A Study on Seasonal Variation of the Groundwater Chemistry in Andhra University Campus, Visakhapatnam

G. V. R. Srinivasa Rao, Y. Abbulu, T. P. Sreejani and S. Priyanka

Abstract An attempt has been made in this work to evaluate the quality of groundwater at Andhra University campus, Visakhapatnam, Andhra Pradesh, India, and its suitability for domestic purpose. Groundwater samples are collected from the twenty-five bore wells located in the campus during the post-monsoon (November 2015–February 2016), Pre-monsoon (March 2016–June 2016) and Monsoon (July 2016–October 2016) periods at regular intervals of time and are analysed for various physico-chemical parameters using standard laboratory procedures. Data analysis is done by using Aquachem 2014.2 software. Piper tri-linear diagrams and Durov diagrams are drawn using the concentrations of various cations and anions. The dominance of major cations and anions is observed as $Mg^{2+} > Ca^{2+} > Na^{+} > K^{+}$ and $Cl^{-} > HCO_3^{-} > SO_4^{2-} > CO_3^{-}$, respectively. From Piper plots, it is observed that majority of groundwater samples exhibited that $Ca^{2+} + Mg^{2+}$ significantly exceeded $Na^{+} + K^{+}$ and $Cl^{-} + SO_4^{2-}$ exceeded $HCO_3^{-} + CO_3^{2-}$ in Post-Monsoon, Pre-Monsoon and Monsoon periods. The pH and TDS parts of the Durov plot reveal that the quality of groundwater is in the range of drinking water standards during all the seasons.

Keywords Piper tri-linear diagram · Durov diagram
Physico-chemical parameters · Aquachem 2014.2

1 Introduction

Water is a valuable and crucial resource for the sustenance of life and for any developmental activity. Most of the times groundwater forms a potential source of water supply all over the world. However, in the recent past groundwater quality is getting deteriorated due to various reasons and making it unsuitable for drinking purposes.

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Hence, it became necessary to assess the groundwater quality spatially over sufficient periods of time to arrive at its suitability for various purposes.

Groundwater, in general, is less susceptible to bacterial pollution when compared with the surface water. But it contains several chemical elements like Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-} and SO_4^{2-} which play an important role in the classification and assessment of quality of groundwater. The groundwater quality data can be interpreted through Piper tri-linear plots and Durov diagrams. The present study involves the assessment of the groundwater quality at Andhra University campus, Visakhapatnam, in terms of Piper tri-linear plots, Durov diagrams by analysing groundwater samples over a period of one year during different seasons.

Earlier studies w.r.t. groundwater chemistry indicate that studies on hydrogeochemistry enable the researchers to evaluate the elevated concentrations of certain ions and their interrelationships which in turn will be helpful to assess the reasons behind like anthropogenic processes. In a study conducted by Seyflaye et al. [1], the high-level concentrations of nitrates are related to the processes like leaching of fertilizers and pesticides into the ground, return flow of irrigation water, etc. The hydro-chemical studies enable to know how the chemical composition of groundwater varies w.r.t. to types of water. Hydro-geochemical parameters of groundwater are largely controlled by the flow patterns of groundwater that follow the topographical features of the study area. In a study conducted by Hamzaoui-Azaza et al. [2], it is observed that the mineralization of the groundwater increased significantly following the direction of flow of groundwater.

The Piper diagrams as well as Durov diagrams drawn for the working of hydrogeochemical facies indicate the variability of water quality parameters falling within acceptable range or not. Ghoraba and Khan [3]. In a study conducted by Ramkumar et al. [4] near a coastal zone, higher concentrations of ions were observed during the post-monsoon indicating the intrusion of saline water into the coastal area. However, in the pre-monsoon season the ionic concentrations indicated the return flow into the coastal aquifer. In a study on groundwater quality in the coastal aquifers at south Chennai, India, Kumar et al. [5] observed that most of the sampling points cluster on Na^{+} and Cl^{-} and the mixed facies of Ca^{+}–Mg^{+}–Cl^{-} of the tri-linear diagram indicated that the dominant ions of groundwater are derived from sea water intrusion.

The hydrogeological facies using Piper and Durov diagrams drawn in a study conducted by Khan et al. [6] in the Indus basin of Pakistan have shown that groundwater mixing creating environmental issues like lowering of water table and saltwater intrusion. In a study conducted in southern Gaza strip, Jabel et al. [7] observed that the groundwater is alkaline in nature with the ionic abundance of the cations following the order $Na^{+} > Mg^{2+} > Ca^{2+} > K^{+}$ and anions $Cl > HCO^{3} > SO_4^{2-} > NO^{3-}$ and F. The Gibb's diagram indicated that the groundwater chemistry is controlled by ion exchange, evaporation and the anthropogenic activities. The isotopic and geochemical modelling techniques enable understanding of shallow water systems and the underlying causes of salination by Abu-Jaber [8].

2 Study Area

Andhra University campus located in Visakhapatnam, Andhra Pradesh, lying between latitude 17° 43′ 5.38″N and longitude 83° 19′ 17.61″E with an area of 422 acres and a varying elevation from 10 MSL to 62.5 MSL is considered as a study area for this research work. The average annual rainfall is 955 mm and the mean annual temperature and humidity are 23.7 °C and 67–78%, respectively. The study area is divided into two campuses, viz. South campus and North campus.

3 Methodology

3.1 Analysis of Groundwater Quality

Groundwater samples collected from the existing 25 bore wells in the campus during the periods November 2015–February 2016 (post-monsoon season), March 2016–June 2016 (pre-monsoon season) and July 2016–October 2016 (monsoon season) were analysed for their physico-chemical parameters. These parameters include pH, electrical conductivity, alkalinity, hardness, total dissolved solids, sulphates, chlorides, bicarbonates, iron, magnesium, calcium, sodium, potassium and fluorides in standard procedures.

3.2 Piper Tri-linear Diagrams

Piper tri-linear plots are plotted using Aquachem 2014.2 for post-monsoon, pre-monsoon and monsoon periods. On the left triangle, the cations are plotted, whereas the anions are plotted on the right triangle. The concentrations of cations and anions are expressed as percentages in meq/l. Each point is then projected into the upper field along a line parallel to the upper margin of the field. The point at which the extension intersects shows the characteristics of water representing the relationship among $Na^+ + K^+$, $Cl^- + SO_4^{-2}$, $HCO_3{}^- + CO_3{}^-$ and $Ca^{+2} + Mg^{+2}$.

3.3 Durov Diagrams

The Durov diagrams are plotted using Aquachem 2014.2. Using these diagrams, the groundwater quality and its evolution can be understood and the geochemical processes can be displayed. In Durov diagram, it is possible to depict pH and TDS in addition to cations and anions.

4 Results and Discussions

The results of the study in terms of the maximum and minimum values of different water quality parameters during the post-monsoon (November 2015–February 2016), pre-monsoon (March 2016–June 2016) and monsoon (July 2016–October 2016) seasons are presented in Table 1.

4.1 *Piper Tri-linear Plots*

It is observed from the Piper plots that 95% of the samples fall under Ca^{2+}–Mg^{2+}–HCO_3^- facies (Type-1 water), 5% of the samples fall under Ca^{2+}–Mg^{2+}–Cl^-–SO_4^{2-} facies (Type IV water), and also majority of groundwater samples exhibit that the combination of $Ca^{2+} + Mg^{2+}$ exceeded the combination

Table 1 Average parametric values (November 2015–October 2016)

S. No.	Parameter	Post-monsoon (November 2015–February 2016)	Pre-monsoon (March 2016–June 2016)	Monsoon (July 2016–October 2016)
1	pH	6.01–7.99	6.01–8.62	6.00–8.62
2	Electrical conductivity (µs/cm)	0.01–20.22	0.10–874.80	0.10–2.90
3	Calcium (mg/l)	78–226	62–380	66–190
4	Magnesium (mg/l)	18–238	10–308	12–358
5	Sodium (mg/l)	10.5–97.2	6.8–99	1.2–98.1
6	Potassium (mg/l)	4.3–30	4.2–28.3	5.7–29.9
7	Bicarbonate (mg/l)	170–690	5–690	5–515
8	Carbonate (mg/l)	20–170	30–240	10–210
9	Chlorides (mg/l)	91.97–219.93	79.97–337.4	37.99–213.93
10	Sulphates (mg/l)	9.8–92.91	6.8–89.95	1.5–92.92
11	Iron (mg/l)	0.01–0.05	0.02–0.5	0.01–0.1
12	Fluoride (mg/l)	0.08–0.50	0.03–0.29	0.04–0.48
13	Total dissolved solids (mg/l)	300–1860	240–1940	200–1860
14	Total alkalinity (mg/l)	225–680	15–740	125–555
15	Total hardness (mg/l)	126–344	110–448	116–450

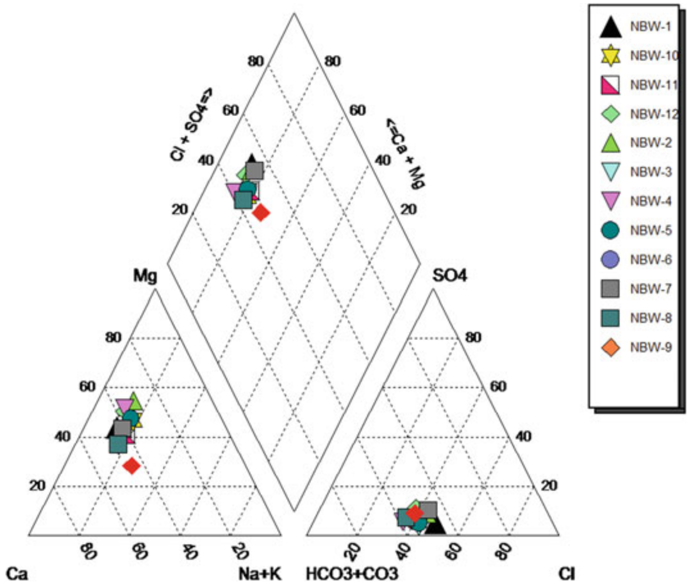

Fig. 1 Piper tri-linear plot for North campus, AU, post-monsoon (November 2015–February 2016)

of $Na^{+}+K^{+}$. Similarly, the $Cl^{-}+SO_4^{2-}$ combination exceeded the $HCO_3^{-}+CO_3^{2-}$ combination in post-monsoon period.

It is observed that during the pre-monsoon period, 33% of the samples fall under Ca^{2+}–Mg^{2+}–HCO_3^{-} facies (Type-1 water), 67% of the samples fall under Ca^{2+}–Mg^{2+}–Cl^{-}–SO_4^{2-} facies (Type-IV water), and also majority of groundwater samples exhibit that the combination of Ca^{2+} + Mg^{2+} exceeded the combination of $Na^{+}+K^{+}$. Similarly, the $Cl^{-}+SO_4^{2-}$ combination exceeded the $HCO_3^{-}+CO_3^{2-}$ combination in pre-monsoon period.

Further, it is observed that during the monsoon period that 50% of the samples fall under Ca^{2+}–Mg^{2+}–HCO_3^{-} facies (Type-1 water), 50% of the samples fall under Ca^{2+}–Mg^{2+}–Cl^{-}–SO_4^{2-} facies (Type-IV water), and also majority of groundwater samples exhibited that the combination of Ca^{2+} + Mg^{2+} exceeded the combination of $Na^{+}+K^{+}$. Similarly, the $Cl^{-}+SO_4^{2-}$ combination exceeded the $HCO_3^{-}+CO_3^{2-}$ combination in monsoon period.

The ionic dominance exhibited the following pattern: $Mg^{2+} > Ca^{2+} > Na^{+} > K^{+}$ and $Cl^{-} > HCO_3^{-} > SO_4^{2-} > CO_3^{-}$. Majority of groundwater samples exhibited that Ca^{2+} + Mg^{2+} significantly exceeded $Na^{+}+K^{+}$ and Cl^{-} + SO_4^{2-} exceeded HCO_3^{-} + CO_3^{2-} in all the three seasons (Figs. 1, 2, 3, 4, 5 and 6).

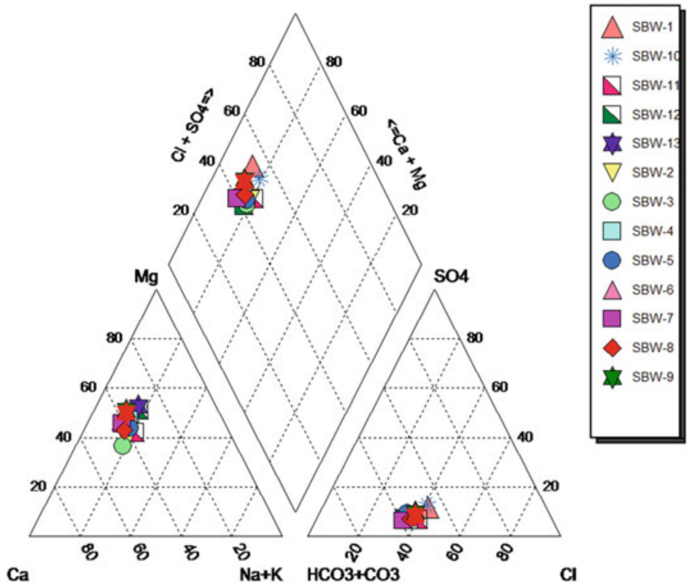

Fig. 2 Piper tri-linear plot for South campus, AU, post-monsoon (November 2015–February 2016)

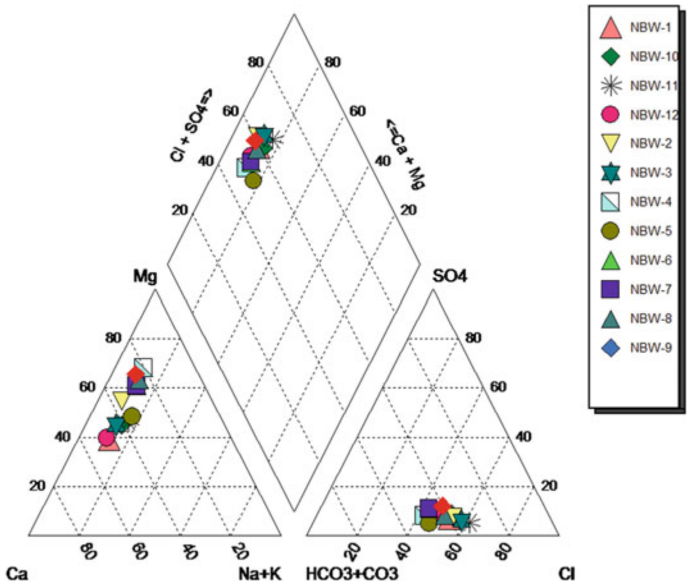

Fig. 3 Piper tri-linear plot for North campus, AU, pre-monsoon (March 2016–June 2016)

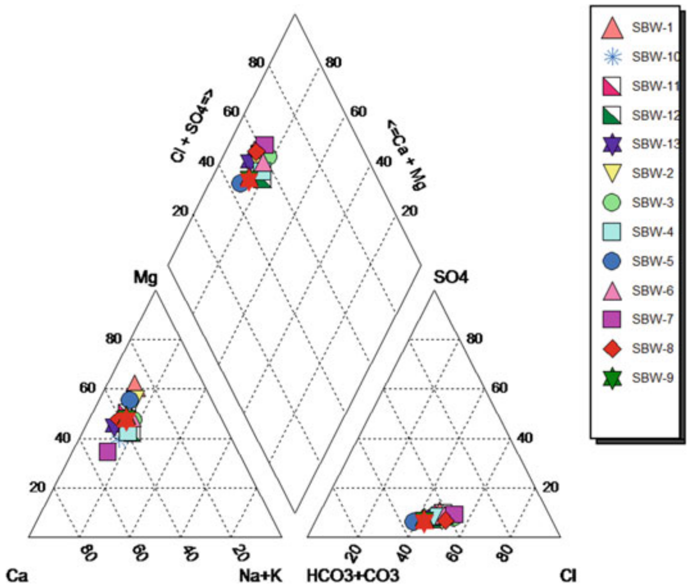

Fig. 4 Piper tri-linear plot for South campus, AU, pre-monsoon (March 2016–June 2016)

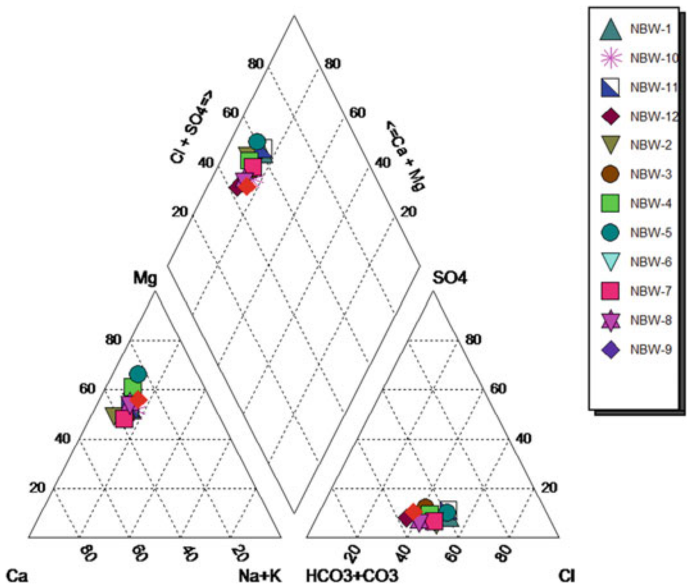

Fig. 5 Piper tri-linear plot for North campus, AU, monsoon (July 2016–October 2016)

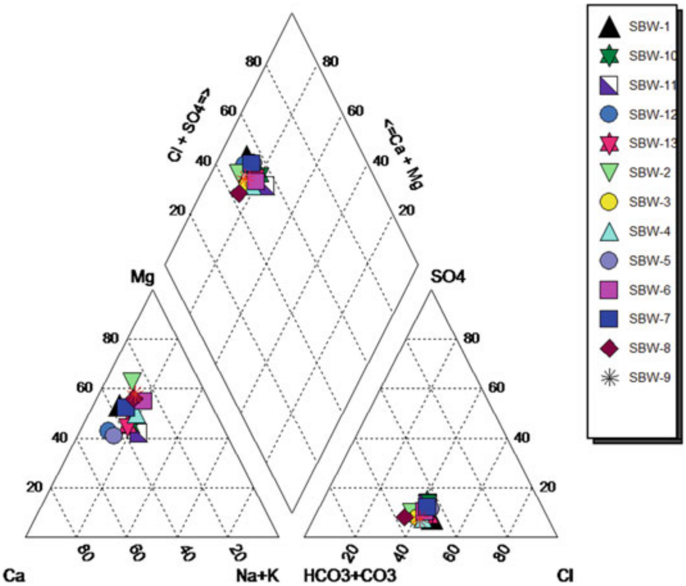

Fig. 6 Piper tri-linear plot for South campus, AU, post-monsoon (July 2016–October 2016)

4.2 Durov Diagrams

From the Durov plots, it is observed that the majority of groundwater samples are in the phase of dissolution in all the three seasons. The pH and TDS values from plots lie in the range of drinking water standards (Figs. 7, 8, 9, 10, 11 and 12).

5 Conclusions

1. The hydro-geochemical studies on groundwater quality in Andhra university using Piper tri-linear diagrams and Durov plots have shown that the $Ca^{2+} + Mg^{2+}$ significantly exceeded $Na^{+} + K^{+}$ and $Cl^{-} + SO_4^{2-}$ exceeded $HCO_3^{-} + CO_3^{2-}$ in post-monsoon, pre-monsoon and monsoon periods.
2. The groundwater in the major portion of the study area falls under type I water in which the dominating ions are Ca^{2+}–Mg^{2+}–HCO_3^{-}.
3. The groundwater in few pockets of the study area falls under the type IV water in which the dominating ions are Ca^{2+}–Mg^{2+}–Cl^{-}–SO_4^{2-}.
4. The presence of hardness in groundwater in the study area is established with the Piper and Durov diagrams.

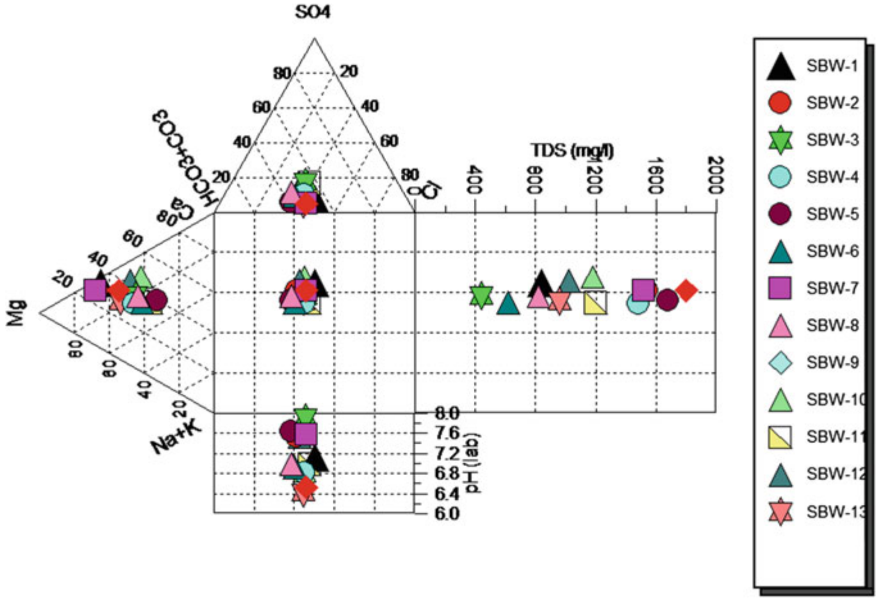

Fig. 7 Durov plot in North campus, AU, post-monsoon (November 2015–February 2016)

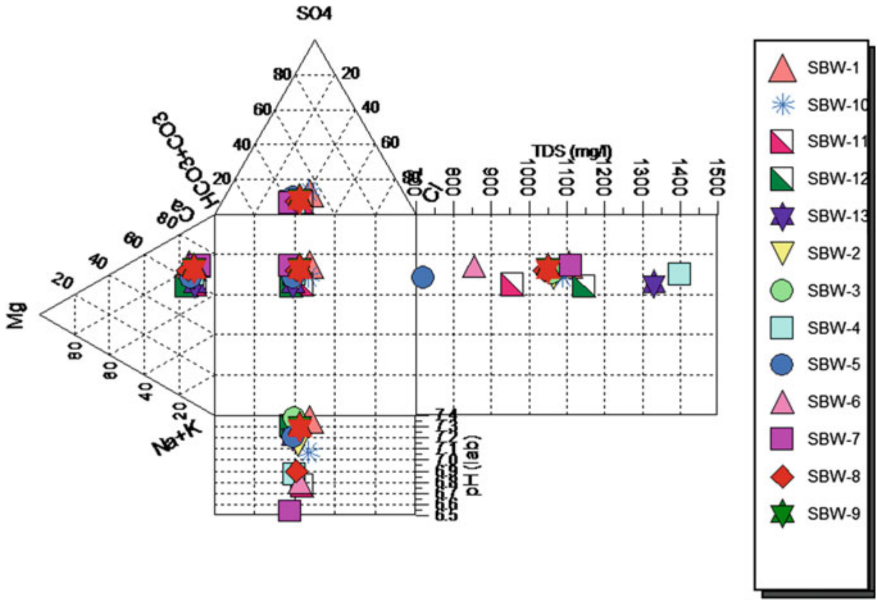

Fig. 8 Durov plot in South campus, AU, post-monsoon (November 2015–February 2016)

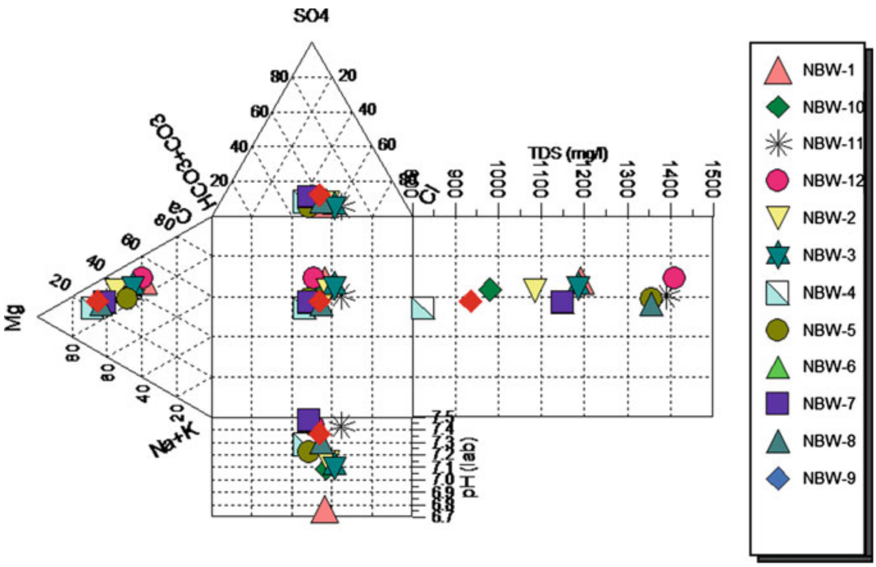

Fig. 9 Durov plot in North campus, AU, pre-monsoon (March 2016–June 2016)

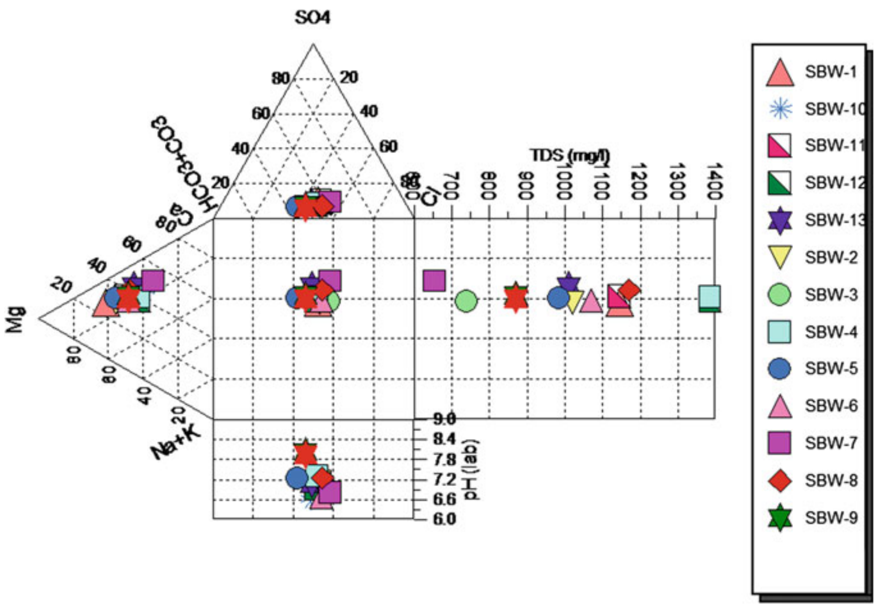

Fig. 10 Durov plot in South campus, AU, pre-monsoon (March 2016–June 2016)

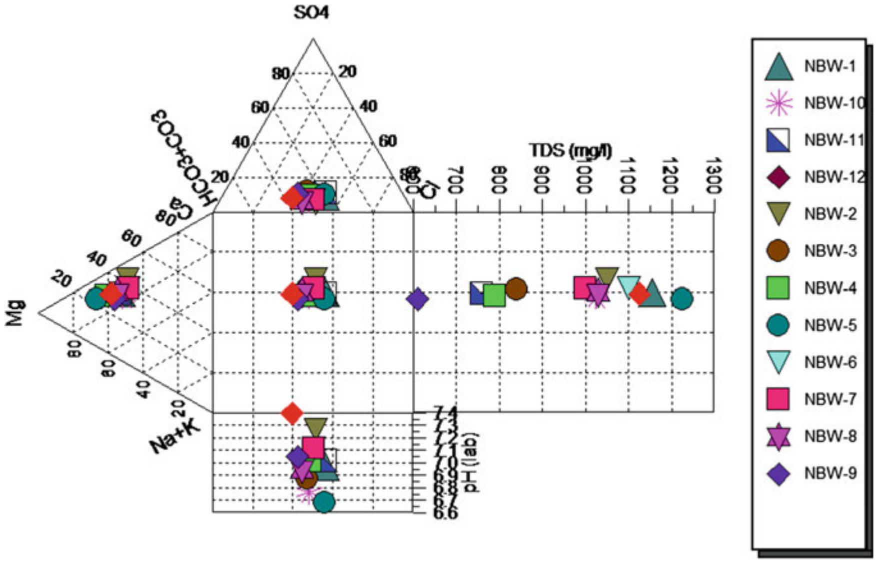

Fig. 11 Durov plot in North campus, AU, monsoon (July 2016–October 2016)

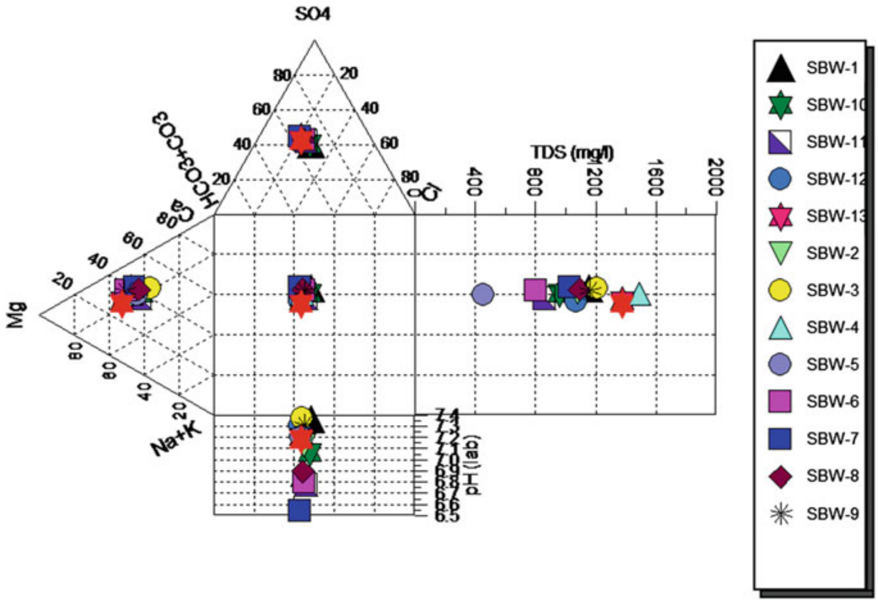

Fig. 12 Durov plot in South campus, AU, monsoon (July 2016–October 2016)

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