International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 525-529

Received: 10-05-2019
Accepted: 12-06-2019

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Effect of aquaculture on ground water quality in Guntur district of Andhra Pradesh, India

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Abstract
Ground water quality was assessed during 2018-19 (pre and post-monsoon) in three different mandals namely Karlapalem, Nizampatnam and Repalle of Guntur district of Andhra Pradesh. For estimating status of water quality of mandals under study, the parameters studied were pH, electrical conductivity, calcium, magnesium, potassium, sodium, carbonates, bicarbonates, chlorides, sulphates, RSC, SAR, biochemical oxygen demand and chemical oxygen demand. The results obtained were compared with water quality standards *viz.,* Indian Standard of drinking water and WHO drinking water standards which indicated that ground water in some samples were unsuitable for domestic purpose. The present investigation revealed that some ground water samples were contaminated due to aquaculture activities as indicated by presence of very high dissolved salts, high biochemical oxygen demand and chemical oxygen demand in the vicinity of the aqua ponds and low in check area.

Keywords: Ground water quality, water quality standards and aquaculture

1. Introduction
China is leading in aquaculture production throughout the World followed by India with an annual fish production of about 9.06 million metric tonnes. About 16 million people are directly or indirectly dependent on this sector (DoF, 2014) [7]. There are 11.1 million hectares of aquaculture ponds globally. Aquaculture ponds cover an area of 0.79 million hectares in India. Andhra Pradesh has a coast line of 970 km with vast scope for production of fish, prawn and other sea products. It also has 181 aqua clusters covering 1.27 lakh hectares area.

Andhra Pradesh ranks first in total fish and shrimp production and contributes more than 70% of cultured shrimp produced in India according to Socio Economic Survey 2017-18 conducted by Planning Department, Government of Andhra Pradesh. The total fish production during 2017-18 was estimated to be 12.60 million metric tonnes and constitutes about 6.3% of the global fish production and around 0.91% to India’s Gross Domestic Product (GDP) according to National Fisheries Development Board of Government of India. The State Government has prepared plans to make Andhra Pradesh a World ‘aqua hub’ by increasing fish production from 25 lakh tonnes from February 2017 to 42 lakh tonnes with Added Gross Value of Rs. 80,000 crore by 2019-20. Aquaculture creates jobs in community thereby increasing revenue in city, state and national level thereby alleviating poverty. It is one of the sectors that encourage local investment as it does not require too much capital to start. Even though aquaculture seems to be a growing sector, it pollutes water systems with excess nutrients from fish feed and wastes, chemicals and antibiotics. Seepage of saline water from the ponds into the surrounding areas leads to salinization of ground waters and disease outbreak. Seepage and discharges from aqua ponds can degrade the quality of water available to downstream users affecting drinking water, agriculture and recreational uses of water bodies (EGSSA, 2009) [9]. Aquaculture facilities have been used in conjunction with animal feed lots to utilize manure and other organic wastes as fertilizer for aquaculture ponds that may add to eutrophication of surface waters and ground water contamination (Pillay, 1992) [23]. The eutrophication of water column is mainly caused by non-consumed feed (Focardi, 2005 and Crab *et al.,* 2007) [11, 6], decomposition of dead organisms, and over fertilization (Gyllenhammar and Håkanson, 2005) [14]. Only 20 to 50% of the total nitrogen supplemented to the cultured organisms was retained as biomass while the rest was incorporated into the water column (Jackson *et al.,* 2003 and Schneider *et al.,* 2005) [16, 28].

Material and methods

The water samples were collected from three mandals viz., Karlapalem, Nizampatnam and Repalle. A total number of 120 water samples were collected with 60 samples during pre-monsoon and 60 samples post-monsoon season and were analysed for various parameters. Plastic bottles of 1 litre capacity were used for collecting samples. Each bottle was washed and rinsed three times with sample water. The bottles were filled leaving no air space and then sealed to prevent any leakage. Each bottle was clearly marked with the name, location, and date of sampling. The chemical analysis was done using the standard methods. pH and electrical conductivity were determined following method of Jackson (1973) [17]. Calcium, magnesium, potassium and sodium were determined as suggested by Tandon (1998) [33]. Carbonates and bicarbonates were determined following method of Richards (1954) [27] and chlorides by Tandon (2005) [34] whereas sulphates were determined following method suggested by APHA (1985). RSC was computed using Eaton (1950) [8] equation.

$$RSC = [CO_3^{2-} + HCO_3^{-}] - [Ca^{2+} + Mg^{2+}]$$

SAR was computed using Ayers and Wescot (1976) [2] equation.

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

Biochemical oxygen demand was determined as suggested by EPA (2006) [10] whereas chemical oxygen demand as suggested by Gupta (2004) [13].

Results and discussion

The results of all the parameters studied in 3 mandals have been demonstrated in Table 1 & 2.

During the pre-monsoon season in Karlapalem, Nizampatnam and Repalle the pH values ranged from 7.92 to 8.87, 7.81 to 8.74 and 7.83 to 8.67 respectively whilst in post-monsoon it ranged from 7.23 to 8.36, 7.25 to 8.06 and 7.31 to 8.09 only. The highest pH (8.87) was recorded in Karlapalem. The results of the present investigation tally with the results of Siraj *et al*. (2016) [31]. Ramesh *et al*. (2008) [26] found that the pH of well water ranged from 7.1 to 8.6 and 7.3 to 9.2 in the first and second year of study in Nellore district of Andhra Pradesh, India respectively indicating that some well waters did not fall within the prescribed limits of BIS drinking water standards. The pH range observed indicated the alkaline nature of the ground water.

During pre-monsoon season, the highest electrical conductivity was recorded in Karlapalem (18.33 dS m-1) followed by Repalle (13.36 dS m-1) and Nizampatnam (4.44 dS m-1) whereas during post-monsoon the highest electrical conductivity was recorded in Repalle (13.70 dS m-1) followed by Karlapalem (8.88 dS m-1) and Nizampatnam (4.36 dS m-1). The water samples from 3 mandals were saline in nature and were far beyond the threshold limits for human consumption (250 µS cm-1) as per WHO. This corroborates with the findings of Mishra *et al*. (2014) and Bhadja & Kundu (2012) [20, 3]. The relatively high electrical conductivity values recorded in the culture ponds might imply that the applied agrochemicals, food additives and shrimp excreta were the major sources of ionic substances in the water column of the culture system (Hassan *et al*., 2015) [15].

The results of calcium content in 3 mandals studied in pre-monsoon ranged from 2.97 to 46.69 me L-1, 2.76 to 9.47 me L-1 and 4.75 to 31.48 me L-1 in Karlapalem, Nizampatnam and Repalle respectively whereas in post-monsoon it ranged from 2.77 to 20.35 me L-1, 2.92 to 8.90 me L-1 and 3.39 to 35.15 me L-1 in Karlapalem, Nizampatnam and Repalle respectively. The results of magnesium content in 3 mandals studied in pre-monsoon ranged from 1.92 to 29.37 me L-1, 1.99 to 6.72 me L-1 and 2.56 to 18.44 me L-1 in Karlapalem, Nizampatnam and Repalle respectively whereas in post-monsoon it ranged from 1.76 to 14.76 me L-1, 1.08 to 5.68 me L-1 and 1.26 to 23.64 me L-1 in Karlapalem, Nizampatnam and Repalle respectively. Calcium and magnesium content were too high compared to international threshold limits for human consumption (300 mg L-1) and (< 0.01 mg L-1) respectively. Singh *et al*. (2015) [30] recorded highest calcium (27.2 me L-1) and magnesium (30.9 me L-1) respectively in Dhanti-Umbharat Research Station, Navsari, India which did not differ much with the results of the present investigation.

Results of sodium and potassium in 3 mandals studied in both seasons ranged from (5.43 to 96.34 me L-1) and (0.95 to 18.33 me L-1) respectively. The results of sodium and potassium obtained in the present investigation coincide with the results of Penmetsa *et al*. (2013) [22] who recorded (1.43 to 50.35 me L-1) and (0.08 to 12.38 me L-1) respectively in East Godavari District of Andhra Pradesh, India respectively. Sodium content was too higher than threshold limits for human consumption (180 to 200 mg L-1) as recommended by WHO. High potassium values in water were due to contamination from nutrient-enriched return irrigation and aqua flows (Penmetsa *et al*., 2013) [22]. High content of these two cations might have come as a result of saltwater intrusion since the study areas are located on the coast line.

Carbonates were not detected in the ground water samples in all three mandals studied in both seasons. The results of bicarbonates in 3 mandals studied in both seasons ranged from 4.36 to 73.32 me L-1. The carbonates content in ground water samples were nil and corroborates with the results of Singh *et al*. (2015) [30] and Bobade (2018) [4]. Bicarbonates are usually thought to enter the ground water system as a result of the uptake of CO2 either from soil zone gases or direct atmospheric inputs (Langmuir, 1971) [19]. Therefore, carbon dioxide from polluted aquaculture effluent may find its way into ground water through seepage thereby increasing its bicarbonates content.

Chlorides estimated during study in 3 mandals in both seasons ranged from 4.88 to 89.14 me L-1. The results of the present investigation did not follow the threshold limits for human consumption (200 to 250 mg L-1). These results of present investigation tally with the results of Ramesh *et al*. (2008) [26], Penmetsa *et al*. (2013) [22] and Rama *et al*. (2013) [24] who recorded (1.8 to 139.83 me L-1), (2.2 to 330.45 me L-1) and (0.60 to 140.20 me L-1) respectively. Ramesh (2001) [25] revealed that chlorides in ground water samples of the Cauvery Delta region exceeded 1000 mg L-1 approximately (28.25 me L-1) during pre-monsoon and monsoon season indicating seawater intrusion. This might have been due to aqua ponds surrounding villages of that area and because they are along the coast line. The results of the present investigation reflect that aquaculture is indeed a potential cause of ground water pollution.

Sulphates estimated in ground water samples of 3 mandals in both seasons during the study period ranged from 0.99 to 20.60 me L-1. The sulphate values revealed that some ground water samples did not tally with the permissible limits of WHO (1993) [37] (250 to 500 mg L-1). This was an indication that there was potential danger of ground water pollution in 3 mandals studied. Janardhana *et al*. (2013) [18] reported that sulphates may come into ground water by industrial or anthropogenic additions in the form of sulphate fertilizers. The results of the present investigation fall within the range of findings of Rama *et al*. (2013) [24] and Penmetsa *et al*. (2013) [22] who recorded (0.00 to 33.60 me L-1) and (0.00 to 29.83 me L-1) respectively.

The results of residual sodium carbonate and sodium adsorption ratio in 3 mandals studied in both seasons ranged from (-3.99 to 9.59) and (3.74 to 16.77) respectively. Verma *et al*. (2017) [36] reported that the residual sodium carbonate values ranged from -21.27 to 39.3 in shallow tube well of West Bengal which tally with the results of the present investigation. Eaton (1950) [8] categorised water with sodium adsorption ratio value <1.25 as suitable for irrigation. Most of the samples studied were unsuitable for irrigation. Todd (1980) [35] classified irrigation waters with sodium adsorption ratio values <10 as excellent. Most of the water samples from all three mandals were not suitable for irrigation. A high sodium adsorption ratio value implies a hazard of sodium (alkali) replacing calcium and magnesium in the soil through a cation exchange process that damages soil structure, mainly permeability, and which ultimately affects the fertility status of the soil and reduces crop yield (Gupta, 2005) [12].

Table 1: Physico-chemical and chemical properties of ground water samples collected around aqua ponds during pre-monsoon season

Parameters	Mandals/locations								
	Karlapalem			Nizampatnam			Repalle		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
pH	7.92	8.87	8.28	7.81	8.74	8.17	7.83	8.67	8.17
EC (dS m^{-1})	1.90	18.33	7.14	1.62	4.44	2.86	2.25	13.36	7.21
Ca (me L^{-1})	2.97	46.69	16.23	2.76	9.47	5.11	4.75	31.48	16.20
Mg (me L^{-1})	1.92	29.37	9.9	1.99	6.72	3.57	2.56	18.44	9.83
K (me L^{-1})	0.95	18.33	7.19	1.62	6.40	3.31	2.34	13.36	7.31
Na (me L^{-1})	10.56	96.34	41.05	7.67	29.56	17.47	13.65	79.97	41.38
CO_3 (me L^{-1})	ND	ND	ND	ND	ND	ND	ND	ND	ND
HCO_3 (me L^{-1})	5.80	73.32	28.66	6.48	19.56	11.49	8.40	53.44	28.88
Cl (me L^{-1})	8.42	89.14	34.19	5.93	23.19	13.35	10.74	60.08	33.64
SO_4 (me L^{-1})	3.40	14.20	8.14	2.89	11.40	6.58	5.80	20.60	11.15
RSC	-2.52	9.59	2.31	-1.09	8.36	2.81	0.43	6.25	2.85
SAR	5.80	16.10	11.04	4.98	13.71	8.20	6.89	16.77	11.24
BOD (mg L^{-1})	3.00	9.80	714	2.20	9.20	6.53	3.40	9.98	7.08
COD(mg L^{-1})	16.00	58.00	36.30	14.00	46.00	26.85	19.00	73.00	40.30

ND=Not detected

Biochemical oxygen demand value recorded at different distances in 3 mandals in both seasons ranged from 1.80 to 9.98 mg L-1. According to WHO (1993) [37], the permissible limit of biochemical oxygen demand in drinking water was 5 mg L-1. However, in all three mandals, not all samples were within the permissible limits, hence, some samples reflected ground water contamination. The present findings are in agreement with the findings of Penmetsa *et al*. (2013) [22]. Cao *et al*. (2007) [5] reported that the urine and faeces from the aquatic animals can cause increase of biochemical oxygen demand. Penmetsa *et al*. (2013) [22] stated that in most cases the biochemical oxygen demand values were higher than the permissible limit due to high organic load in the water. Senarath and Visvanathan (2001) [29] explained that older shrimp needs more feed and produce more waste than younger shrimp, hence, increase in levels of biochemical oxygen demand.

Chemical oxygen demand values recorded in 3 mandals in both seasons ranged from 14.00 to 73.00 mg L-1. According to WHO (1993) [37], some ground waters under study were not suitable for human consumption. Samples with high chemical oxygen demand than the permissible limits indicated the contamination of ground water. The results of the present investigation do not differ much with the results of Penmetsa *et al*. (2013) [22] who recorded maximum chemical oxygen demand of 64.00 mg L-1 in East Godavari District of Andhra Pradesh, India. Senarath and Visvanathan (2001) [29] explained that older shrimp need more feed and produce more waste than younger shrimp hence increase in levels of chemical oxygen demand.

Table 2: Physico-chemical and chemical properties of ground water samples collected around aqua ponds during post-monsoon season

Parameters	Mandals/locations								
	Karlapalem			Nizampatnam			Repalle		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
pH	7.23	8.36	7.85	7.25	8.06	7.46	7.31	8.09	7.78
EC (dS m^{-1})	1.38	8.88	4.27	1.37	4.36	2.47	2.09	13.70	6.09
Ca (me L^{-1})	2.77	20.35	9.07	2.92	8.90	4.86	3.39	35.15	14.31
Mg (me L^{-1})	1.76	14.76	6.08	1.08	5.68	2.94	1.26	23.64	9.22
K (me L^{-1})	1.38	9.59	4.50	1.37	5.05	2.52	2.09	13.70	6.13
Na (me L^{-1})	8.55	47.35	23.98	5.43	27.63	15.21	10.65	68.48	33.05
CO_3 (me L^{-1})	ND	ND	ND	ND	ND	ND	ND	ND	ND
HCO_3 (me L^{-1})	5.52	35.52	16.80	4.36	17.44	9.68	7.44	54.80	24.38
Cl (me L^{-1})	6.93	41.23	19.06	4.88	21.11	11.45	8.55	63.64	28.30
SO_4 (me L^{-1})	1.10	10.10	4.81	0.99	6.20	3.47	3.00	17.90	8.26
RSC	-1.90	3.60	1.66	-0.96	4.18	1.89	-3.99	4.87	0.85

SAR	4.97	11.70	8.69	3.74	10.52	7.20	5.41	12.63	9.58
BOD (mg L^{-1})	2.40	9.00	5.38	1.80	8.30	5.40	2.20	8.90	5.37
COD(mg L^{-1})	16.00	64.00	34.06	14.00	44.00	24.05	15.00	68.00	34.95

ND=Not detected

Conclusion

The pH and EC decreased with increase in distance in all mandals. All the cations viz., Na, Ca, Mg and K and the anions viz., Cl, HCO3, CO3 and SO4 in water samples have shown to decrease with increase in distance. Cations were recorded in the order Na>Ca>Mg>K whilst anions were in the order Cl>HCO3>SO4 with CO3 being absent in all mandals in both seasons. The highest BOD was recorded at the immediate vicinity of the ponds in both seasons. The BOD and COD decreased with increase in distance. Both BOD and COD exceeded their permissible levels for drinking water which was a sign of pollution load in all waters from the three mandals studied. The results on RSC and SAR indicated that most samples from all mandals studied were not suitable for irrigation. Aquaculture is one among the fastest growing food sectors in the world especially in India since it ranks second in the World in total fish production. Aquaculture has been shown to have a potential to meeting domestic needs, fight against unemployment and increasing country's economy. However, aquaculture has been proven to have long time effects on ground water quality. It is therefore recommended that the aqua ponds must be cemented or covered with plastic to avoid seepage. The waste water from the ponds must be treated before they can be used for other purposes like irrigation.

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