

## List of Tables

**Table 1** Categorization for IWQ index parameters (based on, Ayers and Westcot 1985).

Hazards with weight ( <i>w</i> ) and rating ( <i>r</i> )		
<p><b>1. Salinity hazard (N=2; w=5)</b></p> <p>(a) EC &lt; 700 (<i>r</i>=3) 700 ≤ EC ≤ 3000 (<i>r</i>=2) EC &gt; 3000 (<i>r</i>=1)</p> <p>(b) TDS &lt; 450 (<i>r</i>=3) 450 ≤ TDS ≤ 2000 (<i>r</i>=2) TDS &gt; 2000 (<i>r</i>=1)</p> <p><b>2. Permeability hazard (N=1; w=4)</b></p> <p>SAR &lt; 3 (highest score of this study) EC &gt; 700 (<i>r</i>=3) EC = 700 - 200 (<i>r</i>=2) EC &lt; 200 (<i>r</i>=1)</p> <p><b>3. Specific ion toxicity (N=3; w=3)</b></p> <p>(a) SAR &lt; 3.0 (<i>r</i>=3) 3.0 ≤ SAR ≤ 9.0 (<i>r</i>=2) SAR &gt; 9.0 (<i>r</i>=1)</p> <p>(b) B &lt; 0.7 (<i>r</i>=3) 0.7 ≤ B ≤ 3.0 (<i>r</i>=2) B &gt; 3.0 (<i>r</i>=1)</p> <p>(c) Cl &lt; 140 (<i>r</i>=3) 140 ≤ Cl ≤ 350 (<i>r</i>=2) Cl &gt; 350 (<i>r</i>=1)</p>	<p><b>4. Trace metal toxicity (N=7; w=2)</b></p> <p>(a) Fe &lt; 5.0 (<i>r</i>=3) 5.0 ≤ Fe ≤ 20.0 (<i>r</i>=2) Fe &gt; 20.0 (<i>r</i>=1)</p> <p>(b) Mn &lt; 0.2 (<i>r</i>=3) 0.2 ≤ Mn ≤ 10.0 (<i>r</i>=2) Mn &gt; 10.0 (<i>r</i>=1)</p> <p>(c) Cr &lt; 0.1 (<i>r</i>=3) 0.1 ≤ Cr ≤ 1.0 (<i>r</i>=2) Cr &gt; 1.0 (<i>r</i>=1)</p> <p>(d) Pb &lt; 5.0 (<i>r</i>=3) 5.0 ≤ Pb ≤ 10.0 (<i>r</i>=2) Pb &gt; 10.0 (<i>r</i>=1)</p> <p>(e) Co &lt; 0.05 (<i>r</i>=3) 0.05 ≤ Co ≤ 5.0 (<i>r</i>=2) Co &gt; 5.0 (<i>r</i>=1)</p> <p>(f) Cu &lt; 0.2 (<i>r</i>=3) 0.2 ≤ Cu ≤ 5.0 (<i>r</i>=2) Cu &gt; 5.0 (<i>r</i>=1)</p> <p>(g) Zn &lt; 2 (<i>r</i>=3) 2 ≤ Zn ≤ 10 (<i>r</i>=2) Zn &gt; 10.0 (<i>r</i>=1)</p>	<p><b>5. Miscellaneous effects (N=3; w=1)</b></p> <p>(a) HCO<sub>3</sub><sup>-</sup> &lt; 90 (<i>r</i>=3) 90 ≤ HCO<sub>3</sub><sup>-</sup> ≤ 500 (<i>r</i>=2) HCO<sub>3</sub><sup>-</sup> &gt; 500 (<i>r</i>=1)</p> <p>(b) NO<sub>3</sub><sup>-</sup> &lt; 5 (<i>r</i>=3) NO<sub>3</sub><sup>-</sup> = 5-30 (<i>r</i>=2) NO<sub>3</sub><sup>-</sup> &gt; 30 (<i>r</i>=1)</p> <p>(c) 7.0 ≤ pH ≤ 8.0 (<i>r</i>=3) 6.5 ≤ pH &lt; 7.0; 8.0 &lt; pH ≤ 8.5 (<i>r</i>=2) pH &lt; 6.5 or pH &gt; 8.5 (<i>r</i>=1)</p>

**Table 2** List of irrigation water evaluation indices

Parameters name	Equation	Reference
Total hardness, TH	$TH = 2.497Ca^{2+} + 4.115Mg^{2+}$	Todd, (1980); Ragunath, (1987); Hem, (1991)
Percent sodium, Na%	$Na\% = \frac{Na \times 100}{(Ca^{2+} + Mg^{2+} + Na^+)}$	Todd, (1980)
Sodium adsorption ratio, SAR	$SAR = \frac{Na^+}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}}$	Richards, (1954)
Saturated sodium percentage, SSP	$SSP = \frac{(N^+ + K^+) \times 100}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)}$	Todd, (1980)
Residual sodium bi-carbonate, RSBC	$RSBC = HCO_3^- - Ca^{2+}$	Gupta, (1983)
Permeability index, PI	$PI = \frac{(Na + \sqrt{HCO_3^-}) \times 100}{(Na + Ca^{2+} + Mg^{2+})}$	Doneen, (1964)
Magnesium adsorption ratio, MAR	$MAR = \frac{(Mg^{2+} \times 100)}{(Ca^{2+} + Mg^{2+})}$	Ragunath, (1987)
Kelly's ratio, KI	$KR = \frac{Na^+}{(Ca^{2+} + Mg^{2+})}$	Kelley, (1963)

**Table 3** Destructive statistics of chemical composition in groundwater during the PRM and POM and comparison with different irrigation water standards.

Parameter*	Pre-monsoon, PRM (n = 40)				Post-monsoon, POM (n = 40)				Irrigation water standards		
	Mean	Min.	Max.	±SD	Mean	Min.	Max.	±SD	DoE (1997)	UCCC (1974)	FAO (1985)
Depth	50.03	22	125	31.90	50.03	22	125	31.9	-	-	-
pH	7.02	6.65	7.80	0.218	7.83	7.0	8.91	0.404	6.5-8.5	6.5-8.4	6.5-8.5
EC	669.95	366	1035	172.5	956.8	662	1708	206.1	1000	700-3000	3000
TDS	413.15	219	675	113.21	601.5	450.5	1109	156.2	-	450-2000	2000
T. Salinity	77.13	45.8	104.2	13.73	71.22	46.81	87.07	12.7	-	-	-
Ca	95.64	56.6	151.4	22.46	114.4	67.2	187.8	26.87	75	-	400
Mg	32.62	13.0	63.8	12.31	28.96	14.0	52.6	9.438	30-35	-	60
Na	14.12	5.10	71.6	11.68	11.56	3.90	51.6	8.7303	200	70-300	900
K	1.27	0.30	2.90	0.717	1.013	0.20	2.90	0.682	12	-	2
B	0.202	0.001	1.20	0.314	0.223	0.001	1.25	0.343	<1.0	0.7-3	2
Cl <sup>-</sup>	31.19	12.0	562	9.292	27.09	12.9	41.8	7.604	150-600	140-350	1000
HCO <sub>3</sub> <sup>-</sup>	418.6	271.5	703	110.81	448.78	248.5	817	124.45	-	90-500	600
SO <sub>4</sub> <sup>2-</sup>	16.46	2.91	45.7	9.292	15.14	2.95	41.7	9.246	400	-	900
NO <sub>3</sub> <sup>-</sup>	4.14	0.80	14.3	3.805	3.695	0.80	18.3	3.641	10	-	10
PO <sub>4</sub> <sup>3-</sup>	0.99	0.21	2.90	0.604	0.908	0.20	2.10	0.512	0.2	-	2
									Recommended limit**		
									Long-term use	Short-term use	
Fe	7.18	0.60	14.71	2.57	8.11	0.50	17.34	3.12	5	20	
Mn	2.66	0.86	6.08	0.59	3.11	1.56	5.43	0.61	0.2	10	
Cr	0.05	BDL	0.12	0.09	0.05	BDL	0.17	0.08	0.1	1.0	
Pb	0.08	BDL	0.13	0.03	0.07	BDL	0.12	0.04	5	10	
Co	0.05	BDL	0.09	0.05	0.06	BDL	0.12	0.07	0.05	5	
Cu	0.91	0.03	3.11	0.99	0.88	BDL	4.44	1.11	0.2	5	
Zn	1.44	0.99	6.44	1.87	2.01	1.17	7.65	2.43	2	10	

\*All parameters unit are in mg/L except EC in µS/cm, depth in m, and pH

\*\*Ayers and Westcot (1985); Crook (1996)

**Table 4** Pearson's correlation matrix of analyzing groundwater quality parameters in PRM (blue figure) and POM (red figure)

	pH	EC	TDS	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>	B	TH	Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	NO <sub>3</sub> <sup>-</sup>	PO <sub>4</sub> <sup>3-</sup>	Dep.
pH	1	-0.41*	-0.20	-0.39*	-0.38*	-0.37*	-0.47*	0.29	-0.44*	0.03	-0.38*	-0.47*	-0.04	-0.10	-0.11
EC	-0.12	1	<b>0.85**</b>	<b>0.64**</b>	0.33*	0.37*	0.32	-0.12	<b>0.59**</b>	0.33*	<b>0.52**</b>	<b>0.60**</b>	0.48*	0.05	0.04
TDS	-0.22	<b>0.96**</b>	1	<b>0.50**</b>	0.17	0.21	0.10	-0.15	0.41*	0.33*	0.42*	<b>0.57**</b>	<b>0.51**</b>	-0.1	-0.11
Ca <sup>2+</sup>	-0.15	<b>0.78**</b>	<b>0.77**</b>	1	<b>0.54**</b>	0.43*	0.45*	-0.28	<b>0.94**</b>	0.36*	<b>0.81**</b>	<b>0.54**</b>	0.10	0.01	-0.05
Mg <sup>2+</sup>	0.03	<b>0.50**</b>	0.46*	0.45*	1	0.13	0.37*	-0.13	<b>0.80**</b>	0.09	0.45*	0.34*	-0.21	-0.06	0.19
Na <sup>+</sup>	-0.27	0.43*	0.45*	0.25	0.08	1	<b>0.73**</b>	-0.07	0.36*	0.25	0.28	0.28	0.22	-0.02	-0.01
K <sup>+</sup>	-0.11	<b>0.55**</b>	<b>0.54**</b>	0.44*	0.41*	<b>0.62**</b>	1	0.20	0.48*	0.34*	0.36*	0.28	-0.01	0.09	0.05
B	0.26	-0.16	-0.16	-0.31	-0.13	-0.09	-0.20	1	0.03	-0.18	-0.08	0.20	-0.17	-0.09	0.36
TH	-0.1	<b>0.58**</b>	<b>0.55**</b>	<b>0.65**</b>	<b>0.52**</b>	-0.03	0.15	0.02	1	0.29	<b>0.76**</b>	<b>0.53**</b>	-0.02	-0.02	0.04
Cl <sup>-</sup>	0.04	0.39*	0.31	0.30	0.30	0.12	0.22	-0.21	0.30	1	0.27	0.15	0.20	0.13	-0.29
HCO <sub>3</sub> <sup>-</sup>	-0.1	<b>0.76**</b>	<b>0.78**</b>	<b>0.80**</b>	0.46*	0.09	0.34	-0.08	<b>0.68**</b>	0.17	1	<b>0.55**</b>	0.12	-0.02	-0.17
SO <sub>4</sub> <sup>2-</sup>	-0.25	<b>0.76**</b>	<b>0.80**</b>	<b>0.66**</b>	0.35*	0.32	0.47*	0.21	<b>0.52**</b>	0.18	<b>0.61**</b>	1	0.27	0.13	0.02
NO <sub>3</sub> <sup>-</sup>	-0.16	0.29	0.34*	0.18	-0.05	0.31	0.17	-0.16	0.22	0.28	0.10	0.38*	1	0.09	-0.25
PO <sub>4</sub> <sup>3-</sup>	0.11	0.13	0.02	0.06	0.05	-0.05	0.22	-0.1	0.15	0.27	-0.05	0.11	0.03	1	-0.06
Depth	-0.24	-0.12	-0.15	-0.03	0.07	0.06	-0.07	0.28	0.12	-0.21	-0.20	-0.01	-0.19	-0.05	1

\*\*Correlation is significant at the 0.01 level with 95% CI (2-tailed, bold)

\*Correlation is significant at the 0.05 level with 95% CI (2-tailed)

**Table 5** Principal component (5 components extracted) loadings of the analyzed parameters in the study areas (sorted by size)

Parameters	Pre-monsoon (PRM)					Parameters	Post-monsoon (POM)				
	PC1	PC2	PC3	PC4	PC5		PC1	PC2	PC3	PC4	PC5
(1) EC	<b>0.938</b>	0.042	0.076	-0.052	0.101	(1) Ca <sup>2+</sup>	<b>0.891</b>	-0.118	-0.063	0.227	-0.071
(2) TDS	<b>0.937</b>	-0.047	0.042	-0.180	0.093	(2) TH	<b>0.882</b>	-0.308	-0.136	0.248	-0.055
(3) Ca <sup>2+</sup>	<b>0.865</b>	0.110	-0.189	-0.047	-0.020	(3) EC	<b>0.815</b>	0.344	-0.194	-0.196	0.071
(4) SO <sub>4</sub> <sup>2-</sup>	<b>0.828</b>	-0.141	-0.059	-0.062	-0.141	(4) HCO <sub>3</sub> <sup>-</sup>	<b>0.786</b>	-0.051	-0.117	0.310	-0.075
(5) HCO <sub>3</sub> <sup>-</sup>	<b>0.812</b>	0.271	-0.243	-0.269	0.071	(5) SO <sub>4</sub> <sup>2-</sup>	<i>0.724</i>	0.125	-0.210	-0.235	-0.184
(6) TH	<i>0.692</i>	0.367	-0.307	0.035	-0.260	(6) TDS	<i>0.652</i>	<i>0.539</i>	-0.336	-0.082	0.154
(7) K <sup>+</sup>	<i>0.627</i>	-0.303	0.290	0.337	0.391	(7) Mg <sup>2+</sup>	<i>0.596</i>	-0.543	-0.221	0.212	-0.010
(8) Mg <sup>2+</sup>	<i>0.580</i>	0.309	-0.196	0.295	0.305	(8) pH	-0.577	0.276	-0.100	0.388	0.014
(9) Na <sup>+</sup>	0.431	-0.672	0.333	0.065	0.319	(9) NO <sub>3</sub> <sup>-</sup>	0.274	<b>0.787</b>	0.012	-0.241	0.098
(10) pH	-0.224	<i>0.624</i>	0.293	0.039	0.322	(10) K <sup>+</sup>	<i>0.609</i>	-0.290	<i>0.616</i>	-0.156	0.122
(11) Depth	-0.091	-0.314	-0.589	0.439	-0.012	(11)Na <sup>+</sup>	<i>0.551</i>	-0.026	<i>0.601</i>	-0.235	0.385
(12) Cl <sup>-</sup>	0.405	0.292	0.485	0.213	-0.233	(12) Depth	-0.030	-0.498	-0.278	-0.555	0.105
(13) PO <sub>4</sub> <sup>3-</sup>	0.130	0.220	0.341	<i>0.702</i>	-0.322	(13) Cl <sup>-</sup>	0.410	0.335	0.401	0.427	-0.066
(14) NO <sub>3</sub> <sup>-</sup>	0.362	-0.263	0.455	-0.291	-0.505	(14) PO <sub>4</sub> <sup>3-</sup>	0.045	0.105	0.344	-0.182	-0.825
(15) B	-0.288	0.303	0.323	-0.248	0.325	(15) B	-0.253	0.018	0.106	0.304	0.338
% Variance	38.000	11.108	10.195	7.986	7.217	% Variance	36.482	13.213	9.329	8.398	7.066
% Cumulative	38.000	49.108	59.303	67.289	74.506	% Cumulative	36.482	49.696	59.025	67.423	74.489
Eigen value	5.700	1.666	1.529	1.198	1.083	Eigen value	5.472	1.982	1.399	1.260	1.060

Bold numbers indicate strong loading, italic numbers indicate moderate loading.

**Table 6** Restrictions of important parameter indices for rating groundwater quality for irrigation use in the study areas and evaluate the Overall IWQ<sub>index</sub> values.

Category	Degree of restriction on use	Wight (w)	Rating (r)	Category	Degree of restriction on use	Wight (w)	Rating (r)
<b>EC (µS/cm)<sup>1</sup></b>		8		<b>SSP<sup>5</sup></b>		6	
<700	Good		3	0-20	Excellent/Good		5
700-3000	Fair		2	20-40	Permissible		4
>3000	Poor/Rejection		1	40-60	Doubtful		3
<b>TDS (mg/L)<sup>2</sup></b>		8		60-80	Unsuitable		2
<450	Excellent		3	>80	Rejection		1
450-2000	Good		2	<b>TH (mg/L)<sup>6</sup></b>		5	
>2000	Fair		1	<75	Soft		4
<b>Salinity (mg/L)<sup>1</sup></b>		7		75-150	Moderately hard		3
<450	Excellent		3	150-300	Hard		2
450-2000	Good		2	>300	Very hard		1
>2000	Fair		1	<b>RSBC(meq/L)<sup>7</sup></b>		4	
<b>SAR (%)<sup>3</sup></b>		7		<5	Safe		3
<10	Excellent		4	5-10	Marginal		2
10-18	Good		3	>10	Unsafe		1
18-26	Fair		2	<b>PI (%)<sup>8</sup></b>		3	
>26	Poor/rejection		1	>75	Good		3
<b>Chloride(mg/L)<sup>4</sup></b>		7		25-75	Fair		2
5-30	Very fresh		5	<25	Poor/rejection		1
30-150	Fresh		4	<b>MAR (%)<sup>7</sup></b>		2	
150-300	Fresh-brackish		3	<50	Suitable		2
300-10000	Brackish-salt		2	>50	Unsuitable		1
10000-20000	Rejection		1	<b>KR<sup>9</sup></b>		1	
<b>%Na<sup>5</sup></b>		7		<1	Suitable		2
0-20	Excellent/Good		5	1>	Rejection		1
20-40	Permissible		4	<b>IWQ<sub>index</sub><sup>10</sup></b>		-	
40-60	Doubtful		3	<22	Low		-
60-80	Unsuitable		2	22-37	Medium		-
>80	Rejection		1	>37	High		-

$$\text{Overall IWQ index (Pre-monsoon)} = w_1r_1 + w_2r_2 + w_3r_3 + w_4r_4 + w_5r_5 + w_6r_6 + \frac{w_7}{4} \sum_{m=1}^7 r_m + \frac{w_8}{2} \sum_{n=1}^8 r_n$$

$$= 2+4+4.9713+4.1144+8.715+29.8284+29.6983+21.2568=102.58$$

$$\text{Overall IWQ index (Post-monsoon)} = w_1r_1 + w_2r_2 + w_3r_3 + w_4r_4 + w_5r_5 + w_6r_6 + \frac{w_7}{4} \sum_{m=1}^7 r_m + \frac{w_8}{2} \sum_{n=1}^8 r_n$$

$$= 2+4+6+4+5.375+30+25.383+16=93.49$$

**Computed highest score=128.75, and lowest score=36**

<sup>1</sup>UCCC (1974); <sup>2</sup>Bauder et al. (2011); <sup>3</sup>Fipps (2003); <sup>4</sup>Stuyfzand 1989; <sup>5</sup>Wilcox (1955); <sup>6</sup>Sawyer and McCarthy 1967; <sup>7</sup>Gupta and Gupta (1987); <sup>8</sup>Hem (1970); <sup>9</sup>Kelley (1963); <sup>10</sup>Simsek and Gunduz (2007).

**Table 7** Destructive statistics of irrigation water quality indices in groundwater during PRM and POM and percent of suitability for irrigation uses.

Indices	Pre-monsoon, PRM ( <i>n</i> = 40)					Post monsoon, POM ( <i>n</i> = 40)				
	Average	Min.	Max.	±SD	% of sample	Average	Min.	Max.	±SD	% of sample
EC, µS/cm	670	366	1035	172.5	Good-55 Fair-45	956.8	662	1708	206.1	Good-7.5 Fair-92.5
TDS, mg/L	413.2	219	675	113.2	Excellent-65 Good-35	601.5	450.5	1109	156.2	Good-100
TH (mg/L)	362.22	122	562	93.52	Hard- 5% Very hard-95%	404.7	225	615	94.03	Very hard-100%
Na%	7.40	3.31	30.97	4.85	Excellent-100	5.67	2.50	22.03	3.42	Excellent-97.5 Good-2.5
SAR	0.32	0.12	1.67	0.26	Excellent-100	0.25	0.09	1.13	0.18	Excellent-100
SSP	7.76	3.50	31.47	4.91	Excellent-97.5 Permissible-2.5	5.94	2.64	22.6	3.50	Excellent-97.5 Permissible-2.5
RSBC (mEq/L)	2.08	-0.484	5.30	1.32	Safe -97.5 Marginal – 2.5	1.64	-0.75	4.23	1.28	Safe -100
PI	51.16	36.91	71.27	8.02	Excellent-2.5 Fair- 97.5	51.29	38.63	73.85	7.17	Fair- 100
MAR	35.67	19.70	51.64	7.70	Suitable-97.5 Unsuitable-2.5	29.49	20.06	41.15	5.78	Suitable-100
KR	0.08	0.03	0.45	0.07	Suitable-100	0.06	0.03	0.28	0.04	Suitable-100
Mg:Ca	0.346	0.147	0.641	0.12	-	0.26	0.15	0.42	0.07	-
Na:Ca	0.148	0.053	0.747	0.11	-	0.10	0.04	0.41	0.06	-
IWQ <sub>index</sub>	42.85	32.04	45.39	2.44	Excellent-97.5 Good-2.5	38.24	35.43	38.76	0.65	Excellent-97.5 Good-2.5