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**RESEARCH ARTICLE**

# Multivariate statistical analysis of heavy metals in ground water - A case study of Bolaram and Patancheru Industrial Area,Andra Pradesh, INDIA

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## *Abstract*

This paper deals with the multivariate analysis of heavy metals in ground water to find the distribution and sources of these metals in ground water. The concentration of Be, B, V, Cr, Mn, Fe, Ni, Co, Cu, Zn, As, Rb, Sr, Mo, Ag, Cd, Sb, Pb, Ba in ground water of 20 villages which are in close vicinity of Bolaram and Patancheru industrial area were measured by ICP-MS using NIST-6400 standards. Factor analysis was carried using IBM SPSS Statistics 20 software package. Principal component Analysis coupled with correlation Co-efficient analysis were used to analyze the data and to identify possible sources of these heavy metals. For the pre-monsoon ground water 2008 data set, although six factors were extracted, the first three factors account for the approximately 58.7% of the total variance of the data set. For the post-monsoon 2008 ground water data set, the first three factors account for the approximately 60.1% of the total variance of the dataset. The results shows that the factor 1 have high positive loading on Cr, Mo, Cd, Sb, Ba in pre-monsoon 2008 and V, Mn, Zn, As, Pb, Ba in post-monsoon 2008. The high values obtained are an indication of anthropogenic source for these elements in ground water.



## 1 INTRODUCTION:

Ground water pollution problems are not only confined to industrialized countries alone, although developing countries have a relatively small proportion of world industrial production. There are a number of third world cities and city regions with high concentration of industries and significant industrial output. The heavy metals of ground water though occasionally studied, is becoming one of the increased concern due to its adverse effect on human physiology. Some of them are linked for causing cancer and renal failure among those who are exposed to high dose of trace metals especially in industrial areas. The source of heavy metals into the ground water could be geogenic, but occurrence of them in higher concentration above the permissible limit of drinking water standards raises the suspicious of industrial contamination sources. The higher concentration of their presence in industrial effluents percolates down to sub-surface water bodies and gets absorbed in the course as a result of various geochemical processes. Higher concentration of trace metals can also be found in ground water near contaminated sources posing serious health threats(1). Monitoring and assessment of the water pollution has become a very critical area of study because of direct implications of water pollution on the aquatic life and the human beings. The contamination of surface water by heavy metals is a serious ecological problem as some of them like Hg and Pb are toxic even at low concentrations, are non-degradable and can bio-accumulate through food chain. Though some metals like Fe, Cu and Zn are essential micronutrients, they can be detrimental to the physiology of the living organisms at higher concentrations (2, 3). Trace metals can be toxic and even lethal to humans even at relatively low concentrations because of their tendency to accumulate in the body (4).

Several investigations have been made to identify the source of contaminants in ground water, and in most of the cases source are industrial wastes (5).The study area is one of the contaminated areas identified by the Central

Pollution Control Board, New Delhi and frequently referred to as an area of ecological disaster, and has been studied by many authors (6,7,8,9).The above studies though provided a base line however, environmental issues needs to be monitored regularly.

This paper presents and discusses the results of the factor analysis in terms of factoring process. The factor solutions of ground water samples datasets for the pre and post monsoon 2008 are interpreted and discussed.Factor analysis was carried using IBM SPSS Statistics 20 software package. The correlation coefficient matrix of the processed data sets was used as the input for the factor analysis. Principal component analysis was used to extract factors and the Kaiser criterion was used as the factor retention criteria (eigenvalue greater than 1.0). The factor solution was rotated using the Varimax method to enhance the factor solution prior to interpretation (10,11).Thisstudy indicates the necessity and usefulness of multivariate statistical techniques for evaluation and interpretation of the data with the view to get better information about the water quality to prevent the pollution caused by toxic elements. Multivariate statistical approach allows deriving hidden information from the data set about the possible influence of the environment on water quality.

## 2 The Study Area

The Patancheru and Bolaram Industrial Development Areas (IDAs) (78°08′–78°23′ east longitude and 17°30′–17°42′ north latitude) of the Medak district are located about 35 km from Hyderabad, Andhra Pradesh (AP), India; the location is shown in Fig. 1

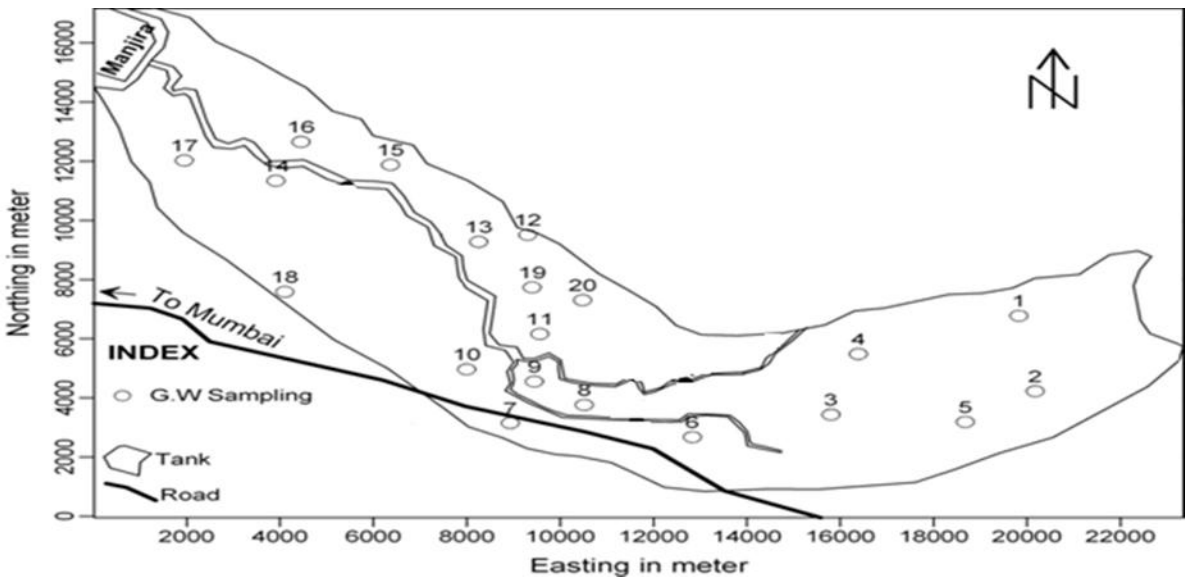



**Figure-1: Sampling location map of the study area**

Ground water sampling

1. Kazipally 2. Mallampet 3.kistareddy pet 4. Sultan pur5.Bolaram6.Patancheru 7.Muthangi 8.Pocharam 9. Ganapathigudam 10.Chitkul 11. Bacheguda 12.Peddakanjerla13.Chinnakanjerla 14.Bithole 15.cheduruppa16.Arutla 17. Ismail khan pet 18. Rudraram19. Inderesham 20.Inole

## 3. Methodology

The objective of sampling is to collect a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material being sampled (12). Samples, however, have to be handled in such a way that no significant change in composition occurs before the tests are carried out. A total number of 40 groundwater samples were collected for successive pre-and post-monsoon seasons corresponding to June and November 2008. The water samples were collected and stored in 1 liter capacity clean plastic bottles. Before collection of samples, the bottles were washed with double distilled water. Prior to collecting the samples, the containers were rinsed by the water to be sampled. The wells were duly pumped before collecting their sample so that the stagnant water, if any, is completely removed from storage within the well assembly. All the samples were filtered using Whattman 42 filter paper and were diluted to bring down the TDS ~200ppm for further analysis by ICP-MS. The trace element samples were treated with 0.6N $HNO_3$.The heavy metal elements analyses were carried out at National Geophysical Research Institute (NGRI), Hyderabad. The elements were analyzed by Inductive Coupled Plasma-Maas Spectrophotometer (ICP-MS). A Perkin Elmer SCIEX®, Model ELAN DRC II inductively coupled plasma-mass spectrometer (ICP-MS) (Concord, Ontario, Canada) was used throughout. Acidified water samples were directly fed into the instrument nebulizer after proper dilution and filtration. Calibration was performed using the certified reference material NIST 1640a (National Institute of Standards and Technology, USA) to minimize matrix and other associated interference effects and accuracy was better than 6% RSD. Relative standard deviation (RSD) was found to be better than 6% in the majority of the cases, which indicates that the precision of the analysis is reasonably good (13). Trace elements analyses were carried out at National Geophysical Research Institute (NGRI), Hyderabad .A.P. India.

## 4.RESULTS AND DISCUSSION

The analytical results of heavy metals concentration in ground water for pre and post-monsoon 2008 are given in Table 1. Multivariate analysis of ground water data was subjected through factor analysis.

Table1. Analytical data of ground water (ppb) in Bollaram and Patancheru industrial area

| S.No. | Cr | | Mn | | Fe | | Ni | | Co | | Cu | | Zn | | As | | Cd | | B | | Pb | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PRE | POST | PRE | POST | PRE | POST | PRE | POST | PRE | POST | PRE | POST | PRE | POST | PRE | POST | PRE | POST | PRE | POST | PRE | POST |
| 1 | 29 | 22 | 345 | 290 | 4384 | 4010 | 33 | 28 | 0.4 | 0.1 | 241 | 202 | 956 | 901 | 263 | 257 | 0.01 | 0.01 | 2513 | 2114 | 30 | 25 |
| 2 | 28 | 20 | 21 | 15 | 3138 | 2879 | 10 | 6 | 0.6 | 0.5 | 99 | 78 | 73 | 65 | 125 | 121 | 0.04 | 0.02 | 476 | 356 | 19 | 15 |
| 3 | 40 | 32 | 244 | 205 | 2171 | 2031 | 40 | 36 | 0.5 | 0.4 | 120 | 106 | 182 | 178 | 68 | 54 | 0.4 | 0.2 | 980 | 884 | 14 | 11 |
| 4 | 95 | 65 | 464 | 403 | 4459 | 3899 | 32 | 26 | 0.3 | 0.3 | 126 | 105 | 1254 | 1140 | 240 | 237 | 1.2 | 0.8 | 1120 | 1024 | 41 | 38 |
| 5 | 34 | 25 | 693 | 590 | 5110 | 4988 | 42 | 36 | 1.7 | 1.1 | 385 | 321 | 97 | 86 | 87 | 68 | 0.04 | 0.02 | 637 | 525 | 11 | 8 |
| 6 | 20 | 10 | 187 | 178 | 2153 | 1987 | 21 | 15 | 0.3 | 0.1 | 153 | 111 | 70 | 65 | 89 | 56 | 0.03 | 0.01 | 350 | 320 | 10 | 8 |
| 7 | 21 | 11 | 116 | 106 | 2512 | 2101 | 25 | 20 | 1.3 | 1.1 | 23 | 21 | 113 | 66 | 81 | 79 | 0.1 | 0.05 | 433 | 398 | 12 | 10 |
| 8 | 23 | 20 | 182 | 178 | 3137 | 2963 | 22 | 19 | 1.1 | 0.8 | 185 | 175 | 113 | 11 | 111 | 105 | 0.9 | 0.04 | 257 | 214 | 14 | 10 |
| 9 | 19 | 15 | 35 | 30 | 3539 | 3020 | 30 | 27 | 1.1 | 0.9 | 105 | 100 | 59 | 55 | 87 | 70 | 0.08 | 0.04 | 425 | 365 | 14 | 12 |
| 10 | 25 | 21 | 211 | 188 | 3112 | 2877 | 20 | 15 | 1.5 | 1.3 | 245 | 210 | 41 | 38 | 60 | 46 | 0.01 | 0.01 | 156 | 125 | 16 | 15 |
| 11 | 32 | 29 | 92 | 86 | 3111 | 2500 | 27 | 25 | 1.3 | 1.1 | 342 | 325 | 39 | 36 | 57 | 49 | 0.06 | 0.04 | 164 | 134 | 17 | 13 |
| 12 | 24 | 20 | 102 | 97 | 4184 | 3895 | 29 | 25 | 0.8 | 0.7 | 450 | 425 | 63 | 46 | 81 | 79 | 0.01 | 0.04 | 280 | 246 | 14 | 10 |
| 13 | 25 | 20 | 99 | 76 | 5312 | 4879 | 32 | 29 | 0.6 | 0.5 | 375 | 345 | 67 | 56 | 80 | 66 | 0.02 | 0.04 | 245 | 188 | 14 | 11 |
| 14 | 35 | 31 | 15 | 123 | 2090 | 1900 | 17 | 11 | 2.1 | 1.9 | 104 | 100 | 141 | 135 | 119 | 103 | 0.9 | 0.45 | 165 | 145 | 13 | 11 |
| 15 | 21 | 18 | 142 | 136 | 4421 | 4023 | 26 | 20 | 1.6 | 1.4 | 85 | 79 | 95 | 77 | 105 | 100 | 0.2 | 0.1 | 213 | 201 | 14 | 12 |
| 16 | 22 | 19 | 148 | 123 | 2395 | 2010 | 27 | 19 | 2.2 | 2 | 78 | 67 | 70 | 66 | 87 | 79 | 0.5 | 0.08 | 185 | 175 | 25 | 21 |
| 17 | 25 | 20 | 102 | 97 | 4527 | 4325 | 16 | 10 | 1.2 | 0.8 | 96 | 86 | 111 | 96 | 412 | 326 | 0.09 | 0.02 | 204 | 187 | 13 | 11 |
| 18 | 31 | 29 | 95 | 86 | 3114 | 2845 | 32 | 26 | 4.5 | 4.3 | 45 | 36 | 71 | 66 | 142 | 136 | 0.3 | 0.1 | 258 | 201 | 23 | 19 |
| 19 | 21 | 16 | 724 | 689 | 5112 | 4876 | 41 | 36 | 1.5 | 1.1 | 95 | 88 | 1852 | 1778 | 551 | 455 | 0.12 | 0.08 | 212 | 145 | 87 | 78 |
| 20 | 19 | 17 | 521 | 459 | 4211 | 3522 | 30 | 25 | 2.1 | 1.8 | 952 | 887 | 687 | 587 | 105 | 89 | 0.13 | 0.07 | 510 | 487 | 55 | 45 |

### 4.1 FACTOR ANALYIS:

Factor analysis is based on the fundamental concept that there exists a certain amount of correlation between pairs of variables in a large multivariate dataset (14, 15,16). Upon entering into a factor analysis one has to examine the correlation matrix for the presence of sufficient inter-correlation between variables to warrant proceeding with the analysis. The correlation matrices, which contain the Pearson’s correlation coefficient for each pair of variables of both pre and post monsoon ground water datasets, are presented in Tables 2 and 3.This section presents and discusses the results of the factor analysis in terms of factoring process. For the ground water pre monsoon data set (rotated solution) given in table 4, six factors account for 83.9% of the total variance, with 23.1% for factor one, 21.9% of factor two,13.7% of factor three. Although six factors were extracted, the first three factors account for the approximately 58.7% of the total variance of the data set. For the post monsoon ground water data set (rotated solution) table 5, six factors account for 83.8% of the total variance, with 24% for factor one, 22.9% of factor two, 13.2% of factor three. Although six factors were extracted, the first three factors account for the (approximately 60.1%) of the total variance of the dataset. The extraction result based on Kaiser Criterion. Overall, factor solutions are able to reproduce a significant amount of the variance in the datasets. The solutions were able to extract more than 80% of the variance in the system. Furthermore, in both solutions the first few factors account, by themselves, for more than 50% of the total variance.

Table 2 : Correlation matrix of pre monsoon ground water for the year 2008

| | Be | B | V | Cr | Mn | Fe | Ni | Co | Cu | Zn | As | Rb | Sr | Mo | Ag | Cd | Sb | Pb | Ba |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Be | 1 | | | | | | | | | | | | | | | | | | |
| B | 0.31 | 1 | | | | | | | | | | | | | | | | | |
| V | 0.16 | 0.35 | 1 | | | | | | | | | | | | | | | | |
| Cr | 0.93 | 0.35 | 0.19 | 1 | | | | | | | | | | | | | | | |
| Mn | 0.29 | 0.29 | 0.69 | 0.26 | 1 | | | | | | | | | | | | | | |
| Fe | 0.22 | 0.17 | 0.33 | 0.11 | 0.5 | 1 | | | | | | | | | | | | | |
| Ni | 0.13 | 0.32 | 0.45 | 0.17 | 0.6 | 0.43 | 1 | | | | | | | | | | | | |
| Co | -0.2 | -0.4 | -0.15 | -0.18 | -0 | -0.1 | 0.07 | 1 | | | | | | | | | | | |
| Cu | -0.1 | 0.05 | -0.14 | -0.13 | 0.3 | 0.35 | 0.22 | -0.02 | 1 | | | | | | | | | | |
| Zn | 0.48 | 0.41 | 0.78 | 0.37 | 0.7 | 0.46 | 0.44 | -0.14 | 0.06 | 1 | | | | | | | | | |
| As | 0.19 | 0.16 | 0.77 | 0.1 | 0.5 | 0.48 | 0.14 | -0.04 | -0.2 | 0.75 | 1 | | | | | | | | |
| Rb | -0.1 | -0.2 | 0.01 | -0.02 | -0.1 | -0.2 | -0.2 | 0 | 0.13 | -0.2 | -0.231 | 1 | | | | | | | |
| Sr | 0.28 | 0.16 | 0.24 | 0.14 | 0.7 | 0.47 | 0.47 | 0.26 | 0.46 | 0.53 | 0.242 | -0.16 | 1 | | | | | | |
| Mo | 0.87 | 0.56 | 0.44 | 0.78 | 0.5 | 0.36 | 0.3 | -0.28 | 0 | 0.78 | 0.425 | -0.1 | 0.42 | 1 | | | | | |
| Ag | -0.1 | -0.3 | -0.38 | -0.04 | -0.3 | -0 | -0.4 | 0.11 | 0.17 | -0.5 | -0.294 | 0.218 | -0.4 | -0.36 | 1 | | | | |
| Cd | 0.61 | 0.03 | -0.1 | 0.66 | 0.1 | -0.2 | -0.1 | 0.07 | -0.3 | 0.2 | 0.028 | -0.24 | 0.04 | 0.46 | -0.081 | 1 | | | |
| Sb | 0.7 | 0.47 | 0.32 | 0.79 | 0.3 | -0 | 0.2 | 0.05 | -0.1 | 0.47 | 0.306 | -0.27 | 0.22 | 0.65 | -0.244 | 0.61 | 1 | | |
| Pb | 0.25 | 0.13 | 0.66 | 0.11 | 0.7 | 0.4 | 0.4 | 0.11 | 0.22 | 0.9 | 0.68 | -0.11 | 0.62 | 0.53 | -0.453 | 0.07 | 0.29 | 1 | |
| Ba | 0.55 | 0.35 | 0.48 | 0.56 | 0.5 | 0.2 | 0.21 | 0.2 | -0.2 | 0.69 | 0.56 | -0.39 | 0.3 | 0.66 | -0.366 | 0.51 | 0.69 | 0.55 | 1 |

Table 3 : Correlation matrix of post monsoon ground water for the year 2008

| | Be | B | V | Cr | Mn | Fe | Ni | Co | Cu | Zn | As | Rb | Sr | Mo | Ag | Cd | Sb | Pb | Ba |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Be | 1 | | | | | | | | | | | | | | | | | | |
| B | 0.32 | 1 | | | | | | | | | | | | | | | | | |
| V | 0.23 | 0.49 | 1 | | | | | | | | | | | | | | | | |
| Cr | 0.86 | 0.31 | 0.24 | 1 | | | | | | | | | | | | | | | |
| Mn | 0.25 | 0.25 | 0.65 | 0.18 | 1 | | | | | | | | | | | | | | |
| Fe | 0.15 | 0.14 | 0.36 | 0.07 | 0.5 | 1 | | | | | | | | | | | | | |
| Ni | 0.09 | 0.33 | 0.4 | 0.16 | 0.6 | 0.42 | 1 | | | | | | | | | | | | |
| Co | -0.2 | -0.4 | -0.29 | -0.02 | -0.1 | -0.2 | -0 | 1 | | | | | | | | | | | |
| Cu | -0.1 | 0.03 | -0.12 | -0.09 | 0.3 | 0.28 | 0.23 | -0.03 | 1 | | | | | | | | | | |
| Zn | 0.44 | 0.4 | 0.77 | 0.3 | 0.8 | 0.43 | 0.42 | -0.17 | 0.04 | 1 | | | | | | | | | |
| As | 0.24 | 0.23 | 0.71 | 0.15 | 0.5 | 0.51 | 0.13 | -0.08 | -0.2 | 0.8 | 1 | | | | | | | | |
| Rb | -0.1 | -0.2 | 0.08 | 0.04 | -0.1 | -0.2 | -0.1 | 0.01 | 0.12 | -0.2 | -0.241 | 1 | | | | | | | |
| Sr | 0.24 | 0.09 | 0.15 | 0.09 | 0.7 | 0.4 | 0.36 | 0.19 | 0.41 | 0.39 | 0.172 | -0.16 | 1 | | | | | | |
| Mo | 0.87 | 0.52 | 0.53 | 0.71 | 0.5 | 0.31 | 0.29 | -0.25 | -0 | 0.76 | 0.494 | -0.09 | 0.35 | 1 | | | | | |
| Ag | -0 | -0.2 | -0.18 | 0.04 | -0.4 | 0.12 | -0.4 | -0.02 | -0.2 | -0.4 | -0.048 | 0.108 | -0.4 | -0.25 | 1 | | | | |
| Cd | 0.77 | 0.13 | 0.05 | 0.8 | 0.1 | -0.1 | -0.1 | -0.06 | -0.2 | 0.3 | 0.229 | -0.22 | 0.05 | 0.62 | 0.008 | 1 | | | |
| Sb | 0.78 | 0.47 | 0.31 | 0.84 | 0.2 | 0.03 | 0.11 | 0.07 | -0.1 | 0.42 | 0.331 | -0.26 | 0.23 | 0.71 | -0.152 | 0.76 | 1 | | |
| Pb | 0.26 | 0.12 | 0.62 | 0.13 | 0.7 | 0.37 | 0.37 | 0.08 | 0.18 | 0.92 | 0.711 | -0.1 | 0.51 | 0.57 | -0.426 | 0.13 | 0.28 | 1 | |
| Ba | 0.44 | 0.32 | 0.47 | 0.51 | 0.4 | 0.2 | 0.13 | 0.25 | -0.2 | 0.67 | 0.62 | -0.39 | 0.2 | 0.59 | -0.256 | 0.47 | 0.59 | 0.57 | 1 |

Table 4 : Rotated sum for the pre monsoon ground water 2008

| | Initial | eigen value | Rotation Sums of Squared Loadings Total | % of Variance | Cumulative % |
|---|---|---|---|---|---|
| Be | 1 | 0.921 | 4.408 | 23.198 | 23.198 |
| B | 1 | 0.722 | 4.165 | 21.918 | 45.116 |
| V | 1 | 0.883 | 2.619 | 13.784 | 58.9 |
| Cr | 1 | 0.944 | 1.881 | 9.899 | 68.799 |
| Mn | 1 | 0.803 | 1.668 | 8.781 | 77.581 |
| Fe | 1 | 0.818 | 1.27 | 6.682 | 84.263 |
| Ni | 1 | 0.679 | | | |
| Co | 1 | 0.824 | | | |
| Cu | 1 | 0.784 | | | |
| Zn | 1 | 0.945 | | | |
| As | 1 | 0.941 | | | |
| Rb | 1 | 0.941 | | | |
| Sr | 1 | 0.825 | | | |
| Mo | 1 | 0.924 | | | |
| Ag | 1 | 0.772 | | | |
| Cd | 1 | 0.785 | | | |
| Sb | 1 | 0.786 | | | |
| Pb | 1 | 0.858 | | | |
| Ba | 1 | 0.854 | | | |

Table 5 :Rotated sum for the post monsoon ground water 2008

| variable | initial | eigen value | Rotation Sums of Squared Loadings Total | % of Variance | Cumulative % |
|---|---|---|---|---|---|
| Be | 1 | 0.91 | 4.571 | 24.059 | 24.059 |
| B | 1 | 0.783 | 4.366 | 22.977 | 47.036 |
| V | 1 | 0.883 | 2.524 | 13.284 | 60.32 |
| Cr | 1 | 0.914 | 1.738 | 9.146 | 69.467 |
| Mn | 1 | 0.828 | 1.413 | 7.439 | 76.906 |
| Fe | 1 | 0.863 | 1.376 | 7.243 | 84.148 |
| Ni | 1 | 0.551 | | | |
| Co | 1 | 0.786 | | | |
| Cu | 1 | 0.708 | | | |
| Zn | 1 | 0.954 | | | |
| As | 1 | 0.922 | | | |
| Rb | 1 | 0.942 | | | |
| Sr | 1 | 0.767 | | | |
| Mo | 1 | 0.911 | | | |
| Ag | 1 | 0.829 | | | |
| Cd | 1 | 0.832 | | | |
| Sb | 1 | 0.868 | | | |
| Pb | 1 | 0.892 | | | |
| Ba | 1 | 0.848 | | | |

Table 6: Factor analysis of gorund water of pre-monsoon 2008

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Be | 0.915 | 0.14 | 0.14 | -0.059 |
| B | 0.302 | 0.09 | 0.111 | 0.444 |
| V | 0.056 | 0.855 | 0.015 | 0.311 |
| Cr | 0.948 | 0.05 | 0.051 | -0.01 |
| Mn | 0.198 | 0.556 | 0.592 | 0.322 |
| Fe | -0.028 | 0.474 | 0.65 | -0.226 |
| Ni | 0.042 | 0.197 | 0.504 | 0.614 |
| Co | -0.042 | -0.023 | 0.072 | 0.031 |
| Cu | -0.136 | -0.163 | 0.847 | -0.062 |
| Zn | 0.362 | 0.806 | 0.248 | 0.3 |
| As | 0.076 | 0.942 | -0.063 | -0.045 |
| Rb | -0.105 | -0.055 | -0.012 | -0.127 |
| Sr | 0.183 | 0.271 | 0.742 | 0.3 |
| Mo | 0.765 | 0.413 | 0.227 | 0.172 |
| Ag | -0.068 | -0.296 | 0.06 | -0.814 |
| Cd | 0.812 | -0.078 | -0.196 | 0.005 |
| Sb | 0.82 | 0.18 | -0.04 | 0.228 |
| Pb | 0.15 | 0.78 | 0.349 | 0.255 |
| Ba | 0.625 | 0.533 | -0.052 | 0.196 |

Table 7: Factor analysis of ground w ater of post monsoon 2008

| | Factors 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Be | 0.146 | 0.923 | 0.086 | 0.151 |
| B | 0.184 | 0.289 | 0.067 | 0.701 |
| V | 0.833 | 0.104 | 0.011 | 0.386 |
| Cr | 0.07 | 0.947 | 0.026 | 0.058 |
| Mn | 0.663 | 0.12 | 0.599 | 0.062 |
| Fe | 0.454 | -0.023 | 0.533 | 0.197 |
| Ni | 0.285 | -0.003 | 0.571 | 0.258 |
| Co | -0.03 | -0.021 | 0.023 | -0.864 |
| Cu | -0.173 | -0.101 | 0.802 | 0.029 |
| Zn | 0.877 | 0.287 | 0.218 | 0.143 |
| As | 0.903 | 0.13 | -0.1 | 0.034 |
| Rb | -0.059 | -0.077 | -0.033 | -0.031 |
| Sr | 0.244 | 0.152 | 0.774 | -0.231 |
| Mo | 0.483 | 0.752 | 0.191 | 0.259 |
| Ag | -0.214 | 0.009 | -0.267 | -0.011 |
| Cd | 0.053 | 0.889 | -0.121 | -0.074 |
| Sb | 0.173 | 0.876 | 0.008 | 0.029 |
| Pb | 0.843 | 0.126 | 0.326 | -0.158 |
| Ba | 0.624 | 0.479 | -0.103 | -0.2 |

### 4.2 Communalities

Communalities are measures of the extracted factors that are able to reproduce the variance of the individual variables. There are no statistical guidelines to qualify communality as being large or small. However, for logical reasons, one should strive for communalities greater than 0.5, which indicates that at least 50% of the variance of the variable is reproduced by the linear combination of the extracted factor (11). Based on this guideline, the communalities are relatively "high," the lowest being that of Ni in pre monsoon data set with a communality of 0.66. At that level the communality is just above the threshold value of 0.5 but the extracted factors are still able to reproduce more than 50% of the variance.

**4.3 Factor solution and interpretation**

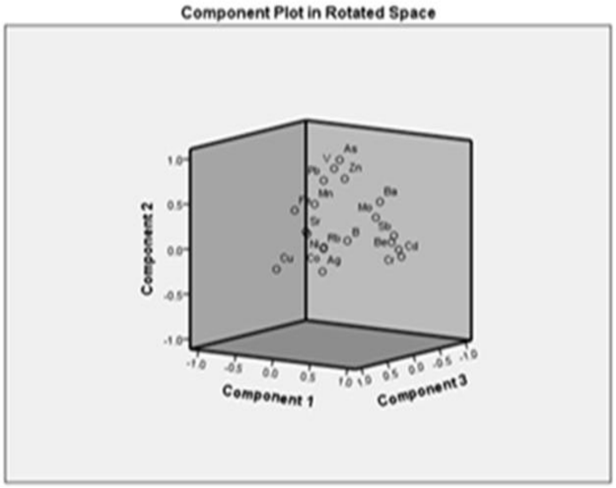
The rotated factor solutions are presented for ground water belongs to pre and post monsoon 2008 in Table 6, 7.Varimax rotation was used in the rotation in this study. The rotation enhances a factor solution for ease of interpretation. The end result of a factor rotation is a factor solution where each factor contains a few variables with high loadings (the degree to which a variable belongs to a certain factor) and the remaining loadings tends towards 0. For each factor, the composing variables are sorted into decreasing loading values. The value of 0.5 is an arbitrary threshold value below which loadings are not considered significant. A factor is considered significant if it contains more than two significantly loading variables. Factors with less than two significantly loading variables do not contribute to the factor solution nor add much about the understanding of the underlying structure within the data, solutions show a significant number of variables with loadings greater than 0.7. Generally both factor solutions, the first three factors contain more than two significantly loading variables.

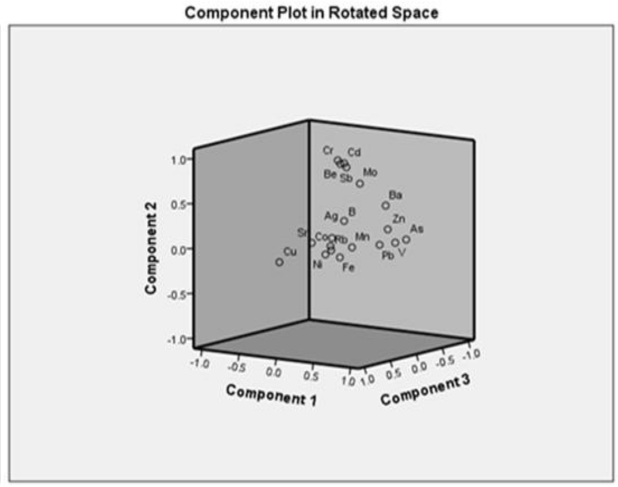
In the dataset belongs to ground water of pre-monsoon (Table 6), 3 out of 19 variables (Ni, Mn, Ba) have cross-load on multiple factors, whereas 1 out of 19 variables. Mn cross load on multiple factors in post-monsoon water dataset (table 7).

Factor 1: Factor 1 exhibits positive loading on Cr, Mo, Cd, Sb, Ba in pre monsoon and V, Mn, Zn, As, Pb, Ba in post monsoon. Although it is difficult to differentiate back ground concentration due to geogenic processes in water, the high variability in the analytical data obtained is indicative of an external source for these elements in ground water. The high values obtained are an indication of an external source for these elements in ground water. High concentration of Cr is seen in ground water it ranges from 18.5 to 94.5ppb in pre monsoon and 10.4 to 65.4ppb in post monsoon for the surface water. The high concentration of Cr are found in ground water of Kazipally, Bolaram, kistareddy pet and sultan pur villages which is due to close vicinity towards industrial area. Cr show the multiple cross load on factor 1 and 3 in both seasons. High concentrations of iron are found inground water which ranges from 2090 ppb to 5312ppb in pre monsoon and from 1900 to 4988ppb in post monsoon. Higher concentration of iron in ground water is due to anthropogenic activities. Ni varies from 10.08 to 42.18ppb in pre monsoon and from 5.6to 35.8ppb in post monsoon for ground water. Zn is released into the hydrological system by the industries located in Bolaram and Patancheru basin. In addition to industrial pollution Zn has agricultural origin coming from extensive use of pesticides and fertilizers by the farmers to improve crop yields in the area. In ground water it varies from 39.12 to 1852.4ppb in pre monsoon and from 35.6 to 1778ppb in post monsoon.

The concentration level of Arsenic level found to be high in ground water. Organic effluents discharged by the industries can combine with arsenic to form non degradable metal complexes and they in turn enter the ground water. Arsenic is mainly released from paints, pharmaceutical, fertilizers and pesticides industries. The concentration As in ground water it varies from 57.3ppb to 551ppb in pre monsoon and from 45.9ppb to 455ppb in post monsoon. High concentration of upto 19.3 ppb were reported by B. Dasaram. Mo varies in ground water from 1.2ppb to 53.1ppb in pre monsoon and from 0.4ppb to 45.1ppb with a mean of 19.86ppb in post monsoon. The positive loading for factor 2, factor 3 and factor 4 are summarized in the given tables below.

| Factors 2 positive loading in pre and post monsoon 2008 | |
|---|---|
| Pre monsoon 2008 | Post monsoon 2008 |
| V, Mn, Zn, As, Pb, Ba | Be, Cr, Mo, Cd, Sb |
| **Factors 3 positive loading in pre and post monsoon 2008** | |
| Pre monsoon 2008 | Post monsoon 2008 |
| Fe, Sr, Sb | B, Fe |
| **Factors 4 positive loading in pre and post monsoon 2008** | |
| Pre monsoon 2008 | Post monsoon 2008 |
| Ni | B |




## 5. Conclusion.

The case study of ground water pollution due to uncontrolled industrial effluent discharges. From the results of factor analysis four factors were identified for ground water controlling their variability in water of patancheru obtained. Pollution around the Bolaram and Patancheru industrial area increased during the past one and half decade due to discharge of industrial effluent in surface water bodies. Multivariate statistical approaches show that the polluted surface water is strongly influencing the quality of ground water in the study area. The present study suggests that regular monitoring of the quality of ground water should be undertaken to identify the source of toxic pollutants and other inhibitory chemicals which affects the water around industries in Patancheru.

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## 7. REFERENCES:

1 U.S.G.S. (1993): National water Summary-1990-1991: Stream Water Quality U.S.Geol. Surv. Water Supply paper No. 2400, 590p.
2 Kar, D., Sur, P., Mandal, S.K., Saha, T. &Kole, R.K. (2008): Assessment of heavy metal pollution in surface water. Int. J. Environ. Sci. Tech., 5(1):119-124.
3 Nair, I.V., Singh, K., Arumugam, M., Gangadhar, K. &Clarson, D. (2010). Trace metal quality of Meenachil River at Kottayam, Kerala (India) by principal component analysis. World Appl. Sci. J., 9(10):1100-1107.
4 Domenico, P.A. and Schwartz, F.W. (1998): Physical and Chemical Hydrogeology, IIndEdtn. John Wiley and Sons, INC, 495p
5 KornprabhaKruawal, Frank Sacher, Andreas Werner, Jutta Muller, Thomas Knepper; (2005): Chemical water quality in Thailand and its impacts on the drinking water production in Thailand. Science of the total Environment, V 340, pp .57-70
6 Govil, P.K; GaneshwarRao, T; & Krishna, A.K; (1998). Arsenic contamination in Patancheru Industrial Area , Medak district, Andra Pradesh. Environmental Geochemistry, v 1, pp. 5-9.
7 Chandarasekhar, K; Chary, N. S; Kamala, C.T; VenkateswaraRao, J; Balaram, V; &Anjaneyulu, Y; (2003): Risk assessment and pathway study of arsenic in industrially contaminated soils of Hyderabad, a case study, Environment International, v. 29.pp. 601-611.

8 GurunadhaRao, V.V.S (2003): Ground water contamination in Patancheru Industrial Development Area; A Post Audit. Proceeding of workshop on Ground water contamination, Central Ground water Board, New Delhi, pp. 31-47.

9 B. Dasaram, V. Sudarshan, M.Satyanarayanan and A. Keshav Krishna (2005): Trace elements Geochemistry of Groundwater- A case study from Patancheru Industrial Area, A.P. India.

10 Davis, John C; (2002): Statistical and Data analysis in Geology 3rd EDITION Wiley NY 638p.

11 Hair, J.F; Black, W.C; Babin, B.J; and Anderson, R.E. (2010): Multivariate Data analysis 7th edition Prentice Hall New Jersey 786 p.

12 APHA, (1992): Standard Methods for Analysis of Water and Waste Water,18th Edition, American Public Health Association, Inc, Washington DC.

13 Satyanarayanan et al (2007):Assessment of ground water quality in a structurally deformed granitic terrain in Hyderabad India, Environ. Monit. Asst. v 131 pp117-127.

14 Joreskog, K. G., Klovan, J. E, and Reyment, R A. (1976): Geological Factor Analysis Elsevier Scientific Publications, Amsterdam, 178 p.

15 Davis, John C. (2002): Statistics and Data Analysis in Geology (3rd ed.).: Wiley, NY., 638 p.

16 Reimann, C., and Filzmoser, P. (1999): Normal and lognormal data distribution in geochemistry: Death of a myth. Consequences for the statistical treatment of geochemical and environmental data. Environmental Geology, 39: 1001-1014