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Research paper

Geochemical assessment of groundwater quality in the Dun valley of central Nepal using chemometric method and geochemical modeling

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ABSTRACT

In order to assess the hydrogeochemistry for suitability of different purposes, a total of 45 groundwater samples in Dun valley of central Nepal has been collected and analyzed for various geochemical parameters. Geologically, the study area comprises of Quaternary alluvium composed of boulder, cobble, pebble, gravel and sand with intercalation of clays. All the physicochemical parameters were within the permissible limits except nitrate. 53% of groundwater samples shows more than permissible limit of nitrate concentration (> 50 mg/l) as prescribed in the WHO are unsuitable for drinking purpose which may be due to local domestic effluents, leakage of septic tanks, nitrate fertilizer input and livestock excreta. On the basis of mineral stability diagram, groundwater appears to be stable within the kaolinite field suggesting weathering of silicate minerals. Piper diagram's classification shows that majority of samples belong to Ca–Mg–HCO_3 hydrochemical facies. Saturation index reveals undersaturation state of carbonate minerals which result in carbonate dissolution and Ca dominant waters along with direct exchange process. Groundwater quality index (GWQI) was calculated and found that majority of the area fall in excellent to good water for drinking uses. Evaluation of groundwater quality indicates that all samples are suitable for agricultural and industrial purposes, but around fifty percent samples are not suitable for drinking uses due to high nitrate concentration.

1. Introduction

Continued population growth, intense agricultural and urban development caused high demand on groundwater resources in arid and semi-arid regions and also greater risk to contamination. Due to inadequate supply of safe surface waters, most of the people depending mainly on groundwater resources for domestic, industrial and irrigation uses. Groundwater development occurs is in critical juncture and needs management of fresh water resources in terms of quantity and quality for sustenance (Reddy et al., 2000). Groundwater quality depends on composition of recharge water, rock–water interaction and water quality may yield information about the environments through which the water has circulated. Each groundwater system in the area has a unique chemistry acquired as a result of chemical alteration of meteoric water recharging the system. Water never exists in its purest form; many of the major and minor elements in limited quantities are essential for the human metabolism but if present in undesirable level they prove very harmful and the same water turns into a disease causing commodity. Knowledge and understanding the quality of groundwater is important because it is a main factor which decides its suitability for the sustainable use of groundwater in different uses. Rate of depletion of groundwater levels and deterioration of groundwater quality due to urbanization, industrialization and increase of irrigation activities is of immediate concern in many parts of the world (Unsal and Celik, 2010; Raju et al., 2014, 2015; Bikundia and Mohan, 2014). The effects of irrigation, fertilization and municipal sewage could increase the nutrients such as nitrate, phosphate and potassium in groundwater which increases the salinization of the soil and groundwater below the irrigated fields. Once pollution enters the subsurface environment, it may remain concealed for many years, rendering groundwater unsuitability for consumption and other uses (Raju et al., 2012; Singh et al., 2015). Nitrate contamination in groundwater is a common problem in many parts of the world from different reasons like fertilizers or byproducts of organic compounds from agriculture, poultry waste, septic systems, municipal waste disposal sites that are leaky, unlined sewerage lines and

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livestock manure (Suthar et al., 2009; Raju et al., 2009; Abdesselam et al., 2013; Ako et al., 2014). Higher concentration of nitrate in shallow aquifers than deep aquifers was observed in the Varanasi area, India which attributed to direct impact of agricultural fertilizers, improper sewage and urbanization (Raju, 2012). Excess nitrates (> 50 mg/l) in the drinking water causes health risks such as conversion of hemoglobin to methemoglobin which depletes oxygen in blood causing methemoglobinemia that may cause mortality by asphyxiation especially in newly born infants, enlargement of thyroid and increasing rates of stomach (Reddy et al., 2011). About 70% of total irrigated area in Nepal is dependent on groundwater resources. Organic N sources like human waste, wastewater and inorganic N sources like fertilizers have higher N content causes nitrate contamination in groundwater. Urea (NH_2CONH_2) is the main nitrogenous fertilizer used in the study area which constitutes about 75% of the total N-fertilizers consumption followed by DAP and potash along with organic waste such as manure piles, animal strand and latrines (Dongol et al., 2005). The annual sale of urea corresponds 7428–85191 million tons followed by DAP of 11377–22001 million tons and potash sale 1688–2820 million tons during 2002–2011 (Ministry of Agriculture and Co-operatives, 2010). Main occupation of the inhabitants apart from agriculture are poultry farming and livestock rearing which produces considerable amount of N and raise several environmental problems. Since, no significant research work has been done on groundwater quality especially nitrate pollution, an attempt is made in this paper to deduce source, processes and evaluate hydrogeochemical parameters of groundwater for sustainability pertinent to its suitability for domestic, agricultural and industrial uses in the Dun Valley of central Nepal.

2. Study area and hydrogeology

The study area lies in Chitwan and Nawalparasi districts of Dun valley, Terai region of the Nepal. The study area lies between 27°42.188′N–84°26.480′E and 27°40.493′N–84°25.455′E covering area of 162.2 km^2 with the elevation of 153–210 m above mean sea level. Narayani River (Fig. 1) is one of the biggest river of Nepal separate two districts of Chitwan and Nawalparasi and flows north to south in the Dun valley. Study area covers rural habitation in Nawalparasi district (Gaindakot municipality) and urban habitation in Chitwan district (Bharatpur municipality). Climate of the study area is classified as subtropical type. The average annual rainfall is about 1700 mm, 75% of which occurs during the monsoon season from June to September. The major crop cultivation is wheat, rice, maize, sugarcane, potatoes and oilseeds.

The study area falls in Terai zone which is the northern edge of vast Indo-Gangetic foreland basin of southern tectonic division of Nepal. The Chitwan Dun valley is a NNW–SSE trending synclinal intermontane valley formed within the Sub-Himalayas (Siwaliks) of Nepal Himalayas. The Siwaliks consist mainly of conglomerates, sandstones and clays. Subsurface lithology is composed of boulder, cobble, pebble, gravel and sand with intercalation of clays as well as detritus of quaternary age. Groundwater is abundant in the aquifers of the 'Terai' (lowland) and the Kathmandu valley. The annual recharge of shallow and deep-water aquifers ranges from 124 mm to 648 mm (NENCID, 1999). Groundwater is the best alternative source of water supply in the Terai region (Sharma et al., 2005). The general groundwater flow direction is from north to south and southeast to northwest, which follows the gradient of the basin. Groundwater occurs in unconfined shallow aquifers (< 50 m) and under semi-confined to leaky confined deeper aquifers (> 50 m) (Gurung, 2005; Neupane and Shrestha, 2009).

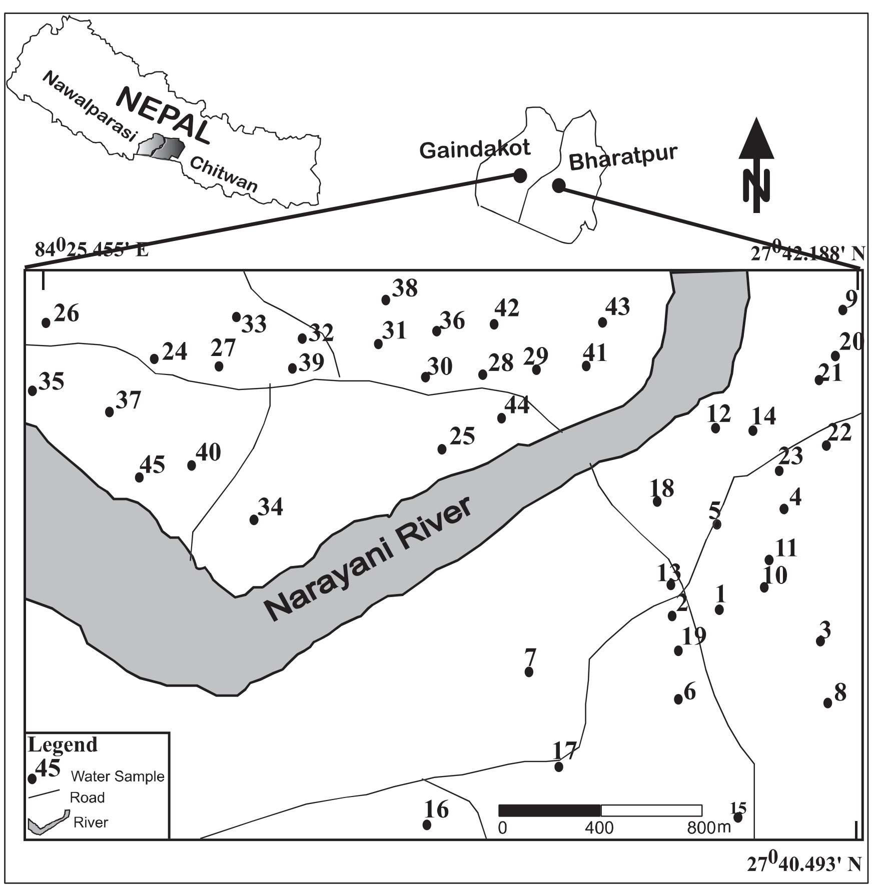

Fig. 1. Physiography and groundwater location map of the study area.