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Physico-chemical parameters of the various stages in different Salt-pans of Tuticorin district

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ABSTRACT

Common salt plays an important role in the world's economy. The most abundant source of common salt is sea water. It is manufactured by various methods, of which the solar evaporation of sea brine, backwater and underground brine is predominant. India has an extensive sea board with favourable periods of dry weather, which aids natural evaporation. Sodium chloride constitutes 80% of the total salts dissolved in sea water. Bittern is an unavoidable material formed during salt production. It is an extraordinary source of magnesium and potassium salts. It is also rich in calcium, magnesium, chloride, sulphate, sodium and trace elements like copper, manganese, iron and zinc. This paper explains the Physico-chemical parameters of brine at various stages viz., source, reservoir, condenser, crystallizer and bittern of the different salt pans of Tuticorin district. The values of the parameters mentioned here were subjected to variations due to seasonal conditions.

Key words: source, reservoir, condenser, crystallizer, bittern.

INTRODUCTION

Common salt is widely distributed on the earth. In India, the entire production of about seven million tons of salt excepting a negligible quantity of rock salt is obtained by solar evaporation. Almost 71% of the earth surface is covered with sea water and it contains 2.5% of common salt. The technology of salt manufacture depends largely on evaporation, solubility and crystallization. Around 30,000 acres of land in Tamil Nadu are being utilized in the manufacture of salt by solar salt operations. Salt is manufactured by the evaporation of sea brine and subsoil brine of different densities of varying Baume degrees. Without adequate supplies and management of salt water resources, socio-economic development simply cannot take place [1]. In Tuticorin district of Tamil Nadu, India, salt is manufactured in five different places viz., Therespuram (sea brine), Roche park (sea brine), Veppalodai (subsoil brine), Tharuvaikulam (subsoil brine), Pattanamaruthor (subsoil brine). Almost every element is found in traces in sea water [2]. Out of the various elements present, chlorine, sodium, magnesium, sulphur, calcium, potassium and bromine are present in higher percentage [3].

Study area

Tuticorin district is located on south east of Tamil Nadu state. The district covers an area of 4621 sq.km and is bounded by the districts of virudhunagar and Ramanathapuram on the east and by Gulf of Mannar on the south-east and by Tirunelveli district on the West and South-west. Its geographical co-ordinates are $8^0$47'0" North, $78^0$8'0" East.

EXPERIMENTAL SECTION

Samples were collected from the above five different salt pans during January to December. Samples from source, reservoir, condenser, crystallizer and bittern were collected from each salt pan. Physical parameters such as atmospheric temperature, temperature of brine, density of the brine, pH, and electrical conductivity were determined. The atmospheric temperature and the temperature of the brine at different stages were recorded using an 110^0C thermometer. The density of the brine at different stages was measured with Baume hydrometer. pH was determined by pH meter, electrical conductivity by conductivity bridge . Chemical parameters such as percentage of calcium, magnesium, chloride, Sulphate, sodium, potassium were determined by standard procedures. [4]

RESULTS AND DISCUSSION

(i) Atmospheric temperature (^{0}C)

Atmospheric temperature of all salt pans was maximum from January to March during the pre-monsoon period. This was in accordance with earlier works.[5] A maximum temperature of 34^0C was recorded in Therespuram and Roche park .As the monsoon commenced, the atmospheric temperature dropped. In August, which is in between the monsoons, it was slightly higher. But as the northeast monsoon became active, the values went on decreasing from September to December and the minimum temperature was recorded as 29^0C in November and December.

(ii) Temperature of the brine (^{0}C)

The brine temperature at different stages of the salt-pans ranged between 29^0C and 40^0C. Uniform increase in temperature from the source to the bittern was also observed. All the salt pans had maximum temperature for various stages from January to March, i.e., during the pre monsoon periods. A maximum temperature of 40^0C was recorded in Veppalodai, Therespuram and Roche Park. High temperature was also recorded in between the monsoon periods. But from September to December when northeast monsoon became active, minimum values were observed and the lowest temperature of 29^0C was recorded in November and December. This was in agreement with earlier works. [6]

(iii) Brine density (^{0}Be)

The concentration of the brine is normally represented as brine density and its unit is degree Baume (^{0}Be). The brine density normally lies in the range of 3.0^0 to 6.5^0Be at source. The Baume degree gradually increases due to evaporation and is between 10^0 to 16^0Be in the reservoir stage. The brine with the density from 16.5^0 to 25^0Be represents the condenser and from 26^0 to 29.5^0Be represents the crystallizer stage. Once sodium chloride crystallizes out the resulting mother liquor called bittern has the density of 30^0Be. The average value for the source samples of all the salt pans ranged between 4.0^0 (Tharuvaikulam, Pattanamaruthor) and 4.4^0Be (Therespuram, Roche park). The average value for the reservoir is between 11.6^0 (Veppalodai) and 13.9^0 Be (Roche park). The average value ranges between 18.9^0 (Tharuvaikulam) and 20.5^0 Be (Therespuram) for condenser and between 24.9^0 (Pattanamaruthor) and 27.3^0 Be (Roche park). The average value of bittern ranged between 29.8^0 (Veppalodai, Tharuvaikulam) and 30.0^0 Be (Therespuram, Roche park)

(iv) pH

The pH of brine at different stages of the salt pan was alkaline. [7] The pH value increases from source to reservoir because of the increasing concentration of iron oxide and calcium carbonate. As the above salts are separated before the condenser level, there was a gradual decrease in the pH values. The average value of source samples ranges between 7.5^0(Roche park, Veppalodai, Tharuvaikulam) and 7.6^0 Be (Therespuram, Pattanamaruthor) and reservoir samples between7.7^0 (Tharuvaikulam) and 7.9^0 Be (Therespuram, Pattanamaruthor).There was a marginal decrease in the average values at condenser and crystallizer stages. In condenser stage, the value was 7.5^0 in all pans except Pattanamaruthor (7.6^0 Be). For the available bittern samples, the pH ranged between 7.0^0 (Therespuram, Tharuvaikulam) and 7.2^0 Be (Roche park)

(v) Electrical conductivity (dsm^{-1})

The values increased gradually from source to the crystallizer stage. It was in accordance with the earlier works that higher salinity is associated with higher electrical conductance. [8] Moreover, the electrical conductivity depends upon the concentration of ionized substances present in the brine. As 70% of sodium chloride gets separated out at 29.5^0Be,i.e., in the crystallizer stage, a decrease in the electrical conductivity value was observed for the bittern sample. The source at different salt pans had an average ranging between 51.0^0 (Pattanamaruthor) and 61.8^0 Be (Therespuram). An average value ranging between 59.7^0 (Pattanamaruthor) and 70.6^0 Be (Therespuram) was

recorded at the reservoir stage of all salt pans. The average value of the condenser stage ranged between 71.3^0 (Pattanamaruthor) and 82.7^0 Be (Therespuram). A maximum value of electrical conductivity was recorded at crystallizer stage which had an average between 87.2^0 (Pattanamaruthor) and 92.8^0 Be (Therespuram). The available bittern samples of the various salt pans had an average ranging between 75.5^0 (Pattanamaruthor) and 82.0^0 Be (Therespuram)

(vi) Percentage of chloride

A gradual increase in the percentage of chloride from source to bittern had been reported earlier. Despite sodium chloride being separated in the crystallizer phase, the continuing increase at bittern stage is due to the remaining sodium chloride and also the maximum amount of magnesium and potassium chlorides which get separated only after 30^0Be. [9] The source at Therespuram had more chloride than the sources of all the remaining salt pans because it uses sea brine for salt making. The average value ranged between 2.3^0 (Veppalodai, Tharuvaikulam, Pattanamaruthor) and 3.1^0 Be (Therespuram) .The average value at reservoir ranged between 5.4^0 (Tharuvaikulam) and 6.7^0 Be (Roche park). The average value at the condensers of all the salt pans ranged between 11.0^0 (Tharuvaikulam) and 12.3^0 Be (Therespuram). The crystallizers of all the pans had the value between 16.6^0 (Veppalodai, Tharuvaikulam) and 18.9^0 Be (Roche park). The average value is between 28.3^0 (Therespuram) and 30.1^0 Be (Pattanamaruthor) for the bittern stage of all the salt pans.

(vii) Percentage of sulphate

A gradual increase in the percentage of sulphate from source to bittern was observed. This was in accordance with earlier works regarding the production of sulphur from brines. [10] Though calcium sulphate is removed in the primary stage i.e., before the condenser level, the continuing increase is due to the remaining gypsum and salts like sulphates of magnesium and potassium which got separated only after 30^0Be. The average value at the sources of various salt pans ranged between 0.28^0 (Tharuvaikulam, Pattanamaruthor) and 0.30^0 Be (Therespuram, Roche park, Veppalodai). The reservoir stage of the various salt pans had the value between 0.92^0 (Tharuvaikulam) and 1.02^0 Be (Roche park) . The average value at the condensers of various salt pans ranged between 1.46^0 (Tharuvaikulam) and 1.72^0 Be (Therespuram, Roche park) and that of crystallizers between 2.09^0 (Tharuvaikulam) and 2.63^0 Be (Therespuram) . The bittern samples had an average of 2.89^0 (Pattanamaruthor) and 3.41^0 Be (Therespuram).

Table -1 Chloride (%)

Salt-Pans	Nature of brine	Stages	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
Therespuram	Sea brine	1	3.1	3.4	3.3	3.2	3.2	3.3	3.4	3.2	2.8	3.0	2.7	2.5	3.1
		2	6.8	7.0	7.1	6.4	6.2	6.4	6.7	6.8	6.4	6.1	6.2	5.9	6.5
		3	12.8	13.2	13.4	12.4	12.0	12.3	12.5	13.1	11.7	11.6	11.0	11.1	12.3
		4	19.4	19.7	18.0	18.5	x	18.6	19.0	19.2	18.2	18.8	x	x	18.8
		5	28.5	28.1	28.5	28.1	x	x	27.5	28.8	x	x	x	x	28.3
Roche park	Sea brine	1	3.4	3.0	3.3	3.1	2.8	3.0	3.1	3.3	2.6	2.7	2.7	2.6	2.9
		2	7.2	6.8	6.9	7.1	6.7	7.0	7.2	7.3	6.1	6.3	6.4	5.7	6.7
		3	12.3	12.1	12.0	11.8	11.9	12.0	12.1	12.1	11.5	11.3	12.2	11.1	11.9
		4	18.8	19.2	19.3	18.7	19.1	18.5	18.7	18.9	x	x	x	x	18.9
		5	28.2	28.4	28.7	28.5	x	x	28.1	28.9	x	x	x	x	28.5
Veppalodai	Sub soil brine	1	2.4	2.3	2.2	2.6	2.4	2.5	2.6	2.5	2.4	1.9	2.0	2.2	2.3
		2	6.2	6.1	5.7	6.4	6.4	5.8	6.7	6.0	6.0	5.0	5.7	5.5	5.9
		3	11.7	11.8	10.9	11.2	10.8	11.2	12.8	12.1	11.5	9.8	9.5	9.6	11.1
		4	16.3	15.9	15.3	16.3	16.5	17.2	17.7	18.2	16.4	x	x	15.8	16.6
		5	30.1	29.7	29.8	29.0	29.4	x	30.2	30.3	x	x	x	x	29.8
Tharuvaikulam	Sub soil brine	1	2.6	2.2	2.4	2.5	2.3	2.5	2.3	2.4	2.5	2.2	2.1	1.9	2.3
		2	6.2	4.8	5.1	5.9	4.7	6.1	6.1	5.9	6.1	5.3	4.6	4.0	5.4
		3	11.6	10.2	10.6	11.4	11.6	12.5	11.3	11.2	12.3	11.1	9.7	8.9	11.0
		4	19.2	15.2	16.7	17.8	17.4	16.2	16.1	17.5	16.8	15.4	14.6	x	16.6
		5	28.6	27.9	29.9	29.4	28.2	30.2	30.1	30.0	x	x	x	x	29.3
Pattanamaruthor	Sub soil brine	1	2.8	2.6	2.3	2.4	2.2	2.2	2.4	2.4	2.1	2.3	2.1	1.9	2.3
		2	6.3	6.1	5.5	6.4	5.0	4.8	5.9	6.2	5.6	6.3	5.7	5.5	5.8
		3	12.4	12.2	11.2	12.3	11.2	10.5	11.5	11.3	10.3	12.8	9.5	9.2	11.2
		4	18.3	18.1	17.8	16.4	x	15.8	17.3	15.4	15.4	16.2	x	x	16.7
		5	30.5	30.2	30.3	30.0	x	x	30.1	29.3	x	x	x	x	30.1

STAGES: 1- SOURCE *4- CRYSTALLISER*
2- RESERVOIR *5- BITTERN*
3- CONDENSER *X- SAMPLE NOT AVAILABLE DUE TO RAIN*

Table -2Sulphate (%)

Salt-Pans	Nature of brine	Stages	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
Therespuram	Sea brine	1	0.35	0.35	0.36	0.28	0.32	0.37	0.24	0.24	0.29	0.21	0.30	0.31	0.30
		2	1.17	1.18	0.90	0.94	1.06	1.02	0.64	0.80	1.24	1.04	1.28	1.02	1.02
		3	2.55	2.06	2.54	1.40	1.65	2.36	1.87	1.04	1.27	1.17	1.26	1.52	1.72
		4	3.25	2.96	3.17	2.47	x	3.05	2.78	2.04	1.32	2.67	x	x	2.63
		5	3.61	3.42	3.46	3.28	x	x	3.45	3.25	x	x	x	x	3.41
Roche park	Sea brine	1	0.38	0.38	0.30	0.31	0.31	0.30	0.21	0.25	0.37	0.28	0.24	0.30	0.30
		2	1.45	1.05	1.46	0.95	1.09	1.25	1.28	0.63	0.58	0.79	0.64	0.78	0.99
		3	2.16	2.14	1.88	1.66	1.67	1.56	1.13	1.20	2.36	1.40	1.89	1.59	1.72
		4	3.16	3.12	2.55	2.34	2.64	2.64	2.07	2.14	x	x	x	x	2.58
		5	3.85	3.67	3.21	2.74	x	x	3.54	2.52	x	x	x	x	3.30
Veppalodai	Sub soil brine	1	0.32	0.32	0.24	0.24	0.32	0.26	0.34	0.27	0.28	0.38	0.32	0.31	0.30
		2	0.88	1.05	0.83	0.76	0.87	0.94	1.09	1.09	1.02	1.18	1.06	1.16	0.99
		3	1.85	1.63	1.27	1.10	1.56	1.22	1.66	1.43	1.51	2.20	1.64	1.66	1.56
		4	2.75	2.58	2.39	2.64	2.64	2.36	2.58	2.44	2.53	x	x	2.98	2.59
		5	3.89	2.97	3.33	3.33	3.67	x	2.93	3.64	x	x	x	x	3.39
Tharuvaikulam	Sub soil brine	1	0.25	0.24	0.32	0.28	0.31	0.37	0.23	0.36	0.24	0.30	0.28	0.21	0.28
		2	0.80	0.70	0.89	0.93	1.06	0.88	0.71	1.47	0.70	1.05	1.04	0.78	0.92
		3	1.21	1.02	1.88	1.46	1.98	1.23	1.15	2.53	1.04	1.54	1.41	1.04	1.46
		4	2.18	2.06	2.74	2.39	2.48	2.37	2.60	3.12	2.06	2.61	2.48	x	2.09
		5	2.42	3.77	3.17	3.61	3.31	3.30	3.19	3.97	x	x	x	x	3.34
Pattanamaruthor	Sub soil brine	1	0.32	0.31	0.28	0.28	0.24	0.30	0.25	0.23	0.26	0.28	0.31	0.30	0.28
		2	1.10	0.79	0.96	1.04	0.90	1.06	0.80	1.24	0.95	1.02	0.98	1.02	0.99
		3	1.85	1.56	1.45	2.50	1.06	1.86	1.20	1.83	1.23	1.68	1.63	1.56	1.62
		4	2.64	2.64	2.46	2.65	x	2.48	2.16	2.60	2.30	2.64	x	x	2.51
		5	2.80	3.41	2.70	3.61	x	x	2.57	3.10	x	x	x	x	2.89

STAGES:

1- SOURCE *4- CRYSTALLISER*
2- RESERVOIR *5- BITTERN*
3- CONDENSER *X- SAMPLE NOT AVAILABLE DUE TO RAIN*

Table -3 Calcium (%)

Salt-Pans	Nature of brine	Stages	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
Therespuram	Sea brine	1	0.05	0.06	0.05	0.04	0.03	0.03	0.04	0.07	0.04	0.03	0.03	0.03	0.042
		2	0.10	0.14	0.17	0.15	0.07	0.08	0.10	0.12	0.09	0.08	0.06	0.07	0.103
		3	0.08	0.10	0.09	0.10	0.05	0.06	0.07	0.09	0.07	0.07	0.04	0.06	0.073
		4	0.06	0.08	0.04	0.08	x	0.05	0.06	0.06	0.05	0.04	x	x	0.058
		5	0.04	0.05	0.03	0.05	x	x	0.04	0.03	x	x	x	x	0.040
Roche park	Sea brine	1	0.05	0.07	0.05	0.06	0.05	0.04	0.06	0.05	0.04	0.04	0.04	0.03	0.048
		2	0.14	0.14	0.10	0.14	0.12	0.10	0.12	0.13	0.11	0.10	0.10	0.09	0.116
		3	0.08	0.09	0.06	0.07	0.08	0.06	0.07	0.09	0.07	0.06	0.07	0.05	0.071
		4	0.07	0.06	0.05	0.05	0.06	0.03	0.06	0.06	x	x	x	x	0.055
		5	0.04	0.03	0.04	0.04	x	x	0.03	0.05	x	x	x	x	0.038
Veppalodai	Sub soil brine	1	0.06	0.06	0.05	0.04	0.05	0.06	0.05	0.05	0.04	0.03	0.03	0.04	0.047
		2	0.15	0.10	0.15	0.12	0.13	0.15	0.06	0.12	0.11	0.10	0.11	0.09	0.116
		3	0.10	0.09	0.08	0.07	0.08	0.08	0.13	0.08	0.06	0.08	0.07	0.06	0.082
		4	0.07	0.07	0.07	0.05	0.06	0.05	0.09	0.05	0.05	x	x	0.04	0.060
		5	0.06	0.06	0.05	0.03	0.05	x	0.08	0.03	x	x	x	x	0.051
Tharuvaikulam	Sub soil brine	1	0.05	0.05	0.05	0.04	0.05	0.04	0.03	0.05	0.04	0.04	0.04	0.05	0.044
		2	0.10	0.14	0.16	0.16	0.18	0.11	0.08	0.13	0.09	0.10	0.12	0.08	0.120
		3	0.07	0.08	0.10	0.11	0.12	0.08	0.06	0.09	0.06	0.07	0.07	0.06	0.081
		4	0.06	0.05	0.08	0.07	0.08	0.07	0.05	0.08	0.05	0.05	0.06	x	0.064
		5	0.04	0.04	0.06	0.04	0.07	0.05	0.04	0.05	x	x	x	x	0.049
Pattanamaruthor	Sub soil brine	1	0.05	0.06	0.04	0.03	0.03	0.05	0.05	0.05	0.05	0.04	0.03	0.04	0.043
		2	0.12	0.14	0.12	0.09	0.06	0.11	0.15	0.12	0.15	0.10	0.05	0.07	0.107
		3	0.09	0.11	0.07	0.06	0.04	0.07	0.07	0.08	0.10	0.06	0.12	0.10	0.081
		4	0.07	0.09	0.06	0.05	x	0.05	0.06	0.05	0.06	0.04	x	x	0.059
		5	0.04	0.06	0.03	0.04	x	x	0.04	0.04	x	x	x	x	0.042

STAGES: 1- SOURCE *4- CRYSTALLISER*
2- RESERVOIR *5- BITTERN*
3- CONDENSER *X- SAMPLE NOT AVAILABLE DUE TO RAIN*

(viii) Percentage of calcium

The percentage of calcium increased from source to reservoir. Since maximum calcium sulphate got separated before the condenser stage, the values went on decreasing from reservoir to bittern through condenser and crystallizer. The average value at the sources of various salt pans ranged between 0.042^0 (Therespuram) and 0.048^0 Be (Roche park). The reservoir stage of the various salt pans had the value between 0.103^0 (Therespuram) and 0.120^0 Be (Tharuvaikulam). The average value at the condensers of various salt pans ranged between 0.071^0 (Roche park) and 0.082^0 Be (Veppalodai) and that of crystallizers between 0.055^0 (Roche park) and 0.064^0 Be (Tharuvaikulam). The bittern samples had an average of 0.038^0 (Roche park) and 0.049^0 Be (Tharuvaikulam).

(ix) Percentage of magnesium

The percentage of magnesium gradually increased from source to bittern stage. This is due to the presence of magnesium chloride and magnesium sulphate in the solution until the brine reaches 30^0Be. [11] The average value at the sources of various salt pans ranged between 0.22^0 (Veppalodai) and 0.18^0 Be (Therespuram). The reservoir stage of the various salt pans had the value between 0.84^0 (Tharuvaikulam) and 0.42^0 Be (Therespuram). The average value at the condensers of various salt pans ranged between 1.59^0 (Tharuvaikulam) and 1.23^0 Be (Therespuram) and crystallizers between 2.50^0 (Pattanamaruthor) and 2.38^0 Be (Therespuram, Roche park). The bittern samples had an average of 3.59^0 (Veppalodai) and 3.47^0 Be (Therespuram).

Table -4 Magnesium (%)

Salt-Pans	Nature of brine	Stages	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
Therespuram	Sea brine	1	0.16	0.24	0.17	0.19	0.15	0.19	0.20	0.18	0.16	0.20	0.19	0.17	0.18
		2	0.32	0.48	0.44	0.54	0.39	0.43	0.55	0.41	0.28	0.45	0.42	0.36	0.42
		3	1.35	1.46	1.63	1.72	1.08	1.28	0.66	1.62	1.17	0.87	1.03	0.94	1.23
		4	1.99	2.69	2.70	2.27	x	2.17	2.58	2.43	2.44	2.12	x	x	2.38
		5	3.24	3.55	3.84	3.64	x	x	3.03	3.51	x	x	x	x	3.47
Roche park	Sea brine	1	0.22	0.15	0.16	0.24	0.17	0.19	0.15	0.21	0.19	0.16	0.19	0.20	0.19
		2	0.60	0.33	0.41	0.86	0.64	0.50	0.52	0.49	0.53	0.42	0.34	1.69	0.61
		3	1.63	0.88	1.63	1.55	1.12	1.36	1.73	1.85	1.35	1.18	0.93	0.91	1.34
		4	2.46	2.24	2.61	2.60	1.91	2.17	2.44	2.57	x	x	x	x	2.38
		5	3.18	3.63	3.42	3.31	x	x	3.48	3.68	x	x	x	x	3.45
Veppalodai	Sub soil brine	1	0.24	0.25	0.21	0.23	0.22	0.19	0.22	0.24	0.21	0.21	0.23	0.23	0.22
		2	0.59	0.94	0.99	0.62	0.94	0.43	0.37	0.84	0.73	0.94	0.86	0.90	0.76
		3	1.35	1.32	1.63	1.85	1.32	1.44	1.67	1.97	1.72	1.28	1.10	1.22	1.49
		4	2.36	2.68	2.44	2.79	2.11	2.32	2.27	2.84	2.54	x	x	2.23	2.46
		5	3.66	3.23	3.56	3.70	3.57	x	3.76	3.65	x	x	x	x	3.59
Tharuvaikulam	Sub soil brine	1	0.17	0.24	0.24	0.23	0.18	0.20	0.22	0.25	0.20	0.24	0.19	0.20	0.21
		2	0.59	0.94	0.46	0.62	0.78	0.44	0.92	1.72	0.92	1.43	0.51	0.75	0.84
		3	1.45	1.75	1.87	1.93	1.64	1.63	1.54	1.77	1.65	1.25	1.26	1.30	1.59
		4	2.24	2.28	2.76	2.84	2.53	2.40	2.31	2.80	2.26	2.15	2.64	x	2.47
		5	3.36	3.39	3.79	3.75	3.57	3.40	3.31	3.65	x	x	x	x	3.53
Pattanamaruthor	Sub soil brine	1	0.24	0.23	0.21	0.19	0.22	0.24	0.25	020	0.21	0.16	0.17	0.21	0.21
		2	0.87	0.78	0.82	0.84	0.57	0.86	0.64	0.67	0.98	0.86	0.87	0.54	0.78
		3	1.59	1.77	1.45	1.85	1.28	1.34	1.85	1.76	1.23	1.32	1.21	1.20	1.49
		4	2.20	2.32	2.67	2.87	x	2.96	2.09	2.75	2.34	2.31	x	x	2.50
		5	3.19	3.79	3.58	3.70	x	x	3.36	3.64	x	x	x	x	3.54

STAGES: 1- SOURCE *4- CRYSTALLISER*
2- RESERVOIR *5- BITTERN*
3- CONDENSER *X- SAMPLE NOT AVAILABLE DUE TO RAIN*

(x) Percentage of sodium

The percentage of sodium gradually increased from source to crystallizer. Maximum sodium chloride got separated in the crystallizer stage and so the value is low at bittern stage. The presence of sodium at the bittern stage indicates that not all sodium gets separated as sodium chloride. [12] The average value at the sources of various salt pans ranged between 0.74^0(Veppalodai) and 0.81^0 Be (Therespuram). The reservoir stage of the various salt pans had the value between 1.07^0 (Veppalodai) and 1.12^0 Be (Therespuram) . The average value at the condensers of various salt pans ranged between 1.24^0 (Pattanamaruthor) and 1.27^0 Be (Therespuram) and at the crystallizers the value ranges between 1.35^0 (Tharuvaikulam, Pattanamaruthor) and 1.43^0 Be Therespuram) The bittern samples had an average of 0.77^0 (Tharuvaikulam) and 0.97^0 Be (Therespuram).

Table -5 Sodium (%)

Salt-Pans	Nature of brine	Stages	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
Therespuram	Sea brine	1	0.83	0.90	0.80	0.86	0.78	0.74	0.82	0.80	0.95	0.73	0.85	0.70	0.81
		2	1.04	1.10	1.26	1.19	1.16	1.15	1.20	1.22	0.99	0.96	1.06	1.10	1.12
		3	1.21	1.25	1.28	1.20	1.22	1.28	1.22	1.27	1.38	1.28	1.23	1.37	1.27
		4	1.36	1.48	1.50	1.50	x	1.34	1.41	1.40	1.34	1.50	x	x	1.43
		5	1.80	0.90	0.74	0.74	x	x	0.80	0.83	x	x	x	x	0.97
Roche park	Sea brine	1	0.81	0.85	0.89	0.75	0.72	0.75	0.84	0.86	0.69	0.75	0.81	0.69	0.78
		2	0.92	1.10	1.12	1.15	0.95	0.97	1.16	1.03	1.22	0.97	1.14	1.17	1.08
		3	1.20	1.28	1.26	1.27	1.22	1.26	1.27	1.24	1.21	1.29	1.27	1.28	1.25
		4	1.36	1.45	1.45	1.41	1.31	1.36	1.43	1.46	x	x	x	x	1.40
		5	0.83	0.68	1.72	0.93	x	x	0.81	0.92	x	x	x	x	0.82
Veppalodai	Sub soil brine	1	0.75	0.90	0.65	0.70	0.65	0.70	0.73	0.87	0.61	0.76	0.87	0.75	0.74
		2	1.04	1.05	1.10	1.19	0.97	0.93	1.12	1.16	0.97	1.16	1.11	1.09	1.07
		3	1.20	1.25	1.25	1.25	1.21	1.24	1.25	1.28	1.28	1.23	1.29	1.26	1.25
		4	1.49	1.30	1.41	1.39	1.31	1.35	1.35	1.41	1.30	x	x	1.32	1.36
		5	0.81	0.76	0.91	0.85	0.82	x	0.82	0.79	x	x	x	x	0.96
Tharuvaikulam	Sub soil brine	1	0.70	0.65	0.75	0.88	0.73	0.64	0.71	0.85	0.84	0.87	0.64	0.76	0.75
		2	1.11	1.15	1.11	1.18	1.17	1.16	1.12	0.98	1.13	0.99	0.97	1.15	1.10
		3	1.20	1.28	1.27	1.22	1.29	1.27	1.20	1.26	1.25	1.23	1.28	1.21	1.25
		4	1.34	1.30	1.37	1.32	1.36	1.35	1.36	1.38	1.31	1.36	1.39	x	1.35
		5	0.70	0.75	0.85	0.83	0.76	0.68	0.78	0.83	x	x	x	x	0.77
Pattanamaruthor	Sub soil brine	1	0.84	0.65	0.76	0.84	0.85	0.65	0.75	0.83	0.80	0.85	0.63	0.75	0.77
		2	1.14	0.95	1.16	1.19	1.16	0.94	1.15	1.12	1.16	1.13	1.08	1.06	1.10
		3	1.22	1.20	1.21	1.27	1.24	1.21	1.23	1.28	1.24	1.22	1.26	1.27	1.24
		4	1.31	1.35	1.36	1.38	x	1.36	1.35	1.35	1.37	1.32	x	x	1.35
		5	0.77	0.85	0.87	0.79	x	x	0.87	0.74	x	x	x	x	0.82

STAGES: 1- SOURCE *4- CRYSTALLISER*
2- RESERVOIR *5- BITTERN*
3- CONDENSER *X- SAMPLE NOT AVAILABLE DUE TO RAIN*

Table -6 Potassium (%)

Salt-Pans	Nature of brine	Stages	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
Therespuram	Sea brine	1	0.030	0.032	0.036	0.030	0.030	0.032	0.030	0.028	0.026	0.026	0.028	0.026	0.029
		2	0.042	0.046	0.042	0.040	0.038	0.042	0.046	0.038	0.044	0.034	0.038	0.034	0.040
		3	0.056	0.056	0.052	0.052	0.048	0.052	0.052	0.050	0.054	0.046	0.046	0.048	0.051
		4	0.064	0.064	0.066	0.060	x	0.062	0.060	0.062	0.068	0.064	x	x	0.063
		5	0.078	0.080	0.082	0.082	x	x	0.078	0.080	x	x	x	x	0.080
Roche park	Sea brine	1	0.034	0.030	0.034	0.032	0.030	0.030	0.030	0.032	0.028	0.026	0.028	0.026	0.030
		2	0.044	0.042	0.046	0.040	0.038	0.044	0.042	0.046	0.036	0.034	0.036	0.040	0.041
		3	0.056	0.054	0.050	0.056	0.052	0.052	0.054	0.052	0.048	0.046	0.048	0.046	0.051
		4	0.068	0.062	0.062	0.066	0.060	0.064	0.066	0.068	x	x	x	x	0.065
		5	0.084	0.076	0.084	0.082	x	x	0.080	0.078	x	x	x	x	0.080
Veppalodai	Sub soil brine	1	0.032	0.034	0.030	0.032	0.030	0.032	0.032	0.032	0.026	0.028	0.026	0.028	0.030
		2	0.042	0.042	0.036	0.040	0.038	0.044	0.044	0.040	0.034	0.032	0.036	0.038	0.038
		3	0.056	0.054	0.048	0.052	0.052	0.052	0.050	0.054	0.042	0.046	.044	0.046	0.049
		4	0.066	0.064	0.062	0.066	0.062	0.060	0.064	0.064	0.058	x	x	0.056	0.062
		5	0.080	0.082	0.080	0.078	0.078	x	0.076	0.082	x	x	x	x	0.079
Tharuvaikulam	Sub soil brine	1	0.034	0.034	0.032	0.030	0.030	0.032	0.030	0.034	0.030	0.028	0.032	0.024	0.031
		2	0.042	0.042	0.046	0.038	0.042	0.042	0.040	0.044	0.038	0.038	0.038	0.034	0.040
		3	0.056	0.056	0.058	0.048	0.050	0.054	0.054	0.056	0.044	0.042	0.046	0.042	0.051
		4	0.068	0.062	0.066	0.062	0.064	0.062	0.062	0.068	0.052	0.054	0.050	x	0.061
		5	0.086	0.080	0.078	0.084	0.080	0.080	0.078	0.084	x	x	x	x	0.081
Pattanamaruthor	Sub soil brine	1	0.034	0.032	0.032	0.034	0.026	0.030	0.028	0.032	0.032	0.030	0.022	0.024	0.029
		2	0.044	0.046	0.040	0.044	0.036	0.038	0.042	0.042	0.044	0.036	0.030	0.036	0.039
		3	0.056	0.052	0.050	0.050	0.048	0.054	0.054	0.056	0.050	0.044	0.042	0.042	0.049
		4	0.064	0.062	0.066	0.062	x	0.066	0.062	0.066	0.058	0.052	x	x	0.062
		5	0.078	0.080	0.080	0.080	x	x	0.078	0.078	x	x	x	x	0.079

STAGES: 1- SOURCE *4- CRYSTALLISER*
2- RESERVOIR *5- BITTERN*
3- CONDENSER *X- SAMPLE NOT AVAILABLE DUE TO RAIN*

(xi) Percentage of potassium

The percentage of potassium gradually increased from source to bittern as no potassium salt is separated before the bittern stage. This was in accordance with the findings of earlier that brines of 30^0 Be or above had maximum amount of potassium. [13] The average value at the sources of various salt pans ranged between 0.029^0 (Therespuram, Pattanamaruthor) and 0.03^0 Be (Roche park, Veppalodai, Tharuvaikulam). The reservoir stage of the various salt pans had the value between 0.038^0 (Veppalodai) and 0.041^0 Be (Roche park). The average value at the condensers of various salt pans ranged between 0.049^0 (Veppalodai, Pattanamaruthor) and 0.051^0 Be (Therespuram, Roche park, Tharuvaikulam) and crystallizers between 0.061^0 (Tharuvaikulam) and 0.065^0 Be (Roche park). The bittern samples had an average of 0.079^0 (Veppalodai, Pattanamaruthor) and 0.081^0 Be (Tharuvaikulam).

CONCLUSION

The physical and chemical parameters and their seasonal fluctuations of the various stages of different salt-pans were studied for a period of one year. The parameters were maximum during the pre-monsoon period and as monsoon proceeded, the values went on decreasing. The monitoring of Physico-chemical parameters of brine at various stages viz., source, reservoir, condenser, crystallizer and bittern of the different salt pans of the district provides ample scope for the management of the salt-pans.

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