International Journal of Advanced Research in Chemical Science (IJARCS)
Volume 2, Issue 11, November 2015, PP 11- 17
ISSN 2349-039X (Print) & ISSN 2349-0403 (Online)
www.arcjournals.org

A Study on Hydro Geochemistry of Ground Waters Near Kakinada Coast in East Godavari District of Andhra Pradesh

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Abstract: *Water is a universal solvent and is essential to all forms of life in the universe. Hectic Agricultural activities, Urbanization, Industrialization pollute the ground water in addition to sea water intrusion in coastal regions and make waters unsuitable for utility. The present research is focused on the characterization of ground water near nonpoint sources of pollution to evaluate the quality for their assessment of their potentials for various applications. Twelve ground water samples were collected and characterized for physicochemical parameters viz, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS),Total Hardness (TH), Total Alkalinity (TA), Ca^{+2},Mg^{+2},Na^{+},K^{+}, Cl^{-}, SO_4^{2-},PO_4^{2-},F^{-} and NO_3^{-} to assess the chemical contamination status. Higher levels of EC, TDS,TH, TA, Ca^{+2} , Mg^{+2}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and NO_3^{-} revealed the unsuitability of waters for drinking, domestic and industrial purposes. The waters are to be treated properly by the available treatment methodologies for considering them for use.*

Keywords: *Ground water, Characterization, parameter, drinking.*

1. INTRODUCTION

Water is essential to all forms of life and makes up 50-97% of the weight of all plants and animals and about 70% of human body [1]. Ground water's quality will be affected by several factors like discharge of agricultural, domestic and industrial wastes, land use patterns, geological formation, and rainfall pattern and infiltration rate in an area [2]. As ground water moves along flow lines from recharge to discharge areas, its chemistry is altered by the effect of a variety of geochemical processes [3].The suitability of water for various uses depends on type and concentration of dissolved minerals and groundwater has more mineral composition than surface water [4].The addition of pollutants and nutrients through the agency sewage, industrial effluents, agricultural runoff etc., in to the water bodies brings about a series of changes in the physicochemical and characteristics of water [5]. The ground water was drastically polluted due to the increased human activities during the last decade [6, 7, 8, 9].The coastal groundwater system is fragile and its evaluation will help in the proper planning and sustainable management (10). Several authors carried out studies on the assessment in the nearby coastal aquifer [11, 12, 13]. The study on sea water freshwater interface has also been attempted [14].The agricultural activities have directly or indirectly affect the concentrations of a large number of chemical species in ground water, Viz., NO_3^{-}, N_2,Cl^{-}, SO_4^{2-}, H^{+}, K, Mg, Ca, Fe, Cu, B, Pb and Zn and also a wide variety of pesticides and other organic components [15] Keeping in view the hectic agricultural, industrial, aqua cultural and expansion in urbanization in addition to significant oil and gas exploration activities in the study area, there is great need in characterizing ground waters near nonpoint sources and locations near coastal region. Hence the present research study has been carried out to evaluate the quality of ground waters in the Kakinada coastal region to find the contamination status and to assess their potential for end use utilities.

2. EXPERIMENTAL

The frequency of sampling was two times one during Pre Monsoon (March-June) and the other during Post Monsoon (November-February). Twelve representative samples of ground water were prepared and the details of Sample code, location, source type and coordinates are presented inTable-1

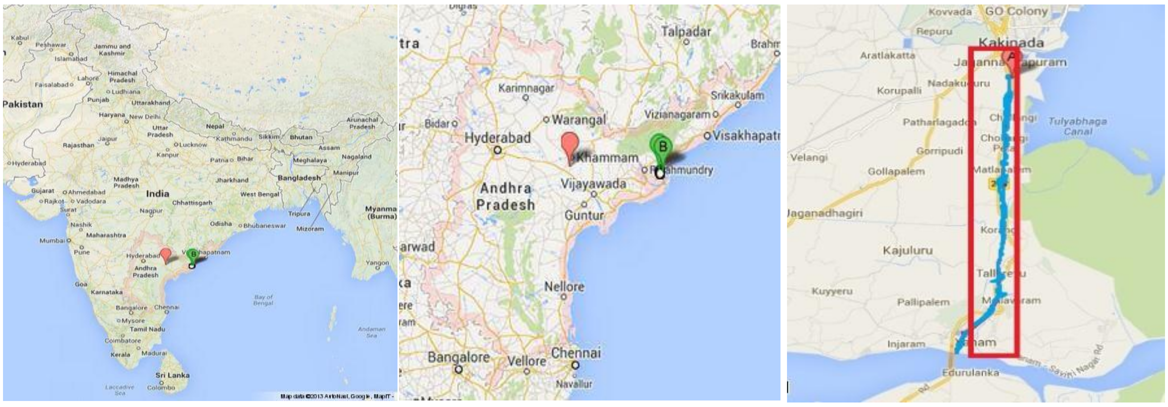
Table1. *Sample code, location, source type, Longitude and Latitude*

Sampling Code	Sampling Location	Type of Source	Coordinates	
			Langitude	Latitude
G-1	Pagadalapeta	BW	$16^{0}.55^{1}$N	$82^{0}.14^{1}$E
G-2	Chollangi	BW	$16^{0}.892^{1}$N	$82^{0}.239^{1}$E
G-3	Matlapalem	OW	$16^{0}.855^{1}$N	$82^{0}.233^{1}$E
G-4	Tallarevu	OW	$16^{0}.781^{1}$N	$82^{0}.233^{1}$E
G-5	Korangi	OW	$16^{0}.812^{1}$N	$82^{0}.231^{1}$E
G-6	PeddabodduRamudupalem	BW	$17^{0}.321^{1}$N	$82^{0}.041^{1}$E
G-7	Georgepeta	BW	$16^{0}.744^{1}$N	$82^{0}.224^{1}$E
G-8	Neelapalli	OW	$16^{0}.735^{1}$N	$82^{0}.227^{1}$E
G-9	Yanam	BW	$16^{0}.733^{1}$N	$82^{0}.216^{1}$E
G-10	Dariyalatippa	OW	$17^{0}.321^{1}$N	$82^{0}.041^{1}$E
G-11	Bhairavapalem	OW	$16^{0}.738^{1}$N	$82^{0}.311^{1}$E
G-12	Gadimoga	BW	$16^{0}.748^{1}$N	$82^{0}.292^{1}$E

G: Ground water, BW: Bore Well, OW: Open Well

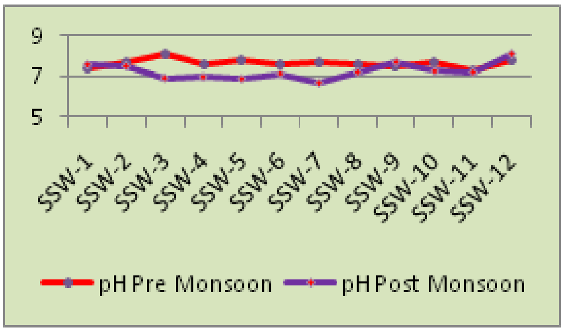
The sample bottles made of plastic usually Polythene were used and preserved for analysis by following the standard procedures [16]. The samples were analyzed for physicochemical parameters which include pH , Electrical Conductivity (EC) , Total Dissolved solids (TDS), Total Alkalinity (TA), Total hardness (TH), Ca and Mg, Na, K, Chloride, Sulphate and Phosphate. pH determined by pH meter (Global-DPH505,India-Model) and Conductivity measured by the digital Conductivity meter (Global-DCM-900-Model). TDS is determined from the relation TDS = Electrical conductivity (EC) ×0.64. Chloride, Total hardness, Total Alkalinity and Chloride were estimated by titrimetry. Sulphate and Phosphate by Spectrophotometer (Model-167, Systronics), Na and K by Flame photometer (Model- 125, Systronics). The analytical data is presented in tables-2, 3 respectively. The parametric values are also represented graphically in figures from 2(a) to 2(n).

The satellite picture of the study area selected is presented in figure-1



Study area – A Nonpoint source and sampling location

Figures-2(a) to (n). *Graphical representation of parameters pH, EC, TDS, TH, Ca^{2+}, Mg^{2+} ,TA, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, PO_4^{3-}, F^{-} and NO_3^{-} in ground waters during Pre and Post monsoon seasons*



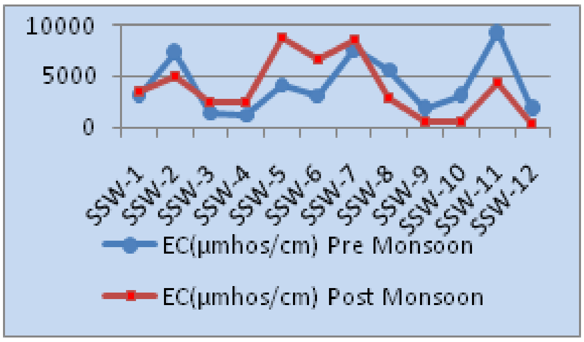


Fig2(a). *pH (Std. 6.5-8.5)*

Fig2(b). *EC*

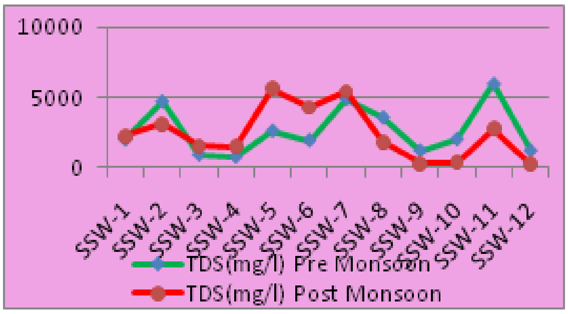


Fig2(c). *TDS (Std. 500 mg/l)*

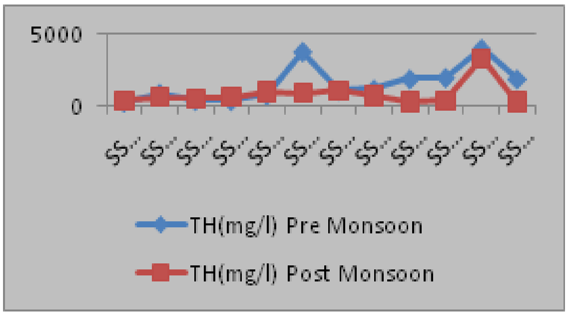


Fig2(d). *TH (Std. 300 mg/l)*

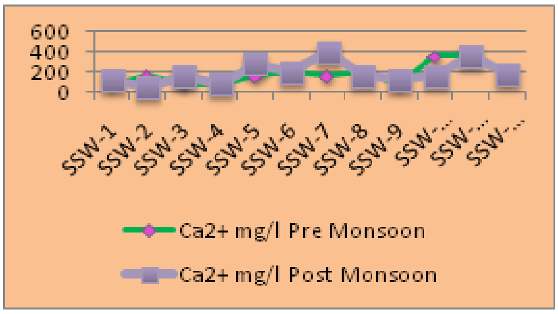


Fig2(e). *Ca^{2+} (Std. 75mg/l)*

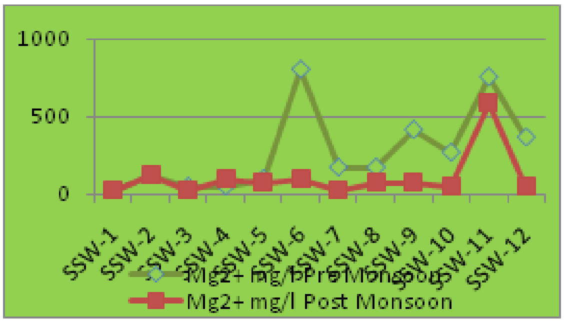


Fig2(f). *Mg^{2+} (Std. 30mg/l)*

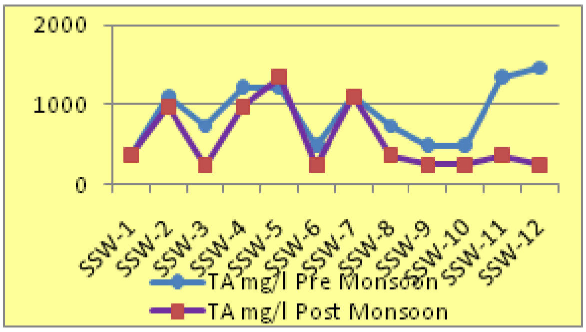


Fig2(g). *TA (Std. 300 mg/l)*

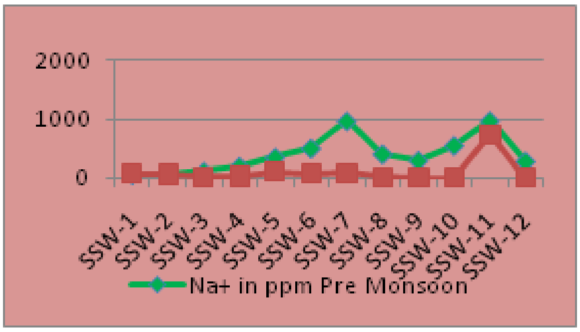


Fig2(h). *Na^{+}(WHO Std. 250mg/l*

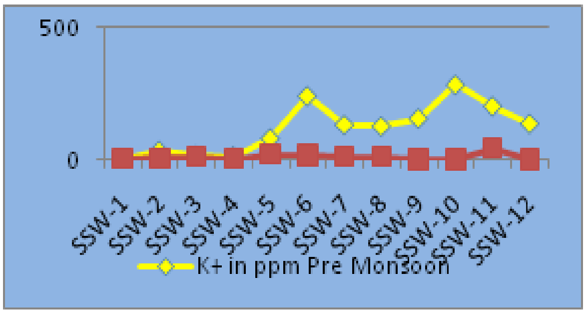


Fig2(i). *K^{+}(WHO Std. 12mg/l)*

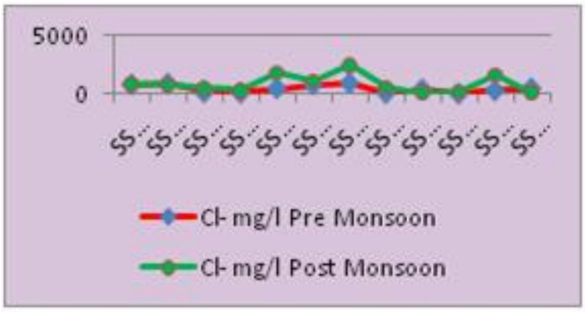


Fig2(j). *Cl^{-}(Std. 250mg/l)*

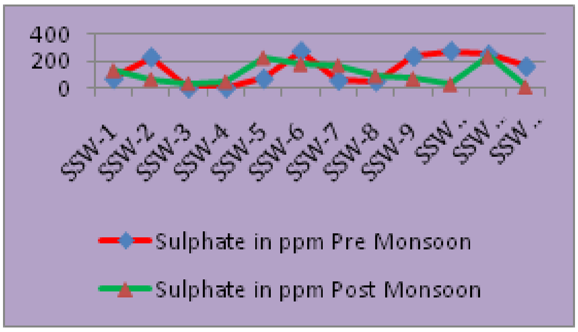


Fig2(k). *$SO4^{2-}$(Std. 200mg/l)*

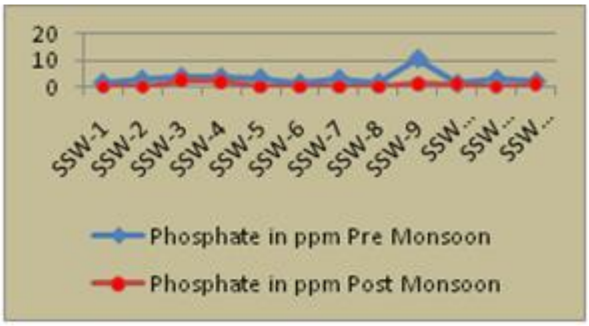


Fig2(l). *$PO4^{3-}$(Std. 5mg/l)*

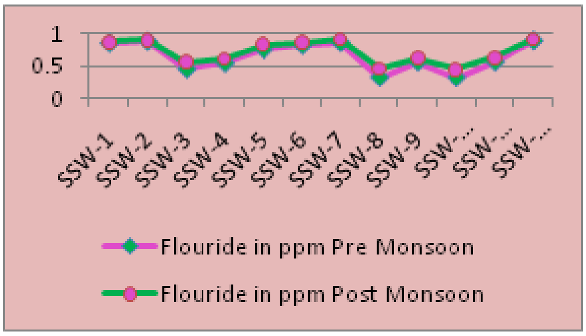


Fig-2(m): *F^-(Std.1mg/l)*

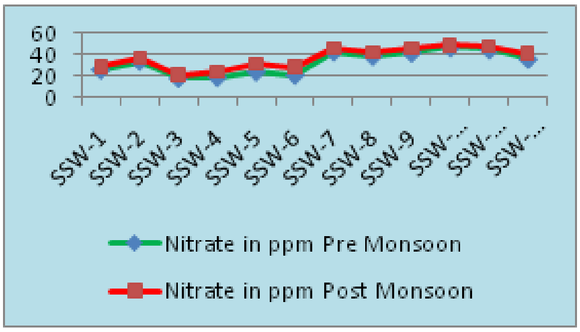


Fig-2(n): *NO_3^-(Std.45mg/l)*

Table2. *Physicochemical characteristics of ground waters*

Sample Code	pH		EC (μmhos/cm)		TDS (mg/l)		TH (mg/l)		TA (mg/l)		Ca^{2+} (mg/l)		Mg^{2+} (mg/l)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	post	Pre	Post	Pre	Pre	Pre	Post	Pre	Post	Pre	Post	Pre	Post
G-1	7.40	7.57	3120	3550	1996	2272	300	400	302	362	80	120	24.4	24.4
G-2	7.70	7.50	7350	4870	4704	3117	900	600	1098	972	160	40	122.0	122
G-3	8.10	6.89	1380	2450	883	1568	400	500	732	240	80	160	48.8	24.4
G-4	7.60	6.95	1160	2390	742	1530	400	600	1220	976	80	80	48.8	97.6
G-5	7.80	6.85	4090	8770	2618	5613	800	1000	1220	1342	160	280	97.6	73.2
G-6	7.60	7.12	3040	6720	1946	4301	3800	900	488	240	200	200	805.2	97.6
G-7	7.70	6.64	7640	8520	4890	5453	1100	1100	1098	1098	160	400	170.8	24.4
G-8	7.60	7.19	5560	2870	3558	1837	1200	700	732	362	200	160	170.8	73.2
G-9	7.50	7.71	1870	480	1197	307	1900	300	488	244	80	120	414.8	73.2
G-10	7.70	7.24	3150	610	2016	390	2000	400	488	244	360	160	268.4	48.8
G-11	7.30	7.19	9310	4330	5958	2771	4000	3300	1342	366	360	360	756.4	585.6
G-12	7.80	8.11	1858	390	1189	250	1900	300	1464	244	160	180	366.0	48.8

Table3. *Physicochemical characteristics of ground water*

Sample Code	Na^+ (mg/l)		K^+ (mg/l)		Cl^- (mg/l)		SO_4^{2-} (mg/l)		PO_4^{3-} (mg/l)		F^- (mg/l)		NO_3^- (mg/l)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
G-1	64	75	2	2	780	851	70	132	1.6	BDL	0.85	0.88	26	29
G -2	79	66	30	4	851	709	228	65	2.8	BDL	0.88	0.91	34	37
G -3	116	18	13	11	142	496	BDL	35	3.8	2.4	0.45	0.56	18	21
G -4	201	28	10	1	106	284	2	48	3.7	2.1	0.54	0.61	19	24
G -5	357	110	78	18	461	1808	70	228	3.3	BDL	0.75	0.84	24	31
G -6	510	75	242	15	780	1099	273	179	1.4	BDL	0.82	0.87	21	28
G -7	973	85	131	10	886	2482	58	171	3.1	BDL	0.86	0.92	43	46
G -8	412	19	125	11	71	567	51	92	1.6	BDL	0.32	0.46	39	42
G -9	301	5	155	0.6	390	71	234	71	10.4	1.2	0.56	0.62	42	46
G -10	557	10	285	0.6	35	213	273	27	1.3	1.0	0.32	0.5	47	49
G -11	979	736	203	42	284	1620	249	237	2.9	BDL	0.56	0.63	45	48
G -12	289	5	135	0.7	461	78	160	8	2.0	1.1	0.9	0.92	36	41.0

3. Results, Discussion and Conclusions

3.1. pH

pH of pre monsoon water samples range from 7.3 to 8.1 and are well within the limit of permissible range (6.5-8.5) of drinking water standards. pH of post monsoon samples varies from 6.64 to 8.11 and are within the permissible limit of drinking water standards.

3.2. Electrical Conductivity (EC)

EC of ground water samples of pre monsoon season ranges from 1160-9310 μmhos/cm. EC of ground water samples of post monsoon period ranges from 390-8770 μmhos/cm.

3.3. Total Dissolved Solids (TDS)

The ground waters of pre monsoon period are with TDS levels ranging from 742 - 5958 mg/l. In all the samples the TDS levels exceeds the permissible limits of drinking water standards. Hence these waters are not suitable for drinking purposes. In ground water samples of post monsoon season, TDS ranges from 250-5613 mg/l. In samples-9, 10 and 12 the TDS is observed within the permissible limits (500 mg/l) while in case of the remaining water samples the TDS exceeded the permissible limit (500 mg/l). Majority of samples of waters are with TDS exceeded the permissible limit indicating the presence of soluble solid matter making the waters unsuitable for drinking.

3.4. Total Hardness (TH)

TH is observed in the range of 300-4000mg/l in subsurface waters of pre monsoon. In sample-1, the TH reached the threshold limit while in the remaining samples, the TH exceeded the permissible limit of 300mg/l. TH is in the range of 300 -3300 mg/l in post monsoon samples. Samples-9 &12 TH reached the threshold limit and in the remaining samples TH crossed the permissible limit. Hence these waters are not suitable for domestic application as they cause encrustation on water supply systems.

3.5. Calcium (Ca^{2+})

Ca^{2+} in ground water samples of pre monsoon season ranges from 80-360mg/l and are on the higher side of the permissible limit. In post monsoon samples Ca^{2+} levels range from 40-400 mg/l. In sample-2, Ca^{2+} is within the permissible limit while in the remaining samples Ca^{2+}exceeded the permissible limit. Hence the waters are not suitable for domestic purposes.

3.6. Magnesium (Mg^{2+})

Mg^{2+}ion concentration in ground water samples of pre monsoon period range from, 24.4 to 805.2 mg/l. Mg^{2+}level in sample-1 are below permissible limit, while other samples are with higher levels of Magnesium. Magnesium in water samples of post monsoon season range between 24.4 – 585.6 mg/l. Water samples-1,3and 7 are with Mg is within the permissible limit while in the remaining samples Mg is on the higher side of permissible limit making the waters unsuitable for drinking as they can cause laxative effect on waters.

3.7. Total Alkalinity (TA)

TA varies from 302-1464 mg/l in water samples of pre monsoon season and in all samples TA exceeded the permissible limit. Waters of post monsoon season are with the TA in the range 240-1342 mg/l. TA exceeded the permissible limitin all samples. Hence these waters are not suitable for drinking purpose as they can cause unpleasant taste to the waters.

3.8. Sodium and Potassium (Na^+& K^+)

Sodium ion concentration ranging from 64-979 mg/l in ground waters collected during pre monsoon period while sodium levels range from 5-736 mg/l in ground waters collected during post monsoon period. Potassium levels in case of ground waters collected during pre monsoon period range from 2-285 mg/l while potassium levels range from 2-18 mg/l in ground water samples collected during post monsoon period. The sodium concentrations in 8 samples of pre monsoon season exceeded the WHO standards and except two samples 1&4 in all other samples of pre monsoon the potassium levels exceeded the WHO standards. In post monsoon season in one sample-11 sodium level exceeded the permissible limit and in two samples 5 &6 the potassium level exceeded the WHO standards. Sodium and Potassium are the most important minerals occurring naturally. The higher values of Na are related to the precipitation or absorption of the cations by soil or coating on the minerals and also due to the percolation of effluents. Sodium is also present in association with high concentration of chloride resulting in salinity. The concentration of Sodium is important in classifying irrigation waters as it reacts with soil permeability. Na^+& K^+ concentrations are also influenced by the cation exchange mechanism. High values of sodium at certain locations are attributed to the possible contamination by industrial effluents and residues such as filter cake. Higher levels of sodium and potassium during pre monsoon season may be due to excess ground water exploitation in the study area locations and further the higher levels of sodium and potassium may also indicate the leaching and dissolution of secondary salts in the pore spaces.

3.9. Chloride (Cl^-)

Chloride ion concentration range from 35 to 886 mg/l in ground water samples of pre monsoon period. They exceeded the permissible limit. In samples-1, 2, 5, 6, 7, 9, 11 & 12 while in samples-3,4,8& 10samples the chloride is within the permissible limit. In post monsoon ground water samples chloride range from 71-2482 mg/l. In SSW-9, 10 & SSW-12 the chloride levels are within the permissible limit while in the remaining samples, chloride crossed the permissible limit of drinking water standards.

3.10.Sulphate (SO_4^{2-})

Sulphate in ground water samples of pre monsoon period range from 2 to 273 mg/l. In samples -2, 6, 9, 10 and 11 Sulphate is on higher side of permissible limit of drinking water standards and in case of remaining water samples Sulphate is within the permissible limit. The high value of Sulphate may be attributed to the release and union of industrial effluent into the sub surface water in the study areas. Sulphate in all post monsoon samples ranges from 8-237 mg/l. In samples -5 and 11 Sulphate is higher than permissible limit while in remaining other samples Sulphate is within the permissible limit.

3.11.Phosphate (PO_4^{3-})

Phosphate levels range from 1.3-10.4 mg/l in ground water samples collected during pre monsoon period while the levels range from 1 –2.4 mg/l in samples of post monsoon season. Phosphate in one sample 9 of pre monsoon season phosphate exceeded the permissible limit in all other samples phosphate is within the permissible limit of WHO standards.

3.12.Fluoride (F^-)

Fluoride ranges from 0.44-0.82 mg/l in ground waters of pre monsoon period while Fluoride ranges from 0.47 to 0.86 mg/l in ground waters of post monsoon season. All the levels are within the permissible limit of drinking water standards.

3.13.Nitrate (NO_{3-})

Nitrate levels in pre monsoon ground waters range from 18-47 mg/l while the levels range from 21-49 mg/l and all the levels are within the permissible limit of drinking water standards. In 50% of samples the levels reached threshold limit of drinking water standards. The high nitrogen content is an indicator of organic pollution. It results from the added nitrogenous fertilizer, decay of dead plants and animals and their residues. They are all oxidized to nitrates by natural process. These factors are responsible for increase in nitrate content. The ground water contamination is due to the leaching of nitrate present in the surface with percolating water. Low nitrate levels may be due to the less usage of nitrogenous fertilizers and fewer disposals of other wastes around the locations or it may be due to denitrification.

4. CONCLUSIONS

pH of ground waters of pre monsoon season indicate slight alkaline nature while the waters of post monsoon season indicate slight acidic or alkaline nature. EC of all water samples of pre and post monsoon season and TDS of almost all water samples of both the seasons explain high soluble solid content in waters which may be due to the larger extent of percolation of agricultural, domestic and due to the association of brackish waters in the study area. High values of total hardness of all water samples of both the seasons and TA levels of majority samples of both seasons indicate the hardness of waters and their unpleasant odour which makes the waters unfit for drinking and domestic application. High concentration of Calcium indicates that the waters can cause encrustation on water supply system. Magnesium in majority samples crossed the permissible limit of drinking water standards and can cause gastrointestinal irritation, if consumed for drinking purposes. Sodium levels in majority pre monsoon water samples exceeded WHO standards, while they are in permissible limit in water samples of post monsoon season. Potassium in majority water samples of pre monsoon are above the WHO standard while Potassium in majority post monsoon samples is within the WHO standards. Chloride concentration in majority samples of pre and post monsoon season indicate the signatures of sea water inundation into ground waters. Sulphate concentration is high in five waters samples of post monsoon season which reveals the discharge in the form of sulphate fertilizers by the manmade activities in the locations. Low phosphate level in waters of both pre and post monsoon season indicate the non-discharge of phosphatic fertilizers into subsurface waters. Nitrate concentrations in waters of both pre and post monsoon seasons indicate that the discharge of agricultural runoff containing nitrogenous fertilizers. The fluoride levels of all waters of both seasons are within the permissible limits.

The research results revealed that the ground waters were contaminated by higher EC, TDS, TH, Ca^{2+}, Mg^{2+},TA, Na^{+}, K^{+}, Cl^{-} and NO_3^{-} which were the main contributors tothe chemical contamination of ground waters in addition to salt water inundation in the study areas . Hence the waters were not suitable either for drinking or for domestic areas

5. Acknowledgements

The authors are thankful to the Management and the Administrative authorities of Pragati Engineering College, Surampalem for their support and cooperation in carrying out the present research work..

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