CHEMICAL TOXICITY AND MICROBIAL CONTAMINATION OF GROUND WATERS NEAR AGRICULTURAL AREAS

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ABSTRACT

Water is essential for all living organisms. The addition of Chemicals will become a prime source for contamination of groundwaters near Agricultural activity areas. Keeping in view the hectic agricultural activity in West Godavari District of AP, India, it is proposed to assess the chemical toxicity of waters to suggest the remedial measures to protect the quality of waters to safeguard the health of the public residing in the nearby habitations of Agricultural activity areas. 16 Groundwater samples were collected and characterized for physicochemical parameters viz., pH, EC, TDS, TA, TH, DO, CO_3^{2-} , HCO_3^- , Cl^- , SO_4^{2-} , PO_4^{3-} , NO_3^- , Ca^{2+} , Mg^{2+} , Na^+ , K^+ to evaluate the quality of waters to assess their potentials for application. The waters were characterized for metal ions viz., Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb, As and Hg. Some waters are observed with Arsenic concentration while the concentrations of other metals are within the permissible limit. Further, the groundwaters were characterized to assess the microbial contamination and the waters were found to contain pathogenic bacterial species which can cause water-borne diseases. A health survey was carried out and the results revealed the sufferings of the people from health problems which are correlated with the presence of pathogenic bacterial species. The research results revealed that waters are with chemical and microbial contamination and proper treatment is to be done for controlling the toxicity.

Keywords: Groundwater, Agriculture, Characterization, Quality, Toxicity.

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INTRODUCTION

Groundwater is consumed by more than 90% population for drinking and other domestic purposes in India¹. Khan et al. revealed that nearly one-fifth of all water used in the world is used from groundwater resources². The studies of Karthik et al. revealed that higher TDS are due to the interaction of soil with water³. The studies of Ibrahim et al., explained that there are regional differences in water characteristics based on geology and climate⁴. Both urban and rural areas depend on Groundwater as the major source for drinking water⁵. The studies of Singh et al. have revealed that the quality of groundwater changes following variation in the physicochemical and biological environment through which it flows⁶. The studies of Talukder, M.S.U. et al., reported that irrigation with poor quality water reduces soil productivity, changes soil characteristics which ultimately reduces the yield^{7,8}.

The studies of K. Boudeffa et al. indicated that water from the downstream has been observed with higher physicochemical parametric values compared to the values of other stations⁹. The research work carried out by Deshpande S.M. et al.,¹⁰ on evaluation of groundwater quality and its suitability for drinking and agriculture showed that with higher concentrations of TDS(26.66%), EC(26.66%), Chloride(33.33%), total hardness(60%) and magnesium (86.66%) are indicators of deterioration in the quality of groundwater as per WHO and BIS standards¹¹. The research results of Piper, R.G. et al., indicates the water suitability for success or failure of a fish culture operations¹². Literature survey¹³ explained that the investigation of groundwater quality is considered commonly for aquaculture as it is free of toxic pollutants and contamination with living organisms. The concentration of chemical constituents will be influenced to a greater extent by geological formations and manmade activities determine the groundwater quality. The higher concentration of metal ions in waters can cause metal toxicity. Excessive utilization of pesticides also becomes a source of groundwater contamination. Pesticides like Calcium arsenate, Lead arsenate,

Sodium arsenate and arsenic acid will also become a major source of metal pollution in waters¹⁴. The research studies carried out by A. M. Shala Abazi et al. indicated the pollution of Stinica river waters due to higher physicochemical parametric levels¹⁵.

Keeping in view the agricultural scenario in the West Godavari region and aquacultural activity in Krishna district it is proposed to carry out the characterization of groundwater near agriculture and aquaculture activity areas to evaluate the chemical toxicity water and also for assessing it's potentials for various applications.

EXPERIMENTAL

Materials and Methods

The sampling locations are identified near the Agricultural activity areas of Tadepalligudem of West Godavari of Andhra Pradesh, India. The samples are collected in polythene bottles and stored for analysis as per the standard procedures¹⁶. The sample code, location along with Coordinates are summarized in Table -1.

Table-1: Sample Code and Location near Agricultural Areas

Sample Code	Sample Location	GPS Co-ordinates	
		Longitude	Latitude
TGE-1	Alampuram, near Kanakadurga hotel	81.57580	16.81099
TGE-2	Near Duvva main road	81.62159	16.78445
TGE-3	Near Duvva main road	81.62160	16.78445
TGE-4	Near Duvva road	81.63793	16.77644
TGW-1	Pentapaadu near Chinna Sivalayam	81.52636	16.78993
TGW-2	Pentapaadu opposite Goyanakadegree college	81.52622	16.78965
TGW-3	Pentapaadu nearGoyanakadegree college	81.52624	16.78976
TGW-4	Pentapaadu nearJaganjivanaraostature	81.52762	16.77883
TGN-1	Pentapaadu near Goyanka degree college	81.52650	16.78997
TGN-2	Pentapaadu near Goyanaka college	81.52620	16.78966
TGN-3	Eluru Road near Muthyalamma temple, Muthyalambapuram	81.49187	16.82149
TGN-4	Eluru Road, near the Market yard	81.51633	16.81687
TGS-1	Pippara Road	81.52765	16.77912
TGS-2	Pippara Road, Main road	81.52753	16.77882
TGS-3	Pippara Road, opposite Srojini rice mill	81.52757	16.77878
TGS-4	Pippara Road, near Sorijini rice mill	81.52763	16.77882

Fig.-1: Study Area Map

The waters were characterized for physicochemical parameters viz., pH, Electrical conductivity (EC), Total Dissolved solids (TDS), Total hardness (TH), Total Alkalinity (TA), Na⁺, K⁺, Calcium and Magnesium, Fluoride, Chloride, Sulphate, Nitrate and Phosphate. pH is determined by pH Meter (Model-PCS Tester35, Eutech) and Conductivity measured by a portable EC sensor (Electrode based). TDS is determined by TDS Sensor (Electrode based), Total hardness, Total Alkalinity and Chloride are estimated by titrimetry. Sulphate and Phosphate by spectrophotometer (Model-106, Systronics), Na⁺ and K⁺ by Flame photometer (Model-128, Systronics), Nitrate by using Ion-selective electrode (Model-HI 3222

pH/ORP/ISE Meter, HANNA). The irrigation parametric levels Percent Sodium (%Na), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Kelly's ratio (KR), Magnesium Hazard (MH) are determined by the using the relations.

$$\text{Percent Sodium (\%Na)} = \frac{\text{Na}^+ \times 100}{\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+} \text{ (meq/l)} \quad (1)$$

$$\text{Sodium Adsorption Ratio (SAR)} = \frac{\text{Na}^+}{\sqrt{\frac{\text{Ca}^{2+} + \text{Mg}^{2+}}{2}}} \text{ (meq/l)} \quad (2)$$

$$\text{Residual Sodium Carbonate (RSC)} = (\text{CO}_3^{2-} + \text{HCO}_3^-) - (\text{Ca}^{2+} + \text{Mg}^{2+}) \text{ (meq/l)} \quad (3)$$

$$\text{Kelly Ratio (KR)} = \frac{\text{Na}^+}{\text{Ca}^{2+} + \text{Mg}^{2+}} \quad (4)$$

$$\text{Magnesium Hazard (MH)} = \frac{\text{Mg}^{2+}}{\text{Ca}^{2+} + \text{Mg}^{2+}} \times 100 \quad (5)$$

Metal ions present in the water sample were characterized by using ICP OES (Avio 200 Perkin Elmer-Model). Microbial Analysis of water samples has been carried out by using standard procedure.¹⁶⁻²⁰

RESULTS AND DISCUSSION

pH

pH levels during pre and post-monsoon seasons range between 7.20-8.55 and 7.72-8.80. the pH of samples TGE-1 during Pre and Post monsoon seasons exceeded the permissible limit and pH of the remaining samples is within the permissible limits of drinking water standards 6.5 – 8.5

Electrical Conductivity

EC levels range from 703-7600 $\mu\text{mhos/cm}$ and 673-2630 $\mu\text{mhos/cm}$ in groundwaters during pre and post-monsoon seasons. All the EC values of samples except sample TGN-4 exceeded the permissible limit indicating the saline nature of waters. In post-monsoon season EC values except in sample TGN-4 exceeded the permissible limit indicating the saline nature in a TGN-4 water sample.

Total Dissolved Solids

TDS of groundwater ranges from 499-5360 mg/l during pre-monsoon season while TDS varied from 480-1890 mg/l in the post-monsoon period and the levels are within the limits of drinking water standards except in sample TGN-4 in both Pre and Post monsoon seasons. Higher TDS values indicate the presence of soluble solids in waters.

Total Hardness

TH of groundwaters during pre-monsoon season ranges from 200-2470 mg/l. TH of groundwaters ranges from 300-1400 mg/l in the post-monsoon season. TH levels in the majority of samples of pre-monsoon and post-monsoon exceeded the permissible limit indicating the hardness of waters.

Total Alkalinity

TA of waters range from 30-80 mg/l during pre-monsoon season and are present below the guideline value while in the post-monsoon season it varies from 800-1650 mg/l and all these levels crossed the permissible limits of drinking water standards. Higher values of TA contribute to change the taste of waters.

CO₃²⁻ Ion

Carbonate levels of waters during pre-monsoon were observed at BDL in all samples except in Two samples TGE-1 and TGS-1 and during post-monsoon season values 180mg/l in sample TGE-1 and 96mg/l in TGS-4 and other samples it is at BDL level.

HCO₃⁻ Ion

Bicarbonate values of waters range from 36.6-97.6 mg/l in both pre-monsoon period and it varies from 780.8-2013.0 mg/l in the post-monsoon season.

Chloride Ion

During pre-monsoon season Chloride ion concentration in waters vary from 127.62-3034.52 mg/l and it ranges from 389.95-2906.90 mg/l during the post-monsoon period. Except in the TGN-4 sample during the pre and post-monsoon period, the Chloride concentrations are within the guideline value of drinking water standards.

Sulphate Ion

Sulphate in waters of pre-monsoon season varies from 92.86-344.29 mg/l while it ranges from 60.14-2045.70 mg/l during the post-monsoon period. In majority waters during pre-monsoon, Sulphate levels are within the permissible limit. During a post-monsoon season in majority waters, the sulphate levels are within the permissible limit.

Nitrate Ion

In waters, Nitrate ion concentration during pre-monsoon season varies from 4.39-86.9 mg/l and it varies from 4.71-73.8 mg/l during post-monsoon season. In majority samples during pre and post-monsoon season, Nitrate levels are within the permissible limit.

Table-2: Physicochemical Parametric Values

Sample Code	Temp °C		pH		EC (µmhos/cm)		TDS (mg/l)		Salinity (mg/l)		TH (mg/l)		Ca Hardness (mg/l)		Mg Hardness (mg/l)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
TGE1	29.6	30.3	8.55	8.80	1817	1630	1290	1150	960	858	200	400	150	200	50	200
TGE2	29.0	30.4	7.66	8.15	2370	1520	1670	1080	1260	804	450	300	300	300	150	BDL
TGE3	29.5	30.2	7.85	8.07	2400	1570	1700	1120	1290	830	390	400	200	300	190	100
TGE4	29.4	30.3	7.83	8.50	2140	1742	1510	1240	1150	922	390	400	350	200	40	200
TGW1	29.5	30.4	8.23	8.19	3560	1600	2520	1140	1940	880	430	500	250	200	180	300
TGW2	29.4	30.3	7.92	7.92	2050	1540	1450	1110	1100	828	380	1100	100	300	280	800
TGW3	29.5	30.4	7.75	7.72	4190	1650	2960	1190	2300	897	760	600	500	300	260	300
TGW4	29.5	30.4	7.71	7.80	2550	1556	1800	1110	1360	824	500	600	350	300	150	300
TGN1	29.2	30.3	7.61	7.75	4200	1110	2960	800	2310	590	520	700	350	300	170	400
TGN2	29.0	30.3	8.10	8.02	3800	1580	2680	1130	2070	841	510	400	300	200	210	200
TGN3	29.5	30.3	7.67	7.74	5600	1510	3950	1080	3140	812	1490	1100	1200	100	290	1000
TGN4	29.4	30.3	7.77	8.05	703	673	499	480	359	346	220	300	200	100	20	200
TGS1	29.4	30.2	8.49	8.04	1894	2520	1340	1810	1000	1380	300	800	250	600	50	200
TGS2	29.6	30.3	7.86	8.05	1571	2630	1110	1890	825	1440	380	600	300	400	80	200
TGS3	26.6	30.2	7.20	8.03	7600	2610	5360	1880	4330	1430	2470	1400	2200	300	270	1100
TGS4	29.5	30.3	7.22	8.48	7140	1650	5060	1230	4080	940	2110	1400	150	300	1960	1100

Phosphate Ion

In waters, Phosphate ion concentration ranges from 0.37-1.5 mg/l during the pre-monsoon period while it ranges from 0.01-1.03 mg/l. In post-monsoon season and all the levels are within the permissible limit.

Ca²⁺ Ion

Calcium ion concentration in waters of pre and post-monsoon periods vary from 40-880 mg/l and 40-160 mg/l. In most of the samples during pre and post-monsoon seasons, the Ca²⁺ levels exceeded the permissible limit.

Mg²⁺ Ion

Magnesium ion concentration in waters of pre-monsoon season varies from 9.76-478.24 mg/l. Its concentration in post-monsoon samples ranges from 24.4-268.4 mg/l. In most of the samples, Mg²⁺ concentrations exceeded the permissible limit.

Na⁺ Ion

Sodium ion concentration in waters in pre and post-monsoon season ranges from 107.4-1909.8 mg/l and 84.4-710.6 mg/l. In the majority of samples, the values exceeded the guideline value of WHO standards.

K⁺ Ion

K⁺ ion concentration in waters in pre and post-monsoon season K⁺ ion concentration ranges from 5.6-50.4 mg/l and 3.9-158.8 mg/l respectively. In most samples, K⁺ ion concentration in pre and post-monsoon is within the permissible limit.

Table-3: Physicochemical Parametric Levels

Sample Code	BiCarbonate Alkalinity (mg/l)		Carbonate Alkalinity (mg/l)		Hydroxyl Alkalinity (mg/l)		TA (mg/l)		HCO ₃ ⁻ (mg/l)		CO ₃ ²⁻ (mg/l)		OH ⁻ (mg/l)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
TGE1	50	1000	20	300	BDL	BDL	70	1300	61.0	1220	12	180	BDL	BDL
TGE2	70	1150	BDL	BDL	BDL	BDL	70	1150	85.4	1403	BDL	BDL	BDL	BDL
TGE3	70	1100	BDL	BDL	BDL	BDL	70	1100	85.4	1342	BDL	BDL	BDL	BDL
TGE4	70	1430	BDL	100	BDL	BDL	70	1530	85.4	1744.6	BDL	60	BDL	BDL
TGW1	80	1650	BDL	BDL	BDL	BDL	80	1650	97.6	2013	BDL	BDL	BDL	BDL
TGW2	60	1300	BDL	BDL	BDL	BDL	60	1300	73.2	1586	BDL	BDL	BDL	BDL
TGW3	70	800	BDL	BDL	BDL	BDL	70	800	85.4	976	BDL	BDL	BDL	BDL
TGW4	50	800	BDL	BDL	BDL	BDL	50	800	61.0	976	BDL	BDL	BDL	BDL
TGN1	80	970	BDL	BDL	BDL	BDL	80	970	97.6	1183.4	BDL	BDL	BDL	BDL
TGN2	80	1050	BDL	BDL	BDL	BDL	80	1050	97.6	1281	BDL	BDL	BDL	BDL
TGN3	50	1080	BDL	BDL	BDL	BDL	50	1080	61.0	1317.6	BDL	BDL	BDL	BDL
TGN4	30	1000	BDL	BDL	BDL	BDL	30	1000	36.6	1220	BDL	BDL	BDL	BDL
TGS1	40	870	20	BDL	BDL	BDL	60	870	48.8	1061.4	12	BDL	BDL	BDL
TGS2	30	1200	BDL	BDL	BDL	BDL	30	1200	36.6	1464	BDL	BDL	BDL	BDL
TGS3	40	850	BDL	BDL	BDL	BDL	40	850	48.8	1037	BDL	BDL	BDL	BDL
TGS4	30	640	BDL	160	BDL	BDL	30	800	36.6	780.8	BDL	96	BDL	BDL

Table-4: Physicochemical Parametric Values

Sample Code	Ca ²⁺ (mg/l)		Mg ²⁺ (mg/l)		Na ⁺ (mg/l)		K ⁺ (mg/l)		Cl ⁻ (mg/l)		SO ₄ ²⁻ (mg/l)		PO ₄ ³⁻ (mg/l)		NO ₃ ⁻ (mg/l)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
TGE1	60	80	12.2	48.8	448.4	297.1	5.6	4.2	304.9	389.9	146.29	165.4	BDL	0.01	56.4	67.4
TGE2	120	120	36.6	BDL	445.0	264.9	15.0	6.7	411.2	389.9	253.71	201.6	BDL	BDL	19.4	15.1
TGE3	80	120	46.36	24.4	564.2	264.1	11.8	7.3	446.7	567.2	243.43	210.8	BDL	0.01	26.4	15.2
TGE4	140	80	9.76	48.8	439.6	307.9	12.0	20.9	340.3	567.2	232.00	232.4	BDL	BDL	16.2	19.7
TGW1	100	80	43.92	73.2	996.0	425.0	14.0	9.7	801.2	921.7	238.71	260.3	BDL	BDL	32.2	27.0
TGW2	40	120	68.32	195.2	582.4	479.3	14.8	8.7	340.3	1276.2	241.43	315.9	BDL	BDL	20.5	24.1
TGW3	200	120	63.44	73.2	859.2	609.8	12.4	9.1	1120.2	1453.4	278.57	321.8	BDL	BDL	34.2	53.4
TGW4	140	120	36.6	73.2	491.8	336.3	13.2	21.2	623.9	1276.2	221.86	221.6	BDL	0.17	17.8	40.1
TGN1	140	120	41.48	97.6	978.4	272.8	9.6	10.7	942.9	1276.2	294.71	170.1	BDL	0.27	74.8	23.5
TGN2	120	80	51.24	48.8	882.4	159.7	11.4	158.8	872.1	1453.4	278.14	105.3	BDL	0.64	86.9	38.6
TGN3	480	40	70.76	244	1115.6	429.7	8.6	3.9	2041.9	2906.9	264.00	274.8	BDL	0.09	41.8	25.7
TGN4	80	40	44.88	48.8	107.4	84.4	14.4	7.6	127.6	1098.9	92.86	60.1	0.37	0.21	4.4	4.71

TGS1	100	40	12.2	48.8	390.4	465.1	9.0	4.2	340.3	1453.5	194.71	219.0	0.43	0.21	15.6	73.8
TGS2	120	160	19.52	48.8	224.6	451.8	50.4	5.4	446.7	1630.7	122.00	236.3	0.86	0.09	11.2	48.1
TGS3	880	120	65.88	268.4	1112.4	608.0	20.4	9.6	3034.5	2197.9	344.29	2045.7	0.40	0.23	33.6	37.0
TGS4	60	120	478.24	268.4	1909.8	710.6	31.2	11.8	2786.4	425.4	298.86	333.4	1.50	1.03	58.3	38.4

Irrigation Parameters

Percent Sodium

Percent Sodium in waters of pre and post-monsoon seasons ranges from 10.1-88.6 me/l and 46.4-87.8me/l respectively. Percent Na exceeded the permissible limit (60me/l) in majority samples

Sodium Adsorption Ratio

SAR in water samples in pre and post-monsoon seasons range from 1.0-37.3 and 3.0-21.9 me/l. The levels are below the permissible limits of irrigation standards (26me/l).

RSC

RSC values in waters in pre-monsoon season observed at BDL. In post-monsoon season it ranges from 6.2-29.0 me/l and in all samples, it crossed the permissible limit.

Kelly's Ratio

KR in water samples in the pre-monsoon period, ranges from 0.13 to 0.62 me/l and in the post-monsoon period, it ranges from 1.2-7.8 me/l and all the values are above the permissible limit (1.0).

Magnesium Hazard: MH in waters during pre-monsoon season ranges from 8.9-92.7. During post-monsoon season MH ranges from 24.5-90.7me/l and in majority samples, MH is within the permissible limit (50) and in the remaining samples, MH crossed the guideline value indicating the Magnesium hazard.

Table-5: Irrigation Parametric Values of Ground Waters

Sample Code	% Na (me/l)		SAR (me/l)		RSC (me/l)		Kelly Ratio		MH	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
TGE1	82.6	76.1	13.8	9.2	BDL	19.0	4.9	3.3	24.5	49.4
TGE2	67.5	78.4	9.2	9.4	BDL	20.0	2.2	3.8	32.8	BDL
TGE3	75.4	73.4	12.5	8.1	BDL	18.0	3.2	2.9	48.1	24.5
TGE4	70.3	74.9	9.7	9.5	BDL	25.6	2.5	3.4	10.0	49.4
TGW1	66.0	83.0	8.2	14.2	BDL	29.0	2.0	5.0	41.3	BDL
TGW2	52.7	76.3	5.1	11.4	BDL	20.0	1.3	3.3	73.2	32.8
TGW3	75.6	86.2	17.6	18.7	BDL	12.0	3.2	6.6	33.7	24.5
TGW4	88.6	87.8	37.3	21.9	BDL	12.0	8.4	7.8	29.5	24.5
TGN1	80.2	78.1	19.1	11.8	BDL	14.5	4.2	3.7	32.2	59.4
TGN2	70.7	80.1	11.3	13.2	BDL	16.0	2.5	4.2	40.6	39.4
TGN3	55.5	81.1	9.7	15.4	BDL	15.7	1.3	4.5	19.1	49.4
TGN4	81.9	69.3	14.4	8.5	BDL	14.1	4.9	2.5	8.9	49.4
TGS1	87.2	62.3	24.6	6.4	BDL	10.5	7.1	1.7	16.3	56.5
TGS2	83.0	46.4	19.7	4.9	BDL	20.0	5.1	1.8	20.7	49.4
TGS3	49.5	63.2	9.8	8.1	BDL	6.2	1.0	1.7	10.7	90.7
TGS4	10.1	53.8	1.0	3.0	BDL	11.4	0.1	1.2	92.7	66.1

Correlation Analysis

Pre-Monsoon

EC strongly correlated with TDS, Salinity, Chloride, Sulphate and Sodium. TDS is strongly correlated with TH, Chloride, Sulphate and Sodium. Salinity is strongly correlated with TH, Chloride, Sulphate and Sodium. TH is strongly correlated with Chloride. Chloride is strongly correlated with Sodium.

Correlation data revealed that EC will be caused by the presence of soluble solids which include the salt content of Sodium salts in the form of Chlorides and Sulphates. Salinity is due to the Sodium, Calcium and Magnesium salts in the form of Chlorides and Sulphates. Total Hardness is due to the Chloride salts. The results indicate that the waters are saline in nature and are with hardness making the waters unsuitable for drinking applications.

Post Monsoon

EC strongly correlated with TDS and Salinity. TDS is strongly correlated with Salinity. Salinity is strongly correlated with Mg^{2+} . Correlation data indicates that EC is due to the presence of Total Dissolved Salts in waters and saline nature of waters. TDS is caused due to the saline nature of waters. TH is due to the Magnesium salts present in waters. The research data indicates that waters are contaminated due to dissolved solids in waters and saline nature of waters and also due to hardness and change the waters unsuitable for drinking and domestic purposes.

Metal Ions

The concentration of Metal ions viz., Cr, Fe, Co, Ni, Cu, Pb and Hg in waters of pre and post-monsoon period were found to be nondetectable while Mn concentration is present in pre-monsoon sample TPGE and TPGS at 12.81 ppb and 168.5 ppb Arsenic concentrations in water samples TGE, TGN and TGS Arsenic concentrations are found to be 2.49 ppb of pre-monsoon season 6.391 ppb and 13.02. In sample TGS, Arsenic metal ion exceeded the permissible limit 10ppb of WHO standards. In sample TPG of pre-monsoon season sample, Mn ion concentration exceeded the permissible limit of 50ppb of WHO standards. In samples of TGE, TGN, and TGS of post-monsoon seasons Arsenic concentrations are found to be 10.24 ppb, 22.3ppb, 14.77 ppb and 17.62 ppb respectively. In all waters samples of post-monsoon season, Arsenic metal ion concentration exceeded the permissible limit (10ppb) of WHO standards. Zinc ion concentration in groundwater sample TGS during pre-monsoon sample is 132.2 ppb and is within the permissible of 5000ppb of WHO guideline value while in other samples of pre-monsoon and post-monsoon are found to be not detectable.

Table-6: Correlation Matrix, Pre Monsoon

	Temp °C	pH	EC (μmhos/cm)	TDS (mg/l)	Salinity (mg/l)	TH (mg/l)	TA (mg/l)	Cl ⁻ (mg/l)	SO ₄ ²⁻ (mg/l)	NO ₃ ⁻ (mg/l)	PO ₄ ³⁻ (mg/l)	Na ⁺ (mg/l)	K ⁺ (mg/l)	Ca ²⁺ (mg/l)	Mg ²⁺ (mg/l)
Temp °C	1														
pH	0.466	1													
EC(μmhos/cm)	-0.555	-0.648	1												
TDS(mg/l)	-0.553	-0.648	1	1											
Salinity (mg/l)	-0.558	-0.654	1	1	1										
TH (mg/l)	-0.634	-0.731	0.934	0.934	0.940	1									
TA (mg/l)	0.159	0.477	-0.163	-0.164	-0.180	-0.455	1								
Cl ⁻ (mg/l)	-0.580	-0.690	0.974	0.974	0.978	0.985	-0.371	1							
SO ₄ ²⁻ (mg/l)	-0.512	-0.538	0.815	0.814	0.807	0.652	0.289	0.691	1						
NO ₃ ⁻ (mg/l)	-0.081	-0.024	0.497	0.497	0.489	0.245	0.404	0.367	0.498	1					
PO ₄ ³⁻ (mg/l)	-0.038	-0.385	0.337	0.339	0.351	0.491	-0.740	0.464	-0.057	-0.023	1				
Na ⁺ (mg/l)	-0.226	-0.515	0.907	0.909	0.906	0.779	-0.053	0.850	0.754	0.606	0.405	1			
K ⁺ (mg/l)	-0.041	-0.359	0.097	0.098	0.105	0.244	-0.647	0.210	-0.181	-0.221	0.741	0.074	1		
Ca ²⁺ (mg/l)	-0.844	-0.497	0.665	0.663	0.667	0.742	-0.255	0.710	0.495	0.033	-0.014	0.305	0.014	1	
Mg ²⁺ (mg/l)	0.037	-0.524	0.595	0.598	0.604	0.620	-0.425	0.631	0.352	0.300	0.764	0.781	0.348	-0.062	1

Table-7: Correlation Matrix, Post Monsoon

	Temp °C	pH	EC (μmhos/cm)	TDS (mg/l)	Salinity (mg/l)	TH (mg/l)	TA (mg/l)	Cl ⁻ (mg/l)	SO ₄ ²⁻ (mg/l)	NO ₃ ⁻ (mg/l)	PO ₄ ³⁻ (mg/l)	Na ⁺ (mg/l)	K ⁺ (mg/l)	Ca ²⁺ (mg/l)	Mg ²⁺ (mg/l)
Temp °C	1														
pH	-0.119	1													
EC(μmhos/cm)	-0.396	0.087	1												

TDS(mg/l)	-0.399	0.085	0.999	1											
Salinity (mg/l)	-0.391	0.086	0.998	0.999	1										
TH (mg/l)	-0.341	-0.151	0.371	0.396	0.405	1									
TA (mg/l)	0.186	0.436	-0.078	-0.097	-0.093	-0.386	1								
Cl ⁻ (mg/l)	-0.197	-0.666	0.286	0.285	0.287	0.467	-0.297	1							
SO4 ²⁻ (mg/l)	-0.383	-0.060	0.525	0.530	0.530	0.601	-0.247	0.396	1						
NO3 ⁻ (mg/l)	-0.128	0.181	0.607	0.606	0.608	0.163	-0.264	0.105	0.066	1					
PO4 ³⁻ (mg/l)	-0.162	0.142	-0.029	0.001	0.010	0.428	-0.477	-0.062	0.041	0.097	1				
Na ⁺ (mg/l)	-0.050	-0.030	0.558	0.581	0.594	0.785	-0.274	0.231	0.484	0.421	0.231	1			
K ⁺ (mg/l)	0.018	-0.051	-0.078	-0.080	-0.087	-0.212	-0.038	0.063	-0.128	0.025	0.444	-0.355	1		
Ca ²⁺ (mg/l)	0.172	-0.096	0.279	0.288	0.282	0.139	-0.120	-0.192	0.225	-0.010	0.023	0.342	-0.101	1	
Mg ²⁺ (mg/l)	-0.244	-0.116	0.160	0.184	0.194	0.949	-0.283	0.486	0.575	-0.021	0.419	0.667	-0.154	0.043	1

Fig.-2: Graphical Representation of Physicochemical Parametric values

Table-8: Concentration of Metal ions

Sample Code	Cr (ppb)		Mn (ppb)		Fe (ppb)		Co (ppb)		Ni (ppb)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
TGE	ND	ND	12.81	ND	ND	ND	ND	ND	ND	ND
TGW	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TGN	ND	ND	5.799	ND	ND	ND	ND	ND	ND	ND
TGS	ND	ND	168.5	ND	ND	ND	ND	ND	ND	ND

Table-9: Concentration of Metal ions

Sample Code	Cu (ppb)		Zn (ppb)		Pb (ppb)		As (ppb)		Hg (ppb)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
TGE	ND	ND	ND	ND	ND	ND	2.494	10.24	ND	ND
TGW	ND	ND	ND	ND	ND	ND	ND	22.32	ND	ND
TGN	ND	ND	ND	ND	ND	ND	6.391	14.77	ND	ND
TGS	ND	ND	132.2	ND	ND	ND	13.02	17.62	ND	ND

Table-10: Details of MPN Index and Bacterial Species identified in Waters

Sample Code	MPN-Count	No. of Bacterial colonies on EMB	Bacterial colony MORPHOLOGY ON EMB	Gram's Nature	* (IMViC TESTS)				Bacteria Species
					I	MR	VP	C	
TGE-1	5	1	Colourless	-ve	+	+	-	+	<i>CitrobacterFreundii</i>
TGE-2	11	1	Colourless	-ve	-	-	-	-	<i>Pseudomonas</i>

TGW-1	9	1	Colourless	-ve	+	+	-	+	<i>Citrobacter</i>
TGW-2	4	2	Colourless	-ve	+	+	-	+	<i>Citrobacter</i>
TGN-1	5	1	Colourless	-ve	-	-	-	-	<i>Pseudomonas</i>
TGN-2	14	1	Colourless	-ve	-	-	-	-	<i>Pseudomonas</i>
TGS-1	25	2	Colourless	-ve	+	+	-	+	<i>Citrobacter</i>
TGS-2	32	2	Colourless	-ve	-	-	-	-	<i>Pseudomonas</i>

*I = Indole, MR=MethylRed, VP=VogesProskauer, C=Citarte

Microbial Analysis

The water sample TGE-1 was found with MPN count of 5 and bacterial species like *CitrobacterFreundii*. Water sample TGE-2 is observed with MPN count 11 and the bacterial species identified is *Pseudomonas*. Water sample TGW-1 is having MPN count 9 and *Citrobacter* bacterial species were identified. Water sample TGW-2 is observed with MPN count 4 and the bacterial species present is *Citrobacter*. Water sample TGN-1 is observed with MPN count 5 and the bacterial species identified is *Pseudomonas*. Water sample TGN-2 is observed with MPN count 14 and the bacterial species identified is *Pseudomonas*. Water sample TGS-1 is observed with MPN count 25 and the bacterial species identified is *Citrobacter*. Water sample TGS-2 is observed with MPN count 32 and the bacterial species identified is *Pseudomonas*. Health Survey: The health survey results indicated the sufferings of children, youth, middle-aged people and senior citizens of 60 years and above with various health problems like fever, gastrointestinal troubles, typhoid and skin diseases.

Fig.-3: Photographs of Identified Bacterial species in the Waters

Table-11: Health Survey of Public and Disease experienced.

Age in Yrs	Diseases Experienced					Total
	Fever	Gastro Intestinal Troubles	Joint Pains	Typhoid	Skin Allergy	
1-10	3	4	2	2	1	12
11-20	4	2	0	2	0	8
21-30	1	5	1	0	0	7
31-40	1	1	0	0	0	2
41-50	5	8	0	0	2	15

51-60	4	5	0	1	1	11
Above 60	1	3	1	1	0	6
Total	19	28	4	6	4	61

NE=Not Expressed

CONCLUSION

The pH of ground waters is mainly within the permissible limits. Higher EC of waters revealed the saline nature. Higher TDS in waters confirm the soluble solid matter in waters which can deplete the quality of waters. The higher salinity of waters can increase the EC values and can cause saline nature to waters. Higher TH values in all most all waters indicate the encrustation nature of waters indicating their unsuitability for domestic purposes. TA of waters during pre-monsoon season is within the permissible limits while TA of waters during post-monsoon season exceeded the permissible limits and change the taste of waters and make the waters unfit for drinking purposes. Higher values of chloride in waters of both seasons can cause corrosive nature to waters. Higher values of Sulphate in fifty percent of waters reveal that in ground waters of such locations are having interactions with some effluent waters discharging from the surrounding areas. Nitrate levels in majority samples are below the permissible limits and only in some samples the levels are higher due to discharge of agricultural run-off into the groundwater sources. Phosphate levels are within the permissible limits indicating the non-discharge of agricultural run-off containing the phosphatic fertilizer residues into groundwater sources. Calcium ion concentrations in majority samples of both pre and post-monsoon seasons crossed the permissible limits indicating their encrustation nature and change the suitability of waters for domestic purposes. Magnesium ion concentrations in the majority of waters of both seasons crossed the permissible limits confirming the magnesium hazard. Sodium-ion concentration in waters of both seasons crossed the guideline value of WHO standards indicating the saline nature of waters and Potassium ion concentrations in majority samples of both seasons are within the permissible limits of WHO standards. The concentration of metal ions Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb and Hg are within the permissible limits. In waters of post-monsoon season, Arsenic metal ion concentration exceeded the permissible limit of 10ppb of WHO standards indicating the Arsenic toxicity of waters which can cause health effects on the cardiovascular system particularly in children and also cause cancer.

Percent Sodium values of majority samples of both the seasons crossed the permissible limits of irrigation standards (60me/l) while SAR levels are within the permissible limits (26 me/l). Though RSC values of Pre-monsoon season are at Below Detectable Limit, they crossed the permissible limits in waters of post-monsoon season. Higher values of Kelly's ratio revealed the unsuitability of waters for irrigation purposes. Magnesium hazard in the case of majority samples is within the permissible limit (50). Higher MH values in the remaining samples deplete the quality of groundwaters and reduce the crop yields if used for irrigation purposes.

All water samples were found to contain MPN count as well as the pathogenic bacterial species like *Pseudomonas*, *Citrobacter* which can cause water-borne diseases like typhoid, viral fevers and dysentery, etc., A higher concentration of Calcium can also cause health problems like joint pains and bone disorders. The health survey results also revealed that the people who are consuming the water for drinking purposes have been suffering from health problems like typhoid, skin diseases, viral fever and joint pains. These health problems indicate the correlation between the presence of pathogenic bacterial species and the higher concentrations of Calcium in waters. The research revealed that the waters are chemically contaminated with a higher concentration of TDS, EC, Salinity and Total Alkalinity with Arsenic metal toxicity. Further the waters are with microbial contamination and as a result, the health problems will be caused. The waters are to be treated with the available ultra and nano filtration to remove the TDS from waters to minimize the chemical contamination whereas the available activated charcoal adsorption is some other green technologies to be used for the removal of Arsenic toxicity. The existing disinfection and sterilization are used to remove microbial contamination.

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