A Model for the Relationship between Boron, Fluoride and Salinity of Groundwater at Safwan. S. 1raq.

S.A.M.AL-Dahaan

Department of Geology, College of Science, University of Kufa. Najaf City, Iraq

E-mail: Saadi.aldahan@uokufa.edu.iq

Abstract

The variability of boron concentration in soil and groundwater mostly depends upon the farm life and clay sediment prevailing. The old farm reflect that the boron is mostly leached out from soil and concentrated in groundwater. It is also found that for the given boron concentration in soil of individual locations, the groundwater is of variable boron content. In term of average, the relation is more active in two directions. The groundwater salinity in term of electrical conductivity EC controls the positive condition of the proportionality. The standard model is 3rd order polynomial regression. This model verifies the condition of EC ≤ 6 ds/m and EC ≥ 7.3- 8.5 ds/m. The segment between 6 ds/m and 7.3 ds/m is a liner relationship. Fluoride concentration in groundwater is variable as that of the boron in the time and location. Under the condition of that B < 0.4 mg/l, Fluoride will never exceed. Also there are two types of boron-fluoride function BFF according to boron concentration. If the boron concentration 0.4 ≤ B ≤ 1.0 mg/l, The BFF will reflect that F is less than B in concentration F≈ 0.5B, and also shows that F > B in concentration if and only if 1 < B < 3.1. Two filters were used for building the BFF according to boron concentration: The final model is constructed by Basic computer program. It includes three variables electrical conductivity, boron and fluoride.

Key words: Boron; Fluoride; Groundwater; Model; Salinity

1. Introduction

Study area represents part of southern sector of western desert at Iraq. It bounded by latitude 30° 05' 00" - 30° 10' 00" and longitudes 47° 40' 00" – 47° 47' 00" (Figure 1).

The aim of study is to find the boron concentration in the groundwater and the relationship between boron, fluoride and salinity as electrical conductivity and trial to get a model for this relation. Boron cannot be free element. It is present combined as, Borates BO_3, BO_4, Colemanite mineral $CaB_3O_4(OH).3.H_2O$, Kernite mineral $Na_2B_4O_6(OH)_2.3H_2O$, Boric acid H_3BO_3 or $B(OH)_3$ and Borax $Na_2BO_7.10H_2O$ (Appelo & Postman 1999). It occurs in the environment naturally due to the release into air, soil and water through weathering. The upper limit of boron concentration in drinking water is 0.5ppm (Hem 1991). The relationship is converse between Boron and rain fall plus irrigate water during washing operation for Borate and leached it down to groundwater. Boron is present in the soil in many forms. The most common is being Boric Acid H_3BO_3 (Hazim 2012).

2. Methodology

Twenty (20) groundwater samples of shallow wells were collected at November 2013 (Figure 1) for measuring boron, fluoride and salinity as electrical conductivity. They measured by:

EC: Conductivity meter in the field and in the laboratory(Boyed 2000).

B&F: by UV Spectrophotometer 220 – 275 nm and 520nm for Fluoride (Adams 2001).

TDS: Vaporization, in 105 C° (Manhi 2012).

The electrical conductivity, total dissolved solids, Boron, Fluoride in the groundwater and Boron in the soil for the samples are showed at Table 1. The mean of electrical conductivity is 7.803 ds/m, standard deviation 2.130 ds/m and coefficient variation is 27.3%.

3. Results and discussion

3.1 Precision of analysis

It is analytical of a random line for the samples as standard deviation of repeaters. Four repeaters for five groundwater wells were chased (table 2). The salinity is between 3.81 –11.32, Standard deviation is ± 0.013 and the coefficient variation is less than 1%. This is meaning good precision. In order to know the precision of analysis, error of user's device is done by other device to prevent the systematic error. The result shows no moral difference in the results and no systematic error as below:

Well No	3	30	52	37	59
Dependable	3.82	7.82	9.50	10.37	11.31
Comparative	3.81	7.83	9.51	10.36	11.32

3.2 Accuracy

It is amount of the measured convergence result from the truth. Accuracy is calculated by dilution for several levels of known concentrations method. Sample number 59 (table 1) is tested as:

C1 = 11.31 … V1 = 0.5 liter … Add one liter from sample number 3 (table 1).

C2 = 3.82 …V2 = 1.0 liter … New volume … V = 0.5 + 1.0 = 1.5 liter.

Known concentration (C) is:

1.5C = 0.5 * 11.31 + 1.0 * 3.82 … C = (5.655 + 3.82) / 1.5 … C = 6.32 ds/m

Diluted sample measured by: Dependable device = 6.37 …. Comparative device = 6.4

The uncertainly (U) or relative error (RE) is:

$$RE = U = \frac{6.37 - 6.32}{6.32} \times 100 \quad = 0.8\% \text{ … Dependable device.} \quad = 1.3\% \text{ … Comparative device.}$$

This result reflects acceptable values for the analysis of groundwater samples (Al-Kubaisi 1996).

3.3 Boron model between soil and groundwater

Correlation relationships are variable between soil boron and groundwater boron. The same value of soil boron may take a variable value of boron in groundwater. This case is depending on the type of soil facies and the amount of farm life which is leading to more leaching for boron by irrigation water (Salih 1989; Arjan 2012; Al-Ansari 2014) as in the following samples:

Soil Boron (ppm)	Groundwater Boron (ppm)
1.6	4.12
1.6	6.02
2.2	6.48
2.2	5.75
3.3	6.07
3.5	4.31

By comparison the average of boron concentration in the soil and groundwater plus the values of standard deviation >50%, we get two types of correlation relationship:

Type one: Soil boron is less than 2.0 ppm.

Soil Boron (ppm)	Groundwater Boron (ppm)
0.6	7.0
1.0	6.8
1.1	6.5
1.6	6.0

Type two: Soil boron is more or equal 2.0 ppm.

Soil boron (ppm)	Groundwater boron (ppm)
2.9	4.0
3.8	5.0
4.8	6.7
5.4	7.6
6.0	8.9
7.0	13.3

The type of soil and groundwater is controlled the relationship between the soil boron and groundwater boron. It is active negative relationship when the value of soil boron is less than 2 ppm (Figure 2). Type of soil at study area is sandy soil.

When the boron concentration value in groundwater is 7 ppm, the relationship is positive. The same method of calculation is applied if the concentration of groundwater boron is less than 7 ppm.

3.4 Model between boron and groundwater salinity:

Many mathematical methods are applied to calculate the model (Gill, R. ed. 1997, Al-Abadi 2002).

Results found two kinds of relationship between salinity of groundwater representative as electrical conductivity EC.ds/m and boron as ppm.

3.4.1 EC< 7.3 ds/m

In this case the boron concentration is less than 2.1ppm.

$BM = -7.86 + 5.714\ EC - 1.16\ EC^2 + 0.018\ EC^3$

The model, salinity value 7.3 ds/m and absolute error μ<5% is checking by programming Basic language as below:

$$U = \frac{ABS\ (BM - BW)}{BW}$$

U = absolute error. ABS = absolute value.

BM = boron model. BW = boron of groundwater.

EC ds/m	BM	BW	U%
3.8	1.49	1.53	0.5
4.3	1.62	1.63	0.6
5.7	1.85	1.86	0.5
6.0	1.94	1.95	0.5

Result of Model is:

Boron model: BM = BM ± 0.01

3.4.2 EC ≥ 7.3 ds/m

The values of boron and salinity are introduced in basic language program. The result is maximum compatibility 0.97 as shown at (Figure 3).The relationship between salinity 8ds>EC> 8ds and boron is third degree relationship. The limits of application are between 7.3-8.5.

The results of model are:

EC ds/m	BM	BW	U%
7.3	2.10	2.10	0.0
7.88	2.76	2.79	1.1
8.34	3.32	3.38	1.8
8.21	3.01	3.01	0.0
8.5	3.98	4.02	1.1

Boron model is: BM = BM ± 0.01

The relationship between salinity EC=6-7.3ds/m is staying liner relationship as:

BM = 2.0 – 0.06 * 7.3 – EC/1.3

Example:

EC = 6.5

BM=2.0–0.06 * 7.3–6.5/1.3

BM = 2.0 – 0.04

BM = 1.96

BM = BM ± 0.01 … 1.95

The true value for model is 1.97

Another example

EC = 7.2

BM = 2.0 – 0.06 * 7.3 – 7.2/1.3

BM = 2.0 – 0.005

BM = 1.995 ppm

The true value is:

BM = ± 0.01 = 2.095 … 2.895: 2.1

3.5 Model between boron and fluoride

Result shows three levels of fluoride are accompaniment to boron:

When the boron concentration is less than 0.40ppm, fluoride is almost absent.

BW (ppm)	F (ppm)
0.30	0.01
0.35	0.01
0.25	nil
0.28	nil

B < 0.40 ppm:

The relationship between fluoride and boron is positive, When the boron concentration is less than 1.0ppm and equal or more than 0.4ppm.

BW (ppm)	F (ppm)	BW (ppm)	F (ppm)
0.40	0.12	0.50	0.35
0.43	0.18	0.60	0.56
0.44	0.22	0.70	0.77

$1.0 > B \geq 0.4$ ppm:

When B concentration is more than 1.0ppm; F concentration is variable as:

$1 < B < 3.1$ ppm … $F > B$

$3.1 \leq B$ ppm … $F < B$

The variable results shows in (table 3), that shows the concentration of boron and floured at groundwater for third type without relationship at model between boron and fluoride.

The relationship can be obtained by using a filter for treatment the fluoride variation with boron variation as:

A-BW ≤ 1.0 ppm: BW= Boron of water

The boron: X = BW ppm

The filter: $Y = 2 - F / BW$

So as to make reverse relationship, the following equation is used:

$\hat{y} = A.\ X^B$ … (figure 4)

$Fm = 2 - \hat{y} * B \pm 0.005$

A = 0.640 … B= - 1.0458

Below the method of calculation filter y:

BW	F	F/BW	2-F/BW	yˆ	Fm/BW	Fm
0.40	0.12	0.30	1.70	1.67	0.33	0.132
0.44	0.22	0.50	1.50	1.51	0.49	0.216
1.00	1.35	1.35	0.65	0.64	1.36	0.360

B-BW ≥ 1.0 ppm:

In this case the filter is boron and fluoride together to make symmetrically relationship with the first relationship.

Boron filter $x = 1 + \frac{BW}{10}$

Fluoride filter $y = \frac{F}{B}$

Where: $\hat{y} = A * X^B$

A = 1.9506 … B = - 2.4253

The minimum and maximum value for filter x and y is 1.0 – 2.0.

Example:

Well number 35 in (table 1) is:

$$x = 1 + \frac{4.1}{10} = 1.41 \qquad \hat{y} = \frac{1.41}{3.4} = 0.413$$

Well number 3 in (table 1) is:

$$x = 1 + \frac{1.1}{10} = 1.11 \qquad \hat{y} = \frac{1.55}{1.1} = 1.409$$

This means decreasing in value of y filter with increasing in value of x filter.

The relationship between boron and fluoride (figure. 4) is showing:

Relationship between 0.0 and 1.0 represents the filter $2 – F/BW$ for boron value $BW \leq 1.0$.

Relationship between 1.0 and 2.0 represents the filters $1 + BW/10$ with F / BW for boron value $BW \geq 1.0$, and the area between two graphs (figure 4) shows value variations for boron and fluoride, so this variation decreased with increased of boron value when boron value is $B > 1.0$.

Model checking for two cases are done as:

BW = 1.0 … boron of water = 1.0ppm.

The offset by fluoride value:

F = 1.35 … fluoride of water = 1.35ppm.

First case with filter: 2 – F / BW.

$$\hat{y} = 2 - \frac{1.35}{1.0} = 0.65 \ldots BW = 1.0ppm.$$

$$\hat{y} = 0.64 * 1.00^{(-1.0458)} = 0.64 \ldots F = 1.35ppm.$$

FM / BW = 2 – 0.64 = 1.36 … 1.35

$$\text{Second case with filter } x = 1 + \frac{BW}{10}$$

$$x = 1 + \frac{1.0}{10} = 1.1 \ldots \; y = \frac{F}{BW} = 1.35$$

$$\hat{y} = 1.9506 * 1.1^{-2.4253} \ldots \; \hat{y} = 1.55$$

So. F = 1.55 * 1 = 1.55 … 1.35.

The second relationship will be $BW > 1.0$ instead of $BW \geq 1.0$ and the first relationship is stay $BW \leq 1.0$ because of absolute difference 14.8% and 21% is more than 10%. The second model $BW > 1.0$ is tested by other analytical results for model building as in (table. 4): Absolute error u is acceptable because of it is less than 5%.

Mean of F = 3.42ppm

Standard deviation for F = 0.50

$S \pm = 0.146 \ldots \quad F = Fm \pm s\, \bar{x}$

$Fm – S\bar{X} < F < Fm + S\bar{X}$

3.6 Standard Model

This model represents the standard values of boron, fluoride and salinity as correlation relationships of limited conditions essentially for salinity and boron. Program of model is of basic language. It is working under model condition paragraph 60. When electrical conductivity EC is input and the output is standard values of boron B and fluoride F, or boron is input and the output is fluoride. At the program, if salinity value is known, variable will be equal one ECB = 1 and moves to paragraph 90 and to subprograms 390, 130 to calculate the boron and fluoride. The subprogram 390 needs the value of electrical conductivity ds/m at paragraph 400, then the limit value more than 8.5 EC and the program moved to 390 paragraph. During paragraph 410 fulfillment, program will move to 570 in case the electrical conductivity is less than 7.3. Model data is stored in the A 3 variable from 0 – 3. The program will move to 460 up to 480 to calculate boron value. The paragraph 500 adjusted electrical conductivity for two possible grades as:

500 EC = INT EC * 100 / 100

INT = absolute value EC*100.

Example: Input EC = 3.80

EC = INT 380 / 100 = 3.80

After that, the program moved to 510 for reformulate boron value at $7.3 \leq EC \leq 6$.

In case non implementation both status, boron value will be liner model as:

B = 2.0 – 0.06 * 7.3 – EC / 4.3

The upper value of boron is 2.0, when the value of EC is 7.3. The number 1.3 is the difference between 7.3 and 6.0 of electrical conductivity. After that subprogram will move to paragraph 100 and then to 130. If boron value $B \leq 0.35$ppm, fluoride is nil and then the program moves again to 10 from the beginning. In case $B > 0.35$ppm the program moves to special state $B > 1$ppm in 160 and then to 290 to get boron value and then filter calculation by 1 + B / 10 so with constants can get y from 290 to 330 for moves again to program beginning 10. When $B \leq 1.0$, program will starts from show information 70 and then to calculate filter y from Z by Z = 2 – y , so the fluoride in 250 and then print fluoride value F after reworded and moves to beginning of the program in 10. Results of input, output for EC, B, and F are below:

EC-INPUT	OUTPUT-B	OUTPUT-F
3.80	1.49	2.07
5.70	1.83	2.37
6.00	1.94	2.46
6.50	1.96	2.47
7.00	1.98	2.49
7.20	1.99	2.49
7.30	2.10	2.57
7.88	2.76	2.98
7.77	2.75	2.97
8.21	3.01	3.10
8.34	3.32	3.23
8.50	3.98	3.44

3.7 Model program

```
10 FOR J=1 TO 5
20 BEEP J*10,J*5
30 DISP "FLUORIDE TO BORON…SAFWAN / ZUBAIR
```

```
40 NEXT J
50 PRINT
60 DISP "EC TO GET BORON (1)…BORON TO GET F(2)
70 INPUT ECB @ CLEAR
80 IF ECB<> 1THEN 110
90 GOSUB 390
100 GOTO 130
110 DISP "INPUT BORON PPM"
120 INPUT BO @ CLEAR
130 IF BO > .35 THEN 160
140 PRINT "F…… IS NIL PPM"
150 PRINT @ GOTO10
160 IF BO > 1 THEN 290
170 DISP " B <= 1 PPM … IT IS"; BO
180 PRINT
190 A = O.64 @ B = -1.0458
200 Y = A*BO^B
210 Y = INT (Y*100)/100
220 PRINT "Y = 2 – F /B  ';Y
230 Z = INT (2 – Y) * 100) /100
240 PRINT "Z = F / B = 2 – Y   ";Z
250 F = INT ((2 – Y) * BO * 100) / 100
260 PRINT " F PPM  "; F
270 PRINT
280 GOTO 10
290 DISP "B > 1PPM … IT IS "; BO
300 PRINT
310 A = 1.956 @ B = -2.4253
320 Y * (1 + BO / 10)^B
330 Z = 1 + BO / 10
340 PRINT " 1 + B / 10  "; Z
350 PRINT "F / B "; INT (Y * 100) / 100
360 PRINT " PPM "; INT (Y * BO * 100) / 100
370 PRINT
380 GOTO 10
390 DISP "INPUT EC … ds / M"
400 INPUT EC @ CLEAR @ IF EC > 8.5 THEN 390
410 IF EC < 7.3 THEN 570
420 A(0) = -1860.0
430 A(1) = 713.42
440 A(2) = -91.05
450 A(3) = 3.8741
```

```
460 B = 0
470 FOR J = 0 TO 3
480 B = B + A(J) * EC^J
490 NEXT J
500 EC = INT (EC * 100) / 100
510 IF EC <= 6 OR EC >= 7.3 THEN 530
520 B = 2.0 - .06 * (7.3 – EC) / 1.3
530 PRINT "EC ds / M"; EC
540 BO = INT (B * 100) / 100
550 RETURN
560 END
570 A(0) = -7.86
580 A(1) = 5.714
590 A(2) = -1.16
600 A(3) = 0.08
610 GOTO 460
```

4. Conclusion

Correlation relationships between soil boron and groundwater boron are variable. It is depending on the type of soil facies and the amount of farm life**.** By comparison the average of boron concentration in the soil and groundwater plus the values of standard deviation >50%, we get two types of correlation relationship: Soil boron is less than 2.0 ppm and Soil boron is more or equal 2.0 ppm. It is active negative relationship when the value of soil boron is less than 2 ppm. It is positive When the boron concentration value in groundwater is 7 ppm. The model between boron and groundwater salinity is third degree relationship when 8ds>EC> 8ds. The limits of application are between 7.3-8.5. The relationship between salinity EC=6-7.3ds/m is staying liner relationship. Model between boron and fluoride shows three levels of fluoride are accompaniment to boron.

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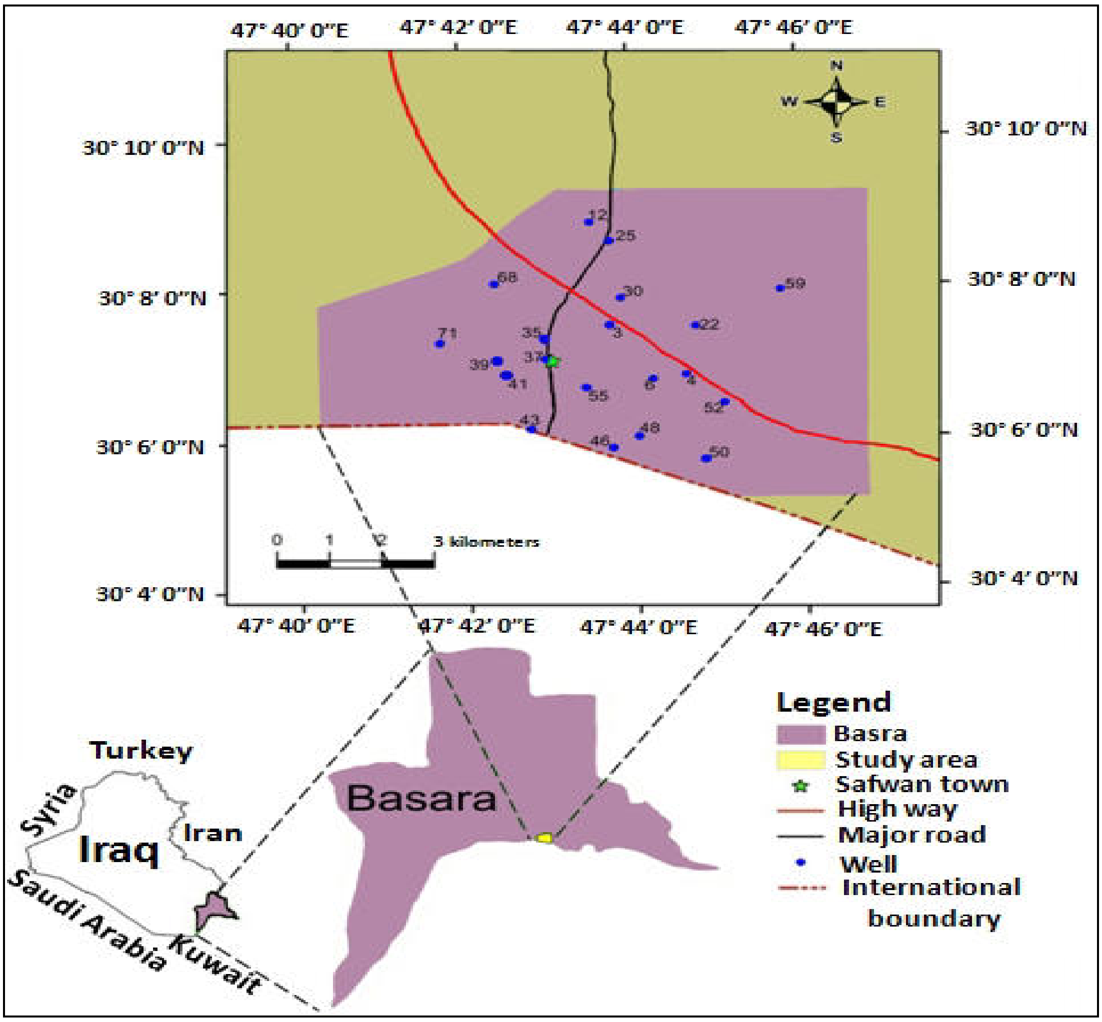

Figure 1. Location map for study area.

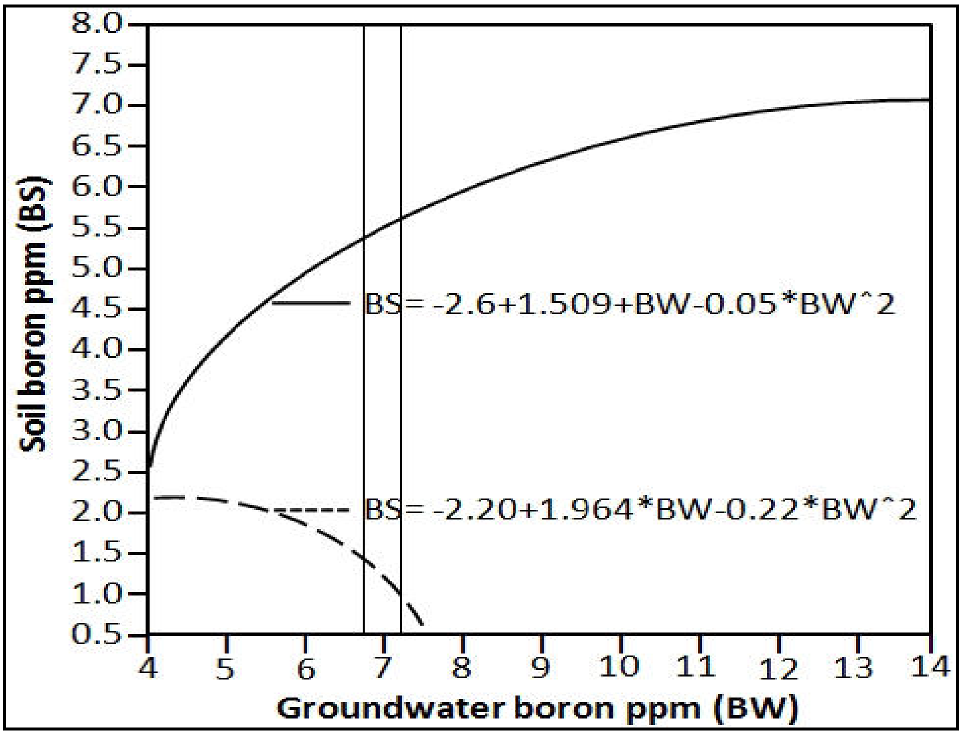

Figure 2. Boron model in soil and groundwater.

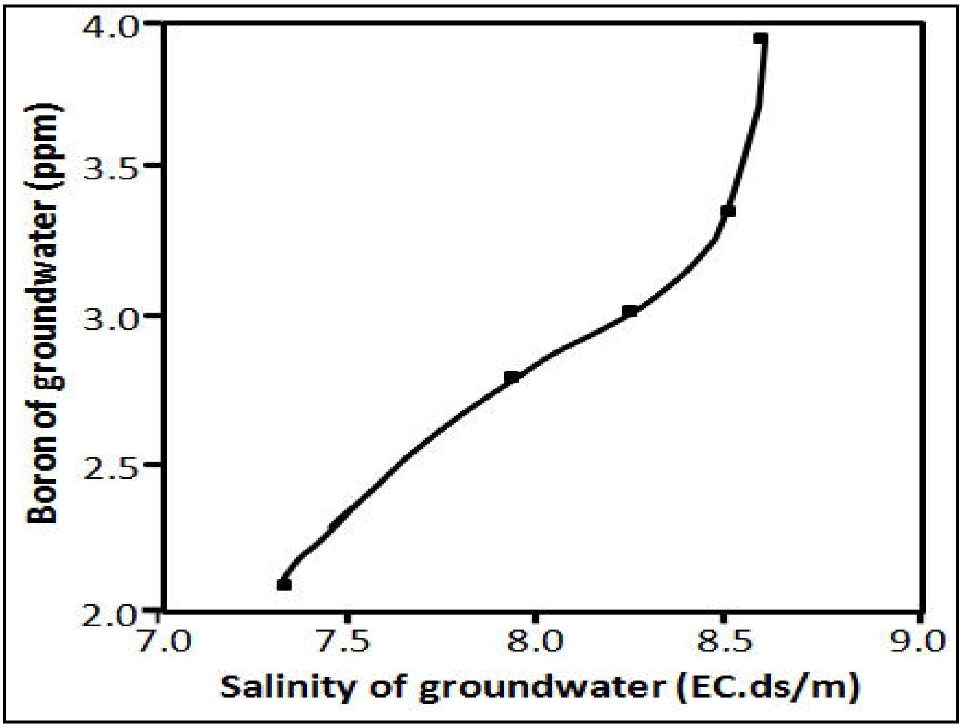

Figure.3. Relationship between salinity and boron.

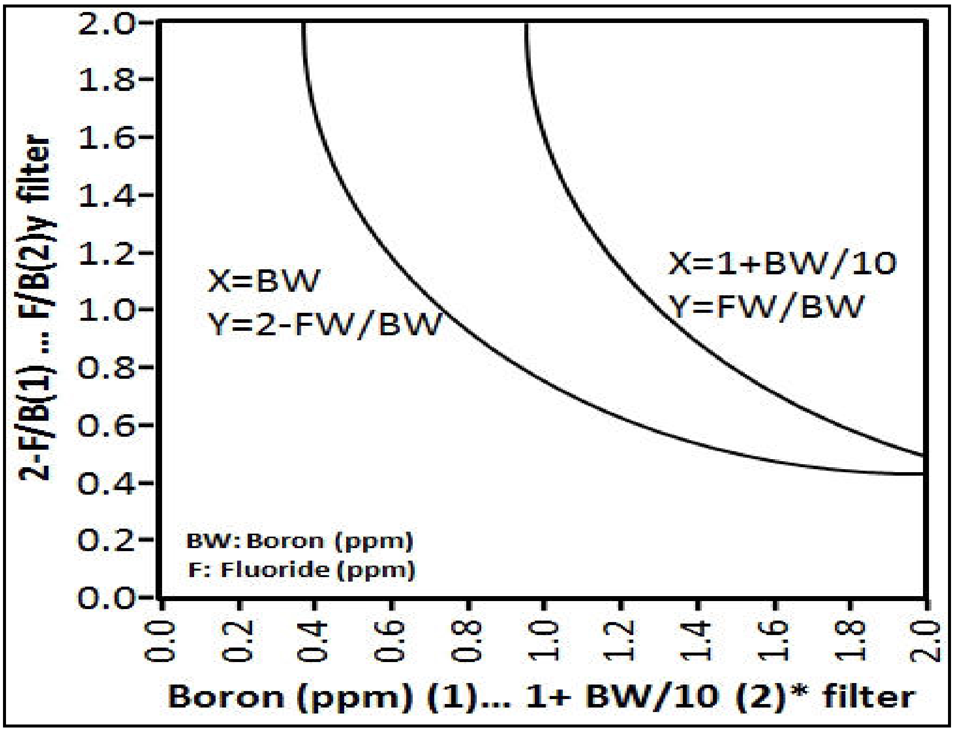

Figure 4. Relationship between boron and fluoride.

Table 1. EC, TDS, B and F in groundwater and Boron in Soil for study area.

Well No	E.C Ds/m	TDS (ppm)	B	F	Soil B	Well No	E.C Ds/m	TDS (ppm)	B	F	Soil B
3	3.82	3700	1.01	1.55	2.20	41	8.30	7203	1.40	1.99	2.70
4	4.31	4200	1.40	2.00	1.16	43	10.21	7867	2.30	2.70	2.20
6	6.61	5895	1.89	2.52	1.00	46	7.30	6430	2.00	2.56	1.08
12	5.02	4643	1.40	2.00	3.80	48	6.50	5773	2.00	2.51	2.20
22	7.20	6385	3.20	3.18	6.48	50	11.05	8976	2.70	3.40	3.24
25	6.71	5605	4.00	3.47	1.08	52	9.50	7740	2.00	2.50	1.60
30	7.82	6847	4.50	3.53	1.60	55	7.37	6501	1.35	1.91	2.20
35	9.72	7703	4.10	3.41	3.80	59	11.31	9321	3.37	3.30	2.20
37	10.37	8070	3.20	3.18	1.60	68	7.30	6435	2.00	2.50	2.70
39	8.93	7621	2.70	3.00	2.70	71	7.21	6393	2.00	2.50	1.60

Table 2. EC, TDS, B and F in groundwater and Boron in Soil for study area.

Well No	E.C Ds/m	TDS (ppm)	B	F	Soil B	Well No	E.C Ds/m	TDS (ppm)	B	F	Soil B
3	3.82	3700	1.01	1.55	2.20	41	8.30	7203	1.40	1.99	2.70
4	4.31	4200	1.40	2.00	1.16	43	10.21	7867	2.30	2.70	2.20
6	6.61	5895	1.89	2.52	1.00	46	7.30	6430	2.00	2.56	1.08
12	5.02	4643	1.40	2.00	3.80	48	6.50	5773	2.00	2.51	2.20
22	7.20	6385	3.20	3.18	6.48	50	11.05	8976	2.70	3.40	3.24
25	6.71	5605	4.00	3.47	1.08	52	9.50	7740	2.00	2.50	1.60
30	7.82	6847	4.50	3.53	1.60	55	7.37	6501	1.35	1.91	2.20
35	9.72	7703	4.10	3.41	3.80	59	11.31	9321	3.37	3.30	2.20
37	10.37	8070	3.20	3.18	1.60	68	7.30	6435	2.00	2.50	2.70
39	8.93	7621	2.70	3.00	2.70	71	7.21	6393	2.00	2.50	1.60

Table 3. Variable concentrations of Boron and Fluoride.

Well No	B (ppm)	F (ppm)	WELL No	B (ppm)	F (ppm)
3	1.10	1.55	41	3.0	3.10
4	1.40	2.00	43	4.0	3.47
6	1.89	2.52	46	4.5	3.53
12	2.60	2.95	48	4.1	3.41
22	2.84	3.00	50	4.8	3.70
25	2.70	3.00	52	4.9	3.70
30	2.30	2.70	55	4.7	3.55
35	2.00	2.53	59	6.1	3.77
37	1.53	2.08	68	6.8	3.30
39	3.10	3.17	71	5.8	3.75

Table 4. Model checking.

BW ppm	1+BW/10	F ppm	F/BW	y^	Fm	u%
2.0	1.2	2.5	1.25	1.254	2.507	<1
3.0	1.3	3.0	1.00	1.032	3.096	3.2
4.0	1.4	3.4	0.85	0.863	3.450	1.5
5.0	1.5	3.75	0.75	0.730	3.648	2.7
6.8	1.68	3.80	0.56	0.554	3.770	< 1
7.2	1.72	3.76	0.52	0.524	3.770	<1
8.3	1.83	3.72	0.45	0.451	3.739	1.9