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Status of Boron in Soil and Groundwater from Sangamner area, Ahmednagar district, Maharashtra India

K.K. Deshmukh
Department of Chemistry, Sangamner Nagarpalika Arts, D.J. Malpani Commerce and B.N. Sarda Science College, Sangamner, Dist. Ahmednagar, MS, INDIA

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Abstract

Boron is widely distributed in surface water and groundwater. The boron concentrations vary greatly depending on boron content of local geologic formations and anthropogenic sources of boron. Boron is naturally released to soil and water by rainfall, weathering of boron - containing minerals, desorption from clays and decomposition of boron containing organic matter. Human made sources include application of boron containing fertilizers or herbicides, application of fly ash, use of waste water for irrigation or land disposal of boron containing industrial waste. Human health is affected by excess of boron in food products. Due to over irrigation the soils from the Sangamner area are suffering from the problems like salinization, alkalization and waterlogging. To minimize their problems and considering the importance of boron in the fertility of soils, it was decided to estimate the boron concentration in the soils and groundwater from Sangamner area. 20 groundwater samples were analyzed for pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, SO_4^{2-}, NO_3^{-} and B. Similarly 20 soil samples were also analyzed for pH, EC, exchangeable cations like Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} by neutral ammonium acetate extract of soil. B was determined by Carmine method. Textural analysis of these soil samples were done by International Pipette method. The boron content of soil was ranged from 0.019 to 8.381 ppm. The salt affected soils in the area showed higher concentration of boron. These soils are from villages like Jorve, Kolhewadi, and Rahimpur in the downstream part wherein salinization is to a greater extent. Upstream part and non - irrigated region of the area was found to be deficient in B. As per Richards classification of boron concentration relative to tolerant of plant, 50% soils are safe, 20% are marginal and 30% soils are unsafe in the area which is in agreement with the groundwater analysis of the area. Toxicity of boron in the area is the impact of salinization and /or alkalization related to intensive irrigation. High levels of boron in salt affected soils can be reduced by leaching as well as leaching after treatment with gypsum and through selection of proper crops.

Keywords: Boron toxicity, irrigated agriculture, salinization, boron deficiency, impeded drainage.

Introduction

Boron is typical and important trace element. It does not appear on the earth in elemental form but is found in combined state as borax, boric acid, tourmaline, colemanite, kernite, ulexite and borates[1]. Orthoboric acid (H_3BO_3) and its salts are the main forms of boron present in the soil. Soil pH, calcium, soil texture, organic matter, light and moisture are some of the factors which are influencing the availability of boron in soil[2]. However, boron greatly influences the metabolism and transport of carbohydrates in plants. It is also involved in membrane integrity and cell wall development, which affect permeability, cell division and cell extension. Boron has active role in various metabolisms in plants such as sugar transport, cell wall synthesis, lignifications, cell wall structure, carbohydrate metabolism, RNA metabolism, respiration, indole acetic acid (IAA) metabolism and phenol metabolism[3]. Studies also reported that boron is essential to human body for numerous processes including effective lipid and mineral metabolism, proper immune system and brain functioning. Boron helps in the metabolism of Ca, Cu, Mg, glucose, triglycerides and estrogen in our life processes[4]. Boron deficiency is much more common in crops that are grown in soil that have higher amount of free carbonates, low organic matter and high pH. Common symptom that appears in plants due to boron deficiency are abnormal growing of plants, thicker and wrinkle leaves, brittle stem, spiral or twisted leaves for grasses, abnormal leaf tips for broad leaf plants etc. Deformed and reduced flowering, improper pollination as well as thickened, curled, wilted and chlorotic new growth are a common symptom of boron deficiency[5]. Symptoms of boron deficiencies are also associated in alkaline soils where boron solubility decreases which result in less plant uptake[6]. Animal diseases are prevalent when excess boron is present in soils and fodder. Human health is influenced by excess of boron[7].

Sangamner area have a unique landform configuration displaying prohibitive slopes along with typical semi arid – arid ecosystem. Hence it is more fragile and prone to degradation even with slight mismanagement, Large scale irrigation without much attention to the soil and water properties is also responsible for the development of salinization, alkalization and waterlogging problems in the area. The excess amount of heavy metals and trace elements like Fe, Mn, Cu, Zn and B from the soil and water are responsible for degradation. Many researchers have studied the role of heavy metals and trace elements in maintaing the soil quality and their importance in crop production as well as their toxicity and deficiency symptoms on the plants in all over the world[8-12]. The soil boron concentration range between plant deficiency and toxicity symptoms is very narrow but both deficiency and toxicity conditions can lead to marked yield reduction of crop plants and economic losses. Therefore to reduce the crop yield losses when grown in low/high B soils and significant risks for human health exposure in Sangamner area, it was decided to evaluate the status of boron content in soil and groundwater from the area.

Study Area: The Sangamner area is located in the Ahmednagar district of Maharashtra. Sangamner is a Taluka headquarter which is located at a distance of 150 km from Pune on Pune-Nashik National Highway No. 50 (Figure-1 and 2).

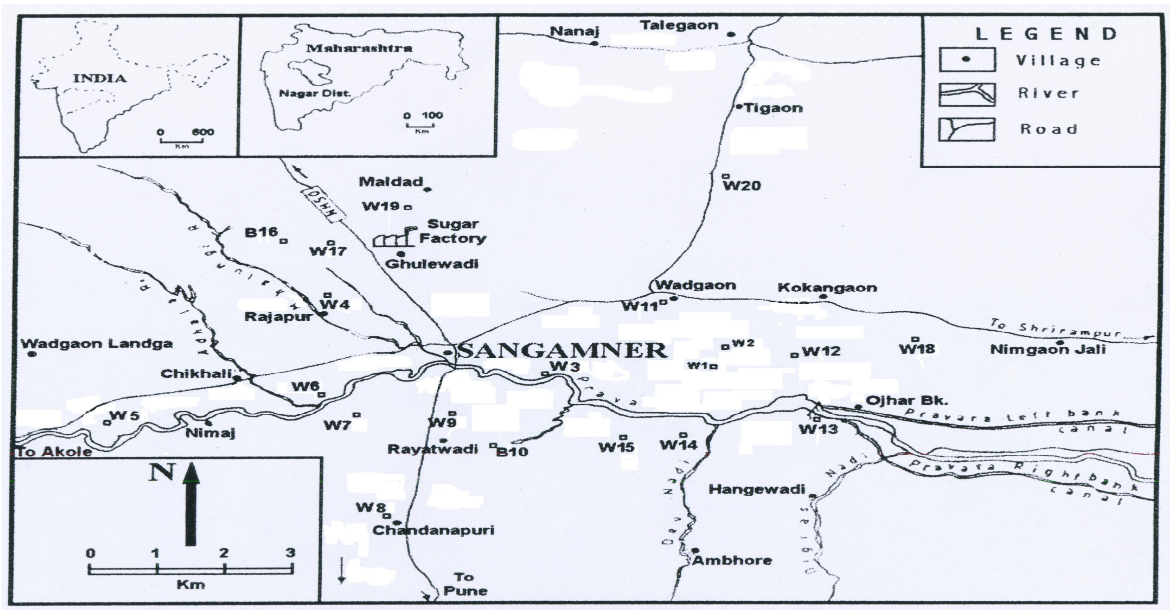

Figure-1
Location map showing groundwater sampling stations in the study area

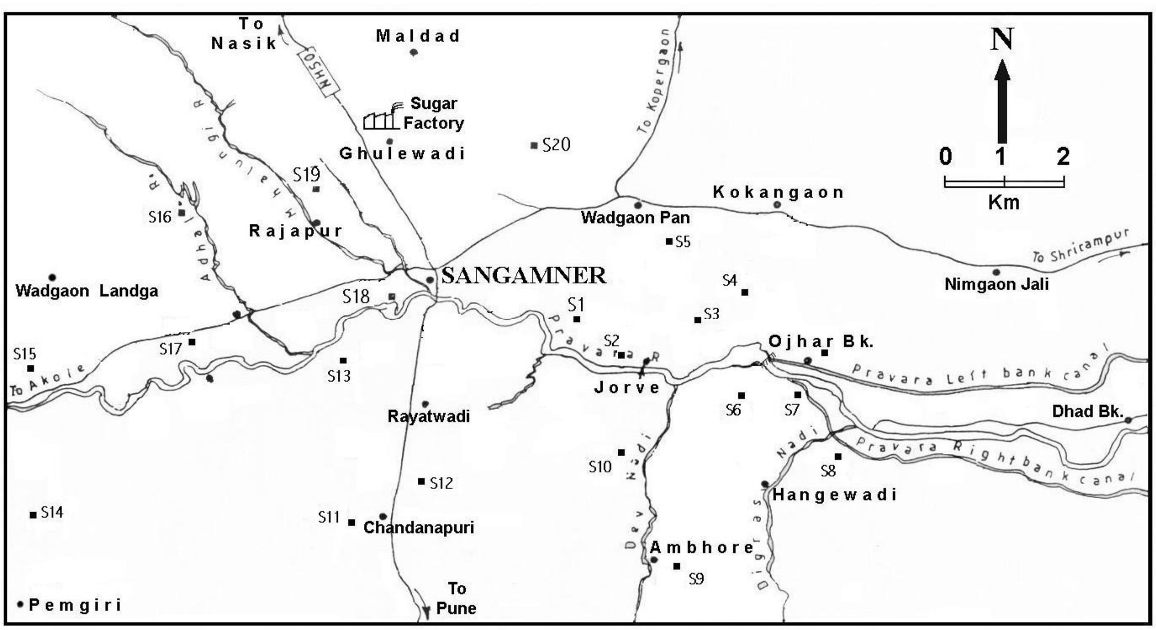

Figure-2
Location map showing soil sampling stations in the study area

The area is drained by the Pravara River which is a tributory of Godavari. Pravara River originates in the mountainous region of Western Ghats and flows into low-lying fertile alluvial plain in the downstream part. Several dams and weirs have been constructed across Pravara River. Of these, Bhandardara dam is located in the source region and the Ojhar weir is in the downstream direction of Sangamner town. They have fulfilled the irrigational water requirement of the area. Majority of the study area is having intensive agriculture. After the set up of co-operative sugar-mill at Sangamner in 1967, the agriculture in the area has noticed rapid changes in the cropping pattern. The industrial units developed in the area generate large volumes of waste water which mixes with surface and groundwater resources thereby polluting them. Degradation of soils and water takes place when waste water is storaged in lagoons due to precaution of effluents. Thus, the soil resources are facing severe threat from both irrigation practices as well as from agro-based industry.

Material and Methods

Soil analysis and extraction of boron from soil: Standard procedures[13-14] were employed for collection and preparation of 20 surface soil samples (figure-2). After drying in air, soil samples were sieved (2mm) and placed in cloth bags. After preparing saturation extract (l:5 soil water ratio) of soils [13,15], pH and EC were recorded. Walkley and Black method[16-18] was used for determination of organic carbon while boron was estimated by azomethine H method[5,19]. The $CaCO_3$ content was estimated by Rapid Titration method[17]. Textural analysis of soil was done by using International Pipette methods [15,17,18].

Groundwater analysis and estimation of boron from groundwater: On the basis of pilot geological and hydro-geological survey of the area, 20 groundwater sampling stations were selected. Then groundwater samples were collected by considering land use, type of crops, amount of fertilizer used, the water quantity, source of water used for irrigation and frequency of application of water. The Polythene bottles of one-liter capacity were used for collection of samples. Throughout boron analysis use of borosilicate glassware was avoided. Plastic containers or corning glassware were used. The samples were collected with due care. The electrical conductivity (EC) and pH were measured immediately at the field site using portable Orion EC and pH meter. Further analyses for major ions were performed in the college laboratory using the standard procedures (APHA, AWWA, WPCF, 1987). Bicarbonate was estimated by titration with HCl. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were analysed titrimetrically while chloride (Cl^-) was estimated by titration with $AgNO_3$. Spectrophotometric method (Hitachi-2000, UV-visible spectrophotometer) was used for analysis of nitrate, sulphate and boron. Sodium and potassium were analysed by flame photometer (Corning 400). The results obtained from soil and groundwater analysis are presented in table 1 and 2.

Table 1
Physico - chemical parameters of groundwater from study area

S. No.	WT	pH	EC	TDS	Na	K	Ca	Mg	Cl	HCO_3	SO_4	NO_3	B
W1	0.9	8.5	4750	3087	560	19	138	106	582	589	169	2	5.57
W2	1.51	7.8	9200	5980	760	1.65	326	309	1503	753	180	38	8.86
W3	12.7	7.9	5408	3515	495	2.1	196	235	710	737	169	19	5.62
W4	7.57	8.6	3815	2480	418	1.25	100	124	667	615	144	21	2.61
W5	4.84	8.3	5209	3386	495	1.2	176	216	1030	745	166	40	3.64
W6	3.03	8.4	5008	3255	458	2.76	140	160	795	744	165	2	3.39
W7	4.54	8.1	4304	2798	318	0.83	236	241	830	566	142	28	5.79
W8	9.09	8.4	5810	3776	188	1.48	304	457	1256	551	161	57	2.95
W9	10.6	8.3	4612	2997	199	1.03	328	214	837	533	126	38	1.6
B10	-	8.2	4814	3129	262	0.63	178	258	1008	502	167	39	4.59
W11	9.09	8.1	2100	1365	65	0.97	182	120	319	523	112	30	3.76
W12	4.84	8.3	2716	1765	144	4.85	441	280	1015	546	164	100	2.73
W13	10.6	8.7	1986	1291	297	0.63	56	20	121	673	79	3	1.09
W14	4.54	8.9	5574	3623	555	2.76	128	187	717	652	167	12	4.86
W15	-	8.7	2192	1425	122	0.77	148	121	334	408	131	20	1.38
B16	-	8.6	890	579	61	0.17	98	48	122	316	39	42	0.556
W17	3.93	8.7	880	572	43	0.57	80	63	70	351	67	3	5.03
W18	7.57	8.1	3090	2009	23	0.68	100	56	78	355	50	14	0.398
W19	3.03	8.3	1390	904	52	0.51	124	73	174	377	55	69	1.601
W20	2.42	8.1	820	533	37	0.74	88	53	110	270	40	18	1.98

Note: 1. All values of the constituents are in ppm, except pH and EC (µS/cm). 2. W- Dugwell, B- Borewell 3. Water Table (WT) depth is in meters.

Table-2
Physico chemical properties of soils from study area

S. No.	pH	EC (dS/m)	Exchangeable cations (meq/100g)				$CaCO_3$ (%)	OC (%)	Boron (mg/L)	Soil Textural Class
			Na^+	K^+	Ca^{++}	Mg^{++}				
S1	8.6	2.84	9.71	0.38	31.75	18.28	11.87	0.64	3.061	Clay
S2	8.3	19.8	10	0.37	44.75	17.03	5.41	0.54	4.262	Clay loam
S3	8.6	17.3	9	0.56	30.5	14.27	15.2	0.88	7.321	Clay loam
S4	8	6.4	4.5	0.36	23.75	15.52	14.16	0.6	8.381	Clay
S5	8.4	4.1	4.47	0.43	30.75	25.54	11.87	0.78	1.753	Clay
S6	8.4	2.9	3.5	0.22	27	21.53	10.41	0.96	0.37	Clay
S7	9.7	6.3	8.5	0.38	12.5	3	14.58	0.40	0.019	Sandy loam
S8	7.8	3.9	6.2	0.91	27.75	25.05	12.08	0.6	1.656	Sandy clay loam
S9	8.4	0.2	2.58	0.19	31.75	17.03	16.16	0.54	0.022	Sandy loam
S10	8.9	1.42	4.34	0.28	27.5	19.78	14.58	0.63	0.824	Sandy clay loam
S11	8.2	1.88	2.067	0.63	34.25	25.29	14.37	0.78	0.020	Sandy clay loam
S12	8.2	0.77	1.96	0.25	45.75	19.28	5.83	0.63	0.023	Sandy clay loam
S13	8.2	0.79	1.34	0.22	43.75	16.78	16.24	0.45	0.019	Sandy clay loam
S14	8.4	0.44	2.48	0.19	55.5	4.5	5.2	0.54	0.019	Sandy clay
S15	8.5	0.383	1.86	0.43	38.25	23.79	13.74	0.34	0.019	Sandy clay loam
S16	8.6	0.45	1.55	0.35	25.25	18.53	8.12	0.57	0.834	Sandy loam
S17	8.5	4.61	8	0.16	24.5	22.29	18.95	0.28	0.498	Sandy loam
S18	8.6	1.84	4.75	0.18	22.5	22.54	14.99	0.51	0.706	Clay loam
S19	8.4	1.3	5.16	0.23	46.5	34.06	8.12	0.6	1.197	Clay
S20	8.4	0.44	2.48	0.36	43.25	29.05	8.74	1.08	0.020	Clay

Results and Discussion

pH, EC and Boron availability in soil: The availability and utilization of boron is determined to a considerable extent by soil pH. Boron is most soluble in acid condition. High soil pH causes boron deficiency in plants forming complex compound. The saline soils are generally much higher in soluble boron than non saline soils as sodium salt of boron are highly soluble[12]. In aqueous solution pH <7, it occurs mainly as undissociated boric acid (H_3BO_3) but at higher pH, boric acid accepts hydroxyl ions from water to form a tetrahedral borate anion $B(OH)^-_4$. Due to higher solubility of boron in acidic condition, it may be leached below the root zone of plants by rainfall or irrigation[20]. In the study area, pH of soil ranges from 7.8 to 9.7 showing weakly to strongly alkaline nature of soil. At high soil pH (S. No. S7,S9,S10,S15,S19) boron content is less and it shows boron deficiency in the study area (figure-2).

The electrical conductivity (EC) of soils increased from 0.2 to 19.8 dS/m. It was observed that the downstream region (S. No. S1, S2, S3, S4 and S17) was showing higher values of EC due to low flushing rate and sluggish groundwater movement. The area comprises villages like Jorve, Rahimpur and Kolhewadi where surface runoff is negligible. This particular area is associated with salt accumulation due to shallow water table. Boron toxicity may occur in such soils because it accumulates as a result of poor leaching. Due to rolling topography, relatively higher gradient, seasonal irrigation and alternating cropping pattern, EC values are lower for upstream and topographically higher areas (S. No. S59, S40, S41, S45, S29).

Organic matter and boron availability in soil: Higher amount of available B are generally found in soil with high organic matter content. In acid conditions, organic matter can protect B from loss by leaching without rendering it unavailable because boron forms complexes with organic matter. Higher B availability in surface soils compared with subsurface soils is related to increased soil organic matter. Application of organic matter to soils can increase B in plants and even cause phytotoxicity[21].

The organic carbon content of the soil was found to be ranged from 0.28 to 1.08% (Table 2). The downstream part of river basin (S. No. S1, S19, S22, S24, S25, S27 and S44) was showing low status of organic carbon. This is attributed to strong alkaline conditions of soil which dissolved the humic substances which are leached out from the soil. The boron is found to be deficient in the upstream part and in the non-irrigated region. This deficiency of boron can be attributed to the lowering of microbial activity and mineralization of organically combined boron due to the drying condition of soil. These results are parallel with the earlier reported results[2,22].

Soil texture and B availability in soil: Boron concentration range depends on soil textural properties and sensitivity varies from crop to crop. Sandy soils with fine textured sub soils generally do not respond to B in the same manner as those with coarse textured subsoil. B added to soil soluble can be leached in low organic matter, sandy soils. Fine textured soils retain B longer than coarse textured soils because of greater B adsorption. The clay retains more B than sand does not imply that B uptake clays is greater than sands. At equal solution of B concentration, plants absorb more from sandy soils than from fine textured soils, where B uptake can be impeded by higher levels of available calcium[21].

In the study area clay and clay loam type of soils are predominantly from downstream part and in the catchment of Ojhar weir (S. No. S1, S2, S3, S4, S5, S6, S18, S19 and S20). This is possibly due to inadequate drainage, unfavorable topography and siltation at Ojhar weir. The soils samples from the study area are showing clay and clay loam type have high B content (table-2). On the contrary the samples (S. No. S7,S8,S9,S10,S11,S12,S15,S16 and S17) are showing sandy clay loam and sandy clay types of soils (Table-2) have low B content. This is to say that sandy soils are coarse textured soils which have low moisture retention and high permeability due to which soluble B leached out.

Boron Toxicity: Boron is the most commonly encountered element found in toxic concentrations in groundwater. The problem of boron levels for plant is emphasized because the range between nutritionally deficient and toxic level of boron is relatively narrow. However, toxicity of B varies from plant to plant. Plants do not show symptoms of boron deficiency if irrigated with water having 1 mg/l of boron. But injury may develop on more sensitive plants when irrigated with boron in excess of 3 mg/l. When water-containing boron is used for irrigation, part of it is absorbed by the soil, with the balance remaining in soil solution. However, it depends on the properties of soils such as soil texture, nature of clay, type of minerals, organic matter, $CaCO_3$ content, salinity and sodicity of soil which affect B absorption[23]. The factors identified which have played an important role in the development of boron toxicity are calcium boron ratio, geology and topography, salinity and sodicity in the study area.

Calcium boron ratio: Boron is remarkable in soil by its very narrow range between deficiency for plant growth and toxicity. Less than 1 ppm of boron may mean a deficiency and more than 3 ppm may be toxic[14]. The boron affects the actively dividing plant tissues and rotting of the softer plants recognizes its deficiency. It is associated with calcium uptake by plants and infertility studies. It is often useful to measure boron-calcium ratios. In addition, boron deficiency decreases the permeability of plasma membrane and boron deficient plant is connected with transpiration[14]. One of the reason of boron toxicity in soil is irrigation with water containing appreciable amounts of B[8]. This is the common occurrence in arid regions and the problem is intensified in saline alkali soils where sodium is the predominant cation and insufficient calcium is present[22].

The significance of B in soil quality can be determined in terms of ratio of exchangeable Ca:B. When this ratio is close to 300 then it is average soils. Higher ratio indicated good soils and lower ratio poor or deteriorated soils. Both Ca and B are concentrated in the cell wall of plant tissue, so there could be a close relationship between them with regard to their effect growth[24]. In the study area, Ca/B is less than 300 for the samples (S. No. S1, S2, S3, S4, S5 and S8) which are located in the downstream area of Pravara river where salinity is higher[25]. Ca:B is more than 300 for the samples (S. No. S21, S29, S40, S41, S42, S45, S48 and S59) which are observed in the non irrigated area where deficiency of boron occurred.

Geology and topography: Boron toxicity in soil is mainly due to anthropogenic and excessive use of agrochemicals. Boron occurs as borosilicate in igneous, metamorphic, sedimentary rocks which are resistant to weathering and not readily available to plants. But weathering in the pedosphere, which includes reactions of acid-bases, oxidation- reduction and dissolution- precipitation, converted the immobile boron to mobile form resulting boron toxicity in soil and water[10]. As regards the geology of the study area, it is broadly constituted of basaltic flows belonging to Deccan volcanic province. Alluvial and colluvial deposits respectively occur along the river channels and hill slopes. A thin veneer of residual soil is developed on the valley floor and top of plateau. Since boron is released naturally by weathering boron containing minerals, it leaches in groundwater on weathering of rocks due to various reactions and causes boron toxicity in the study area (W1, W2, W3, W7, B10, W14 and W17).

Salinity and sodicity: It is noticed that the greater the ability of the soil to absorb boron, the lower will be the boron content in the plant. In salt affected soils, excessive concentration of boron in addition to salinity and/or sodicity restricts plant growth. It is also adversely affects crop production. Toxic concentration of B may be present in these soils due to long term use of irrigation waters containing fairly high proportion of boron. Many workers have detected the boron toxicity in salt affected soils [2,26-29]. In the present study, boron concentration in the groundwater and soil was estimated (table-1 and 2).

In relation to boron toxicity, Tondon classified the waters into four different classes[5]. Based on this, the groundwater from the study area are classified (table-3.)

Table-3
Classification of groundwater from study area for boron toxicity

Toxicity Level	Concentration of B	No. of samples with locations
Low	<1 ppm	B16 and W18 **= 2(10%)**
Medium	1 to 2 ppm	W9,W12,W15,W19 and W20 **= 5(25%)**
High	2 to 3 ppm	W4, W5, W6, W8 W11 and 12 **= 6(30%)**
Very high	> 4 ppm	W1, W2, W3, W7, B10, W14 and W17**= 7(35%)**

It is seen from the above table that the boron content in 10% samples was below 1 ppm. This indicates that 10% samples have lower values of boron thereby reflecting less toxicity hazard. In contrast, the remaining 90% samples belong to medium, high and very high category of boron toxicity. This suggests that in irrigated agricultural area, groundwater is rich in B (figure-1). However, it is interesting to note that some of the wells from the plateau, top hill slopes and near sugar factory region have displayed high values of B (figure-1). The high concentration of B does not cause any toxicity in the area because soils are calcareous in nature[11]. The high concentrations of B are not expected to cause any toxicity. This is attributed to B from soils precipitates as calcium borate[30]. The possible means to counteract the toxicity of boron is through proper selection of crops. Alfalfa, wheat, barley, oats, cotton, sugarbeet, sorghum and maize are reported to be tolerant to boron (5-10 mg/l). The oil seeds, legumes, citrus and horticultural plants are in general sensitive to boron. The tolerance of crops to boron increases in the presence of soluble calcium, nitrogenous and phosphates fertilizers and decrease with increase in salinity[30]. Therefore, adequate fertilization could help in minimizing boron toxicity.

It is observed that the boron toxicity found to be higher in the downstream part of the basin (figure-1 and 2). However, it is further inferred that boron is in toxic concentration in saline groundwater from irrigated agriculture possibly due to restricted leaching. Hence, the toxicity of boron is the impact of salinization and/or alkalization. There is no economically feasible method for removing boron from irrigation water. Similarly, there is at present no chemical or soil amendment which can economically be added to the soil to render boron non-toxic. However, high levels of boron in saline soils can be easily reduced by leaching alone and in alkali soils by leaching after treatment with gypsum. The application of gypsum not only improves the soil permeability and allows increased leaching but also lowers the availability of boron. It is known that B occurs in toxic concentration in the form of sodium metaborate. However, sodium metaborate reacts with gypsum to form sodium sulphate and calcium metaborate. The solubility of calcium metaborate is very low (0.4 %) as compared to sodium metaborate (26 to 30 %) at 20-35^{o}C. The large difference renders boron to precipitate.

Classification of soils on the basis of boron availability from the study area: The boron content in the soil varies from 0.019 to 8.381 ppm (table 2). The salt affected soils (S. No. S1, S2, S3, S4 and S5) showed high content of B which are located in the downstream region of Pravara River. Excessive concentrations of boron were detected remarkably by different plant species. The permissible limits of boron concentration relative to boron tolerance of crop plants have been classified by Richards (1968)[31]. According to Richards, the safe limit for sensitive plants for boron concentrations in the soil is 0.7ppm while marginal limit ranges from 0.7 to 1.5ppm and unsafe is greater than 1.5ppm. Considering these limits, soils from the area are categorized (table 4).

Table-4
Classification of soils based on boron concentrations from the study area

Class	Boron concentration(ppm)	Locations and No. of Samples
Safe	< 0.7	S6, S7, S9, S11, S12, S13, S14, S15, S17, S20 **= 10 (50%)**
Marginal	0.7 to 1.5	S18, S19, S16, S10 = **4(20%)**
Unsafe	> 1.5	S1, S2, S3, S4, S5, S8 **=6 (30%)**

It is noticed that boron concentration for crops is safe for 10 (50%) samples (table 4). 4(20%) samples were marginal and 6 (30%) samples are unsafe. This indicates that 50% samples have crossed the safe limit of boron and showed toxic concentration of B. These samples (S. No. S1, S2, S3, S4, S5 and S8) are located in the downstream part of Pravara River and in the back-waters of Ojhar Weir. This is attributed to high soil pH, high EC, blocked drainage restricts leaching, high and fluctuating water table and soil texture is clayey. Leaching and treatment of soil with gypsum can reduce the high concentration of boron. However, the remaining 10(50%) samples are in the safe limit. It is also noticed that out of 10 samples, majority of the samples are deficient in boron concentration. This might be due to highly calcareous nature of soil since calcium carbonate has been noted to cause decrease in the concentration of soluble soil B[32].

Conclusion

In order to know the status of boron in soil and groundwater from Sangamner area, 20 soil and groundwater samples were analyzed for different parameters. The pH of soil ranges from 7.8 to 9.7 showing alkaline nature. The EC values varies from 0.2 to 9.8 dS/m. The higher values of pH and EC were noticed in the downstream part of Pravara River which is due to low flushing rate and sluggish groundwater movement. This leads to salinity and sodicity in the area. The B content is higher in saline soils than non – saline soils in the area. The organic carbon content is found to be varied from 0.28 to 1.08% in the soil. B availability in surface soils is higher as compared with subsurface soils. This is attributed to increased soil organic matter. The downstream part of Pravara River showed low status of organic matter. This is due to strong alkaline condition of the soil. Fine textured soils retain B longer than coarse textured soils because of greater B adsorption. The textural analysis revealed the predominance of clay to clay loam textural type of soils which are located in the downstream part i.e. in the catchment of Ojhar weir. The clay and clay loam type of soils from the study area have high B content as compared to sandy clay loam and sand clay type of soils. As far as boron toxicity is concerned, 50% soil samples are unsafe for crop development which is located in the downstream region of Pravara River and in the backwater areas of Ojhar weir. Such boron toxicity is the effect of salinization and/or alkalization of soil and ground water. However high levels of boron can be reduced from saline / sodic soils by leaching using gypsum as amendment and by selection of boron tolerant crops in the study area.

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