log\left[\frac{C_n}{1.5 \cdot B_n}\right] \quad (3)$$

Where C_n represents the measured concentration of the element n and B_n is the geochemical background value of the respective element in host soil.

I_{geo} is divided into following categories depending on pollution level :

$I_{geo} \leq 0$ unpolluted environment

$0 < I_{geo} \leq 1$ unpolluted to moderately polluted

$1 < I_{geo} \leq 2$ moderately polluted

$2 < I_{geo} \leq 3$ moderately to strongly polluted

$3 < I_{geo} \leq 4$ strongly polluted

$4 < I_{geo} \leq 5$ strongly to extremely polluted, and

$I_{geo} > 5$ extremely polluted

2.5.3 Pollution Index (PI)

Pollution Index (PI) can be defined as the ratio of the metal concentration at the study site to the corresponding metal background soil concentration. It is given by the formula [22] :

$$PI = \frac{C_n}{B_n} \quad (4)$$

where C_n is the concentration in SPM of element *n* and B_n is the background soil concentration of same element.

Pollution level of metals in dust is classified as follows:

PI ≤ 1 low level of pollution

1 < PI ≤3 middle level of pollution

PI > 3 high level of pollution

Again PI values were calculated for each element at a site and give an indication of its contamination level.

2.5.4. Integrated Pollution Index (IPI)

The integrated pollution index is defined as the mean value of the pollution index PI of an element for one city consisting of several sampling sites. IPI for this study is categorized as [8]:

IPI ≤ 1 low level of pollution

1 < IPI ≤ 2 middle level of pollution

IPI ≥ 2 high level of pollution

Therefore IPI value can be used to determine the contamination level of an element within a city from multiple sampling sites.

3. Results and Discussion

From 35 to 39 elements were determined in soil and APM samples collected from the cities of Faisalabad and Gujranwala. These include Al, As, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Ga, Hf, Hg, K, La, Lu, Mg, Mn, Mo, Na, Nd, Rb, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Th, Ti, V, Yb, Zn, Zr determined using INAA and Cd, Cu, Ni, Pb by AAS techniques. The average concentrations obtained for the APM and soil samples from all sampling sites are presented in Figs. 1 and 2 for the two cities. The upper, lower and middle of the box represent the 3rd quartile, the 1st quartile and the median values of each element for 5 sites within each city. It is to be noted that median values do not lie in the middle of each box. The lower and upper whiskers represent the minimum and maximum elemental concentrations. From these results it can be seen that from 35 to 39 elements were determined in Faisalabad and 35 to 38 elements in Gujranwala. Moreover the compositions of the unpolluted soils of both cities have comparable values.

Overall air filter samples collected from both cities have higher amounts of most elements as compared to their respective soil samples. Fig. 1 shows that Ga, Mo, Sn and Sr in soils of Faisalabad and Ga, Hg, Mo, Sn and Sr in soils of Gujranwala were not detected implying their presence in APM due to some anthropogenic sources. When the elemental composition of Faisalabad and Gujranwala SPM are compared it is seen that Al, Ca, Co, Cs, Eu, Ga, La, Lu, Mg, Mn, Mo, Na, Nd, Sc, Se, Sm, V, Yb and Zr are high in SPM of Faisalabad while Ba, Ce, Cr, Fe, Hf, Hg, Rb, Sb, Sn, Sr, Ta, Tb, Ti and Zn have higher values in Gujranwala SPM.

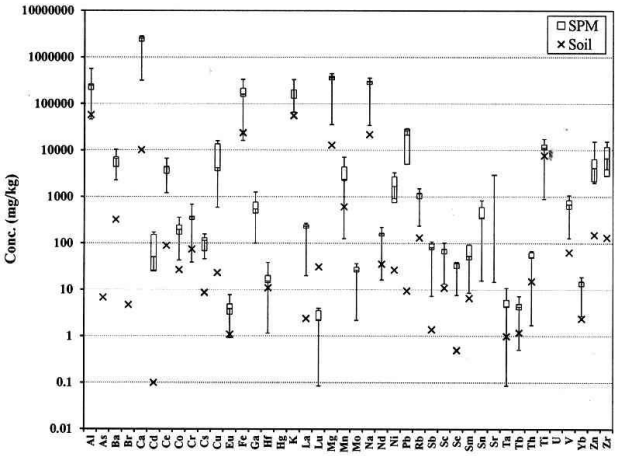

Fig. 1: Faisalabad SPM and soil composition

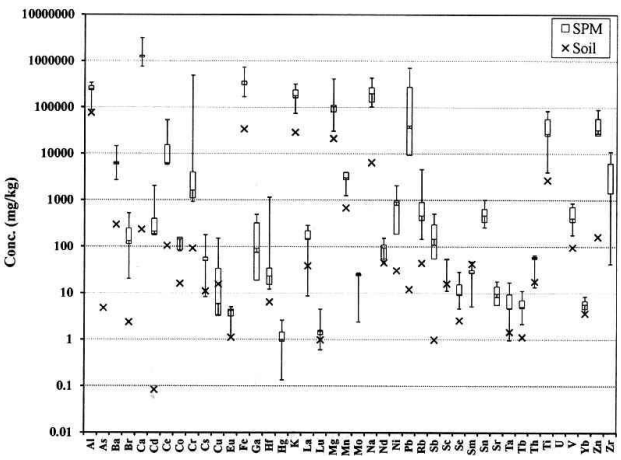

Fig. 2: Gujranwala SPM and soil composition

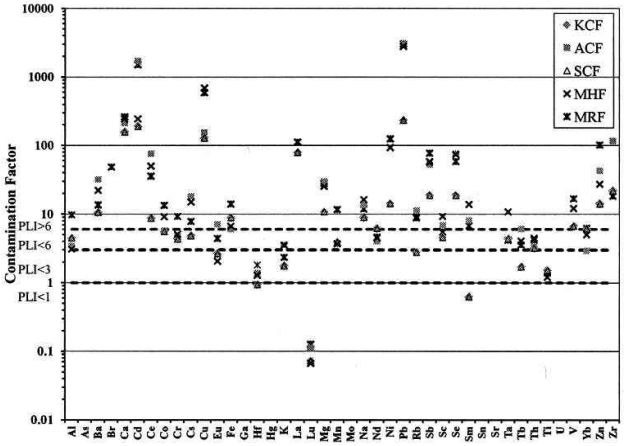

Fig. 3: Contamination Factors for Faisalabad city

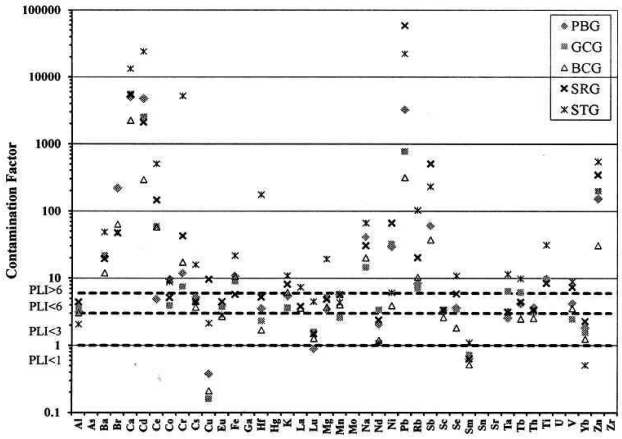

Fig. 4: Contamination Factors for Gujranwala city

However, K and Th contents are comparable in both cities. Hg was only detected in Gujranwala while Zr was quantified in Faisalabad only [23-26]. In Faisalabad the sites MRF and ACF appear to be more polluted than the remaining 3 sites while the pollution level at STG site is the highest in Gujranwala. KCF and BCG are the least polluted sites in Faisalabad and Gujranwala respectively. The MRF and SCF sites are both located in densely populated areas while chrome plating units and tanneries are located at the STG site.

3.1 Pollution load Index (PLI)

The contamination factors obtained for the cities of Faisalabad and Gujranwala have been plotted in Figs. 3 and 4 respectively where the various PLI categories have also been indicted by dashed line. From these plots it can be seen that CF for all elements is high indicating considerable to very high pollution level. The CFs for Ba, Br, Ca, Cd, Ce, Cs, Cu, La, Mg, Na, Ni, Pb, Sb, Se, V, Zn and Zr are much higher in Faisalabad while in Gujranwala Ba, Br, Ca, Cd, Ce, Cr, Na, Ni, Pb, Rb, Sb, Ti and Zn are higher. Higher CFs for these elements may indicate the contribution of numerous anthropogenic sources such as construction, metal works, transport etc as well as natural sources such as weathering of rocks and windblown dust. The various pollution indices calculated in this paper are summarized in Table 2. The PLI data for Faisalabad and Gujranwala show considerable to high pollution levels at all sites in both cities. From this table it can be seen that, according to PLI values, all sites in Faisalabad and Gujranwala are highly polluted except for BCG site in Gujranwala which falls in the considerably polluted category.

3.2 Geo-accumulation Index (I_{geo})

The geo-accumulation indices calculated for all quantified elements in SPM of Faisalabad and Gujranwala cities are presented in Figs. 5 and 6 respectively. From these plots and the summarized I_{geo} data in Table 2 it can be seen that, 28.57 % of the elemental data for Faisalabad falls in the extremely contaminated category while 25.71 % of the data are in the moderately contaminated category.

Table 2: Summary of parameters

Parameter	Faisalabad					Gujranwala				
	KCF	ACF	SCF	MHF	MRF	PBG	GCG	BCG	SRG	STG
PLI										
Contamination Level	High	High	High	High	High	High	High	Considerable	High	High
PLI	>6	>6	>6	>6	>6	>6	>6	3 ≤ PLI < 6	>6	>6
I_{geo} (% data in each category)										
$I_{geo} \leq 0$	8.82	6.90	2.94	9.38	5.71	9.09	6.67	15.15	5.88	8.82
$0 < I_{geo} \leq 1$	14.71	3.45	5.88	3.13	5.71	9.09	16.67	18.18	5.88	8.82
$1 < I_{geo} \leq 2$	23.53	24.14	26.47	25.00	17.14	39.39	33.33	24.24	41.18	11.76
$2 < I_{geo} \leq 3$	23.53	20.69	17.65	15.63	22.86	15.15	16.67	12.12	11.76	23.53
$3 < I_{geo} \leq 4$	14.71	6.90	14.71	15.63	14.29	3.03	6.67	9.09	5.88	8.82
$4 < I_{geo} \leq 5$	0.00	10.34	5.88	6.25	5.71	6.06	3.33	6.06	8.82	5.88
$I_{geo} > 5$	14.71	27.59	26.47	25.00	28.57	18.18	16.67	15.15	20.59	32.35
PI (% data in each category)										
PI≤1	8.82	3.45	2.94	3.13	2.86	9.09	6.67	6.06	2.94	2.94
1<PI≤3	14.71	6.90	5.88	9.38	8.57	9.09	16.67	27.27	8.82	14.71
PI>3	76.47	89.66	91.18	87.50	88.57	81.82	76.67	66.67	88.24	82.35

Similarly for Gujranwala city, about 24 % of the I_{geo} results are in the extremely contaminated category while ~30% of the data falls in the moderately contaminated class. Moreover Table 2 also shows that the majority of the sites in Faisalabad and Gujranwala are moderately to strongly polluted.

Fig. 5 shows that Faisalabad city is heavily contaminated by Ca, Cd, Ce, Cu, La, Ni, Pb, Sb, Se, Zn and Zr. Different possible sources may be identified for the release of these elements. These may include traffic derived emissions (Cd, Mg, Pb, V and Zn), suspended soil, road dust and construction materials (Ca, Cs, Na, Mg, Se, Zr), fossil fuel and industrial emissions and incinerators (Sb, Se, V), advance ceramics, electronics and metal smelters (Ce, La, Mg, Sb, V, Zn, Zr) [23-26]. Only one site (MRF) from this city showed heavy contamination of Co and Fe levels that can be attributed to traffic derived emissions, construction activity and road dust. Extreme contamination of Br and Zn was observed for densely populated residential MRF site with markets. Sources of these two elements are probably automobiles workshops and some small industries. Extremely contaminated category for some of these elements reflects 100 times enrichment above the background values [26]. These high particulate matter contaminant levels of Faisalabad city can be conveniently attributed to the presence of more than 174 brick kilns, 122 foundries and 13 tanneries.

I_{geo} for most of the sites in Gujranwala city (Fig. 6) indicates heavy contamination of Ba, Br, Ca, Cd, Ce, Cr, Hf, Na, Ni, Pb, Sb and Zn that pinpoints to their presence

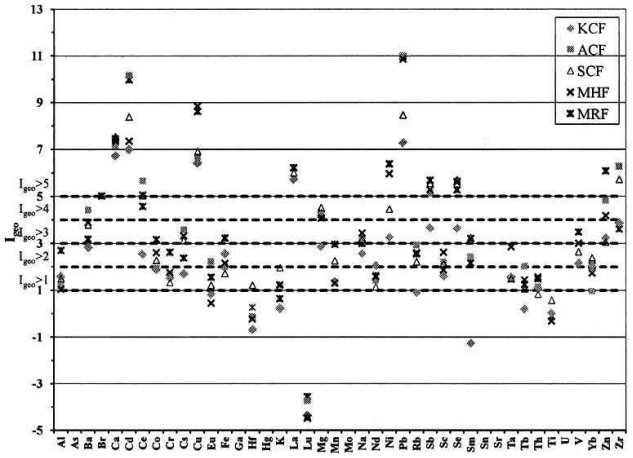

Fig. 5: I_{geo} for Faisalabad city

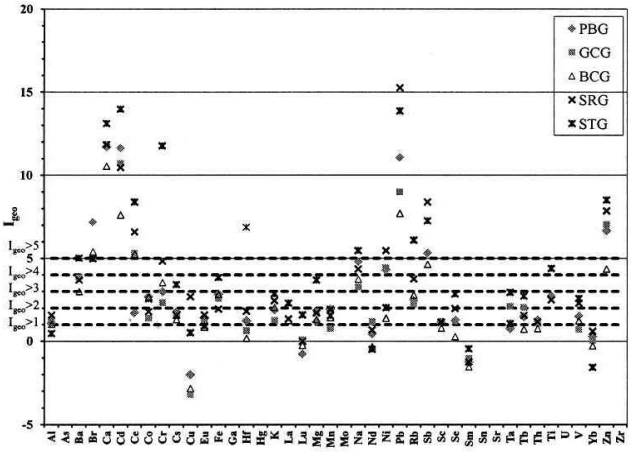

Fig. 6: I_{geo} for Gujranwala city

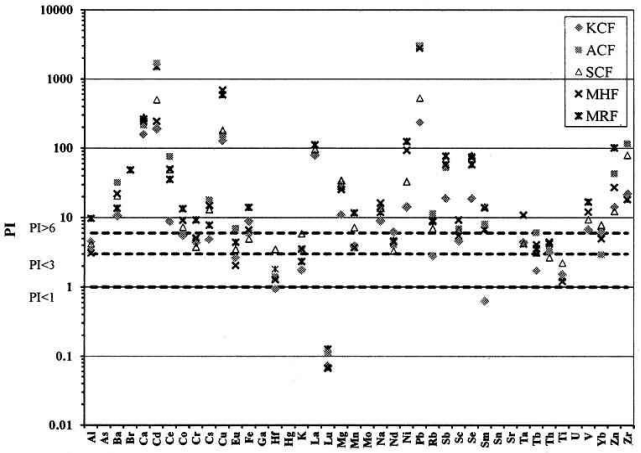

Fig. 7: PI for Faisalabad city

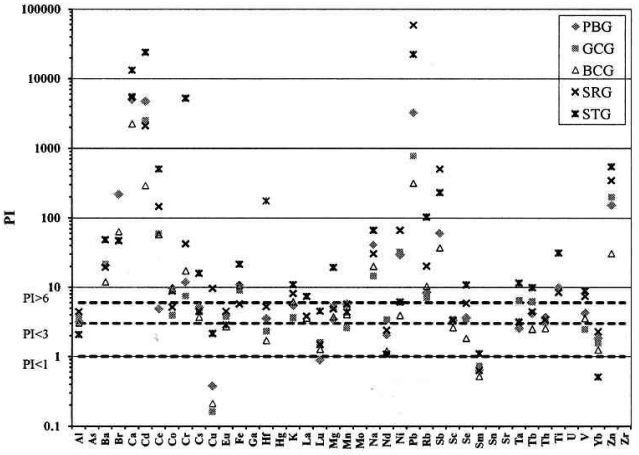

Fig. 8: PI for Gujranwala city

due to vehicular emissions and agricultural practices [26, 28]. Extreme contamination of Ca, Ce, Sb and Zn was obtained for most of the studied sites is possibly due to sources such as construction, ceramics production, vehicular emissions and wearing processes [26]. One of the sites from this city (STG) showed heavy contamination of Ca, Cr, Cs, Fe, Hf, Mg and Rb levels. The STG site also showed extreme contamination of Ba, Cr, Na and Rb. The presence of chrome plating units and tanneries using Cr salts in this area could explain the higher I_{geo} categories for Cr. Gujranwala city has more than 125 brick kilns, 187 engineering works units and 314 foundries which contribute to toxic contaminants.

3.3. Pollution Index (PI)

The pollution indices (PI) calculated for all quantified elements in the APM of Faisalabad and Gujranwala cities are presented in Figs. 7 and 8 respectively which are very similar to Figs. 3 and 4. Once again the various PI categories have also been indicted on these plots and data for individual sites is summarized in Table 2. In both cities majority of the elements are in high pollution level category for all sites. In Faisalabad and Gujranwala, PIs data that occurs in high level of pollution are 91.43 % and 85.29 % respectively predicting that to some extent Faisalabad is more polluted as compared to Gujranwala.

3.4 Integrated pollution index (IPI)

The IPI data for the Faisalabad and Gujranwala cities have been plotted in Fig. 9. From this plot it can be seen that different elements have lower or higher IPI values for both cities. For example both Ca and Cr have much higher IPI values in Gujranwala. These reflect the differences in the types of sources available in both cities. Moreover it was found that for both cities about 90% of quantified elements are in the high pollution category. However Hf, Lu and Ti from Faisalabad and Lu, Nd, Sm and Yb from Gujranwala cities were found to be at middle pollution level.

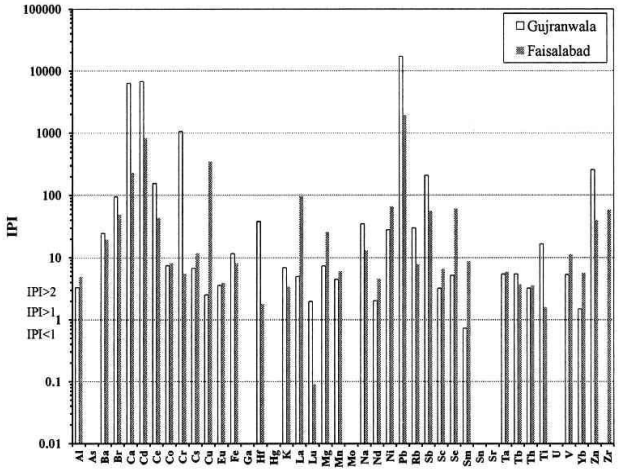

Fig. 9: IPI for Faisalabad and Gujranwala cities

Comparing the results for all calculated indices it can be seen that the elements Ba, Br, Ca, Cd, Na, Pb, Sb and Zn have mean PLI, I_{geo}, PI and IPI values for both cities which are in the highly polluted category. Moreover Cu, La, Sc, V and Zr have pollution indices corresponding to high or extreme levels in Faisalabad only while and Cr and Ti are highly polluting only in Gujranwala. These results again show that Faisalabad has a poorer air quality and both cities have different pollution sources.

4. Conclusion

Pollution load index (PLI), geo-accumulation index (I_{geo}), pollution index (PI) and integrated pollution index (IPI) were calculated from elemental data obtained for air particulate samples collected at 10 sites in the industrial cities of Faisalabad and Gujranwala. From the results obtained it can be concluded that Faisalabad has poorer air quality than Gujranwala. There are elements such as Ba, Br, Ca, Cd, Na, Pb, Sb and Zn which are major pollutants in both cities. Moreover Cr and Ti are highly polluting in Gujranwala only while Cu, La, Sc, V and Zr are highly polluting in only Faisalabad. Thus the results of

short term studies can provide some information regarding pollution sources. From the limited amount of information gathered in this work it is suggested that in Faisalabad and Gujranwala growth of vegetation is required to decrease the contribution of crustal soil and road dust to the SPM as well as improvements in the control of vehicular and industrial emissions. Moreover a more comprehensive study is required to verify these results and to perform source apportionment.

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