J. Ind. Geophys. Union, 29(5) (2025), 299-311
https://doi.org/10.71122/JIGU.29(5)2025.0029

Hydro-geophysical assessment of aquifer zones in Niger semi-arid regions

Rehmat Khan[1], Tanvi Arora[1,2]*, Sohelkhan Pathan[1, 2], Ronak Dahiya[2] and Rishu Pandey [1]
[1]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, 201002, India
[2]CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad 500 007, India
*Corresponding Author: tanvi.ngri@csir.res.in

Abstract

Recognizing the critical role of groundwater as the primary drinking water source for millions worldwide, particularly in semi-arid regions like Niger, the UN Sustainable Development Goal (UN-SDG) aims to prioritize its sustainable management. Addressing water scarcity challenges through accessible, pure, and naturally filtered groundwater supports UN-SDG objectives for clean water and sanitation (Goal 6), ensuring its availability for domestic, agricultural, and industrial needs. This research contributes to the understanding groundwater potential zones and aquifer protective capacity in Niger's semi-arid region, supporting sustainable water resource management in Niger's semi-arid regions, Tillabery, Niamey, Dosso, Thoua, and Maradi. Using Vertical Electrical Sounding (VES) techniques, 166 data points were collected employing the Schlumberger electrode configuration. Geoelectric properties (resistivity and layer thickness) were derived, and Dar-Zarrouk parameters were calculated. Contoured maps visualizing longitudinal conductance (S), transverse resistance (T), and electrical anisotropy (λ), helped classify groundwater potential zones. The northeastern part showed low resistance, indicating a good groundwater potential zone. The aquifer is encountered at a depth of 11 m to 15 m in a sandy clay environment. Assessment of longitudinal conductance revealed a moderate to very good aquifer protective capacity, particularly in the southwestern and central-western sectors. To validate, eighteen borehole sites were analyzed, correlating findings with borehole drilling data to create a 3D aquifer thickness model. We found that the aquifer thickness is from 1.5 to 3.5 meters in certain regions exhibiting robust protective capacity, enhancing aquifer resilience against surface contamination. Analysis of the electrical anisotropy coefficient provided insights into geological structures like fractures and bedding planes, influencing fluid flow dynamics and contaminant movement.

Keywords: Vertical Electrical Sounding (VES), Dar-Zarrouk parameters, Arc Scene, 3D Aquifer model, Semi-arid region, Niger

INTRODUCTION

Niger is a country located in the African continent within the semi-arid Saharan region, and its main challenge is aridity. The study area is mostly desert and the bulk of the population relies on the Niger River for agriculture and irrigation. (Arora et al., 2023). The population relies on groundwater for essential drinking and domestic water needs, which requires a comprehensive understanding of the aquifer in the challenging hard rock terrain. Reliable information on groundwater recharge mechanisms and rates are scarce in this region, so reliance on seasonal rainfall and flooding is evident to replenish shallow aquifers. Unfortunately, diminishing rainfall by 25-40% since 1930-1960, has made this vital water source precarious (Nicholson et al., 2000). Although recharge rates are generally low across the country, some areas witness adequate water yields from the dug wells, albeit in scarce numbers. Compelling groundwater exploration in the Niger, demands a systematic scientific approach due to inherent uncertainties. With the climate patterns shifting and rainfall increasingly erratic, a nuanced understanding of aquifer composition becomes pivotal for sustainable water management. Addressing these challenges will ensure water security and resilience in evolving climatic conditions.

Leduc et al. (1997) used hydrodynamics and geochemical methods during the early 1990s to evaluate natural groundwater recharge on a regional scale in unconfined aquifers. To determine delineation of aquifer zones, they relied on direct current (DC) resistivity soundings, which is a widely used geophysical technique (Van Nostrand and Cook, 1960; Zohdy, 1974; Koefoed, 1979; Patra and Mallick, 1980; Dutta et al., 2006; Dar et al., 2017; Arora et al., 2023). The electrical resistivity of the subsurface is closely linked to pore spaces, with layers featuring larger pores filled with fluid exhibiting lower resistivity than those with more compact pore structures. Groundwater exploration can be challenging due to the geological heterogeneity of the subsurface. It introduces complexities, highlighting the need for a nuanced understanding of subsurface geological variations. Thus, a scientific approach integrating hydrodynamics, geochemistry, and geophysical techniques can contribute to a more comprehensive understanding of natural groundwater recharge dynamics on a regional scale.

Groundwater exploration was conducted in the present study area, utilizing 166 electrical-sounding surveys by employing the Schlumberger electrode configuration. The gradual variation in DC sounding provides a reliable representation of subsurface changes with depth, similar to other geophysical methods. This data was then inverted to create a representative subsurface model. To enhance the reliability of the information, data from 18 specific sites were cross-referenced with borehole drilling data. These records provided a comprehensive understanding of subsurface characteristics, enabling the identification and delineation of potential aquifer zones. The obtained information was validated at 18 specific sites through correlation with borehole drilling data. This integration of data from borehole drilling served as a critical source, offering a comprehensive understanding of subsurface characteristics. This approach facilitated the delineation of potential aquifer zones tailored specifically for prospecting