The Nucleus 53, No. 2 (2016) 99-106

www.thenucleuspak.org.pk

The Nucleus

ISSN 0029-5698 (Print)
ISSN 2306-6539 (Online)

Air Pollution Risk Assessment: A Comparative Study of Industrial Cities of Pakistan

Y. Faiz, S. Waheed* and M. Daud

Chemistry Division, Directorate of Science, PINSTECH, P.O. Nilore, Islamabad, Pakistan

swaheed161@hotmail.com; yasir1dgk@gmail.com; daud@pinstech.org.pk

ARTICLE INFO

Article history :
Received : 23 July, 2015
Revised : 18 April, 2016
Accepted : 22 April, 2016

Keywords :

Air Particulate Matter (APM),
Air Quality,
Faisalabad,
Gujranwala,
Elemental Dose,
Hazard Quotient (HQ),
Hazard Index (HI)

ABSTRACT

Currently in Pakistan there is little information regarding dose assessment for trace elements in air particulate matter (APM). US EPA health risk assessment model has been employed to calculate the elemental dose for thirty four elements quantified using instrumental neutron activation analysis (INAA) technique in APM and soil samples collected from Faisalabad and Gujranwala cities. Hazard Quotient (HQ) and Hazard Index (HI) have been assessed for Al, Ba, Co, Cr, Mn, Sb, Sr, V and Zn. Alarming elemental doses were observed as 1.91, 1.28, 1.26, 2.21 and 1.97 respectively for Al, Fe, K, Mg, and Na in suspended particulate matter (SPM) of Faisalabad. Likewise in Gujranwala the levels were 1.66, 9.84, 2.62, 1.32, 1.03 and 1.49 for Al, Ca, Fe, K, Mg and Na, respectively. For Faisalabad high HI values were evaluated for Al, Cr and Sb with respective values of 2.00, 1.01 and 1.46. Similarly, in SPM of Gujranwala the HI values for these elements were also high (1.73, 2.49E+02 and 3.94 respectively). Critically, high Cr hazard levels due to tanneries and chrome plating industries in Gujranwala city indicate alarming health hazard. Overall, Al, Cr and Sb are the current challenges to be managed.

1. Introduction

Worldwide in the past few decades, numerous research papers on air particulate matter (APM) have been published regarding the concentration of trace metals, their toxicity dose assessment and source identification to check the pollution scenarios [1-2]. Airborne particulate matter is built up through contributions of both natural and anthropogenic sources. The inventory of natural sources includes terrestrial dust, sea spray, biogenic emanations, volcanic emissions and emissions from fires [3]. Rapid growth of power production requires utilization of coal, gas and oil. These together with numerous other anthropogenic sources like smelters, incinerators, open hearth furnaces and automobile sources significantly add different trace elements and their compounds to the particulate matter, thus posing threats to human health and the environment [3-4]. The APM consist of metal pollutants and their major attributes altered due to geochemical reaction [5]. Suspended particulate matter is the most important atmospheric pollutant in the study area. Metallic fraction of particular matter is reported to have toxic effects on human beings. Impending threats to health by these metallic pollutants has opened altogether new paths in research studies, like identification of transfer modes of these particulates in the urban media and their exposure estimates through different routes. Pollutants in dust can easily penetrate the human bodies by inhalation, ingestion and dermal absorption, posing potentially lethal effects on human health [6-7]. These accumulated metals in the tissues and sensitive internal organs of human body can affect the central nervous system or endocrine system and act as cofactors, initiators or promoters of many chronic diseases [3, 5, 8-9].

Risk assessment from these pollutants has been widely employed by regulatory authorities to define soil screening levels or soil guideline values. Some studies are also available in literature about risk characterization of trace metals in urban environments [10-12]. Hazard identification provides useful information regarding the acquired data and the presence of these elements in an environment that may cause serious health effects for the adjacent community. In the present study suspended particulate matter (SPM) data obtained from two major industrial cities of Pakistan i.e. Faisalabad and Gujranwala has been analyzed to assess the pollution levels in these cities and their associated health hazard and risks posed by the amounts of pollutants measured.

2. Materials and methods

2.1 Sampling Sites

The Faisalabad and Gujranwala cities from the Punjab province in Pakistan were selected for the SPM sampling. Sampling sites in both cities were selected to obtain a range of pollution levels, from highly polluted to low pollution sites. Faisalabad city located in Northeast of the province between longitude 73.08° East and latitude

* Corresponding author

Table 1: Detail of different sampling sites for Faisalabad and Gujranwala cities

Sr. No.	Site code	Site name	Site Description
Faisalabad (longitude 73.08° east and latitude 31.43° north)			
1	KCA	Kotwali Chowk	Hospital, garden, institutes, commercial area, health and other offices
2	ACJ	Abdullah Crossing Junction	Schools, Railway station, DHQ hospital, residential area, textile mill, play grounds
3	SCA	Shami Chowk	Dense residential area, hospital
4	MTH	Mian Muhammad Trust Hospital	Markets, offices, hotels, workshops, main bus stop
5	MRA	Maqbool Road	Dense residential area, grain and other markets, Automobiles workshops, small industries
Gujranwala (longitude 74.18° east and latitude 32.16° north)			
1	PBA	Pindi Bypass	Heavy traffic burden, residential area with some green area
2	GCA	Gondalwala Chowk	Traffic load, residential area, heavy traffic, markets
3	BPC	Baghbanpura Chowk	Extremely dense residential area with markets
4	SRA	Sheikhupura Road	Schools, parks, sports complex, metal works units and industries
5	SRG	Sialkot Road	Chrome plating units and tanneries, residential colonies, motorcycle market

31.43° North has population of nearly 5 million and is leading industrial domain of Pakistan. It is bounded in the North by Gujranwala and Sheikhupura districts, in the East by Sheikhupura and Sahiwal districts, in the South by Sahiwal and Toba Tek Singh districts and in the West by Jhang district. The city is especially famous for its widespread textile industry, power loom factories and therefore called Manchester of Asia. Besides there are numerous engineering, chemicals and food processing units. The city also manufactures hosiery, carpet and rugs, knitwear and sportswear, packaging materials, printing and publishing and pharmaceutical products among many other goods [13].

The Gujranwala (32.16° N, 74.18° E) is an industrial city in the province of Punjab and is the seventh largest city of Pakistan with population of over 3.45 million. The Chenab River forms the Northern boundary of the Gujranwala. Beyond the river, it is bounded by Gujrat and Mandi Bahauddin districts, on the East by Sialkot district, on the South by Sheikhupura district and on the West by Hafizabad district. The city has many large and small industrial units that manufacture industrial and agricultural machinery, fans, motor pumps, washing machines and electrical appliances [13]. In addition many poultry feed, soap, ball point, rubber tube, metal utensils, melamine utensils, cutlery, ceramics tiles, sanitary products, wool and cotton textiles and steel pipe industries and many other small manufacturers of similar products are also functioning in this city. During the sampling of particulate matter in both cities, meteorological parameters like temperature, relative humidity, atmospheric pressure, wind speed and wind direction were also recorded.

2.2 Sample Preparation

In each city sampling of APM was carried out using high volume air sampler (HV-500F, AC 100 V 50 /60 Hz. No. 13249, 10-A, SIBATA Scientific Technology Ltd, Japan) with flow rate of 800 liters/min. Additionally airflow rate was monitored every 10 minutes to check decreases in the flow rate and pressure of the sampler. The filters were replaced by new pre-weighed filters when the sampler stopped functioning due to drop in the flow rate to its half (400 l/min).

The samplers were installed at five different sampling stations on preplanned locations as given in Table 1. Samplers were mounted on one and a half meter high wooden stand and placed a few meters away from the roadside for sampling. Each sampler was mounted with quartz filters for SPM collection and after exposure the loaded filters were stored in clean and labeled plastic bags. SPM of less than 10μm diameter is collected. In both cities about 15 to 20 exposed filters were collected from each site. In order to calculate the enrichment factors and source identification, corresponding soil samples were also obtained from these sites as mentioned in our earlier work [14]. These soil samples were directly collected from the surface with a clean spatula, stored in clean plastic bags and carefully tagged. All filters and soil samples were then transferred to main analytical facility at Pakistan Institute of Nuclear Science and Technology (PINSTECH) for quantification of different elements.

2.3 Irradiation and INAA Measurements

Exposed quartz filters were handled with Teflon-coated forceps after transportation to the INAA laboratory at Pakistan Institute of Nuclear Science and technology. Filter samples along with the standard comparison samples and suitable International Atomic Energy Agency (IAEA) certified reference materials, CRMs (IAEA S-7 and IAEA SL-1) as quality control materials and unexposed blank quartz filter were packed individually in pre-cleaned polyethylene capsules for different irradiation schemes. Details of optimized radio-assay scheme used and instrumentation used for INAA are given in our earlier work [8, 14].

2.4 Hazard Index (HI) and Elemental Dose (ED) Assessment

Elemental pollution may affect human beings through ingestion, inhalation and dermal contact therefore it is imperative to determine hazard index (HI) and elemental dose (ED) for the quantified elements.

2.4.1 Hazard Quotient (HQ) and Hazard Index (HI)

A quantity that takes into account the combined contribution of ingestion, inhalation, and dermal contact doses by a single value is called Hazard Index (HI) and is used to estimate the elemental risk. A value of HI greater than one is not recommended as it indicates potential adverse health effects. The HQ and HI have only been determined for Al, Ba, Co, Cr, Mn, Sb, Sr, V and Zn due to lack of Reference Doses (RfDs) of other elements using Eqs. 1 and 2 respectively [15-16].

$$\mathrm{HI} = [\mathrm{HQ}]_{\mathrm{ingestion}} + [\mathrm{HQ}]_{\mathrm{inhalation}} + [\mathrm{HQ}]_{\mathrm{dermal}} \quad (1)$$

$$\mathrm{HQ_i} = \left(\frac{D}{RfD}\right)_{\mathrm{i}} \quad (2)$$

Where HQ is Hazard Quotient or non-cancer risk and "*i*" = ingestion, inhalation and dermal.

D and *RfD* are respectively the dose from element *i* and corresponding reference dose of that element.

2.4.2 Elemental Dose (ED)

For human risk characterization different types of measures and parameters are employed to determine the potential risk of general populace. Intake of toxic metals and its related health risk are normally assessed using carcinogenic and non-carcinogenic methods. Human exposure is variable and there is tolerable daily intake level assessed safe for human being. Moreover, if a body is exposed to a daily dose which exceeds the corresponding reference dose, the receptor is considered to be potentially at risk. The United States Environmental Protection Agency (US EPA) methodology employed for non-cancer risk evaluation is calculated by using the Hazard Quotient (HQ) which is a ratio between the estimated dose of contaminant and the Reference Dose. When the estimated dose is below the Reference Dose there will not be any risk for all exposure routes and pathways. In addition Hazard Index (HI) is calculated to specify individual pollutants as sum of the HQs from all exposure routes [16]. Non-cancerous dose from elements for all the three exposure pathways i.e. ingestion, inhalation of particulates and dermal absorption and deposition of APM through contact with exposed skin is estimated with the generic relationships given below in Equations 3 to 5 [16-17]. Toxic values used in the calculations were taken from the compilation of US Department of Energy's Risk Assessment Information System (RAIS) [18].

Ingestion Dose:

$$D_{ing}\,(\mu\mathrm{g.\,g^{-1}\,day^{-1}}) = \mathrm{C}\,(\mu\mathrm{g.\,g^{-1}}) \times \frac{\mathrm{lnR} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{BW} \times \mathrm{AT}} \times 10^{-6} \quad (3)$$

Inhalation Dose:

$$\mathrm{D_{inh}}\,(\mu\mathrm{g.\,g^{-1}\,day^{-1}}) = \mathrm{C}\,(\mu\mathrm{g.\,g^{-1}}) \times \frac{\mathrm{lnR} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{PEF} \times \mathrm{BW} \times \mathrm{AT}} \times 10^{-6} \quad (4)$$

Dermal Contact Dose:

$$\mathrm{D_{dermal}}\,(\mu\mathrm{g.\,g^{-1}\,day^{-1}}) = \mathrm{C}\,(\mu\mathrm{g.\,g^{-1}}) \times \frac{\mathrm{SA} \times \mathrm{SL} \times \mathrm{ABS} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{BW} \times \mathrm{AT}} \times 10^{-6} \quad (5)$$

Table 2 has been incorporated to define the symbols, meanings and the values of the symbols used in these relationships.

Table 2: Factors and meanings of the factors

Notations	Denotations	Value	Reference
C	Concentration of trace element in road dust (exposure point concentration)		[26]
IngR	Ingestion rate	200 mg day $^{-1}$	-
EF	Exposure frequency (site specific)	180 day yr $^{-1}$	-
ED	Exposure duration (site specific)	6 yr	-
BW	Average body weight	15 kg	[26]
AT	Averaging time	ED × 365 days	-
InhR	Inhalation rate	7.6m^3 day $^{-1}$	[27]
PEF	Particle emission factor	1.36×10^9 m^3 kg^{-1}	[26]
SA	Skin area exposed	2800 cm^2	[26]
SL	Skin adherence factor	0.2 mg cm^{-2} day^{-1}	[26]
ABS	Dermal absorption factor	0.001	[26]

Table 3: Ingestion, inhalation, dermal and total dose from trace elements quantified for Faisalabad city. (All values in µg.g^{-1}day^{-1})

Elements	Mean	D_{ing}	D_{inh}	D_{derm}	D_{total}
Al	2.90E+05	1.91E+00	5.33E-05	5.34E-03	1.91E+00
Ba	6.41E+03	4.22E-02	1.18E-06	1.18E-04	4.23E-02
Br	2.29E+02	1.51E-03	4.21E-08	4.22E-06	1.51E-03
Ce	3.90E+03	2.56E-02	7.16E-07	7.18E-05	2.57E-02
Co	2.21E+02	1.45E-03	4.06E-08	4.06E-06	1.46E-03
Cr	4.05E+02	2.66E-03	7.44E-08	7.46E-06	2.67E-03
Cs	1.02E+02	6.72E-04	1.88E-08	1.88E-06	6.74E-04
Eu	4.33E+00	2.85E-05	7.95E-10	7.97E-08	2.85E-05
Fe	1.95E+05	1.28E+00	3.58E-05	3.59E-03	1.28E+00
Ga	6.65E+02	4.37E-03	1.22E-07	1.22E-05	4.38E-03
Hf	1.97E+01	1.29E-04	3.61E-09	3.62E-07	1.30E-04
K	1.91E+05	1.26E+00	3.51E-05	3.52E-03	1.26E+00
La	2.30E+02	1.51E-03	4.23E-08	4.24E-06	1.52E-03
Lu	2.79E+00	1.83E-05	5.13E-10	5.14E-08	1.84E-05
Mg	3.35E+05	2.20E+00	6.15E-05	6.16E-03	2.21E+00
Mn	3.69E+03	2.43E-02	6.78E-07	6.80E-05	2.43E-02
Mo	2.81E+01	1.85E-04	5.17E-09	5.18E-07	1.85E-04
Na	2.83E+05	1.86E+00	5.21E-05	5.22E-03	1.87E+00
Nd	1.62E+02	1.07E-03	2.98E-08	2.99E-06	1.07E-03
Rb	1.03E+03	6.79E-03	1.90E-07	1.90E-05	6.81E-03
Sb	7.80E+01	5.13E-04	1.43E-08	1.44E-06	5.14E-04
Sc	7.23E+01	4.75E-04	1.33E-08	1.33E-06	4.77E-04
Se	3.05E+01	2.01E-04	5.60E-09	5.62E-07	2.01E-04
Sm	5.76E+01	3.79E-04	1.06E-08	1.06E-06	3.80E-04
Sn	4.63E+02	3.04E-03	8.51E-08	8.52E-06	3.05E-03
Sr	2.94E+03	1.94E-02	5.41E-07	5.42E-05	1.94E-02
Ta	6.00E+00	3.95E-05	1.10E-09	1.10E-07	3.96E-05
Tb	4.47E+00	2.94E-05	8.21E-10	8.23E-08	2.95E-05
Th	5.43E+01	3.57E-04	9.98E-09	1.00E-06	3.58E-04
Ti	1.24E+04	8.17E-02	2.28E-06	2.29E-04	8.20E-02
V	7.20E+02	4.73E-03	1.32E-07	1.33E-05	4.75E-03
Yb	1.35E+01	8.88E-05	2.48E-09	2.49E-07	8.90E-05
Zn	6.02E+03	3.96E-02	1.11E-06	1.11E-04	3.97E-02
Zr	7.90E+03	5.20E-02	1.45E-06	1.46E-04	5.21E-02

3. Results and Discussion

Elemental data for characterized trace elements in air particulate matter and soil samples collected from Faisalabad and Gujranwala cities of Pakistan are presented in our earlier work [8]. Our current work focuses on data analysis for the determination of ED and HI. The calculated doses from ingestion, inhalation and dermal contact of determined elements in SPM collected from Faisalabad and Gujranwala cities respectively along with the total accumulative dose resulting from ingestion, inhalation and dermal contact of metals are presented in Tables 3 and 4. Table 3 shows that in Faisalabad Mg, Al, Na, Fe and K respectively present in the SPM contribute to a maximum dose of 2.21, 1.91, 1.87, 1.28 and 1.26 µg g^{-1} day^{-1}. Table 4 for Gujranwala city shows Ca, Fe, Na, K and Mg in studied SPM shows maximum dose of 9.84, 2.62, 1.49, 1.32 and 1.03 µg g^{-1} day^{-1} respectively. Other elements that presented doses of the order of 10^{-2} – 10^{-3} µg g^{-1} day^{-1} are Ba, Ce, Mn, Sr, Ti, Zn, Zr and Br, Co, Cr, Cs, Ga, La, Nd, Rb, Sn and V. The presence of these elements in air shows signs of coal combustion that is used for power generation, used in numerous brick kilns around these cities and through domestic usage of coal. Moreover input of these elements could be due to large number of two and three wheeler motorcycles and rickshaws in both cities. The remaining elements lie in lower range of 10^{-4} – 10^{-5} µg g^{-1} day^{-1}. Table 3 and 4 also show that major route of exposure of these elements through APM for humans is through ingestion while negligible risk contribution is through inhalation and dermal contact exposures.

Table 4: Ingestion, inhalation, dermal and total dose from trace elements quantified for Gujranwala city (All values in $\mu g.g^{-1}day^{-1}$)

Elements	Mean	D_{ing}	D_{inh}	D_{derm}	D_{total}
Al	2.52E+05	1.65E+00	4.62E-05	4.63E-03	1.66E+00
Ba	7.34E+03	4.82E-02	1.35E-06	1.35E-04	4.84E-02
Br	2.27E+02	1.49E-03	4.17E-08	4.18E-06	1.50E-03
Ca	1.49E+06	9.82E+00	2.74E-04	2.75E-02	9.84E+00
Ce	1.63E+04	1.07E-01	2.99E-06	3.00E-04	1.07E-01
Co	1.21E+02	7.96E-04	2.22E-08	2.23E-06	7.98E-04
Cr	9.92E+04	6.52E-01	1.82E-05	1.83E-03	6.54E-01
Cs	7.50E+01	4.93E-04	1.38E-08	1.38E-06	4.95E-04
Eu	4.00E+00	2.63E-05	7.35E-10	7.36E-08	2.64E-05
Fe	3.97E+05	2.61E+00	7.29E-05	7.30E-03	2.62E+00
Ga	1.89E+02	1.24E-03	3.47E-08	3.48E-06	1.25E-03
Hf	4.28E+01	2.81E-04	7.86E-09	7.88E-07	2.82E-04
Hg	1.32E+00	8.66E-06	1.01E-05	2.42E-08	1.88E-05
K	2.00E+05	1.31E+00	3.67E-05	3.68E-03	1.32E+00
La	1.93E+02	1.27E-03	3.55E-08	3.55E-06	1.27E-03
Lu	1.96E+00	1.29E-05	3.60E-10	3.61E-08	1.29E-05
Mg	1.57E+05	1.03E+00	2.88E-05	2.89E-03	1.03E+00
Mn	3.09E+03	2.03E-02	5.68E-07	5.69E-05	2.04E-02
Na	2.25E+05	1.48E+00	4.14E-05	4.15E-03	1.49E+00
Nd	9.20E+01	6.05E-04	1.69E-08	1.69E-06	6.07E-04
Rb	1.33E+03	8.76E-03	2.45E-07	2.45E-05	8.79E-03
Sb	2.10E+02	1.38E-03	3.86E-08	3.87E-06	1.38E-03
Sc	5.13E+01	3.37E-04	9.42E-09	9.44E-07	3.38E-04
Se	1.34E+01	8.81E-05	2.46E-09	2.47E-07	8.84E-05
Sm	3.10E+01	2.04E-04	5.70E-09	5.71E-07	2.04E-04
Sn	5.36E+02	3.52E-03	9.85E-08	9.87E-06	3.53E-03
Sr	9.69E+03	6.37E-02	1.78E-06	1.78E-04	6.39E-02
Ta	7.92E+00	5.21E-05	1.46E-09	1.46E-07	5.22E-05
Tb	6.21E+00	4.08E-05	1.14E-09	1.14E-07	4.09E-05
Th	5.69E+01	3.74E-04	1.05E-08	1.05E-06	3.75E-04
Ti	4.48E+04	2.95E-01	8.24E-06	8.26E-04	2.96E-01
V	5.17E+02	3.40E-03	9.50E-08	9.52E-06	3.41E-03
Yb	5.51E+00	3.62E-05	1.01E-09	1.01E-07	3.63E-05
Zn	4.22E+04	2.78E-01	7.75E-06	7.77E-04	2.78E-01

The values of reference dose for all three exposure routes and the calculated values of HI for Faisalabad city are given in Table 5. The maximum HI values of 2.0, 1.01 and 1.46 correspond to Al, Cr and Sb respectively. These values are higher than the recommended limit, implying an environmental hazard risk. Al contents are higher in this city than Gujranwala. Major contribution of Al to HI is probably through natural sources of soil (as the city encounters frequent dry periods and heavy dust storms [19-20]. High Al from soil can be attributed to unpaved roads and bare road sides without grass. Another source of this element can be containers used in the manufacture and processing of some foods, cosmetics and medicines, and also from water purification plants. Main Al contribution was observed for the SPM collected from Kotwali Chowk (KCA) and Maqbool Road (MRA) areas [14]. Since to the North of both sites is the city of Gujranwala therefore, Al-containing particles are possibly transported from this city. High Al contents can also be attributed to the vehicular source as this element is used in engines, body frame, axis and wheel rims. Moreover, foundries for castings Al located in these areas may also contribute to SPM inventory. The estimated HI for Cr is high due to elevated levels of this element in filters collected from KCA and MRA sites. Cr compounds are irritating to eyes, mucous membranes and skin. Chronic exposure to chromium (VI) compounds can cause

Table 5: Ingestion, inhalation, dermal hazard quotients (HQ) and hazard index (HI) calculated for selected trace elements of Faisalabad

Element	RfD_{ing}	RfD_{inh}	RfD_{derm}	HQ_{ing}	HQ_{inh}	HQ_{derm}	∑HQi=HI
Al	1.00E+00	1.43E-03	1.00E-01	1.91E+00	3.73E-02	5.34E-02	2.00E+00
Ba	7.00E-02	1.43E-04	4.90E-03	6.02E-01	8.24E-03	2.41E-02	6.35E-01
Co	2.00E-02	1.43E-04	4.90E-03	7.26E-02	2.84E-04	8.29E-04	7.37E-02
Cr	3.00E-03	2.86E-05	6.00E-05	8.88E-01	2.60E-03	1.24E-01	1.01E+00
Mn	4.60E-02	1.43E-05	1.84E-03	5.28E-01	4.74E-02	3.69E-02	6.12E-01
Sb	4.00E-04	--	8.00E-06	1.28E+00	--	1.80E-01	1.46E+00
Sr	6.00E-01	--	1.20E-01	3.23E-02	--	4.52E-04	3.27E-02
V	7.00E-03	--	7.00E-05	6.76E-01	--	1.89E-01	8.66E-01
Zn	3.00E-01	--	6.00E-02	1.32E-01	--	1.85E-03	1.34E-01

Table 6: Ingestion, inhalation, dermal Hazard Quotients and Hazard Index calculated for selected trace elements of Gujranwala

Element	RfD_{ing}	RfD_{inh}	RfD_{derm}	HQ_{ing}	HQ_{inh}	HQ_{derm}	∑HQi=HI
Al	1.00E+00	1.43E-03	1.00E-01	1.65E+00	3.23E-02	4.63E-02	1.73E+00
Ba	7.00E-02	1.43E-04	4.90E-03	6.89E-01	9.43E-03	2.76E-02	7.26E-01
Co	2.00E-02	1.43E-04	4.90E-03	3.98E-02	1.55E-04	4.55E-04	4.04E-02
Cr	3.00E-03	2.86E-05	6.00E-05	2.17E+02	6.37E-01	3.04E+01	2.49E+02
Mn	4.60E-02	1.43E-05	1.84E-03	4.42E-01	3.97E-02	3.09E-02	5.13E-01
Sb	4.00E-04		8.00E-06	3.45E+00		4.83E-01	3.94E+00
Sr	6.00E-01		1.20E-01	1.06E-01		1.49E-03	1.08E-01
V	7.00E-03		7.00E-05	4.86E-01		1.36E-01	6.22E-01
Zn	3.00E-01		6.00E-02	9.25E-01		1.30E-02	9.38E-01

permanent eye injury, unless appropriately treated. High Cr levels can be observed for the presence of tanneries and electroplating industries in the vicinity [21]. Highest HI for Sb in Faisalabad was also calculated for MRA site. Since the wind flows from North in this area therefore some impact of transported Sb particles may also be coming from Gujranwala. Many compounds of Sb are toxic and Sb poisoning is medically very familiar to as poisoning. In small doses, antimony can cause headache, depression and dizziness [22]. But in case of high doses cause frequent vomiting that may lead to death in a short period of time [23]. High HI for Sb can be attributed to the chemicals used in gardens, paints, tanneries, plastic industry, batteries and to numerous chemical industries located in these areas.

Hazard Indices calculated for Gujranwala city are presented in Table 6. Most of HI values for Gujranwala are comparable with those calculated for Faisalabad; however its HI values for Al, Cr and Sb are 1.73, 2.49E+02 and 3.94 respectively. Elevated levels of Al were quantified for APM collected from Baghbanpura Chowk (BPC) Sheikhupura Road (SRA) sites probably due to suspended soil. These areas experience wind mostly from South and Southwest coming from Sheikhupura and Lahore cities, therefore vehicular contribution of this element is also possible. Especially high HI levels for Cr due to the presence of the small tanneries and chrome plating industries around Sialkot road (SRG) imply alarming health risk for the inhabitants of Gujranwala city. Moreover, wind direction in this area is mostly from Southeast with Sialkot and Lahore located in this direction with main lather industries in these cities. In Pakistan largest leather producing industries are located in Sialkot where tanneries effluent show average value of Cr as 200.6 while its NEQS is 1.0. High Sb in the particulate matter of SRA area with parks, metal works units and other industries contributes to elevated HI value. It is important to note here that HI for Zn is at its critical value in Gujranwala and indicates the presence of anthropogenic sources like heavy vehicular activity where it may be released from the wearing of tyres [24].

Fig. 1 has been incorporated for hazard risk comparison between the two cities. The indices of these elements calculated for Faisalabad are in the sequence Al > Sb > Cr > V > Ba > Mn > Zn > Sr > Co, while for Gujranwala the sequence is Cr > Sb > Al > Zn > Ba > V > Mn >Co > Sr. HI value for Al is slightly lower while HI for Cr is comparatively higher in Gujranwala city as compared to Faisalabad. Ba is comparable in both cities. Moreover HI for Sb, Sr and Zn are higher in Gujranwala city whereas Cr hazard levels are very high in Gujranwala. It is suggested that to protect the health of the local population of these cities necessary control measures and mitigation strategies should be enforced especially to control the release of Al, Cr, Sb and Zn emissions. Their SPM contents can also be reduced by proper carpeting of all roads, vegetation plantation and construction of pavements to reduce exposed soil [25].

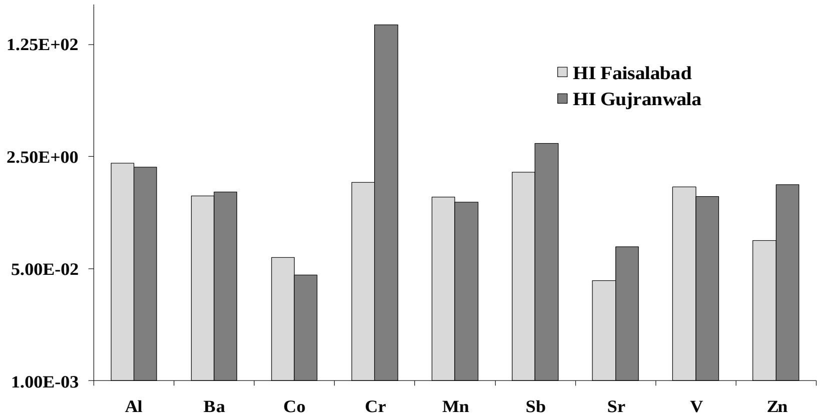

Figure 1: Comparison of hazard indices of Faisalabad and Gujranwala

4. Conclusions

Theoretical risk assessment for different inorganic elements in SPM collected on filter papers in the cities of Faisalabad and Gujranwala has been studied. Elemental doses and hazard indices have been evaluated for different elements formerly characterized using INAA. In Faisalabad Al, Fe, K, Mg, and Na while in Gujranwala Al, Ca, Fe, K, Mg and Na were found to contribute to alarming levels of ED. For elements for which reference doses (RfDs) were available like Al, Ba, Co, Cr, Mn, Sb, Sr, V and Zn, HQ and HI have also been calculated. High HIs of 2.0, 1.01 and 1.46 for Al, Cr and Sb were observed Faisalabad SPM whereas, HIs values in Gujranwala SPM were 1.73, 2.49E+02 and 3.94 respectively corresponding to Al, Cr and Sb. Cr exceeds the critical level in Gujranwala probably due to tanneries, chrome plating industries and other metallic industries posing serious health hazard index.

Acknowledgements

We are grateful for the technical assistance provided by Mr. Lal Habib and acknowledge the Reactor Operation Group at PINSTECH for the neutron irradiation of the samples.

References

[1] S. M. Almeida, M. C. Freitas, M. Reis, T. Pinheiro, P. M. Felix, and C. A. Pio, "Fifteen years of nuclear techniques application to suspended particulate matter studies", J. Radioanal.Nucl. Chem., vol. 297, pp. 347-356, 2013.

[2] Y. Faiz, M. Tufail, M. T. Javed and M. M. Chaudhry, "Road dust pollution of Cd, Cu, Ni, Pb and Zn along Islamabad Expressway, Pakistan", Microchem. J., vol. 92, pp. 186–192, 2009.

[3] W. H. Schroeder, M. Dobson, D. M. Kane and N. D. Johnson, "Toxic Trace Elements Associated with Airborne Particulate Matter: A Review", Air Waste Manag. Assoc., vol. 37, pp. 1267-1285, 1987.

[4] World Health Organization (WHO). "The world health report: a safer future : Global public health security in the 21st century", Geneva, Switzerland. F. Zereini, C. L. S. Wiseman (Eds.). Urban Airborne Particulate Matter: Origin, Chemistry, Fate and Health Impacts, Springer- Verlag, Berlin, 2007.

[5] F. Zereini and C. L. S. Wiseman, "Platinum Group Elements in Trace Elements in Soils", P. S. Hooda (Ed.), John Wiley & Sons Ltd, Chichester, UK, 2010.

[6] S. Charlesworth, E. De. Miguel and A. Ordóñez, "A review of the distribution of particulate trace elements in urban terrestrial environments and its application to considerations of risk", Environ. Geochem. Health., vol. 33, pp. 103-123, 2011.

[7] A. Mukhtar and A. Limbeck, "Recent developments in assessment of bio-accessible trace metal fractions in airborne particulate matter: A review", Analytica Chim. Acta., vol. 774, pp. 11-25, 2013.

[8] S. Waheed, A. Rahman, N. Khalid and S. A. Ahmad, "Assessment of air quality of two metropolitan cities in Pakistan: Elemental analysis using INAA and AAS", Radiochim. Acta., vol. 94, pp. 161-166, 2006.

[9] M. Waisberg, P. Joseph, . Hale, D. Beyersmann, "Molecular and cellular mechanisms of cadmium carcinogenesis", Toxicol., vol. 192, pp. 95-117, 2003.

[10] M. Nadal, M. Schuhmacher, J. L. Domingo, "Metal pollution of soils and vegetation in an area with petrochemical industry", Sci. Total Environ., vol. 321, pp. 59-69, 2004.

[11] F. Dominici, D. Roger, R. D. Peng, C. D. Barr and M. L. Bell "Protecting human health from air pollution: Shifting from a single-pollutant to a multi-pollutant approach", Epidemiology, vol. 21, pp. 187–194, 2012.

[12] P. Shi, J. Xiao, Y. Wang and L. Chem, "Assessment of ecological and human health risks of heavy metal contamination in agriculture soils disturbed by pipeline construction", Int. J Environ. Res. Public Health, vol. 11, pp. 2504–2520, 2014.

[13] E. Sánchez-Triana, S. Enriquez, J., Afzal, A. Nakagawa and A. S. Khan, "Cleaning Pakistan's air: Policy options to address the cost of outdoor air pollution", World Bank Group Publications, Washington, DC, USA. ISBN: 978-1-4648-0235-5, 2014.

[14] S. Waheed, A. Rahman, M. Daud, S. Rahman, Z. Islam and S. Ahmad, "Air quality evaluation of some industrial cities of Pakistan using INAA and AAS", Radiochim. Acta., vol. 93, pp. 487–495, 2005.

[15] A. D. Lemly, "Evaluation of the hazard quotient method for risk assessment of selenium", Ecotoxicol. Environ. Safety, vol. 35, pp. 156–162, 1996.

[16] G. F. Nordberg, K. Nogawa, M. Nordberg and J. M. Friedmann, "Cadmium. Handbook on the Toxicology of Metals", Amsterdam: Elsevier, pp. 445–486, 2007.

[17] U.S. EPA, "Soil screening guidance: Technical background document", Office of Solid Waste and Emergency Response. U.S. Environmental Protection Agency. Washington, DC, 1996.

[18] US. DoE, "RAIS: Risk Assessment Information System", U.S. Department of Energy. 2004.

[19] S. Waheed, N. Siddique, M. Arif, M. Daud and A. Markwitz, "Size-fractionated airborne particulate matter characterization of a residential area near Islamabad airport by IBA methods", J. Radioanal. Nucl. Chem., vol. 293, pp. 279–287, 2012.

[20] W. Liu, P. K. Hopke, Y. Han, S. M. Yi, M. T. Holsen, S. Cybart, K. Kozlowskic and M. Milligan, "Application of receptor modeling to atmospheric constituents at Potsdam and Stockton, NY", Atmos. Environ., vol. 37, pp. 4997-5007, 2003.

[21] A. N. Costa, V. Moreno, M. J. Prieto, A. M. Urbano and M. C Alpoim,. "Induction of morphological changes in BEAS-2B human bronchial epithelial cells following chronic sub-cytotoxic and mildly cytotoxic hexavalent chromium exposures", Mol Carcinog., vol. 49, pp. 582–591, 2010.

[22] I. I. Roberts, O. E. Orisakwe, "Evaluation of potential dietary toxicity of heavy metals in some common Nigerian beverages: A look at antimony, tin and mercury", QScience Connect vol. 2, p. 2011:2 doi: 10.5339/connect.2011.2, 2011.

[23] S. Sundar, J. Chakravarty, "Antimony Toxicity", Int. J Environ Res Public Health. vol. 7(12), p. 4267–4277, 2010.

[24] E. Von-Schneidemesser, E. A. Stone, T. A. Quraishi, M. M. Shafer, J. J. Schauer, "Toxic metals in the atmosphere in Lahore, Pakistan", Sci. Total Environ., vol. 408, p. 1640-1648, 2010.

[25] Y. Faiz, N. Siddique, M. Tufail, "Pollution level and health risk assessment of road dust from an expressway", J. Environ. Sci. Health, Part A., vol. 47, p. 818–829, 2012.

[26] U.S. EPA. "Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E) EPA/540/R/99/005". Supplemental Guidance for Dermal Risk Assessment -Interim Guidance., Washington, D.C. 2001.

[27] R. Van den Berg, "Human exposure to soil contamina-tion: a qualitative and quantitative analysis towards proposals for human toxicological intervention value", RIVM Publications, 1995.