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ENVIRONMENTAL IMPACT OF AN ABANDONED COMPOSTING UNIT IN BANGALORE

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ABSTRACT
Solid waste management still remains one of the most vicious problems to be resolved due to the lack of serious strategic efforts by the municipal authorities resulting into an existing inefficient, outdated and unscientific solid waste management system of Bangalore city. An abandoned composting unit, Karnataka Compost Development Corporation (KCDC) has been selected to investigate the impact of leachate on groundwater and surface water source (Haralakunte Lake) in the vicinity of the unit. The characterization of leachate, surface water and groundwater samples revealed that the water reserves have been deteriorated by the percolation of untreated leachate. The spatial and temporal changes in the groundwater quality are shown with the aid of contour plots. The deterioration of groundwater quality is evident from the hydrochemical facies plotted using Piper and Durov diagrams showing a shift in the ionic composition which is further corroborated with the help of cluster analysis.

KEYWORDS: solid waste management; impact; abandoned composting unit; KCDC; groundwater quality; surface water; Bangalore.

INTRODUCTION
Water is the most essential and precious of all the natural resources. Generally the ground water is considered to be less polluted as compared to the surface water, due to lesser exposure to the external environment but lack of sanitation and improper waste management are likely to ruin the purity of the groundwater leading to increased pollution levels, hence it has been reported that about 40% or even more disease outbreaks are attributed to be waterborne in nature (Gupta and Iqbal, 2009). Solid waste disposal sites pose a serious threat of pollution to the environment, especially when located very close to human settlements and water sources and operated unscientifically. The municipal solid waste, in addition to the biodegradable waste, might also contain inorganic chemicals, complex organic compounds, detergents and metals. These contaminants as such are toxic; the toxicity can be further enhanced by the uncontrolled microbial action leading to the discharge of more toxic compounds (Gupta and Iqbal, 2009). The moisture content of the waste along with the precipitation entering the waste leads to the extraction of the water soluble compounds and particulate matter of the waste and the subsequent generation of leachate laden with toxic contaminants. It is established that the leachate generated from the closed landfills can have equal or more contamination potential in comparison to the active landfill sites and hence, the remediation actions and post-closure monitoring should be ensured at the closed landfills till the leachate generated is stabilized and poses no further threat to the environment (Alappat and Kumar, 2005).

STUDY AREA
Karnataka Compost Development Corporation (KCDC) was established in 1975 to treat Bangalore city's garbage for the production of compost based organic manure and vermi-compost. The dumping site is located in southwestern part of Bangalore, one of the most urbanized areas near Haralakunte Township about 2 km away from NH-7 and is located at 12˚ 54' N latitude and 77˚ 39' E longitude. It is covered in survey of India (SOI) toposheet no. 57H/09 and occupies an area of 11.16 hectares approximately. KCDC used to treat around 300 Metric tons of garbage per day by aerobic decomposition windrow method. Now it is an abandoned solid waste disposal site as it has stopped receiving waste since May 2008. The age of the dumpsite is around 33 years. The geology of the study area is mainly granitic gneisses belonging to Precambrian age and the soil is sandy loam and clayey loam type.The untreated leachate from the site finds entry into the dug well located behind the waste dump and into the nearby Haralakunte Lake as there is no impervious barrier to contain the leachate. The lake is spread over 1 hectare and is situated in the downstream of composting unit. Long time before, the lake water was used for agriculture, drinking purposes and to wash the cattles. Presently the lake water is not being used for any of the above purposes because of the pollution due to the inflow of sewage from nearby colonies and the leachate from the dumpsite. During rainy season severe flooding occurs, due to the lack of proper storm water management and the haphazardly cropped up residential colonies which block the natural drainage of the area (Cumar and Nagaraja, 2010).

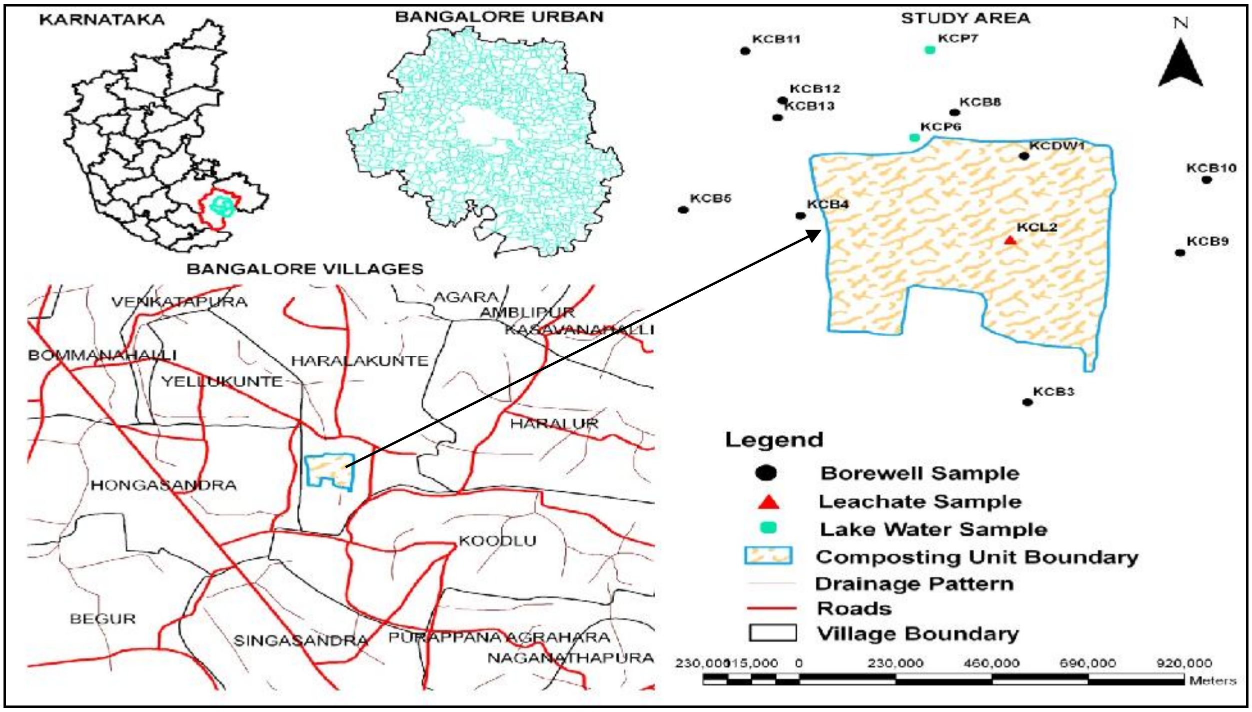


Figure1. Location map of study area, KCDC, Bangalore

MATERIALS AND METHODS

The sampling and analysis was carried out for both pre-monsoon and post-monsoon seasons of the year 2009. The leachate sample was collected from the drains of the composting unit in polyethylene bottle of 1 litre capacity. Similarly 9 bore well water samples, 1 dug well sample and 2 lake water samples were collected in the vicinity of the composting unit so as to examine its impact on the nearby water quality. The boundary of the composting unit and location of the sampling points was marked using a garmin GPS. pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured in the field itself using HACH HQ 30d meter. Nitrate and fluoride were analyzed using ion selective electrode method, phosphate and sulphate using spectrophotometer(Jenway-6400), bicarbonate, calcium, magnesium, chloride, total Kjeldahl and ammonical nitrogen by titrimetric methods; sodium and potassium by flame photometry, biological oxygen demand (BOD) by modified Winkler's method and COD by open reflux method. For heavy metal analysis (Fe, Zn, Ni, Cu, Pb, Cr and Cd), samples were separately collected in 100ml polyethylene containers, acidified onsite to pH 2 and analyzed using an Atomic Absorption Spectrophotometer (Shimadzu AA-6300). The samples collected were refrigerated at 4˚C until analyzed. Analytical methods followed were according to "Standard methods for examination of water and wastewater" (APHA, 2005). The accuracy of chemical analysis was determined using the normalized inorganic charge balance of the major ionic constituents (Edmund and Huh, 1999). The ionic balance for all the samples was within a limit of ≤10% (Hem, 1975).

RESULTS AND DISCUSSION

Leachate Composition

The leachate composition depends principally on the type of waste, waste degradability, age of the fill, stage of degradation, moisture content and precipitation. Also the physiochemical processes like dissolution, precipitation, adsorption, dilution and volatization control leachate quality (Klimiuk and Kulikowska, 2008). The colour of the leachate was brownish black indicating the presence of humic compounds.

The pH of leachate is found to be 8.35 and 8.37 in the pre-monsoon and post-monsoon seasons respectively indicating that the leachate has almost become stabilized and the biochemical activity is in its final stage as alkaline pH is characteristic of leachate from aged wastes (Fatta, Loizidou and Papadopoulos, 1999). Such a leachate would require high coagulant dose if chemical treatment is to be carried out. The moderately high values of TDS (6970mg/l in pre-monsoon and 5168mg/l in post- monsoon) and EC (12008 mg/l in pre-monsoon and 8390 mg/l in post-monsoon) are attributable to large concentration of cations and anions indicating the presence of inorganic materials in the samples. The TDS exceeded the recommended concentration set by MoEF (2000) for the disposal of leachate in both pre-monsoon and post-monsoon seasons (Table 1). Leachate was found to contain high Cl^- exceeding the recommended standards for disposal of leachate in both pre-monsoon and post-monsoon seasons (Table 1). Since Cl^- is inert and non-biodegradable, it can be used as an indicator of contamination of nearby water reserves, contacted by the untreated leachate (Tatsi and Zouboulis, 2002). The BOD_5 and COD far exceeded the recommended standards (Table 1). The BOD5/COD ratio is found to be 0.45 in pre-monsoon and 0.31 in post-monsoon seasons respectively indicating the presence of still some biodegradable organic compounds.

TABLE 1. Physico-chemical characteristics of leachate: pre and post-monsoon 2009

Parameters	Pre-monsoon	Post-monsoon	Percent decrease or increase in concentration	Standards for disposal into inland surface water (MoEF)
Temp	31.6	28.7	9.18	
pH	8.35	8.37	-0.24	5.5 - 9.0
TDS	6970	5168	25.85	2100
EC	12008	8390	30.13	
SO_4^{2-}	278	243	12.59	
HCO_3^-	1952	1708	12.5	
Cl^-	2000	1100	45	1000
NO_3^-	34	21	38.24	
PO_4^{2-}	2.5	1.689	32.44	
BOD_5	1090	580	46.79	30
COD	2400	1867	22.21	250
TKN	263	202	23.19	100
AN	207	134	35.27	50
F^-	0.4	0.2	50	2
Ca^{2+}	320	244	23.75	
Mg^{2+}	207	120	42.03	
Na^+	912	630	30.92	
K^+	216	163	24.54	
Fe	13.15	10.64	19.09	
Zn	4.97	2.34	52.92	5
Ni	0.316	0.128	59.49	3
Cu	3.116	2.48	20.41	3
Pb	0.155	0.1	35.48	0.1
Cr	0.099	0.08	19.19	2
Cd	0.209	0.156	25.36	2
BOD_5/COD	0.45	0.31	31.11	0.12

All values are in mg/l, except temp (˚C), pH, EC (μS/cm)

TABLE 2. Physico-chemical characteristics of lake water: pre and post-monsoon 2009

Parameters	KCP6			KCP7		
	Pre-monsoon	Post-monsoon	Percent decrease or increase in concentration	Pre-monsoon	Post-monsoon	Percent decrease or increase in concentration
Temp	31.7	29.1	8.2	31.6	29.1	7.91
pH	8.5	8.9	-4.71	8	8.1	-1.25
TDS	2690	2100	21.93	2580	1900	26.36
EC	4464	3484	21.95	4128	3040	26.36
SO_4^{2-}	188	118	37.23	167	104	37.72
HCO_3^-	866	695	19.75	769	561	27.05
Cl^-	940	880	6.38	820	790	3.66
NO_3^-	23	18	21.74	20	14	30
PO_4^{2-}	3.284	2.149	34.56	2.865	1.608	43.87
BOD	90	40	55.56	46	29	36.96
COD	347	213	38.62	293	187	36.18
TKN	84	62	26.19	62	50	19.35
AN	50	39	22	45	28	37.78
F^-	0.6	0.5	16.67	0.5	0.5	0
Ca^{2+}	156	112	28.21	144	104	27.78
Mg^{2+}	68	49	27.94	73	49	32.88
Na^+	500	463	7.4	450	395	12.22
K^+	101	88	12.87	87	73	16.09
Fe	4.65	3.25	30.11	2.96	2.82	4.73
Zn	0.89	0.67	24.72	0.63	0.49	22.22
Ni	0.09	0.06	33.33	0.02	0.014	30
Cu	0.12	0.08	33.33	0.08	0.05	37.5
Pb	0.04	0.02	50	0.02	0.016	20
Cr	0.013	0.008	38.46	0.01	0.007	30
Cd	0.002	0.001	50	0.001	0.001	0

All values are in mg/l, except temp (˚C), pH, EC (μS/cm)

Among the nitrogenous compounds most of the total Kjeldahl nitrogen (TKN) is found to be in the form of ammonical nitrogen (AN) while the concentration of nitrates is low possibly due to the stabilization process involving the deamination of amino acids present in organic compounds (Crawford and Smith, 1985; Tatsi and Zouboulis, 2002). Also both TKN and AN concentration exceeded the standards set for the leachate disposal in the two seasons. Relatively lower concentration of heavy metals in the leachate could be a consequence of increase in pH value which reduces the metal solubility and also due to the adsorption and precipitation reactions occurring during the stabilization of leachate.

Lake Water Composition

To determine the impact of the leachate on the surroundings, characterization of lake water quality has been carried out and shown in Table 2. The lake water is highly polluted due to the influx of leachate from the dumping site along with the sewage from the nearby residential colonies. Sample no. KCP6 taken just adjacent to the composting unit and a recipient of both leachate and sewage is found to have higher concentration of contaminants when compared with KCP7, a recipient of sewage alone. The samples collected during post-monsoon showed lesser contaminants an outcome of dilution with rain water.

Very high values of TDS and EC (Table 2) for the lake water during both the seasons are attributable to the mixing of leachate and sewage into the lake water. The leachate and sewage discharge containing higher concentration of NO_3^- and PO_4^{2-} elevated their concentration in the lake water also. The COD of unpolluted water is normally less than 20mg/l but the value is on higher side for both the lake water samples for pre-monsoon as well as post-monsoon seasons (Table 2) due to a variety of chemical compounds contributed by leachate and sewage. The BOD is also very high, far exceeding the standard of 3mg/l, which could be ascribed to the organic loadings of both leachate and sewage. High concentration of NO_3^-, PO_4^{2-}, BOD, COD and TKN are the indicators of the organic matter in the lake contributing to eutrophication. Sodium and potassium were also found to be very high, being the indispensable nutrients for the microbial biota causing eutrophication. The trend in heavy metal concentration is: Fe>Zn>Cu>Ni>Pb>Cr>Cd for both pre-monsoon and post-monsoon seasons. The physicochemical characteristics of the lake water also indicate the impact of polluted lake water on the groundwater samples (KCB8, KCB12 and KCB13) located in the vicinity of the lake. Lake water pollution affects a large number of organisms which depend on the lake ecosystem such as periphytons, flagella bodies, insects, mollusks etc (Department of Mines & Geology Report, March 2011).

Groundwater Composition

The spatial and temporal variation in pH, total dissolved solids, Cl^-, NO_3^-, PO_4^{2-}, total Kjeldahl nitrogen, ammonical nitrogen, iron and zinc in the groundwater samples around the composting unit is shown in Figure 2. The dispersion of leached contaminants into the groundwater aquifer system is indicated by the clustering of high concentration contour lines. The contour plot (Fig. 2) indicates alarmingly high concentration of contaminants resulting from their anthropogenic inputs due to the seepage of leachate into the downstream water samples taken from the immediate vicinity of the composting unit and the dwindling of concentration of contaminants with the increase in distance from the dumping site.

pH of all the ground water samples is within the range of BIS standards (1992) and it varied from 6.8 to 7.7 in both the seasons. TDS and EC (Table 3 & Fig. 2 b1, b2) is found to be very high for the downstream samples (KCDW1, KCB4, KCB5, KCB8, KCB13 and KCB12) located in the immediate vicinity of the composting unit indicating the impact of leachate on the ground water quality. TDS values have exceeded the desirable limit set by BIS (1992) in almost all the samples. Increase in the TDS concentration decreases the palatability of water and may have laxative effect causing gastro-intestinal irritation (WHO, 1997). HCO_3^- concentration is very high and exceeded the desirable limit set by BIS (1992) in almost all the samples. The natural source of HCO_3^- in the groundwater is the dissolution of carbonate minerals and the diffusion of CO2 gas from the atmosphere. The anthropogenic CO2 emanating from municipal solid waste decomposition and oxidation of organic matter leaked from old latrines and sewage systems are considered as a chief source of HCO_3^- in the downstream water samples as opined by Mor *et al.*

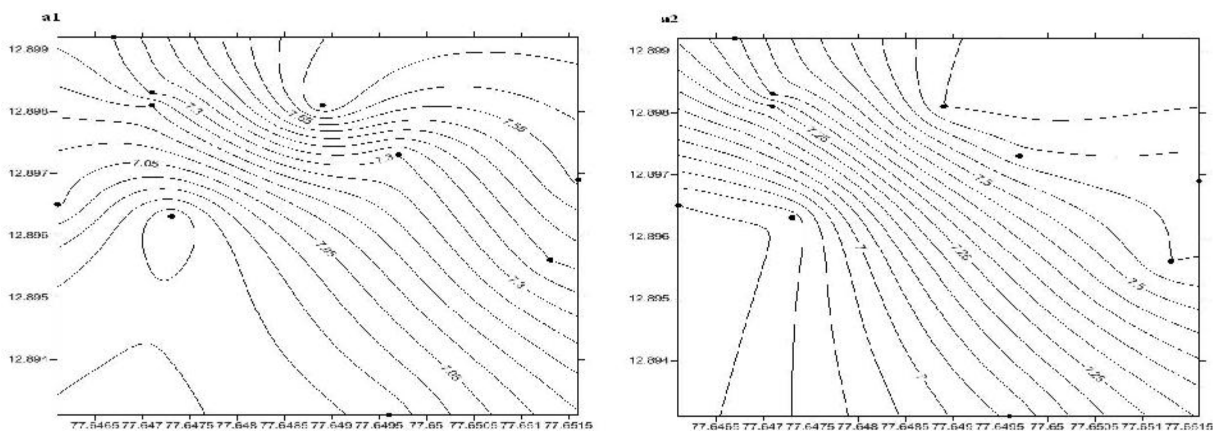
Higher concentrations of Cl^-, NO_3^- and PO_4^{2-} (Table 3 & Fig. 2 c1, c2, d1, d2, e1, e2) and the presence of total Kjeldahl nitrogen (TKN) and ammonical nitrogen (AN) (Table 3 & Fig. 2 f1, f2, g1, g2) in the groundwater samples (KCDW1, KCB4, KCB5, KCB8, KCB13, KCB12) have biochemical significance as a useful indicator of organic pollution (Chapman, 1992; Kapetanios and Loizidou, 1993). It indicates the seepage of leachate from landfill and the sewage from the nearby residential colonies to be the source of contamination. High Cl^- concentration in groundwater can affect the people suffering from heart and kidney disorders. Also if NO_3^- exceeds the permissible limit it can cause methaemoglobinaemia and at very high concentrations can cause gastric cancer (WHO, 1997).

The iron levels exceeded the BIS (1992) limit in KCDW1, KCB4, KCB8, KCB11, KCB13 and KCB12. The rock types found in Bangalore yield less iron content in the groundwater which could be from nil to 0.2 mg/l (Reddy, 2003). Higher concentration of Fe in the downstream water samples could be the result of the impact of leachate and sewage on the aquifer. Cu, Pb and Cd exceeded the BIS limit only in the case of KCDW1. Most of the physicochemical parameters exceeded the BIS (1992) limit in the case of KCDW1, KCB4, KCB5, KCB8, KCB13 and KCB12 in both the monsoon seasons.

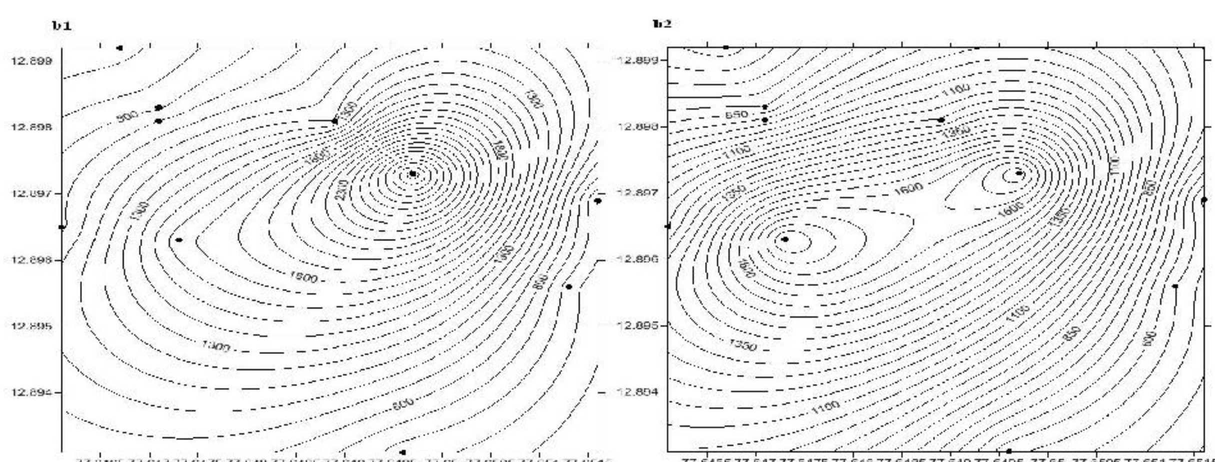
TABLE 3. Descriptive statistics of groundwater: pre and post-monsoon 2009

Parameters	Pre-monsoon 2009				Post-monsoon 2009				Desirable Limit (BIS1992)	Permissible Limit (BIS1992)
	Min	Max	Mean	S. D	Min	Max	Mean	S. D		
Temp	31.5	32	31.6	0.14	28.5	29.2	28.88	0.21		
pH	6.8	7.7	7.3	0.27	6.8	7.7	7.3	0.33	6.5-8.5	No relaxation
TDS	480	3200	1076	830.85	485	1859	995	510.72	500	2000
EC	768	5710	1813	1503.45	805	3211	1650	874.4		
SO_4^{2-}	21	202	61	53.39	33	139	60	35.82	200	400
HCO_3^-	293	1061	470	229.05	329	915	505	203.67	244	732
Cl^-	130	900	310	227.69	130	640	313	167.47	250	1000
NO_3^-	4	20	12	6.02	4	24	13	6.8	45	100
PO_4^{2-}	0	1.892	0.238	0.59	0	1.797	0.239	0.55		
TKN	0	151	36	45.67	0	112	34	36.07		
AN	0	106	25	32.76	0	62	13	19.61		
F^-	0.3	0.7	0.4	0.13	0.2	0.5	0.31	0.09	1	1.5
Ca^{2+}	76	280	119	60.33	68	220	116	47.27	75	200
Mg^{2+}	29	122	49	28.83	27	105	49	24.37	30	100
Na^+	58	480	145	127.25	59	350	146	98.93		
K^+	4	98	16	28.97	4	70	14	19.91		
Fe	0.021	5.73	0.919	1.73	0.035	3.96	0.82	1.19	0.3	1
Zn	0.068	1.43	0.449	0.46	0.056	1.13	0.469	0.43	5	15
Ni	0.002	0.19	0.023	0.06	0.003	0.1	0.022	0.04		
Cu	0.002	1.09	0.112	0.34	0.005	0.73	0.081	0.23	0.05	1.5
Pb	0.001	0.08	0.01	0.02	0.002	0.05	0.011	0.02	0.05	No relaxation
Cr	0.000	0.041	0.004	0.01	0.000	0.03	0.003	0.01	0.05	No relaxation
Cd	0.001	0.12	0.013	0.04	0.001	0.048	0.005	0.01	0.01	No relaxation

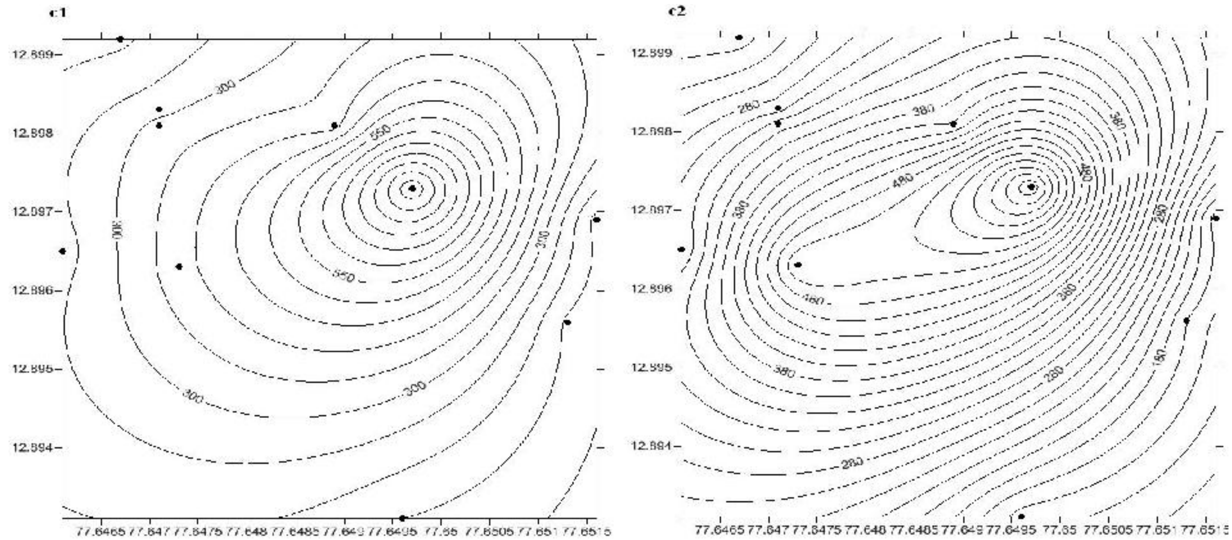
All values are in mg/l, except temp (˚C), pH, EC (µS/cm)



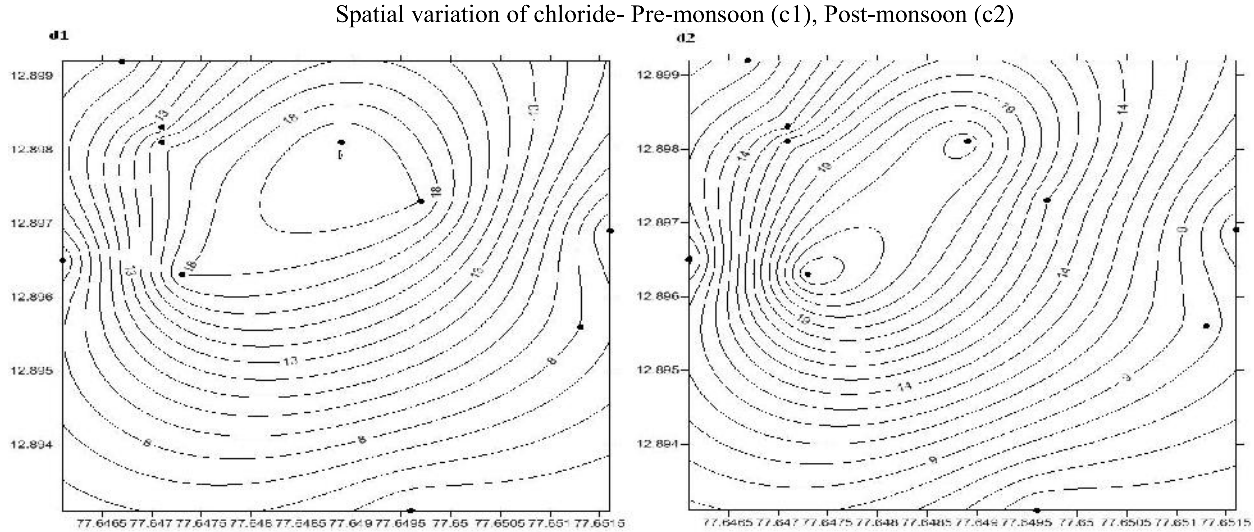
Spatial variation of pH- Pre-monsoon (a1), Post-monsoon (a2)



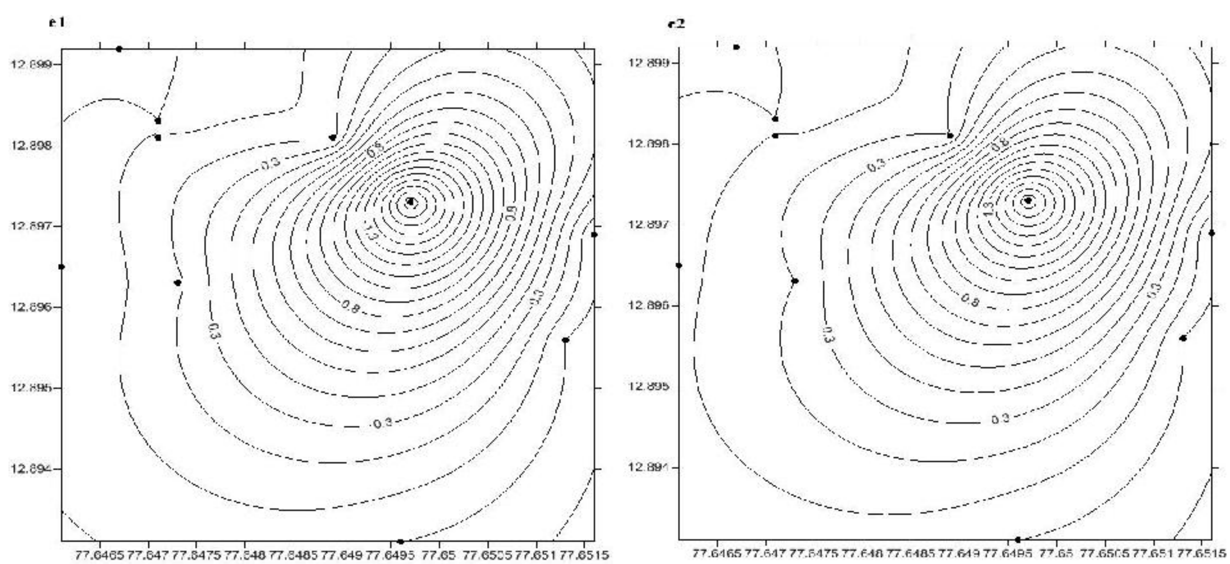
Spatial variation of total dissolved solids- Pre-monsoon (b1), Post-monsoon (b2)



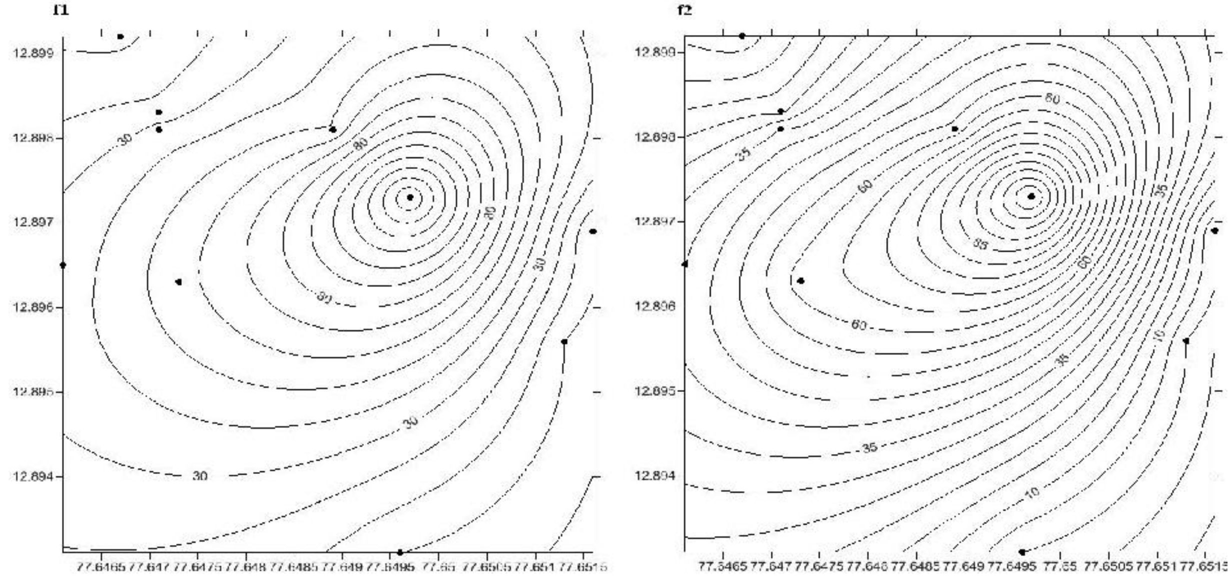
Spatial variation of chloride- Pre-monsoon (c1), Post-monsoon (c2)



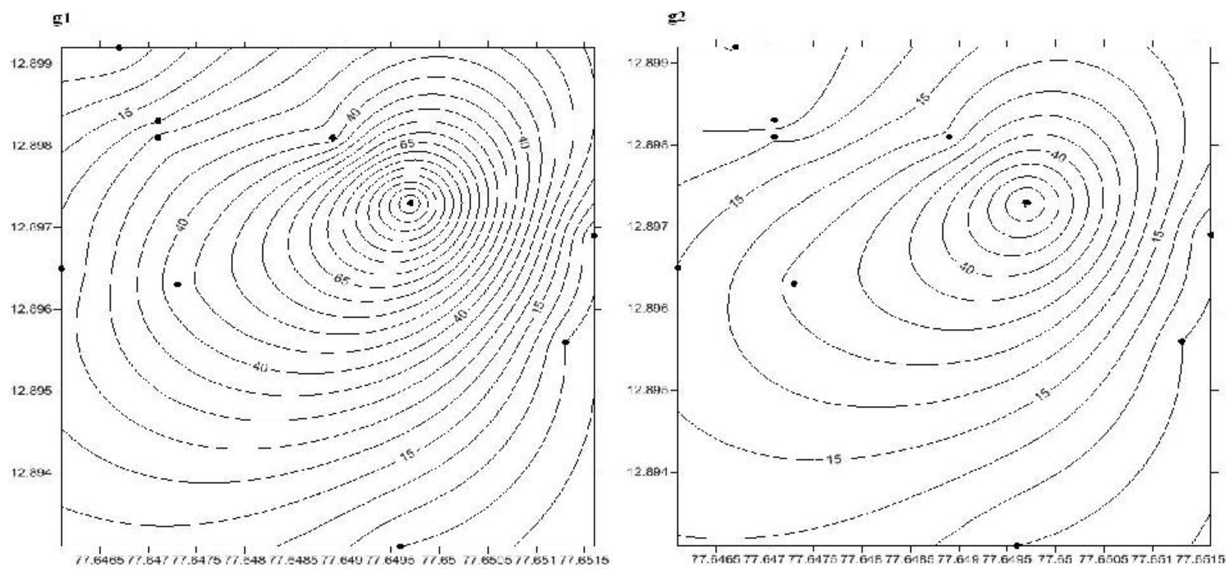
Spatial variation of nitrate- Pre-monsoon (d1), Post-monsoon (d2)



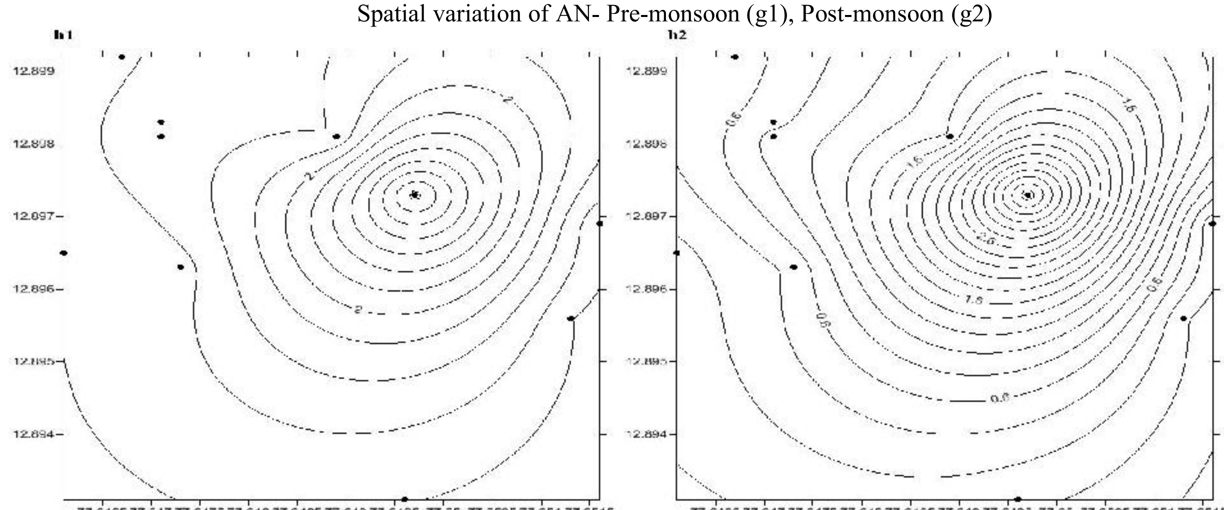
Spatial variation of phosphate- Pre-monsoon (e1), Post-monsoon (e2)



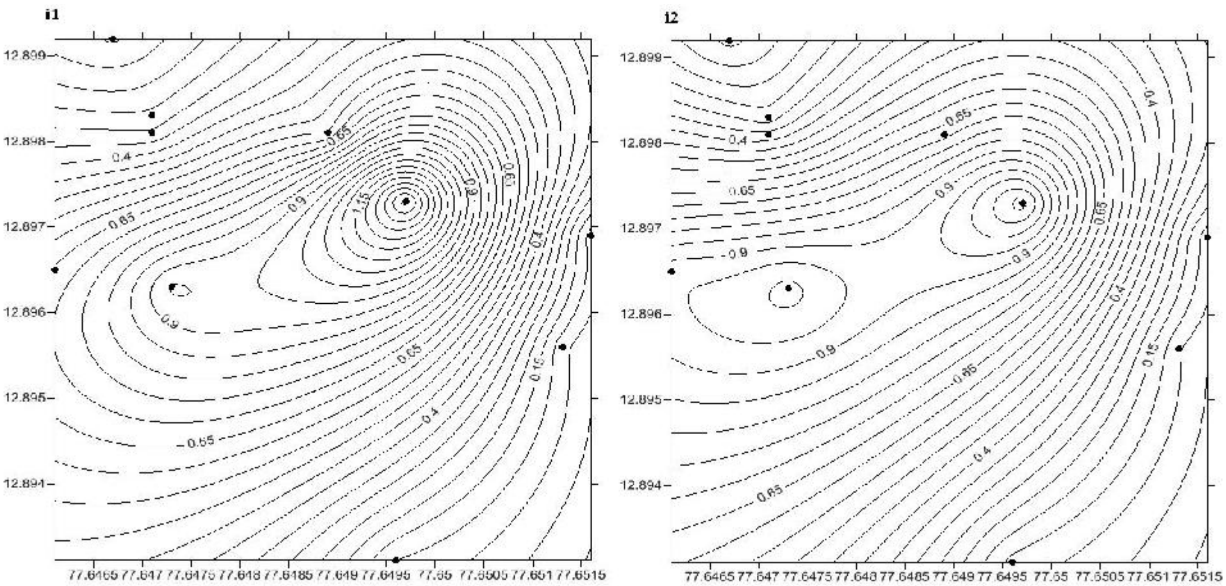
Spatial variation of TKN- Pre-monsoon (f1), Post-monsoon (f2)



Spatial variation of AN- Pre-monsoon (g1), Post-monsoon (g2)



Spatial variation of Fe- Pre-monsoon (h1), Post-monsoon (h2)



Spatial variation of Zn- Pre-monsoon (i1), Post-monsoon (i2)

FIGURE 2. Spatial variation of physico-chemical parameters in groundwater samples

Hydrochemical Facies

In Durov diagram, the major ions are plotted as percentages of milli-equivalents in two base triangles and projected onto a square grid that lies perpendicular to the third axis in each triangle. Durov diagram shows the clustering of data points to specify the samples that have similar compositions (Hem, 1989). All ions with concentrations more than 10% of the molar concentration in the solution are considered to be the major ions while the minor and trace elements are excluded (Guler et al., 2002). It helps to distinguish between polluted and unpolluted water samples easily (Fig 3a).

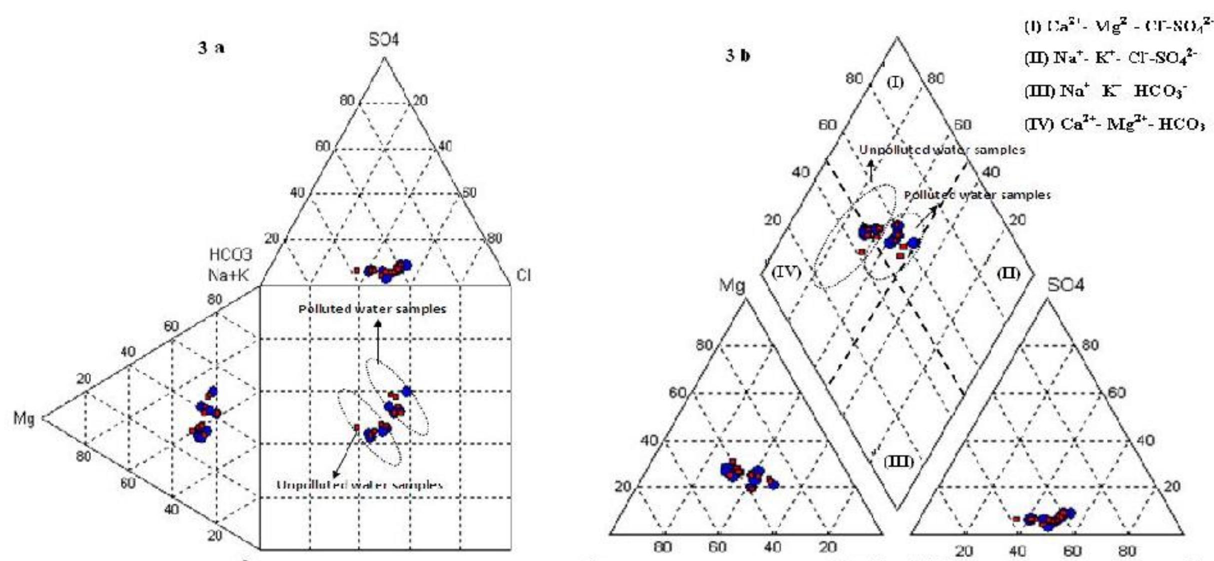


FIGURE 3. Durov (3a) and Piper (3b) plot of groundwater samples (blue dots Pre-monsoon, red squares Post-monsoon)

Piper's (1944) tri-linear diagram (Fig. 3b) was plotted using the concentration of major cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (SO_4^{2-}, HCO_3^{-} and Cl^{-}) in milliequivalents per liter, which depicts the geochemical evolution of groundwater in the study area. The diagram consists of two triangular fields in which the percentage epm values of cations and anions are plotted separately and are projected on to the central diamond shaped field to show the overall chemical characteristics of groundwater samples. Hydrochemical facies reveal the outcome of chemical reactions stirring between the minerals within the lithologic framework and groundwater along with the contamination from anthropogenic sources (Ravikumar et al., 2010). All the groundwater samples in the study area belong to I and IV hydrochemical facies (Fig. 3b). Most of the unpolluted water samples in the upstream and quite distant from the composting unit showed a decreasing order of cation facies as $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$ and anion facies as $HCO_3^{-} > Cl^{-} > SO_4^{2-}$ while the contaminated water samples showed a decreasing order of cation facies as $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$ and anion facies as $Cl^{-} > HCO_3^{-} > SO_4^{2-}$ (Table 4). Ca^{2+} and HCO_3^{-} are the dominant cations and anions respectively in the unpolluted water samples while the dominant cations and anions in the contaminated water samples are Na^+ and Cl^- indicating their anthropogenic input into the aquifer from the seepage of leachate and mixing of sewage. Thus this plot helped in differentiating the contaminated water samples from the water samples reflecting the natural background water chemistry.

TABLE 4. Water types of groundwater samples

Pre-monsoon				Post-monsoon			
Water types	Sampling ID's	No. of samples	%	Water types	Sampling ID's	No. of samples	%
Na-Ca-Mg-Cl-HCO3	KCDW1, KCB4, KCB8, KCB12, KCB13	5	50%	Na-Ca-Mg-Cl-HCO3	KCDW1, KCB4, KCB8, KCB13	4	40%
Ca-Na-Mg-HCO3-Cl	KCB3, KCB10, KCB11	3	30%	Ca-Na-Mg-HCO3-Cl	KCB3, KCB5, KCB10	3	30%
Ca-Na-Mg-Cl-HCO3	KCB5	1	10%	Ca-Na-Mg-Cl-HCO3	KCB11	1	10%
Ca-Mg-Na-HCO3-Cl	KCB9	1	10%	Ca-Mg-Na-HCO3-Cl	KCB9	1	10%
				Na-Ca-Cl-HCO3	KCB12	1	10%

Cluster Analysis

A multivariate statistical analysis technique called hierarchical cluster analysis was applied to the groundwater quality data using Ward's method and Euclidean distance as a measure of similarity. The physicochemical parameters analyzed were used as the criteria to assess the spatial heterogeneity among the sampling points. The sampling points were grouped according to the similarity with each other and based on the degree of contamination. The dendrogram of sampling points yielded four and three major groupings for pre and post-monsoon analysis respectively (Fig. 4a, 4b).

Pre-monsoon

KCDW1 is the most contaminated water sample, acting as a cesspool of leachate so it forms a separate group. It is followed by KCB4 which is also highly contaminated and grouped separately. KCB8, KCB12, KCB13 and KCB5 are moderately contaminated and formed a separate group. KCB9, KCB10, KCB11 and KCB3 are clustered together as they are not influenced by the leachate outflow from the composting unit.

Post-monsoon

In the post-monsoon season the spatial variation among the sampling points showed a slightly different trend. KCDW1 and KCB4 are grouped together due to the direct influence of leachate along with dilution effect of rainwater, as the most polluted samples. KCB12, KCB13, KCB8 and KCB5 being moderately polluted again formed a separate group as in pre-monsoon. KCB9, KCB10, KCB11 and KCB3 were again clustered together as in pre-monsoon indicating that they are unaffected by the composting unit.

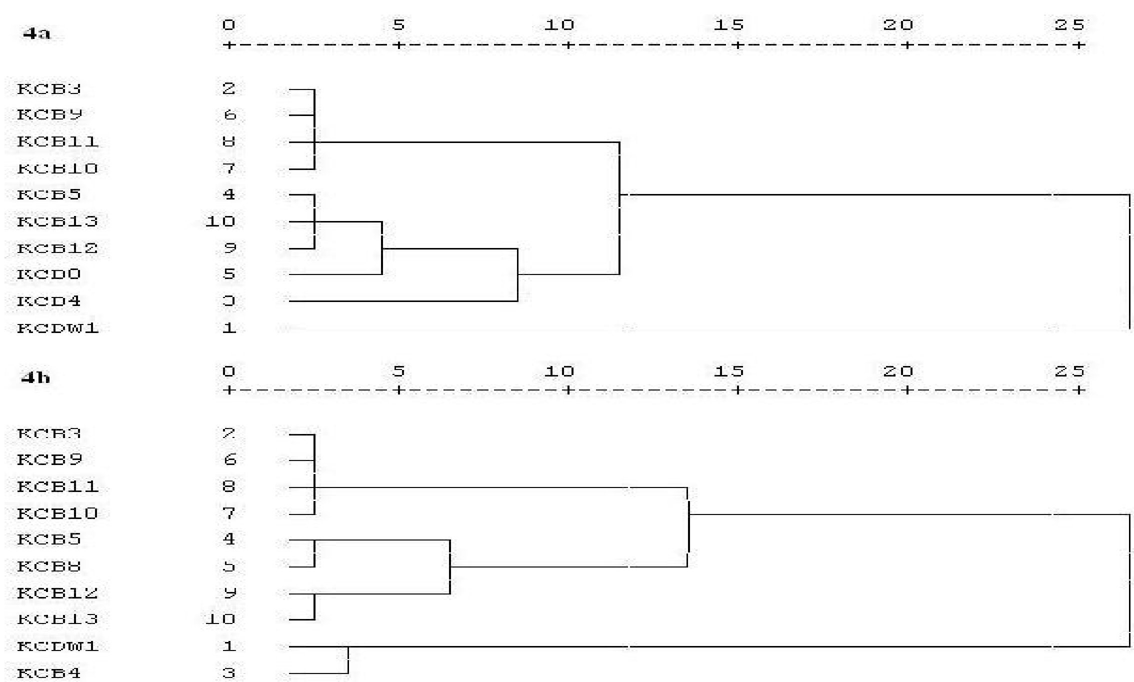


FIGURE 4. Dendrogram showing clustering of groundwater sampling points during Pre-monsoon (4a) and Post-monsoon (4b)

Though the impact of leachate on the groundwater quality cannot be interpreted quantitatively using this technique, it substantiates the findings of the physicochemical analysis, contour plots and the hydrochemical relationship depicted using Piper and Durov diagrams.

CONCLUSION

It is evident from the results of this study that the groundwater and even the surface water body in the vicinity of the composting unit have suffered serious deterioration in the quality because of the seepage of the untreated leachate from the composting unit along with the mixing of the sewage from the residential colonies. It shows the sheer negligence of the municipal authority as it has not carried out a site suitability analysis before the commencement of this waste disposal unit and also no measures have been employed for treating the leachate. Also the dug well located behind the composting unit acted as a cesspool or leachate collection pond. Not even the containment of the untreated leachate by means of liners has been practiced. This composting unit has not only endangered the water resources in its vicinity but also affected the health of people who depend on them. Contamination of the groundwater is a very serious problem as it can hardly be reformed and it persists for decades together because the groundwater travel times are very slow and the onsite treatment may not be an economically feasible option.

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