



Chemical and Pathogen Impacts on Human Health near Aquaculture Areas in West Godavari District of Andhra Pradesh, India

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 05-10-2020

Revised: 25-11-2020

Accepted: 08-12-2020

Key Words:

Groundwater
Aquaculture
Microbial characterization
Water quality
Toxicity

ABSTRACT

Water is essential for all living organisms in the universe. Chemicals can cause contamination in groundwater near aquacultural activity areas. Keeping in view the hectic aquacultural activity in surrounding locations of Akividu town in West Godavari District of AP, India, it is proposed to assess the chemical and microbial contamination of waters to suggest remedial measures to protect the quality of water for safeguarding the health of the public residing in the nearby habitations who consume these waters for drinking purposes. 16 Groundwater samples were collected and analyzed for assessing the physicochemical parameters viz., pH, Electrical conductivity (EC), Total Dissolved solids (TDS), Total hardness (TH), Total Alkalinity (TA), Na⁺, K⁺, Calcium, Magnesium, Chloride, Sulphate, Nitrate and Phosphate, Irrigation parameters like %Na, SAR, KR RSC, and microbial analysis. The study results revealed that the samples were contaminated chemically and also with pathogenic bacteria like *Pseudomonas*, *Citrobacter freundii* and *Escherichia coli* which can cause water-borne diseases. Further, a health survey was carried out to verify the adverse effects to be caused by the chemical and microbial contamination of water on people's health. The health survey results indicated the sufferings of the people who consume this water for drinking and domestic purposes. The waters are to be treated accordingly to control the chemical and bacterial contamination by using the available treatment methodologies before considering them for drinking purposes.

INTRODUCTION

Groundwater recharge is being done by various water bodies. Physico-chemical characteristics of an aquatic body not only reflect the type and diversity of aquatic biota but also the water quality and its contamination (Mir et al. 2004). Research studies (Raveen et al. 2008) revealed the necessity for the restoration of degrading freshwater bodies to ensure the sustainability of a healthy ecosystem. The environmental impact of aquaculture in the country came to the limelight for the first time with the reports of NEERI (1995). Intensive aquaculture requires huge quantities of freshwater from groundwater sources (Ramesh et al. 2008). Using significant volumes of groundwater to create the required salinity levels of brackish water for aquaculture activity can cause salinization of groundwater aquifers (Dahdouh-Guebas et al. 2006). The research studies (Alagarswamy 1995) revealed that shrimp farming and other farming systems can lead to pollution and result in adverse impacts on the environment. Higher quantities of nitrogen and phosphorus in feeds during aquaculture can also cause an increase in nutrient concentration in waters. The excess nutrient concentrations may deteriorate the water in the aquatic environment

(Falconer et al. 2018). The research studies indicated that the values of SAR and RSC indicate 97% of the waters and their suitability for domestic, irrigation, and industrial purposes (Nagaraju & Papanna 2009).

The bacteria and pathogenic organisms present in drinking water can cause health hazards like dysentery, cholera, fevers, hepatitis, intestinal disorders, etc. Presence of *coli form* in water is an indicator of harmful bacteria but all the bacteria are not harmful (Massoud et al. 2010, Joao 2010). Microbial pathogenic bacteria in water can cause diarrhoeal diseases nearly up to 82% of diseases (WHO 2010). Several microbial communities that survive in waters start multiplying and depreciate the water quality (Ikonen et al. 2017). Pathogen contamination of waters is a significant health risk and also a threat to the water supplies essential for living and other recreational activities. Low levels of contact with contaminated water are significant and can cause an outbreak of gastroenteritis (Madoux-Humey et al. 2016, Boehm & Sassoubre 2014). Though *coli forms* do not cause serious illness, they act as an indicator for the presence of more (Ibrahim et al. 2014). Approximately 3.4 million people particularly children die from water-borne diseases (WHO

2014). Various studies (Arnone & Walling 2007) revealed that gastrointestinal problems can be caused by different microbes and germs present in water bodies which indicate the symptoms like diarrhea, nausea, vomiting, fever, and abdominal pains (Arnone & Walling 2007).

Keeping in view of hectic aquaculture activity and the release of backwaters due to its activity and the seepage of these waters into groundwater sources, it is proposed to carry out the characterization of groundwater near aquaculture activity areas to evaluate the chemical and pathogenic impacts through groundwater sources on the public health through their utility for drinking and domestic purposes

and to suggest remedial measures to protect the health of the public.

MATERIALS AND METHODS

The sampling locations are identified near aquacultural activity areas around Akividu of West Godavari District of Andhra Pradesh, India. The samples were collected in polythene containers and preserved for analysis as per the standard procedures (Ramteke & Moghe 1988, APHA 1992). The details of sample code, sampling locations along with their coordinates are presented in Table 1 and the study area map is presented in Fig. 1.

Table 1: Sample code, location and coordinates.

Sample Code	Sample Location	GPS Co-ordinates	
		Latitude	Longitude
AE-1	Cherukuvada main road, near Hossanna mandir	16.58411	81.39045
AE-2	Cherukuvada main road, near Anjanayaswami temple	16.58390	81.39041
AE-3	Akivedu, near Vinayaka Industry	16.58473	81.40942
AE-4	Cherukuvad (undi road), near Church	16.58644	81.41901
AW-1	Manchineeti Cheruvugattu	16.57885	81.38296
AW-2	Kaikaluru road, near SV Godowns	16.57785	81.35683
AW-3	Near SV Godowns	16.57880	81.35907
AW-4	Near SV Godowns	16.57856	81.35921
AN-1	Near Alapadu main road	16.57494	81.32997
AN-2	Kolletikota, near Alapadu turning	16.58087	81.32201
AN-3	Kalletikota road, near Alapadu Panchayathi Cheruvu	16.58207	81.32103
AN-4	Kolletikota road, near Hanuman Temple	16.59303	81.31828
AS-1	Main road, near Telephone Exchange	16.58241	81.38025
AS-2	Near Telephone Exchange	16.58257	81.38027
AS-3	Argumuru Garuvu	16.58253	81.39849
AS-4	Main road, near Anjanaya temple	16.58435	81.40992

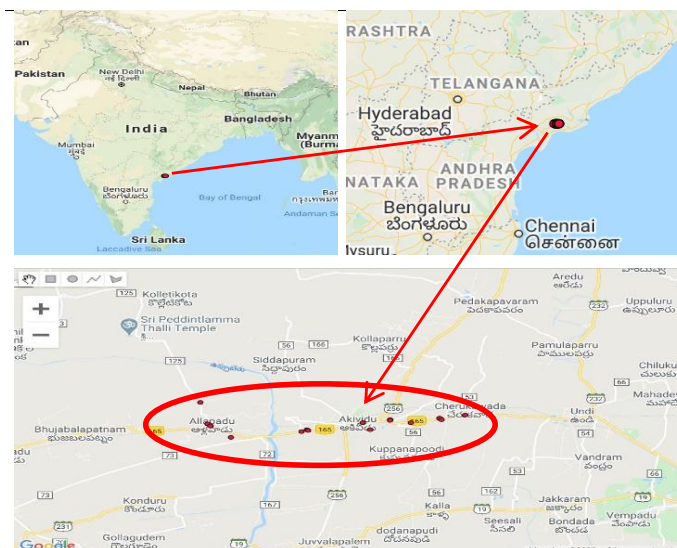


Fig. 1: Study area map (Google map).

Physicochemical Parameters

The waters were characterized for physicochemical parameters viz., pH, Electrical conductivity (EC), Total Dissolved solids (TDS), Total hardness (TH), Total Alkalinity (TA), Na⁺, K⁺, Calcium and Magnesium, Chloride, Sulphate, Nitrate, and Phosphate. pH is determined by pH Meter (Model-PCS Tester35, Eutech) and conductivity measured by portable EC sensor (Electrode based). TDS is determined by TDS Sensor (Electrode based). Total Hardness, Total Alkalinity, and Chloride are estimated by titrimetry. Sulfate and Phosphate are estimated by spectrophotometer (Model-106, Systronics), Na⁺ and K⁺ by Flame photometer (Model-128, Systronics), and Nitrate by using Ion-selective electrode (Model-HI 3222 pH/ORP/ISE Meter, HANNA). The irrigation parametric levels, Percent Sodium (%Na), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Kelly's Ratio (KR), Magnesium Hazard (MH) are determined by using equations.

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

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

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

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

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

Microbial Characterization

MPN Count: MPN count in water samples was done by the standard MPN index method.

Identification of Bacteria: The identification of bacterial species was carried out by the cultural characteristics using staining reactions to identify the shape and the color of the microorganisms and biochemical characterization which include IMViC (Indole production test, Methyl red test, Voges Proskauer test, Citrate utilization) tests (Obiri-Danso & Jones 1999a, 1999b, Sohan & Iqbal 2012).

RESULTS AND DISCUSSION

The values of physicochemical characteristics of the groundwater near aquacultural areas are presented in Tables 2, 3 and 4 and values for irrigational param-

Table 2: Physicochemical characteristics of groundwater near aquacultural areas.

Sample Code	Temp (°C)		pH		EC (µmhos/cm)		TDS (mg/L)		Salinity (mg/L)		TH (mg/L)		TA (mg/L)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
AE-1	29.0	30.4	8.43	8.15	3920	1575	2770	1120	2150	826	350	500	70	1300
AE-2	28.9	30.5	8.10	6.93	8630	1230	6080	870	4960	640	1700	2150	130	1700
AE-3	29.0	30.4	7.60	7.57	3730	1270	2640	917	2040	977	780	1150	80	1070
AE-4	28.9	30.4	8.45	7.84	2630	1510	1850	1070	1400	795	430	450	100	1660
AW-1	29.1	30.5	8.08	8.14	3100	927	2190	663	1680	481	630	300	100	1420
AW-2	29.0	30.3	8.75	7.94	5720	670	4040	476	3210	3850	580	2800	90	1850
AW-3	29.0	30.5	8.83	8.18	3100	4320	2190	3080	1680	2410	240	700	80	2030
AW-4	29.1	30.5	7.84	8.11	15000	1745	10590	1250	9030	932	2300	700	100	1570
AN-1	29.1	30.3	7.77	8.19	14710	4320	10385	3080	8770	2420	2800	900	70	1700
AN-2	29.1	30.4	8.33	8.92	10100	5250	7140	3740	5910	2970	1060	600	100	1830
AN-3	29.1	30.4	8.03	8.67	7370	3680	5190	2630	4200	2020	820	1000	90	890
AN-4	29.1	30.4	7.73	8.12	6900	3680	4860	2660	3900	2080	860	1700	50	1650
AS-1	29.0	30.5	7.68	8.15	1659	1320	1180	937	873	690	240	300	50	1130
AS-2	29.1	30.5	8.21	7.25	2060	736	1460	524	1110	379	370	100	60	280
AS-3	29.0	30.4	8.14	7.20	2370	1400	1670	1010	1260	742	470	900	60	1250
AS-4	29.1	30.4	8.11	7.49	3070	1600	2170	1140	1660	852	1110	700	50	350
BIS value	-		6.5-8.5		-		500		-		200		200	

Table 3: Physicochemical characteristics of groundwater near aquacultural areas.

Sample Code	Cl ⁻ (mg/L)		SO ₄ ²⁻ (mg/L)		PO ₄ ³⁻ (mg/L)		NO ₃ ⁻ (mg/L)	
	Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
AE-1	1155.67	744.45	73.57	133.57	0.61	1.13	29.5	17.4
AE-2	2431.87	2906.9	334.57	270.71	2.33	1.78	36.4	30.5
AE-3	765.72	744.45	244.29	1742.80	0.11	0.62	109.0	13.4
AE-4	446.67	744.45	178.00	128.71	0.13	0.53	54.2	43.7
AW-1	517.57	567.2	225.29	56.85	3.19	1.07	19.3	18.4
AW-2	1474.72	15030.8	307.14	3.54	0.00	1.29	95.3	69.7
AW-3	588.47	1807.95	235.71	308.71	0.64	4.73	112.0	70.1
AW-4	5835.07	921.7	348.43	170.00	3.86	0.7	153.0	19.2
AN-1	6083.22	2197.9	334.57	114.14	3.29	0.43	66.9	36.3
AN-2	3708.07	2552.4	184.86	307.57	0.14	1.93	60.3	337
AN-3	2502.77	2197.9	135.14	234.85	1.01	3.89	47.6	37.9
AN-4	2396.42	2906.9	257.00	230.85	1.63	1.4	50.2	71.7
AS-1	233.97	212.7	118.57	101.42	0.50	1.2	194.0	48.4
AS-2	304.87	567.2	170.57	60.00	0.47	3.87	191.0	9.65
AS-3	588.47	921.7	128.71	219.71	2.08	1.01	18.9	19.9
AS-4	907.52	1276.2	74.14	145.00	3.39	0.14	29.3	17.5
BIS value	250		200		-		45	

Table 4: Physicochemical characteristics of groundwater near aquacultural areas.

Sample Code	Ca ²⁺ (mg/L)		Mg ²⁺ (mg/L))		Na ⁺ (mg/L)		K ⁺ (mg/L)	
	Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
AE-1	120	80	12.2	73.2	1936.2	293.8	59.4	10.6
AE-2	500	160	109.8	427	828.0	607.6	23.6	6.4
AE-3	200	120	68.32	207.4	1722.8	400.0	605.0	13.5
AE-4	120	80	31.72	61	497.6	228.0	186.4	93.7
AW-1	220	80	19.52	24.4	678.2	89.3	332.7	24.2
AW-2	180	160	31.72	585.6	2296.8	1962.2	18.4	29.2
AW-3	40	120	34.16	97.6	1137.3	872.7	16.5	25.5
AW-4	760	120	97.6	97.6	3738.0	384.6	114.8	8.5
AN-1	780	160	207.4	122	3576.8	925.1	109.6	14.5
AN-2	400	80	14.64	97.6	2378.2	916.5	70.8	293.9
AN-3	240	120	53.68	170.8	1669.0	807.8	25.4	66.1
AN-4	260	80	51.24	366	1662.4	901.1	111.2	26.3
AS-1	80	80	9.76	24.4	238.8	122.6	255.2	151
AS-2	120	40	17.08	BDL	276.0	77.9	401.8	17.1
AS-3	100	120	53.68	146.4	564.6	235.5	17.6	9.8
AS-4	220	80	136.64	122	540.2	326.9	26.0	8.5
BIS Value	75		30		-		-	

Table 5: Irrigation parametric values of groundwater near aquacultural areas.

Sample Code	% Na (me/L)		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
AE-1	90.8	55.8	45.1	5.8	BDL	16.1	12.1	1.3	14.0	59.4
AE-2	51.1	38.4	8.8	5.8	BDL	BDL	1.1	0.6	26.0	81.0
AE-3	70.8	43.1	26.9	5.2	BDL	BDL	4.8	0.8	35.3	73.4
AE-4	61.9	46.8	10.5	4.7	BDL	24.3	2.5	1.1	29.7	55.0
AW-1	58.3	37.1	11.8	2.3	BDL	22.4	2.3	0.7	12.4	32.8
AW-2	89.3	60.5	41.6	16.3	BDL	BDL	8.7	1.6	22.0	85.4
AW-3	90.6	72.4	32.1	14.4	BDL	26.8	10.4	2.7	57.7	56.5
AW-4	76.9	54.4	34.0	6.4	BDL	17.6	3.5	1.2	17.0	56.5
AN-1	72.7	68.9	29.5	13.5	BDL	16.2	2.8	2.3	29.8	55.0
AN-2	81.8	67.3	31.8	16.4	BDL	24.2	4.9	3.4	5.5	66.1
AN-3	81.1	62.2	25.4	11.2	BDL	BDL	4.5	1.8	26.4	69.5
AN-4	78.4	53.6	24.7	9.6	BDL	BDL	4.2	1.2	24.0	88.0
AS-1	47.9	35.2	6.7	3.1	BDL	16.6	2.2	0.9	16.3	32.8
AS-2	40.5	58.2	6.3	3.4	BDL	3.6	1.6	1.7	18.5	0.0
AS-3	71.6	36.3	11.4	3.4	BDL	7.3	2.6	0.6	46.2	66.1
AS-4	51.0	50.4	7.1	5.4	BDL	BDL	1.1	1.0	49.8	70.9
Standard Value	60		26		1.0		1.0		50	

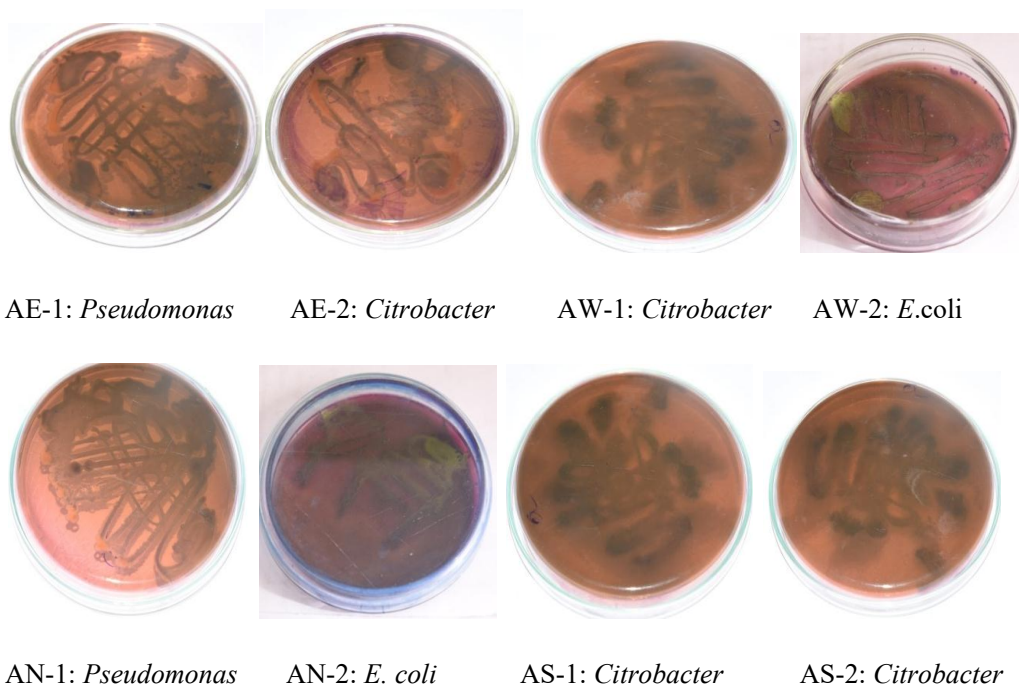


Fig. 2: Photographs of the identified microbial species.

Table 6: Correlation analysis.

	Pre Monsoon														
	Temp	pH	EC	TDS	Salinity	TH	TA	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	PO ₄ ³⁻	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
Temp	1														
pH	-0.314	1													
EC	0.341	-0.273	1												
TDS	0.341	-0.273	1	1											
Salinity	0.344	-0.277	1	1	1										
TH	0.285	-0.421	0.905	0.905	0.908	1									
TA	-0.361	0.256	0.373	0.373	0.367	0.282	1								
Cl ⁻	0.402	-0.306	0.991	0.992	0.993	0.906	0.269	1							
SO ₄ ²⁻	-0.04	-0.115	0.665	0.665	0.663	0.639	0.517	0.597	1						
NO ₃ ⁻	0.083	-0.158	-0.022	-0.021	-0.009	-0.075	-0.218	-0.012	0.148	1					
PO ₄ ³⁻	0.391	-0.386	0.468	0.468	0.474	0.684	0.037	0.49	0.286	-0.271	1				
Na ⁺	0.362	-0.138	0.875	0.876	0.875	0.712	0.214	0.88	0.573	0.026	0.255	1			
K ⁺	0.05	-0.459	-0.293	-0.292	-0.286	-0.179	-0.104	-0.295	0.023	0.433	-0.216	-0.197	1		
Ca ²⁺	0.307	-0.401	0.952	0.952	0.954	0.978	0.368	0.944	0.675	-0.02	0.63	0.763	-0.159	1	
Mg ²⁺	0.171	-0.385	0.603	0.602	0.603	0.850	0.004	0.623	0.417	-0.199	0.682	0.437	-0.193	0.723	1
	Post Monsoon														
	Temp	pH	EC	TDS	Salinity	TH	TA	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	PO ₄ ³⁻	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
Temp	1														
pH	-0.2	1													
EC	-0.23	0.675	1												
TDS	-0.231	0.674	1	1											
Salinity	-0.612	0.548	0.582	0.582	1										
TH	-0.431	-0.201	-0.07	-0.067	0.536	1									
TA	-0.16	0.349	0.405	0.404	0.544	0.4	1								
Cl ⁻	-0.536	0.057	-0.094	-0.094	0.737	0.803	0.357	1							
SO ₄ ²⁻	-0.05	-0.138	-0.015	-0.012	-0.086	0.085	-0.075	-0.18	1						
NO ₃ ⁻	-0.156	0.577	0.632	0.63	0.563	0.01	0.402	0.165	-0.034	1					
PO ₄ ³⁻	0.372	0.166	0.326	0.325	0.201	-0.094	-0.04	-0.003	-0.108	0.13	1				
Na ⁺	-0.606	0.314	0.36	0.36	0.939	0.775	0.53	0.883	-0.081	0.365	0.141	1			
K ⁺	-0.014	0.593	0.457	0.454	0.308	-0.237	0.208	-0.033	-0.061	0.874	0.073	0.084	1		
Ca ²⁺	-0.386	-0.097	0.106	0.105	0.443	0.701	0.513	0.506	0.14	-0.11	-0.11	0.603	-0.291	1	
Mg ²⁺	-0.418	-0.206	-0.09	-0.087	0.524	0.995	0.367	0.807	0.074	0.026	-0.088	0.763	-0.22	0.629	1

eters in Table 5. The details of MPN count and the identified bacterial species are presented in Table 7. The Photographs of the identified microbial species in waters are presented in Fig. 2.

The MPN count observed in waters is presented in Fig. 3. A health survey was carried out in the study area and the age details of the public and diseases experienced by them are summarized in Table 8.

The percentage of diseases experienced by the people in the study area is represented in Fig. 4.

Physicochemical characteristics: The analytical results of physicochemical parameters are presented in Tables 2, 3 and 4 along with the BIS standard values which reveal that the temperature during the collection of samples ranges from 28.9°C to 29.1°C and the pH of waters during pre-monsoon and post-monsoon seasons range from 7.60-8.83 and 6.93-8.92 respectively. The values indicate the slight alkaline nature of waters. Microorganisms depend on water for their growth depending on the water activity gradient. All microorganisms prefer pH 7 (neutral) for their optimum growth but they can grow more in acidic pH values. They

Table 7: Details of MPN count and identified *bacterial species* in waters.

Sample Code	MPN Index	No. of bacterial colonies on EMB	Bacterial colony Morphology on EMB	Gram's Nature	* (IMViC tests)				Bacteria Species
					I	MR	VP	C	
AE-1	02	02	Colourless	-ve	-	-	-	-	<i>Pseudomonas</i>
AE-2	31	02	Colourless	-ve	+	+	--	+	<i>Citrobacter freundii</i>
AW-1	22	01	Colourless	-ve	+	+	-	+	<i>Citrobacter freundii</i>
AW-2	02	01	Green Metallic Sheen	-ve	+	+	-	-	<i>E. coli</i>
AN-1	02	01	Colourless	-ve	-	-	-	-	<i>Pseudomonas</i>
AN-2	02	02	Green Metallicsheen	-ve	+	+	-	-	<i>E. coli</i>
AS-1	01	01	Colourless	-ve	+	+	-	+	<i>Citrobacter freundii</i>
AS-2	01	01	Colourless	-ve	+	+	-	+	<i>Citrobacter freundii</i>

*I = Indole, MR=Methyl red, VP=VogesProskauer, C=Citarte

Table 8: Details of people's age and disease experienced.

Age in Yrs	Diseases Experienced					Total
	Fever	Gastro Intestinal troubles	Joint pains	Typhoid	Skin Allergy	
1-10	12	0	1	0	5	18
11-20	0	0	0	0	1	1
21-30	2	3	3	0	1	9
31-40	3	5	1	1	5	15
41-50	2	6	1	0	1	10
51-60	0	1	0	0	2	3
Above 60	0	1	1	0	0	2
Total	19	16	7	1	15	58

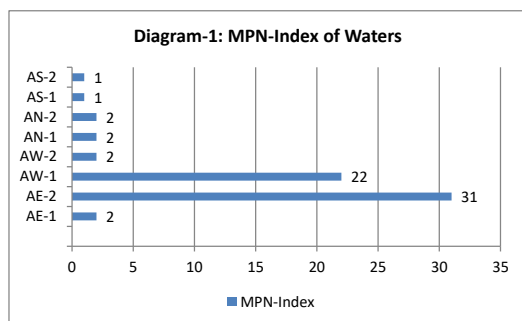


Fig. 3: MPN Index of waters.

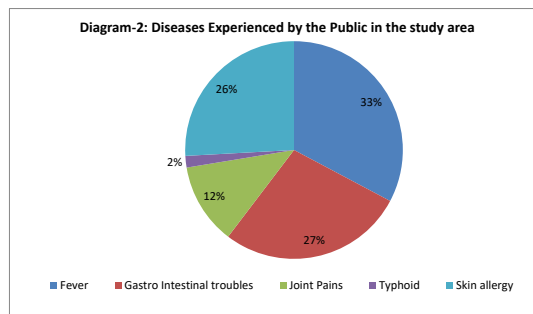


Fig. 4: Diseases experiences by the public in the study area.

stop their growth at pH 5.0 whereas some microorganisms can grow as low as 4.6-4.4 (pH 4.6 was considered to be the lower growth limit). The observed pH values of water samples are in the range of 6.93-8.92 in both seasons and are observed around pH 7 which is favorable for the growth of microorganisms in the waters of the study area (Meter Group n.d.). Higher EC values indicate the presence of salt content in the waters and it is revealed by the higher values of TDS and salinity. TDS values crossed the permissible limit in all parameters. Total hardness values in all samples in the study area exceeded the permissible limit. TA values during the pre-monsoon season are within the permissible limit while it crossed the permissible limit during post-monsoon in all samples. Chloride and sulfate ion concentration values during pre- and post-monsoon seasons crossed the permissible limit during pre- and post-monsoon seasons. Phosphate ion concentration values range from 0.11-3.86 mg.L⁻¹ and 0.14-4.73 mg.L⁻¹ during pre- and post-monsoon seasons respectively. Nitrate ion concentration values during pre- and post-monsoon seasons are within the permissible limit in the majority of samples collected near the aquaculture activity area. Calcium and magnesium values in the waters exceeded the permissible limit in the majority of the samples. Na levels during pre-monsoon range from 238-3738 mg.L⁻¹ and during post-monsoon range from 77.9-1962.2 mg.L⁻¹. K levels range from 16.5-605.0 mg.L⁻¹ during pre-monsoon season and it ranges from 6.4-293.9 mg.L⁻¹ during post-monsoon which reveals higher levels of salt content present in the waters collected near aquaculture activity areas.

Irrigation parameters: Irrigation parametric values are presented in the Table 5 along with the BIS standard values which reveal percent sodium values during pre-monsoon season exceeded in major locations while during the post-monsoon season these values are within the permissible limit in the majority of the sample which reveals the unsuitability of these waters in terms of %Na values for irrigation during the pre-monsoon season while these waters can be considered for irrigation in the majority of the sampling locations. SAR in most of the samples during pre- and post-monsoon seasons indicates the suitability for irrigation in terms of SAR values. RSC values during pre- and post-monsoon seasons in the study area are within the irrigation standards which confirm the suitability for irrigation. Kelly's ratio values during pre- and post-monsoon seasons exceeded the permissible limit for irrigation. Magnesium hazard values during pre-monsoon season in the majority of the samples are within the irrigation standards while in post-monsoon these values exceeded irrigation standard value.

Correlation analysis: During the pre-monsoon season, EC, TDS, salinity, chloride, TH, sodium, calcium, and magnesium values strongly correlated and influences the water

quality in the study area (Table 6). While in the post-monsoon season, EC, salinity, TH, chloride, TH, sodium, magnesium, and nitrate correlated strongly and majorly affects the water quality (Table 6).

MPN count: The water sample AE-1 was found with an MPN count of 2 and water sample AE-2 with MPN count 31. Water sample AW-1 is observed with MPN count 22 while the water sample AW-2 is with MPN count 2. Water sample AN-1 is found to contain MPN count 2 and the water sample AN-2 with MPN count 2. Water samples AS-1 and AS-2 are observed with MPN count 1 each. Except for the water samples AS-1 and AS-2, the remaining samples are observed with MPN count 2 and more than 2 which indicates microbial contamination of these water samples in the study area.

Bacterial species: The bacteria *Pseudomonas* generally tend to live and breed in water, soil, and damp areas. People with a weakened immune system are prone to severe infections like fever, skin rashes, joint pains, and ear infections. *C. freundii* is a species of facultative anaerobic gram-negative bacteria. Bacteria are often found in the water, soil, food, and intestines of humans and animals. The bacteria can cause several types of infections in bones, intestines, respiratory and urinary tracks. *E. coli* is a type of bacteria and normally exists in the intestines. Most types of *E. coli* are harmless and even help the digestive tract healthy. But some strains can cause diarrhea if contaminated water is consumed or by eating contaminated food. *E. coli* stains can also cause abdominal cramps, fever, and acute kidney failure.

The water sample AE-1 was found to have *bacterial species Pseudomonas* and the water sample AE-2 was found to have *C. freundii*. Water sample AW-1 was found to have *C. freundii* and the water sample AW-2 was found to have *E. coli*. Water sample AN-1 was found to have *Pseudomonas* while the water sample AN-2 was found to have *E. coli*. Water sample AS-1 was found to contain *C. freundii* while the water sample AS-2 was found to have *C. Freundii*. Due to the presence of pathogenic bacteria like *Pseudomonas*, *C. freundii*, and *E. coli* in the waters of the study area, health problems like fever, bone-related problems like joint pains, gastrointestinal troubles, and skin diseases can be caused.

Health survey: The health survey information (Table 8) revealed the details of the sufferings of people residing in the nearby areas of the aquacultural activity. People of different ages (from 1yr to 60 yrs) and the health problems viz., fever, gastrointestinal troubles, typhoid, and skin diseases experienced by them are correlated with the presence of the pathogenic species present in waters.

CONCLUSION

The parametric values of temperature and the pH of water

samples are in favor of pathogenic *bacterial* growth in waters of the study areas indicating the microbial contamination of waters. Physicochemical parametric values of the majority of the parameters confirm the chemical contamination of waters and indicate their unsuitability for drinking purposes. Irrigation parameters like %Na, SAR, Kelly's Ratio, and MH also reveals the unsuitability of these waters in the majority of the sampling locations. The study results revealed that health problems like fever, gastrointestinal troubles, bone-related health problems like joint pains, and skin diseases experienced by the people residing in the nearby areas of aquacultural areas are the actual contribution of *pathogenic bacteria* like *Pseudomonas*, *C. freundii*, and *E. coli* in waters. Disinfection and sterilization are to be done continuously every time to eliminate microbial contamination. Very sensitive and frequent monitoring of waters is suggested and a wide range of biosensor systems are to be developed for usage from time to time to assess the quality of waters to protect the health of the people if these waters are proposed for consumption or drinking.

ACKNOWLEDGEMENT

The authors express their sincere thanks and gratitude to the authorities of Pragati Engineering College (A), Surampalem, A. P India for their support in carrying out the analysis in R&D laboratories. The authors also convey their thanks to the faculty, Department of Microbiology, Y.N.College (A), Narasapuram for their cooperation in microbial analysis.

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