Hydrochemistry and evaluation of groundwater suitability for irrigation and drinking purposes in the Markandeya River basin, Belgaum District, Karnataka State, India

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Abstract Markandeya River basin stretches geographically from 15°56’ to 16°08’ N latitude and 74°37’ to 74°58’ E longitude, positioned in the midst of Belgaum district, in the northern part of Karnataka. Since the quantity and quality of water available for irrigation in India is variable from place to place, groundwater quality in the Markandeya River basin was evaluated for its suitability for drinking and irrigation purposes by collecting 47 open and bore-well samples during the post-monsoon period of 2008. The quality assessment was made by estimating pH, electrical conductivity, total dissolved solids, hardness, and alkalinity besides major cations (Na⁺, K⁺, Ca²⁺, and Mg²⁺) and anions (HCO₃⁻, Cl⁻, SO₄²⁻, PO₄³⁻, F⁻, and NO₃⁻). Based on these analyses, irrigation quality parameters like, sodium absorption ratio, %Na, residual sodium carbonate, residual sodium bicarbonate, chlorinity index, soluble sodium percentage, non-carbonate hardness, potential salinity, permeability index, Kelley’s ratio, magnesium hazard/ratio, index of base exchange, and exchangeable sodium ratio were calculated. According to Gibbs’ ratio, majority of water samples fall in the rock dominance field. The groundwater samples were categorized as normal chloride (95.75%), normal sulfate (95.75%), and normal bicarbonate (61.70%) water types based on Cl, SO₄, and HCO₃ concentrations. Based on the permeability index, majority of the samples belongs to classes 1 and 2, suggesting the suitability of groundwater for irrigation. The negative index of base exchange indicates the existence of chloro-alkaline disequilibrium (indirect base exchange reaction) in majority of the samples (68.08%) from the study area.

Keywords Markandeya river basin · Soluble sodium percentage (SSP) · Permeability index (PI) · Kelly index (KI) · Potential salinity (PS)

Introduction

Fresh water is limited, but demand is increasing day by day. Where surface water is not available, sufficient, convenient, or feasible for consumption, but groundwater potential is suitable in quantity or quality, groundwater consumption has great importance. As for contamination, it cannot be polluted easily comparing with surface water because it is protected naturally, less affected by drought even when close to point of use, and does not require much treatment, so it is more
reliable. Agriculture is a dominant sector in the economic development of India, as it is the source of sustenance for the majority of the population, and contributes 46% of the gross national product (Singh 1983). About one billion people are directly dependent upon groundwater resources in Asia alone (Foster 1995), and the dependence on groundwater has increased tremendously in recent years in many parts of India, especially in the arid and semi-arid regions, due to the vagaries of monsoon and the scarcity of surface water. Even though the quantity and quality of water available for irrigation is variable from place to place in India, many groundwater exploitation schemes in developing countries like India are designed without due attention to quality issues. Rapidly shrinking surface water resources due to over-exploitation and resultant contamination with several chemical and biological agents all over the globe have shifted tremendous pressure on the groundwater resources, contributing to the complexity of its quality assessment. Furthermore, continuously reduced annual recharge of the groundwater aquifers over the decades has lowered the groundwater table, influencing the redox chemistry of the aquifer and solid–water interfaces, causing mobilization of several chemical constituents of the aquifer matrices. Usually, water quality gets modified in the course of movement of water through the hydrological cycle that depends on the natural and anthropogenic processes which can alter these systems by contaminating them or modifying the hydrological cycle. The composition of groundwater in a region can be changed through the operation of the processes such as evaporation and transpiration (evapo-transpiration), wet and dry depositions of atmospheric salts, selective uptake by vegetation, oxidation/reduction, cation exchange, dissociation of minerals (soil/rock–water interactions), precipitation of secondary minerals, mixing of waters, leaching of fertilizers and manure, pollution of lake/sea, and biological process (Appelo and Postma 1993).

Quality of surface water, weathered mantle, underlying soil characteristics, and atmosphere are responsible for contribution of dissolved solids to water and in determining the composition and quality of the groundwater in a region. The type and extent of chemical contamination of the groundwater is largely dependent on the geochemistry of the soil through which the water flows prior to reaching the aquifers (Zuane 1990). Since it is impossible to control the dissolution of undesirable constituents in the waters after they enter the ground (Johnson 1979; Sastri 1994), groundwater quality data give important clues to the geologic history of rocks (lithology) of the area and indications of groundwater recharge, movement, and storage (Walton 1970) and the residence time of water in contact with rock material. It was observed that the criteria used in the classification of waters for a particular purpose considering the individual concentration do not find its suitability for other purposes, and better results can be obtained only by considering the combined chemistry of all the ions rather than individual or paired ionic characters (Handa 1964, 1965; Hem 1985). Hence, in order to assess the fate and the impact of the chemical discharge onto the soil, it is important to understand the hydrogeochemistry of the chemical–soil–groundwater interactions (Miller 1985) and to determine the origin of chemical composition of groundwater (Zaporozejc 1972).

A number of studies on groundwater quality with respect to drinking and irrigation purposes have been carried out in the different parts of India (Durvey et al. 1997; Agrawal and Jagetia 1997; Niranjan Babu et al. 1997; Subba Rao et al. 1999; Majumdar and Gupta 2000; Dasgupta and Purohit 2001; Khurshid et al. 2002; Sujatha and Reddy 2003; Sreeedvi 2004; Pulle et al. 2005; Husain et al. 2005; Sunitha et al. 2005; Subba Rao 2006). So far, the geochemistry and the suitability of the groundwater for drinking and agricultural purposes in the Markandeya River Basin study area has not been studied in great detail. Since groundwater is intensively used for irrigation and drinking purposes, an effort is made in the current paper to discern the hydrogeochemistry of groundwater and to classify the water in order to evaluate its suitability for municipal and irrigation/agricultural use.