Plant Sci. Arc.
Plant Science Archives
An International Journal of Plant Biology

Original Research Article
ISSN 2518-6965
www.plantarc.com

A Study on Impact of Agricultural Activities on the Groundwater Quality of Medchal Malkajgiri District, Telangana State, India

V. Rajkumar[*1], K. Shailaja[1], S. Gangadhar Rao[2]

[1]*Department of Environmental Science, University College of Science, Osmania University, Hyderabad, Telangana, – 500 007, India*
[2]*Department of Botany, University College of Science, Osmania University, Hyderabad, Telangana, – 500 007, India*

Citation: V. Rajkumar, K. Shailaja, S. Gangadhar Rao (2024). A Study on Impact of Agricultural Activities on the Groundwater Quality of Medchal Malkajgiri District, Telangana State, India. *Plant Science Archives.* **05-10. DOI: https://doi.org/10.51470/PSA.2024.9.3.05**

Corresponding Author: **V. Rajkumar** | E-Mail: **(vaddemanrajkumar@gmail.com)**

Received 08 May 2024 | Revised 18 June 2024 | Accepted 09 July 2024 | Available Online 05 August 2024

ABSTRACT

The main aim of the present study is to evaluate the impact of agricultural activities on the groundwater quality in the eleven selected village areas of Medchal-Malkajgiri district of Telangana State, India. Forty Groundwater samples were collected during pre-monsoon and post-monsoon. The groundwater samples collected were analyzed for key agricultural nutrients, including Nitrates (NO_3^-), Phosphates (PO_4^{3-}), and Potassium (K^+), as well as various physico-chemical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Total Alkalinity (TA), Sodium (Na^+), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Carbonates (CO_3^{2-}), Bicarbonates (HCO_3^-), Chloride (Cl^-), Fluoride (F^-), and Sulphates (SO_4^{2-}). The analyses followed the American Public Health Association (APHA) Standard Methods for the Examination of Water and Wastewater. The results were then compared against the Bureau of Indian Standards (BIS) 2012 and World Health Organization (WHO) 1999 guidelines for drinking water quality. The analytical results reveal that nitrates are within the acceptable limit during pre-monsoon season but five samples (25%) were exceeding the acceptable limits in post-monsoon season. It clearly indicates that the agricultural activities may be affecting the quality of groundwater in the study area. The concentration of TDS, TA, HCO_3^- and Cl^- are also showing higher values.

Keywords: *Agricultural activities, Groundwater quality, Nitrates, Physico-chemical parameters, APHA, BIS, WHO*

INTRODUCTION

Groundwater is one of the planet's most crucial freshwater resources, serving as a lifeline for human survival, economic growth, and environmental sustainability. Globally, it plays a vital role in agriculture, industry, and domestic water supply, providing essential freshwater to both rural and urban populations [1-2]. With the growing demands of agriculture, driven by population growth and intensified irrigation practices, the pressure on groundwater resources has surged, leading to both quantitative depletion and quality degradation. Agriculture alone accounts for approximately 65% of global water use, with industry and power generation consuming 25%, and domestic purposes accounting for the remaining 10% [3-4]. The quality of groundwater is influenced by both natural geochemical processes, such as mineral weathering, dissolution, precipitation, and ion exchange, as well as various anthropogenic activities. These human-induced factors include agricultural runoff, sewage discharge, mining, and industrial waste [5-7]. In regions with irregular monsoon patterns, growing urbanization, and extensive agricultural activities, the demand for sufficient, high-quality groundwater has become even more critical. Groundwater chemistry is primarily shaped by the surrounding lithology, flow dynamics, geochemical reactions, residence time, and the solubility of minerals. However, human activities—especially in agriculture—Science significantly alter the natural recharge of groundwater [8]. Excessive irrigation and leakage from sewage systems have exacerbated groundwater contamination. Agricultural practices, in particular, contribute to increasing salinity and elevated nutrient concentrations, notably nitrates, phosphates, and potassium, in groundwater supplies.

Nutrient pollution from agriculture, such as the leaching of fertilizers, is one of the major threats to groundwater quality. This is evident in the growing instances of salinization and nitrate contamination, which have been documented globally. Nutrients in groundwater serve as critical indicators for assessing the impact of agricultural activities on the shallow subsurface environment . High concentrations of nitrates in groundwater—often above permissible limits for drinking water—pose significant risks to human health and environmental stability [9-10]. Furthermore, long-term use of fertilizers in agricultural fields contributes to groundwater pollution, which manifests as elevated nutrient levels and salinity, the presence of nutrients, particularly nitrates, phosphates, and potassium, in groundwater is closely tied to agricultural activities. Sustainable water management practices are essential to preserve groundwater quality and ensure its availability for future generations.

Fertilizers are widely used to enhance the availability of essential nutrients—nitrogen, phosphorus, and potassium—to plants. Of these nutrients, nitrate is the most readily leached into groundwater due to its high solubility, mobility, and persistence under aerobic conditions. In contrast, potassium and phosphate are less frequently found at elevated concentrations in groundwater [11]. This is primarily because potassium and phosphate are often present in smaller quantities in fertilizer mixes, and phosphate tends to be adsorbed by clay particles in the soil, reducing its mobility. However, when potassium chloride (KCl) is used in fertilizers, there may also be an associated increase in chloride concentrations in groundwater [12-14]. Agricultural and domestic activities contribute significantly to nutrient loading in groundwater.

Unlike major ions, which are less impacted by human activities, nutrients like nitrates, phosphates, and potassium are directly influenced by agricultural practices such as fertilization and irrigation. These practices can result in two main impacts on groundwater: (i) salinization of soil and groundwater beneath the agricultural fields, especially in arid regions due to high evapotranspiration, and (ii) elevated nitrate concentrations from fertilizer leaching . In arid and semi-arid regions, irrigation can exacerbate salinity in the root zone. To prevent salinization, farmers often apply excess water, which can leach salts and nutrients, such as nitrates, down to the groundwater.

Excessive fertilization introduces long-term risks to groundwater quality by increasing the likelihood of nitrate, phosphate, and pesticide leaching. Nitrate contamination, in particular, is a well-documented consequence of agricultural activities on a regional scale . While phosphorus and potassium are less mobile, agricultural runoff can still contribute to their elevated concentrations in both surface and groundwater [15-16]. Many studies indicate that over-fertilization does not enhance crop yields but instead increases nutrient loads, specifically nitrogen and phosphorus, in both surface and groundwater, posing environmental hazards. The present study focuses on understanding the nutrient chemistry of groundwater in agricultural regions and evaluates the spatial and seasonal variations of groundwater quality in the Medchal-Malkajgiri District of Telangana State, India. This region is heavily dependent on agriculture, with irrigated lands dominating the landscape. Groundwater serves as the primary source of water for both agricultural and domestic purposes, making its quality critical for the well-being of the local population.

Study Area

The study area (Fig.1.) covers the selected areas i.e. Lalgadi Malakpet, Thurkapally, Muraharipally, Kolthur, Sampambole, Peta, Vaagunuthi, Gangadharpally, Anna Sagar, Ksheera Sagar and Zapthi Singaipally of Medchal-Malkajgiri district of Telangana State, India. The average annual highest temperature in Medchal-Malkajgiri is 40.0°C (104.0°F), and the May 24th, 2024 is the hottest day on average. The average annual lowest temperature in Medchal-Malkajgiri is 13.8°C (56.8°F), and the December 24th, 2023 is the coldest day on average. It receives an average annual rainfall of 900.9 mm. Rainfall is the major source of for groundwater recharge.

Patterns of Land use and Agricultural Activity

The agricultural lands dominate the study area, where groundwater serves as the sole source of irrigation. The agricultural calendar is divided into two main cropping seasons. The primary season, known as Kharif, spans from July to October and is characterized by the cultivation of paddy as the major crop. During the second cropping season, from November to March, farmers grow a variety of crops including paddy, vegetables such as spinach, bottle gourd, tomato, bitter gourd, and cauliflower, as well as pulses. To sustain the agricultural productivity of these crops, local farmers rely heavily on chemical fertilizers. The most commonly applied fertilizers in the region for paddy cultivation include Urea, NPK complex fertilizers, Diammonium phosphate ((NH4)2HPO4), Zinc Sulphate (ZnSO4), and Muriate of Potash (KCl). The recommended application rate of nitrogen (N) fertilizers for paddy is 120 kg N/ha, while for other crops like vegetables and pulses, the recommended nitrogen application ranges between

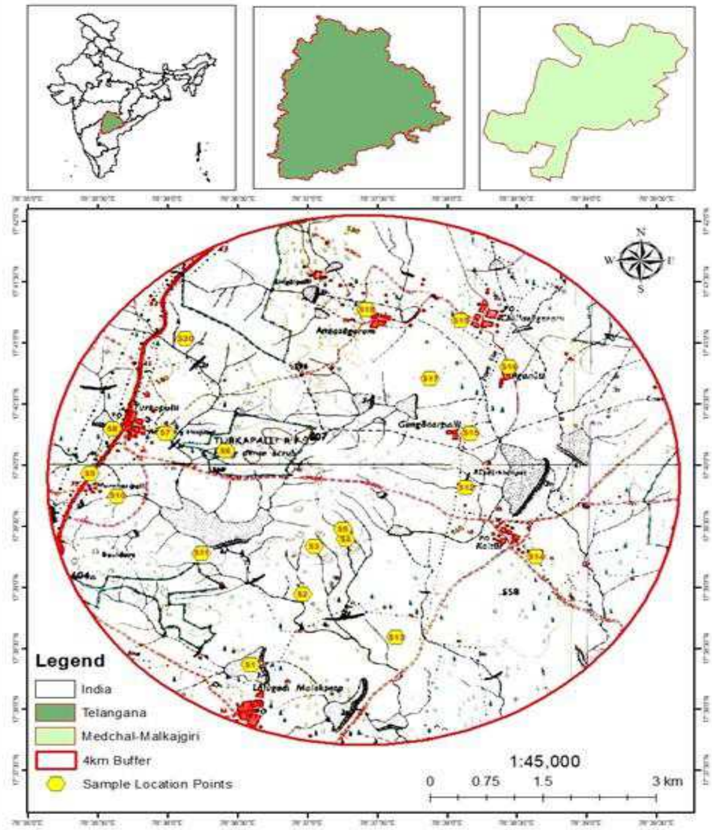

Figure 1 : Map showing the locations of Groundwater Samples

40 to 100 kg N/ha, depending on the specific crop requirements. This extensive use of fertilizers, particularly nitrogen-rich compounds, poses potential risks of nutrient leaching into the groundwater. Given the reliance on groundwater for both irrigation and domestic use, the excessive use of fertilizers increases the likelihood of nitrate contamination, which could affect the overall water quality in the region. Monitoring nutrient levels in groundwater is essential to managing the potential environmental impact of agricultural activities and ensuring sustainable water use.

Materials and Methodology

Total Forty (40) samples were collected from bore wells in the study area from agricultural fields and residential areas. Samples were collected (Table. 1) during December (Post-Monsoon) - 2023 and May (Pre-Monsoon) – 2024 in 1 litre PVC bottles. The collected groundwater samples were analysed in the laboratory for agricultural nutrients such as Nitrates (N), Phosphates (P), Potassium (K) and other physico-chemical parameters such as pH and Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Total Alkalinity (TA), Carbonates (CO_3^{2-}), Bicarbonates (HCO_3^-), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^+), Fluoride (F^-), Chloride (Cl^-) and Sulphate (SO_4^{2-}) as per the Standard Methods for Examination of Water and Wastewater [16]. Obtained results were compared with Indian Standards – Drinking Water Specification (IS 10500:2012) of Bureau of Indian Standards [17].

The verification of analytical accuracy for the concentrations of major ions (expressed in meq/L) was cross-checked using the charge-balance error (CBE) method, ensuring that the error remained within the acceptable limit of ±5% . The CBE was calculated using the following equation:

$$CBE = \frac{\sum Cations - \sum Anions}{\sum Cations + \sum Anions} \times 100$$

Table 1: Description of the Groundwater Sampling Locations

S. No	Sample Code	Location Name	Latitude	Longitude
1	S1	Lalgadi Malakpet Village	17.6395	78.6099
2	S2	Dairy Farm, Lalgadi Malakpet Village	17.6491	78.616
3	S3	Workers Camp, Thurkapally Village	17.6556	78.6175
4	S4	Loyola Farms, Thurkapally Village	17.6566	78.6212
5	S5	33/11 KV Sub Station, Thurkapally Village	17.658	78.6208
6	S6	ICICI Sub Station, Thurkapally Village	17.6687	78.6069
7	S7	Gram Panchayat Nursery, Thurkapally Village	17.6711	78.5996
8	S8	Residential Area, Thurkapally Village	17.6717	78.5933
9	S9	Residential Area, Muraharipally Village	17.6655	78.5907
10	S10	Near Prajay water front, Muraharipally Village	17.6625	78.5939
11	S11	Agriculture Field, Muraharipally Village	17.6547	78.6039
12	S12	Residential Area, Kolthur Village	17.6637	78.6356
13	S13	Agriculture Field, Sampambole Village	17.6432	78.6272
14	S14	Agriculture Field, Kolthur Village	17.6542	78.6438
15	S15	Overhead Water Tank, Peta Village	17.6711	78.636
15	S16	Agriculture Field, Vaagunuthi Village	17.6801	78.6407
17	S17	Agriculture filed, Gangadharpally Village	17.6785	78.6312
18	S18	Agriculture Field, Anna Sagar Village	17.688	78.6237
19	S19	Agriculture Field, Ksheera Sagar Village	17.6865	78.6349
20	S20	Agriculture Field, Zapthi Singaipally Village	17.684	78.602

Results and Discussion

The analytical results of NPK and other physico-chemical parameters are presented in Table 2 & Table 3, during pre-monsoon and post-monsoon season respectively. The results compared with BIS 2012 are presented in Table 4 & Table 5, during pre-monsoon and post-monsoon seasons respectively.

Table 2: Analytical results of NPK and other Physico-Chemical Parameters (Pre-Monsoon)

S. No	NO_3^-	PO_4^{3-}	K^+	pH	EC	TDS	TH	TA	Na^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	F^-	Cl^-	SO_4^{2-}
S1	15	0.001	3.9	8.2	938	600	213	199	127	64	13	15	184	0.22	246	25
S2	13	0.012	2.1	8.1	1119	716	214	237	181	71	9	20	217	0.20	307	33
S3	38	0.001	2.4	8.1	1069	684	217	201	149	59	17	10	191	0.17	254	41
S4	10	0.002	2.5	8.3	1155	739	245	286	178	67	19	15	271	0.22	298	20
S5	38	0.031	3.8	8.2	1044	668	194	273	174	58	12	20	253	0.20	229	17
S6	11	0.004	2.6	8.0	579	370	176	211	79	59	7	15	196	0.14	119	24
S7	26	0.007	2.3	8.1	949	608	256	244	117	81	13	20	224	0.30	217	19
S8	4	0.058	1.7	8.3	739	473	241	246	94	70	16	15	231	0.26	171	23
S9	4	0.051	3.1	7.9	846	542	173	255	151	61	5	15	240	0.16	213	24
S10	7	0.004	3.9	8.1	886	567	284	226	110	84	18	20	206	0.15	221	20
S11	28	0.012	4.1	7.9	921	590	306	236	97	93	18	25	211	0.19	173	93
S12	5	0.005	5.7	8.0	478	306	218	171	33	69	11	5	166	0.20	94	23
S13	10	0.072	5.1	7.9	912	584	273	234	104	88	13	15	219	0.17	193	31
S14	11	0.087	6.3	8.3	1331	852	293	314	179	73	27	10	304	0.25	329	28
S15	4	0.001	4.9	8.0	352	226	129	86	39	27	15	15	71	0.23	87	16
S16	5	0.006	4.7	8.2	714	457	167	233	119	57	6	10	223	0.25	141	16
S17	13	0.002	1.9	8.2	487	312	154	199	71	45	10	20	179	0.30	93	13
S18	7	0.003	3.1	8.0	832	532	279	264	93	64	29	15	249	0.25	204	22
S19	13	0.003	1.4	8.1	684	438	227	206	81	53	23	15	191	0.20	175	19
S20	8	0.001	2.6	7.9	805	515	235	235	113	66	17	15	220	0.20	187	21
Min	4	0.0010	1.4	7.9	352	226	129	86	33	27	5	5	71	0.14	87	13
Max	38	0.0866	6.3	8.3	1331	852	306	314	181	93	29	25	304	0.30	329	93
Avg.	13.5	0.0181	3.4	8.1	842	539	225	228	114	65	15	16	212	0.21	198	26

(Note: All the parameters expressed in mg/L, except EC in µS/cm, No units for pH)

Table 3 : Analytical results of NPK and other Physico-Chemical Parameters (Post-Monsoon)

S. No	NO_3^-	PO_4^{3-}	K^+	pH	EC	TDS	TH	TA	Na^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	F^-	Cl^-	SO_4^{2-}
S1	27	0.010	3.7	8.3	802	513	230	170	101	82	6	5	165	0.37	232	15
S2	51	0.016	2.8	8.4	1128	722	245	245	196	65	20	10	235	0.16	340	28
S3	49	0.001	3.0	8.3	1113	712	260	215	156	68	22	5	210	0.23	277	19
S4	45	0.001	2.7	8.3	1092	699	240	282	187	65	19	5	277	0.27	312	16
S5	31	0.025	2.8	8.4	1023	655	238	270	162	71	15	10	260	0.30	237	24
S6	17	0.005	2.6	8.4	534	342	235	183	49	84	6	5	178	0.23	85	32
S7	31	0.010	2.0	8.3	899	575	253	245	127	73	17	10	235	0.27	240	6
S8	12	0.070	3.9	8.4	681	436	235	224	82	76	11	5	219	0.20	147	29
S9	9	0.050	2.0	8.3	894	572	195	256	147	67	7	10	246	0.24	230	30
S10	37	0.030	4.1	8.4	829	531	296	193	95	79	24	5	188	0.14	175	31
S11	55	0.015	4.6	8.3	956	612	309	180	89	91	20	10	170	0.20	147	125
S12	14	0.005	2.9	8.4	603	386	303	180	39	80	25	5	175	0.24	157	31
S13	46	0.080	2.2	8.1	791	506	272	249	88	81	17	5	244	0.15	167	35
S14	63	0.091	2.5	8.2	1359	870	360	311	190	72	44	20	291	0.31	390	20
S15	15	0.001	1.4	8.4	278	178	83	88	47	25	5	10	78	0.36	92	18
S16	39	0.050	2.4	8.4	815	522	239	269	132	82	8	15	254	0.30	162	23
S17	16	0.044	1.5	8.3	396	253	135	165	57	41	8	10	155	0.33	72	21
S18	9	0.002	3.2	8.2	987	631	325	274	116	69	37	5	269	0.24	217	32
S19	40	0.013	2.9	8.3	992	635	365	246	100	66	49	5	241	0.30	232	13
S20	13	0.001	3.4	8.4	1060	678	312	278	154	82	26	15	263	0.17	225	31
Min	9	0.001	1.4	8.1	278	178	83	88	39	25	5	5	78	0.14	72	6
Max	63	0.091	4.6	8.4	1359	870	365	311	196	91	49	20	291	0.37	390	125
Avg.	31	0.026	2.8	8.3	862	551	256	226	115	71	19	9	218	0.25	207	29

(Note: All the parameters expressed in mg/L, except EC in µS/cm, No units for pH)

Table 4 : Comparison of NPK and other Physico-Chemical Parameters with BIS-2012 (Pre-Monsoon)

S. No	Parameters	BIS 2012	Conc. Observed			No. of Samples Exceeding the Limit	% of Samples Exceeding the acceptable Limit
			Min	Max	Average		
1	NO_3^-	45	4.1	37.8	13.5	Nil	Nil
2	PO_4^{3-}	0.1*	0.001	0.087	0.018	Nil	Nil
3	K^+	10	1.4	6.3	3.4	Nil	Nil
4	pH	6.5-8.5	7.9	8.3	8.1	Nil	Nil
5	EC	1500	352	1331	842	Nil	Nil
6	TDS	500	226	852	539	13	65
7	TH	200	129	306	225	14	70
8	TA	200	86	314	228	16	80
9	Na^+	200	33	181	114	Nil	Nil
10	Ca^{2+}	75	27	93	65	4	20
11	Mg^{2+}	30	5	29	15	Nil	Nil
12	CO_3^{2-}	-	5	25	16	-	-
13	HCO_3^-	200	71	304	212	13	65
14	F^-	1.0	0.14	0.30	0.21	Nil	Nil
15	Cl^-	250	87	329	198	4	20
16	SO_4^{2-}	200	13	93	26	Nil	Nil

*(*World Health Organization, 1999)*

Table 5 : Comparison of NPK and other Physico-Chemical Parameters with BIS-2012 (Post-Monsoon)

S. No	Parameters	BIS 2012	Conc. Observed			No. of Samples Exceeding the Limit	% of Samples Exceeding the acceptable Limit
			Min	Max	Average		
1	NO_3^-	45	9.0	63	31	5	25
2	PO_4^{3-}	0.1*	0.001	0.091	0.026	Nil	Nil
3	K^+	10	1.4	4.6	2.8	Nil	Nil
4	pH	6.5-8.5	8.1	8.4	8.3	Nil	Nil
5	EC	1500	278	1359	862	Nil	Nil
6	TDS	500	178	870	551	15	75
7	TH	200	83	365	256	14	70
8	TA	200	88	311	226	13	65
9	Na^+	200	39	196	115	Nil	Nil
10	Ca^{2+}	75	25	91	71	9	45
11	Mg^{2+}	30	5	49	19	3	15
12	CO_3^{2-}	-	5	20	9	-	-
13	HCO_3^-	200	78	291	218	13	65
14	F^-	1.0	0.14	0.37	0.25	Nil	Nil
15	Cl^-	250	72	390	207	4	20
16	SO_4^{2-}	200	6	125	29	Nil	Nil

*(*World Health Organization, 1999)*

Nitrates (NO^{3-})

Nitrate is a significant contributor to groundwater pollution resulting from agricultural activities. Nitrates primarily originate from nitrogenous fertilizers, organic manure, and waste from humans and animals. Due to its high mobility in groundwater, nitrate is not easily adsorbed or precipitated on aquifer solids . According to BIS 2012 standards, the acceptable limit for NO^{3-} - N in drinking water is 45 mg/L. In the current study, nitrate concentrations during the pre-monsoon season ranged from 4 mg/L to 38 mg/L, with an average of 13.5 mg/L. All groundwater samples were found to be within the BIS 2012 acceptable limit. However, during the post-monsoon season, nitrate concentrations increased, ranging from 9 mg/L to 63 mg/L, with an average of 31 mg/L. Five samples (25%), namely S2, S3, S11, S13, and S14, exhibited concentrations exceeding the BIS 2012 acceptable limit for drinking water. This increase is attributed to the percolation of nitrates into the groundwater during rainfall [16-19].

The risk of nitrate pollution in groundwater depends on both the nitrogen load and the vulnerability of the aquifer . Nitrate leaching from agricultural areas, especially from the application of agrochemicals, is a major source of contamination. In the study area, the application of 500 kg/ha of fertilizer leads to excess nitrate in groundwater, with a spatial impact extending up to 2.0 km from bore wells . Other potential sources of nitrate contamination include effluent discharge from intensive livestock units, leachate from manure storage, leaking slurry pits, and the spreading of slurry or manure as organic fertilizer, all of which can contribute to groundwater pollution .

Phosphates (PO_4^{3-})

Phosphates are common constituents of agricultural fertilizers, manure, and organic wastes. In the present study PO_4^{3-} values ranged from 0.001 mg/L to 0.087 mg/L with an average of 0.018 mg/L and 0.001 mg/L to 0.091 mg/L with an average of 0.026 mg/L during pre-monsoon and post-monsoon seasons respectively. All the samples are within the acceptable limit of 0.1 mg/L [20-24].

Potassium (K^{+})

In the present study K^{+-} values ranged from 1.4 mg/L to 6.3 mg/L with an average of 3.4 mg/L and 1.4 mg/L to 4.6 mg/L with an average of 2.8 mg/L during pre-monsoon and post-monsoon seasons respectively. The BIS 2012 acceptable limit is 10 mg/L. All the samples are within the acceptable limit.

Physico-Chemical Parameters

In this study, the pH of groundwater samples ranged from 7.9 to 8.3, with an average of 8.1 during the pre-monsoon season, and from 8.1 to 8.4, with an average of 8.3, during the post-monsoon season. The BIS acceptable pH limit for drinking water is 6.5–8.5, and all the groundwater samples fell within this range. Electrical Conductivity (EC) values ranged from 352 µS/cm to 1331 µS/cm, with an average of 842 µS/cm during pre-monsoon, and from 278 µS/cm to 1359 µS/cm, with an average of 862 µS/cm during post-monsoon. All samples were within the BIS acceptable limit of 1500 µS/cm.

Total Dissolved Solids (TDS) ranged from 226 mg/L to 852 mg/L, with an average of 539 mg/L during the pre-monsoon season, and from 178 mg/L to 870 mg/L, with an average of 551 mg/L during post-monsoon. The BIS acceptable limit for TDS is 500 mg/L, with 65% of samples during pre-monsoon and 75% during post-monsoon exceeding this limit.

TDS is an indicator of groundwater salinity, influenced by both natural and anthropogenic factors such as weathering, rock–water interaction, household, industrial, and irrigational activities. Total Hardness (TH) ranged from 129 mg/L to 306 mg/L, with an average of 225 mg/L during pre-monsoon, and from 83 mg/L to 365 mg/L, with an average of 256 mg/L during post-monsoon. The BIS acceptable limit for TH is 200 mg/L, with 70% of samples in both seasons exceeding this limit. Total Alkalinity (TA) ranged from 86 mg/L to 314 mg/L, with an average of 228 mg/L during pre-monsoon, and from 88 mg/L to 311 mg/L, with an average of 226 mg/L during post-monsoon. TA values exceeded the BIS limit of 200 mg/L in 80% of samples during pre-monsoon and 65% during post-monsoon.

Sodium (Na^{+}) concentrations ranged from 33 mg/L to 181 mg/L, with an average of 114 mg/L during pre-monsoon, and from 39 mg/L to 196 mg/L, with an average of 115 mg/L during post-monsoon, with all samples within the BIS acceptable limit of 200 mg/L. Calcium (Ca^{2+}) concentrations ranged from 27 mg/L to 93 mg/L, with an average of 65 mg/L during pre-monsoon, and from 25 mg/L to 91 mg/L, with an average of 71 mg/L during post-monsoon. About 20% of samples during pre-monsoon and 45% during post-monsoon exceeded the BIS acceptable limit of 75 mg/L. Magnesium (Mg^{2+}) concentrations ranged from 5.0 mg/L to 29 mg/L, with an average of 15 mg/L during pre-monsoon, and from 5.0 mg/L to 49 mg/L, with an average of 19 mg/L during post-monsoon. About 15% of the samples exceeded the BIS acceptable limit of 30 mg/L during the post-monsoon season. Carbonate (CO32-) concentrations ranged from 5.0 mg/L to 25 mg/L, with an average of 16 mg/L during pre-monsoon, and from 5.0 mg/L to 20 mg/L, with an average of 9.0 mg/L during post-monsoon. Bicarbonate (HCO^{3-}) concentrations ranged from 71 mg/L to 304 mg/L, with an average of 212 mg/L during pre-monsoon, and from 78 mg/L to 291 mg/L, with an average of 218 mg/L during post-monsoon. HCO3- values exceeded the BIS acceptable limit of 200 mg/L in 65% of samples during both seasons.

The fluoride (F-) values ranged from 0.14 mg/L to 0.3 mg/L, with an average of 0.21 mg/L during the pre-monsoon season, and from 0.14 mg/L to 0.37 mg/L, averaging 0.25 mg/L in the post-monsoon season. All samples remained within the acceptable limit of 1.0 mg/L set by the Bureau of Indian Standards (BIS) for both seasons. Chloride (Cl-) values varied from 87 mg/L to 329 mg/L, averaging 198 mg/L in the pre-monsoon season, and from 72 mg/L to 390 mg/L during the post-monsoon season. The BIS acceptable limit for Cl- is 250 mg/L, with 20% of samples exceeding this limit in both seasons. The elevated Cl- concentrations are attributed to the disposal of agrochemicals and domestic wastewater into groundwater sources. Sulfate (SO_4^$^{2-)}$ values ranged from 13 mg/L to 93 mg/L, with an average of 26 mg/L during the pre-monsoon season, and from 6.0 mg/L to 125 mg/L, averaging 29 mg/L in the post-monsoon season. All samples were within the acceptable limit of 200 mg/L set by the BIS for both seasons.

CONCLUSION

The present study aims to assess the influence of agricultural activities on groundwater quality. A total of 40 groundwater samples were collected from bore wells in selected areas of the Medchal-Malkajgiri district, Telangana, India, during both the pre-monsoon and post-monsoon seasons. The samples were analyzed for nitrogen (N), phosphorus (P), potassium (K), and other physico-chemical parameters to evaluate nutrient concentrations and their spatial and seasonal variations in the groundwater of the study area. The results indicate that agricultural practices, including the application of fertilizers, soil mineralization processes, and irrigation return flow, significantly influence the concentrations of NPK nutrients and other major ions in the region's groundwater. Spatially the nitrate levels are higher in the groundwater samples which collected from the bore wells of agricultural fields than the groundwater samples collected from the bore wells of residential areas. Seasonal variation studies reflected that the concentration of nitrate were double in post-monsoon. The concentration of salinity parameters such as EC, TDS and Cl^{-} also increased during post-monsoon season. It is clearly indicating that the percolation of nitrates and other ions during rains of monsoon season reaches to the groundwater and values are higher in post-monsoon season. The study recommends that ongoing efforts be made to educate farmers on the optimal use of fertilizers in relation to crop requirements and irrigation schedules. This approach is essential for preserving the groundwater quality in the study area.

Acknowledgements
The authors wish to acknowledge the Coordinator and faculty members of Department of Environmental Science, University College of Science, Osmania University for providing research opportunity.

REFERENCES

1. Li, P., Tian, R., Xue, C., Wu, J., (2017). Progress, opportunities and key fields for groundwater quality research under the impacts of human activities in China with a special focus on western China. Environ. Sci. Pollut. Res. 24 (15), 13224–13234.

2. ImpEE Project (2006). Improving Engineering Education, Water. Cambridge University.

3. K. Srinivasamoorthy, M. Gopinath, S. Chidambaram, M. Vasanthavigar, V.S. Sarma. (2014). Hydrochemical characterization and quality appraisal of groundwater from Pungar sub basin, Tamilnadu, India. Journal of King Saud University – Science (2014) 26, 37–52.

4. Karanth, K. R. (1987). Groundwater Assessment, Development and Management. New Delhi: Tata-McGraw-Hill.

5. Albus, W.L., Knighton, R.E., (1998). Water quality in a sand plain after conversion from dryland to irrigation: tillage and cropping systems compared. Soil and Tillage Research 48, 195–206.

6. Oren O, Yechieli Y, Bo¨hlke JK, Dody A (2004) Contamination of groundwater under cultivated fields in an arid environment, central Arava Valley, Israel. J Hydol 290:312–328.

7. Rajmohan, N., & Elango, L. (2005). Nutrient chemistry of groundwater in an intensively irrigated region of Southern India. Environmental Geology, 47, 820–830.

8. Stigter TY, Ooijen SPJV, Post VEA, Appello CAJ, Dill AMMC (1998). A hydrogeological and hydrochemical explanation of the groundwater composition under irrigated land in a mediterranean environment, Algarve, Portugal. J Hydrol 208:262–279.

9. British Geological Survey (2009). Groundwater Information Sheet. The Impact of Agriculture. Water Aid.

10. Singh, B., Singh, Y., Sekhon, G.S., (1995). Fertilizer-N use efficiency and nitrate pollution of groundwater in developing countries. Journal of Contaminant Hydrology 20, 167–184.

11. Allaire-Leung, S.E., Wu, L., Mitchell, J.P., Sanden, B.L., (2001). Nitrate leaching and soil nitrate content as affected by irrigation uniformity in a carrot field. Agricultural Water Management 48, 37–50.

12. Rhoads, J.D., Loveday, J., (1990). Salinity in irrigated agriculture. In: Stewart, B.A., Nielsen, D.R. (Eds.), Irrigation of Agricultural Lands, ASA Monograph No. 30, Am. Soc. Agron., Madison, WI, pp. 1089–1142.

13. Hadas, A., Sagiv, B., Haruvy, N., (1999). Agricultural practices, soil fertility management modes and resultant nitrogen leaching rates under semi-arid conditions. Agricultural Water Management 42, 81–95.

14. Nolan BT (2001). Relating nitrogen sources and aquifer susceptibility to nitrate in shallow groundwaters of the United States. Groundwater 39:290–299.

15. Pixie A. Hamilton, Dennis R. Helsel (1995) Effects of Agriculture on Ground-Water Quality in Five Regions of the United States. Groundwater: Volume 33, Issue 2 Pages: 180-332.

16. APHA (2017). Standard Methods for the Examination of Water and Wastewater Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 17th Edition.

17. Bureau of Indian Standards (BIS 2012). Indian Standard Drinking Water Specification IS 10500: 2012.

18. Domenico PA, Schwartz FW (1998) Physical and chemical hydrogeology, 2nd edn. Wiley, New York, p 506p.

19. Hem JD (1985). Study and interpretation of the chemical characteristics of natural waters, US Geological Survey Water Supply paper 2254:263.

20. Schmoll, O, Howard, G, Chilton, PJ and Chorus, I. (2006). Protecting groundwater for health: managing the quality of drinkingwater sources. WHO/IWA Publishing. London and Seattle.

21. Benson VS, VanLeeuwen JA, Stryhn H, Somers GH (2007) Temporal analysis of groundwater nitrate concentrations from wells in Prince Edward Island, Canada: application of a linear mixed effects model. Hydrogeol J 15(5):1009–1019.

22. Nemcic-Jurec J, Jazbec A (2016) Point source pollution and variability of nitrate concentrations in water from shallow aquifers. Appl Water Sci 7(3):1337–1348.

23. Cho, J-C, Cho, HB and Kim S-J. (2000). Heavy contamination of a subsurface aquifer and a stream by livestock wastewater in a stock farming area, Wonju, Korea. Environmental Pollution, 109, 137-146.

24. WHO, World Health Organization (1999).

25. Masoud, M., El Osta, M., Alqarawy, A. et al. (2022) Evaluation of groundwater quality for agricultural under different conditions using water quality indices, partial least squares regression models, and GIS approaches. Appl Water Sci 12, 244.

26. Y.S.A. Loh, B.A. Akurugu, E. Manu, A.S. Aliou (2020).Assessment of groundwater quality and the main controls on its hydrochemistry in some Voltaian and basement aquifers, northern Ghana. Groundwater. Sustain. Dev., 10.

