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Status of Water Quality from Agriculture Drains in Guntur District, Andhra Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Quality of agriculture drain water was assessed from selected locations in Guntur district, Andhra Pradesh, India. Waste water samples collected from agriculture drains were analysed for quality parameters such as pH, electrical conductivity, total dissolved solids, total hardness, chlorides, carbonates, bicarbonates, calcium, magnesium, sulphates, phosphates, sodium, potassium, ammonical nitrogen, nitrates nitrogen, dissolved oxygen and chemical oxygen demand. Piper diagram, water quality indices such as sodium adsorption ratio, percent sodium, residual sodium carbonate, magnesium ratio, permeability index and potential salinity were used to assess the suitability of drain water for irrigation. The EC values of water samples ranged from 0.57-5.01 dS/m with an average value of 1.27 dS/m. Water of 16 agriculture drains were found to be unsuitable for irrigation with regard to percent sodium (%Na) and 6 drains with regard to potential salinity.

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1. INTRODUCTION

Water is vital for all the living beings without which no life is imagined. Fresh water availability (i.e, 3% of total water resources present on the globe) is constant on which human race is depending from millions of years. The demand for water is increasing rapidly with the increasing population creating a wide gap between water availability and demand. Water quality is deteriorating by various activities that cause water pollution. Due to the anticipated climate change, the gap between population growth and demand for irrigation water of required quality will continue to challenge us in the future also [1]. Implementation of irrigation techniques reduces the natural water flows and also contaminates the water with nutrients, major ions and other trace elements which will generate environmental impacts. Ameir *et al.* [2] assessed irrigation water quality of El-Salam canal, Egypt and recommended to treat the drainage water before mixing with irrigation water. Gola *et al*. [3] assessed drain water used for irrigation for the Delhi region and found varied concentrations of multiple heavy metals which makes the drain water unsuitable for irrigational purposes. Gabr [4] evaluated irrigation and drainage water for sustainable cultivation at East South El-Qantara, North Sinai, Egypt and found that irrigation water quality was slightly saline, whereas drainage water and groundwater were medium saline. Nasr *et al.* [5] investigated drainage water quality for safe reuse in irrigation applications- a case study in Borg El-Arab, Alexandria and concluded that vegetables irrigated with such drainage water are not safe for human and animal consumption. Hence, assessing the water quality and understanding the factors influencing water quality is vital for effective water management and sustainable development of water resources. Drainage system, irrigation techniques, initial soil salinity, soil structure and infiltration rate, agricultural practices and climate are the major factors that influence the chemical composition of drainage water [6].

2. MATERIALS AND METHODS

2.1 Study Area

Guntur district is one of the central coastal districts of Andhra Pradesh with a geographical area of 11,328 km^2. This study was conducted during the period of December 2020- January 2020. Out of the total geographical area, the net area sown is 56.81%, 10.27% of the area is covered by forests, 3.04% by barren and uncultivable lands and the rest 4.8% by cultivable waste and current fallows [7]. Guntur district lies between North latitudes $15^0 18' 00''$ & $16^0 50' 00''$ and East longitudes $79^0 10' 00''$ & $80^0 55' 00''$. The annual rainfall of the district is 889.1 mm, out of which 59% and 26% was contributed by Southwest and northeast monsoons respectively. The location map of the study area with sampling sites was shown in Fig. 1.

2.2 Sampling and Quality Analysis

A total of 50 agriculture drainage water samples (D_1 to D_{50}) were collected from study area and the location of water sampling sites were recorded using Global Positioning System. Water samples were collected in one liter bottles and were tightly capped without air gap in order to prevent contamination. The collected water samples were shifted to laboratory for quality analysis. Water quality parameters such as electrical conductivity, pH, total dissolved solids, calcium, magnesium, total hardness, carbonates, bicarbonates, chlorides, sodium, potassium, sulphates, phosphates, ammonical nitrogen, nitrates nitrogen, dissolved oxygen, biological oxygen demand and chemical oxygen demand were determined using standard water quality procedures.

The pH and EC were measured using calibrated pH and EC meter. Calcium, magnesium and total hardness were determined titrimetrically using standard EDTA. Carbonates and bicarbonates were determined by titrating against standard H_2SO_4 and chlorides by standard $AgNO_3$. Sodium and potassium was measured using flame photometer whereas, sulphates and phosphates were measured using spectrophotometer. Nitrogen of ammonical and nitrates form was measured using Kjeldal apparatus. Dissolved oxygen was determined tirtimetrically using iodometric test and COD by reflux apparatus.

2.3 Analytical Methods

In order to assess the suitability of collected drainage water from agriculture drains, EC and pH values were investigated. Along with EC and pH, some of the water quality parameters such as Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), percent sodium (% Na), Magnesium Ratio (MR), Permeability Index (PI) and Potential Salinity (PS) values were also calculated to judge the water suitability for irrigation. Low salinity waters can be tolerated by almost all plants and soil types, whereas waters with very high salinity cannot be used for irrigation except for extreme salt-tolerant plants. On the other hand, medium salinity waters can be used for moderately salt-tolerant plants and high salinity waters for irrigation purposes with some management practices.

2.3.1 Sodium adsorption ratio

SAR is also an important parameter which can judge the degree of suitability of water for irrigation. SAR is calculated using the following equation:

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \text{ [8]}$$

In the above equation, all ion concentrations are in meq/L. Water quality classification based on SAR are shown in Table 1.

Table 1. Classification of irrigation water based on SAR

Water quality	SAR
Excellent	<10
Good	10-18
Doubtful	18-26
Unsuitable	>26

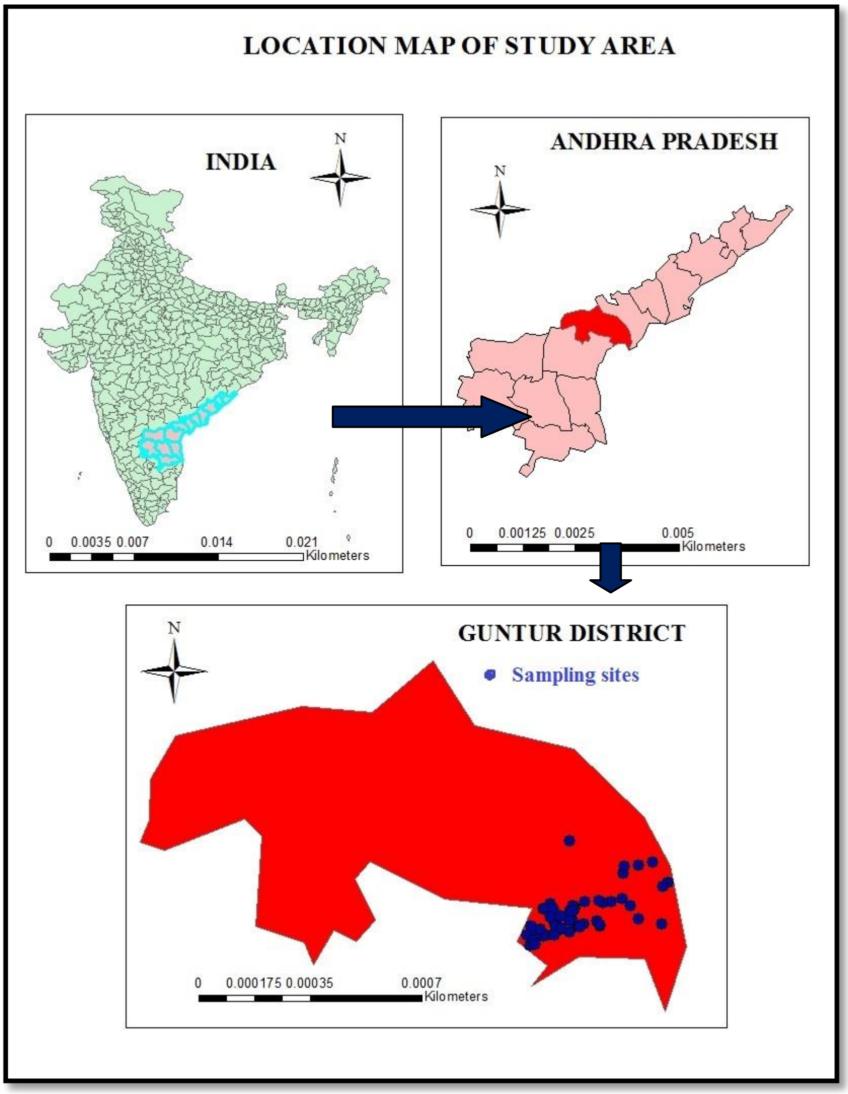

Fig. 1. Location map of study area

2.3.2 Percent sodium (%Na)

The Percent sodium (%Na) represents sodium in irrigation waters can also be used to assess the suitability of water for irrigation. It is obtained by using equation and the classification based on %Na was shown in Table 2.

Table 2. Classification of irrigation water based on %Na

Water quality	Sodium (%)
Excellent	<20
Good	20-40
Permissible	40-60
Doubtful	60-80
Unsuitable	>80

$$\%Na = \frac{(Na)^{+} * 100}{(Na^{+} + Ca^{2+} + Mg^{2+} + K^{+}}$$

2.3.3 Residual Sodium Carbonate (RSC)

Residual sodium carbonate represents the excess sum of carbonates and bicarbonates in irrigation drain water over the sum of calcium and magnesium. RSC values less than 1.25 meq/L are considered as good for irrigation purpose, 1.25-2.50 meq/L as moderate and greater than 2.50 meq/L as unsuitable for irrigation [9]. The equation for calculating RSC was shown below.

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

2.3.4 Magnesium Ratio (M.R.)

Magnesium ratio above 50% can cause sodicity problem in soil and hence it should be lower than 50% in irrigation waters. It is calculated by using the following formula [10].

$$M.R. = \left[\frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \right]$$

2.3.5 Potential salinity

Potential salinity indicates the hazard of high salt concentration due to chlorides and sulphates which can increase the osmotic potential of soil solution when the available moisture in the soil is less than 50%. Waters based on potential salinity are classified as good when it is less than 3 mmolc L^{-1}, moderate when it ranges between 3-15mmolc L^{-1} and not recommended when it is greater than 15 mmolc L^{-1} [11]. Potential salinity is calculated by using the following equation.

$$P.S. = cl^{-} + \frac{1}{2} SO_4{}^{2-}$$

2.3.6 Permeability index

Another index which classifies the irrigation water suitability based on soil permeability is permeability index. Generally, the permeability of soil is affected by long term use of water rich in Na, Ca, Mg and HCO_3. The classification of irrigation water based on permeability index is shown in Table 3.

Permeability index is calculated by using the following equation

$$PI = \left[\frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \right] \times 100$$

The laboratory determinations required to evaluate common irrigation water quality problems was shown in Table 4.

3. RESULTS AND DISCUSSION

3.1 Analysis of Water Quality Parameters

The basic descriptive statistics and water quality parameters of collected agriculture drainage samples were provided in Table 5 and Table 6 respectively. The pH values of collected water samples varied between 6.94-8.35 with a mean value of 7.34. For irrigation waters, the recommended pH values should range between 6.5-8.5 [12]. In pressurized irrigation systems, clogging will takes place with a pH value greater than 7.0 and severe clogging may takes place with a pH value over 8. The water collected from the agricultural drains was not found to be problematic for irrigation with regard to pH values.

Table 3. Classification of irrigation water based on permeability index

PI > 75	Class-1	Most suitable for irrigation
PI= 25-75	Class-2	Moderately suitable for irrigation
PI < 25	Class-3	Unsuitable for irrigation

Table 4. Laboratory calculations required to evaluate common irrigation water quality problems [12]

S.No	Water parameter	Unit	Usual range in irrigation water
1	Electrical conductivity	ds/m	0-3
2	Chlorides	meq/l	0-30
3	Carbonates	meq/l	0-1
4	Bicarbonates	meq/l	0-10
5	Calcium	meq/l	0-20
6	Magnesium	meq/l	0-5
7	Sulphates	meq/l	0-20
8	Phosphates	mg/l	0-2
9	Sodium	meq/l	0-40
10	Potassium	mg/l	0-2
11	Ammonical nitrogen	mg/l	0-5
12	Nitrates nitrogen	mg/l	0-10
13	Sodium adsorption ratio.	mg/l	0-15

The EC values of water samples ranged from 0.57-5.01 dS/m with an average value of 1.27 dS/m. The usual range of EC in irrigation waters is 0-3 [12]. The EC values of D12, D36, and D39 were found to be greater than 3 dS/m and hence unsuitable for irrigation. Plant productivity of crops and native vegetation will reduce due to high levels of soluble salts [13].

Sodium ion ranged between 4.02-34.78 meq/L with a mean value of 8.65 meq/L. The usual range of sodium in irrigation water ranged from 0-40 meq/L [12] Potassium ion ranged from 1-37.5 mg/L with an average value of 4.45 mg/L. The Calcium concentration varied from 2.40-10.60 meq/L, whereas magnesium varied from 0.40-7.00 meq/L.

The individual anions varied from CO_3^- (0.00 – 1.60 meq/L), HCO_3^- (2.60- 9.20 meq/L), SO_4^{2-} (1.70- 39.13 mg/L), PO_4^{3-} (0.01-3.64 mg/L), Cl^- (2.40-36.40 meq/L), NO_3^- (4.20-44.80 mg/L). Ammonical nitrogen varied from 0.00-37.80 mg/L with a mean value of 8.06 mg/L. Total dissolved solids of water samples varied from 364.80 to 3206.40 mg/L with a mean concentration of 816.64 mg/L. Total hardness ranged from 170.00 to 880.00 mg/L with a mean value of 283.8 mg/L. Dissolved oxygen of drainage waters varied from 0.40 to 5.20 mg/L with a mean value of 2.64 mg/L, whereas chemical oxygen demand ranged from 30.00 to 230.00 mg/L with a mean value of 59.40 mg/L.

Table 5. Descriptive statistics of water parameters

Parameter	No. of samples	Minimum	Maximum	Mean	Std. Deviation
pH	50	6.94	8.35	7.34	0.27
EC (dS/m)	50	0.57	5.01	1.27	0.78
TDS (mg/L)	50	364.80	3206.40	816.64	505.27
Ca (meq/L)	50	2.40	10.60	4.06	1.41
Mg (meq/L)	50	0.40	7.00	1.61	1.11
Carbonates (meq/L)	50	0.00	1.60	0.13	0.30
Bicarbonates (meq/L)	50	2.60	9.20	5.29	1.25
TH (mg/L)	50	170.00	880.00	283.80	118.99
Na (meq/L)	50	4.02	34.78	8.65	6.17
K (mg/L)	50	1.00	37.50	4.45	5.35
Sulphates (meq/L)	50	1.70	39.13	8.60	7.57
Phosphates (mg/L)	50	0.01	3.64	0.27	0.59
Cl (meq/L)	50	2.40	36.40	9.47	5.82
Amm_N (mg/L)	50	0.00	37.80	8.06	6.22
Nitrates_N (mg/L)	50	4.20	44.80	12.61	6.93
DO (mg/L)	50	0.40	5.20	2.64	1.28
COD (mg/L)	50	30.00	230.00	59.40	31.90

Table 6. Water quality parameters of agriculture drainage waters

Sample No	Location	EC (dS/m)	SAR	%Na	RSC (meq/L)	MR%	PS (mmolc L^{-1})	PI
D1	Bhattiprolu	0.86	2.95	48.55	-0.20	20.83	5.28	71.65
D2	Ilavaram	0.78	2.59	42.31	-1.20	25.81	5.66	63.18
D3	Rajavolu	1.18	5.31	58.86	1.00	32.35	8.42	75.84
D4	Vellaturu	0.57	3.50	56.41	0.00	29.41	5.23	80.46
D5	Ravianantavaram	0.75	3.23	53.64	0.40	10.53	5.24	78.80
D6	Penumudi	0.71	2.86	48.64	0.40	22.73	5.64	74.43
D7	Kuchinapudi	0.9	3.17	49.25	0.80	34.62	6.04	73.32
D8	Aduvuladeevi	1.01	6.28	65.34	0.80	29.63	7.28	81.50
D9	Repalle	1.14	5.85	63.38	0.40	14.29	8.08	79.52
D10	Tadivakavari palem	0.95	4.46	60.88	1.00	20.00	8.44	82.88
D11	Pedamatla pudi	1.52	7.53	68.31	0.20	26.67	11.24	81.57
D12	Pittalavanipalem	3.1	16.67	81.85	-1.60	32.26	23.61	88.04
D13	Manthenavari palem	0.67	3.01	49.53	0.40	17.39	5.62	74.21
D14	Machavaram	1.3	6.95	67.37	-0.20	25.93	11.62	81.45
D15	Nizampatnam	2.24	12.38	76.85	-2.60	26.47	20.42	83.96
D16	Gokarnamatam	0.75	3.44	52.94	0.00	26.09	6.83	74.99
D17	Kotta reddy palem	0.62	3.17	54.66	0.60	17.65	5.64	81.41
D18	Nandirajuthota	1.38	5.65	59.33	2.20	27.03	8.18	76.10
D19	Perli	0.7	3.08	50.78	0.20	22.73	5.66	74.84
D20	Chintayipalem	0.64	3.31	54.24	0.00	15.79	5.84	77.88
D21	Muttayipalem	1.47	6.70	65.86	-1.00	20.69	11.26	79.03
D22	Maruproluvaripalem	1.4	7.28	68.58	-0.80	37.04	10.92	81.24
D23	Bapatla	1.18	5.74	62.47	-1.20	34.48	8.88	76.54
D24	Poturajukottapalem	1.89	8.33	70.04	-1.40	35.48	14.52	79.88
D25	Buddam	1.14	5.65	61.73	-0.20	30.00	8.47	77.24
D26	Chebrolu	0.96	3.38	49.22	2.20	14.29	5.62	75.05
D27	East Golla Palem	0.65	3.00	51.67	0.00	31.58	5.66	75.33
D28	Yajali	1.18	3.95	51.54	0.40	31.25	8.44	71.84
D29	Karlapalem	2.3	7.60	63.32	-3.80	39.13	15.79	73.04
D30	Tummalapalli	0.93	3.30	51.67	1.00	30.43	8.48	76.73
D31	Ganapavaram	1.1	4.21	56.34	0.60	19.23	8.47	76.72
D32	Pedapuluguvaripalem	1	4.21	57.15	0.80	16.67	7.70	78.51

Sample No	Location	EC (dS/m)	SAR	%Na	RSC (meq/L)	MR%	PS (mmolc L^{-1})	PI
D33	Pothanakattavaripalem	0.92	3.15	50.42	1.00	26.09	6.47	76.19
D34	Hyderpeta	1.35	4.25	54.12	1.40	37.50	8.50	74.25
D35	Narravaripalem	1.04	4.50	60.47	1.80	23.81	8.07	82.90
D36	Pinniboinavaripalem	5.01	11.73	66.29	-11.80	39.77	36.63	71.00
D37	Pittuvaripalem	1.01	4.40	59.09	0.40	22.73	8.11	78.92
D38	Bharthipudi	0.92	3.63	55.84	1.00	21.05	8.47	81.71
D39	Pandurangapuram	3.14	3.96	44.14	-5.60	26.23	19.15	56.19
D40	Mulapalem	1.06	3.88	53.98	1.40	15.38	8.85	76.33
D41	Sammetavaripalem	1.63	6.40	66.24	0.80	26.92	12.83	81.75
D42	Appikatla	0.97	3.69	55.68	0.80	30.00	7.31	80.37
D43	Neredupalle	1.06	4.03	56.24	1.20	37.50	8.08	78.73
D44	Perlipadu	1.08	3.95	55.30	1.80	20.00	8.45	78.73
D45	Singhupalem	0.89	3.08	50.42	0.80	22.73	6.88	76.36
D46	Pedapalli	0.79	3.07	50.99	0.60	20.00	7.28	77.78
D47	Nagaram	1.98	7.18	65.89	-0.40	30.30	14.50	78.66
D48	Khajipalem	2.24	7.10	67.27	0.40	36.84	18.85	87.11
D49	Darivathakottapalem	0.78	2.48	39.77	-0.60	44.12	2.87	59.04
D50	Kankatapalem	0.96	1.82	28.78	-6.40	44.90	2.60	40.76

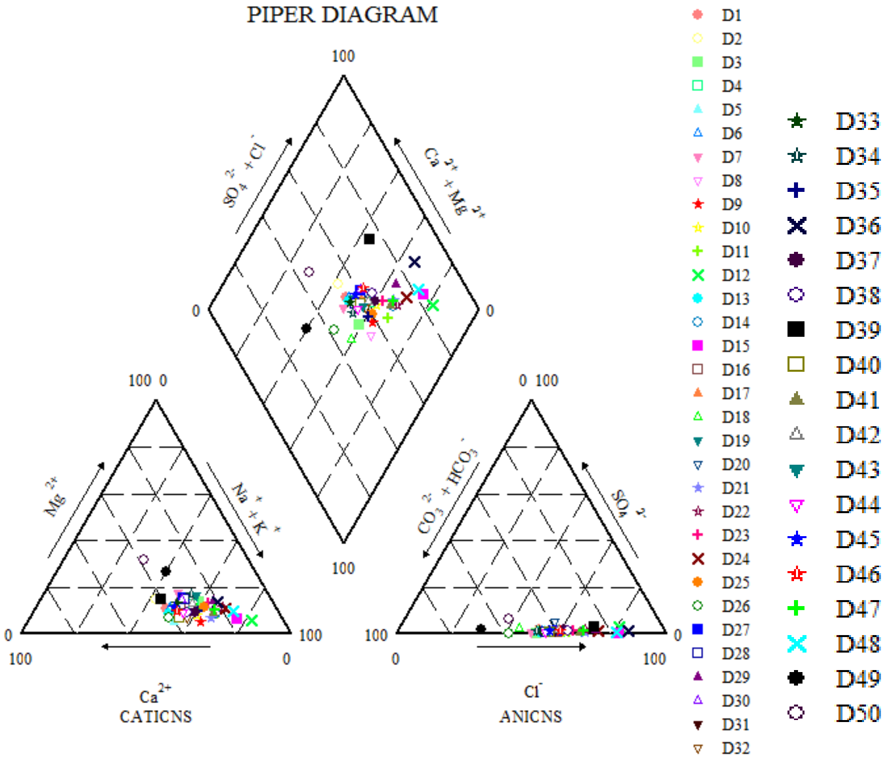

Fig. 2. Piper diagram showing the hydrochemical facies

3.2 Hydrochemical Facies

The primary chemical composition of agricultural drainage water was visualized using piper diagram to determine the water types as shown in Fig. 2. According to this diagram, 4% of waters were HCO_3^- - Ca type, 20% of the samples were mixed type and remaining 76% of the samples were Cl-Na type waters.

3.3 Suitability of Agriculture Drainage Water for Irrigation

From Table 6, it was found that SAR values for all the samples were below 18, and hence suitable for irrigation with regard to SAR. Soil structure related problems may occur with SAR values greater than 18 [8]. According to Na%, sample numbers D8, D9, D11, D12, D14, D15, D21, D22, D23, D24, D25, D29, D36, D41, D47 and D48 are found to be unsuitable for irrigation with values greater than 60. Na% values below or upto 60 indicates the suitability of waters for irrigation [14].

All the samples, except D18 and D26 (moderately suitable) are found to be good according to their calculated RSC values. All the samples fall under magnesium ratio (MR) less than 50%, and hence considered as suitable for irrigation. Permeability index is another parameter which judges the sample suitability for irrigation. According to permeability index (PI), 68% of the samples found to be most suitable for irrigation and rest 32% were classified as class 2 and assessed as moderately suitable for irrigation. Potential salinity indicates 84% of the samples were moderately suitable for irrigation, 12 % of the samples were not suitable for irrigation and 2% of the samples were good for irrigation purpose.

4. CONCLUSIONS

Water quality of 50 agriculture drainage water samples and their suitability for irrigation was assessed in this study. In order to visualize the water chemistry and to conduct water classification piper diagram was used. In the selected sites, most of the waters (76%) were Cl-Na type, few (20%) were mixed type and very few (4%) samples were HCO_3^- - Ca type. In the water quality assessments for determining the suitability of agriculture drain water for irrigation, it was observed that 32% of samples had %Na problems and 12% of the samples had potential salinity (PS) problems. Hence, in the present study the water samples collected from the drains located in Karlapalem, Pinniboinavari palem, Pandurangapuram, Kankatapalem, Nizampatnam and Pittalavani palem contain more salts. It can be concluded that, it is wise to avoid drainage waters directly for irrigation and they should be treated before using for irrigation for better land and water management.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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