

## Multivariate analysis of trace metals in textile effluents in relation to soil and groundwater

S. Manzoor, Munir H. Shah, N. Shaheen, A. Khalique, M. Jaffar\*

*Department of Chemistry, Quaid-i-Azam University, Islamabad 45320, Pakistan*

Received 8 July 2005; received in revised form 17 November 2005; accepted 20 January 2006

Available online 4 April 2006

### Abstract

This paper deals with the multivariate analysis of metal data in effluents, soil and groundwater to find the distribution and source identification of the selected metals in the three media. Samples were collected from three textile industries located in Hattar Industrial Estate, Pakistan. Metals were estimated by flame atomic absorption spectrophotometry. The results showed elevated levels of Cr, Pb, Ni, Co, Fe, Ca, Na, K and Zn in these media, following the order: soil > effluent > water. Principle component analysis (PCA) of the data showed that the textile effluents are contaminating the soil wherein Cr and Pb were dominant toxic metals having concentrations of 5.96 mg/kg and 4.46 mg/kg, respectively. Other toxic metals such as Co, Cd, Zn, Ni, Mn and Fe, were found to have common origin in the textile effluents. The correlation study along with linear regression and PCA, supported the fact that various elevated metal concentrations emerged from the textile industrial effluents ultimately leading to contamination of the soil and groundwater in their proximity. The estimated metal levels in the water/soil system are compared with the safe limits laid down by WHO.

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*Keywords:* Metals; Principal component analyses; Textile effluents; Soil contamination; Groundwater

### 1. Introduction

In the wake of intense industrial activities all over the world, degradation of environmental quality is resulting in serious long-term adverse health effects [1]. The problem of environmental pollution arising from essential industrial growth is, in practical terms, the problem of disposal of industrial waste, whether solid, liquid or gaseous. These wastes have the potentiality of ultimately polluting soil and water they come in contact with. Studies have shown that areas in close proximity of industrial activity are marked by contamination of soil, water and agricultural fields, downstream [2,3]. The effluent based soil and water pollution aspects have thus remained the main focus point of several studies on the distribution of heavy toxic metals in effluents in relation to their impact on ground water quality, depth of aquifer, type of soil and human activities in and around the target area. To this effect, relevant data are reported in literature for K, Na, Cd, Cu, Pd, Ni, and Zn [4–7]. Earlier research evidences that

boosted up industrial production gives rise to saturation levels of Cr, Cu, Zn, and Ni in the environment in areas close to industrial estates [8]. Specific studies on evaluating the toxicity caused by textile effluents rich in the toxic metals have also been carried out [9,10].

As in any developing country, the industrial growth in Pakistan has been currently boosted up to substantially enhance the economic growth without implementation of regulatory control measures for effluent quality. The Industrial Estate, Hattar, NWFP (Fig. 1) houses a large number of textile units where from the effluents rich in organic and inorganic contents as well as heavy metals, have been found to result in toxic effects on nearby plants and vegetation [11,12]. The environmental contamination situation in the area is becoming more serious day by day. This situation demands a strict treatment program for the effluents from textile industry involving safe disposal of the effluents so that the soils are safeguarded against elevated levels of the toxic metals, as reported for other parts of the world [13–16]. It is high time that characterization and distribution of toxic metals in textile effluents be monitored to evolve data that might be used in futuristic effluent management and control studies, as reported earlier [17–20].

\* Corresponding author. Tel.: +92 51 9219811; fax: +92 51 2873869.  
E-mail address: mjaffarqau@yahoo.co.uk (M. Jaffar).

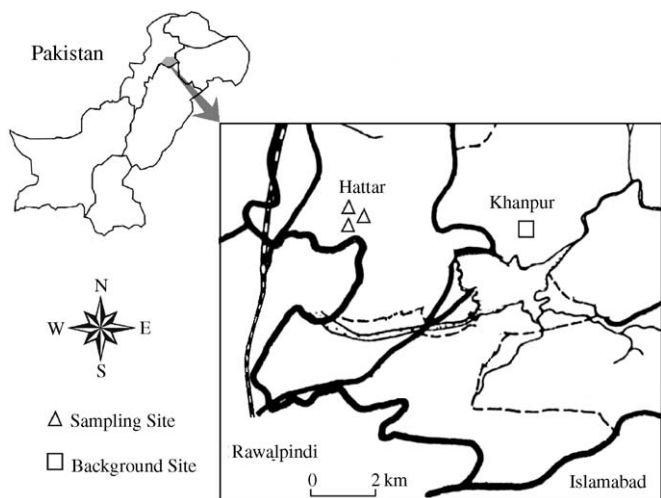


Fig. 1. Location map of sampling and background sites.

The present study was undertaken keeping in view the environmental significance of the potential influence of toxic textile effluents on nearby soil and water system. Metal characterization and source identification constitute important aspects of a study dealing with environmental degradation, usually evaluated through simple and multiple correlation patterns existing between various metals in the effluents and soils, using principal component loadings for the selected trace metals (Na, K, Ca, Mg, Fe, Mn, Co, Ni, Pb, Cr, Cd, and Zn). It is anticipated that the findings would provide baseline for future studies aimed at evolving source appointment for effluent affected soils. This would help to evolve an industrial pollution abatement program considering the trends of distribution of toxic metals in effluents and relevant soils in the light of their internationally laid down safe standards [21,22].

## 2. Materials and methods

### 2.1. Study area and sampling

The study area, Hattar ( $33^{\circ}51'N$ ,  $72^{\circ}51'E$ ) housing the textile units, included in the present study, is located in the North West Frontier Province (NWFP) of Pakistan. Hattar is a mountainous range, with plains elevated to 500 m altitude and at a distance of some 55 km from federal capital, Islamabad and 145 km from provincial capital, Peshawar. A survey of hazardous waste producing industries in NWFP, lists 348 industrial units including textile [31]. Other industrial units adjoining the textile units include paper/pulp, paint/varnishes, rubber/plastics, oil/soap and chemicals and petroleum products. The effluents from these units are discharged independently but they are ultimately flushed out from a main drain that opens in adjoining land. No waste/wastewater treatment facility exists at any of the industries in the area, obviously leading to an adverse environment impact.

Following standard analytical procedures and sampling guidelines [32–34], the sampling was conducted on twice a week basis, from three textile industries, namely, Sac Textiles, Unitech

Textiles and DS Textiles during September–December, 2002. A total of 90 samples (30 each for effluent, soil and water) were collected for analysis from each of these industries. All samples were collected in triplicate. The sampling sites were considered independent as these were located on the main drains of the industries separated from each other by 400–500 m. For background analysis, the samples of soil and water were obtained from a remotely located site, Khanpur, shown in Fig. 1. The water table at the site ran between 35 and 50 m, and the water from the source is used as drinking water. The effluent samples were collected in duly labeled strong polythene bottles (1 L) from the main discharge point of the individual industries. The surface soil (1–5 cm) samples, considered affected by the effluents, were collected up to 50 m from the discharge point. Prior to sampling, the soil samples were cleaned manually for any leafy, dry foreign matter. A 250 g portion of the soil was collected in zip-mouthed polyethylene bag.

### 2.2. Methods and analysis

All chemicals and reagents used in the study were of analytical and spectroscopic grade (certified minimum 99.9% purity), procured from E. Merck, Germany or BDH, England. Pyrex glassware was used for processing of samples, dilution and making up the volume, etc. Distilled water made in all-glass apparatus was used throughout the work. Standard optimum analytical conditions were maintained during the work, to ensure optimal accuracy and precision. Inter-laboratory comparison of the finished data was conducted at Nutrition Division, National Institute of Health, Islamabad, Pakistan. Standard reference material (NIST, SRM1573a, TL) was used periodically to have a check on the accuracy of the results and the precision of the instrument used.

#### 2.2.1. Soil

A 25.0 g portion of a soil sample was dissolved in 500 mL of distilled water and stirred mechanically on an electric shaker for 2 min and allowed to settle subsequently for 30 min [35,36]. The supernatant layer of the solubilized metal matrix was separated through filtration and used for the direct estimation of heavy metals, using Flame AAS system (Shimadzu Model-AA 670).

#### 2.2.2. Effluents and groundwater

The water extract was used for metal analysis as the labile metals pose higher health risk. The effluents filtered through  $0.5 \mu\text{m}$  cellulose filters were directly aspirated without the addition of any pH adjusters and stabilizers. Where required the sample solutions were diluted with distilled water appropriately in case if the concentration of a metal in the effluent was too high. The standard linear calibration method was applied for the quantification of metals using standard solutions in the appropriate range of concentration of metals in the given media. Automatic background compensation was carried out by the Shimadzu AAS system throughout this study. STATISTICA software was used to compute the relevant statistical analysis of the data [37].

Table 1

Basic statistical parameters of selected metals in effluent (mg/L), soil (mg/kg) and water (mg/L) samples from textile industries ( $n=90$ )

Metals	Effluents					Soil					Water				
	Min	Max	Mean	S.D.	Skewness	Min	Max	Mean	S.D.	Skewness	Min	Max	Mean	S.D.	Skewness
Na	71.00	3127	606.5	473.5	2.940	1116	37460	12069	14357	0.750	7.500	325.0	201.1	122.8	-0.640
K	2.200	62.80	17.91	12.18	1.580	0.260	1716	409.8	551.7	0.920	0.290	62.80	7.520	10.47	2.400
Ca	0.300	313.6	124.9	42.44	0.660	124.0	6120	1263	1096	1.960	17.80	103.2	67.15	20.48	-0.090
Mg	6.200	87.00	33.81	19.60	0.420	0.780	296.0	98.62	75.55	0.290	0.100	93.80	31.42	29.32	0.780
Fe	0.039	30.39	2.140	4.280	4.250	0.780	196.0	15.02	26.44	4.380	0.005	1.070	0.110	0.210	3.530
Mn	0.011	0.970	0.160	0.200	3.040	0.020	7.000	1.210	1.450	2.040	0.004	0.180	0.040	0.030	1.630
Cr	0.023	2.671	0.710	0.620	1.030	0.240	34.06	5.960	6.650	2.410	0.010	0.940	0.220	0.250	1.320
Co	0.046	1.703	0.460	0.410	1.440	0.100	18.40	2.750	3.200	2.850	0.001	0.465	0.080	0.080	2.550
Cd	0.004	0.181	0.040	0.030	1.710	0.020	1.400	0.170	0.190	3.840	0.001	0.210	0.020	0.040	3.920
Ni	0.013	2.482	0.260	0.400	4.320	0.020	18.40	1.510	3.000	4.470	0.009	0.585	0.080	0.100	3.270
Pb	0.013	2.340	0.280	0.320	3.800	0.020	23.02	4.460	5.420	1.580	0.001	2.340	0.260	0.330	3.570
Zn	0.014	2.482	0.260	0.420	3.810	0.020	49.64	2.610	6.030	5.840	0.007	1.340	0.180	0.260	2.520

### 3. Results

The data pertaining to the distribution of selected metals in the effluent, soil and water samples from three textile industries are reported in Table 1 as descriptive statistical parameters. In total, these data represent 90 samples pertaining to the three media for each industry.

Data on metal distributions in the three media on the basis of mean metal concentrations in effluent samples show Na, Ca, Mg, K, and Fe as dominant metals, with highest mean concentration of Na, followed by Ca, Mg, K and Fe, at 606.5, 124.9, 33.81, 17.91 and 2.14 mg/L, respectively. The S.D. values related to the distribution of these metals in the soil samples show a very high dispersion around the mean metal concentrations. The salient findings from these data on soil samples was relatively very high concentration of Cr, which exhibited about 34.0 mg/kg Cr in a dozen of samples, against an average level of 5.96 mg/kg as the mean value. The highest concentration of Co, Pb and Zn being used in these industries was also a parallel case. The chromium content of underground reservoir stands at 0.94 mg/L, against 0.22 mg/L as the mean value for the water samples, and 0.097 mg/L as the background level calculated ( $n=30$ ).

Statistical correlation study of the data pertaining metal-to-metal relationships in the three media was conducted on mutually inclusive basis. The metal-to-metal correlation coefficient evaluation yielded  $r$  values  $>0.322$  or  $\leq 0.322$  as significant at  $p < 0.001$ , revealing that there was statistically significant correlation between Fe and Cr ( $r=0.359$ ), Fe and Ni ( $r=0.430$ ) and Ni and Co ( $r=0.488$ ) in the effluent samples as shown in Table 2. For the soil matrix, the correlation study brought out some positive correlations between pairs of metals (Table 2). The listed  $r$ -values bring out a strong relationship of Cr with Ni, at ( $r=0.556$ ). The Ni concentration related to Fe in the effluent samples and to Cr in the soil samples indicated highly dependent concentration levels of the metals in the two media. The third correlation aspect between metal pair in water system shows significant relationship between Mg and Mn ( $r=0.463$ ), Cr and Mg ( $r=0.392$ ), Fe and K ( $r=0.337$ ) and Na and Mg ( $r=0.327$ ). An important cross-correlation ( $r=0.442$ ) also exists for effluent-

soil system for Pb and Cd. The corresponding effluent-water relationship emerged as significantly positive, between Fe and Mg ( $r=0.247$ ), Cr and Ca ( $r=0.260$ ), Fe and Mn ( $r=0.276$ ) and Co and Fe ( $r=0.229$ ), not given in the Table due to their lower level of significance compared with the pair of metals reported in Table 2. A similar correlation study also conducted on metal-to-metal interdependence for the soil-water system.

The study based on metal-to-metal correlations was further substantiated by the linear regression relationships given in Table 2, which lists only significant linear regression equations in terms of pairs of metals for the three media. The metal-to-metal correlations studies could provide a meaningful interpretation of the data only if source identification analysis could be carried out for the distribution of metals in the three media. For this purpose the principal component loading study, using varimax-normalized rotation for the three media was conducted, given in Table 3 through 5.

Table 2

Significant correlation and linear regression analysis for effluent, soil and water samples from textiles industries ( $n=90$ )

Matrix	Regression equation	Correlations ( $r$ )
Effluent	[Zn] = 4.565 [Cd] + 0.092	0.313
	[Cr] = 0.052 [Fe] + 0.603	0.359
	[Ni] = 0.040 [Fe] + 0.176	0.430
	[Pb] = 0.243 [Co] + 0.171	0.311
	[Ni] = 0.476 [Co] + 0.045	0.488
Soil	[Ca] = 1.135 [K] + 797.9	0.571
	[Ni] = 5.743 [Cd] + 0.542	0.368
	[Pb] = 9.011 [Cd] + 2.940	0.320
	[Ni] = 0.250 [Cr] + 0.020	0.556
	[Zn] = 0.308 [Cr] + 0.776	0.340
	[Fe] = 0.022 [K] + 5.868	0.466
	[Mg] = 0.024 [Na] + 69.14	0.464
[Cr] = 0.045 [K] + 4.105	0.375	
Water	[Fe] = 0.066 [K] + 0.058	0.337
	[Cr] = 0.034 [Mg] + 0.109	0.392
	[Mg] = 0.078 [Na] + 15.74	0.327
	[Mn] = 0.050 [Mg] + 0.025	0.463

**Table 3**  
Principal component loadings (varimax-normalized) for metals in the effluent samples from textile industries ( $n = 90$ )

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Na	0.272	0.033	-0.024	0.664	-0.044
K	0.036	0.069	0.072	0.009	0.896
Ca	-0.118	-0.134	-0.452	0.681	0.021
Mg	-0.005	-0.151	0.399	0.636	0.088
Fe	0.838	0.019	0.035	0.032	-0.236
Mn	-0.094	0.577	0.091	-0.015	0.176
Cr	0.458	0.350	0.026	0.392	0.026
Co	-0.515	0.147	0.573	-0.051	-0.251
Cd	0.030	0.766	-0.065	0.004	-0.034
Ni	0.751	-0.068	-0.060	0.115	0.378
Pb	0.032	-0.003	0.843	0.015	0.135
Zn	0.056	0.671	0.023	-0.092	-0.068
Eigen values	2.24	1.65	1.38	1.16	1.02
% total variance	18.7	13.8	11.5	9.67	8.51
Cumul. eigen values	2.24	3.89	5.28	6.44	7.46
Cumul. %	18.7	32.4	44.0	53.6	62.1

The principal component analysis (PCA) was applied for factor loadings in each media. For the effluent data set, five factors were extracted, together embodying more than 62% of total variance (Table 3). Contribution towards total variance of the five factors being 18.7%, 13.8%, 11.5%, 9.67% and 8.51%, respectively. Table 4 brings out the principal component loadings for soil samples having a total variance of 65.1%, where four factors were extracted with contributions of 32.5%, 13.9%, 9.80% and 8.89%, respectively. The counterpart principal component loadings for groundwater samples (Table 5) contributing more than 68% of total variance for five factors is 21.0%, 19.9%, 10.1%, 8.90% and 8.52%, respectively.

Comparison is made between the mean metal levels in ground water from textile industry in relation to the corresponding background concentration levels of the metals in samples taken from remote locations from the industrial units as depicted in Fig. 2; elaborating also the WHO permitted levels for drinking water. A similar comparison is made between the levels of metals in

**Table 4**  
Principal component loadings (varimax-normalized) for metals in the soil samples from textile industries ( $n = 90$ )

	Factor 1	Factor 2	Factor 3	Factor 4
Na	-0.247	0.761	0.169	-0.372
K	0.727	-0.152	0.229	0.474
Ca	0.489	0.096	0.106	0.542
Mg	0.590	-0.302	0.163	0.386
Fe	0.756	-0.071	-0.002	-0.006
Mn	0.502	0.213	0.528	-0.438
Cr	0.056	0.024	0.748	0.335
Co	0.188	0.755	-0.122	0.251
Cd	0.189	-0.208	0.246	0.562
Ni	0.099	-0.166	0.822	0.208
Pb	-0.256	0.652	-0.105	-0.226
Zn	0.049	-0.054	0.223	0.701
Eigen values	3.90	1.67	1.18	1.07
% total variance	32.5	13.9	9.80	8.89
Cumul. eigen values	3.90	5.57	6.75	7.82
Cumul. %	32.5	46.4	56.2	65.1

**Table 5**  
Principal component loadings (varimax-normalized) for metals in water samples from textile industries ( $n = 90$ )

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Na	0.846	-0.032	-0.250	0.225	-0.182
K	0.863	-0.058	-0.089	0.167	-0.055
Ca	0.132	0.802	-0.244	0.011	0.079
Mg	-0.363	0.756	-0.094	0.115	0.229
Fe	0.628	0.191	0.343	-0.306	0.104
Mn	-0.025	0.663	0.159	0.303	0.228
Cr	0.139	0.751	-0.010	-0.184	-0.321
Co	0.171	-0.104	0.575	0.252	-0.307
Cd	-0.023	0.100	-0.018	0.649	-0.142
Ni	-0.061	0.103	-0.001	-0.063	0.886
Pb	-0.259	-0.091	0.767	-0.078	0.159
Zn	0.375	0.000	0.103	0.642	0.145
Eigen values	2.51	2.39	1.21	1.07	1.02
% total variance	21.0	19.9	10.1	8.90	8.52
Cumul. eigen values	2.51	4.90	6.11	7.18	8.20
Cumul. %	21.0	40.8	50.9	59.8	68.4

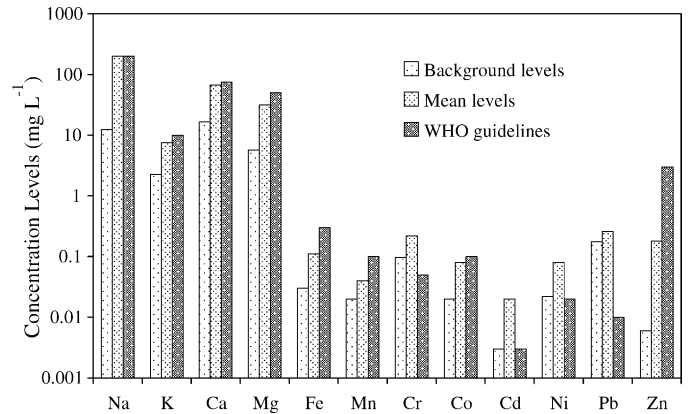


Fig. 2. Comparison average metal levels in ground water based on present study vs. corresponding background levels and WHO safe limits.

various soils in relation to the background concentration levels of the metals in virgin soil from the remote areas as shown in Fig. 3. These figures provide evidence that the levels of some metals such as Pb, Cr, Mn and Ni in the background samples have

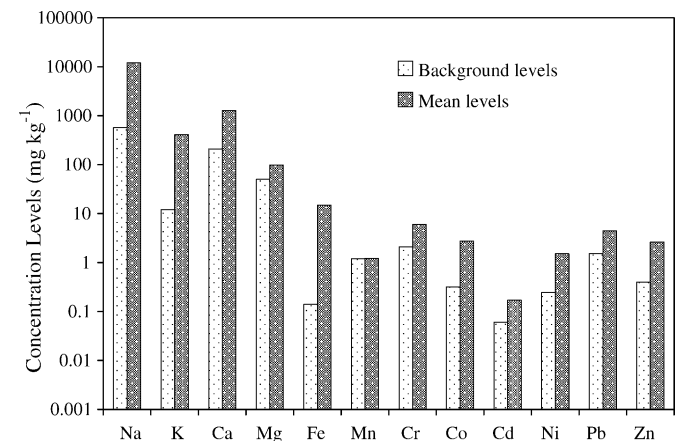


Fig. 3. Comparison average metal levels in soils based on present study vs. the background levels.

comparable level of those found in water and soil samples from these industries. This could have arisen due to natural enrichment depending specifically on individual, metals soil chemistry.

#### 4. Discussion

From the results of mean metal concentration, it is evident that Na, Ca, Mg, K, and Fe emerge as dominant metals in the three media. The concentrations of these metals are highest in soil samples in agreement with a previous finding reported in literature [23,24]. The study reveals moderately high metal concentrations in the effluent samples and marginally low concentrations in the water samples [33]. The distribution, therefore, indicates a large flux of these metals accumulated in the soil in close vicinity to the industries. The S.D. values related to the distribution of these metals in the soil samples show a high dispersion around the mean metal concentrations, following, on the average, the order: soil > effluents > water. Though empirical in nature, this relationship indicates the role of effluents towards enhanced metal accumulation in nearby soil systems. Therefore, the possible contribution of the effluents towards contamination of ground water in the area cannot be ruled out. To support this observation, the mean metal concentrations in ground water samples from textile industry were compared with those for background water taken from distant areas from the industry, as shown in Fig. 2, indicating increased concentrations of toxic metals such as Cr, Cd, Ni, Pb and Zn.

The order of distribution of these metals in relation to distribution in relevant effluent, soil and water samples is worth consideration. For the effluent samples, the highest mean concentration was that of Na, followed by Ca, Mg, K and Fe. A small variation in the pattern of concentration distribution was observed in the case of soil samples where Na, Ca and Fe remained at their respective concentration ranking, while K and Mg exchanged their ranking positions with effluent samples. This observation could probably be explained on the basis of possible chemical exchange processes among cations, under given prevailing conditions of pH and temperature [25]. To support the view point, the background concentration levels of metals for virgin soil were analyzed and compared with those in the soil samples under study (Fig. 3). The comparison indicated that the soil in the adjoining area of the industries had accumulated enhanced levels of toxic metal like Cr, Cd, Ni, Pb and Zn, which also manifested higher concentration levels in the ground water samples [38,39]. The study, therefore, evidences that the soils in proximity to the industries have accumulated toxic metals such as Cr, Co, Cd, Ni, Pb and Zn, with concentrations in the three media far exceeding the limit for their safe use laid down by the world health authorities [21,22]. A different situation was also observed where the background samples were found to contain metal levels close to those in contaminated soil (Fig. 3). This could be due to rock/soil composition, natural enrichment or contamination, in addition to a multitude of physico-chemical processes that are responsible for metal dispersion in this medium.

The evaluation of metal-to-metal correlation coefficients (6 correlations tested) pertaining to the effluent data showed that

the concentrations of Fe, Co, Cr and Ni mutually depend on each other, possibly because of the fact that they originate from a single source. For the soil matrix, the correlation study showed that K was very significantly related to Ca, Fe, Cr, Cd, Ni, Pb and Zn (Table 2), as supported by an earlier study [26]. However, no other metal showed such a strong correlation behavior, due perhaps to the fact that the K chemicals are used in these industries in large bulk during various chemical processes, thus overwhelmingly outweighing other metal salts towards saturation of the soil. In the case of soil samples, Cr was found to have a strong relationship with Ni. However, Ni related to Fe in the effluent samples, and to Cr in the soil samples indicated a high concentration correlation with Cr in the two media. Another correlation aspect in water system showed stronger relationship between Mg and Mn ( $r=0.463$ ), Cr and Mg ( $r=0.392$ ), Fe and K ( $r=0.337$ ) and Na and Mg ( $r=0.327$ ). The water medium, therefore, is influenced by the positive correlation between these metal pairs. A cross-correlation study between effluent and soil multiple-metal correlations showed that in the effluent–soil system Pb and Cd ( $r=0.442$ ) were strongly correlated. The corresponding effluent–water relationship emerged out to be significantly positive, for the following metal pairs: Fe and Mg ( $r=0.247$ ), Cr and Ca ( $r=0.260$ ), Fe and Mn ( $r=0.276$ ) and Co and Fe ( $r=0.229$ ). Despite the fact that these correlations were significantly strong, they did indicate a positive interrelationship between effluent and water metal concentrations, especially for Cr, Mg, Fe, and Co. Correlation study conducted for the soil–water system showed a strong positive correlation between various pairs of metals including Na, Mg, Fe, Cd, Pb and Zn. It may be anticipated that the soil system rich in these metals could substantially affect the ground water concentration.

The above observation based on metal-to-metal correlations was further substantiated by the linear regression equations in terms of pairs of metals with respective concentrations in the three media. The regression equations (Table 2) support the correlation coefficient analysis earlier described and discussed in terms of an intimate concentration dependence of various pairs of metals, notably Ca–K, Cr–Mn, Pb–Cd, Zn–Ni, Pb–Cr, etc.

The PCA using varimax-normalized rotation was applied for factor loadings in each media, as suggested in literature [27–30]. The essential feature of the PCA is to reduce a large number of variables into a new set of reduced variables based on their mutual dependence. For the effluent data set, five factors were extracted, embodying together more than 62% of total variance (Table 3). The first factor with highest total variance (18.68%) showed the highest loadings for Fe, Cr and Ni, with significant loadings from Co. These metals originate from some common processes in the textile industry; a fact duly supported by correlation and regression analyses. Factor 2, with a total of 13.76% variance has higher loadings for Cd, Zn and Mn, and with significant contribution of Cr, manifesting the common use of the metals in the textile industry. Factor 3 showed the higher loadings for Co and Pb with 11.53% total variance, being used in the same industrial processes. The higher loadings for Na, Ca and Mg in factor 4 contributing 9.67% of total variance with significant loadings for Cr, was found to be based on the common use of the chemicals containing these metals in these industries. The

last factor, with a total variance of 8.51%, has higher loadings for K with significant contribution from Ni.

Table 4 brings out the principal component loadings for soil samples. Four factors (eigen value > 1) were extracted in this case, with a total variance of 65.1%. The first factor with a variance of 32.5% showed maximum loadings for K, Mg, Fe and some significant loadings for Mn, probably originating from soil texture/rock type and industrial effluents. Factor 2, with loadings for Na, Co and Pb (13.9% of total variance), could be contributed from the industrial effluents. Factor 3, contributes for Mn, Cr, and Ni with 9.80% of total variance, with some significant contributions of Cd too, mainly originating from the industrial effluents and accumulating in the adjacent soils. The last factor with 8.89% of total variance has maximum loadings for Ca, Cd and Zn, with some significant contributions of other metals like K, Mg, Mn and Cr. The industrial effluents are thus found to contaminate the soils adjacent to the textile units, and could be considered as main contributors to this effect. This observation is supported further by the fact that each industry has its own characteristic chemical process that ultimately affects the effluent and soil composition in the adjoining area.

The counterpart principal component loadings for groundwater samples are given in Table 5. Five factors with eigen value > 1 were extracted in this case, together contributing more than 68% of total variance. Factor 1, with maximum loadings for Na, K and Fe, and with significant contribution of Zn and Mg, has 20.96% of total variance showing the contribution of water-soluble metals originating from the soil and effluents from textile industries. Factor 2, contributing 19.89% of total variance, showed the maximum loading for Ca, Mg, Cr and Mn, which mainly originate from the industrial effluents. Factor 3 accounts for 10.1% of total variance, with maximum loading for Co and Pb. This factor is common in all the three media with origin from the textile effluents. Factor 4, (variance of 8.9%) has maximum loadings from Cd and Zn, conceived to originate from the soils contaminated by the textile effluents over a long time scale. The last factor only contributes for Ni with 8.52% of total variance, finding again its origin from the industrial effluents.

## 5. Conclusions

In conclusion, the present study supported by the principal component analysis revealed that the textile effluents are posing a great threat by contaminating the adjacent soils and relevant water bodies. Toxic metals like Co, Cd, Pb, Zn, with some other metals such as, Cr, Mn, Ni, Fe, Ca, Na, K and Mg, find common factors in all the three media, manifesting that these metals originate from textile effluents. Comparison of the background levels of soil and water samples with the textile industry samples revealed that enhanced levels of Cr, Cd, Ni and Pb are posing a great threat to the health of the people inhabiting the area. There is a dire need to implement strict regulatory procedures for the safe discharge of effluents from the industries. Towards this end, the relevant authorities must ensure recycling of effluents along with mandatory quality assurance requirements. It is high time that the issue of environmental contamination in the area adjoining the textile units be kept under constant mon-

itoring and surveillance as proposed by world health bodies [21,22].

## Acknowledgments

We are thankful to Chief, Nutrition Division, NIH, Islamabad, for inter-laboratory comparison. One of us (S. Manzoor) is grateful to Quaid-i-Azam University, for the award of Research Fellowship to carry out this investigation. Collaboration by the administration of relevant industries in Hattar is also gratefully acknowledged for permission of sampling.

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