Soil & Environ. 27(1): 88-92, 2008

Characterization and quantification of mineral phases in the soil of metropolitan Faisalabad causing air pollution

M.Y. Hussain[1], Islam-ud-Din[2], M. Yousaf[1*] and M. Imran[1]
[1]Department of Physics, Faculty of Sciences, University of Agriculture, Faisalabad
[2]Department of Mathematics and Statistics, Faculty of Sciences, University of Agriculture, Faisalabad

Abstract

Soil is believed to be the source of particulate matter that when suspends in air can cause air pollution which upon inhaling can affect human health. A study was conducted to examine mineral phases found in the soils and air collected from urban areas of Faisalabad. X-ray diffraction technique was employed for the qualitative and quantification characterization of mineral phases existing both in soil and air samples collected from various locations of the city. The results of qualitative phase analysis confirmed the presence of illite, albite, calcite and quartz both in soil and air samples whereas the quantitative phase analysis showed that illite was the dominant constituent both in soil and air samples having weight percentages ranging from 78.5 to 88.2% in soil and for air samples, it ranged from 71.1 to 81.6 weight percent. The other mineral phases, namely, albite, calcite, and quartz were present in minor quantities varying in weight percentages raging from 6.1 to 13.7%, 1.5 to 4.9% and 1.76 to 3.2% in soil, respectively whereas in air their respective weight percentages were from 8.5 to 9.38%, 5.1 to 7.6%, 1.1 to 2.3%, respectively. Statistical analysis reveals that all the mineral phases homogeneously exist in the soil of the investigated areas of Faisalabad city.

Keywords: Pollution, mineral phase analysis, X-ray diffraction technique, characterization

Introduction

The atmosphere of a certain locality continuously absorbs a wide range of substances of different phases such as solids, liquids and gases both from natural and man-made sources such that these substances travel through air and disperse in the atmosphere. Any other particulate material added into the naturally occurring air causes pollution, and hence the portion of these particulate materials when interact with the environment to cause toxicity and diseases turn into pollutant (Stern and Athur, 1976) and these could be harmful to man and the other living beings (Hamid, 1994; O'Neil and Hajat, 2005). The particulates having size 1 to 10 µm alone or in combination with the other pollutants can cause health problems like sickness of respiratory tract, cough, phlegm, shortness of breath and chest pain, particularly in young children (Heinrich and Slama, 2007; Miller, 1999). Further, these particulates existing in air may reduce visibility and also cause contamination of surface water, impairment to the growth of agricultural crops, forest decline and are equally harmful to our lives, living conditions and cultural assets (Qureshi, 1999). The major source of particulate matter suspended in air is soil. Thus, the coexistence of soil-dust is most probably the result of uncontrolled disposal of solid waste in open lands and fields such that their undigested amount go to air as a result of erosion of soil by strong winds etc. (Hamid, 1994). The study of phase analysis of particulate matter existing in air is an active field of research (Schutz *et al*., 1987). In this study soil and air samples from different localities of urban areas of Faisalabad were colleted and XRD technique (Davis *et al*., 1985; Zhou and Tazaki, 1996; Esteve and Ruis, 1997) was employed for the qualitative identification and quantitative characterization of mineral phases present in these samples.

Materials and Methods

Samples of soil and air were collected from different locations; Jaranwala road, Jhumra road, Old green market road and Sityana road in almost 10 km circle within municipal range. The collected samples were oven dried after drying in shade and then strained for the removal of fibrous material, if any. The dried samples were stored in clean, dry and capped bottles. The sieved and dried samples were ground by mortar and pestle for a sufficient time until homogenized to powder. Reduction of powders to fine particles ensures enough participation in the x-ray diffraction process and the recommended size is around 1-5 µm, especially if quantification of various phases is required (Klug and Alexander, 1974; Cullity, 1978). Samples were loaded into the specific rectangular aluminum sample holder of the diffractometer (Rint 2000 series Rigaku) already washed thoroughly with acetone. The loaded sample holder was then placed in the goniometer of the diffractometer. Hanawalt method was employed for qualitative phase analysis. In this method 'd' values and 'integrated intensities' of the reflections in XRD pattern were employed (Cullity, 1978) for phase identification.

*Email: myh_49@yahoo.co.uk

Matrix-flushing method was used (Chung, 1974) for the quantitative phase analysis. This method gives the percentage composition of a component 'i' in a mixture of 'n' components, as is given in Equation (1):

$$X_i = \left[\frac{K_i}{I_i} \sum_{i=1}^{n} \frac{I_i}{K_i} \right]^{-1} \times 100 \qquad (1)$$

In this equation I_i is the integrated intensity and K_i is the relative intensity ratio given by $K_i = I_i/I_{KCl}$ calculated by mixing the component 'i' with a standard material KCl in a ration of 50:50. Relative intensity of a mineral was calculated by the ratio of the intensity of that mineral to the intensity of KCl and the relative intensities found for illite, quartz, albite, calcite, clinochlore, talc and gypsum were 0.20, 0.85, 0.36, 0.74, 0.23, 0.32 and 0.83, respectively. The integrated intensity (I_i) of each of the mineral was calculated by multiplying maximum intensity (I_{max}) and FWHM (full width at half maximum). Using the values of K_i and I_i in Equation 1, the weight percentage of the phases present in a sample was computed.

Results and Discussion

In this study, phases such as albite, dolomite, chlorite/clinochlore, pyrite, mullite, halite, illite, quartz, kaolinite, calcite, gypsum, magnetite, glaubesite, aragonite, cristobalite, crocidolite, briotite and anthrophyllite (Rich and Barnhisel, 1977) were searched for all the samples but only the phases, namely illite, albite, calcite and quartz were identified (Table 1 a, b). In our study, (Table 2) shows that for Jaranwala road, Jhumra road, Old green market road, Samundry and Sityana roads, the illite was the dominant constituent found in all the samples of soil with its weight percentage 78.5, 81.2, 85.2, 87.8 and 88.2%, respectively. Similarly in air samples, illite was found as a dominant constituent in weight percentages 80.4, 77.2, 81.6, 71.1 and 74.3% for all the places, respectively. The second largest phase found in soil samples was albite having weight percentage 13.7, 7.28, 11.1, 6.3 and 6.1%, respectively. Albite was also the second largest phase found for air samples in weight percentages 8.9, 9.08, 9.0, 8.5 and 9.38%, respectively.

The third phase in soil samples was calcite having weight percentage 4.9, 3.56, 1.5, 2.3 and 3.16%, respectively. It was also the third largest phase for air samples having weight percentages 7.2, 5.1, 6.98, 6.8 and 7.6%, respectively. The fourth phase found in soil samples was quartz having its weight percentage 3.2, 1.76, 2.2, 2.2 and 2.25%, respectively. Quartz was also the fourth largest phase found in air samples having weight percentages 2.0, 1.1, 2.3, 1.1 and 1.5%, respectively. The results of our study are in close agreement with those obtained by Esteve and Rius (1997) that they had found similar results in their studies by using X-ray diffraction technique. Davis and Jixiang (2000) identified the mineral phase in their study by using X-ray diffraction technique which is broadly similar to those found in our study.

The purpose of this study for the identification of minerals phases in the soil was to investigate for the source of air pollutants existing in the local atmosphere of urban Faisalabad. It is found that the mineral phases namely illite, albite, calcite and quartz found in soil samples were also present in the air samples. This study proposed that the identified minerals at all the selected sites were accumulated into the air of urban areas of Faisalabad city possibly through wind erosion and human related activities. Moreover, these results also reveal that the mineral phases, which are high in weight percentage in the soil, are also high in the air of local area. However, the weight percentage of some mineral phases is high in air than their presence in soil, and this may be possible because of the migratory effect by wind erosion. This fact leads us to infer that soil of a certain locality is an active source for the air pollution of that area. However, for the phases, which do not exist in the local soil but are present in the air of that area, it is proposed that their source may be away from the territory of urban Faisalabad. In addition, the homogeneity in the identified phases in these samples at all the selected sites is apparently due to the fact that suspended particulate matter over the Faisalabad city is well mixed as a product of continuous deposition and uptake from the ground.

To see the difference among different phases regarding soil pollutants as source to air pollution, analysis of variance technique was employed for each mineral phase for the selected areas and the results obtained are presented in Table 3. The dominant phases in focus were illite, quartz, albite and calcite respectively. The p-values (0.721, 0.893, 0.343 and 0.768) show that mineral phases illite, quartz, albite and calcite cannot be considered significantly different in all the areas. These results also help to make an assessment that in all the investigated areas, the mineral phases in soil are almost behaving equally in causing the air pollution of the local environment.

For controlling the suspended particulate matter in the air, it is suggested that government must run a campaign on missionary basis for a lot of tree

Table 3. Analysis of variance for mineral phases found in the samples collected from various localities of urban Faisalabad

Pollutant	DF	MS	MSE	P-value
illite	2	11.3	5.7	0.721
quartz	2	0.99	0.49	0.893
albite	2	98.7	49.4	0.343
calcite	2	6.2	3.1	0.768

Table 1(a). Qualitative phase analysis of the mineral phases found in the soil samples collected from various localities of urban Faisalabad

Peak	Jaranwala road			Jhumra road			Old green market road			Samundry road			Sityana road		
	d-value (A^o)	Integrated Intensities (I_o)	Identified mineral phases	d-value (A^o)	Integrated Intensities (I_o)	Identified mineral phases	d-value (A^o)	Integrated Intensities (I_o)	Identified mineral phases	d-value (A^o)	Integrated Intensities (I_o)	Identified mineral phases	d-value (A^o)	Integrated Intensities (I_o)	Identified mineral phases
2	-	-	-	-	-	-	4.22	168.08	CA	-	-	-	-	-	-
3	-	-	-	4.22	181.44	CA	3.50	77.66	AL	4.22	134.84	CA	4.22	144.02	CA
4	-	-	-	3.53	96.72	CL	3.32	112.96	IL	3.50	84.72	AL	3.50	79.07	AL
5	-	-	-	3.32	127.48	IL	3.22	264.75	AL	3.32	101.66	IL	3.32	860.61	IL
6	4.43	62.64	IL	3.18	182.14	AL	3.01	74.03	CA	3.18	131.31	AL	3.18	106.60	AL
7	4.22	268.28	CA	3.01	182.85	CA	-	-	-	3.01	100.25	CA	3.01	113.66	CA
8	-	-	-	2.27	73.42	AL	2.27	74.83	AL	2.86	65.65	G	2.56	57.18	IL
9	3.64	54.16	AL	-	-	-	-	-	-	2.45	42.39	AL	2.45	87.54	AL
10	3.50	84.78	AL	1.81	105.19	Q	1.81	116.49	Q	-	-	-	2.27	56.48	AL
11	-	-	-	154	56.04	Q	1.54	61.23	Q	1.81	108.01	Q	2.12	34.38	Q
12	3.32	744.18	IL	1.37	115.54	Q	1.37	106.60	Q	1.66	45.69	Q	-	-	-
13	3.18	234.39	AL							1.54	67.82	Q	1.81	92.48	Q
14	3.01	172.26	CA							1.37	51.13	Q	1.37	62.17	Q
16	2.27	129.90	AL												
17	2.12	103.78	Q												
19	1.81	129.90	Q												

Legend: **T** (Talc); **IL** (Illite); **Q** (Quartz); **CA** (Calcite); **AL** (Albite); **G** (Gypsum); **CL** (Clinochlore)

Table 1(b). Qualitative phase analysis of the mineral phases found in the air samples collected from various localities of urban Faisalabad

Peak	Jaranwala road			Jhumra road			Old green market road			Samundry road			Sityana road		
	d-value (A^o)	Integrated Intensities (I_o)	Identified mineral phases	d-value (A^o)	Integrated Intensities (I_o)	Identified mineral phases	d-value (A^o)	Integrated Intensities (I_o)	Identified mineral phases	d-value (A^o)	Integrated Intensities (I_o)	Identified mineral phases	d-value (A^o)	Integrated Intensities (I_o)	Identified mineral phases
4	-	-	-	4.66	22.13	T	3.50	42.86	AL	4.66	35.30	T	-	-	-
5	5.43	49.42	IL	4.43	42.36	IL	3.32	401.71	IL	4.43	27.78	IL	4.43	46.59	IL
6	4.22	100.95	CA	4.22	114.37	CA	3.18	79.77	AL	4.22	108.72	CA	4.22	124.25	CA
7	-	-	-	3.01	182.85	CA	3.01	127.08	CA	-	-	-	-	-	-
8	-	-	-	3.50	91.07	AL	2.81	45.18	AL	3.50	68.48	AL	3.65	28.12	CL
9	3.67	30.14	IL	3.32	540.10	IL	2.56	24.49	IL	3.32	464.54	IL	3.50	62.12	AL
10	3.50	67.07	AL	3.18	114.37	AL	2.49	33.91	CA	3.18	100.25	AL	3.32	413.01	IL
11	3.32	391.12	IL	3.01	132.72	CA	2.45	30.61	AL	3.01	165.19	CA	3.18	93.89	AL
12	3.18	78.36	AL	2.86	27.31	G	2.27	39.53	AL	2.81	41.65	CA	3.01	157.43	CA
13	3.01	130.61	CA	2.54	36.00	CL	2.08	35.30	CA	2.54	67.03	CL	2.82	38.83	CA
14	2.86	26.37	G	2.44	50.12	CL	-	-	-	2.44	25.90	AL	-	-	-
16	2.44	28.26	AL	-	-	-	1.81	49.42	Q	2.12	43.77	Q	2.37	23.29	CL
17	2.27	52.24	CA	1.86	33.88	CA	1.54	28.26	Q	2.08	38.12	CA	2.27	54.36	AL
20	1.90	21.66	CA	1.53	27.75	Q	-	-	-	1.87	22.60	T	-	-	-
21	-	-	-	1.37	30.35	Q	-	-	-	1.81	30.61	Q	1.90	44.68	CA
22	1.81	42.36	Q	-	-	-	-	-	-	-	-	-	1.86	38.12	CA
23	-	-	-	-	-	-	-	-	-	-	-	-	1.81	36.26	Q

Legend: **T** (Talc); **IL** (Illite); **Q** (Quartz); **CA** (Calcite); **AL** (Albite); **G** (Gypsum); **CL** (Clinochlore)

Table 2. Weight percentage of phases in soil samples

Phases	Jaranwala road		Jhumra road		Old green market road		Samundry road		Sityana road	
	Soil	**Air**	**Soil**	**Air**	**Soil**	**Air**	**Soil**	**Air**	**Soil**	**Air**
Illite	78.5	80.4	81.2	77.2	85.2	81.6	87.8	71.1	88.2	74.3
Albite	13.7	8.9	7.28	9.08	11.1	9.0	6.3	8.5	6.1	9.38
Calcite	4.9	7.2	3.56	5.1	1.5	6.98	2.3	6.8	3.16	7.6
Quartz	3.2	2.0	1.76	1.1	2.2	2.3	2.2	1.1	2.25	1.5
Clinochlore	0	0	6.5	4.4	0	0	0	8.93	0	5.2
Gypsum	0	1.3	0	0.9	0	0	1.36	0	0	0
Talc	0	0	0	1.9	0	0	0	3.3	0	0

plantation for the eradication of the unnecessary addition of dust in the atmosphere of Faisalabad city since trees are the best antidote for the cleaning of air. The concerned authorities, the corporate sector and general public must fight together against the demon of pollution as this is the real threat to the human health.

References

Chung, F.H. 1974. Quantitative interpretation of x-ray diffraction patterns of mixtures. Matrix Flushing Method for quantitative multicomponent analysis. *Journal of Applied Crystallography* 7: 519-525.

Cullity, B.D. 1978. Elements of x-ray diffraction, 2nd Edition. Addison-Wesley Publishing Company. Menlo Park, California. p. 415-417.

Davis, B., L. Johnson, R. Stevens, W. Courtney and D. Safriet. 1985. Quartz content and elemental composition of aerosols from selected sites of environmental protection agency (EPA) inhalable particulate network. *Government Reports, Announcements and Index* 24: 771-782.

Davis, B.L. and D. Jixiang. 2000. Airborn particulate study in five cities of China. *Atmospheric Environment* 34: 2703-2711.

Esteve, V. and J. Rius. 1997. Quantitative X-Ray diffraction phase analysis of coarse airborne particulate collected by cascade impactor sampling. *Atmospheric Environment* 31(23): 3963-3967.

Hamid, S.M. 1994. Fundamentals of Environmental Pollution. CBS publishers and Distributors, 485, Jain Bhawan, Bhola Nath Nagar, Delhi-32, India. 12p.

Heinrich, J. and R. Slama. 2007. Fine particles, a major threat to children. *International Journal of Hygiene and Environmental Health* 210(5): 617-622.

Kenneth, W. and W. Cecilf. 1981. Air pollution its origin and control. 2nd Edition. Harper and Row Publishers, New York. 9p.

Klug, H.P. and L.E. Alexander. 1974. X-Ray Diffraction Procedures. John Wiley and Sons. New York. 996p.

Miller, G.T. 1999. Sustaining the Earth. An Integrated Approach. 4th Edition. Cole Publishing Company. p. 264-274.

O'Neil, M.S. and S. Hajat. 2005. Impact of control for air pollution and respiratory epidemics on the estimated associations of temperature and daily mortality. *International Journal of Biometeorology* 50: 121-129.

Qureshi, I.H. 1999. Air pollution sources, impact and monitoring. *The Nucleus* 36(3-4): 117-123.

Rich, C.I. and R.I. Barnhisel. 1977. Preparation of clay samples for X-ray Diffraction Analysis. p. 797-808. In: Minerals in Soil Environments. Published by Soil Science Society of America, Madison, Wisconsin, USA.

Schuetz, L. and M. Sebert. 1987. Mineral aerosols and source identification. *Journal of Aerosol Science* 18(1): 1-10.

Stern and C. Athur. 1976. Air Pollution. 3rd Edition, Academic Press, New York. 1p.

Zhou, G.P. and K. Tazaki. 1996. Seasonal variation of gypsum in aerosol and its effect on acidity of wet precipitation on seaside of Japan. *Atmospheric Environment* 30(19): 3301-3308.