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Measurements of boron concentration from rivers in northern Basrah Governorate using SSNTDs

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ABSTRACT

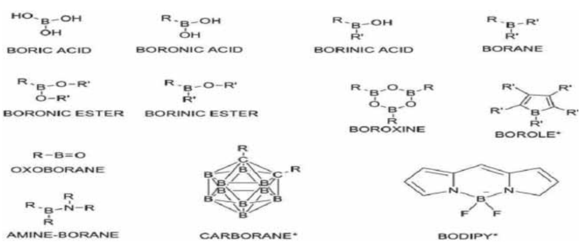
Consumption of boron-contaminated food and drinking water poses several health risks to consumers. As a result, the boron content in food particles must be measured. Drinking water samples were obtained from several locations in northern Basrah, Iraq, for this investigation. The Solid State Nuclear Track Detector (SSNTDs) technique was used to examine the obtained water samples to identify boron levels. Boron levels were found to range from 0.28 ppm in Al Alwa (Al Qurnah) (tap water) to 1.85 ppm in Oil Street. This study's findings were compared to international standard values and previously published research. These findings may be utilized by the Iraqi government to develop guidelines to decrease radioactive contamination of drinking water in Basrah. The 41 surface water samples tested in this study had boron levels that were lower than the international standard limits. As a result, the boron level in Basrah's drinking water is normal. However, there is a chance that boron contamination will become a serious concern shortly. As a result, additional research is required in the future.

Key words: boron concentration, CR-39, neutron source, northern Basrah Governorates, water samples

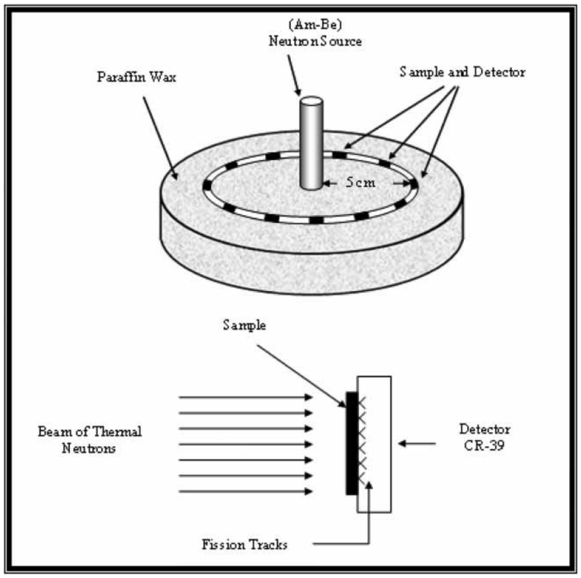
HIGHLIGHTS

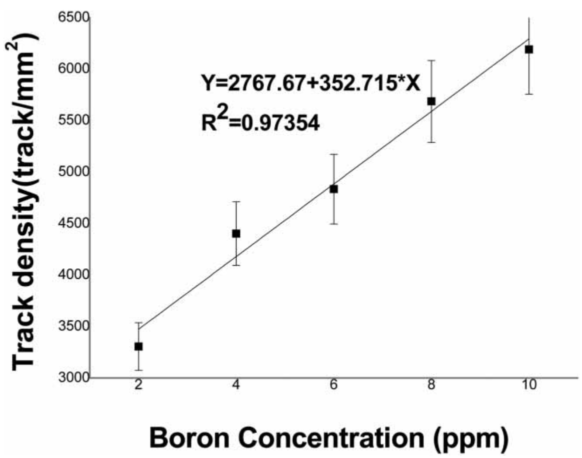
- The research aims to determine the concentration of boron in the north of Basra.
- The research includes practical measurement methods carried out at the University of Baghdad, College of Education for Pure Sciences, Ibn Al-Haytham.
- Forty-one samples of water were collected and the trace detector CR-39 was used.
- All samples were irradiated by the neutron source.
- The intensity of traces was calculated by light microscopy.

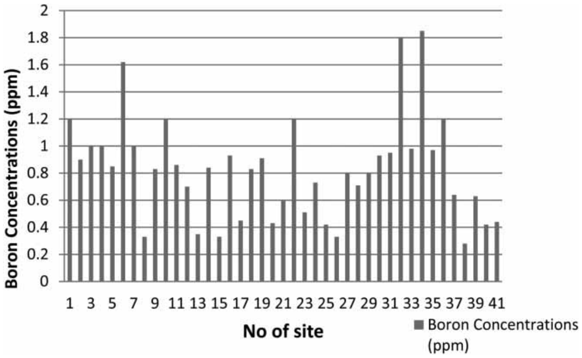
GRAPHICAL ABSTRACT




Al Qurnah
Al Huwair
Al Sharish
Shafi
Ad Dayr
Al-Hartha


(Am-Be)
Neutron Source
Paraffin Wax
Sample and Detector
5cm
Sample
Beam of Thermal Neutrons
Detector CR-39
Fission Tracks


Y=2767.67+352.715*X
R2=0.97354
Track density(track/mm2)
Boron Concentration (ppm)
6500
6000
5500
5000
4500
4000
3500
3000
2
4
6
8
10



INTRODUCTION

Boron is an element that occurs naturally in rocks, soil, and water. It belongs to the non-metallic element family (Brdar-Jokanović 2020). It has an atomic weight of 10.81 and an atomic number of 5. Boron has two isotopes: boron-10, which has a 19.8% abundance, and boron-11, which has an 80.2% percent abundance (Nielsen *et al.* 1992). Boron levels in the Earth's crust are believed to be less than 10 parts per million, although they have been discovered to be as high as 100 parts per million in locations where boron levels are greater (Young 2008). SSNTDs of various materials are useful for fundamental scientific and technological research (Lyday 2005). In the disciplines of radiation protection and environmental radiation monitoring, SSNTDs are commonly employed. The idea of SSNTDs was discovered some years ago; Salman *et al.* (2015) described the basic concepts, while Durrani *et al.* (Parks 2005) provided a comprehensive explanation. Nikezic & Yu (2003) published on the specifics of alpha particle detection. As a result, certain elements of interest are only highlighted in this study. Depending on the chemical treatment (called etching) and observation technique, there are fundamentally two criteria: the particle's range and energy deposition should be acceptable (Hermsdor 2009). The early results of boron level detection data gathered from numerous places in Northern Basrah, Iraq, are described in this study. The major objective is to investigate the complex changes and interactions with water flow, as well as to determine the number of dangers posed by these fluids. In reality, the research area is located inside the Governorate of northern Basrah. Figure 1 depicts the chemical structure of boron.

SSNTDs of diverse materials are important for fundamental research and technological development (Salman & Qasim 2013). SSNTDs are frequently utilized in environmental radiation monitoring and radiation protection. Somogyi (Somogyi & Szalay 1973; Durrani & Bull 1987) presented the fundamental concepts of SSNTD theory some years ago. The specifics of alpha particle detection are crucial from the standpoint of the BNCT (Nikezic & Yu 2003). For the ^{10}BNCreaction to

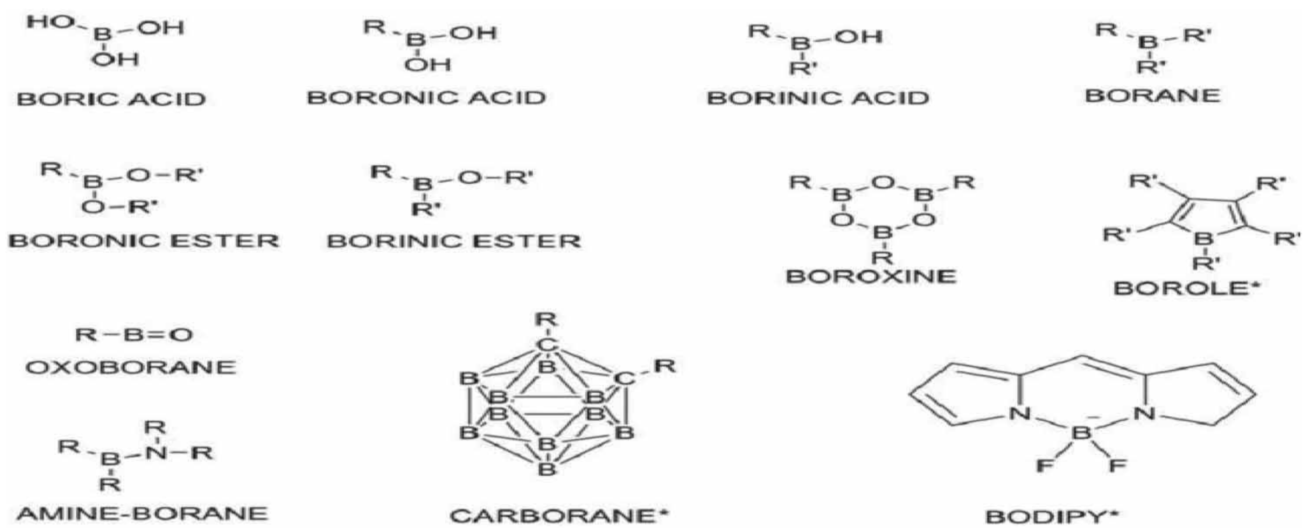


Figure 1 | Depicts boron-containing compounds (BCCs). The fundamental core structures for BCCs are depicted in this document.

occur, a sample having one of the recognized boron compounds, even if only in trace amounts, numerous hundreds are involved in today's applications and on a rising level, ^{10}B, a source fixed for radioactivity with thermal or minor neutron energy (0.025 eV or lower), and a reaction fragment identifying method are required. The process occurs as a result of a neutron contact with a boron nucleus, following which it disintegrates into two fragments of the $^{10}B + n$ compound nucleus (to set aside a little amount of time, on the range of picoseconds). The two fragments come first, receiving the kinetic energy as a result of the strong Coulomb field traveling in the opposite direction by the rule of momentum conservation (Algrifi & Salman 2022), which is produced via the following procedure:

$$^{10}B + n \rightarrow [^{11}B] \rightarrow \begin{cases} ^{7}Li + {}^{4}He + 2.79\,MeV & (\text{branching ratio } 6.1\%) \\ ^{7}Li + {}^{4}He + \gamma(0.48\,MeV) & (\text{branching ratio } 93.9\%) \end{cases} \quad (1)$$

This response occurs in the case of the varied branching relationship: The first reaction has a lower frequency of occurrence (6.1%), but it has a better reaction with fewer photons, resulting in a greater Linear Energy Transfer (LET) or dE/dx. The opposite reaction, which occurs earlier, is followed by a 0.48 MeV photon. If the alpha particle (4He+) has enough kinetic energy to move over the sample surface, it can be identified using nuclear track methods, for example. As an efficient systematic technique for boron research, the alpha particle fingerprint assumed by a sufficient identifying significance offers information on the existence of boron and is reasonably predictable. This research summarizes the major findings from boron amount data gathered from several locations in northern Basrah city. Our primary objective is to carry out research on the intricate exchanges and interactions with the water flow and determine the number of risks introduced by these fluids. The research region is located in northern Basra, Iraq, as shown in Figure 2.

Boron toxicity

The current understanding of boron's hazardous level in humans has to be enhanced. Only human poisoning instances and animal toxicity research have provided minimal data on this area. According to these findings, the acute fatal dosage of boric

Figure 2 | Northern Basrah Governorate (Google Earth).

acid for newborns is 3000–6000 mg while for adults it is 15,000–20,000 mg. Clinical signs of boron poisoning have been documented at doses ranging from 100 to 55,500 mg, depending on age and body weight, indicating that there is no considerable risk of toxicity in people. The principal boron-related harmful impact in animals is on the reproductive system. Boron has particularly negative effects on the male reproductive tract of rats, mice, and dogs, including decreased scrota, spermiation inhibition, seminiferous tubule degeneration and atrophy, and the lack or loss of germ cells. Boron reduced ovulation in female rats and produced kidney lesions in female mice. For 9 weeks, rats were given boron concentrations of 0, 3000, 4500, 6000 and 9000 ppm (0, 26, 38, 52, and 68 mg/kg/day) to investigate the association between lesion development and various boron concentrations. They discovered that levels of 3000 and 4500 ppm decreased sperm production, whereas doses of 6000 and 9000 ppm induced atrophy. Boron risk analyses show that at current projected dietary or municipal drinking water levels of exposure, there is no appreciable risk of toxicity to humans, however boric acid and sodium borates have minimal acute toxicity. They are neither irritants nor sensitizers to the skin. Although certain sodium borates produce eye irritation in animals, no significant ocular effects have been reported in people after 50 years of occupational exposure. At large levels, boron compounds are poisonous to all species studied, although they are not mutagenic or carcinogenic. Developmental and reproductive toxicity is the most common long-term effects. There are no epidemiological studies on the effects of boron on the development of the human fetus that we are aware of. Fetal toxicity has been found in mice, rats, and rabbits in the laboratory. In all exposed groups, the average fetal body weight was considerably lowered in a dose-dependent manner when compared to controls. High perinatal mortality, lower fetal body weight, cardiovascular system, central nervous system, eye malformations, and axial skeleton deformities are all described as developmental toxicities associated with boron exposure. There is no specific information on boron's potential to cross the placenta or accumulate in fetal tissues. However, findings from animal research imply that developmental toxicity in humans may be a cause for worry after boron exposure (Bakidere *et al.* 2010).

Animals and people who are deficient in boron respond well to boron intakes either by dietary methods or in nutritional quantities. Participants in human depletion-repletion tests reacted to a 3 mg/day boron supplement after ingesting a meal with just 0.2–0.4 mg/day of boron. According to one study, a diet of roughly 1 g boron/g covers the needs of almost all chicks. This animal study implies that a boron intake of at least 0.5 mg/day would be advantageous to many people, based on the premise that humans consume a 500 g diet per day, which is consistent with human studies. To satisfy the normative demands of adults, the human and animal data were combined to arrive at a mean population boron consumption of 1.0 mg/day. In healthy people, a boron intake of 1.0 mg/day should offer maximal beneficial action. Individuals with pathological disorders linked to chronic inflammation and oxidative stress may benefit from higher doses. Boron is a generally safe food additive. In the United States and Canada, the safe upper intake level (UL) for boron has been determined at 20 mg/day. The World Health Organization originally recommended a UL of 13 mg per day, but this was later increased to 0.4 mg/kg body weight or around 28 mg per day for a 70 kg individual. The European Union set a total boron UL based on body weight, which is about 10 mg/day for individuals (Harold 2017).

MATERIAL AND METHODS

In April 2021, samples were collected from 41 stations and sites in the Basrah governorate. Boron concentration in soils was measured using passive techniques; SSNTDs were used for the measurements, and films from the CR-39 detectors with dimensions of 1×1 cm. Many soil samples from various locations were provided. One milliliter of various boron concentration standards was sprayed onto the same region of the CR-39 track detector and allowed to dry. The standard samples were subjected to a thermal neutron source for the same amount of time (7 days) after drying. A type $^{10}B\ (n,\alpha)\ ^{7}Li_3$ shows that a nuclear reaction has occurred. Alpha particles have an energy of 2.31 MeV and can leave a trace in the CR-39 plastic detector. After that, distilled water is used to rinse the samples in a 6.25 N (Normality) NaOH solution at 60 °C in a bath maintained at a constant temperature for 6 hours (etching duration). A transmission optical microscope was used to measure track diameters and density, and an appropriate calibration curve was utilized to determine boron concentration. Neutrons produced by $^{241}Am - {}^{9}Be$ were used to irradiate the components of each detector set.

Irradiation of the samples

The pellets (water samples) were shielded with a CR-39 detector and placed on a paraffin wax plate 5 cm from the neutron source ^{241}Am-^{9}Be, with the thermal neutron flux (5×10^3 n cm^{-2} S^{-1}) as indicated in Figure 3.

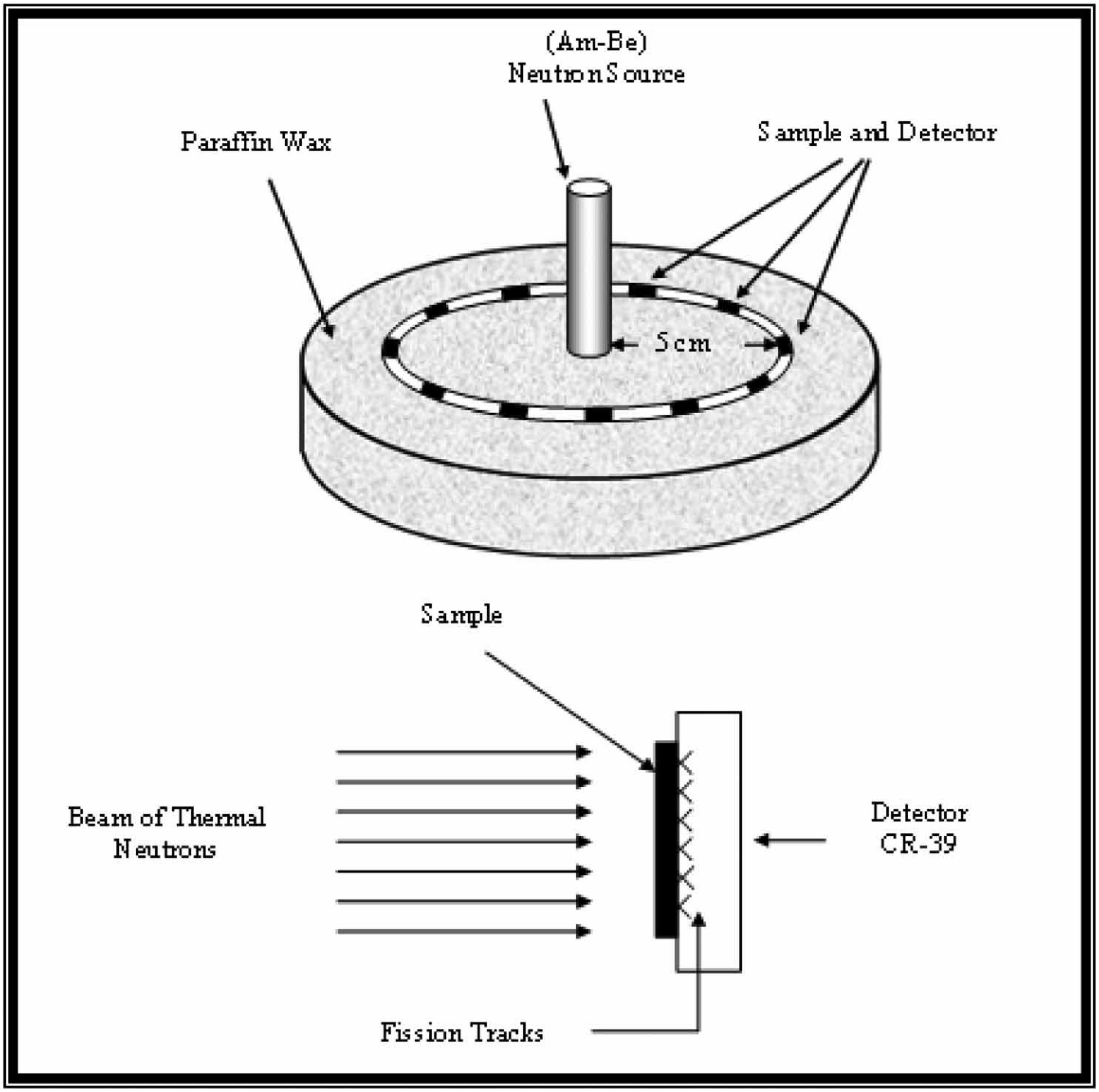


Figure 3 | Soil samples and detectors being irradiated in front of a neutron source that produces thermal neutrons.

Chemical etching and scanning using a microscope

The CR-39 detectors were removed after 7 days of radioactivity and etched in a 6.25 N aqueous solution of NaOH maintained at 70 °C for 6 hours, which is the standard etching period (Singh *et al.* 2001). The detectors were washed in distilled water before being air-dried. The tracks confirmed in CR-39 detectors were tallied using an optical microscope with a magnification of 400×. The density of the tracks in the detectors was calculated using the following formula:

$$\text{Track density } (\rho_x) = \frac{Nave}{A} \quad (2)$$

where ρ_x = track density (Track/mm^2); N = Average of total tracks; A = Area of field view (0.07 mm^2).

Water sample calibration curve

For the calibration of our study and the density of track, the curve plot between the standards for various boron solutions of specified concentrations was set from 2 to 1 ppm, using neutron-induced radiography (NIR), which is based on the solid-state nuclear detectors (SSNTDs) CR-39 principle. The concentration of boron was calculated using the Regression equation: $y = 2767.67 + 352.715^*X$, $R^2 = 0.97354$, which compares the track densities detected on the detectors of the samples to those of the reference samples. The slope factor was calculated after observing a linear calibration as illustrated in Figure 4. The results are experimented with within mg B/l units.

RESULT AND DISCUSSION

The track's density and boron concentration samples were analyzed using a CR-39 detector, as shown in Table 1. River water samples were collected from 41 places in the northern Basrah Governorate. Figure 5 depicts the connection between boron content and the number of soil sample locations.

Water samples in Table 1 and Figure 5 were used to determine the level of boron content throughout the graph. Figure 5 shows the findings for these 41 samples, which are divided into 36 locations ranging from W1 to W41. Boron concentration was reported to be as high as 1.85 ppm in Oil Street and as low as 0.28 ppm in AlAlwa AlQurnah. In 1993, the World Health Organization (WHO) developed a boron guideline of 0.3 mg/L for health reasons. In 1998, this amount was largely increased to 0.5 mg/L. Furthermore, it was clear in 2000 to discontinue utilizing the 0.5 mg/L recommendation until evidence from continuous research development which may make changes for the current perspective of boron toxicity or technology for boron treatment (World Health Organization 1998; Vadivel *et al.* 2012). The European Union established a boron restriction of 1.0 mg/L for drinking water in 1998 (Council of the European Union Council Directive 98/83/EC November3 1998; Neelesh *et al.* 2012). New Zealand has set a boron guideline of 1.4 mg/L for drinking water (New Zealand Ministry of Health Drinking-Water Standards for New Zealand; Wellington PO Box 5013 Wellington New Zealand 2000; Abdul & Master 2012). According to IMAC, the safe boron content in Canada is 5 mg/L. This value has been determined by the Canadians

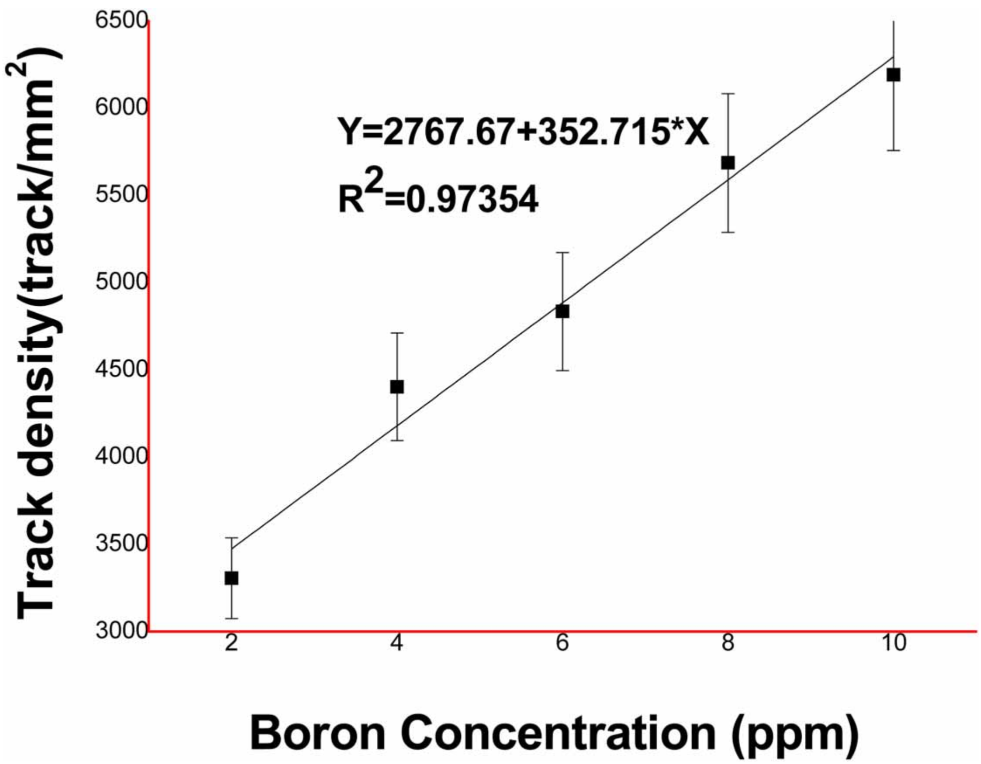


Figure 4 | For standard boron samples, the relationship between track density and boron concentration (ppm) is shown.

Table 1 | Boron content in water measured using the SSNTDS technique in northern Basra Governorate

No of site	Location of samples	Boron Concentrations (ppm)
W1	Al Traba	1.2
W2	Saleh River	0.9
W3	Center Al Madina	1
W4	Anter River	1
W5	Al Huwair	0.85
W6	Al Ahwar	1.62
W7	Al Sura	1
W8	Al Neherat	0.33
W9	Al Khas	0.83
W10	AL Housh	1.2
W11	Abu Ghraib	0.86
W12	Majnon	0.7
W13	Al Alwa Al Qurnah	0.35
W14	Al Awjan	0.84
W15	Mzieraa	0.33
W16	Al Basha River	0.93
W17	Al Sharish	0.45
W18	Ahmed bin Ali	0.83
W19	Al Alwa Al Huwair	0.91
W20	Al Aghmieg	0.43
W21	Talhah	0.6
W22	Um Al Shuwayj	1.2
W23	Al Shafi Seid Saleh	0.51
W24	Al Ez River	0.73
W25	Al Naem	0.42
W26	Adam's tree	0.33
W27	Al Huwair Al Sagher	0.8
W28	Al Awja	0.71
W29	Huwair Al Sada	0.8
W30	Al Seda	0.93
W31	Al Fatheia	0.95
W32	Al Samaid	1.8
W33	Al Ardhania	0.98
W34	Oil Street	1.85
W35	Khmesa	0.97
W36	Al Fesla	1.2
W37	AL Housh (tap water)	0.64
W38	AlAlwa AlQurnah (tap water)	0.28
W39	Al Huwair (tap water)	0.63
W40	Al Sharish (tap water)	0.42
W41	AlShafi Seid Saleh(tap water)	0.44

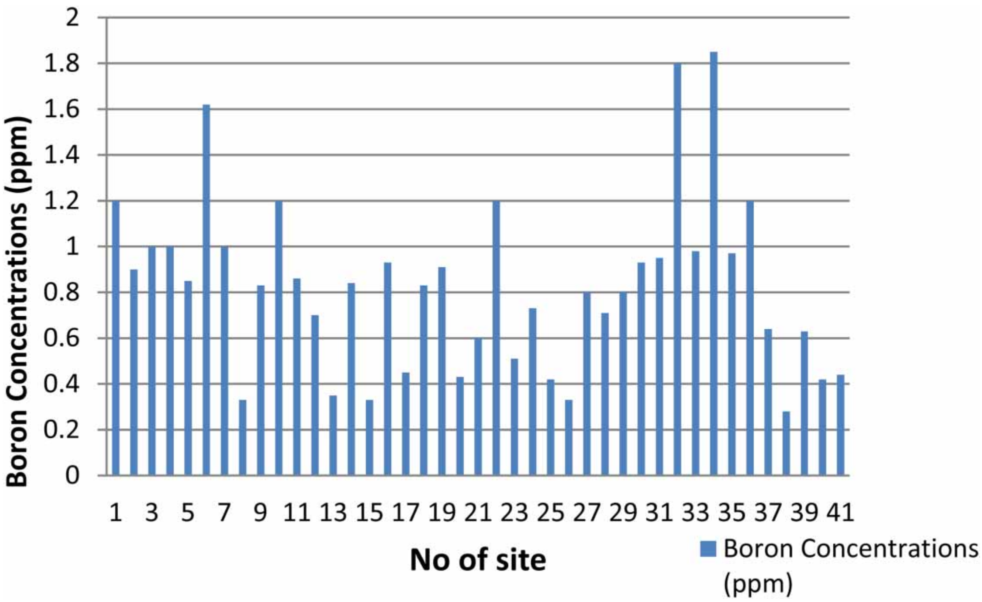


Figure 5 | Boron concentrations in northern Basrah Governorate.

based on realistic treatment technology. Due to insufficient technology, it is now difficult to reduce boron concentrations to less than 5 mg/L. They will revisit this IMAC when new information becomes available (Federal–Provincial–Territorial Committee on Drinking Water in April 2003).

CONCLUSION

Soils may be found in various rural places in rural regions, including the northern Basrah Governorate in Iraq. Chemical soil study findings indicated the presence of boron in New Zealand, with a limit of 1.4 ppm and an IMAC of 5 ppm, with a range of 0.28–1.85 ppm. Boron concentrations are modest and within natural limits in the majority of water samples. The correlation issue between the boron content of widespread samples and the Track density (track/m2) of samples in water samples is 97.35%, which is a very good connection. Getting the right entry to secure consuming water is critical for human health and is a chief source of public health troubles through knowledge of the suitability of water for drinking and irrigation.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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