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Research Article



SEASONAL VARIATION IN GROUND WATER QUALITY NEAR MUNICIPAL SOLID WASTE DUMPSITE USING MULTIVARIATE STATISTICAL ANALYSIS

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Abstract

Open dumps are well known to release large amounts of hazardous chemicals to nearby groundwater, surface water and soil, via leachate. The ground water samples were analysed both in pre and post monsoon season to know the effect of dilution by rainwater on the pollutants. The statistical analysis (factor analysis by PCA method) of results of the physico-chemical characteristics of ground water samples around the autonagar MSW dumpsite explained the extent of pollution in the study area which leads to the understanding of anthropogenic and geogenic source of pollution. Both pre and post monsoon seasons indicate more or less the same trend in the loadings with the exception that in post monsoon 2009 the loading parameters has interchanged from factor-1 to factor-2. The similarity indicates that the contamination of groundwater is nearly same in both the seasons but the intensity of contamination decreased in post monsoon season.

Keywords: Open dumps, hazardous chemicals, physico-chemical characteristics, PCA method

Introduction

Groundwater is a globally important and valuable renewable resource for human life and economic development. In urban centers groundwater supplies are important as a source of relatively low cost and generally high quality of municipal water supply. Most of the groundwater is of good quality water because of natural purification processes, unless it is intensively polluted by anthropogenic activities. Classical unlined sanitary landfills and open dumps are well known to release large amounts of hazardous chemicals to nearby groundwater, surface water and soil, via leachate. It is known that such releases contain a wide variety of potential carcinogens and potentially toxic chemicals that represent a threat to public health. However, little quantitative information is present on the total hazard caused by the landfills on people who live

near the landfill (G.Fred Lee et.al 2005). Therefore, this study was aimed to analyze groundwater pollution and assess the adverse risks due to the autonagar municipal solid waste-dumping site within its vicinity. The composition of ground water is dependent on natural factors (geological, topographical, meteorological, hydrological and biological) in the drainage basin and varies with the run off volumes, weather conditions and water levels. (Jamie Bartram et.al 1996). Precipitation due to rain is a major component of the water cycle, and is responsible for depositing most of the fresh water in the groundwater table. Therefore precipitation by rainfall may decrease the pollutants in the ground water. The ground water samples were analysed both in pre and post monsoon season to know the effect of dilution by rainwater on the pollutants.

Study Area

The Autonagar municipal dumpsite in Hyderabad is spread over an area of 47 acres and used to receive an average of 800 mt garbage per day. About 8.7 lakhs m³ MSW has been dumped at this dumpsite, which weighs ~ 4.35 lakhs tonne. The Municipal Corporation of Hyderabad (MCH) stopped dumping of garbage at Autonagar site in 2005. The study area (around the dumpsite) is covered by granite. The area is semi-arid with subtropical climate conditions. The temperature varies from 25 to 45^oC. It receives more than 80% precipitation from south-west monsoon with an average rainfall of 812 mm.

Materials and Methods

A total number of 30 groundwater samples (FIG-1) were collected for physico-chemical analysis in two successive pre-and post-monsoon seasons of 2009. The major ion analyses were carried out at National Geophysical Research Institute, Hyderabad.

The water samples were analyzed (Table-1a & 1b) as per the standard methods (APHA 2005). Values of pH were measured by a portable digital water analyses kit with electrodes. The values of electrical conductivity (EC) were measured by portable kit with electrodes in the lab. The concentrations of Ca⁺², Mg⁺², Cl⁻, CO₃²⁻, HCO₃⁻ were determined by volumetric method. Fluoride was analyzed by ion selective electrode. Flame emission photometry has been used for the determination of Na⁺ and K⁺. Sulphate was determined by UV spectrophotometer. Metals were analyzed (Table-2a & 2b) using ICP-MS (V.Balaram et.al 2007)

Results and Discussion

The statistical analysis (using factor analysis by PCA method) of results of the physico-chemical characteristics of ground water samples around the autonagar MSW dumpsite explained the extent of pollution in the study area which led to the understanding of anthropogenic and geogenic source of pollution. The factor analysis was carried out for pre and post monsoon seasons of 2009, giving three factors each (Table-3a & 3b)

Factor-1 exhibits 23.475 % of the total variance of 59.3 % in pre-monsoon 2009. In pre-monsoon 2009 Factor-1 (r = 0.507 to 0.909) gave positive loading on EC, TDS, Mg, Na, HCO₃, Cl, F, SO₄, TH, Se and Sr. All these parameters exhibited high loadings in association with bicarbonate indicating the alkaline nature which provides their dissolution in ground water from the soils, hence indicating their anthropogenic source of pollution. It also

explains that these major ions are responsible for total dissolved solids and hardness of the groundwater. The hardness present is permanent hardness and may be due to MgSO₄ and MgCl. Factor-2 (r = 0.525 to 0.905) exhibited 22.851% of the total variance of 59.3% with positive loadings on HCO₃, Fe, Ba, Pb, Cu, Zn, Se, B, Mn and Cd. Factor-3 exhibits 12.974% of the total variance of 59.3% with positive loading on K, COD, BOD, Ni and Cr, indicating the organic load in the ground water from anthropogenic source. Potassium is derived from the reaction with clay. Potassium released from MSW landfills is exceptionally high and thus potassium compounds may be applied as an indicator for other toxic compounds in ground water.

Both pre and post monsoon seasons indicate more or less the same trend in the loadings with the exception that in post monsoon 2009 the loading parameters has interchanged from factor-1 to factor-2. The similarity indicates that the contamination of groundwater is nearly same in both the seasons but the intensity of contamination decreased in post monsoon season.

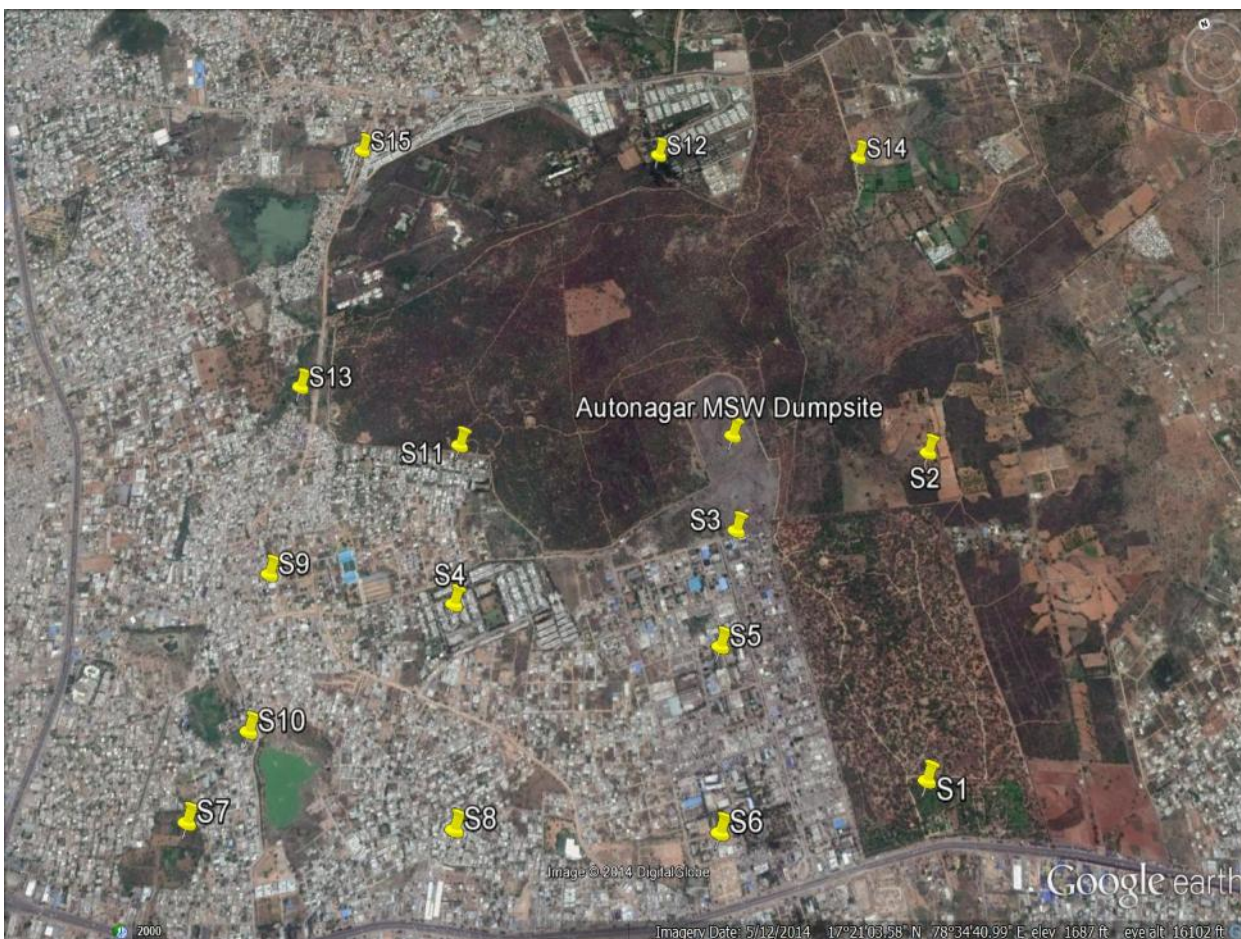
The physico-chemical analysis values of ground water samples around MSW dumpsite is compared with BIS/WHO/EPA drinking water standards.

The parameters pH, Ca, Mg, SO₄, Fe, Mn, Cu, Ni, Cd, Pb, Sr, Co and As are within the permissible limits for drinking water for all the samples for both the seasons. Except S3 and S11 all the samples have COD value within the permissible limit of 10 mg/L (BIS). The high COD values of S3 and S11 samples is due to severe ground water pollution by the biodegradable and non biodegradable matter from the autonagar MSW dumpsite.

Except S2 and S3 all the samples have Zn value within the permissible limit of 1500 ppb as per BIS. Zinc exhibited positive loadings in pre and post monsoon seasons. High concentration of zinc is found in samples (S2 and S3) which are near to the MSW dumpsite or at lower elevation w.r.t. the dumpsite, indicating its anthropogenic source. Zinc (Zn) is a metal normally found in small amounts in nature. Although zinc occurs naturally, mostly zinc finds its way into groundwater because of human activities.

The environmental releases of zinc from sources of human origin far exceed the releases from natural sources (Fishbein 1981). Galvanized liners or fittings or metal pipes coated with zinc, present in many older wells or plumbing systems, can leach zinc into drinking water (Sharrett et al. 1982a). Water containing zinc at concentrations above 5.0 mg/L tends to have a milky appearance, develops a greasy film when boiled, and

Fig-1 Ground water sampling locations around autonagar MSW dumpsite



has an undesirable sharp taste. It may also leave a whitish residue on pipes and fixtures.

Except S1, S2, S3, S4, S10, S11 and S12 all the samples have Se value within the permissible limit of 10 ppb as per BIS. Selenium exhibited positive loadings in pre and post monsoon seasons. The very high concentration is found in samples (S1, S2, S3, S4, S11 and S12) which are near to the MSW dumpsite or at lower elevation w.r.t. the dumpsite, indicating its anthropogenic source. The concentration of selenium in sample S10 is high because it is near to the surface water pond. Selenium showed positive loadings along with bicarbonates. Alkaline and oxidizing conditions favor the formation of selenates (NRC 1983). Selenates are soluble in water and are leached from well-aerated alkaline soils that favor its oxidation. S1 showed abnormally higher value of selenium concentration, even though it is far away (1.7 Km) from MSW dumpsite and also at higher elevation w.r.t. dumpsite. The higher concentration of selenium for ground water sample S1 may be due to the

agricultural activity near the sampling location and not due to the MSW dumpsite. Selenium can become mobilized and concentrated by weathering and evaporation in the process of soil formation and alluvial deposition in arid and semiarid climates (Presser 1994), and through leaching of irrigated agricultural soils and remobilization in irrigation water. (Presser and Ohlendorf, 1987).

Except S2 and S3 all the samples have Boron value within the permissible limit of 1000ppb as per BIS. Boron exhibited positive loadings in both pre and post monsoon seasons. The very high concentrations are found in samples (S2 and S3) which are near to the MSW dumpsite and at lower elevation w.r.t. the dumpsite, indicating its anthropogenic source. Boron does not naturally occur in elemental form. Boron has a high affinity for forming very stable bonds with electronegative atoms (atoms that donate electrons) and as a result often exists in compounds bound to

(Table-1a & 1b) Analysis of water samples

Table-1a																
SAMPLE	pH		EC		TDS		Ca		Mg		Na		K		CO3	
	pre09	post09	pre09	post09	pre09	post09	pre09	post09	pre09	post09	pre09	post09	pre09	post09	pre09	post09
S1	7.1	7	1.2	0.9	685	530	93.2	75	40	20	73.2	45	1.5	1	30	15
*S2	7.5	7.78	1.36	1.2	920	800	140	128	68	45	50	30.5	2.4	1.9	28	20
*S3	7.5	7.56	1.9	1.8	1250	1120	152.2	138	42.1	28	100	80	1.8	0.85	28	20
*S4	7.3	7.35	1.4	1.1	880	780	110	102	55	53	51	35	1	1.3	13.2	13.8
S5	7.6	7.7	0.98	0.91	663.49	543.53	100	84	40	27	62	44	1.3	0.92	9.5	5.7
S6	7.7	7.8	1.2	0.99	710	600	93	77	48	35	75	55	3.1	2.1	14	9.4
S7	7.57	7.67	1.39	1.3	850	738	115	80	60	52	80	60	2	1.1	40	35
S8	7.65	7.76	0.92	0.71	500	330	58	39	31	12	45	30	1.7	0.9	35	20
S9	7.18	7.08	0.76	0.7	485	440	79	72	19.2	21	38	30	1	0.83	28	20
S10	7.44	7.43	1.58	1.19	1100	894	128	98	68.2	48.15	150	115.17	2.1	1.4	32	28
*S11	7.57	7.65	1.37	1.05	850	638	98	78	29	20	70	52	40	25	28	12
*S12	7.45	7.56	2.1	1.78	1318	1120	118	89.2	95	75.12	100	80	1.8	1	23.2	14.1
*S13	7.8	7.78	1.3	0.98	730	600	90	70.4	35	25	90	90	2.1	1.1	28	20
*S14	7.67	7.78	1.2	0.87	600	500	72	68	53	50.2	30	24	1.3	1.2	20.45	15
*S15	7.33	7.32	1.61	1.55	1130	960	183	168	63.4	50	80	72	6.3	3.8	8.2	7.8

Table-1b

SAMPLE (year2009)	HCO3		Cl		F		NO3		SO4		TH		DO		COD		BOD	
	pre	post	pre	Post	pre	Post	Pre	post	pre	post	pre	Post	pre	post	pre	post	pre	post
S1	200	148	135.2	100	0.52	0.15	14	8.2	50	30.5	397	270	3.3	5.5	6.8	4.2	4.3	3.9
*S2	350	267	182	145	1.5	1.2	11.2	12	45.3	40.1	629	505	4.9	6.3	10.2	7.8	6.9	5.2
*S3	172	148	150	140	0.9	0.98	168.3	138.3	92.2	78.1	553	460	3.2	4	17.2	12.5	6.2	4.9
*S4	268.8	240	135	125.3	1.28	1	149	115	78.2	55	501	472	3.2	5.3	8.1	5.2	4.3	3.9
S5	182	150	100	83	0.992	0.51	85.3	63.2	82.4	65.2	414	321	4.2	6	5.5	3.6	4.2	3
S6	180	140	140	127	0.53	0.24	80.3	68	75.3	58.2	429	336	5.1	6.9	4	2.8	3	2.8
S7	250.2	215.8	140	140	1.2	1	93	88	66	60	534	413	6	6.2	3.5	2.2	3	2.4
S8	138	98	102	80	0.53	0.23	17.2	11.8	45	32.2	272	147	5.9	6.9	3.2	2.1	2.9	2.2
S9	140	130	80.2	78	0.81	0.24	51.2	43.2	59.2	45.2	276	266	6.1	7.1	4	3	3.3	3.2
S10	245	210	254	230.9	1.4	1	72.1	48.9	121	97	600	442	5	6	3.9	2.8	3.8	2.9
*S11	175.2	150	210	98.9	1.89	1.23	33.6	20.7	100.2	80.3	360	277	4	5	16.1	13.8	12.2	12
*S12	300	200	428	350	3.1	1.5	65	45.2	115	75	685	531	6.8	7	8.9	6.5	5.2	4.5
*S13	105	83.4	120	100	2.3	1.2	100	83.2	110	80	369	279	4	5.3	7.8	4.9	4	3.2
*S14	250	235	58	53	1.2	1.1	7.2	5.8	57	52.8	397	376	7	6.7	5.1	3.1	3.8	3
*S15	232	210	220	220	1	0.98	140	120	100	100	720	625	6.1	6.8	6.9	3.5	5.5	4.9

Table-2a & 2b Metals analyzed using ICP-MS

Table-2a																
SAMPLE	Fe		Ni		Ba		Pb		Co		Cu		Zn		As	
	Pre09	Post09	Pre09	Post09	Pre09	Post09	Pre09	Post09	Pre09	Post09	Pre09	Post09	Pre09	Post09	Pre09	Post09
S1	520	513	0.182	0.143	115.27	116.7	0.07	0.0675	0.48	0.334	0.223	0.286	138.26	123.54	1.504	1.092
*S2	678.	765	7.08	7.25	274.82	321.2	4.23	3.562	1.072	1.782	32.37	32.55	4190.33	4780	1.481	1.782
*S3	627	718	4.981	6.031	173.31	174.5	5.78	6.16	0.576	0.461	4.82	4.23	2109.2	3359.102	1.027	1.386
*S4	652	635	3.505	4.85	139.28	159.3	6.08	6.547	0.458	0.439	13.739	14.39	58.93	61.32	1.326	1.378
S5	500	499	0.144	0.129	38.37	34.73	0.58	0.694	0.281	0.431	0.57	0.73	52.39	44.71	1.02	1.631
S6	427	479	0.142	0.127	40.28	38.25	0.33	0.429	0.302	0.285	0.283	0.331	43.02	39.892	0.782	0.654
S7	415	476	3.08	3.27	80.08	72.96	0.28	0.31	0.472	0.418	0.3802	0.51	32.97	28.56	0.981	0.881
S8	450	482	3.87	3.59	63.78	62.49	0.39	0.332	0.36	0.358	0.298	0.33	39.23	43.12	0.872	0.763
S9	459	415	3.76	3.56	55.42	49.26	0.83	0.791	0.298	0.254	0.3682	0.391	17.92	15.98	0.803	0.774
S10	520	549	5.912	6.81	58.92	57.31	0.23	0.188	0.726	0.753	0.523	0.77	98.93	102.33	0.982	0.832
*S11	598	674	7.98	8.45	98.92	135.5	0.92	0.815	0.385	0.479	14.89	16.82	280.6	339.5	1.24	1.332
*S12	668.5	718	2.058	2.981	130.33	141.1	0.98	1.204	0.589	0.492	5.9	7.059	78.98	87.74	1.52	1.54
*S13	589.7	670.4	3.009	4.138	50.38	67.2	0.38	0.358	0.487	0.662	3.32	3.913	100.37	131.37	1.807	2.887
*S14	618.0	666.7	2.083	3.563	99.76	100.5	0.42	0.379	0.272	0.381	1.89	2.771	380.2	422.29	0.781	0.896
*S15	664.13	670.0	8.099	9.057	183.72	180.7	0.87	0.882	1.987	2.36	5.393	5.884	118.01	138.12	2.124	3.651

Table-2b																
SAMPLE	Se		Sr		Li		Be		B		Cr		Mn		Cd	
	Pre09	Post09	Pre09	Post09	Pre09	Post09	Pre09	Post09	Pre09	Post09	Pre09	Post09	Pre09	Post09	Pre09	Post09
S1	11.33	10.33	1198.8	901.22	16.23	15.33	0.2	0.198	800.3	786.55	0.072	0.0812	21.89	19.763	0.052	0.498
*S2	19.98	22.91	1801.7	1988.61	17.3	20.54	0.701	1.229	1432.7	1783.34	10.27	13.22	78.8	95.561	3.822	4.04
*S3	11.07	13.081	1573.7	1764.7	11.09	14.85	0.603	1.085	1392.9	1589.79	14.87	18.67	50.5	63.309	0.032	0.057
*S4	10.08	12.53	1571.81	1643.55	10.23	12.93	0.504	0.773	600.23	863.28	9.103	13.08	38.08	37.85	0.027	0.073
S5	8.97	7.172	589.2	559.07	6.24	5.995	0.082	0.024	283.1	300.65	7.59	9.534	10.02	10.347	0.031	0.047
S6	7.99	7.207	819.09	820.332	7.2	5.764	0.1	0.097	381.9	368.12	0.842	1.045	0.592	0.476	0.01	0.014
S7	9.23	8.067	1390.37	1288.7	4.3	5.521	0.032	0.041	250.53	340.76	1.032	2.046	0.674	0.572	0.051	0.042
S8	8.26	7.826	613.48	579.99	4.2	3.994	0.015	0.026	287.83	316.59	0.892	1.476	0.392	0.554	0.04	0.027
S9	8.02	6.839	593.89	563.71	5.03	4.39	0.03	0.043	278.19	300.74	1.023	1.117	0.482	0.458	0.022	0.043
S10	13.09	11.891	1575.5	1538.73	5.12	4.762	0.88	0.894	397.61	307.71	6.018	7.53	0.707	0.803	0.0391	0.0365
*S11	12.87	14.642	803.79	1095.68	12.81	15.68	0.032	0.072	820.03	880.36	20.86	23.17	14.29	15.69	0.021	0.017
*S12	19.82	21.43	1998.28	2286.59	20.08	22.883	0.029	0.0336	783.48	892.14	7.08	9.646	28.9	30.236	0.032	0.056
*S13	9.02	11.02	877.36	850.56	8.32	11.349	0.064	0.0843	693.2	761.25	7.012	8.86	0.401	0.847	0.041	0.0862
*S14	7.9	8.32	750.91	849.29	10.35	11.748	0.029	0.058	789.3	824.36	18.08	19.239	26.9	29.125	0.029	0.0338
*S15	9.93	10.739	1821.13	1939.54	13.1	15.413	0.072	0.114	815.93	893.32	7.5	8.51	60.2	65.39	0.0621	0.0841

Variables	Premon09			Postmon09		
	Factors			Factors		
	1	2	3	1	2	3
pH	-0.005	-0.09	0.147	0.093	-0.064	0.011
EC	0.885	0.15	0.147	0.205	0.846	0.058
TDS	0.855	0.174	0.121	0.231	0.859	0.079
Ca	0.499	0.289	0.025	0.385	0.41	0.034
Mg	0.844	0.329	-0.287	0.065	0.731	-0.165
Na	0.723	-0.318	-0.009	-0.274	0.702	0.043
K	-0.043	-0.103	0.91	-0.056	-0.097	0.957
CO3	-0.007	0.045	0.055	0.026	0.104	-0.159
HCO3	0.507	0.689	-0.207	0.392	0.298	-0.008
Cl	0.909	0.044	0.178	0.047	0.942	-0.044
F	0.729	0.052	0.39	0.233	0.613	0.396
NO3	0.269	-0.255	-0.12	-0.217	0.32	-0.167
SO4	0.713	-0.441	0.313	-0.351	0.576	0.324
TH	0.765	0.352	-0.154	0.283	0.673	-0.072
DO	0.148	-0.017	-0.27	-0.149	-0.029	-0.413
COD	0.208	0.313	0.74	0.407	0.19	0.736
BOD	0.125	0.264	0.918	0.21	0.07	0.946
Iron	0.439	0.529	0.386	0.578	0.456	0.361
Nickel	0.102	0.318	0.511	0.293	0.191	0.556
Barium	0.218	0.847	0.136	0.882	0.22	0.203
Lead	0.053	0.581	0.043	0.476	0.11	0.043
Cobalt	0.286	0.267	0.012	0.446	0.198	0.003
Copper	0.079	0.839	0.373	0.804	0.03	0.396
Zinc	0.004	0.905	0.099	0.888	0.018	0.017
Arsenic	0.369	0.116	0.256	0.141	0.259	0.052
Selenium	0.66	0.609	0.213	0.723	0.574	0.285
Strontium	0.753	0.429	-0.125	0.46	0.787	0.09
Lithium	0.485	0.525	0.332	0.631	0.528	0.32
Berilium	0.26	0.477	-0.152	0.656	0.152	-0.009
Boron	0.228	0.713	0.38	0.839	0.231	0.219
Chromium	0.112	0.303	0.699	0.264	0.108	0.668
Manganese	0.19	0.79	0.111	0.805	0.21	0.055
Cadmium	-0.028	0.905	0.006	0.92	-0.092	-0.069
%variance	23.475	22.851	12.974	24.048	20.405	12.795
%cumulative	23.475	46.326	59.3	24.048	44.453	57.248

Table-3b: Comparison of Factor Loadings of Pre and Post monsoon 2009

	Factor Loadings (pre-monsoon 2009)	Factor Loadings (Post-monsoon 2009)
Factor-1	EC, TDS, Mg, Na, HCO ₃ , Cl, F, SO ₄ , TH, Se and Sr	Fe, Ba, Cu, Zn, Se, Li, Be, B, Mn and Cd
Factor-2	HCO ₃ , Fe, Ba, Pb, Cu, Zn, Se, B, Mn and Cd	EC, TDS, Ca, Mg, Na, Cl, F, SO ₄ , TH, Co, As, Li and Se
Factor-3	K, COD, BOD, Ni and Cr	K, COD, BOD, Ni and Cr

oxygen atoms. Boron containing minerals are common in nature as sodium borosilicate minerals and boric acid. Boron concentrations in groundwater are derived from leaching of rocks and soils that contain borate and borosilicate minerals.

Except S2 all the samples have Barium value within the permissible limit. The EPA sets a maximum limit for barium in drinking water to 200 ppb. The highest value for barium above the EPA permissible limit is for sample S2 which is very close to the autonagar MSW dumpsite. Barium exhibited positive loadings in pre and post monsoon seasons. Barium in water comes primarily from natural sources (WHO, 2004). The nitrates and halides of barium are soluble in water; Organic barium

compounds are ionic and are hydrolyzed in water (Cotton & Wilkinson, 1980). The concentration of barium ions in natural aquatic systems is limited by the presence of naturally occurring anions and possibly also by the adsorption of these ions onto metal oxides and hydroxides (Hem, 1959), but barium has not shown any positive loadings with nitrate, chloride and fluoride indicating that the geogenic source of barium in groundwater samples is absent. Therefore the presence of barium in the ground water samples is due to the anthropogenic source.

Except S10 (for pre monsoon) and S12 all the samples have chloride value below the permissible limit of 250 mg/L as per BIS. Chloride exhibited high loadings in pre and post-monsoon seasons of 2009 indicating that it is the dominant species among the anions, which contribute for the TDS. For post monsoon season of year 2009 it showed moderate loadings. The chloride concentration of S12 is higher as it is within 1Km distance from the MSW dumpsite and lies downstream with respect to dumpsite. The samples S10 and S15 are close to the polluted surface water ponds. Chloride is one of the major inorganic anions in ground water.

Fluoride exhibited low to moderate loadings in both the seasons. The concentration of fluoride in samples S2, S11, S12, and S13 exceed the permissible limit of 1.5 mg/L as per BIS. The samples S2, S11 and S12 are within 1Km distance from the MSW dumpsite. The high value for sample S13 even though it is more than 2Km away from dumpsite may be due to its downstream w.r.t dumpsite and also close to the surface water pond. Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering and deposition of atmospheric volcanic particles. Fluoride can also come from Runoff and infiltration of chemical fertilizers in agricultural areas, septic and sewage treatment system discharges and Liquid waste from industrial sources. (Smedley et al. 2002; Edmunds and Smedley 2012).

The parameters TDS, DO and BOD values of all the samples are beyond the permissible limit for drinking water.

Except S1, S2, S8, S11 and S14 all the samples have nitrate value beyond the permissible limit. Nitrate exhibited the same trend in loadings for both the seasons, which indicates that ground water is contaminated with NO₃⁻. The standard nitrate concentration for drinking water is 45 mg/L and there is no relaxation in permissible limit as per BIS. This may be due to presence of samples downstream w.r.t dumpsite. The samples S3 and S4 are having highest value of nitrate indicate their source is MSW leachates, whereas

for S13 the reason for high concentration of nitrate may be due to its close proximity from the polluted surface water pond. Nitrate can reach the ground water as a consequence of agricultural activity, from wastewater treatment and from oxidation of nitrogenous waste products in human and animal excreta. In soil, wastes containing organic nitrogen are first decomposed to ammonia, which is then

oxidized to nitrate and nitrite. Surplus nitrate readily moves with the ground water (Van Duijvenboden 1989).

Conclusion

Both pre and post monsoon seasons indicate more or less the same trend in the loadings with the exception that in post monsoon 2009 the loading parameters has interchanged from factor-1 to factor-2. The similarity indicates that the contamination of groundwater is nearly same in both the seasons but the intensity of contamination decreased in post monsoon season. The parameters pH, Ca, Mg, SO₄, Fe, Mn, Cu, Ni, Cd, Pb, Sr, Co and As are within the permissible limits for drinking water for all the samples for both the seasons. The parameters TDS, DO and BOD values of all the samples are beyond the permissible limit for drinking water. It is also observed that the ground water samples which are within 1Km distance from the MSW dumpsite and downstream w.r.t MSW dumpsite have higher values of the parameters, where as the samples which are far from the dumpsite and upstream w.r.t dumpsite have lower values.

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