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Groundwater Flow Dynamics in Shallow Coastal Plain Sands Aquifer, Abesan Area, Eastern Dahomey Basin, Southwestern Nigeria.

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Abstract Thirty hand-dug wells were identified and evaluated to study the groundwater flow dynamics and anionic species distribution in the study area. Topography and water table levels method with the aid of Surfer were adopted in the delineation of six recharge and discharge zones correspondingly. Dissolved anionic species of Cl-, HCO3-, SO42- and NO3- were determined using titrimetric and spectrophotometric method. The prominent anions in order Cl- > HCO3- > SO42- > NO3- at discharge and recharge area are Cl- and HCO3- ranging from 0.22ppm to 3.67ppm and 2.59ppm to 0.72ppm respectively. Analysis of groundwater head distribution and flow vector in Abesan area confirmed that Cl- concentration is higher than HCO3-concentration in recharge zones and conversely in discharge zones. A large percentage of the samples showed that the anions falls within the permissible limit of the W.H.O standard. Water Quality assessment revealed saltwater intrusion imprints in the groundwater of the study area. Potential salinity and SO42-/Cl- ratios signifies that most of the groundwater in Abesan falls in a water class found to be insuitable for irrigation and not saline. Continuous dissolution of these anionic species may pose a significant threat to the inhabitants of Abesan area in the nearest future.

Keywords: groundwater flow, recharge, discharge, anionic species, Abessan.

1. Introduction

Groundwater flow in the subsurface is driven by changes in energy – water flows from high energy areas to low energy (Ann and Matthew, 2009). Groundwater moves from areas of higher elevation or higher pressure/hydraulic head (recharge areas) to areas of lower elevation or lower pressure/hydraulic head. The groundwater system consists of the subsurface water, the geologic media containing the water, flow boundaries, and sources (such as recharge) and sinks (such as springs, interaquifer flow, or wells). Water flows through and stored up in the system (Alley et al., 2002). Under ordinary conditions, the travel time of water from and out of the groundwater system can vary less than a day to more than a million years depending on the spatial and temporal gradients of hydraulic head, hydraulic conductivity and porosity of the system. Water stored in the network can range in age from recent precipitation to water trapped in the sediments as they were deposited (Bentley, 1999, Alley et al., 2002).

1.1 Factors affecting groundwater flow

The type of geologic materials that are present and the length of time that water (resident time) is in contact with those materials are the two fundamental controlling factors on water chemistry in drainage basins (Thomas et al., 1998). The rate at which water migrates between groundwater and surface water provides a significant pathway for chemical transfer between terrestrial and aquatic systems. As water moves in the subsurface, it takes the chemistry of the surroundings and incorporates it into itself. Aquifers and individual wells can be contaminated by substantially different processes (Carrillo-Rivera et al., 2007, Thomas et al., 1998, Back, 1966). Chemical reactions that affect the biological and geochemical characteristics of a basin include; acid-base reactions, precipitation, and dissolution of minerals, sorption and ion exchange, oxidation-reduction reactions, biodegradation and dissolution and exsolution of gases (Thomas et al., 1998). As weathering progresses, the absorption of dissolved solids increases depending on the chemical composition of the minerals weathered and the relative abundance of the major inorganic chemicals dissolved in the water changes. Anionic species such as bicarbonate and carbonate ions are abundant in groundwater, but Chloride ions generally occurs in small amounts in groundwater but is abundant in seawater. (Thomas et al., 1998). Aquifers can be contaminated by agricultural-chemical use over large parts of recharge areas. Properly constructed wells down gradient from recharge areas can withdraw water with dissolved contaminants derived from those areas. Agricultural chemicals can contaminate improperly constructed wells without appreciably affecting the aquifer. This contamination can occur when chemicals present near a well move from the surface down the outside of the well casing or laterally into the well through hydrologic units that are not isolated during well construction (Burkart and Stoner, 2001).

1.2 Why study groundwater flow

Groundwater recharge and discharge are critical to the global hydrological cycle but are not noticeable. They are also unsafe to the analysis of groundwater flow systems and water budgets. Recharge and discharge activities are typically spatially limited to a minor percentage of an aquifer, therefore may not be nearly as conspicuous as aspects of the hydrological cycles (Seth, 2007). It is necessary to know the direction of groundwater flow to determine groundwater potential, groundwater recharge and discharge zones and analyse how groundwater gets contaminated through human activities in any area (Akinfaderin et al, 2019, Omowumi and Saloko, 2018). Characterization of shallow groundwater yield and flow pattern are also important to understand areas of high yield capability and areas where groundwater level is close to the surface and to suggest proper development, management and exploration of groundwater (Ashaolu and Adebayo, 2014).

1.3 Scope of work

Abesan community has one of the highest populations and a residentially developing area in the southwestern part of Nigeria (Figure 1). The inhabitants only rely on groundwater extracted from hand-dug wells. The water from most of the hand-dug wells was shallow and susceptible to contamination. Groundwater improvements, therefore, constitute a viable option for potable water provisions as citizens require access to significant quantities and high-quality groundwater supply for their daily activities. This research work centres in studying the groundwater flow dynamics in order to determine the distribution of ions and contamination at strategic areas at Abesan and its environment in Lagos State, Nigeria. The overall objectives of this research work are to determine the hydraulic head distribution, analyse the groundwater flow direction, delineate the recharge and discharge zones and identify wells around these zones, to determine the pattern of distribution of ions around the zones, and compare the flow characteristics to the delivery of ions in the area.

2. Research Methology

2.1 Field Methods

Desk Study, reconnaissance survey, and Water sampling phase were carried out for field methods. Thirty wells were analysed and GPS readings, height of the rim above the ground, ground surface elevation, time and other parameters on the hydrogeochemical research data form was made. Samples were examined at Geochemistry and Marine Science Technology Laboratories in the Federal University of

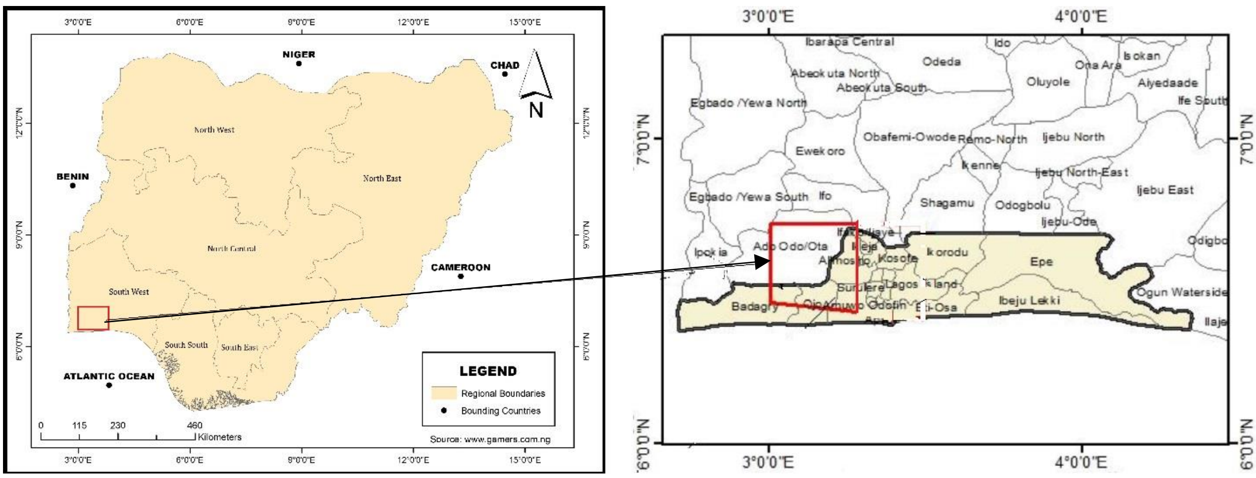


Figure 1: Map of Study Area (Ojeh et al., 2016)

2.2 Laboratory Methods

Anions were analysed using titrimetric and spectrophotometric procedures. Chloride and bicarbonate were analysed using the titrimetric method. Mohr method of titrimetry was employed to analyse Chloride. Whereas the bicarbonate ion was determined using Hydrochloric acid as titrant and Phenolphthalein and methyl red as an indicator. The following ions were analysed using spectrophotometric method; nitrate and sulphate.

2.3 Analytic Methods

2.3.1 WHO standard comparison

The level of the chemical parameters of the water samples were compared with the WHO standards for drinking water in ppm (WHO, 2017).

2.3.2 Water Quality assessment of Abesan groundwater

Salt water intrusion assessment was undertaken for Abesan groundwater to determine the influx of relative concentrations of some of the characteristic ions of seawater such as Cl, Na and Mg. Saltwater intrusion is a form of groundwater contamination which have led to the abandonment of wells. This assessment is possible through the $Cl^-/(CO_3^{2-} + HCO_3^-)$ ratio as a criterion to evaluate saltwater intrusion aspect ((Sarada and Bhushanavathi, 2015). This ratio is considered to be indicative of groundwater contamination by seawater (Simpson, 1946). This assessment has been successfully employed in various researches (Sarada and Bhushanavathi, 2015). In addition, SO_4^{2-}/Cl^- ratio generally decreases with increase of the salinity of water (Herrera, 2008; Kouzana, 2009; Petlas, 2006).

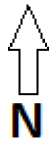
Another water quality index is Potential Salinity ratio, this has been used to classify waters for irrigation purpose. Potential Salinity ratio ($Cl^- + (SO_4^{2-}/2)$) relates to the irrigation water classes rating used to classify water samples using the chemical data (Abdul Hakim, 2013). Areas having potential salinity higher than 3 are not suitable (Abdul Hakim,

3. Results and Discussion

The hydraulic head distribution revealed that wells studied in Abesan area are higher in the recharge zone than discharge zones (Figure 2). The water flow direction in Abesan area is basically towards the south. However, there is a topographic influence on flow direction at the northern segment of Abesan area creating a sloping flow direction to the south. This variation of hydraulic head and flow directions resulting to discharge could be as a result of the rainfall regime and anthropogenic activities such as pumping pattern activities and at recharge, zones could be as a result of changes in rainfall regime, aquifer yield, direct injection of water into the subsurface or irrigation prevailing in Abesan area.

Variation in the chemistry of Abesan groundwater was observed with chloride displayed as the most dominant anion with HCO_3^-, SO_4^{2-} and NO_3^- in descending order of dominace. The result confirmed that chloride concentration is higher than bicarbonate concentration in recharge zones. Conversely, there is a high concentration of bicarbonate and low concentration of chloride inland towards the continent, therefore, bicarbonate content in the discharge zones is more than the chloride content. The source of the chemistry the Abesan groundwater was further analysed using Gibbs plot which displayed that most are of rock origin, some of evaporation origin and few of precipitation origin.

The quality assessment of Abesan groundwater appears to be in good state however there have been traces of contamination in some locations. A large percentage of the samples showed that HCO_3^-, Cl^-, $SO_4^{2-}$and NO_3^- falls within the permissible limit of the W.H.O standard. This contamination is were revealed using the $Cl^-/(CO_3^- + HCO_3^-)$ ratio which indicated that most of the samples were greater than 0.5 showing that here are traces of saltwater intrusion in the groundwater of the study area. 24% of the sample collected represented normal groundwater (no saltwater contamination), 38% slightly contaminated groundwater, 25% moderately contaminated groundwater and 13% injuriously contaminated groundwater. This shows that the Abesan area is indicative of groundwater contamination by seawater. Potential Salinity and SO_4^{2-}/Cl^- ratios signifies that Abesan groundwater is suitable for irrigation and it representative of non – saline water.



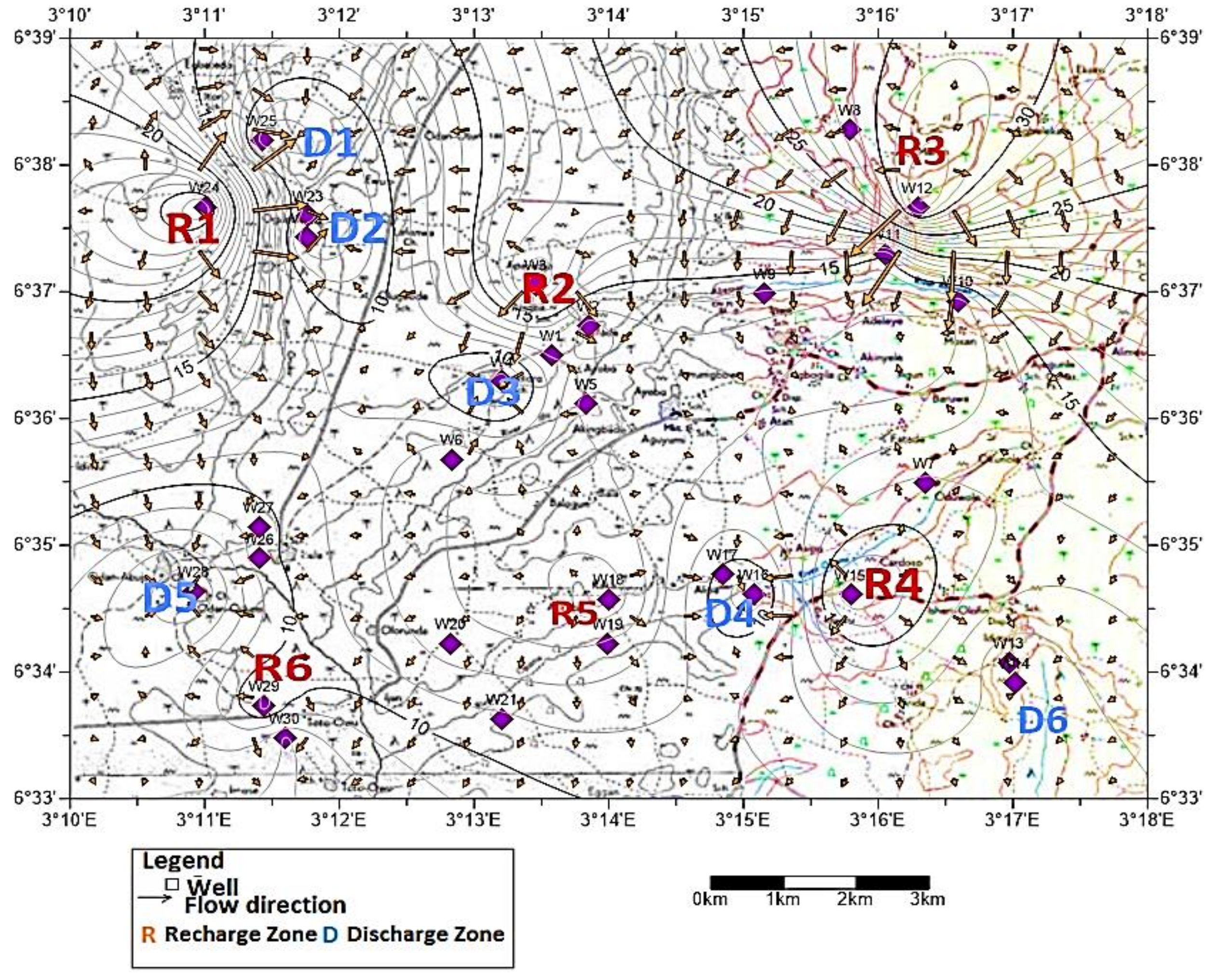


Figure 2: Groundwater head distribution, flow vector, recharge and discharge zones in Abesan.

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