The role of ion pairs and ion activity in classification of ground waters for irrigation in Erbil plain

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Abstract:

This study was conducted to investigate the effect of ion pairs and ion activity on classification of ground waters. The investigation was included chemical analyses of water of (38) wells, according to Richards (US) classification (1954) the water of (18) wells having C_2S_1 class, water of (16) wells having C_3S_1 class and the water of (4) wells were not suitable for irrigation since they have C_4S_1 class. Correcting ion pairs and ionic activity caused the change of water class of well number (38) from C_4S_1 to C_4S_2 class. On the other hand, correcting ion pairs and ion activity caused the change of water classes of wells number (24, 25 and 27) from moderate class to good class and has changed water of well number 30 from bad to moderate class, the similar effect of ion pairs and ion activity noticed in some other classifications.

Keywords: Water classification, ion pairs, ion activity, Ground water.

I. Introduction:

Water is an essential element for maintaining a productive environment and adequate food supply for human, animal and plant population [1]. The areas of irrigated lands in Iraqi Kurdistan region is expanding very slowly due to the shortage of irrigation water and irrigation projects. The irrigation water quality depends on the water resources, chemical composition of the rocks, soils in surrounding catchment areas, impoundment run-off water, environmental factors……. ..etc. Numerous studies have been done on groundwater quality in Kurdistan Region during the last six decades, but they have not included ion pairs and ionic activity. It has been shown that the ion pairs and ionic activity are playing an important role in limiting groundwater suitability and their classification for irrigation [3], therefore it is necessary to highlight on their role in groundwater classification for irrigation.

The phenomenon of ion pairs has been defined as a process when soluble cations and anions in irrigation water will approach to each other for a distance of five angstrom or less, this causes the connect ions which have different charges through columbic force while each of the connected ions keeps its hydration shell, (4and 5).

The relation between concentrations and the ionic activity was described by [5] as follow:

$$a = y * c \quad \text{..... [4]}$$

Where: a = Ionic activity, γ = Activity coefficient, and c = Ion concentration.

The ionic strength (I) of water was calculated by the following expression:

$$I = \frac{1}{2}\sum_{i=1}^{n} c_i z_i^2$$ ……..... [5]

Where: Ci is the actual molar concentration of each ion in the solution and Zi is its valence.

The ionic strength plays an important role in the Davies equation as follows :

$$log\,\gamma_i = -A\,z_i^2\left(\frac{\sqrt{I}}{1+\sqrt{I}} - 0.3I\right)$$ ..... [6]

Where: I = Ion strength (mol.L^{-1}). A = 0.509 at 25 Cº has been modified to be use up to I = 0.1 mol.L^{-1}. , B = 0.3285 at 25 Cº , Zi = Ionic charge, d = Ion size parameter.

There are numerous classifications for irrigation water; in this investigation the following classifications were depended:

A. US DA classification (1954) [6]:

and sodium adsorption ratio (SAR).

B. Doneen Classification (1954)

This investigator was depended on soil permeability and salinity potential (SP) of irrigation water for classification of waters into (3) classes as follow [7]:

Water quality	SP=[Cl^- +0.5 SO_4^{2-}] $mmol_c.L^{-1}$		
	High	Moderate	Low
Good	<7	<5	<3
Moderate	7-15	5-10	3-5
Bad	>15	>10	>5

C. Wilcox classification (1955):

Depending on residual sodium carbonate (RSC = [CO_3+HCO_3] - [Ca+Mg]) the irrigation water had been classified to into three classes [8] as follow:

Water class	RSC($mmol_c.L^{-1}$)
Probably safe	<1.25
Marginal	1.25-2.50
Unsuitable	>2.50

D. Ayers and Westcot classification:

The most accepted classification of irrigation water depending on ECiw, the permeability of the soil, toxic effect of ions and the side effects of some ions was proposed by [9].

Potential irrigation problem	Degree of restriction of use		
	None	Slight to moderate	Severe
EC (dS..m^{-1})	<0.7	0.7-3.0	>3.0
SAR	<3.0	3-9	>3.0

Since there are numerous studies about the water quality for irrigation purpose, but most of them are not included ion pairs and ionic activity for the above reasons, the aim of this study was to throw light on the role of correcting ion pairing and ionic activity in classification of some ground waters in Erbil plain, Kurdistan region, Iraq for irrigation purpose.

II. Materials and methods:

This study was conducted during the hydrological year from October 2009 to September 2010 which involved the following steps:

Water samples were taken at seasonal intervals during the water year (from October 2009 to September 2010) from 38 locations in Erbil plain (figure, 1) water samples were collected at each location according to [10]. In return to laboratory water samples were kept in a refrigerator. The chemical properties of water samples did not differ significantly among the studied seasons and did not caused change in water class ,therefore the classification was done depending on means of the water chemical properties during the studied period. The water chemical analyses included (pH, EC, concentration of (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-} , Cl^{-} and SO_4^{2-}) which were determined according to the standard methods mentioned by APHA (1989). Ion pairs and ion activity were determined according to ion pair program [11].

III. Results and discussion:

Classification of water for irrigation:

The results of ground water classification according to [6, 7, 8 and 9] were recorded in table (I). Effect of ion pairs and ionic activity on water classification. Correcting for ion pairs was caused conversion of some studied water from one class to another depending on some global classification of irrigation water as follows:

wells.

Correcting ion pairs has led to an increase

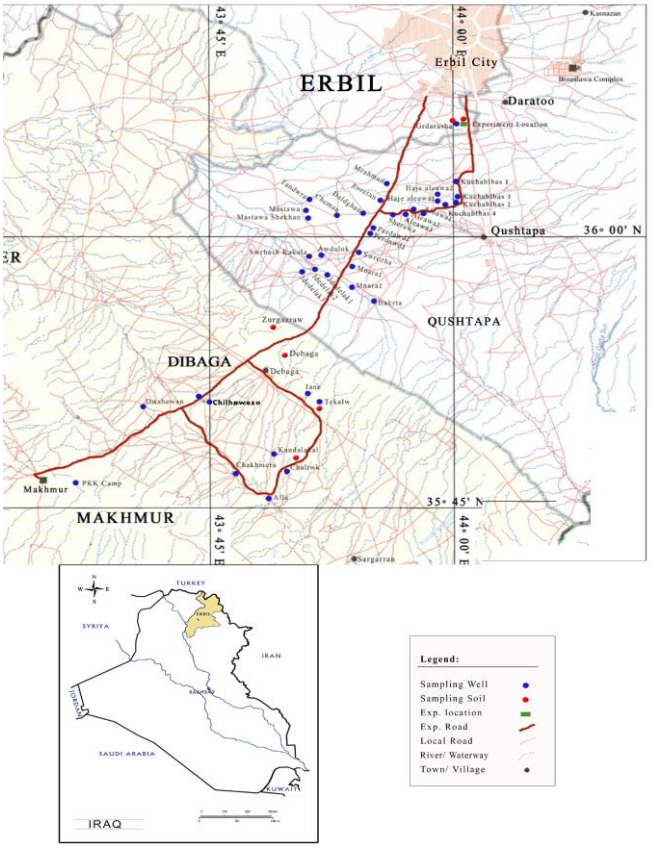

Fig.1: Locations map of the studied area.

in the SAR to a certain level without conversion water quality from class to another class (figure, 2). While correcting ion pairs and ionic activity was caused a conversion of water class of well number (38) from (C_4S_1) to (C_4S_2) class depending on [7]. Depending on [10] correcting of ion pairs caused change of water class of the well number (38) from (slight to moderate severe class) degree of restriction of use classes to (severe class) degree of restriction of use classes. While the correction of ion pairs and activity caused the change of water class of the well (23) from (none severe class) to

(Slight to moderate severe) degree of restriction of use classes respectively. This may be due to high contribution of Ca^{2+}

and Mg^{2+} in ion pairing (0.03- 6.36) and (0.02-5.46) mmolc.L^{-1} respectively in comparing with sodium ion (Na^{+}) (0.001-0.734) mmolc . L^{-1}, the highest activity coefficient of Na^{+} (0.88) in comparing with Ca^{2+} and Mg^{2+} (0.62 and 0.64) mmolc.L^{-1} respectively. This caused an increase in SAR values after correcting ion pairs and activity. Correcting of ion pairs and ionic activity caused (1.11 and 1.25) times increase in SAR values. This due to the reasons mentioned before. Similar results were recorded by [11 and 12].

Effect of ion pairs and ionic activity on groundwater classification depending on salinity potential:

Figures (3, 4 and 5) show the effect of correcting ion pairs and ionic activity on water classification for irrigation purpose depending on salinity potential (SP) as follow:

1- For low permeable soils the water of wells (24, 25 and 27) were changed from moderate class to good class and water of the well number (30) was changed from bad class to moderate class after correcting ion pairs. While after correcting ion pairs and ionic activity water of the wells (26, 28, 29 and 31) were changed from moderate classes to a good class and water of wells (32 and 33) changed from bad class to moderate class. This due to the high contribution of SO_4^{2-} in ion pairs which caused a decrease in the salinity potential of the irrigation water (figure, 3).

2- For moderate permeable soils, the correcting ion pairs of irrigation water caused change water class of well number (30) from moderate to good class and well numbers (35) and (36) from bad to moderate class, while correcting both ion pairs and ion activity caused a change in water class of the well number (32 and 33) from moderate to good class and water class of well number (34) changed from bad to moderate class. These changes were due to the reasons mentioned before (figure 4).

3-For the high permeable soils, correcting of ion pairs caused a change in water quality of the well number (32 and 33) from moderate class to good class, while correcting of both ion pairs and ion activity caused conversion in water quality of wells numbered (35 and 36) from moderate to good class and change in water quality of well (38) from bad to moderate class (figure, 5). These could be due to high contribution of SO_4^{2-} in ion pairs (0.024 - 12.929) mmolc. L^{-1} and low value of its activity coefficient (0.60). The above results are similar to those recorded by [13, 14 and 15].

Table.I: Classification of the studied water depending on some classification systems.

Well No.	USDA (1954)	Doneen(1954) depending on soil permeability			Wilcox (1955)		Ayers and Wescot (1985)		Don(1995)
		Low	Moderate	High	RSC	EC	SAR	EC	
1 - 18	C_2S_1	1-23 Good	(1-29) and 31 Good	1-31 Good	1 to 38 Probably safe from	1-18 Good	(1-30), (32-33) and (35-36) N0ne	1-16 None	1-18 Good
19-34	C_3S_1					19-33 Permissible		17-36 Slight to Moderate	19-33 Permissible
35-38	C_4S_1	24-29 and 31 Moderate	(30,32 and 33 Moderate	32-36 Moderate		34-36 Doubtful			
	C_2S_1	32-38 and 30 bad	34-38 Bad	37-38 Bad		37-38 Unsuitable	(31,34,37 and 38) Slight to Moderate	37-38 Severe	34-36 Doubtful
									37-38 Unsuitabl

Table.II: The mean of some chemical properties of the studied water.

No.	mmol$_c$.L^{-1}								pH	EC dS.m^{-1}
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^{-}	SO_4^{2-}	HCO_3^{--}		
1.	0.82	0.70	1.72	0.03	0.35	0.20	0.32	2.45	7.54	0.34
2.	2.23	1.33	0.45	0.02	0.31	0.33	0.48	2.98	7.48	0.41
3.	2.45	1.32	0.41	0.02	0.35	0.29	0.25	3.30	7.26	0.41
4.	2.31	1.12	0.62	0.02	0.36	0.27	0.53	2.95	7.69	0.42
5.	1.88	1.51	0.94	0.02	0.33	0.41	0.54	2.62	7.62	0.43
6.	2.34	1.47	0.52	0.02	0.42	0.38	0.51	3.00	7.23	0.45
7.	2.35	1.58	0.53	0.02	0.46	0.64	0.51	3.05	7.25	0.45
8.	2.70	1.43	0.43	0.03	0.32	0.26	0.87	3.13	7.48	0.46
9.	2.84	1.54	0.63	0.02	0.40	0.43	0.53	3.71	7.30	0.49
10.	2.73	1.74	0.70	0.03	0.39	0.46	1.19	3.17	7.57	0.51
11.	2.95	1.79	0.70	0.03	0.44	0.64	1.57	2.84	7.41	0.54
12.	2.90	1.58	0.98	0.03	0.49	0.44	0.91	3.74	7.40	0.56
13.	3.13	1.65	0.66	0.02	0.57	0.67	0.76	3.27	7.12	0.56
14.	3.64	1.98	0.72	0.02	0.45	0.85	2.35	2.94	7.38	0.64
15.	3.96	1.97	0.60	0.02	0.41	0.53	2.55	3.09	7.56	0.65
16.	3.35	2.69	1.28	0.02	0.45	0.32	1.68	5.00	7.24	0.69
17.	3.46	2.53	1.22	0.04	0.61	0.63	1.41	4.49	7.33	0.70
18.	3.41	2.58	1.05	0.03	0.43	0.41	1.61	4.89	7.19	0.72
19.	2.31	2.65	2.44	0.04	1.15	1.64	2.06	2.77	7.24	0.78
20.	3.91	2.56	1.88	0.03	0.54	0.30	1.72	5.53	7.08	0.79
21.	4.41	3.18	1.67	0.03	0.57	0.45	2.84	5.38	7.15	0.83
22.	3.35	3.47	1.74	0.03	1.22	0.27	3.53	3.96	7.30	0.87
23.	3.58	3.54	5.04	0.05	0.98	1.04	3.79	4.19	7.38	1.04
24.	3.76	4.12	3.18	0.06	1.45	2.13	3.22	4.14	7.18	1.13
25.	7.74	2.55	3.19	0.03	0.70	0.25	5.03	6.92	7.04	1.19
26.	4.46	5.38	3.62	0.03	1.24	0.32	5.93	6.11	7.08	1.24
27.	3.88	5.00	3.77	0.19	1.30	0.59	4.04	6.12	7.45	1.29
28.	7.41	4.09	2.57	0.03	0.77	0.23	6.51	6.85	7.05	1.33
29.	4.68	5.78	3.87	0.07	1.55	0.49	4.96	7.21	7.16	1.37
30.	5.83	6.21	4.65	0.04	1.82	0.56	7.14	7.32	7.07	1.56
31.	4.28	4.42	7.68	0.06	1.16	1.95	6.52	5.68	7.19	1.56
32.	8.83	4.93	5.53	0.04	2.18	0.75	10.47	6.16	7.31	1.86
33.	6.14	8.27	4.91	0.05	2.51	0.62	9.11	7.82	7.21	1.94
34.	5.53	5.48	13.30	0.11	5.63	0.55	17.16	1.77	7.62	2.45
35.	7.76	11.02	6.33	0.05	2.56	0.54	16.46	7.40	7.07	2.49
36.	12.43	10.85	2.02	0.13	1.86	0.08	18.36	5.38	7.08	2.59
37.	18.19	15.56	17.55	0.13	11.47	3.27	31.57	3.57	7.19	4.92
38.	16.68	14.58	30.05	0.15	4.39	2.60	50.16	3.02	7.52	5.65

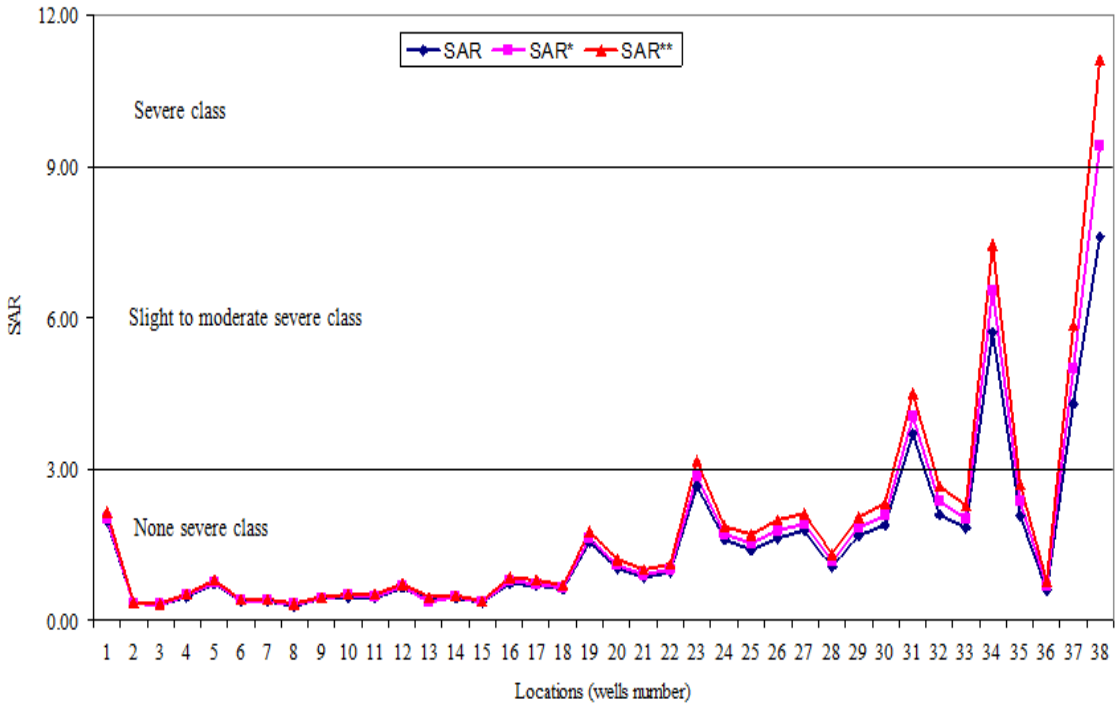

Fig. 2: Effect of ion pairs and ionic activity on SAR values**.**
SAR= Sodium adsorption ratio before correcting ion pairs. SAR*= Sodium adsorption ratio after correcting ion pairs.
SAR**= Sodium adsorption ratio after correcting ion pairs and ionic activity.

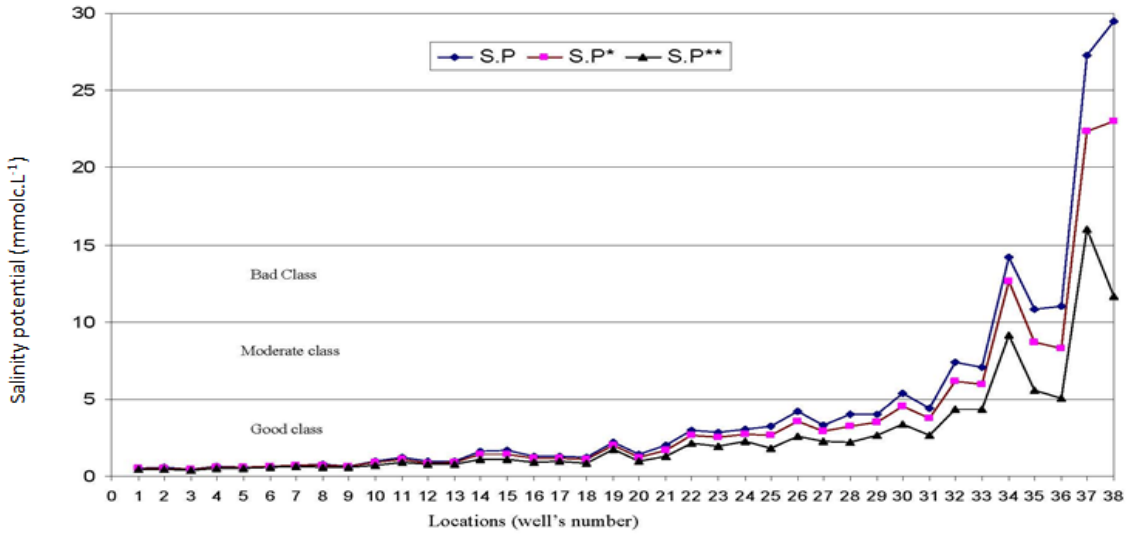

Fig. 3: Effect of ion pairs and activity on salinity potential of irrigation water for low permeable soils. S.P = Salinity potential before correcting ion pairs. S.P* = Salinity potential after correcting ion pairs. S.P** = Salinity potential after correcting ion pairs and activity.

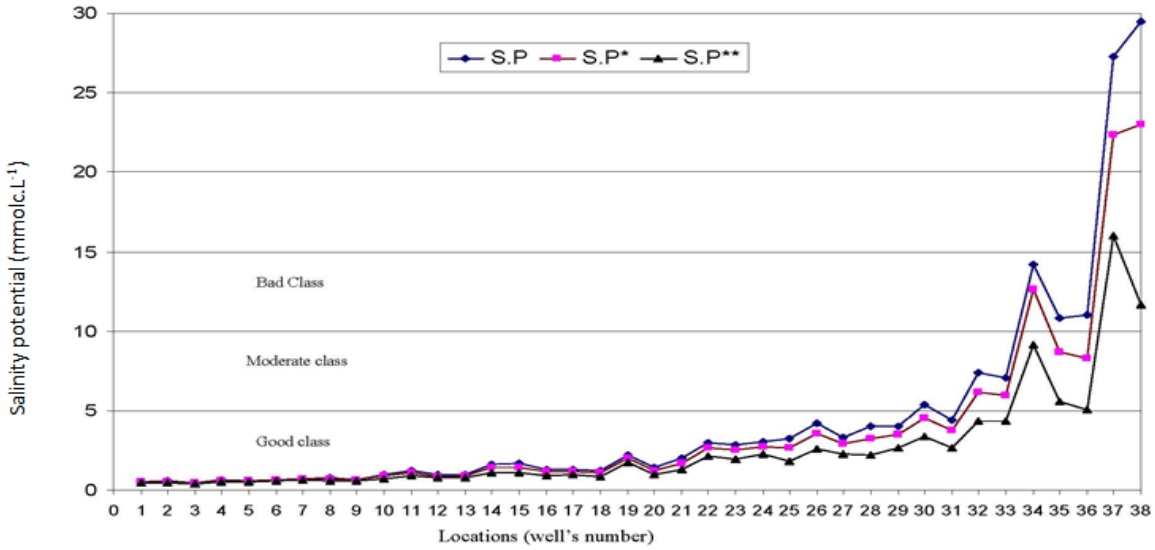

Fig. 4 Effect of ion pairs and activity on salinity potential of irrigation water for moderate permeable soil. S.P = Salinity potential before correcting ion pairs. S.P* = Salinity potential after correcting ion pairs. S.P** = Salinity potential after correcting ion pairs and activity.

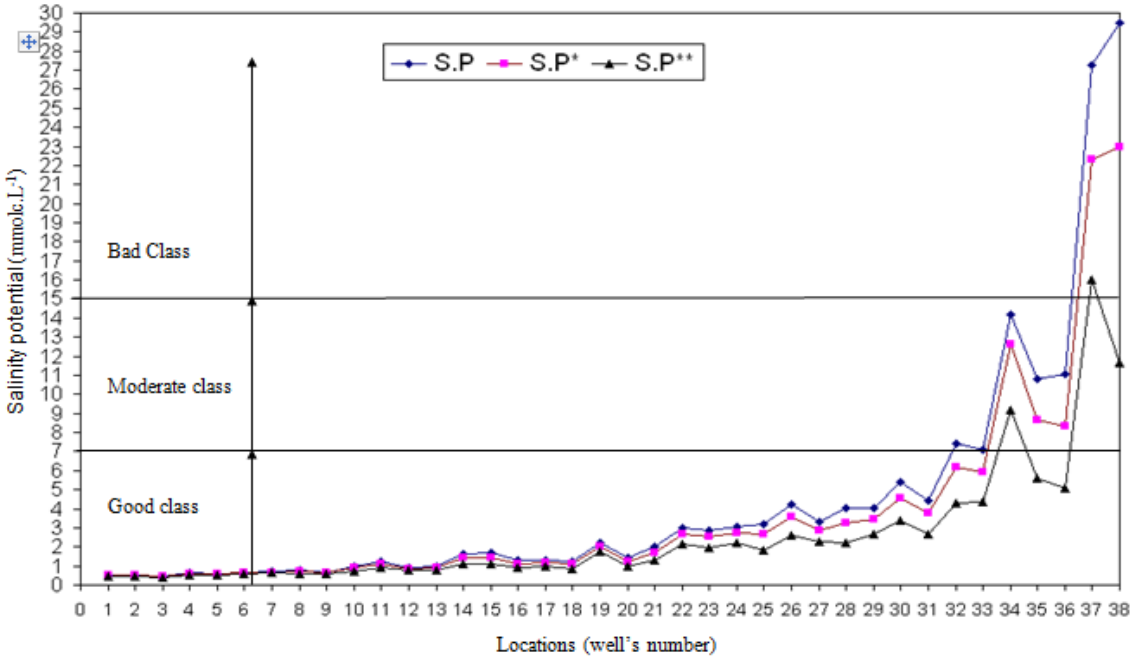

Fig. 5 Effect of ion pairs and activity on salinity potential of irrigation wate for high permeable soils. S.P = Salinity potential before correcting ion pairs. S.P* = Salinity potential after correcting ion pairs. S.P** = Salinity potential after correcting ion pairs and activity.

IV. Conclusion:

Correcting ion pairs and activity causes increase in SAR value of irrigation water, on the other hand causes decrease in salinity potential of irrigation water. Conversion the water class from class to another class depends on type and amount of ion pairs in irrigation water.

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