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Statistical evaluation of groundwater quality in and around Dindigul region, Tamilnadu, India

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ABSTRACT

The study was carried out to assess the quality of ground water in and around Dindigul region, Tamilnadu, India. Twenty three groundwater samples were taken from the bore wells with necessary precautions. All the groundwater samples were subjected to analysis of physico-chemical parameters and heavy metals. Each parameter was compared with the standard limit prescribed by the WHO. The analyses show that Cl and Ca are the dominant anion and cation, respectively. The average abundance order of heavy metal contents in groundwater samples are Fe> Pb> Cd> Cr>Mn>Zn>Cu. The value of zinc, iron and manganese are below the permissible limit in all groundwater samples. But the value of chromium, lead and cadmium are exceeded the permissible limit in few groundwater samples. The statistical parameters such as mean, variance, standard deviation and co-efficient of variation are calculated. Pearson's correlation co-efficient for physicochemical parameters and heavy metals were worked out. EC, TDS, Cl, Na, Ca and F are significantly correlated (0.61<r<0.99). The strong correlation between EC and TDS (r = 0.99) indicates a common chemical behavior.

Key words: Correlation, Dindigul, Groundwater, Heavy metal, Water quality.

INTRODUCTION

Water is an important parameter for the development of any nation as it is directly related to growth of the economy [1]. Over past few decades it has been observed that the shortage of freshwater is gradually increasing due to parallel demanding of clean water in agriculture, domestic and industrial units [2,3].

Groundwater is the main source of potable water supply for domestic, agricultural and industrial uses. It is under intense pressure of degradation and contamination due to urbanization, agricultural and industrial related activities. Improper wastes disposal and unscientific anthropogenic activities over the years have adversely affected the surface and groundwater quality. The major problem with the groundwater is that once contaminated, it is very difficult to restore it. The human activities like industrialization, urbanization and domestic activities, which been affecting water quality and leads to large scale water pollution [4].

Agricultural practices and industrial activities such as mining, battery manufacturing, plating, ceramics, glass, leaching from landfills and tannery effluents wastes are the main sources of heavy metal in water bodies [5-7]. It is very difficult to find the reason for degradation of water quality.

The existence of strong correlations among various water quality parameters and their combined effect of interrelatedness indicate the water quality. The statistical analysis of water quality parameters in terms of correlation and regression also provide necessary clue for implementation of rapid water quality management programmes [8].

Several studies [9-12] have been undertaken based on statistical analysis and assessed the quality of groundwater in different places. Therefore it is always a need and concern to protect and manage the quality of groundwater based on the above aspects of groundwater contamination.

Dindigul is the headquarters of Dindigul district is a rapidly growing city and is one of the well known places for tannery industries [13]. Most of the tannery units are located in the central part of the town and along Madurai, Vattalagundu, and Ponmandurai roads. During the past few decades, the groundwater is being contaminated giving rise to health problems and epidemic [14].

In fact, the processing of leather requires a large amount of freshwater along with various chemicals. The water table is deep due to over exploitation for irrigation and tanning purposes through dug wells, dug – cum bore wells and bore wells [15]. When the untreated tannery effluents are discharged into the groundwater for a prolonged period, seriously affect the groundwater quality of that locality. The effluents discharged from the tanneries pollute the groundwater permanently and make it unfit for drinking and irrigation purposes. The groundwater regime in upper Balar basin, Tamilnadu has been highly contaminated in several locations due to discharge of effluents from a large number of tanneries.

The leather tannery operations around the Dindigul are polluting the Kodaganar river and threatening its use for domestic, irrigation and general consumption.

Hence the present study has been undertaken to investigate the quality of groundwater and correlation coefficient of the various physico chemical parameters.

Description of the study area

Dindigul area is a hard rock, drought prone region and is situated in the Dindigul district of Tamilnadu, India. It lies in between $10^0 13^/$ - $10^o 26^/$ north latitudes and $77^o 53^/$ - $78^o 01^/$ east longitudes. It covers an area of about 240 km^2. The highest elevation (altitude) in the hilly area (Sirumalai hill) is of order of 1350 m. But it varies from 360 m in Southern portions to 240 m in the Northern parts of the area. Runoff from precipitation within the basin ends in small streams flowing towards main river Kodaganar. The average annual rainfall is in the order of 915.5 mm during the year of 2010 - 2011 [16].

MATERIALS AND METHODS

In this study, bore wells frequently use by the public is surveyed and analyzed for physical, chemical and heavy metal characteristics of water for the safe drinking water source. 23 ground water samples were collected during November 2012 from different bore wells in and around Dindigul Town, Tamilnadu. The sampling places are referred as stations (S1 – S23). The stations are Dindigul central bus stand (S1), Dudley school (S2), Dindigul government hospital (S3), St. Mary's school (S4), East govindapuram (S5), Dindigul taluk office (S6), Mariamman kovil (S7), Begambur mosque (S8), District treasury office (S9), Annamalai mills girls HSS (S10), Government industrial estate (S11), Railway station (S12), SP Camp office (S13), MSP School (S14), St. Joseph Hospital (S15), Cauvery water tank (S16), Chatra kulam (S17), West Ashok Nagar (S18), K.K Nagar (S19), Rockfort (S20), Paraipatti (S21), Poochinaickan Patti (S22), Bharathipuram (S23). The water samples are subjected to the analysis of physico-chemical parameters as per the standard procedure [17]. The obtained results are compared with the standard values for drinking water quality provided by the World Health Organisation [18]. The Pearson correlation analysis has been carried out to find out correlation for groundwater quality parameters.

RESULTS AND DISCUSSION

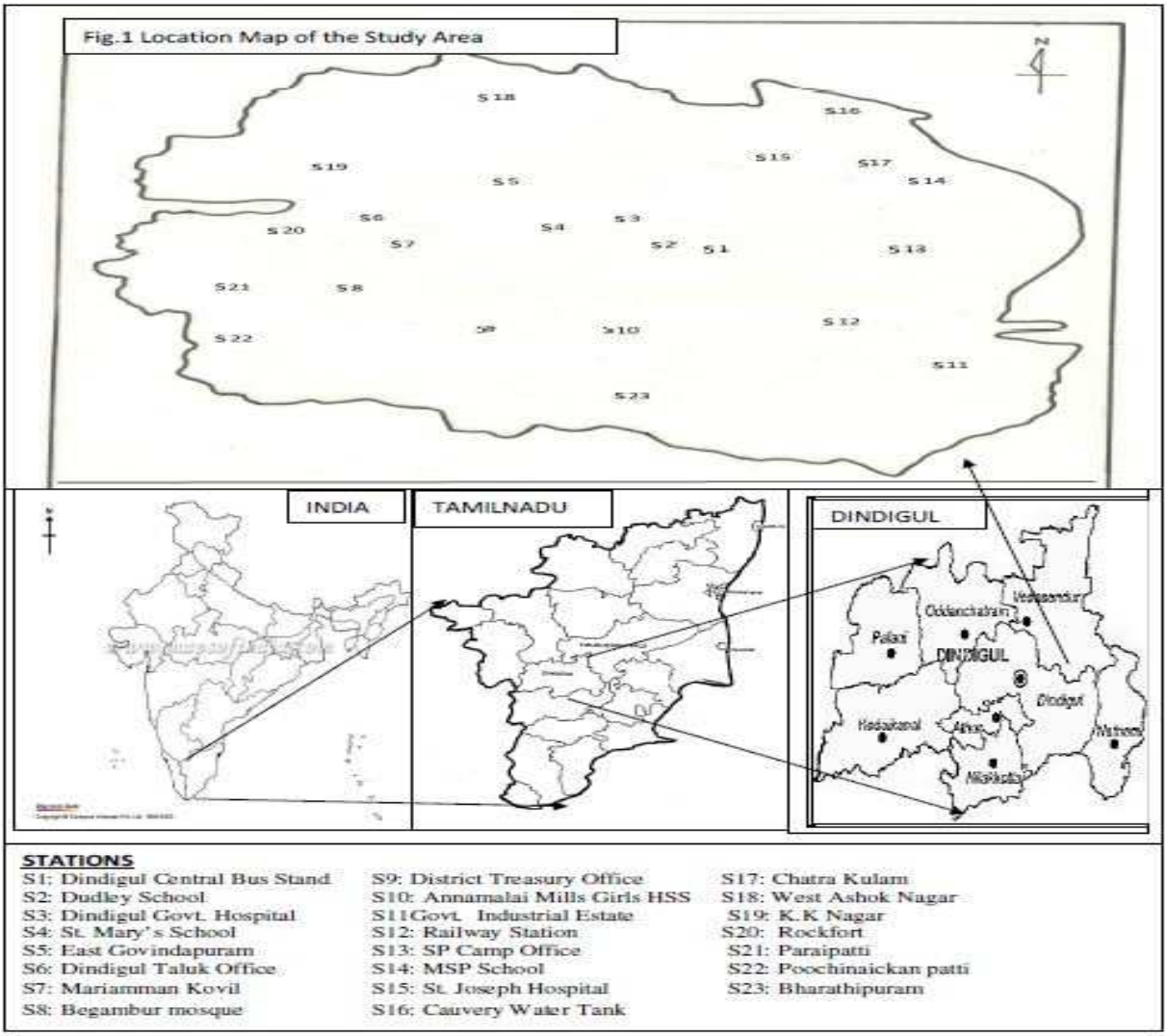
The groundwater samples were collected in and around Dindigul town, Tamilnadu, India. The statistical summaries of physicochemical parameters are tabulated in Table 1 and the Pearson Correlation analysis for physicochemical parameters with heavy metals are shown in Table 2. The experimental results are discussed and compared with the limits recommended by WHO.

Physico chemical parameters

The pH values are found to be in the range of 7.02 - 7.65 [Table 1] for the groundwater samples. The most of the groundwater samples are found to be within the permissible limit of WHO (6.5-8.5). The electrical conductivity

values are recorded within the range of 0.69 - 1.56 dsm^{-1} for the groundwater samples. The value of the total dissolved solids lie between 442 and 998 mg/l. TDS values are found within the permissible limit of 1500 mg/l for all the groundwater samples.

Figure 1: Location map of the Study Area



Carbonate values are not found in the groundwater sample, this may be due to the low pH value [19]. The bicarbonate values are recorded between 123 and 186 mg/l (Table 1). The values of chloride are found in the range of 103 - 258 mg/l. Most of the groundwater samples are having chloride within the permissible limit (250 mg/l).

The value of sodium and potassium are recorded from 20 to 96 mg/l and 0.12 and 0.25 mg/l for the groundwater samples respectively. Sodium and potassium values are found within the permissible limit of WHO in most of the groundwater samples.

The calcium and magnesium values are recorded between 74 and 220 mg/l and 48 and 95 mg/l respectively for the groundwater samples. Calcium values are exceeding the prescribed limit of WHO (200 mg/l) at station S1 but magnesium values are found within the permissible limit of WHO (150 mg/l). The values of fluoride are found in the range of 2.47 and 5.26 mg/l for the groundwater samples. The fluoride values are exceeding the permissible limit of WHO (1.0 mg/l) in most of the groundwater samples.

Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals [8]. The sulphate values are found between 42 and 97 mg/l for the groundwater samples. The values of phosphate are recorded between 0.01 and 0.06 mg/l for the groundwater samples. The highest value (0.06 mg/l) is at station S4 and minimum value is (0.01 mg/l) at station S11. Both sulphate and phosphate values are found within the permissible limits of WHO.

The DO values are recorded in the range of 0.2 to 0.6 mg/l. Low value of DO is indicating high deoxygenation in the groundwater which may be due to biological decomposition of organic matter. The BOD values are recorded in the range of 48 to 150 mg/l for the groundwater samples. The values of COD are found to be in the range of 25 - 95 mg/l for the groundwater samples. Both BOD and COD values are exceeded the permissible limit suggested by WHO in all sampling stations. This indicates that the groundwater is highly polluted with both oxidizable organic and inorganic pollutants [20].

Heavy Metals

Presence of heavy metals in groundwater is directly related to soil characteristics or anthropogenic activities that determine the rate of water movement [21].

The values of Zinc are found in the range of 0.01 to 0.06 mg/l for the groundwater samples. The highest value of zinc (0.06 mg/l) is observed at S5 and the lowest value (0.01 mg/l) is observed at S6. The maximum permissible limit of zinc is 5 mg/l. The values of zinc are found below the permissible limit of WHO (5 mg/L) in all the groundwater samples. The cadmium values are found in the range of 0.02 to 0.15. The cadmium values are within the permissible limit of WHO (0.1mg/l). The cadmium values are slightly exceeding the permissible limit of WHO (0.1 mg/l) in the sampling stations S6, S7, S8, S11 and S16.

The values of chromium are found to be in the range of 0.02 to 0.12 mg/l for all the groundwater samples. It is clear that the chromium concentrations in groundwater samples are exceeded the maximum permissible limit of WHO (0.05 mg/l) in few sampling stations. The excess of chromium at few sampling stations may be due to seepage of the tannery effluents which are located nearer to the tanneries.

The copper values are found within the range between 0.01 and 0.06 mg/l for the groundwater samples. The values of copper are found within the permissible limit of WHO (1.0 mg/l) for all the groundwater samples. If copper present in higher amount (above 0.05 mg/l), it gives astringent taste to water and causes discoloration and corrosion of pipes, fitting and utensils. The iron values are recorded between 0.02 and 0.17 mg/l for the groundwater samples. The iron values are found within the maximum permissible limit of 0.3 mg/l prescribed by WHO for all the groundwater samples.

The values of manganese are found between 0.01 and 0.09 mg/l for the groundwater samples. According to WHO, the maximum permissible limit of manganese is 0.1 mg/l. The manganese values are not exceeded in all the groundwater samples in the study area. The value of lead is found between 0.02 and 0.17 mg/l for the groundwater samples. The maximum value of lead is found at S11 and minimum value is found at S5. In this study, it is found that the value of lead is exceeded the permissible limit of WHO (0.01 mg/l) in all the groundwater samples.

Correlation Analysis

Pearson's correlation analysis is applied for the values of physicochemical parameters and heavy metals (Table 2). EC, TDS, Cl, Na, Ca and F are significantly correlated ($0.61<r<0.99$). High positive correlation is observed between Na^+ and Cl^- ($r = 0.94$) virtually in all the groundwater samples. The strong correlation between EC and TDS ($r = 0.99$) indicate a common chemical behavior. Major elements such as Na, Cl and Ca are significantly correlated with EC ($0.60<r<0.67$). Fairly good correlation is observed for Cl and Ca with HCO_3 ($r =0.8$). K and NO_3 show less positive and negative correlation with EC ($r=0.03$ and $r=-0.2$). A strong correlation is observed for K and NO_3 (-0.55), PO_4 and NO_3 (-0.61), Mn and SO_4 (-0.74) and Cd and NO_3 (-0.56). Zn shows moderate correlation with Fe and F ($r=0.75$). The pair having very high positive correlation between them shows the dependency of one parameter on the other and the pair having very negative correlation between them shows inverse relation between them.

Table 1 Statistical summary of physicochemical parameters

	pH	EC	TDS	CO_3^{2-}	HCO_3^-	Cl^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	SO_4^{2-}	PO_4^{3-}	F^-	DO	BOD	COD
Min	7.02	0.69	442	-	119	103	20	0.1	74	48	0.02	42	0.01	2.4	0.2	48	25
Max	7.65	1.56	998	-	186	258	96	0.2	220	95	0.09	97	0.06	5.2	0.6	150	95
Mean	7.25	1.070	691.56	-	142.8	136	41.5	0.1	128.1	76.0	0.05	63.4	0.031	3.4	0.3	89.7	44.5
Std. dev.	0.17	0.212	140	-	20.3	44.6	23.9	0.02	39.8	15.2	0.02	16.8	0.013	0.8	0.1	30.1	21.1
Std. err. of mean	0.03	0.044	29.192	-	4.2	9.311	4.9	0.01	8.3	3.187	0.004	3.5	0.003	0.18	0.02	6.285	4.40
Variance	0.03	0.045	19599.98	-	412.6	1993.8	571.3	0.01	1587.8	233.6	0.0	282.3	0.0	0.7	0.01	908.4	446.7
Range	0.63	0.87	556	-	67	155	76	0.14	146	47	0.07	55	0.05	2.7	0.4	102	70

Table 2 correlation matrix of various physicochemical parameters with heavy metals

	pH	EC	TDS	HCO3	Cl	Na	K	Ca	Mg	NO3	SO4	PO4	F	DO	BOD	COD	Zn	Cu	Fe	Mn	Cr	Pb	Cd
pH	1																						
EC	0.7623	1																					
TDS	0.7757	0.9947	1																				
HCO3	0.4112	0.6129	0.5990	1																			
Cl	0.3532	0.6041	0.5473	0.8094	1																		
Na	0.5047	0.6703	0.6256	0.7699	0.9419	1																	
K	0.4448	0.3575	0.3175	- 0.0058	0.3765	0.4089	1																
Ca	0.5308	0.6732	0.6477	0.8367	0.8267	0.9314	0.2429	1															
Mg	0.3632	0.3034	0.3283	0.3174	0.2796	0.4813	0.3671	0.6291	1														
NO3	- 0.1013	-0.2239	-0.2221	0.0482	-0.3178	-0.3379	-0.5594	-0.0992	-0.2698	1													
SO4	0.3139	0.5834	0.5390	0.7496	0.8900	0.9375	0.4004	0.8891	0.5203	-0.3520	1												
PO4	0.2888	0.3571	0.3454	0.0314	0.2337	0.1436	0.7291	-0.0144	0.0503	-0.6191	0.1668	1											
F	0.4056	0.4648	0.5438	0.4168	0.0644	0.1730	-0.1062	0.3200	0.5336	-0.2363	0.2039	0.1081	1										
DO	0.0216	-0.3113	-0.3334	- 0.3244	-0.0329	0.0775	0.4252	-0.1126	0.0380	-0.3970	0.1230	0.0993	-0.2820	1									
BOD	0.5204	0.6822	0.6618	0.7794	0.8354	0.9260	0.3845	0.9556	0.6975	-0.3366	0.8900	0.2147	0.3862	-0.0893	1								
COD	0.5972	0.7495	0.7097	0.7963	0.8966	0.9351	0.5271	0.9265	0.5609	-0.2344	0.8893	0.2987	0.2306	-0.0809	0.9370	1							
Zn	0.2024	0.2247	0.2955	0.1105	-0.1769	-0.1607	0.1131	0.0053	0.5129	-0.1310	-0.0902	0.3282	0.7585	-0.4177	0.1327	0.0732	1						
Cu	0.5284	0.2118	0.2772	0.2165	-0.0090	0.0413	0.0251	0.0570	0.2501	-0.1521	-0.0828	0.0502	0.6729	0.0407	0.0800	0.0649	0.5216	1					
Fe	0.1293	0.1387	0.2336	0.1131	-0.3069	-0.2250	-0.3457	-0.0614	0.3031	-0.0807	-0.1544	-0.0554	0.9083	-0.2671	-0.0180	-0.1819	0.7503	0.6535	1				
Mn	0.1108	-0.3509	-0.2861	- 0.2594	-0.6120	-0.6270	-0.3725	-0.5114	-0.2364	0.4419	-0.7468	-0.2123	0.1829	-0.1154	-0.5619	-0.5415	0.3115	0.6163	0.4207	1			
Cr	0.0699	-0.1504	-0.1655	- 0.4650	-0.3060	-0.2104	0.2252	-0.3519	-0.3309	-0.0416	-0.1514	-0.0091	-0.3146	0.7434	-0.4318	-0.3062	-0.4263	-0.0304	-0.1826	0.0348	1		
Pb	- 0.1035	-0.3373	-0.3733	- 0.3432	-0.2231	-0.1238	-0.0681	-0.1566	-0.2429	0.4117	-0.1168	-0.5699	-0.5653	0.5300	-0.3689	-0.2469	-0.6447	-0.2178	-0.4289	0.0369	0.7282	1	
Cd	- 0.1882	0.1338	0.0899	0.2338	0.5490	0.5358	0.5112	0.4069	0.4557	-0.5668	0.7279	0.2593	0.0138	0.3142	0.4949	0.4918	0.0234	-0.2293	-0.1644	-0.7723	-0.0052	-0.0562	**1**

CONCLUSION

In the present study, the Statistical assessment of groundwater quality of Dindigul town is carried out. From the analysis, it is concluded that the condition of the groundwater is critical and may be affected by the industrial and anthropogenic activities. Decreasing trend of fluoride and DO and increasing trend for BOD and COD of the groundwater is observed from the present study. This indicates the contamination of groundwater in most parts of Dindigul town. Trace element like Pb is exceeding the prescribed limit of WHO in all the groundwater samples. The heavy metals like Cd, and Cr are also slightly exceeding the prescribed limit of WHO at few sampling stations.

Correlations between major ions show expected relationship between Na^+ and Cl^- (r = 0.94); EC and TDS (r = 0.99); Cl and Ca with HCO_3 (r =0.8); Ca and SO_4 (r=0.88) Mg and Ca (r=0.63), derived mainly from the geochemical and biochemical processes within the aquifer. The poor correlation of the ions likes NO_3^-, Cr, Pb and Cd with pH has no significant effect over the groundwater composition.

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