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# Groundwater Quality Assessment and Hydro-geological Investigation in Atal Nagar, Chhattisgarh, India

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## Abstract

In the study area, the primary source of water is groundwater, which is used for a number of purposes including drinking, domestic, and industrial purposes. pH, turbidity, conductivity, total dissolved solids (TDS), alkalinity, total hardness, calcium, magnesium, sodium, potassium chloride, fluoride, sulphate, iron, and nitrate were all measured for fifteen groundwater samples. In the study region, the groundwater is neutral to slightly alkaline. Most of the water sample is hard-very hard in nature. All the sample shows TDS value less than 1000 indicates the study area is suitable for drinking and irrigation purpose. According to Piper's diagram classification, the majority of the samples belong to the $CaMgHCO_3$ hydro-chemical facies. The Gibb's diagram depicts the majority of samples fall into the evaporite dominant zone in [Cl/(Cl + $HCO_3$)] against TDS plot, suggesting that evaporite mineral dissolution is the dominant process regulating ground water and geochemistry of water. The [Na / (Na + Ca)] v/s TDS plot shows rock-water interaction and chemical weathering of rock-forming minerals which cause high fluoride concentration in groundwater of the study area. Agricultural practises, anthropogenic activities, ion exchange, and weathering have all contaminated groundwater in the study area.

*Keywords:* Ground Water Quality, Hydro-geochemistry, Drinking Water, Contamination. Atal Nagar, Chhatisgarh

## Introduction

Water is more precious than all other natural resources on the planet. Groundwater is used by the bulk of India's rural population. Groundwater has become a more important and reliable sources of fresh water for potable and agricultural uses in India in the last few decades (Wagh *et al.,* 2019). The groundwater regime of any area is controlled by parameters like lithology, structures, geomorphology, slope, land use/ land pattern etc (Manjare and Pophare, 2020). CGWB (2013) estimated that approximately $245\times10^9 m^3$ of groundwater is being used for irrigation and also nearly 90% of rural population of the country uses groundwater for drinking and domestic purposes (Adimalla *et al.*, 2018). Irrigated farming is the world's largest abstractor and primary user of groundwater assets, with groundwater irrigating approximately 65 percent of total agricultural land. Since groundwater is the primary source for various purposes in the study area, including drinking and irrigation, it's critical to evaluate its hydro-chemical characteristics and suitability for drinking, domestic, and irrigation. Water quality plays an important role in promoting agricultural production and standard of human health (Tiwari and Singh, 2014; Singha *et al.*, 2017). For the assessment and management of groundwater resources, it is essential to understand the hydrogeological and hydro-geochemical properties of the aquifer (Umar *et al.*, 2001). The geochemical composition of groundwater is mainly influenced by natural factors such as wet and dry deposition of atmospheric salts, precipitation, evapotranspiration, soil matrix, rock-water interaction, residence time, etc., and anthropogenic factors which include human activities related to surface runoff and groundwater recharge from agricultural uses and the generation and disposal of industrial wastes, leachate from solid waste dumping, on-site sanitation systems, and disposal of domestic waste (Todd 1980; Toth 1999; Sefie *et al.*, 2018; Karroum *et al.*, 2017; Devic *et al.*, 2014; Barbieri *et al.*, 2014; Mukate *et al.*, 2017; Wagh *et al.*, 2019). The rapid increase in water diversion from aquifers over the last 15 years has resulted in groundwater depletion, also known as long-term water-level reductions. On the other hand, recent changes in agricultural land use and irrigation could result in groundwater contamination from agricultural fertilisers and pesticides applied to fields. Understanding the quality of irrigation groundwater is also critical for evaluating the necessary management changes for long-term productivity.

Groundwater has become a necessary resource over the past decades due to the increase in the usage for drinking, water supply, irrigation and industrial uses (Khadri and Moharir, 2016). As a result, having a detailed understanding of a region's groundwater situation is critical. Groundwater quality is just as important as its quantity. Geological and climatic conditions are the primary determinants of groundwater quality. Ground water quality in many part of India is affected by high concentration of Nitrate ($NO_3^-$) derived from anthropogenic sources (Ingewar *et al.*, 2021). Increasing water withdrawals and consumption, intensive urbanization, industrial growth, over usage of fertilizers and pesticides in agricultural regions, human and animal wastage and unplanned drainage systems are some of the important causes for the deterioration of the quality of groundwater (Adimalla *et al.*, 2018). By focusing on groundwater sources in the evaluation, groundwater resource assessment highlights the consistency of groundwater. Groundwater infrastructure assessment is a hybrid of process review and large-scale monitoring (Alley and Cohen, 1991).The importance of groundwater quality in maintaining groundwater protection and excellence cannot be overstated. As a result, deciding the quality of groundwater is important not only for current but also for potential use. Groundwater quality with respect to groundwater table differs from season to season and place to place (Gabr *et al.*, 2021). Geology, the degree of chemical weathering of different rock types, the consistency of recharge water, and water–rock interaction all have an effect on groundwater quality. The study's main objectives are to (a) define the major hydro-geochemical processes, (b) assess groundwater quality, and (c) pinpoint regions where groundwater is suitable or unsuitable for drinking, domestic, or irrigation use.

## Study Area

The study area is part of the Chhattisgarh super group, which is situated in the heart of the state and is bounded on the east by longitudes 81°32'05" and 82°59'05" and on the north by latitudes 19°46'35" and 21°53'00" (Fig.1). The study region has a tropical to sub-tropical climate. The winter season lasts from December to February. The coldest month is January, with a mean daily maximum temperature of 30°C and a minimum temperature of about 10°C. During the winter, the temperature will drop below 10°C at night. The study area consist of three main cropping season it includes Kharif season from June to October, Rabi season from October to February and Zaid season from March to May. Major crops during the Kharif season are paddy and vegetables and during the Rabi season Gram, vegetables, wheat, mustard and lentil and Lathyrus. During Zaid season summer paddy and vegetables are the main crops (Thakur *et al.*, 2018). For the present study

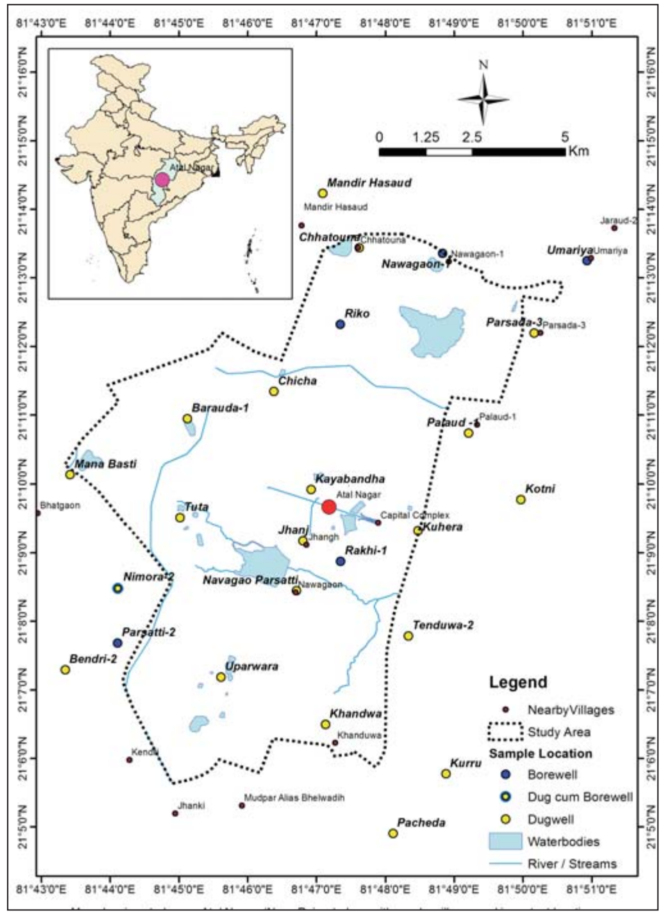


**Fig.1.** Location map of the study area

total 15 samples were collected from the study area (Fig. 1) and analysed by using the American Public Health Association's standard methods (APHA, 2017).

## Geological Settings

The study region is situated in Raipur Group's Charmuria, Chandi, and Hiri formations. One of India's most significant carbonate aquifer systems, it consists primarily of limestone and dolomite (Dar *et al.*, 2015). The lower limestone/dolomite member of the Chandi Formation is separated from the upper Deodonger member, which is made up of thinly laminated siliceous shale and sandstone (Murti, 1987). The thickness of the Chandi limestone ranges from 103 to 136 metres (Sinha *et al.*, 2002). Raipur is built on the Proterozoic Chandi Formation of the Raipur Group (Chhattisgarh Super Group), which consists of limestone, shale, and sandstone with dolerite intrusions in some areas (Fig.2). The Niwari stromatlitic limestone and Deodongar shale and sandstone members of the Chandi Formation are horizontal to gently dipping. The limestone in the Mahadevghat and Purena sections is typically massive to thickly bedded, jointed, and karstic in nature, with cracks, solution cavities, and sink holes.

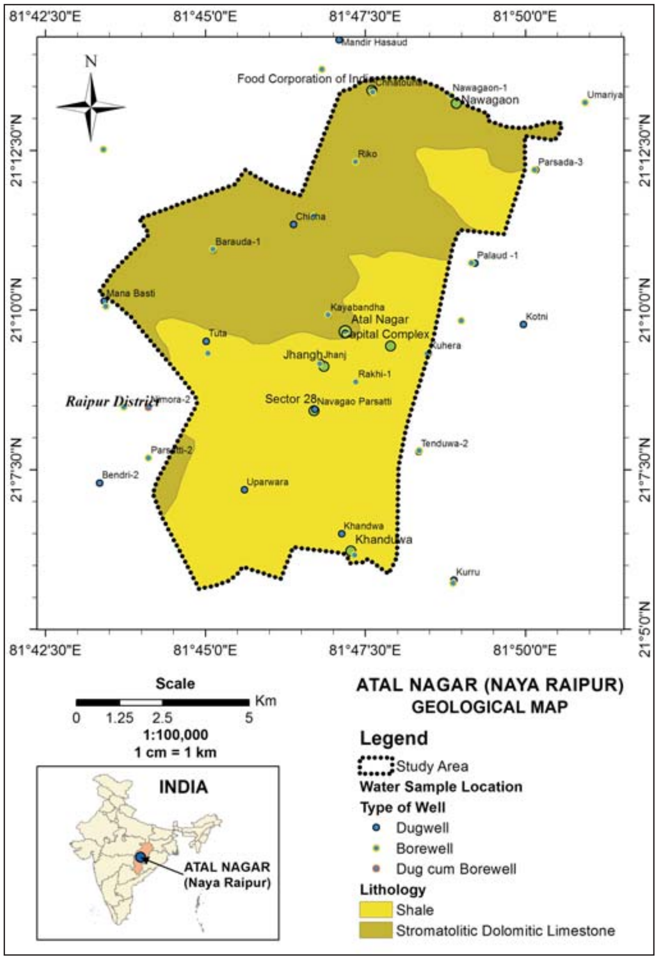


**Fig.2.** Geological details of the study area (*Modified after*, Murti, 1987; Sinha *et al.*, 2002 )

## Hydrogeological Study

In the Chandi Formation, groundwater exists in both phreatic and semi-confined conditions in the study region. The dug wells in the area tap the upper part of the shale or limestone. The drilled wells' diameters vary from 2 to 6 metres, and their depths range from 7 to 21 metres. Water-bearing horizons are usually found at depths of 13 to 45 metres and 65 to 85 metres. The depth of bore wells in the area ranges from 30 to 120 mbgl, with a diameter of 0.10 to 0.15 m. In the district, hard rock areas have been proven to be potential aquifers.

## Material and Methods

Water quality studies involve physical, chemical, hydrological and biological characteristics of water and their complex and delicate relations. To determine the composition of water, fifteen groundwater samples were taken in the study area. For ensuring the data quality and consistency, the standard procedures recommended by APHA were followed. The samples were collected in pre-washed high density polyethylene bottles after rinsing the bottles for 2-3 times with water to be sampled. The collected water samples were sealed immediately to prevent oxidation of water. A selection measure was developed in the current study prior to data collection to assist in the identification of appropriate sampling sites for the groundwater quality assessment. The study area's base map was scanned and digitised from Survey of India (SOI) Toposheets No. 64G/12 and 64G/16 (1:50,000). For groundwater quality assessment, ArcGIS 10 was used to chart and analyse the data. The region was divided equally into 21 grids to promote the representative collection of groundwater samples from the area and to determine its suitability for domestic and irrigation purposes. Correlation matrix among the groundwater physiochemical parameters are prepared to understand the dependency among the parameters.

The suitability of groundwater in the study area was determined by analysing the analytical results for drinking and agricultural purposes. The pH and electrical conductivity (EC) of the water were determined in situ using a Hanna (HI9828 USA) multi-parameter probe, and the major ions (Ca, Mg, Na, K, $HCO_3$, $SO_4$, Cl) were analysed using the American Public Health Association's standard methods (APHA, 2017). A flame photometer was used to evaluate sodium (Na) and potassium (K) among the analysed ions. Volumetric methods were used to determine total hardness (TH) as $CaCO_3$, calcium (Ca), magnesium (Mg), bicarbonate ($HCO_3$), and chloride (Cl), while colorimetric methods were used to measure sulphates ($SO_4$). Three replicates were run for each sample for cation analysis. AquaChem 4.0 software was used to map the hydro-chemical facies (Piper diagram) in the study area. The suitability of groundwater for agricultural and domestic use was determined by comparing the values of various water quality criteria to the World Health Organization's (WHO, 2004) and Indian Standard Specification Institute's (ISI, 1993) drinking water guidelines.

## Results and Discussion

The results of the research were used to assess the suitability of the groundwater in the study region for drinking and agricultural purposes. Further down, the behaviour of major ions (Ca, Mg, Na, K, $HCO_3$, $SO_4$, Cl), as well as important physical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), and total hardness (TH), and the suitability of groundwater in the study area, are discussed. The obtained results were evaluated in accordance with the norms prescribed under 'Indian standard drinking water specification IS10500 (BIS, 1991; Shankar *et al.*, 2008). The pH values of the 92% of samples are found to be in the permissible range of 6.5-8.5 prescribed for drinking water according to BIS (2012). Most of the samples collected from the study area indicate the groundwater is neutral to alkaline in nature. According to BIS (2012), the highest optimal level of TDS is 500 mg/l, and the maximum

**Table 1:** Results of Hydrochemical analysis of samples from the study area and the acceptable limit of groundwater

| Sl. No. | Sample No. | Parameters Chemical Parameter | Drinking Water IS:10500-2012 Desirable | Drinking Water IS:10500-2012 Maximum | Maximum | Minimum | Mean |
|---|---|---|---|---|---|---|---|
| 1. | DW - 01 | pH (-) | 6.5 to 8.5 | No relaxation | 7.98 | 6.24 | 7.08 |
| 2. | DW - 02 | Turbidity (NTU) | 1 | 5 | 0.36 | 0.16 | 0.21 |
| 3. | BW - 01 | Conductivity (μs/cm) | >1000 | 3200 | 1690 | 90 | 622.8 |
| 4. | DW - 03 | Total Dissolve Solids (mg/l) | 500 | 2000 | 900 | 50 | 360.71 |
| 5. | BW - 02 | Total Hardness ( mg/l) | 200 | 600 | 796 | 16 | 252.42 |
| 6. | DW - 04 | Calcium as Ca (mg/l) | 75 | 200 | 267.73 | 0.49 | 72.44 |
| 7. | BW - 03 | Magnesium as Mg (mg/l) | 30 | 100 | 69.98 | 0.49 | 17.99 |
| 8. | BW - 04 | Chloride (mg/l) | 250 | 1000 | 382.30 | 5.48 | 93.86 |
| 9. | DW - 05 | M-Alkalinity (mg/l) | 200 | 600 | 330 | 54 | 183.5 |
| 10. | BW - 05 | Fluoride as F (mg/l) | 1.0 | 1.5 | 0.6 | 0.09 | 0.20 |
| 11. | BW - 06 | Sulphate as $SO_4$ (mg/l) | 200 | 400 | 51.985 | 0.69 | 15.27 |
| 12 | DW - 06 | Iron (mg/l) | 0.3 | No relaxation | 0.29 | 0.09 | 0.13 |
| 13. | BW - 07 | Nitrate (mg/l) | 45 | No relaxation | 5.98 | 0.12 | 1.08 |
| 14. | DW - 07 | Sodium (mg/l) | --- | --- | 56 | 5 | 28.35 |
| 15. | BW - 08 | Potassium (mg/l) | --- | --- | 30 | 1 | 6.40 |

permissible level is 2000 mg/l (Table 1). According to this classification, 82% of samples fall within the maximum Acceptable range, while only 17% exceed the maximum allowable limits (Table 1). All the water samples collected from the study area has TDS below 1000 mg/l. According to Davis and De Wiest (1966) classification, TDS value below 500 mg/l is desirable for drinking, if TDS value ranges between 500-1000 is permissible for drinking and TDS value between 1000-3000 it is useful for irrigation purpose. Based on this classification, the groundwater of the study area is suitable for drinking and irrigation purpose (Adimalla, 2019). The maximum allowed limit of TH for drinking, according to the BIS is 600 mg/l, with 200 mg/l being the most appropriate limit. Based on this classification, 3% of the samples exceed the allowed limits; such water is unfit for domestic use because it coagulates soap lather. In the study area only 3% of ground water has TH below 75 mg/l, 7% of groundwater has TH in between 75-150 mg/l, 67% of water sample indicates TH in between 150-300 and 25% of sample has TH greater than 300 mg/l. Based on TH, the ground water is classified into soft (<75), moderately hard (75-150), hard (150-300) and very hard (>300) (Sawyer and McCarthy 1967). According to this classification, 67% of the sample shows hard to very hard in nature (Adimalla, 2019).

Piper's trillinear diagram (Piper, 1953) is an effective pictorial method to classify the groundwater, based on basic geochemical characters of the constituent ionic concentrations (Adimalla, 2019). The piper trilinear diagram combines three areas of plotting, two triangular areas (cations and anions) and an intervening diamond-shaped area (combined field) (Jain, 2018; Singha and Pasupuleti, 2020). The samples in the study area fall in the Ca-$HCO_3$ region, which means the groundwater is shallow and fresh, according to the piper diagram (Fig.3). Gibbs (1970) proposed two diagrams to better describe hydro-geochemical process involving atmospheric precipitation, rock–water interaction, and evaporation. A Gibbs diagram plots the ratio of cations [Na / (Na + Ca)] and anions [Cl/(Cl + $HCO_3$)] against TDS. In [Na / (Na + Ca)] v/s TDS plot, the samples are fall in between rock dominance and evaporite. The samples fall in the rock-dominance zone due to the increasing rock-water interactions or weathering of host rock and chemical weathering of rock-forming minerals, which cause mineral dissolution, there by leading to high fluoride concentration in the groundwater of this region (Adimalla, 2019; Singha *et al.*, 2019). The

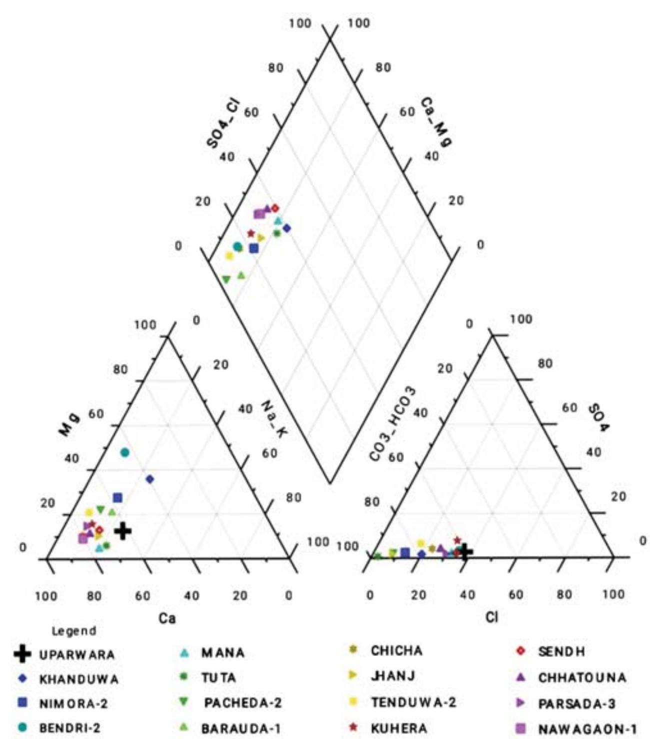


**Fig. 3.** Trilinear Piper diagram showing chemical facies of water samples from study area (Piper, 1953)

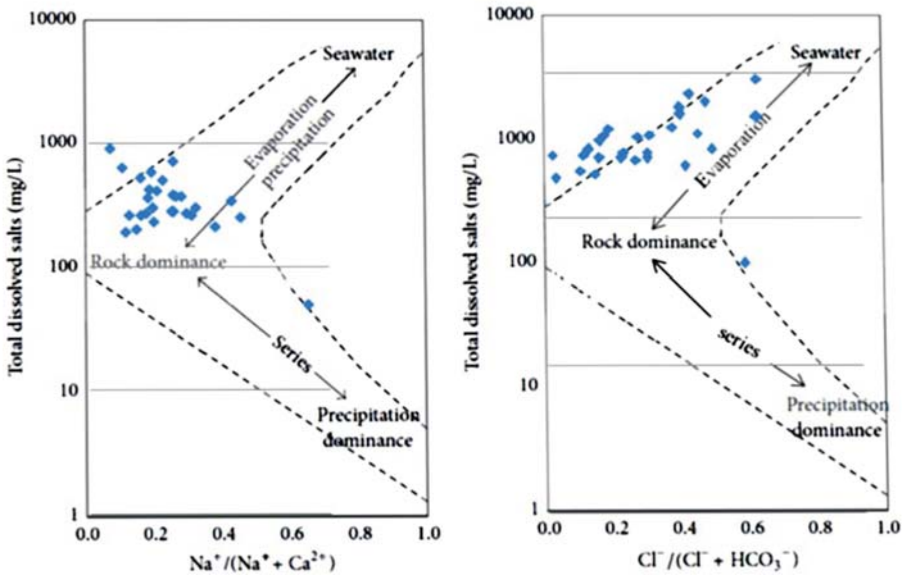


**Fig. 4.** Mechanism controlling groundwater chemistry of the study area (Gibbs, 1970)

[Cl/(Cl + $HCO_3$)] against TDS plot depicts the study region's evaporite supremacy (Fig.4). The groundwater samples are fell into the evaporation dominant area, signifying the role of evaporation on shallow groundwater chemistry (Kaur *et al.*, 2017). To determine the dominant hydro-chemical processes and mode of ion exchange, chemical data from groundwater samples were plotted on the Durov diagram (Durov, 1948; Lloyd and Heathcode, 1985). The trilinear Durov diagram is based on the percentage of major ion milliequivalents (Alam *et al.*, 2012). The reverse ion exchange mechanism, as depicted in the Durov diagram, is primarily responsible for regulating the ground water chemistry in the study region (Fig.5).

For $Ca^{2+}$ + $Mg^{2+}$ and $Na^+$ + $K^+$ *vs* TC, the chemical data from the groundwater samples is plotted (Total Cation). The majority of the samples are far below the theoretical line (1:1), meaning that cations are collected by ion exchange (Fig.6). During weathering and circulation of water in rocks and soils, ions leached out and dissolve in groundwater (Naseem *et al.*, 2010). The geological formations, water-rock interaction and relative mobility of ions are the prime factors influencing the geochemistry of the groundwater (Yousef *et al.*, 2009; Naseem *et al.*, 2010). The importance of weathering is greater in the study area, indicating (Fig. 6a). A high concentration of Na in relation to Cl or a reduction of Na in relation to Cl is also signs of cation exchange reactions (Sethy *et al.*, 2016). If halite dissolution is responsible for sodium, the Na/Cl molar ratio should be approximately equals to one, whereas a ratio greater than one is typically interpreted as Na released from a silicate weathering reaction (Mayback, 1987; Rajmohan and Elango, 2004). In the present study, the majority of the samples have a Na/ Cl ratio of less than one, indicating that Cl concentration is higher than Na in the research area (Fig. 6c). The Na/Cl ratio is less than one is indicates the possibility of ion exchange (Rajmohan and Elango 2004). The concentration of Cl in groundwater is due to the evaporation of enriched irrigation return flow related to the water rock interaction (Varol and Davraz, 2015). Figure 6e is showing relationship between ($Ca^{2+}$ + $Mg^{2+}$) – ($SO_4^{2-}$ + $HCO_3^-$) and $Na^+$ + $Cl^-$. If ion exchange is the dominant process in the system, the water should form a line

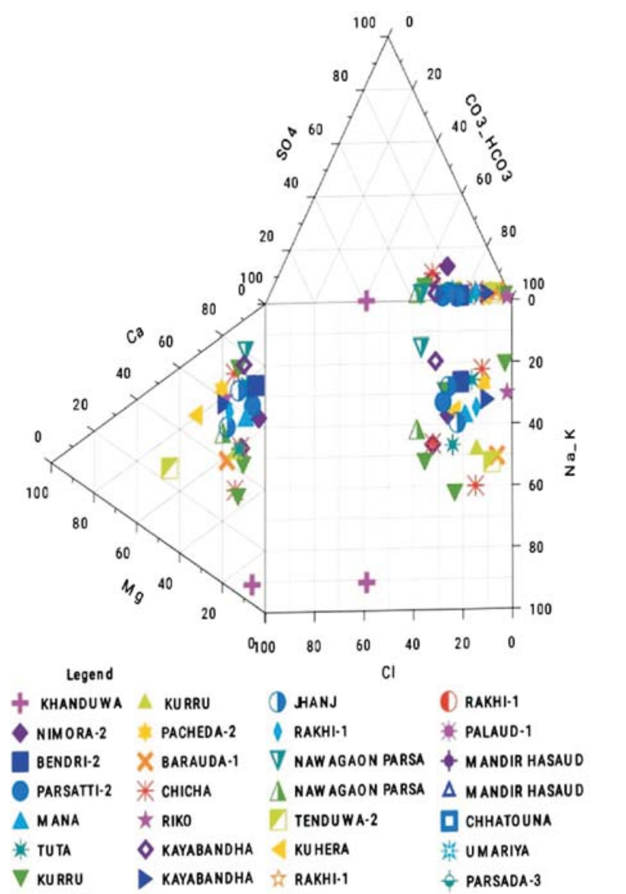


**Fig. 5.** Plot of percentage of major ion milliequivalents of water samples from study area (Durov, 1948)

with a slope of -1 (Rajmohan and Elango, 2004). The study area shows a negative linear trend with a slope of unity, considering the participation of cations in the ion exchange reaction. $Ca^{2+}$ levels are found between 9.61 and 213.22, while $Na^{+}$ levels are found between 3 and 22 mg/l (Fisher and Mullican, 1997). The negative slope of less than unity and a pattern of $(Ca^{2+} + Mg^{2+}) – (SO_4^{2-} + HCO_3^{-})$ versus $Na^{+} + Cl^{-}$ is shown in figure 6e. Plot of Ca + Mg versus $HCO_3$+$SO_4$ supplies information about weathering and dissolution of minerals, and it can further yield information related to the main minerals contributing to groundwater mineralization (Houatmia *et al.*, 2016; Jain and Vaid, 2018). The graph of $(Ca^{2+} + Mg^{2+})$ versus $SO_4^{2-} + HCO_3^{-}$ shows that the majority of samples are above the 1:1 ratio axis, it indicating the excess bicarbonate (Rajmohan and Elango, 2004).

## Conclusions

The main aim of the study was to look at the hydro geochemistry of groundwater samples obtained from Atal Nagar (Naya Raipur), Raipur District. Most of the samples collected from the study area indicate the water sample is neutral to alkaline. Almost 67% of the sample shows hard to very hard nature. The entire water sample has TDS value less than 1000 mg/l indicating the groundwater of the study area is suitable for drinking and irrigation purpose. From the piper trilinear diagram, it is observed that all the samples in the study area fall in the Ca-$HCO_3$ region indicating groundwater is shallow and fresh. The $[Cl/(Cl + HCO_3)]$ against TDS plot in the Gibb's diagram depicts the role of evaporation on shallow groundwater chemistry in the study area. And [Na / (Na + Ca)] v/s TDS plot shows the samples are fall in between rock dominance and evaporite. It is due to the rock-water interaction or weathering of host rock and chemical weathering of rock-forming minerals which causes leading the fluoride concentration in groundwater. From the Durov diagram it is observed that the reverse ion exchange mechanism is the primarily responsible for regulating the ground water chemistry in the study region. The Limestone, Shale, and Sandstone of the Chandi formation are the main aquifers of the study region, according to the hydrogeological investigation. The research area contains unconfined (shallow) and semi-confined (deeper) aquifers, as well as some perched aquifers. From the Scatter plots between various ions in groundwater of the study area it is observed that Na/ Cl ratio of less than one and negative slope of $(Ca^{2+} + Mg^{2+}) – (SO_4^{2-} + HCO_3^{-})$ versus $Na^{+} + Cl^{-}$ indicating possibility of ion exchange. Evoporite minerals play the major controlling process of ground water hydro-geochemistry. The above studies will be beneficial in determining the quality of groundwater condition for efficient groundwater resource management and consumption for drinking and irrigation.

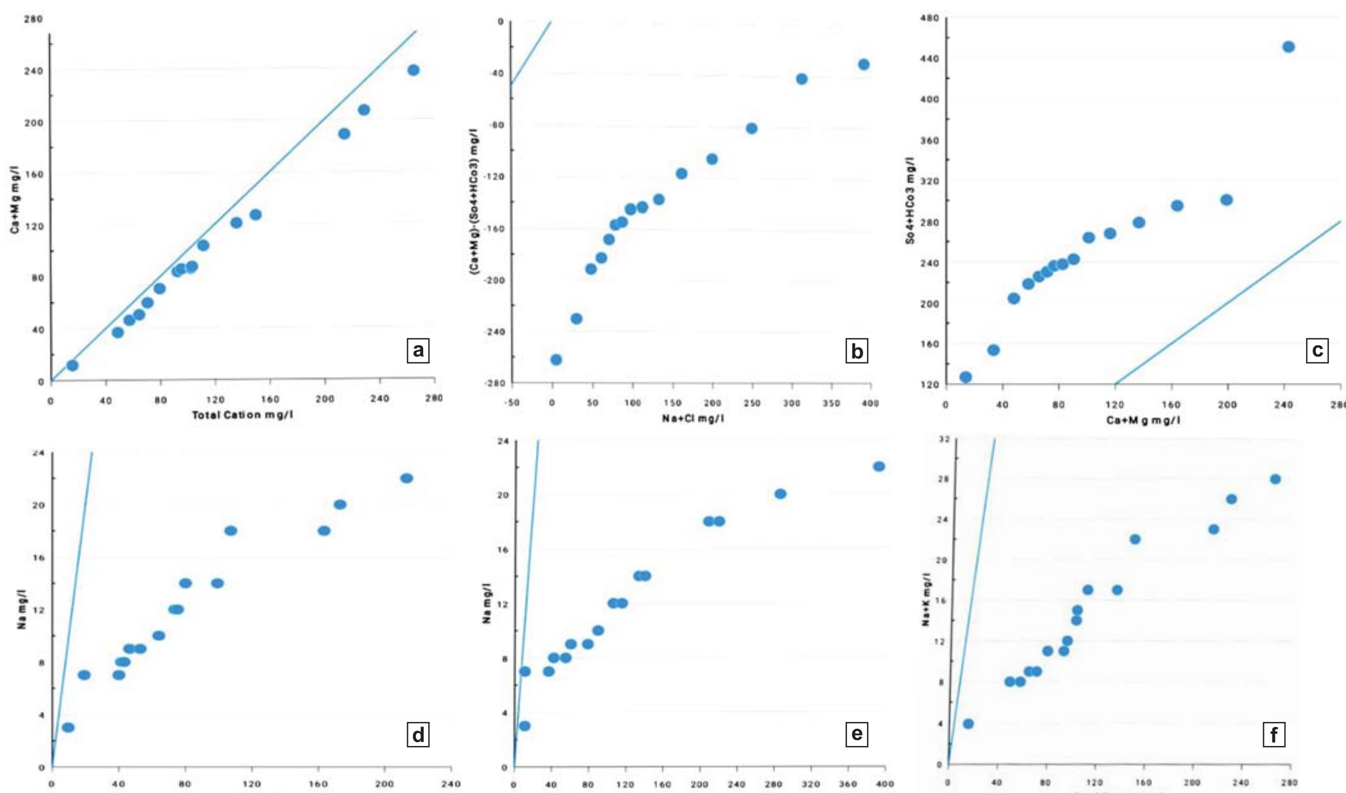


**Fig. 6.** Graphs of different parameters in groundwater of study area (solid line denotes 1:1) a: Scatter plot between Ca+Mg and Total Cations, b: Scatter plot between Na+K and Total Cations, c: Scatter plot between Na and Cl, d: Scatter plot between Ca and Na, e: Scatter plot between (Na+ Cl)- $SO_4$ +$HCO_3$ and Na, f: Scatter plot between (Ca+ Mg)- $SO_4$ +$HCO_3$ and Na

## Authors' Contributions

**K. Panigrahi:** Investigation, Conceptualization, Methodology, Writing - Original Draft, Investigation, Formal Analysis. **Bhumika Das:** Visualization, Supervision, Editing, Writing - Reviewing and Editing.

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## Reference

Adimalla, N., Li, P. and Venkatayogi, S. (2018). Hydrogeochemical evaluation of groundwater quality for drinking and irrigation purposes and integrated interpretation with water quality index studies. Environment. Process., v. 5(2), pp. 363-383.

Adimalla, N. (2019). Groundwater quality for drinking and irrigation purposes and potential health risks assessment: a case study from semi-arid region of South India. Expos. Health, v. 11(2), pp. 109-123.

Alam, M., Rais, S. and Aslam, M. (2012). Hydrochemical investigation and quality assessment of groundwater in rural areas of Delhi, India. Environ. Earth Sci., v.66, pp. 97-110.

Alley, W.M. and Cohen, P. (1991). A scientifically based nationwide assessment of groundwater quality in the United States. Environment. Geol. Water Sci., v. 17(1), pp. 17-22.

APHA (2017). American Public Health Association. Standard methods for examination of water and wastewater, 23rd Ed., APHA, AWWA, WPCF, Washington.

BIS (1991). Specificaton for Drinking Water, 18:10500.1991, Bureau of Indian Standards, New Delhi.

BIS (2012). Bureau of Indian Standards, New Delhi.

Barbieri, M., Sappa, G., Vitale, S., Parisse, B. and Battistel, M. (2014). Soil control of trace metals concentrations in landfills: a case study of the largest landfill inEurope, Malagrotta, Rome. Jour. Geochem. Explor., v. 143, pp. 146-154.

CGWB (2013). Central Groundwater Board, Ministry of Water Resources, Government of India. Groundwater Brochure, Mahabubnagar District; Nizamabad District, Hyderabad District; Andhra Pradesh Southern Region Hyderabad.

Dar, F.A., Perrin, J., Ahmed, S., Narayana, A.C. and Riotte, J. (2015). Hydrogeochemical characteristics of karst aquifer from a semi-arid region of southern India and impact of rainfall recharge on groundwater chemistry. Arabian Jour. Geosci., v. 8(5), pp. 2739-2750.

Davis, S.N. and DeWiest, R.J. (1966). Hydrogeology. Wiley, Newyork.

Devic, G., Djordjevic, D. and Sakan, S. (2014). Natural and anthropogenic factors affecting the groundwater quality in Serbia. Sci. Total Environ., v. 468, pp. 933–942.

Durov, S.A. (1948). Natural waters and graphic representation of their compositions. Dokl. Akad. Nauk. SSSR, v. 59, pp. 87–90.

Fisher, R.S. and Mullican III, W.F. (1997). Hydrochemical evolution of sodium sulfate and sodium- chloride groundwater beneath the northern Chihuahuan Desert. Trans-Pecos, Texas, USA. Hydrogeol. Jour., v. 5(2), pp. 4-16.

Gabr, M.E., Soussa, H. and Fattouh, E. (2021). Groundwater quality evaluation for drinking and irrigation uses in Dayrout city Upper Egypt. Ain Shams Engineer. Jour., v. 12(1), pp. 327-340.

Gibbs, R.J. (1970). Mechanisms controlling world water chemistry. Science, v. 170(3962), pp. 1088-1090.

Houatmia, F., Azouzi, R., Charef, A. and Bédir, M. (2016). Assessment of groundwater quality for irrigation and drinking purposes and identification of hydrogeochemical mechanism evolution in Northeastern, Tunisia. Environ. Earth Sci, v. 75, 746p.

ISI (1993). Indian standards specification for drinking water IS: 10500.

Ingewar, M., Malpe, D.B., Yenkie, R. and Hazarika, B. (2021). Assessment of irrigation water quality of Ghatanji area, Yavatmal district, Maharashtra. Jour. Geosci. Res., v. 6(1), pp.121-128.

Jain, C.K. and Vaid, U. (2018). Assessment of groundwater quality for drinking and irrigation purposes using hydrochemical studies in Nalbari district of Assam, India. Environment. Earth Sci., v. 77(6), pp. 1-14.

Karroum, M., Elgettafi, M., Elmandour, A., Wilske, C., Himi, M. and Casas, A. (2017). Geochemical processes controlling groundwater quality under semi arid environment: a case study in Central Morocco. Sci. Total Environ., v. 609, pp. 1140–1151.

Kaur, T., Bhardwaj, R. and Arora, S. (2017). Assessment of groundwater quality for drinking and irrigation purposes using hydrochemical studies in Malwa region, southwestern part of Punjab, India. Appl. Water Sci., v. 7(6), pp. 3301-3316.

Khadri, S.F.R. and Moharir, K. (2016). Groundwater quality mapping in man river basin of Akola and Buldhana districts, Maharashtra. Jour. Geosci. Res, v. 1(1), pp. 61-66.

Lloyd, J.W. and Heathcote, J.A. (1985). Natural inorganic hydrochemistry in relation to groundwater, 1st Ed., Clarendon Press, Oxford, pp. 33–182.

Manjare, B.S. and Pophare, A.M. (2020). Identification of Groundwater prospecting zones in Morna River Sub-Basin, Central India. Jour. Geosci. Res., v. 5(2), pp. 139-145.

Mayback, M. (1987). Global chemical weathering of surficial rocks estimated from river dissolved loads. Am. Jour. Sci., v. 287, pp. 401–428.

Mukate, S., Panaskar, D., Wagh, V., Muley, A., Jangam, C. and Pawar, R. (2017). Impact of anthropogenic inputs on water quality in Chincholi industrial area of Solapur, Maharashtra, India. Groundw. Sustain. Dev., pp. 359–371. https://doi.org/10.1016/j.gsd.2017.11.001

Murti, K.S. (1987). Stratigraphy and sedimentation in Chattisgarh Basin. In: B.P. Radhakrishna (Ed.), Purana Basins of Peninsular India (Middle to Late Proterozoic). Mem. Geol. Soc. India, pp. 239-260.

Naseem, S., Hamza, S. and Bashir, E. (2010). Groundwater geochemistry of Winder agricultural farms, Balochistan, Pakistan and assessment for irrigation water quality. Europ. Water, v. 31, pp. 21-32.

Piper, A.M. (1953). A graphic procedure in the geochemical interpretation of water analyses. US Geol. Survey Groundwater, Note 12, Washington D.C.

Rajmohan, N. and Elango, L.J.E.G. (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, v. 46(1), pp. 47-61.

Sawyer, C. and McCarthy, P. (1967). Chemical and sanitary engineering, 2nd Ed., McGraw-Hill, New York.

Sefie, A., Aris, A.Z., Ramli, M.F., Narany, T.S., Shamsuddin, M.K.N., Saadudin, S.B. and Zali, M.A. (2018). Hydrogeochemistry and groundwater quality assessment of the multilayered aquifer in Lower Kelantan Basin, Kelantan, Malaysia. Environ. Earth Sci., v. 77(10), pp. 1-15. https://doi.org/10. 1007/s12665-018-7561-9

Sethy, S.N., Syed, T.H., Kumar, A. and Sinha, D. (2016). Hydrogeochemical characterization and quality assessment of groundwater in parts of Southern Gangetic Plain. Environment. Earth Sci., v. 75(3), 232p.

Shankar, B.S., Balasubramanya, N. and Reddy, M.M. (2008). Impact of industrialization on groundwater quality–a case study of Peenya industrial area, Bangalore, India. Environment. Monitor. Assessm., v. 142(1), pp. 263-268.

Sinha, U.K., Kulkarni, K.M., Sharma, S., Ray, A. and Bodhankar, N. (2002). Assessment of aquifer system using isotope techniques in urban centres Raipur, Calcutta Jodhpur, India (No. IAEA-TECDOC--1298).

Singha, S.S. and Pasupuleti, S. (2020). Hydrogeochemical modeling based approach for evaluation of groundwater suitability for irrigational use in Korba district, Chhattisgarh, Central India. SN Appl. Sci., v. 2(9), pp. (1-13).

Singha, S., Pasupuleti, S., Durbha, K.S., Singha, S.S., Singh, R. and Venkatesh, A.S. (2019). An analytical hierarchy process-based geospatial modeling for delineation of potential anthropogenic contamination zones of groundwater from Arang block of Raipur district, Chhattisgarh, Central India. Environment. Earth Sci., v. 78(24), pp. 1-19.

Thakur, N.K., Khalkho, D., Katre, P., and Tonde, J. (2018). Development of optimal crop plan for IGKV, farm Raipur, Chhattisgarh. Jour. Pharmacogn. Phytochem., v. 7(2), pp. 172- 176.

Tiwari, A.K. and Singh, A.K. (2014). Hydrogeochemical investigation and groundwater quality assessment of Pratapgarh district, Uttar Pradesh. Jour. Geol. Soc. India, v. 83(3), pp. 329-343.

Todd, D.K. (1980). Groundwater hydrology, 2nd (ed). Wiley, New York, 552p.

Tóth, J. (1999). Groundwater as a geologic agent: an overview of the causes, processes and manifestations. Hydrogeology, v. 7(1), pp. 1-14.

Umar, A., Umar, R. and Ahmad, M.S. (2001). Hydrogeological and hydrochemical framework of regional aquifer system in Kali-Ganga sub-basin, India. Environment. Geol., v. 40(4), pp. 602-611.

Varol, S. and Davraz, A. (2015). Evaluation of the groundwater quality with WQI (Water Quality Index) and multivariate analysis: a case study of the Tefenni plain (Burdur/Turkey). Environment. Earth Sci., v. 73(4), pp. 1725-1744.

Wagh, V.M., Panaskar, D.B., Jacobs, J.A., Mukate, S.V., Muley, A.A. and Kadam, A.K. (2019). Influence of hydro-geochemical processes on groundwater quality through geostatistical techniques in Kadava River basin, Western India. Arabian Jour. Geosci., v. 12(1), 7p.

WHO(2004). Guidelines for drinking water quality. World Health Organization, Geneva.

Yousef, A.F., Salem, A.A., Baraka, A.M. and Aglan, O.S. (2009). The impact of geological setting on the groundwater occurrences in some Wadis in Shalatein Abu Ramad Area, South Eastern Desert, Egypt. Europ. Water Pub. (EWRA), v. 25(26), pp. 53-68.

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