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Reckoning of water quality with using GPS system for Irrigation purpose in Coastal areas of Sirkali Taluk of Nagapattinam District, Tamilnadu-India

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ABSTRACT

Agriculture is the backbone of developing countries, the 26, December 2004 'Tsunami' had a major impact on the quality of groundwater along the south- east coast of India, but especially in the tsunami-affected coastal areas of SirkazhiTaluk of the Nagapattinam district of Tamilnadu, India. Major pollution resulted primarily from increases in the salinity of ground water. The post- tsunami water quality posed problems to general health and contributed significantly to agricultural and environmental degradation in the same districts. The present study focus on analysis of underground water quality parameter for irrigation purpose in coastal area. Totally, 105 water samples were collected from different locations. GPS technique is used to identify the coastal area and collected the samples. Physiochemical parameters such as pH, electrical conductivity(EC), total dissolved solids(TDS), carbonate, bicarbonate, chloride, calcium, magnesium, sulfate, sodium, potassium of all collected samples were analyzed to determine the contamination. The sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) levels were also calculated using standard equations. The results showed the significant variations in water quality in the study area, which helped analysis suitable to irrigation purpose in future.

Key words: irrigation water, physicochemical parameter, RSC, SAR, Salinity

INTRODUCTION

Irrigation water quality belongs to the suitability for its use for irrigation purposes. Good quality water is the thinkable to maximize crop yield under good soil and water management practices. After all, with poor quality water, soil and cropping problems can be conventional to reduce yield unless special management practices are adopted to counteract these problems. Capability problems, resulting from using poor quality water, vary conforming to the kind and the degree of hazards caused by the use of such water (Bassuony, 2014).poor quality of groundwater/drainage water increases soil salinity, and with decreased crop yields besides effecting structural deterioration of agricultural lands. The poor quality of the irrigation water applied will also affect the soil chemical properties which further predominance soil dispersion, aggregate breakdown, surface sealing and crust formation (Shainberg and Letey 1984).Sodic soils are associated with structural changes that principally affect permeability of soils. Effect of salinity and alkalinity of water is extensively studied under saturated (Chaudhari and Somawanshi 2004, Dane and Klute 1977) and unsaturated conditions (Quirk and Schofield 1955, Mclntyre 1979,Shainberg et al., 2001, Levy et. al., 2005,). Soil accumulated stability, slaking and dispersion were related to SAR and electrolyte concentration by Abu-Sharar et al. (1987). Increasing sodicity and decreasing the concentration of the applied water pyramidsphysico-chemical dispersion. This diffusion, in turn, leads to a reduction in soil hydraulic conductivity (Shainberg and Letey, 1984,Pupisky and Shainberg, 1979, Frenkel et al., 1978). If the level of Na+ in the soil is high, the colloidal portion behavior will be affected. High carbonate ($CO3^{-}$) and bicarbonate (HCO3-) in water essentially increases the sodium hazard of the water to a level greater than that demonstrate by the SAR. High CO3= and HCO3- tend to precipitate calcium carbonate (CaCO3) and magnesium carbonate (MgCO3) when the soil solution concentrates during soil drying. The consolidation of calcium and magnesium in the soil solution are reduced relative to sodium and the SAR of the soil solution tends to increase. When high consolidation of sodium affect a soil, the trailing loss of structure reduces the hydraulic conductivity. (Hardy et al., 1983 ,Shainberg and Letey, 1984, Hanson et al.,1999, and Levy et al.,1999). Limited freshwater opportunity and increasing demand on food are making even marginal and poor quality waters, an important source for irrigation. The salt effect on soil hydraulic properties would not be ignored because it can lead to serious degradation of irrigated soils (Dane and Klute 1977). The above information all told, the contaminated irrigation water is affected soil (structure, nutrient elements), plants and crop yields.Sirkazhi Taluk was a major cultivated area in Nagapattinam district at before the tsunami, especially near costal revenue villages was a highly paddy growing area in sirkazhi Taluk.But the tsunami

incident totally changed that, lot of irrigation water contaminated by salinity water. So yield reduction was step by step decreased. Above ten thousand hectares of agricultural lands are not cultivated now. A formers are losing their lives. Fig.1.shows the Satellite imge of cultivation affected areas by saline water in sirkazhi taluk.

MATERIALS AND METHODS

Study Area

Nagapattinam district ,the land of religious harmony, known for its rich religious heritage was carved out by bifurcating the composite Thanjavur district on 18-10-1991.This district is spread over eight taluk with a total geographical extent of 2715.83 sq.km with the head Quarters at Nagapattinam .This district lies on the shores of the Bay of Bengal,between Northern Latitude 10.7906 degrees and 79.8428 degrees Eastern Longitude .The district capital 'Nagapattinam' Lies on the eastern coast ,350 kilometers down south from the state capital 'Chennai' and 145 kilometers east , from Tiruchirappalli a central place of the state. The study area is sirkazhi Taluk of Nagapattinam district coastal region in the southern Tamilnadu State located in the coastal region of the Bay of Bengal 11.0290373 Latitude and 79.8506815 Longitude. This taluk is spread over in 27,726 hectares of Agriculture land. Table.1 shows the study area and GPS location.

Water Sampling

Totally 105 irrigation water sample was collected 35 costal revenue villages by using white colour polystyrene bottle of one liter capacities .Before collecting the samples, the bottle was washed properly and rinsed thoroughly several times with same underground water. Each sample were labeled with correct GPS location and address for analysis purpose. The underground water sample were collected of location data shown in Table.1.Then the quality of underground water analyzed in the laboratory determined many parameters such as pH, EC,TDS, Ca,Mg, Na ,K, SO_4,Cl, CO_3, and HCO_3 are determined by standard methods and by using standard instruments. Then the water quality results are compared with standard values Recommended by World Health Organization (WHO) and Bureau of Indian Standards (BIS) for irrigation purpose.

Global Positioning System (GPS) System

The GPS surveying techniques ware used to identify the specific locations of various underground water samples situated at different villages of the costal area table.1.Since the global positioning system (GPS) is an integral part of topographic surveys. The GPS datasets were originally stored as point measurement. Each point had northing, easting, and elevation values.

Water quality measurements

The water pH,EC,TDS,Cations and Anions were determined as follows:

i. The water reaction (pH) was determined using a pH meter (802, digital pH meter,Systronics).
ii. The total soluble salts were measured by using an Electrical conductivity meter (EC) in dS/m^{-1} at 25^0C (MK-509, Systronics)
iii. The soluble Cations was determined by using Flame photometer apparatus (µ Controller Based Flame photometer with CompressorType : 128,systronics)
iv. The soluble anions was determined by using Titrimetric method.

Some quality important water ratings For irrigation purpose recommended by WHO,BIS

Electrical conductivity(EC)

Meaning its electrical conductivity expressed in (dsm^{-1}) represents the total. Salt content of irrigation water. The major anions are carbonates,bicarbonates,sulphate and chloride with low concentric of fluride and nitrate. Table.3, shows classification of irrigation water based on Electrical Conductivity.

Sodium Absorption Ratio (SAR)

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

The ratio of sodium contents to that of calcium and magnesium in the water is called Sodium Absorption Ratio. Sodium Absorption Ratio also denotes sodium hazard. Table.4, shows classification of irrigation water based on Sodium Absorption Ratio.

Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate indicates bicarbonate hazard. It is determined by the proportion of carbonate ions to that of calcium and magnesium ions

$$\mathbf{RSC\ (Meq/lit) = (CO_3^{2+} + H\ CO_3^{2+)} – (Ca^{2+} + Mg^{2+})}$$

The increased Residual Sodium Carbonate value leads to alkali formation because of the precipitation of calcium and magnesium carbonate/ bicarbonate or sodium and bicarbonate. Table.5, shows classification of irrigation water based on Residual Sodium Carbonate.

Geo Chemical Type

Geo chemical type refers to predominate soluble salt present in the irrigation water .The broad Geo chemical type are,

1.Chloride Water, 2.Sulphate Water, 3.Bicarbonate

Calcium bicarbonate and calcium sulphate waters have the low conductance, Sodium chloride water has the highest conductance, when calcium and magnesium is more than half of the total cations it is considered calcium/ magnesium type. When sodium and potassium is more than half of the total cations, the water is considered sodium type. If bicarbonate is than 50% of the total anions, it is considered type. The content of chloride plus sulphate exceeds 50% of the total anions,it is considered chloride type. Table.4, shows problems associated with some Geo Chemical types of water.

Result and Discussion

The revenue village wise water sample analysis reports are presented in the (table.7). pH is one of the important parameters of irrigation water .Generally pH values for normal irrigation water should be between 6-7.Above value are considered as of increasing hazard (Singh e tat.2000, Danko,1997).The pH is logarithmic, meaning that a change of 1.0 units is a tenfold change in either basicity or acidity . Therefore a change of even less than 1.0 units may be significant. The result showing that the pH value in all locations and in the all the samples ranging from 7.25 to 8.18 in sirkazhi Taluk at costal revenue village (Table.7 and Fig.5) . The minimum pH value 7.25 is at Mangaimadam and the maximum pH value 8 .18 is Maadhanam . The very more level,pH value is present in three villages such as (Arapallam 8.05,Melaiyur 8.10,and Maadhanam 8.18).

The concentration of the total salt content in irrigation water is estimated in terms of Electrical conductivity (EC) and it may be the most important parameter for assessing the suitability of irrigation water (Belan,1985,Ayayi e tal.,1990) Generally, the ranges considered for irrigation water suitability are from 0 to 2.0 (dsm^{-1}) (WHO,BIS).Above value is considered salinity hazards.The EC in all locations range from 0.9223 to 2.39. The minimum EC value 0.9223 is at Edamanal and the maximum EC value at 2.39 is Pazhaiyapalaiyam, and the average EC value is in all locations 1.56(Table.7). Based on the electrical conductivity classification,8.57% of villages cover under C1classification and this village underground water does not have salinity ,70.43% of villages cover under C2 classification and this village underground water contains Medium salinity level ,and 20% of villages cover under the C3 classification its denoted this village's water have salinity(Fig.2).

Total dissolved solid (TDS) is also a criterion for the assessment of salt content in the water as salts constitute an important part of TDS (FAO,1985). The irrigation water with total dissolved solid (TDS) is considered suitable and good ,and more than 2000mg/l is unsuitable to irrigation purpose.The TDS in all location ranges from 591 to 1529.66mg/l.The minimum TDS value 591mg/l is at Varisaipathvadagal, maximum TDS value 1529.66mg/l at Pazhaiyapalaiyam and the average value is in all locations 1003.46mg/l (Table.7 and Fig.6).

Sodium Absorption Ratio also denotes sodium hazard .Based on Sodium Absorption Ratio classification.100% of villages cover under the S1 classification, it denotes all location underground waters have a safe sodium hazard. And 0% of villages cover under S2,S3 classification (Fig.3). Residual Sodium Carbonate indicates bicarbonate hazard. It is determined by the proportion of carbonate ions to that of calcium and magnesium ions. Based on Residual Sodium Carbonate classification, 88.57% of villages cover under R1 classification, 8.57% of villages cover under R2 classification and 2.86% of villages cover under R3 classification (Fig.4).

Geo chemical type refers to predominate soluble salt present in the irrigation water.)Based on Geo chemical type,28.57% of villages cover under NaCl type,40% for $NaHCO_3$,11.44% for $MgHCO_3$,8.57% for $CaHCO_3$ and $CaCl_2$,2.85% villages cover under $MgCl_2$ type(Fig.7).

Conclusion

The result of the waters samples investigation shows that the six Geo chemical types waters were identified, such as $CaHCO_3$,$NaHCO_3$,$MgHCO_3$,CaCl,NaCl,MgCl. Accordingly ,permanent hardness and salinity problems are probable. Based on Electrical Conductivity 8.57%of the waters have excellent irrigation water quality,70.43% of the waters have medium salinity and 20% of the waters have high salinity or doubtful to irrigation, there is a risk of yield production for most of commonly cultivated crops. Based on sodium hazard 100% of the waters have good quality, they are in safe against to sodium hazard. Based on carbonate hazard 88.57% of the waters have excellent quality, 8.57% of the waters have moderate carbonate hazard and 2.86% of the waters have highly carbonate hazard or unsafe irrigation waters. Finally ,based on Geo chemical types 8.57% of the waters are in calcium bicarbonate type, it indicates this waters have low concentration and it does not give any problem to cultivation. 40% of the waters are in sodium bicarbonate type, it indicates this water has intermediate concentration and alkalinity problem.11.43% of the waters are in magnesium bicarbonate type it is similar to calcium bicarbonate and it indicates this water have low concentration and it does not give give problem. 29% of the waters are in sodium chloride type,it indicates this waters have high concentration or alkalinity problem .8.57% of the waters are in calcium chloride type, its indicate this water have high concentration and high salinity problem. And 2.85% of the waters are in magnesium chloride type, it indicates this waters have moderate salinity problem.

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(Tables & Figures)

Fig.1.Satellite imge of cultivation affected areas by saline water in sirkazhi taluk

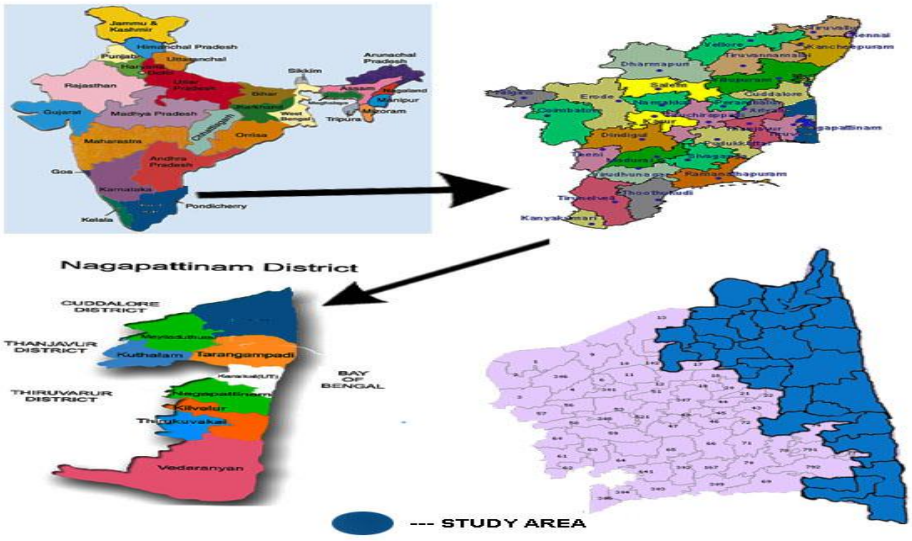

Fig.2. location map of sample collected costal area of Sirkazhi Taluk –Tamilnadu

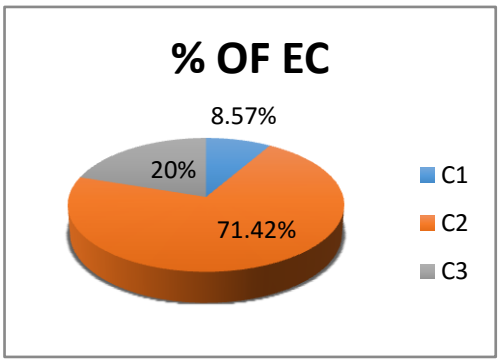

Fig:2. The % of EC of all location

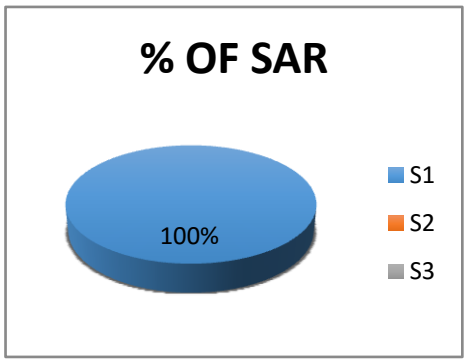

Fig:3. The % SAR of all location

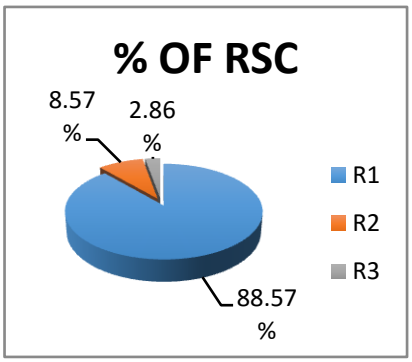

Fig:4.The% of RSC of location

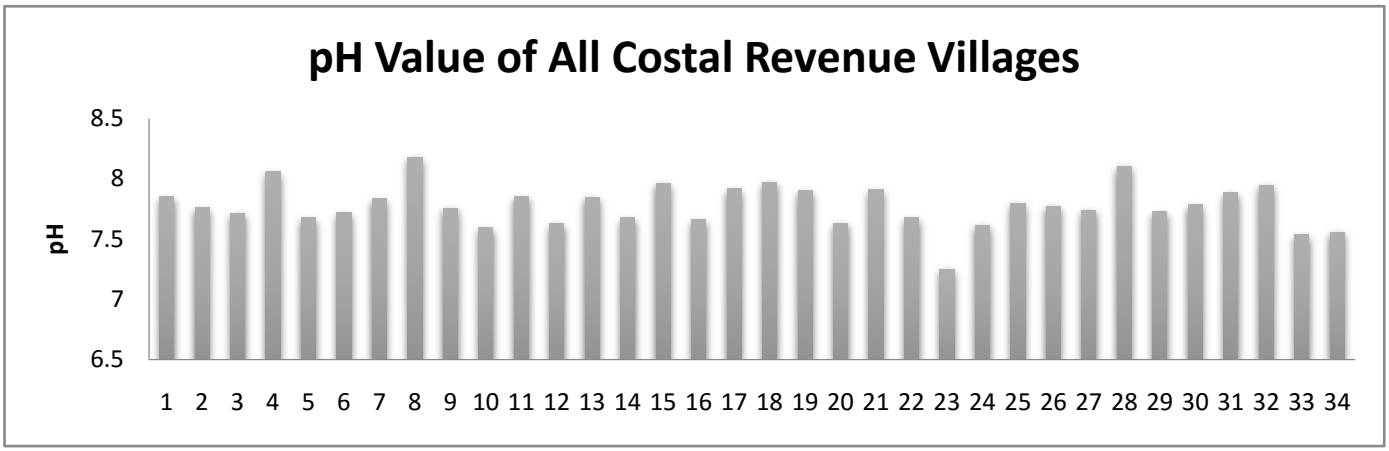

Fig:5.The pH value of all costal revenue village of SirkazhiTaluk,Nagapattinam District-Tamilnadu

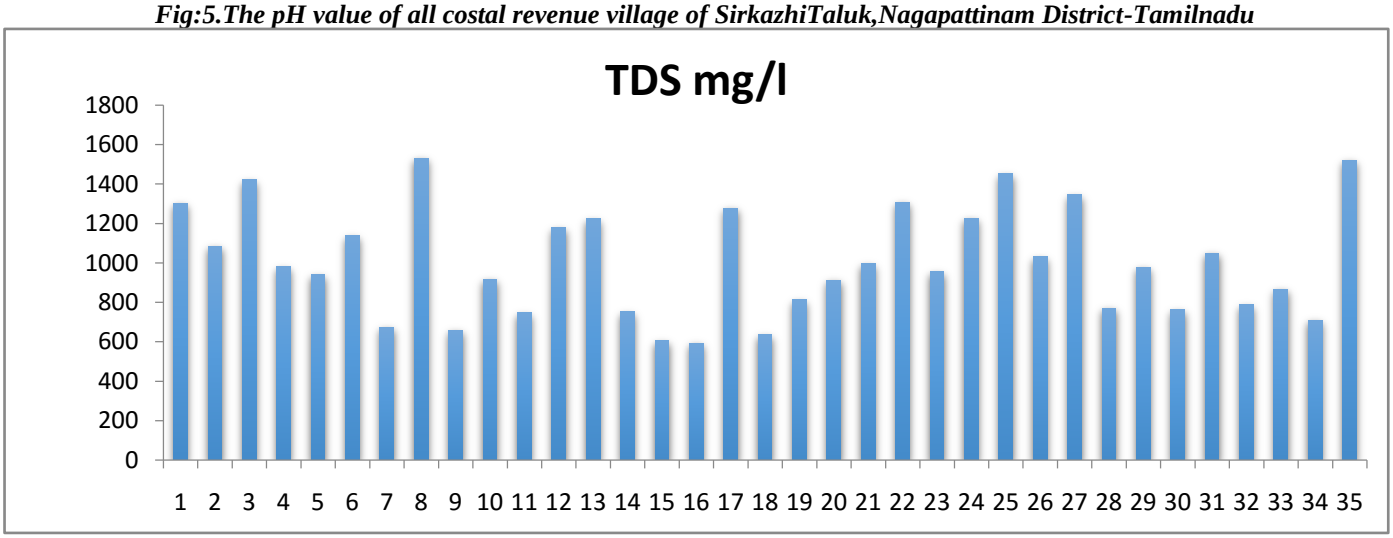

Fig:6.The TDS value of all costal revenue village of SirkazhiTaluk,Nagapattinam District-Tamilnadu

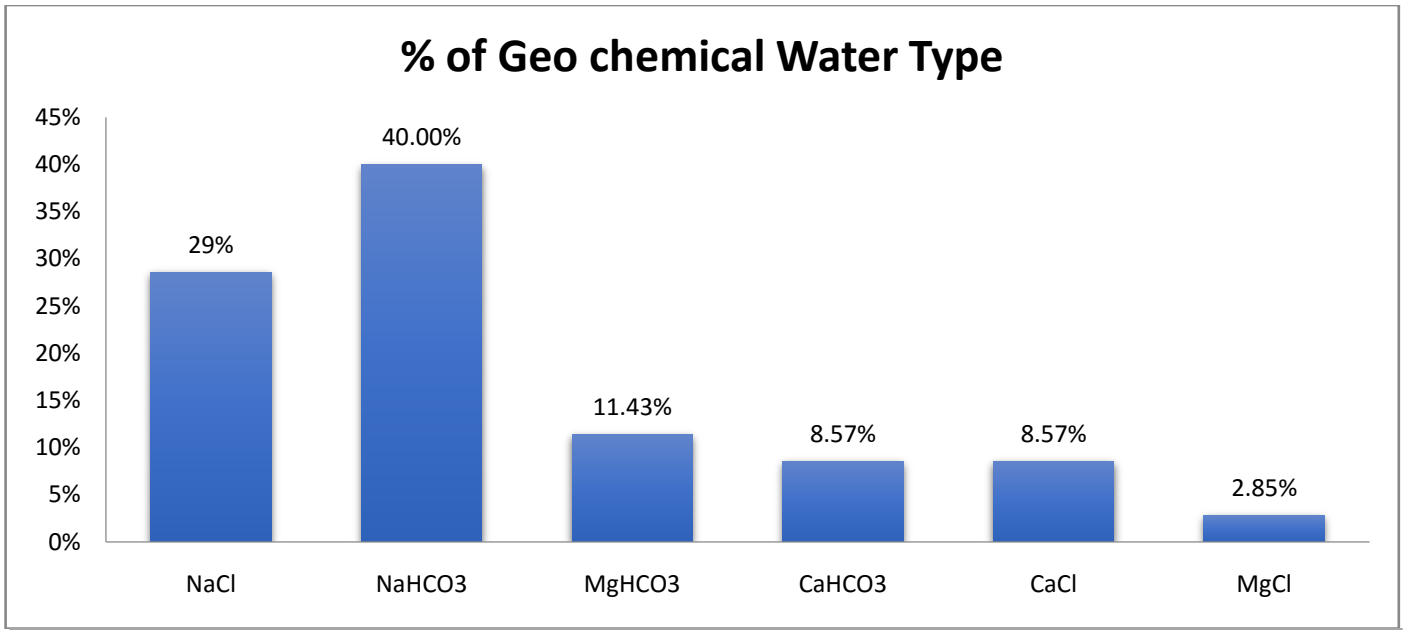

Fig:7.The % of Various Type Water In Costal Revenue Village Sirkazhitaluk-Nagapattinam District

Table:1.Gps Location Data of Sample Collected Coastal Area of Sirkazhi Taluk -Tamilnadu

S.NO	VILLAGE NAME	SAMPLE-1 LOCATION		SAMPLE-2 LOCATION		SAMPLE-3 LOCATION	
		LONGITUTE^0 E	LATITUTE^{0}N	LONGITUTE^0 E	LATITUTE^{0}N	LONGITUTE^{0}E	LATITUTE^{0}N
1	ALAKUDI	79.7.69122	11.374512	79.7098206	11.3468035	79.7130885	11.383628
2	MEHENTRAPALLI	79^0.767089	11.3552895	79.792311	11.365823	79.790460	11.363629
3	PUTHUPATTINAM	79.8131648	11.3193474	79.810300	11.331299	79.811824	11.331363
4	MUDHALAI MEDU	79.7513063	11.3305297	79.7591976	11.3429095	79.769434	11.350886
5	AARAPALLAM	79.7591976	11.3429095	79.7670123	11.3550131	79.7532172	11.3401644
6	PULIYANDHURAI	79.8136559	11.348863	79.767089	11.3552895	79.7642389	11.3521932
7	THANDAVANGULAM	79.8131648	11.3193474	79.799558	11.2806557	79.807361	11.303528
8	PAZHAIYAPALAIYAM	79.7792386	11.288338	79.8065089	11.3157187	79.7877799	11.2934519
9	MAADHANAM	79.7513063	11.3305297	79.758874007	11.29835216	79.766153	11.298055
10	KATTUR	79.7131821	11.4113457	79.8136559	11.348863	79.7776476	11.3922826
11	AHARAVATTARAM	79.774278	11.2896393	79.7767583	11.2889887	79.7792386	11.288338
12	MAHARAJAPURAM	74.7792386	11.288335	79.8157375	11.24777415	79.7746362	11.2936038
13	VETTANGUDI	79.7860874	11.2702060	79.79207	11.2520318	79.7792678	11.2883813
14	ALANGADU	79.755763	11.2483195	79.750619	11.2483021	79.7706846	11.2581747
15	KADAVASAL	79.79207	11.2520318	79.79281	11.2520420	79.7838591	11.252372
16	VARISAIPATHU VADAKAL	79.7792678	11.2883813	79.78815	11.253912	79.784243	11.255267
17	THIRUMULLAI VASAL	79.8192325	11.2403698	79.8106432	11.2289728	79.7934645	11.2061788
18	EDAMANAL	79.7706846	11.2581747	79.7690291	11.2510061	79.7706846	11.2581747
19	RADHANALLUR	79.8192325	11.2403698	79.8060697	11.2462008	79.8204342	11.2410063
20	THIRUKARAIKKAYUR	79.7772445	11.2374523	79.7672145	11.2481231	79.7823418	11.223541
21	THIRUNAHARI	79.8192325	11.2403698	79.7964963	11.2097911	79.787469	11.2096313
22	THENNAMPATTINAM	79.8033508	11.2255006	79.787459	11.2096313	79.8140009	11.2179338
23	NEPATHUR	79.7934645	11.2061785	79.7435231	11.2062341	79.7904667	11.2079051
24	MANGAIMADAM	79.80857159	11.18948806	79.81176731	11.18950784	79.804993	11.194661
25	MUTHAL PERUNHOTTAM	79.83082618	11.20162288	79.83132686	11.20140694	79.831363828	11.2013948

26	IRANDAMPERUNTHOTTAM	79.831584109	11.831584109	79.8317513210	11.20127706	79.8282915865	11.1956221
27	AHARA PERUNTHOTTAM	79.822035	11.189204	79.822654	11.185583	79.824159	11.184741
28	MANIKIRAMAM	79.824556	11.1452993	79.8199747	11.1488791	79.8199747	11.1488791
29	MELAIYUR	79.8199747	11.1468791	79.8053401	11.1844758	79.8392016	11.1567777
30	KEEZHAIYUR	79.8392016	11.156777	79.8392016	11.1567777	79.8392016	11.1567771
31	VANAKIRI	79.8291373	11.1417196	79.8291373	11.1417196	79.83991615	11.1453899
32	ALALASUNTHARAM	79.797515067	11.31897286	79.752399731	11.31864689	79.7431296314	11.3182432
33	ACHALAPURAM	79.7254736	11.3099142	79.7564412	11.3289478	79.7532767758	11.3266757
34	NALLANAYAKKA PURAM	79.74282631	11.31834750	79.742739482	11.31843785	79.742584143	11.3183520
35	UMAIYAL PETTAI	79.7713634	11.2584211	79.7713634	11.2584211	79.764766	11.264640

Table :2. These ratings could be used as guidelines when recommendation are given

Water Quality Ratings	EC (dsm^{-1})	SAR (Meq/lit)	RSC (Meq/lit)
Good	Less than 2.0	Less than 10.0	Nil
Marginal water	2-4	Less than 10.0	Less than 2.5
Saline water	More than 4.0	Less than 10.0	Nil
Sodic water	Less than 4.0	More than 10.0	Usually more than 2.5

Table :3.Calassification of irrigation water based on electrical conductivity

Class	E.C (dsm^{-1})	Salinity status	Suitability
C_1	0.0-1.0	Low salinity water	Excellent
C_2	1.01-2.0	Medium salinity water	Good
C_3	2.01-4.0	Salinity water	Doubtful
C_4	4.01-6.0	High salinity water	Injurious
C_5	>6.0	Very high salinity water	Unsuitable

Table:4.Classification of irrigation water based on Sodium Absorption Ratio

Class	SAR	Suitability
S1	< 10	Safe
S2	10.01-20.0	Moderate
S3	>20.0	Unsafe

Table:5.Classification of irrigation water based on Residual Sodium Carbonate

Class	RSC (Meq/lit)	Suitability
R1	< 1.25	Safe
R2	1.26-2.50	Moderate
R3	>2.50	Unsafe

Table:6.Problems associated with some geo chemical types of water

$CaHCO_3$	Low concentration, no problem
$NaHCO_3$	Intermediate concentration, alkalinity problem
$MgHCO_3$	Low concentration, no problem
NaCl	High concentration, salinity or alkalinity problem
CaCl	High concentration, salinity problems
MgCl	High concentration, moderate salinity problems

Table:7.Water Samples analysis Average Values of Costal Revenue Village Sirkazhi Taluk-Tamilnadu

S. no	VILLAGE NAME	T.S	pH	EC (dsm-1)	TDS mg/l	ANIONS/(meq/lit)				CATIOMS/(meq/lit)				RSC	SAR	RATING			Geo
						CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	(Meq/lit)	(Meq/lit)	EC(dsm-1)	SAR	RSC	Chemical type
1	ALAKUDI	3	7.85	2.033	1301.33	0.1	9.9233	10.166	0.1733	4.196	6.236	9.72	0.25	1.9	4.1466	C3	S1	R2	NaCl
2	MEHENTRAPALLI	3	7.69	1.693	1083.66	…	9.9233	7.606	0.1066	6.033	6.4	4.463	0.0766	…	2.0966	C2	S1	R1	$MgHCO_3$
3	PUTHUPATTINAM	3	7.76	2.226	1421.66	….	8.8	13.166	0.3433	6.233	4.533	10.95	0.0966	0.0966	4.82	C3	S1	R1	NaCl
4	MUDHALAI MEDU	3	7.713	1.533	981	….	5.5066	6.42	0.2066	5.003	3.956	6.386	0.1333	0.2	2.99	C2	S1	R1	NaCl
5	AARAPALLAM	3	8.056	1.47	940.66	0.333	5.54	8.7	0.1866	3.866	5.196	5.94	0.1166	0.033	2.7366	C2	S1	R1	NaCl
6	PULIYANDHURAI	3	7.676	1.776	1137	….	8.966	8.766	0.1533	4.646	7.146	5.876	0.1133	0.0166	2.4166	C2	S1	R1	$MgHCO_3$
7	THANDAVANGULAM	3	7.716	1.05	671.66	0.1333	7.033	3.1	0.25	3.733	2.766	3.993	0.02	0.7	2.17	C2	S1	R1	$NaHCO_3$
8	PAZHAIYAPALAIYAM	3	7.833	2.39	1529.66	0.2	7.966	15.4	0.3466	5	4.433	14.456	0.0266	…	5.4366	C3	S1	R1	NaCl
9	MAADHANAM	3	8.18	1.03	659	…	6.3	3.766	0.25	3.633	2.333	4.333	0.0166	0.9333	2.4366	C2	S1	R1	$NaHCO_3$
10	KATTUR	3	7.753	1.43	915.33	….	6.633	7.266	0.25	7.733	5.566	3.41	0.0133	…	1.67	C2	S1	R1	CaCl
11	AHARAVATTARAM	3	7.593	1.166	746.66	….	7.166	4.3	0.2166	3.533	2.733	5.396	0.0166	1.0333	2.9466	C2	S1	R1	NaHCO3
12	MAHARAJAPURAM	3	7.853	1.843	1179.33	…	9.466	8.7	0.2833	4.3	3.866	10.26	0.02	1.3	5.0233	C2	S1	R2	$CaHCO_3$
13	VETTANGUDI	3	7.626	1.91	1222.33	….	6.7	12	0.37	7.633	4.933	6.516	0.0166	…	2.4833	C2	S1	R1	CaCl
14	ALANGADU	3	7.846	1.17	751.33	0.1333	7.8	3.666	0.1066	3.133	2.733	5.833	0.02	2.0666	3.3966	C2	S1	R2	$NaHCO_3$
15	KADAVASAL	3	7.676	0.946	605.66	0.0333	6.566	2.8	0.0666	3.133	3	3.333	0.0166	0.4666	1.8966	C1	S1	R1	$NaHCO_3$
16	VARISAIPATHU VADAKAL	3	7.96	0.923	591	0.2666	6.266	2.633	0.07	3.1	2.666	3.446	0.0166	0.7666	2.0533	C1	S1	R1	$NaHCO_3$
17	THIRUMULLAI VASAL	3	7.66	1.993	1276	…	7.033	13.833	0.7333	6.166	4.433	9.266	0.0166	0.4666	3.9433	C2	S1	R1	NaCl
18	EDAMANAL	3	7.916	0.993	635.66	0.2333	6.466	3.133	0.1066	3.8	2.166	3.966	0.0133	0.6666	2.32	C1	S1	R1	$NaHCO_3$
19	RADHANALLUR	3	7.97	1.27	813	0.4333	6.7	5	0.5333	3.366	4.3	4.006	0.01	0.1	2.8033	C2	S1	R1	$MgHCO_3$
20	THIRUKARAIKKAYUR	3	7.9	1.426	912.66	0.8666	6.566	6.733	0.09	4.766	5.433	4.226	0.0166	0.8666	2.2333	C2	S1	R1	MgCl
21	THIRUNAHARI	3	7.63	1.533	994.33	…	7.466	7.333	0.58	5.733	4.666	5.1	0.0166	…	1.5866	C2	S1	R1	$CaHCO_3$
22	THENNAMPATTINAM	3	7.91	2.043	1308	0.2666	8.666	11.333	0.1733	4.3	5.233	10.923	0.0266	1.1333	4.84	C3	S1	R1	NaCl
23	NEPATHUR	3	7.676	1.49	953.66	…	6.466	7.566	0.7733	5.5	5.1	4.296	0.0166	0.7333	2.1333	C2	S1	R1	CaCl
24	MANGAIMADAM	3	7.25	1.916	1226.66	…	9.433	9.333	0.4166	4.633	4.366	10.163	0.0233	0.7666	4.52	C2	S1	R1	$NaHCO_3$
25	MUTHAL PERUNHOTTAM	3	7.613	2.266	1450.66	…	9.633	12.6	0.4466	5.5	4.433	13.06	0.0233	0.2666	5.9633	C3	S1	R1	NaCl
26	IRANDAMPERUNTHOTTAM	3	7.796	1.61	1030.33	0.2	9.6	6.1	0.2166	4.5	3.966	7.623	0.0233	1.3333	3.7033	C2	S1	R2	$NaHCO_3$
27	AHARA PERUNTHOTTAM	3	7.77	2.1	1344	0.2	10.066	10.333	0.4166	5	4.533	11.46	0.02	0.7333	5.2833	C3	S1	R1	NaCl
28	MANIKIRAMAM	3	7.74	1.203	770.33	0.06	7.4	4.366	0.21	3.7	2.733	5.596	0.0166	1.0333	3.06	C2	S1	R1	$NaHCO_3$
29	MELAIYUR	3	8.103	1.526	977	0.333	7.6	7.133	0.2033	4	3	8.27	0.0166	1.1666	4.3	C2	S1	R1	$NaHCO_3$

30	KEEZHAIYUR	3	7.726	1.193	763.33	0.0333	7.833	3.966	0.1066	4.333	2.9	4.7	0.0233	0.6333	2.47	C2	S1	R1	$NaHCO_3$
31	VANAKIRI	3	7.786	1.636	1049	0.2666	9.4	6.633	0.14	4.133	3.166	9.096	0.0333	2.3666	4.72	C2	S1	R3	$NaHCO_3$
32	ALALASUNTHARAM	3	7.883	1.23	787	0.0666	6.233	5.8	0.21	2.9933	6.08	0.2	0.03	0.2666	2.8766	C2	S1	R1	$MgHCO_3$
33	ACHALAPURAM	3	7.946	1.383	865.33	…	9.333	4.34	0.16	5.466	4.066	4.106	0.08	…..	2.21	C2	S1	R1	$CaHCO_3$
34	NALLANAYAKKA PURAM	3	7.536	1.106	708	…	5.773	5.153	0.15	3.54	3.08	4.376	0.0966	0.0666	2.3566	C2	S1	R1	$NaHCO_3$
35	UMAIYAL PETTAI	3	7.556	2.373	1519	0.1666	10.033	13.133	0.42	4.866	4.7	14.156	0.02	0.5666	6.3166	C3	S1	R1	NaCl
35	RANGE	--	7.25-8.18	0.923-2.39	591-1529.6	0.033-0.866	5.506-10.066	2.8-15.4	0.066-0.773	2.9933-7.733	2.166-7.14	0.2-14.456	0.01-0.1333	0.1-2.3666	1.586-6.3166	---	----	----	------
37	MEAN	3	7.556	1.567	1003.46	0.12263	7.7787	7.4936	0.2704	4.6058	4.195	14.156	0.0426	0.647954	3.3245	C2	S1	R1	$NaHCO_3$