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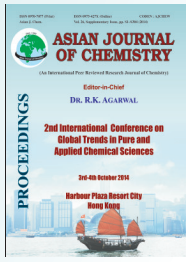

Physico-Chemical, Biochemical and Heavy Metals Analysis of Subsurface Waters Near Non-Point Source for Assessing Their Quality for End User Application

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Keeping in view the hectic agricultural activities in East Godavari region of Andhra Pradesh, India and utilization of subsurface waters by rural public in habitations in the nearby agricultural non point source, it is proposed to analyze the subsurface waters for physico-chemical parameters *viz*., pH, electrical conductivity, total dissolved solids, total hardness, Ca^{2+}, Mg^{2+}, total alkalinity, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, PO_4^{3-}, F^{-}, NO_3^{-}, heavy metals like Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Pb, As and also to analyze for bacterial species to evaluate the quality of subsurface waters for consideration for end user application. The research results revealed that the waters are chemically contaminated and unsuitable for drinking and domestic utility. Though the heavy metal levels are within the permissible limits of drinking waters standards, the waters are found to contain pathogenic bacteria like *Klebsiella*, *Proteus*, *Enterobacter*, *Pseudomonas* and *E. coli* indicating the microbial contamination making these waters unsuitable for drinking and domestic purposes.

Keywords: Subsurface water, Non-point, Bacteria, Heavy metal, Drinking.

INTRODUCTION

Subsurface or ground water is a significant source of drinking water for many rural and small communities. Several studies revealed that over pumping of ground water, for aquaculture and agricultural activity, lowered the ground water level and land to subside below sea level in some coastal regions[1]. The studies of Elhatip *et al*.[2], revealed that 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.

Agriculture is the most pervasive cause of nonpoint source water quality problems[3]. Agricultural non-point source also significantly affects groundwater sources[4]. Heavy metals enter the human body through food, water, air or absorption through the skin in agriculture and in manufacturing, pharmaceutical, industrial, or residential settings. Jain *et al*.[5], studied the trace element concentrations of ground water in around Kakinada coastal aquifer and the study results revealed that Fe and Mn at certain locations are higher than the desirable limits prescribed for drinking water.

Pathogens can cause disease in humans and are communicated from one organism to other by direct contact, or by contamination of food or water. The proportion of waterborne disease outbreaks associated with the distribution system failures and has been increasing over the years[6].

Keeping in view of the hectic agricultural activities and other high pollution sources in East Godavari region and existence of habitations in the nearby non point source with there is need to characterize the subsurface waters for assessing their quality for end user application.

EXPERIMENTAL

The sampling stations are identified in the nearby an agricultural run off being a nonpoint source selected for the present research study are located in East Godavari region of Andhra Pradesh between the latitudes 16°, 7381' to 17^0, 3842' N and longitude 81°, 9289' to 82°, 2325' E. The subsurface water sampling locations were identified in the nearby an agricultural run off being a non point source stream and the details are presented in Table-1.

Polythene containers were employed for sampling and preserved for characterization by following standard procedures[7]. The samples are characterized for physico-chemical parameters *viz*., pH, electrical conductivity, total dissolved solids, total alkalinity, total hardness, calcium and magnesium, Na, K, chloride, sulphate and phosphate. The pH was determined by pH meter (Global-DPH 505, India-Model) and con-

TABLE-1
SAMPLE CODE AND SAMPLING LOCATIONS

Sampling code	Type of source	Sampling location
SSW-1	BW	Tatipudi
SSW-2	BW	Angara
SSW-3	BW	Teki
SSW-4	BW	Yandagandi
SSW-5	BW	Pamarru
SSW-6	OW	Tamarapalli
SSW-7	BW	Dangeru
SSW-8	BW	Gangavaram
SSW-9	BW	Kolanka
SSW-10	BW	Tallarevu

ductivity measured by the digital conductivity meter (Global-DCM-900-Model). Total dissolved solids was determined from the relation total dissolved solids = electrical conductivity X0.64. Chloride, total hardness, total alkalinity and chloride are estimated by titrimetry. Sulphate and phosphate by spectrophotometer (Model-167, Systronics), Na and K by flame photometer (Model-125, Systronics) and the analytical data is presented in Tables 2 and 3.

Subsurface water samples are collected from various locations and three representative samples are prepared for pre monsoon and three samples for post monsoon period and the heavy metal ions Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Pb, As and U are analyzed by inductively coupled plasma mass spectrometry technique (Model-8081 Make-Aligent Technologies) and the analytical data related the heavy metal ions is presented in Table-4a,b, respectively.

Bacterial analysis: The subsurface water samples are collected in sterilized containers[8] and immediately transported to the laboratory for the bacterial analysis. The most probable number technique is employed for the enumeration for the *Coliform* count in water samples[9,10]. The analysis involved the presumptive test using lactose broth and Nutrient agar, confirmatory test using eosin methylene blue agar, pure colonies of the isolated were subjected to Grams stain, motility, Indole, methyl red, Voges-Proskuer test, Citrate utilization test, Urease test, catalase and oxidase test[11]. The bacterial *spps* identified in subsurface waters of pre monsoon and post monsoon seasons.

RESULTS AND DISCUSSION

pH: The pH of pre monsoon water samples range from 7.6 to 8.2 and were well within the permissible range (6.5-8.5) of drinking water standards[12]. The pH levels of post monsoon samples range from 7.79 to 8.8. Except SSW-1 all are within the permi-ssible limits of drinking water standards[12].

Electrical conductivity: Electrical conductivity values of subsurface water samples during pre monsoon season range from 851-3800 μmhos/cm. For subsurface water samples collected during post monsoon period electrical conductivity values range from 434-4780 μmhos/cm.

Total dissolved solids: Total dissolved solids levels within the permissible limit (500 mg/L) can be considered for drinking purposes[12]. Total dissolved solids level of water samples during pre monsoon season range from 545-2432 mg/L. The total dissolved solids levels exceeded the permissible limit[12] of drin-

TABLE-2
PHYSICO-CHEMICAL CHARACTERISTICS OF SUB SURFACE WATERS

Sample code	pH		Electrical conductivity (μ mhos/cm)		Total dissolved solids (mg/L)		Total hardness (mg/L)		Ca^{2+} (mg/L)		Mg^{2+} (mg/L)		Total alkalinity (mg/L)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
SSW-1	7.9	8.80	1600	1042	1024	667	300	200	80	60	24.4	12.2	488	365
SSW-2	8.1	8.31	1810	623	1158	399	600	200	120	40	73.2	24.4	488	146
SSW-3	7.7	8.19	2180	482	1395	309	500	300	160	40	24.4	48.8	610	219
SSW-4	7.9	8.76	2520	1670	1613	1069	500	200	120	40	48.8	24.4	976	463
SSW-5	7.6	7.79	2450	1976	1568	1265	500	400	120	80	48.8	48.8	732	537
SSW-6	7.7	8.03	3800	4780	2432	3059	800	1200	160	360	97.6	73.2	854	122
SSW-7	8.2	8.40	2470	2390	1581	1530	300	500	80	80	24.4	73.2	732	316
SSW-8	7.8	8.20	1640	438	1050	280	300	600	80	80	24.4	97.6	488	268
SSW-9	7.7	8.49	851	1374	545	879	300	500	80	80	24.4	73.2	854	268
SSW-10	7.8	8.34	3410	434	2182	278	500	200	120	40	48.8	24.4	122	97

TABLE-3
PHYSICO-CHEMICAL CHARACTERISTICS OF SUB SURFACE WATERS

Sample code	Na (mg/L)		K (mg/L)		CI^- (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
SSW-1	147	20	38	1.4	142	71	56	27	3.0	BDL	0.44	0.47	11	15
SSW-2	169	9	44	0.6	213	71	78	22	3.0	BDL	0.48	0.52	14	17
SSW-3	188	5	46	0.4	177	36	70	16	2.2	BDL	0.58	0.64	9	13
SSW-4	225	31	32	0.6	213	106	71	64	3.4	0.2	0.62	0.68	12	16
SSW-5	221	20	43	13.2	213	177	73	70	11.4	BDL	0.63	0.71	13	15
SSW-6	448	55	112	3.4	355	496	79	237	1.1	BDL	0.71	0.76	15	19
SSW-7	265	20	38	17.7	248	213	44	81	2.7	BDL	0.62	0.68	14	18
SSW-8	148	6	36	0.5	106	36	59	8	4.2	BDL	0.49	0.54	10	12
SSW-9	133	15	29	11.2	36	71	17	53	3.0	BDL	0.46	0.52	11	13
SSW-10	334	8	118	0.3	674	36	99	15	3.3	0.2	0.82	0.86	18	16

TABLE-4
(a) CONCENTRATIONS OF Cr, Mn, Fe, Co AND Pb

Sample code		Heavy metal contamination (ppm)									
		Cr		Mn		Fe		Co		Pb	
Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
S-1	S-4	0.0018	0.0003	0.0007	0.0005	0.0077	0.0042	0.00001	0.00001	0.0006	0.0009
S-2	S-5	0.0008	0.0005	BDL	0.0011	BDL	0.0061	0.0001	BDL	0.0005	0.0007
S-3	S-6	0.0008	0.0004	0.0009	BDL	0.0087	BDL	0.0001	0.00003	0.0003	0.0004

(b) CONCENTRATIONS OF Ni, Cu, Zn, Cd, Al and As

Sample code		Heavy metal contamination (ppm)											
		Ni		Cu		Zn		Cd		Al		As	
Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
Pre	Post	Pre	Post	Pre	Pre	Pre	Post	Pre	Post	Pre	Post	Pre	Post
S-1	S-4	0.0005	0.0006	0.00004	0.00004	0.0016	0.0015	0.00004	0.00001	0.0074	0.0087	0.0004	0.0007
S-2	S-5	0.0009	0.0005	0.00004	0.00004	0.0047	0.00003	0.00004	0.00003	0.0084	0.0062	0.0013	0.0014
S-3	S-6	0.0008	0.0005	0.00004	0.00004	0.001	0.0004	0.00004	0.00001	0.006	0.0044	0.0039	0.0034

king water standards indicating the presence of soluble salt content and making them unsuitable for drinking purposes. In case of subsurface water samples collected during post monsoon season total dissolved solids levels range from 278-3059 mg/L. SSW samples 2, 3, 8 and 10 were observed with total dissolved solids values lower than the drinking water standards[12]. The remaining water samples were observed with higher total dissolved solids levels compared to the drinking water standards[12] and were unsuitable for drinking purposes.

Total hardness: Total hardness levels were observed in the range of 300-800 mg/L in pre monsoon subsurface water samples. Total hardness levels were observed in the range of 200-1200 mg/L in case of post monsoon water samples. In samples SSW-1, 2, 4 and 10 the levels are within the permissible limits[12] while in case of SSW-3 the total hardness levels reached the threshold value and in the remaining samples total hardness levels exceeded the permissible limit of 300 mg/L[12]. The waters in which the total hardness levels exceeded the limit can cause encrustation on water supply system and these waters were unsuitable for domestic purposes.

Ca^{2+}: Ca^{2+} levels in water samples collected during pre monsoon season range from 80-160 mg/L and the levels are higher than the permissible limit[12]. In case of post monsoon samples Ca^{2+} levels range from 40-360 mg/L. In samples SSW-2, 3, 4 and 10 Ca^{2+} levels are within the permissible limit[12] while in the remaining samples Ca^{2+} levels exceeded the permissible limit[12]. The subsurface waters with higher calcium levels can cause encrustation on water supply system and were unsuitable for domestic utility.

Mg^{2+}: Mg^{2+} ion concentrations in pre monsoon sub surface water samples range from, 24.4-97.6 mg/L. Mg^{2+} levels in ground water samples GW-1,3,7,8 and 9 are below permissible limit while other water samples were observed with higher levels of magnesium. The magnesium levels in water samples collected during post monsoon season range between 12.2-97.6 mg/L. The water samples SSW-3, 5, 6, 7, 8 and 9 were observed with Mg levels higher than the permissible limit[12] making these waters unsuitable for drinking purposes.

Total alkalinity: Total alkalinity values range from 122-976 mg/L in water samples collected during pre monsoon season. The only SSW sample SSW-10 was observed with 122 mg/L which was within the permissible limit[12] while the total alkalinity levels in the remaining SSW samples crossed the permissible limit[12]. In subsurface water samples collected during post monsoon season the total alkalinity levels observed in the range from 97- 537 mg/L. In case of water samples SSW-2, 6 &10, the total alkalinity levels are within the permissible limit[12] while in other samples total alkalinity values exceeded the permissible limit making the waters to lose their taste and making them unsuitable for drinking purposes.

Cl^-: The permissible limit of chloride in drinking water is 250 mg/L and beyond this level the waters lose palatability and become corrosive. Chloride ion concentration range from 36 to 674 mg/L in sub surface water samples collected during pre monsoon period. SSW samples 6 & 10 were observed with chloride levels higher than permissible limit[12] while in other samples chloride levels were than the permissible limit[12] and hence these waters will exhibit corrosive nature and were unsuitable for drinking purposes. In SSW samples 1, 2, 3, 4, 5, 7, 8, 9 and 10, chloride levels were within the permissible limit[12] of drinking water standards and in the remaining water sample-6 chloride level crossed the permissible limit[12] and unsuitable for drinking purposes.

SO_4^{2-}: Waters with sulphate levels within 250 mg/L can be consider for drinking purposes[12]. Sulphate levels in subsurface water samples collected during pre monsoon period range from 17 to 99 mg/L. In all water samples in pre monsoon season sulphate levels were within the permissible limit[12]. All SSW samples were observed with sulphate levels within the permissible limit[12] of drinking water standards. Sulphate levels in all post monsoon water samples range from 8-237 mg/L and were within the permissible limit of drinking water standards. All SSW samples were observed with Sulphate levels within the permissible limit[12] of drinking water standards.

PO_4^{3-}: Phosphate levels range from 1.1-11.4 mg/L in subsurface water samples collected during pre monsoon period while phosphate levels were observed as 0.2 mg/L in respect of SSW samples 4 & 10 and in other samples, phosphate level was observed at BDL in subsurface waters of post monsoon season.

Na^+ and K^+: The subsurface waters collected during pre monsoon season were observed with Na^+ concentration in between 133 to 448 mg/L. While sodium levels in post monsoon water samples range from 5 to 55 mg/L. Potassium levels in pre monsoon water samples range from 29 to 118 mg/L. While K^+ levels range from 0.3 to 17.7 mg/L in water samples collected during post monsoon season.

Heavy metals: The concentrations of heavy metal ions *viz.*, Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Pb and As. are within the permissible limits. Al (0.03 ppm), Cr (0.05 ppm), Mn (0.1), Fe (0.3 ppm), Co (0.05 ppm), Ni (0.02 ppm), Cu (0.05 ppm), Zn (5 ppm), Cd (0.01 ppm), Pb (0.1 ppm), As (0.01 ppm) and U (0.03 ppm) of drinking water standards.

Bacterial species: All subsurface water samples collected during pre and post monsoon season were observed with not only most probable number count but also with several other *bacterial species*. The water samples collected during pre monsoon season 1 is identified with *Klebsiella* and *Proteus spp*. Samples-2, 5, 6, 7 and GW-8 were observed with *Proteus spp*. Water sample 3 and 9 are found contain with *Pseudomonas*. Subsurface water samples-4 is observed with *Pseudomonas* and *Proteus spp*. Sample-10 is found to contain *E. coli* and *Proteus spp*. Water samples. In post monsoon subsurface water samples-1, 5, 6, 7 and 8 are observed with *Proteus spp*. Samples-2 and 3 are identified with *Pseudomonas* and *Proteus spp*. Water sample-4 is with *E. coli* and *Pseudomonas spp*. Sample-9 is found to contained with Pseudomonas *spp* and Sample-10 is with *E. coli* and *Proteusspp*.

Conclusion

The pH of subsurface waters of both pre and post monsoon season indicate the slight to moderate alkaline nature of waters. Higher levels of total dissolved solids indicate the presence of soluble solids in these waters. Total hardness levels in majority water samples exceeded the permissible limit indicating the hardness of waters their unsuitability for domestic purposes. Higher calcium levels also indicate the unsuitability of waters for domestic purposes as they cause encrustation in water supply systems total alkalinity levels also exceeded the permissible limits, waters will lose their taste and hence unsuitable for drinking purposes. Chloride in majority samples is below the permissible limits. Lower sulphate levels indicate the non discharge of industrial effluents into subsurface waters. Fluoride and nitrate levels are within the permissible limit. The concentrations of heavy metal ions *viz*., Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Pb and As, are within the permissible limits and hence these metals may not cause any concern at present, however there is need to monitor the levels below the permissible limit or otherwise the metals can cause concern on human health if these waters are consumed by the public residing in the nearby habitats of the non point source.

In majority subsurface waters in the proposed study area the most probable number count is zero indicating the absence of microbial contamination during pre monsoon and post monsoon seasons. But pathogenic bacteria like *Proteus*, *Klebsiella*, *E. coli* and *Pseudomonas* species are present in water samples of pre or post monsoon season. Hence the waters are with bacterial contamination and can cause concern on human health by spreading waterborne diseases. Though these subsurface waters are observed with heavy metal levels within the permissible limits, these waters are contaminated due to higher levels of chemical parameters and due to the presence of bacterial *spps* and hence the waters are highly unsuitable either for drinking or domestic utility. It is suggested that the impacts from agricultural activities on subsurface water can be minimized by employing effective management practices to protect the quality of subsurface waters which are highly suitable to local conditions of the study area.

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