Physico-chemical properties of soils around aqua ponds in Guntur district of Andhra Pradesh, India

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Abstract

Physico-chemical properties of soil around aqua ponds were studied during 2018-19 (pre and post-monsoon) to assess the extent of soil pollution due to aquaculture in three different mandals namely Karlapalem, Nizampatnam and Repalle of Guntur district of Andhra Pradesh. For estimating status of soils of mandals under study, the parameters studied were pH, electrical conductivity, CEC, exchangeable sodium percentage, organic carbon, available nitrogen, available phosphorus available potassium, available sulphur, calcium, magnesium, micronutrients (Zn, Mn, Fe, Cu) and heavy metals (Cr, Pb, Cd). The present investigation revealed that all soil samples collected in three mandals studied did not show any sign of soil pollution except soil salinization and excess sodium.

Keywords: Soil pollution, physico-chemical properties and aquaculture

Introduction

Aquaculture deals with the interaction of soil, water and biota. It is one among the fastest growing food sectors in the World contributing to nearly 50% of the total fish per capita consumption. 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). 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.

Rapid growth of shrimp and prawn farming in India lead to short and long-term negative environmental impacts which were causing increased soil salinity, land degradation and sedimentation. Salinization of soil in nearby agricultural land is one of the major environmental issues in aquaculture areas (Jayanthi *et al.*, 2004). The shrimp farming, delivers high volume of organic and inorganic effluents and toxic chemicals to the ecosystem resulting in high soil toxicity (Flaherty *et al.*, 1999). Aquaculture farms were sometimes abandoned and the soil from those former farms remained hypersaline/acidic and eroded (Rodr´ıguez-Valencia *et al.*, 2010). The application of lime and other chemicals used in aquaculture to treat the soil can also modify its physico-chemical characteristics (Martínez-Córdova *et al.*, 2009). Rice farms are the favoured sites for conversion into aqua ponds because they pose several characteristics well suited for aquaculture (Siddique *et al.*, 2012). Transformation of rice fields into shrimp farms has changed the land use or land coverage of the densely populated coastal areas in tropical Asia and Latin America (Flaherty *et al.*, 1999).

Material and methods

The soil samples were collected from three mandals *viz.*, Karlapalem, Nizampatnam and Repalle. A total number of 120 soil samples were collected at the rate of 60 samples during pre-monsoon and 60 samples post-monsoon season and were processed for analysis. The samples were collected following the procedure given by Jackson (1973). 'V' shaped pit was made to a depth of 15 cm and the 4 sub samples were collected at random in a zig zag manner on the farmers field. All sub samples representing farmer's field area were pooled and mixed together and reduced to one kg by following quaternary technique. The samples thus collected were shade dried, powdered and grounded with a wooden hammer and passed through a 2 mm sieve. Finally, the samples were transferred to air tight polythene bags and were labelled with information like sample number, place and depth of sampling, GPS coordinates etc. Soil samples were analysed for various parameters like pH, Electrical Conductivity, CEC, Organic Carbon, Available Nitrogen, Available Phosphorous, Available Potassium, Available Sulphur, Calcium, Magnesium, Micronutrients (Fe, Mn, Zn and Cu) and Heavy Metals (Cr, Pb and Cd). Exchangeable Sodium Percentage values were computed. pH, EC, Available potassium and Available calcium and magnesium were determined following method given by Jackson (1973). CEC was determined by Bower`s method as described by Jackson (1967). Organic Carbon was estimated by the wet digestion method (Walkely and Black, 1934). Available nitrogen was determined by alkaline potassium permanganate method as developed by Subbiah and Asija (1956) using Kelplus automatic digestion and distillation unit. Available phosphorus was extracted from soil by using Olsen's extractant (0.5N sodium bicarbonate with pH 8.5). The phosphorus content in the extract was determined by ascorbic acid method (Watanabe and Olsen., 1965). The available sulphur was extracted by calcium chloride dihydrate as suggested by Williams and Steinbergs (1959). The Available micronutrients *viz.*, Fe, Mn, Zn and Cu in soil samples were extracted with DTPA extractant solution of pH 7.3 (Lindsay and Norwell, 1978), whereas, the content of DTPA extractable heavy metals *viz.*, cadmium, chromium and lead in soil were estimated using 1:2 soil extract ratio using Atomic Absorption Spectrophotometer.

Exchangeable sodium percentage was computed by analyzing exchangeable Na^+ and CEC as proposed by Rashidi and Seilsepour (2008).

$$\text{ESP } (\%) = \frac{\text{Na}^+}{\text{CEC}} \times 100$$

Results and discussion

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

Among 3 mandals studied, the highest mean pH values were recorded in Karlapalem, followed by Repalle and Nizampatnam. The minimum and maximum pH recorded in 3 mandals studied was 6.80 in Nizampatnam and 9.04 in Karlapalem respectively. The pH of 3 mandals ranked from neutral (6.5 to 7.5) to strongly alkaline (8.5 to 10.0). The results of the present investigation agree with the findings of Mahajan and Billore (2014) who recorded maximum pH of 8.92 in Nagchoon pond, Khandwa, MP, India. Similarly, Shaikh (1996) reported the high pH of 9.1 at Bilawali Tank, Indore. There was a decrease in pH in post-monsoon season from all 3 mandals under investigation.

The highest electrical conductivity was recorded in Repalle followed by Nizampatnam and Karlapalem respectively. The electrical conductivity values recorded in soils from 3 mandals studied ranged from 0.08 to 13.77 dSm^{-1}. Therefore, the electrical conductivity ranked from low salinity (< 0.25 dSm^{-1}) to very high salinity (> 2.25 dSm^{-1}). The electrical conductivity value of soil samples collected from Repalle (1.14 to 13.77 dSm^{-1}) indicated that they were extremely saline in nature, whereas electrical conductivity of soils from Karlapalem (0.21 to 2.16 dSm^{-1}) and Nizampatnam (0.08 to 2.03 dSm^{-1}) were low to moderate. The results of the present investigation agree with the results of Singh *et al.* (2015), Joseph *et al.* (2003) and Das (1971). Venkaiah (1999) elucidated that the variation in the spread of salts may be attributed to the EC of the pond water, slope of the soil, nature of the sub soil and the management practices around the aqua ponds. He also stated that low spread of salts might be due to presence of deep drainage channel by the side of the pond which prevents the spread of salts. Satyanarayana *et al.* (1990) and Narasimha Rao & Narasimha Rao (1987) reported salt accumulation around fish ponds in Guntur district of Andhra Pradesh. The discharge of salt water from shrimp farms caused salinization in adjoining rice and other agricultural lands (Primavera, 2006 and Briggs, 1993). Raghuram *et al.* (2015) reported that seepage is very high in sandy soil and moves to more distance which causes high content of salt deposition when compared to clay soils.

The minimum and maximum CEC in soils from 3 mandals studied was recorded from Repalle mandal only *i.e.*, 25.02 and 61.72 meq l^{-1} respectively. High CEC was recorded in Repalle (61.72 meq l^{-1}) followed by Karlapalem (55.84 meq l^{-1}) and Nizampatnam (54.76 meq l^{-1}). Similar to the present results, Singh *et al.* (2015) recorded high CEC value (67.15 and 79.19 meq l^{-1}) in the soils adjacent to aqua ponds at Dhanti-Umbharat Research Station, Navsari, India. Soils with high clay content usually have high CEC (Munsiri *et al.*, 1995 and Brady and Weil, 1999).

Exchangeable sodium percentage values in 3 mandals studied were high in Repalle soils followed by Karlapalem and Nizampatnam. The exchangeable sodium percentage in soils collected from 3 mandals decreased in post-monsoon season. The minimum and maximum exchangeable sodium percentage in soils from 3 mandals studied was recorded from Repalle mandal only *i.e.*, 11.64 to 55.37% respectively. Therefore, the exchangeable sodium percentage of 3 mandals ranked between none to slight sodic (<

15%) and high to very high sodic (50 to 70%) according to FAO. The results of the present investigation coincide with the result of Singh *et al.* (2015) who recorded maximum exchangeable sodium percentage of 54.52% at Dhanti-Umbharat Research Station, Navsari, India.

Among 3 mandals studied, the highest organic carbon was recorded in Karlapalem followed by Repalle and Nizampatnam. The minimum and maximum values of organic carbon content of 3 mandals studied was recorded in Nizampatnam only i.e., 0.26 and 0.77% (low to high), organic carbon content of soils of Karlapalem ranged from 0.31 to 0.75% (low to medium), whereas, those of Repalle ranged from 0.35 to 0.74% (low to medium).

The results of the present investigation fall within the range of the results of Krishnani *et al.* (2011) who recorded organic carbon ranging from 0.22 to 3.74% in shrimp fields of Kerala and they also fall within the range of results recorded by Rama *et al.* (2013) which ranged from 0.15 to 1.05%. Banerjea (1967) reported that soil with less than 0.5% organic carbon was low productive, 0.5 to 1.2% average productive, 1.5 to 2.5% high productive and greater than 2.5% as less productive. Therefore, the results of the present investigation indicated that the soils from 3 mandals studied were low to less productive. Prihutomo *et al.* (2016) stated that the low values of organic carbon might have occurred as a result of exploitation of soil resources for aquaculture activities for many years.

The highest available nitrogen was recorded in Karlapalem followed by Nizampatnam and Repalle. The minimum and maximum available nitrogen content in soils from 3 mandals studied was recorded in Nizampatnam (100 kg ha^{-1}) and Karlapalem (226 kg ha^{-1}) respectively. The available nitrogen content in soils adjacent to ponds in 3 mandals ranked low (< 280 kg ha^{-1}) because it ranged between 100 to 226 kg ha^{-1}. The results of the present investigation agree with the results of Singh *et al.* (2015) who recorded available nitrogen of 234 and 248 kg ha^{-1} from two different locations at Dhanti-Umbharat Research Station, Navsari, India.

Among 3 mandals studied, the highest available phosphorus was recorded in Karlapalem followed by Nizampatnam and Repalle. The minimum and maximum available phosphorus content in soils from 3 mandals studied was recorded in Repalle (5.3 kg ha^{-1}) and Karlapalem (48.0 kg ha^{-1}) respectively. Available phosphorus content in soils from 3 mandals ranked between low (< 25 kg ha^{-1}) and medium (25 to 59 kg ha^{-1}). Singh *et al.* (2015) recorded 26.10 kg ha^{-1} in soils collected at the vicinity of the aqua ponds at Dhanti-Umbharat Research Station, Navsari, India. Similarly, Rama *et al.* (2013) recorded available phosphorus content between 34.59 and 51.89 kg ha^{-1} in East and West Godavari Districts of Andhra Pradesh and their results do not differ much with the present results.

The highest available potassium was recorded in Repalle followed by Karlapalem and Nizampatnam. Available potassium in soils of Nizampatnam and Karlapalem showed a decrease in post-monsoon season, whereas in Repalle there was an increase. The minimum and maximum available potassium content in soils from 3 mandals studied was recorded in Nizampatnam (20 kg ha^{-1}) and Repalle (126 kg ha^{-1}) respectively. Available potassium content in soils of 3 mandals studied indicated that they are low (< 145 kg ha^{-1}) with respect to available potassium. The results of the present investigation corroborates with the results of Choubey (1991) who recorded the available potassium ranging from 160 to 171 kg ha^{-1} in Gandhisagar reservoir. Venkaiah (1999) stated that the increase of available nitrogen was due to increase in organic matter and due to application of fertilizers to the crops which were not utilised to their full extent by crops due to higher soluble salt content. Venkaiah also stated that increased available phosphorus and potassium might be due to contamination of soils with effluents from ponds which contain considerable amount of phosphorus and potassium. Narasimha Rao and Narasimha Rao (1987) recorded increased soil phosphorus and potassium in the immediate vicinity of the fish ponds. The presence of nitrogen, phosphorus and potassium in the vicinity of the aqua ponds maybe due to the fertilisers and processed feed applied in the ponds which have a way of being deposited in such soils through seepage.

Among 3 mandals under investigation, the highest available sulphur was recorded in Repalle followed by Karlapalem and Nizampatnam. The available sulphur content in soils of 3 mandals ranged from 2.1 ppm (Nizampatnam) to 19.5 ppm (Repalle). Among the three mandals, only Repalle soil was sufficient in available sulphur, whereas, soils of Karlapalem and Nizampatnam were deficient. Mahajan and Billore (2014) recorded sulphates ranging from 5.34 to 13.56 ppm at Nagchoon pond and their results do not differ much with those of the present investigation. Janardhana Rao *et al.* (2013) reported that sulphates may come into soil by industrial or anthropogenic additions in the form of sulphate fertilizers.

Among 3 mandals under study, the highest available calcium was recorded in Repalle followed by Karlapalem and Nizampatnam. Available calcium content of the soil in 3 mandals ranged between 7.00 and 66.70 meq l^{-1}. Therefore, available calcium content in soils of 3 mandals under study was grouped under low category (< 145 meq l^{-1}). The highest calcium content of the present investigation recorded lies within the results obtained by Claude (2000).

Table 1: Physico-chemical properties of soil 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	7.63	9.04	8.26	7.1	8.38	7.96	7.39	8.23	7.92
EC (dSm^{-1})	0.33	2.16	0.68	0.11	2.03	0.95	114	13.77	6.97
CEC (meq l^{-1})	29.70	55.84	41.67	30.74	54.76	43.11	28.67	61.04	46.17
ESP (%)	13.51	47.48	28.20	14.81	54.12	24.98	16.63	54.19	30.64
OC (%)	0.39	0.75	0.55	0.30	0.62	0.48	0.35	0.74	0.50
N (kg ha^{-1})	110	226	142	100	214	131	100	163	115
P_2O_5 (kg ha^{-1})	10.7	48.0	20.5	9.0	35.7	18.6	9.0	27.1	14.3
K_2O (kg ha^{-1})	74	118	96	26	98	67	90	117	104
SO_4-S (ppm)	1.8	10.5	4.5	1.9	7.8	3.7	10.6	19.5	15.5
Ca (meq l^{-1})	29.00	55.20	38.37	18.00	39.40	29.85	13.80	37.20	20.71
Mg (meq l^{-1})	14.50	58.30	33.96	4.70	63.60	34.38	32.40	76.70	48.95
Zn (ppm)	0.43	1.92	1.05	0.43	1.79	0.98	0.42	2.01	1.26
Mn (ppm)	0.98	3.75	1.86	0.62	4.70	1.90	0.78	3.87	2.24
Fe (ppm)	4.92	17.54	9.69	4.61	14.77	8.93	6.12	19.98	12.65
Cu (ppm)	2.03	11.46	7.45	3.78	15.53	10.44	1.92	11.10	7.41
Cr (ppm)	0.021	0.147	0.070	0.036	0.131	0.076	0.040	0.219	0.114
Pb (ppm)	0.019	0.120	0.066	0.020	0.127	0.065	0.032	0.270	0.081
Cd (ppm)	0.001	0.008	0.005	0.002	0.020	0.010	0.009	0.132	0.059

Among 3 mandals under study, the highest available magnesium content was recorded in Repalle followed by Karlapalem and Nizampatnam. A minimum of 4.70 meq l^{-1} in Nizampatnam and maximum of 76.70 meq l^{-1} in Repalle of available magnesium content was recorded in 3 mandals under study. The highest magnesium content of the present investigation recorded lies within the results obtained by Claude (2000) (34.07 to 784.44 meq l^{-1}).

The results of zinc, manganese, iron and copper in 3 mandals studied ranged from 0.37 to 2.01 ppm, 0.78 to 4.70 ppm, 4.04 to 19.98 ppm and 0.98 to 15.53 ppm respectively. Rama *et al.* (2013) recorded 11.3 ppm of copper at Prathellameraka in West Godavari District, Andhra Pradesh which does not differ much with the present results. Gul *et al.* (2015) recorded manganese concentration of 4.794 ppm in pond soil of Sibi district, Pakistan which coincides with the present findings. Zinc results of the present investigation lie within the results obtained by Claude (2000) (0.0 and 24.5 ppm) and also copper results fall within the range of Claude findings (0.0 and 36.8 ppm). Rama *et al.* (2013) and Omofunmi *et al.* (2016) recorded as high as 55.56 and 55.7 ppm of iron respectively. Venkaiah (1999) reported that higher concentration of micronutrients in soil might be due to presence of higher organic carbon content in the vicinity of the ponds. Munsiri *et al.* (1995) stated that feed added to the ponds might contribute to increase in concentration of copper and zinc in sediment. They further reported that higher iron concentration may have resulted from conversion of ferrous iron to ferric iron when water seeped into a zone of higher redox potential in the T horizon.

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	7.16	9.01	8.08	6.80	816	7.57	7.51	8.48	8.05
EC (dSm^{-1})	0.21	1.03	0.55	0.08	0.86	0.26	2.98	10.54	6.17
CEC (meq l^{-1})	26.19	47.47	38.07	26.19	49.38	37.44	25.02	60.72	40.67
ESP (%)	12.70	54.69	26.88	12.72	39.67	22.71	11.64	55.37	47.83
OC (%)	0.31	0.70	0.51	0.26	0.77	0.50	0.44	0.64	0.55
N (kg ha^{-1})	100	195	132	100	151	116	100	138	114
P_2O_5 (kg ha^{-1})	6.9	29.5	14.6	12.3	25.4	17.5	5.3	26.3	14.4
K_2O (kg ha^{-1})	39	110	71	20	67	50	99	126	117
SO_4-S (ppm)	2.8	9.8	5.8	4.9	10.6	7.2	5.6	18.3	11.5
Ca (meq l^{-1})	29.70	66.70	52.42	7.00	52.70	35.99	12.90	32.70	24.55
Mg (meq l^{-1})	11.80	23.60	17.53	10.10	23.30	14.16	5.30	42.90	22.95
Zn (ppm)	0.39	1.73	1.04	0.49	1.91	1.00	0.37	1.71	1.20
Mn (ppm)	0.98	2.54	1.55	0.79	3.19	1.58	1.07	3.09	1.81
Fe (ppm)	4.04	17.62	8.22	3.71	14.69	8.05	4.50	17.68	11.20
Cu (ppm)	1.31	10.83	5.96	1.98	14.49	8.80	0.98	9.75	5.85
Cr (ppm)	0.012	0.142	0.065	0.040	0.133	0.070	0.039	0.220	0.111
Pb (ppm)	0.014	0.107	0.054	0.012	0.119	0.055	0.017	0.197	0.064
Cd (ppm)	0.001	0.007	0.004	0.001	0.011	0.006	0.004	0.122	0.051

The data on heavy metals such as chromium, lead and cadmium recorded during study period ranged from 0.012 to 0.220 ppm, 0.014 to 0.270 ppm and 0.001 to 0.132 ppm respectively. Bowen (1966) and Etherington (1982) suggested the critical levels of heavy metals as 5 ppm for chromium, 0.5 ppm for cadmium and 2.10 ppm for lead. The findings of the present investigation indicated that there was no sign of heavy metals pollution in all 3 mandals studied. Tyler (1972) reported a relationship between organic matter content and heavy metals distribution under polluting environment. Chelation was ascribed as an important mechanism for the metals which form complexes with ions like lead etc. (Begovich and Jackson, 1995). It is also possible that heavy metals from feeds, pesticides and insecticides can accumulate in pond sediments hence find their way into soils surrounding the aqua ponds via seepage. Heavy metal concentrations of the present study varied in the order of lead>chromium>cadmium. Similarly, Das *et al*, (2017) reported the same order.

Conclusion

The soil samples collected in Repalle were sodic and saline in nature. All soil samples collected in 3 mandals studied did not show any sign of soil pollution except soil salinization and excess sodium. There was no significant difference in physical properties of soil in all mandals in both seasons. pH, electrical conductivity and exchangeable sodium percentage of soil decreased with increase in distance from the aqua ponds. Bulk density, pore volume, CEC, organic carbon, available nitrogen, available phosphorus, available potassium, available sulphur, calcium, magnesium, micronutrients and heavy metals did not follow any trend. The results of heavy metals did not show any sign of soil pollution in 3 mandals studied. 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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