



Ionic Ratio Analysis for Groundwater Quality Assessment in the Suryaganga River Basin, Amravati District, Maharashtra

S. D. Mohod* , P.S. Parimal

Department of Geology, G S Tompe College, Chandur Bazar, Amravati, Maharashtra, 444 704, India

ABSTRACT: Groundwater quality in the Suryaganga River Basin, Amravati District, Maharashtra, was assessed using ionic ratio analysis to understand the controlling hydrogeochemical processes. A total of 80 groundwater samples were collected during 2023, evenly distributed across the pre-monsoon and post-monsoon seasons, to study seasonal variations and provide a comprehensive understanding of groundwater conditions in the basin. Scatter plot relationships such as $(Ca^{2+} + Mg^{2+})$ vs. $(SO_4^{2-} + HCO_3^-)$, Na^+ vs. Cl^- , and Na^+ vs. HCO_3^- were employed to evaluate ion interactions and geochemical behaviour. The $Ca / (Ca + SO_4)$ ratio was further applied to determine the source of calcium in groundwater. Results indicate that cation exchange and silicate weathering are the major processes influencing groundwater chemistry. This study provides valuable insights into the geochemical controls on groundwater quality and contributes to sustainable water resource management in the Suryaganga river basin.

KEY WORDS: Groundwater quality, Ionic ratio analysis, Scatter plot, Hydrogeochemical processes, Suryaganga River Basin, Amravati District, Maharashtra.

I. INTRODUCTION

Water quality analysis has become a crucial aspect of groundwater studies, as changes in groundwater quality can result from rock-water interactions or various anthropogenic influences [1-2]. Groundwater quality changes as it moves from recharge to discharge areas, influenced by various processes, including evaporation, transpiration, selective uptake by vegetation, oxidation, reduction, cation exchange, mineral dissociation, precipitation of secondary minerals, mixing with other water sources, and the leaching of fertilizers, manure, and biological materials [3]. In India, the rapid growth of population, urbanization, industrialization, and increased agricultural activities have adversely affected groundwater resources in recent years [4]. Ionic ratios and scatter plots help identify the sources of dissolved ions and reveal geochemical processes like silicate weathering, carbonate dissolution, and salinization.

II. STUDY AREA

The Suryaganga River Basin, situated in the Amravati and Teosa Talukas of Amravati District, Maharashtra, is a tributary of the Wardha River. It is geographically situated between $21^{\circ}3'24.30''N$ and $78^{\circ}2'27.42''E$ and experiences a tropical monsoonal climate, where water availability is largely controlled by seasonal rainfall. The basin covers an area of 391.22 km² with a perimeter of 107.92 km and is delineated on Survey of India Toposheet Nos. 55G/16, 55H/13, 55L/1, and 55K/4 at a scale of 1:50,000. The climate is characterized by hot summers (March–June) with temperatures ranging from 40°C to 44°C, and moderately cold winters (November–February) with temperatures between 10°C and 15°C. The basin receives an annual rainfall of 825.8 - 1250 mm, leading to pronounced seasonal variations in water availability, which significantly influence the hydrological and groundwater conditions within the basin.

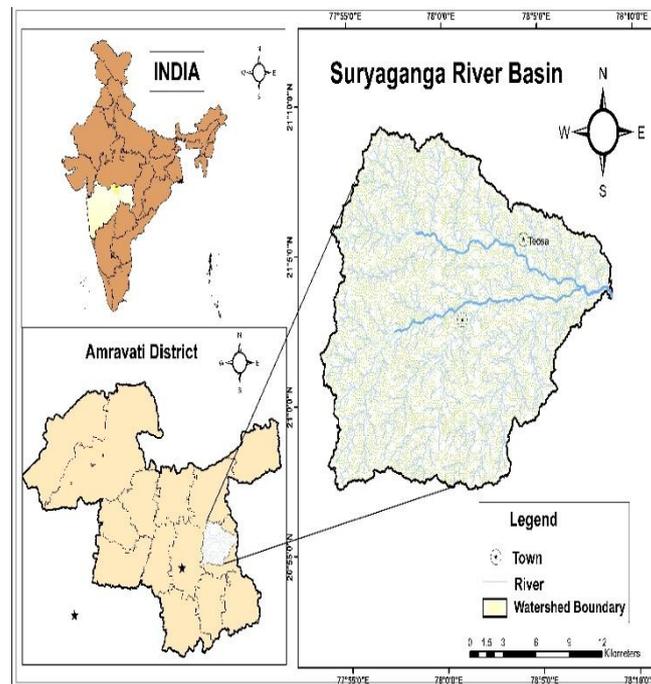


Figure 1. Location map of Suryaganga river basin

III. GEOLOGY

The Suryaganga River Basin is predominantly underlain by basaltic lava flows of the Deccan Trap Supergroup, specifically belonging to the Sahyadri Group, which comprises the Chikhli, Karanja, and Ritpur Formations [5]. The basalts exhibit a range of textures, from massive and compact types to weathered, vesicular, and amygdaloidal varieties. Quaternary alluvial deposits are largely restricted to the eastern part of the basin, near the confluence with the Wardha River. Additionally, a minor occurrence of cherty limestone from the Ritpur Formation is present in a very small portion of the basin. This geological framework plays a significant role in controlling the hydrogeological characteristics and groundwater potential of the region.

IV. IONIC RELATIONS AND SOURCES OF MAJOR COMPONENTS

The weathering processes in the aquifer were studied using scatter plots of major ions and their combinations [6]. These plots help identify the geochemical reactions and mineral weathering that influence the quality and composition of groundwater.

V. MATERIALS AND METHODS

Eighty groundwater samples were collected from bore and dug wells in 2023, comprising 40 pre-monsoon and 40 post-monsoon samples to capture seasonal variations. Samples were taken in clean polyethylene bottles after flushing wells for 5 - 10 minutes. Field parameters such as pH and electrical conductivity (EC) were measured with pre-calibrated portable meters. Major ions were analyzed in the laboratory following [7] standards: Ca^{2+} and Mg^{2+} by EDTA titration, Cl^- by AgNO_3 titration, HCO_3^- by acid titration, Na^+ and K^+ using a flame photometer, SO_4^{2-} by spectrophotometric turbidimetry, and NO_3^- and F^- using a Consort C960 electrochemical analyser.

VI. $\text{Ca}^{2+} + \text{Mg}^{2+}$ vs $\text{SO}_4^{2-} + \text{HCO}_3^-$

The scatter diagram of $\text{Ca}^{2+} + \text{Mg}^{2+}$ vs $\text{HCO}_3^- + \text{SO}_4^{2-}$ (Fig. 2) shows that most groundwater samples from shallow and deep aquifers, in both pre- and post-monsoon periods, fall below the 1:1 equiline. If ion exchange is dominant, the points shift to the right, reflecting an excess of SO_4^{2-} and HCO_3^- [8-9]. Conversely, if reverse ion exchange occurs, the points shift to the left, showing a significant excess of Ca^{2+} and Mg^{2+} over SO_4^{2-} and HCO_3^- [10-11]. Most of the groundwater



samples collected during both seasons are located to the right of the 1:1 line, indicating a dominance of ion exchange. However, a few samples are positioned to the left of the line, suggesting reverse ion exchange. The data points below the 1:1 equiline (Fig. 2) further emphasize the role of cation exchange and silicate weathering in shaping the groundwater chemistry across the aquifer system [12-13].

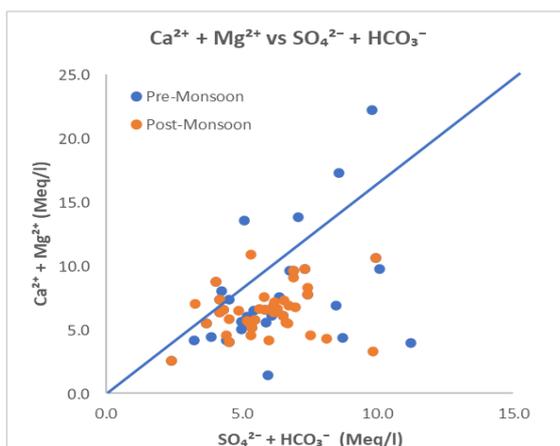


Figure 2. Relationship between $(Ca^{2+} + Mg^{2+})$ and $(SO_4^{2-} + HCO_3^-)$

VII. NA vs Cl

The scatter diagram of Na^+ vs Cl^- (Fig: 3) shows that most groundwater samples from both shallow and deep aquifers, during pre- and post-monsoon periods, fall below the 1:1 equiline. Na^+/Cl^- ratio greater than 1 indicates that silicate weathering is a significant source of sodium in the groundwater [11,14-15]. In the study area, elevated sodium concentrations were observed during both seasons. This increase may be attributed to the weathering of sodium-bearing minerals such as plagioclase and hornblende present in the sediments [14-16]. Chloride concentrations in groundwater samples are higher in specific areas during both pre- and post-monsoon periods. The elevated chloride content, which exceeds sodium levels, may be attributed to base exchange phenomena or pollution from anthropogenic activities [11].

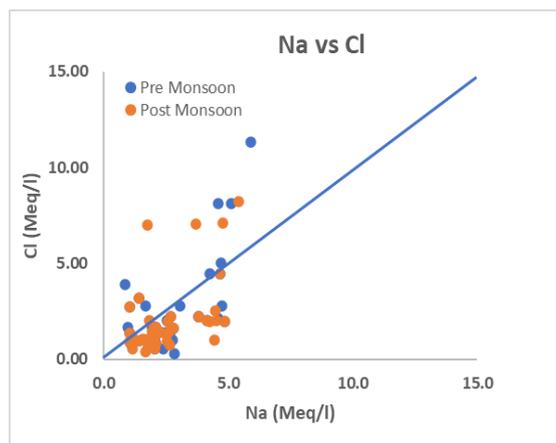


Figure 3. Na^+ vs Cl^- scatter plots for pre- and post-monsoon 2023

VIII. Na^+ vs HCO_3^-

The Na^+ versus HCO_3^- plot (Fig 4) shows that most groundwater samples lie above the equiline, indicating a relative excess of bicarbonate. HCO_3^- is one of the dominant anions in the study area. As noted [17], such a shift above the equiline can result from ion exchange processes, which are commonly associated with silicate weathering. The elevated HCO_3^- concentrations further support the dominance of silicate weathering in the region, [15].

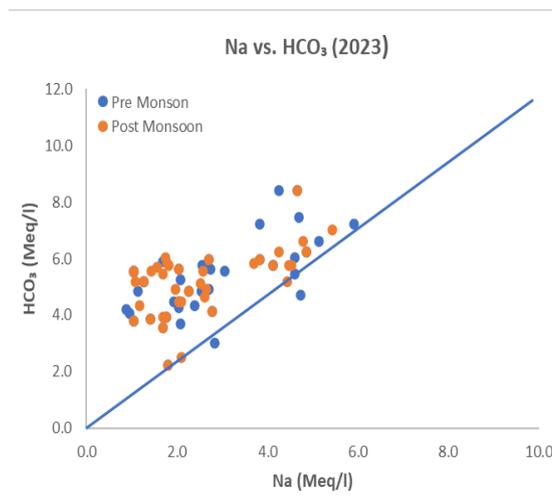


Figure 4. Na^+ vs HCO_3^- plots for pre-post-monsoon 2023, indicating silicate weathering dominance.

IX. $Ca/Ca + SO_4$

The $Ca/Ca+SO_4$ ratio is a key indicator used to determine the source of calcium in groundwater. A ratio greater than 0.5 suggests that calcium is being removed due to processes like ion exchange or calcite precipitation, whereas a ratio lower than 0.5 points to calcium originating from sources such as gypsum-carbonate or silicates [11,15 and 18]. In the study area, most groundwater samples, from both aquifers, show a $Ca/Ca+SO_4$ ratio above 0.5 during both the pre- and post-monsoon periods. This indicates a higher presence of sodium in the water. However, a few samples with a ratio below 0.5 suggest that calcium is mainly sourced from gypsum-carbonate or silicate minerals.

X. CONCLUSIONS

The scatter plot $Ca^{2+} + Mg^{2+}$ vs $HCO_3^- + SO_4^{2-}$ diagram shows that most groundwater samples from both pre- and post-monsoon periods lie below the 1:1 equiline. This indicates higher concentrations of SO_4^{2-} and HCO_3^- compared to $Ca^{2+} + Mg^{2+}$, highlighting the dominance of ion exchange and silicate weathering. The Na^+ vs Cl^- scatter diagram shows that most groundwater samples fall below the 1:1 equiline, indicating that sodium primarily comes from silicate weathering. The Na^+ vs HCO_3^- plot shows most groundwater samples above the equiline, indicating an excess of bicarbonate. This suggests that ion exchange processes, associated with silicate weathering. Most groundwater samples in the study area have a $Ca/ Ca + SO_4$ ratio above 0.5, indicating calcium removal through processes like ion exchange or calcite precipitation. A few samples with a ratio below 0.5 suggest that calcium comes from silicate minerals.

REFERENCES

1. Batabyal, A. K., & Chakraborty, S. (2015). Hydrogeochemical analysis and evaluation of groundwater quality in Bardhaman District, West Bengal, India. In *Proceedings of the 47th Annual Convention of the Indian Water Works Association* (pp. 174). Kolkata, India: IWWA Kolkata Centre.
2. Wilcox, L. V. (1955). *Classification and use of irrigation waters* (U.S. Department of Agriculture Circular No. 969, p. 19). Washington, DC: U.S. Department of Agriculture.
3. Appelo, C. A. J., & Postma, D. (1993). *Geochemistry: Groundwater and pollution*. Balkema.
4. Datta, S. P., Biswas, D. R., Saharan, N., Ghosh, S. K., & Rattan, R. K. (2000). Effect of long-term application of sewage effluents on organic carbon, bio-available phosphorus, potassium and heavy metals status of soils and uptake of heavy metals by crops. *Journal of the Indian Society of Soil Science*, 48(4), 836–839.
5. Central Ground Water Board (CGWB). (2018). Groundwater Information Report: Amravati District, Maharashtra. Ministry of Jal Shakti, Government of India.
6. Vasu, D., Singh, S. K., Tiwary, P., Sahoo, S., Chandran, P., & Mandal, B. (2017). Influence of geochemical processes on hydrochemistry and irrigation suitability of groundwater in part of semi-arid Deccan Plateau, India. *Applied Water Science*, 7(8), 3803–3815.
7. American Public Health Association (APHA). (1995, 2005). Standard methods for the examination of water and wastewater (19th ed.). Washington, D.C.: American Public Health Association.
8. Cerling TE, Pederson BL, Damm KLV (1989) Sodium-calcium ion exchange in the weathering of shales: Implications for global weathering budgets. *Geology* 17:552–554
9. Fisher RS, Mullican WF (1997) Hydro chemical evolution of sodium sulphate and sodium chloride groundwater beneath the Northern Chihuahuan desert, Trans-Pecos, Texas, USA. *Hydro geol J* 5:4–16



10. Rajmohan, N, & Elango, L. (2004). Identification and evolution of hydrogeochemical processes in the groundwater environment in an area of the Palar and Cheyyar River Basins, Southern India. *Environmental Geology*, 46(1), 47–61.
11. Srinivasamoorthy, K., Gopinath, M., Chidambaram, S., Vasanthavigar, M., & Sarma, V. S. (2014). Hydrochemical characterization and quality appraisal of groundwater from Pungar sub-basin, Tamil Nadu, India. *Journal of King Saud University – Science*, 26(1), 37–52.
12. Datta, P. S., & Tyagi, S. K. (1996). Major ion chemistry of groundwater in Delhi area: Chemical weathering processes and groundwater flow regime. *Journal of the Geological Society of India*, 47, 179–188.
13. Kaur, T., Bhardwaj, R., & Arora, S. (2017). Assessment of groundwater quality for drinking and irrigation purposes using hydrochemical studies in Malwa region, southwestern part of Punjab, India. *Applied Water Science*, 7(6), 3301–3316.
14. Meybeck, M. (1987). Global chemical weathering of surficial rocks estimated from river dissolved loads. *American Journal of Science*, 287, 401–428.
15. Srivastava, A. K., & Parimal, P. (2020). Source rock weathering and groundwater suitability for irrigation in Purna alluvial basin, Maharashtra, central India. *Journal of Earth System Science*, 129(1), 52.
16. Subba Rao, N. (2018). Groundwater quality from a part of Praksam District, Andhra Pradesh, India. *Applied Water Science*, 8(30), 13,201–13,218.
17. Srivastava, A. K., & Parimal, P. S. (2014). Hydrochemical facies and ionic ratios of groundwater in Purna alluvial basin, Maharashtra. *Gondwana Geological Magazine, Special Publication*, 14, 117–126.
18. Romy, A., Quamrul, H. M., Chowdhury, S. J., & Kazi, M. A. I. (2009). Hydrochemistry and origin of salinity in groundwater in parts of Lower Tista Floodplain, Northwest Bangladesh. *Journal of the Geological Society of India*, 74, 223-232.