Available online at www.joac.info

ISSN: 2278-1862

Journal of Applicable Chemistry

2013, 2 (5):1391-1401

(International Peer Reviewed Journal)

Quality Evaluation of Subsurface Waters near an Industrial Effluent Stream by Physicochemical and Microbial Characterization for Assessing theirPotential for Application

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Received on 14th September and finalized on 18th September 2013.

ABSTRACT

The present proposed research study is to characterize the subsurface water samples collected from ten rural locations near an industrial effluent stream flowing between Peddapuram and Kakinada revenue divisions of East Godavari district for evaluating their quality. The subsurface water samples collected during pre monsoon and post monsoon seasons were characterized for physicochemical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH),Total Alkalinity (TA), Carbonate, Bicarbonate alkalinities, Ca^{+2}, Mg^{+2}, Na, K, Cl^{-}, SO_4^{-2} and PO_4^{-3} to assess their quality for end use application. Most of the parametric values of many subsurface water samples exceeded the permissible limits of drinking water standards of IS: 10500-1992 indicating the unsuitability of these subsurface waters for drinking as well as domestic application. Irrigation standard parameters like Percent Sodium(%Na), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Kelly' Ratio(KR), Magnesium Hazard (MH) were also calibrated and the parametric levels are within the permissible limits of irrigation standards and the results confirmed that majority of subsurface waters were suitable for irrigation purposes. Microbial analysis of these subsurface waters also confirmed the presence of bacterial species viz., E.coli, Proteus, Pseudomonas, Klebsiella and Enterobactor indicating the bacterial contamination and hence these waters can cause concern on human health if consumed for drinking purposes.

Keywords: Subsurface Water, Parameter, Irrigation, Bacteria, Contamination.

INTRODUCTION

Presently in our country most of the industries are situated along the banks of rivers for availability of water and disposal of the wastes easily. The wastes contain chemical contaminants which can alter the pH of water [1-3]. Ram S. Lokhande etal.,[4] carried out studies on physicochemical parameters of Kasardi river flow along Taloja Industrial area in Mumbai, India and the research results revealed that the river waters were highly polluted. Literature survey [5-7] revealed that one third of the total water pollution in our country comes in the form of Industrial effluent discharges and surface water is the main source for

waste disposal and the levels of surface water pollution was observed to be 20 times higher than the safe levels. In the present modern era of civilization, water and its management are the real measures which cause impacts on our lives and earth than ever before [8] Industrial effluent on entering the surface water modify the chemistry of the water and enhance the parametric levels above the permissible limits and this could have substantial impact on humans either directly or indirectly since less than 1 percent of fresh water in the world is accessible for use [9]. Ramesh etal.,[10] carried out research study on assessment of ground water quality in designated Peenya Industrial Area and Estate Bangalore, India and the study results revealed that various parameters exceeded the drinking water standards.

Studies of Suman Panwar [11] on assessment of ground water quality in Contiguous of Integrated Industrial estate, Pantnagar, Uttarakhand revealed that ground water becomes contaminated due to anthropogenic activities and the studies further suggested a proper treatment to Ground waters before use for drinking and domestic purposes. A research study by Sheik Rameeza et al., [12] on study of ground water quality in industrial zone of Visakhapatnam revealed that the water was slightly alkaline (pH:6.5-8.5), moderately low (TH:64-292 mg/l) and TDS (380-1600 mg/l) and the other parametric levels indicate the unsuitability for drinking purposes. The study area is represented in figure 1.

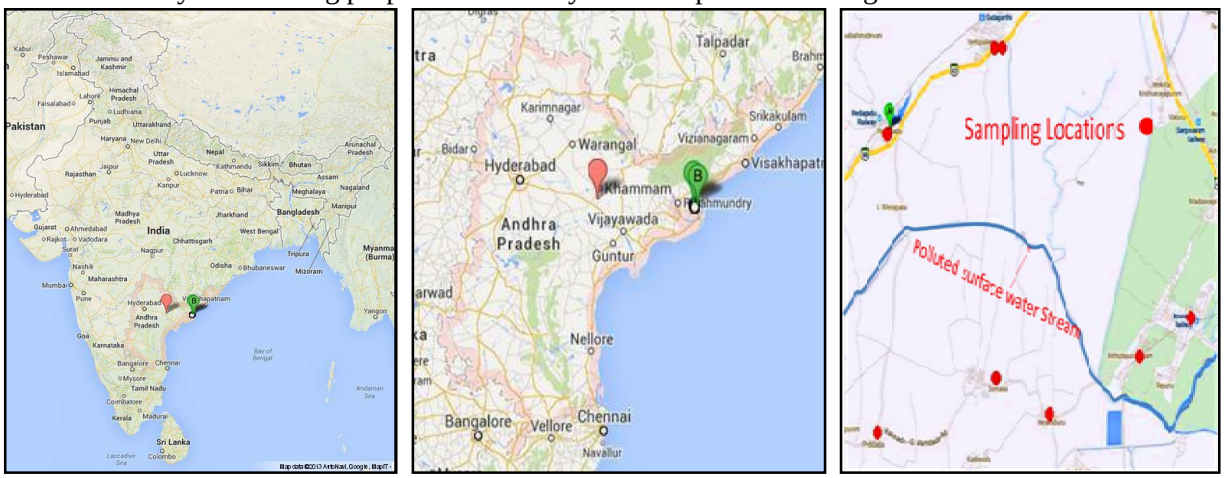


Figure 1. Study area map and polluted surface water source

MATERIALS AND METHODS

The sampling locations of the study area selected for the present research study in East Godavari region is situated along the northern coast of Andhra Pradesh between the latitudes $16^0.1454^1$ to $17^0.022^1$ N and longitude $80^0.6618^1$ to $82^0.1999^1$ E. The subsurface water sampling locations were identified in the nearby industrial effluent stream and the details are presented in table 1.

Table 1. Details of sample code and Sampling location

Sample code	Location
GW-1	Medapadu
GW-2	Sriramavetlapalem
GW-3	Vetlapalem
GW-4	Peddada
GW-5	Pedapudi
GW-6	Domada
GW-7	Karakuduru
GW-8	Atchutapuram
GW-9	Rameswaram
GW-10	Kovvada

Polythene containers were employed for sampling and preserved for analysis by following the standard procedures[13]. The samples were analyzed for physicochemical parameters which include pH , Electrical conductivity (EC) , Total Dissolved solids (TDS), Total Alkalinity (TA), Total hardness (TH), Calcium and Magnesium, Na, K, Chloride, Sulphate and Phosphate. pH determined by pH meter (Global-DPH 505,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 parameters for consideration of these waters for irrigation purpose include Percent Sodium, Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate(RSC), Kelly's Ratio (KR), Magnesium Hazard(MH) were calibrated by using the following relation

Percent Sodium (me/l)=

$$\%Na = \frac{Na^{+} \times 100}{Ca^{+2} + Mg^{+2} + Na^{+} + K^{+}}$$

Sodium Adsorption Ratio (SAR)=

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

Residual Sodium Carbonate (me/l)=

$$RSC = (CO_3^{-2} + HCO_3^{-}) - (Ca^{+2} + Mg^{+2})$$

Kelly's Ratio =

$$KR = \frac{Na^{+}}{Ca^{+2} + Mg^{+2}}$$

Magnesium Hazard=

$$MH = \frac{Mg^{+2}}{Ca^{+2} + Mg^{+2}} \times 100$$

Bacterial Analysis: The samples were collected in sterilized containers [14] and immediately transported to the laboratory for the bacterial analysis. The Most Probable Number (MPN) technique was employed for the enumeration for the *Coliform* count in water samples [15, 16]. It involved the presumptive test using lactose broth and Nutrient agar, confirmatory test using Eosin Methylene Blue (EMB) agar, pure colonies of the isolated were subjected to Grams stain, motility, Indole, Methyl red, Voges-Proskuer test, Citrate utilization test, Urease test, Catalse and Oxidase test[17].

The Physicochemical Parameters were analyzed as per the standard procedures [13] and the analytical data was presented in tables2, 3 and 4.

Table 2. Physicochemical Characteristics of Subsurface Waters

Sample Code	pH		EC(µmhos cm^{-1})		TDS(mg L^{-1})		TH(mg L^{-1})	
	Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	post	Pre	Post	Pre	Post	Pre	Post
GW-1	7.9	7.1	515	510	330	326	300	250
GW-2	6.8	7.21	946	1700	605	1088	300	500
GW-3	8.6	7.89	955	870	611	557	400	200
GW-4	7.8	7.44	3180	2520	2035	1613	400	500
GW-5	8.1	7.57	1214	380	777	243	400	300

GW-6	7.1	7.88	1070	3450	685	2208	1200	500
GW-7	7.6	7.73	3220	3850	2061	2464	700	700
GW-8	7.8	7.4	1430	890	915	570	400	300
GW-9	8.2	7.02	1350	1438	864	920	400	400
GW-10	8.4	7.3	393	395	252	253	300	250

Table 3. Physicochemical Characteristics of Subsurface Waters

Sample Code	Ca^{+2} (mg L^{-1})		Mg^{+2} (mg L^{-1})		TA(mg L^{-1})		CO_3^{-2}(mg L^{-1})	
	Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
GW-1	80	80	24.4	12.2	200	180	BDL	BDL
GW-2	80	40	24.4	97.6	300	500	BDL	80
GW-3	100	40	36.6	24.4	400	300	BDL	40
GW-4	120	40	24.4	97.6	600	380	BDL	80
GW-5	120	40	24.4	48.8	400	140	BDL	BDL
GW-6	200	100	170.8	61	200	340	BDL	40
GW-7	80	100	122	109.8	700	540	BDL	40
GW-8	120	80	24.4	24.4	200	260	BDL	BDL
GW-9	120	80	24.4	48.8	400	320	BDL	40
GW-10	80	40	24.4	36.6	200	160	BDL	BDL

Table 4. Physicochemical Characteristics of Subsurface Waters

Sample Code	HCO_3^-(mg L^{-1})		Na(mg L^{-1})		K (mg L^{-1})		Cl^- (mg L^{-1})		SO_4^{2-}(mg L^{-1})		PO_4^{3-}(mg L^{-1})	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
GW-1	200	180	44.9	5.01	13.3	0.31	35	35	230	8	3.8	0.6
GW-2	300	420	73.4	20.73	10	0.16	71	142	50	62	10.4	1.0
GW-3	400	260	155.9	17.23	2.6	0.04	71	106	32	36	2.9	0.8
GW-4	600	300	323.6	27.89	26.5	3.65	248	319	24	91	4.7	1.2
GW-5	400	140	152.4	7.2	6.6	0.85	71	106	27	19	3.2	1.0
GW-6	200	300	1170.6	39.69	23.3	6.39	284	603	249	59	2.1	0.5
GW-7	700	500	332.2	39.66	10.2	16.91	496	567	31	36	3.7	1.3
GW-8	200	260	173.3	12.45	16.3	0.9	142	213	12	14	2.0	1.1
GW-9	400	280	110.3	13.55	45.3	7.22	213	177	20	42	3.4	3
GW-10	200	160	37.3	4.47	8.6	1.11	35	71	20	22	4.1	0.9

The parameters related to irrigation were calibrated and the analytical data was presented in table 5.

Table 5. Irrigation Parameters

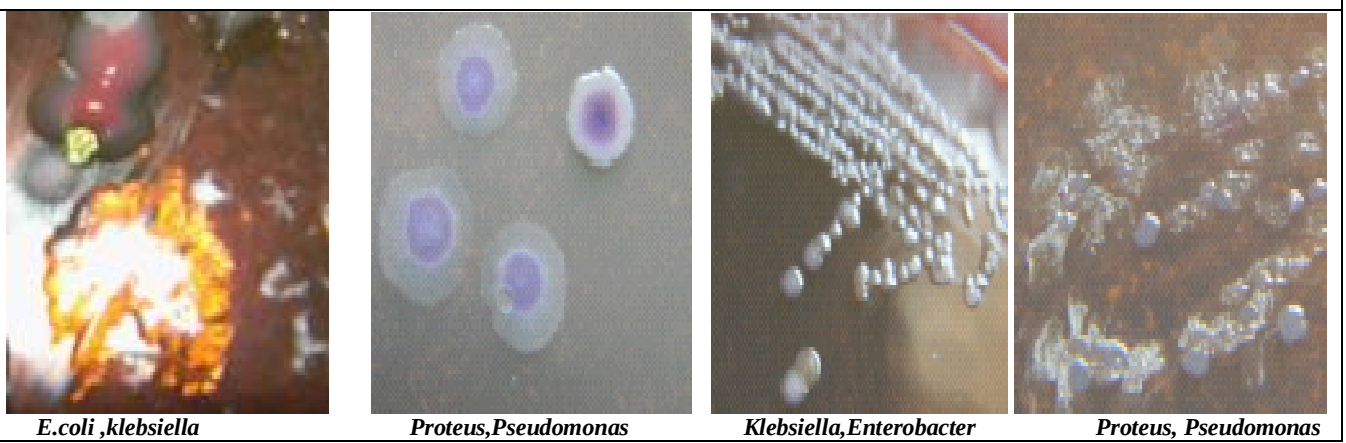
Sample Code	%Na		SAR (me/l)		RSC (me/l)		Kelly's Ratio		MH	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	post
GW-1	23.68	4.19	1.13	0.14	BDL	BDL	0.328	0.044	32.80	19.61
GW-2	33.95	8.41	1.85	0.41	BDL	BDL	0.536	0.092	32.80	79.61
GW-3	45.89	15.93	3.41	0.53	BDL	0.977	0.855	0.190	36.93	49.39
GW-4	61.98	10.91	7.06	0.55	1.884	BDL	1.769	0.124	24.55	79.61
GW-5	44.93	5.02	3.32	0.18	BDL	BDL	0.833	0.053	24.55	66.13
GW-6	67.72	14.67	14.80	0.78	BDL	BDL	2.151	0.175	57.74	49.39
GW-7	50.74	10.82	5.51	0.66	BDL	BDL	1.050	0.125	70.93	63.73
GW-8	47.38	8.30	3.78	0.31	BDL	BDL	0.948	0.091	24.55	32.80
GW-9	34.49	6.79	2.41	0.30	BDL	BDL	0.603	0.075	24.55	49.39
GW-10	20.81	2.71	0.94	0.10	BDL	BDL	0.273	0.028	24.55	42.26

The details of microbial analytical data was presented in table 6 and identified bacteria are shown in photographs.

Table-6: Details of Microbial Analytical data

S.No	Sample No	MPN COUNT Pre Monsoon	MPN COUNT Post Monsoon	Organisms Isolated Pre Monsoon	Organisms Isolated Post Monsoon
1.	GW-1	17	70	*E.coli*	*E.coli, Enterobacter*
2.	GW-2	<2	4.5	*Pseudomonas, Proteus*	*E.coli*
3.	GW-3	12	33	*E.coli, Proteus*	*Enterobacter, Pseudomonas,*
4.	GW-4	8	27	*Proteus ,Enterobacter*	*Klebsiella, Proteus*
5.	GW-5	<2	10	*Proteus*	*E.coli , Pseudomonas,*
6.	GW-6	22	95	*Klebsiella*	*E.coli, Klebsiella*
7.	GW-7	14	24	*E.coli , Pseudomonas*	*E.coli, Enterobacter*
8.	GW-8	<2	20	*Proteus*	*Klebsiella, Enterobacter*
9.	GW-9	17	45	*E.coli, Proteus*	*E.coli, Klebsiella, Pseudomonas*
10.	GW-10	11	47	*E.coli*	*E.coli, Klebsiella*

Photographs of identified *Bacteria*



E.coli ,klebsiella *Proteus,Pseudomonas* *Klebsiella,Enterobacter* *Proteus, Pseudomonas*

RESULTS AND DISCUSSION

pH: pH of pre monsoon water samples range from 6.8 to 8.6 and are well within the permissible range (6.5-8.5) of drinking water standards[18]. The pH levels of post monsoon samples vary from7.02 to 7.89 and are also within the permissible limits of drinking water standards[18]. Waters with pH value ranging between 6.5 - 8.4 can be used for irrigation without any problem and waters with pH between 5.1-6.4 and 8.5-9.5 can be considered as moderate class [19]**.** The water sample GW-3 collected during pre monsoon was observed with pH 8.6 and hence the waters was classifies under moderate class.

Electrical conductivity (EC): EC values of subsurface water samples during pre monsoon season range from 393-3220 µmhos cm^{-1}. EC values of subsurface water samples collected during pre monsoon season GW-1 & GW-10 indicate their suitability in the range excellent to good for irrigation purposes as their EC values are within the limit [20] (750µmhos cm^{-1}). EC values of water samples except GW-4 and 7 were in the range of above 750 and within 2250 µmhos cm^{-1} indicating their suitability under category good to injurious and suitable only with permeable soil and moderate leaching. Water samples GW-4 and 7 were observed with EC values greater than 2250 µmhos cm^{-1} indicating their unsuitability for irrigation purposes. For subsurface water samples collected during post monsoon period EC values range from 380-3850 µmhos cm^{-1} water samples GW-1,5 and 10 were observed with EC values bellow 750 µmhos cm^{-1} indicating their category under excellent for irrigation purposes. Water samples GW-2,3,8 and 9 were with EC values in the range 750-2250 µmhos cm^{-1} indicating their category under 'good' for irrigation while EC values of water samples GW-4,6and 7 were with 2250 µmhos cm^{-1} indicating their unsuitability for irrigation purposes.

Total Dissolved Solids (TDS): TDS level of water samples during pre monsoon season range from 252 mg L^{-1} - 2061 mg L^{-1}. The levels in respect of water samples GW-1 & GW-10 are within the permissible limit [18] and in other samples the TDS levels are above the permissible limits indicating the presence of soluble solids in water. In case of subsurface water samples collected during post monsoon season TDS levels range from 243 mg L^{-1} - 2464 mg L^{-1}. In case of samples GW-1, 5 and 10 the TDS levels are within the permissible limits (500mg L^{-1}) while in case of other water samples the TDS levels exceeded the permissible limit. In majority of samples the TDS levels exceed the limit indicating the presence of soluble solids in water samples making these waters unsuitable for drinking purposes. In case of subsurface waters GW- 1, 3, 5, 8 and 10 the TDS levels were observed within 700 mg L^{-1} and were excellent for irrigation while waters GW-2, 4, and 9 were observed with TDS levels in the range 700-2000 mg L^{-1} and were good for irrigation; however they were harmful to sensitive crops. Waters GW- 6 and 7 were observed with TDS levels higher than 2000 mg L^{-1} and were unfit for irrigation. Subsurface water samples GW-1, 2, 3, 6 and

10 were observed with TDS levels within 700 mg L^{-1} and are within the permissible limit [18] and can be considered under category excellent to good for irrigation and while GW- 5, 8 and 9 were observed with TDS levels in between 700-2000 mg/l and can be considered under category good for irrigation; however they were harmful to sensitive crops. GW- 6 and 7 were observed with TDS levels greater than 2000 mg L^{-1} and were unfit for irrigation.

Total Hardness (TH): Total hardness levels were observed in the range of 300 -1200 mg L^{-1} in pre monsoon subsurface water samples. In case of samples Gw-1,2 and 10 the total hardness levels reached the threshold value while in the remaining samples, the total hardness levels exceeded the permissible limit of 300mg L^{-1} [18]. Total hardness levels were observed in the range of 200 -700mg L^{-1} in case of post monsoon water samples. In samples GW-1, 3 and 10 the levels are within the permissible limits while in case of samples Gw-5&8 the TH levels reached the threshold value and in the remaining samples TH levels exceeded the permissible limit of 300mg L^{-1} .

Ca^{+2}: Ca^{+2} levels in water samples collected during pre monsoon season range from 80-200mg L^{-1} and the levels are higher than the permissible limit (75mg L^{-1}) [18]. In case of post monsoon samples Ca^{+2} levels range from 40-100mg/l. In samples GW-2, 3, 4, 5 and 10 Ca^{+2} levels are within the permissible limit (75mg/l) while in the remaining samples Ca^{+2} levels exceeded the permissible limit.

Mg^{+2}: Mg^{+2} ion concentrations in pre monsoon sub surface water samples range from, 24.4 to 170.8mg L^{-1}. Mg^{+2} levels in ground water samples GW-1,2,4,5,8,9 and 10 are below permissible limit (30mg L^{-1}) [18] while other water samples were observed with higher levels of Magnesium. The Magnesium levels in water samples collected during post monsoon season range between 12.2 – 109.8 mg L^{-1}. The water samples GW-2, 4, 5, 6, 7, 9, and 10 were observed with Mg levels higher than the permissible limit [18] making these waters unsuitable for drinking purposes.

Total Alkalinity (TA): Total Alkalinity values range from 200-700mg L^{-1} in water samples collected during pre monsoon season. In water samples GW-1, 6, 8 &10 TA levels reached the threshold limit (200mg L^{-1}) [18] and in other samples TA levels exceeded the permissible limit. In water samples collected during post monsoon season the Total Alkalinity levels observed in the range from 140-540mg L^{-1}. In case of water samples GW-1,5 and10, the TA levels are within the permissible limit(200mg L^{-1}) while in other samples TA values exceeded the permissible limit [18].

Chloride (Cl^-): Chloride ion concentration range from 35 to 496 mg L^{-1} in sub surface water samples collected during pre monsoon period. Chloride levels exceeded the permissible limit (250mg L^{-1}) [18] in case of GW-6 and GW-7 while in other samples the chloride levels are within the permissible limit. In post monsoon subsurface water samples chloride ion concentration range from 35-603 mg L^{-1}. the levels exceeded the permissible limit in samples GW-4, 6 and 7 and the chloride levels are within the permissible limits in the remaining water samples. The higher concentration of chloride in ground water samples attributed to dissolution of salt deposits, discharge of effluents from industrial sewage discharges contamination from refuse lechates and also sea water intrusion. Chloride levels in subsurface waters GW-1, 2, 3, 5, 8 and 10 collected during pre monsoon season and samples GW-1, 2, 3, 5 and 10 collected during post monsoon season were observed in the range of 0-142 mg L^{-1} and classified as class-I waters and excellent for irrigation. Subsurface waters GW-4, 6 and 9 collected during pre monsoon and GW-4, 8 and 9 collected during post monsoon season were observed with chloride levels in between 142-355 mg L^{-1} and were good for irrigation; however they may cause concern on sensitive crops. Subsurface waters of pre monsoon GW-7 and post monsoon sample GW-6 and 7 were observed with chloride levels above 355 mg L^{-1} and hence unfit for irrigation.

Sulphate (SO_4^{-2}): Sulphate levels in subsurface water samples collected during pre monsoon period range from 12 to 249 mg/l and the levels were on higher side of permissible limit 200mg L^{-1} and in case of

samples GW-1,6 and in case of remaining water samples Sulphate levels are within the permissible limit. The higher values of Sulphate may be attributed to the release and union of industrial effluent into the sub surface water in these areas. The Sulphate levels in pre monsoon season GW-2, 3, 4, 5, 7, 8, 9, and 10 range between 0-192 mg L^{-1} and these waters were classified as class-I and were excellent for irrigation while waters GW-1 and 6 were observed with Sulphate levels in between 192-480 mg L^{-1} and these waters were classified as class-II and were good for irrigation; however harmful to sensitive crops. Sulphate levels in all post monsoon water samples range from 8-91 mg L^{-1} and all the values were within the limit of 142 mg L^{-1} and classified as class-I waters and can be considered excellent for irrigation.

Phosphate (PO_4^{-3}): Phosphate levels range from 2.0-10.4mg L^{-1} in subsurface water samples collected during pre monsoon period while phosphate levels range from 0.5 –1.3 mg L^{-1} in subsurface waters of post monsoon season.

Sodium and Potassium (Na and K): The subsurface waters collected during pre monsoon season were observed with Na concentration in between 37.3 to 1170.6 mg L^{-1}. While Sodium levels in post monsoon water samples range from 4.47 to 39.69 mg L^{-1}. Potassium levels in pre monsoon water samples range from 2.6 to 45.3mg L^{-1}. While K levels range from 0.04 to 16.91 mg L^{-1} in water samples collected during post monsoon season.

Percent Sodium (%Na): Percent Sodium values for pre monsoon subsurface waters range from 20.81 to 67.72me L^{-1}. The values in respect of water samples GW-1, 2, 9 and 10 were identified as 'Good' water class for consideration for irrigation purposes. Ground water samples 3, 5, 7 & 8 were identified under 'permissible' category for consideration for irrigation purposes while water samples GW-4 and 6 were identified under doubtful category. Waters with Percent sodium value above 60 me L^{-1} are not considered suitable for irrigation [21]. In the subsurface waters collected in post monsoon season Percent Sodium values range from 2.71 to 15.93 me L^{-1} and all are under excellent quality for consideration for irrigation purposes [22].

SAR: SAR indicate the suitability of sub surface waters for irrigation and it is evaluated by determining the SAR value and they were categorized under different irrigation classes on the basis of salinity and alkalinity hazards. SAR indicates the Sodium hazard in relative to Ca^{+2} and Mg^{+2} concentrations. Water with SAR value less than 18 me/l can be considered to use for irrigation purposes and can also be extended up to 26 me L^{-1} [23]. The SAR levels varied from 0.94 to 14.80 me L^{-1} in respect of subsurface waters collected during pre monsoon season. The SAR level in only sample was observed at 14.80me L^{-1} and this water sample can be considered under water class 'Good' while in case of the remaining water samples SAR levels are less than 10 indicating that these waters can be considered under water class "Excellent' indicating the suitability of these waters for irrigation purposes. In case of subsurface water samples SAR values range from 0.10 to 0.78me L^{-1} and hence these waters can be classified under category 'Excellent' indicating that no alkali hazard can be expected to the crops.

RSC: Besides SAR and Percent Sodium, the excess sum of carbonate and bicarbonate in subsurface water over the sum of Calcium and Magnesium also influence the suitability of sub surface waters for irrigation. Waters with RSC values <1.25 were classified as unsuitable for irrigation. RSC values of subsurface waters GW-4 collected during pre monsoon season were observed at 1.884 and hence these waters are to be used with precaution for irrigation while in other waters the RSC levels were at levels of BDL indicating these water class as 'good' and their suitability for irrigation. RSC values of subsurface waters collected during post monsoon season range from BDL to 0.977 indicating the water class as 'Good' revealing the suitability of subsurface waters for irrigation [24].

Kelly's Ratio (KR): The level of Na^{+} measured against Ca^{+2} and Mg^{+2} is termed as Kelly's Ratio, based on which water can be rated [25,26]. Kelly's subsurface water having Kelly's ratio more than one is

considered as unfit for irrigation. Kelly's ratio of sub surface water samples GW-4,6 and 7 were more than 1 indicating the unsuitability of these waters for irrigation. While the other water samples were observed with Kelly's ratio less than 1 and are suitable for irrigation purposes. In case of water samples collected during post monsoon season KR was observed below 1 indicating all subsurface waters are suitable for irrigation purpose.

Magnesium Hazard (MH): Presence of Magnesium in water would adversely affect the soil quality rendering it unfit for cultivation [27]. If Magnesium hazard was less than 50, then the water was safe and suitable for irrigation [28]. The MH levels of the pre monsoon season water samples range from 24.55 to 70.93. Water samples GW-6 and 7 were observed with MH level 57.74 and 70.93 respectively indicating their unsuitability for irrigation purposes while the water samples observed with MH level less than 50 were suitable for irrigation purposes. The MH levels of water samples collected during post monsoon season range from 19.61 to 79.61. Water samples GW-2,4,5and 7 were observed with MH levels greater than 50 indicating their unsuitability of these waters for irrigation purposes while the remaining water samples with less than 50 MH level were suitable for irrigation purposes.

Bacterial Species: All subsurface water samples collected during pre and post monsoon season were observed with not only MPN count but also with several other bacterial species. The water samples collected during pre monsoon season GW-1 and GW-10 were found to contain *E.coli spp.* Water samples GW-2 was observed with *Pseudomonas* and *Proteus* species. Water samples GW-3 and GW-9 were observed with *E-Coli and Proteus spp* subsurface water samples GW-4 was observed with *Proteus* and *Enterobacter*. *Proteus spp* were identified in water samples GW-5 and GW-8. Water sample GW-6 was found to contain *Klebsiella* species. In post monsoon subsurface water samples GW-1 and GW-7 contained *E.coli* and *Enterobacter spp,* GW-2 with *E.coli spp,* GW-3 observed with *Enterobacter* and *Pseudomonas spp*. Water samples GW-4 and was observed with *Klebsiella* and *Proteus spp*. GW-5 was with *E.coli* and *Pseudomonas spp* and GW-7 sample was observed with *E.coli* and *Enterobacter spp*. GW-8 sample was observed with *Klebsiella* and *Enterobacter spp.* GW-9 sample was observed with *E.coli, Klebsiella* and *Pseudomonas spp* while in GW-10 *E.coli* and *Klebsiella* species were identified.

APPLICATIONS

The results of Microbial analysis of these subsurface waters indicate the presence of bacterial species in these water viz., *E.coli, Proteus, Pseudomonas, Klebsiella and Enterobacter* indicating the bacterial contamination and hence these water can cause concern on human health if consumed for drinking purposes. The results also indicate whether suitable for Irrigation purpose or not.

CONCLUSIONS

pH values of majority subsurface water samples collected during pre and post monsoon season indicate slight to alkaline nature. Based on EC values majority subsurface water samples were categorized as Excellent to good for utilization for irrigation and the presence of total dissolved salts in majority subsurface waters made them unsuitable for drinking or domestic purposes. Due to the presence of higher levels of total hardness and calcium levels, the subsurface waters can cause incrustation in water supply and adverse effects on domestic use and hence the waters are unsuitable for drinking and domestic utility. Total Alkalinity levels in case of majority water samples range at threshold limit or exceeded the permissible limits as such the waters will be with unpleasant taste and hence these waters are not suitable for drinking purposes. Chloride levels in case of water samples both in pre and post monsoon seasons are within permissible limits and also in majority samples Chloride levels are within 355mg L^{-1} and are categorized as class I and II and can be considered for utility for irrigation and hence except GW-7 during pre monsoon and GW-6 and 7 during post monsoon season the remaining waters are suitable for irrigation purposes. Sulphate levels in respect of majority sub surface waters collected during pre and post monsoon

seasons are within the permissible limits of both drinking water standards and also irrigation standards and hence can be utilized for irrigation purposes. In sub surface water samples GW-4 and GW-6 during pre monsoon season Percent sodium levels exceeded 60me L^{-1} and hence cannot be considered for irrigation while in the remaining water samples and all the water samples collected during post monsoon season were found to contain Percent Sodium levels within the permissible limit (60me L^{-1}) and hence can be considered for irrigation purposes. SAR levels of sub surface water of both pre and post monsoon season are within the permissible limit of 26me L^{-1} and hence all the waters can be considered for utility for irrigation purposes. Subsurface water collected during pre monsoon GW-6 and 7 were with Magnesium Hazard level with more than 50%. While the water samples collected during post monsoon season GW-2,4,5 and 7 are with MH levels more than 50% and hence these samples are unsuitable for irrigation purposes while the remaining water can be considered for irrigation purposes while the remaining waters can be considered for irrigation purposes. The presence of MPN count along with other *bacterial spp E.coli. Enterobacter, Pseudomonas, Proteus and Klebsiella* indicates the microbial contamination and hence these waters are highly unsuitable for drinking and domestic purposes. Proper treatment is to be proposed to these subsurface waters even for considering these water for irrigation and to protect the quality of the soil to achieve better crop yields in the study area.

ACKNOWLEDGEMENTS

The authors sincerely thank the faculty of Microbiology Department and the authorities of RIMS, Kakinada for their cooperation extended in completing the Microbial analysis.

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