

## **GEOELECTRIC EVALUATION OF GROUNDWATER QUALITY IN SHARADA INDUSTRIAL AREA OF KANO STATE**

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### **ABSTRACT**

The study employed direct current electrical method and physicochemical analyses to evaluate the groundwater quality in Sharada industrial area. The study area is located between longitude 8° and 9°E and latitude 10° and 12°N spanning over 6 km<sup>2</sup>. The geoelectrical methods used were electrical resistivity, Induced Polarization (IP) and Spontaneous polarization (SP) using Vertical Electrical Sounding (VES) techniques. Forty-three VES were conducted. Six samples of soil and water sample were analyzed. The results reveal that deeper basement zones [notably locations A (11°57'53"N, 8°30'20"E), D4(11°57'41"N, 8°30'16"E), and S4(11°57'52"N, 8°30'14"E)] possess the most favorable and protected aquifer systems, making them suitable for sustainable groundwater extraction. In contrast, shallow basement zones especially those adjacent to industrial activities exhibit increased vulnerability to contamination, as reflected in the degraded water quality of Samples C(11°57'48"N, 8°30'42"E), D(11°57'53"N, 8°30'49"E), E(11°58'53"N, 8°30'20"E), and F(11°57'53"N, 8°30'21"E). The geoelectrical and polarization methods proved effective in delineating safe groundwater extraction zones and mapping subsurface flow dynamics. While most physicochemical parameters fall within WHO/FEPA standards, elevated TDS, TSS, and low pH in select samples indicate localized pollution likely linked to industrial activities.

**Keywords; Groundwater, Geoelectrical, Industrial, Physicochemical, Vulnerability.**

### **1. INTRODUCTION**

Water is an essential commodity that supports all forms of plant and animal life [1]. About 60% of human body is water as life began in water and life is nurtured with water [2]. Access to adequate safe drinking water is of prime importance to many governmental and international organizations and without doubt it is the principal component of primary health care and a basic component of human development as well as a pre-condition for man's success to deal with hunger, poverty and death [3]. Water is primarily used for industrial, domestic, agricultural activities and necessary for sustainable economic development of an area as it is the next major support to life after air [4].

The availability of pipe-borne water, borehole water and shallow wells in urban areas is an indication that water is a vital component of human existence. It is generally found from two major natural sources; Surface water such as fresh water lakes, rivers, streams and Groundwater such as borehole water and well water [5]; [6]. Provision of adequate and safe water for drinking is important for the development of any country [4]. The quality of water that human beings ingest is critical in determining the quality of their lives [7]. The World Health Organization has frequently insisted that the single major factor adversely influencing the general health and life expectancy of a population in many developing countries is the ready access to potable water [8]. The usefulness of water for a particular purpose is determined by the water quality [7].

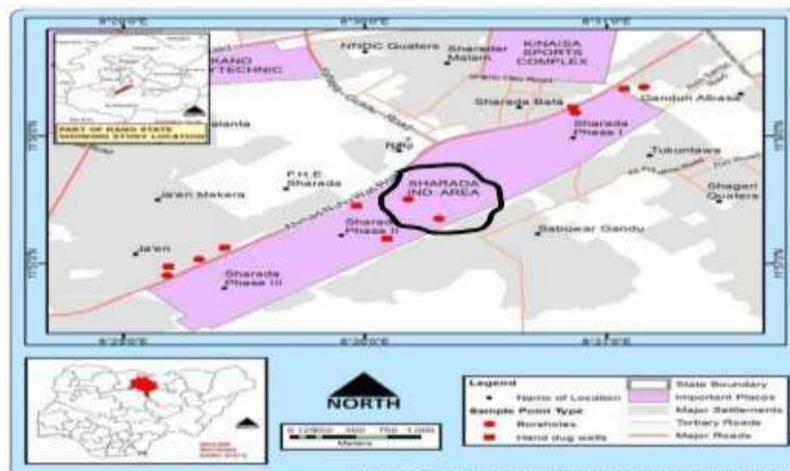
Traditionally, subsurface groundwater is exploited by borehole drilling or hand dug wells. However, these approaches certain drawbacks such as high cost, time consumption, intrusive, complicated and provides only point information of an area. Major constraint is the fact for cost effective sightly of these sources of water. Information about the general nature of the subsurface and the groundwater are needed. Geoelectrical method provides insight into the constitute of region without disturbing the study site at reduce of cost technical involvement. Therefore, the study would employ the vertical electrical sounding methods to evaluate stratigraphic setting, groundwater distribution and quality in conjunction physical chemical analysis of water and soil strategically to be collected about the area.

[9] state that the VES method has been used to study seawater intrusion in coastal areas of Nigeria. Also, [10] examine the potential aquifer of profile one’s geoelectric section, the horizons of layer four were better potential aquifers as the highly fractured and weathered ignimbrite zone of layer five of VES13 was 219 m deeper than the depths of the other VES points, and along with profile two geoelectric section, the horizon of layer four VES23 layer five has the lowest resistivity with large thickness at a depth of 252.8. [11] show that an aquifer system that is free from any form of contamination and can be obtained at a reasonable depth of 19.00m and above. Vertical Electrical Sounding (VES) has proved to be very reliable for ground water studies and therefore the method can excellently be used for shallow and deep ground water geophysical resistivity investigation. In general, geoelectrical methods are combined with hydrochemical data to study seawater intrusion phenomena effectively [12]; [13]. Aquifers contaminated with seawater are characterized by high TDS (Total Dissolved Solids) and chlorine ion values.

Therefore, in this work, an attempt would be made to assess and evaluate the quality of groundwater in Sharada Industrial area of Kano using Vertical Electrical Sounding.

**1.2 DESCRIPTION OF LOCATION AND GEOLOGY OF THE STUDY AREA**

Kano metropolis covers an area of about 600 km<sup>2</sup> located between longitude 8° and 9°E and latitude 10° and 12°N. Kano industries are concentrated in three industrial estates which are: Bompai, Challawa and Sharada. The climate area of Kano is the tropical wet and dry type with dry season between for 4 - 5 months and wet season between May and September [14]. Sharada is one of the popular industrial areas in Kano which is located in Kano Municipal Local Government and Kumbotso Local Government area of Kano State as shown in



**Figure 1. The location of the study area**

## 2. THEORETICAL BACKGROUND

### 2.1 Electrical Resistivity Method

Electrical resistivity is a fundamental and diagnostic physical property that can be determined by a wide variety of techniques resistivity method induced polarization method, self-potential method and including electromagnetic induction. Some techniques make use of fields within the Earth while others require the introduction of artificially-generated currents into the ground [15], The induced-polarization (IP) and self-potential (SP) methods of geophysical exploration are based on measurement, normally made at the surface of Earth, of electric potentials that are associated with subsurface charge distribution. In the IP method, the charge distribution are induced by an application of external electrical energy, while in the SP method, subsurface charge distributions are maintained by persistent, natural electrochemical process [16].

Geo-electrical methods are applied to map the resistivity structure of the underground. Rock resistivity is of special interest for hydro-geological purpose; it allows, e.g to discriminate between fresh water and salt water, between softy-rock sandy aquifers and clayey material, between hard rock porous/fractured aquifers and low-permeable clay stones and marlstones, and between water-bearing fractured rock and its solid host rock. The resistivity ( $\rho$ ) for a homogeneous and isotropic layer according to [16] for a four electrode system is

$$\rho = KR \tag{1}$$

where K is the geometrical factor and R is the resistance of the medium. And K is given by

$$K = 2\pi \left\{ \frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right\} \tag{2}$$

$$\text{whereas the } R = \frac{V}{I} \tag{3}$$

Where V is the voltage across the potential electrodes produced by the injected current I However according to [16], the resistivity of inhomogeneous and anisotropic medium is expressed as

$$\rho = \rho_1(1 + 4D) \tag{4}$$

where  $\rho_1$  = resistivity of the top layer and  
D = disturbing potential due to effect of anisotropy (layering).

### 2.2 Self-Potential (SP) Method

The self-potential is based upon measuring the spontaneous or natural potentials developed in the earth by electrochemical actions between minerals and subsurface fluids or by electro-kinetic processes involving the flow of ionic fluids. It differs from other geo-electric methods (i.e. Resistivity and Induced Polarization (IP) methods) which requires electric currents to be artificially introduced into the ground [17] . The SP method is one of the simplest and oldest among all geophysical techniques used to locate sulphide ore-bodies. Specific applications of SP method include mapping of seepage flow associated with dams, dikes, and reservoir floors and delineation of flow patterns in the vicinity of water wells, faults, landslides, and sink-holes. As the method offers relatively rapid field data acquisition, it is often cost effective for initials investigation of an area prior to more intensive studies using other geophysical methods [17].

### 2.3 Induced Polarization (Ip) Method

Induced polarization (IP) is a current-stimulated electric phenomenon observed as a delayed voltage response in the earth materials. The electrical conduction in most rocks is essentially electrolytic, by transport of ions through interstitial water pores.

However, when a current is passed through a rock containing metallic minerals, the ionic conduction is hindered to a considerable extent by the mineral grains in which the current flows in electronic. This leads to the accumulation of ions at the interface between the mineral and solution, resulting in a growth of electrochemical voltage at the metallic grain surface.

The process is similar to electrode polarization that occurs at the surface of metal electrodes dipped in an electrolyte. When the external applied current is switched off, the electrochemical voltage is dissipated, but does not drop to zero instantaneously. The decay in voltage is observed to vary with time, and can be measured as a fraction of, the voltage,  $V$ , that existed when the current was flowing. The ratio  $\Delta V/V$  gives a measure of the concentration of metallic minerals in the rock formation. This is, in brief, the principle of the induced polarization method. This effect is also observed even when the rock material does not contain metallic minerals.

Induced polarization (IP) measures the polarization effect within subsurface materials when subjected to an electric field. It characterizes the chargeability; a property related to the rock's ability to hold and release charge. This study utilized the induced polarization to measure the chargeability of the subsurface using the following formula;

$$M = \frac{V(t_f) - V(t_0)}{V(t_0)} \quad (5)$$

where 'M' is the chargeability,  $V(t_f)$  is the voltage at a specific final time after the current injection has ceased and  $V(t_0)$  is the initial voltage or background voltage.

Environmental applications of IP surveys include the delineation or margins between hazardous wastes and the surrounding soils, location of specific deposit of chargeable material in a waste dump, and the mapping of infiltrated salty plumes in clayey country rock [17].

### Physicochemical Analysis

Physicochemical parameters of water indicate the safety of potable water and their analysis is very important for public health and pollution studies. Physicochemical parameters include pH, total dissolved solids (TDS), color, Turbidity, electrical conductivity, odour. [18].

## 3. MATERIALS AND METHOD

The materials used for data collection in the survey include ABEM SAS1000 Terameter, hammer, measuring tape, electrodes, 12V battery, solar panel and global positioning system (GPS).

### 3.1 Method of data acquisition

The detailed field procedure was carried out following the steps highlighted by Jamluddeen et al (2014). It involves measurement at forty-three VES points adopting Schlumberger configuration. The Terameter was kept in VES station 1 after having measured the latitude, longitude and the elevation of the station with global positioning system. The current electrodes and the potential electrodes were driven into the ground at distances 2 m and 0.5

m respectively on both sides of the Terrameter. Connections were established between wires on wheels and the Terrameter with the help of connecting wires. The Terameter was also connected to a 12 V car battery which powers the machine. After all connections have been established, the Terameter is switched on and allowed to boot. After booting, it was set to resistivity mode and then the electrode distances i.e., 2m and 0.5 m were imputed into the machine. Thereafter, the machine measured the apparent resistivity and displayed the result in ohm meter. After the first measurement, the Terameter was switched off and the current electrodes were shifted to a distance of 3 m on both sides of the machine with the help of the field assistants. Then the whole process is repeated hence the apparent resistivity were measured and recorded. Then the electrodes were shifted according to distances shown in table 1. Where AB/2 represents current electrode spacing and MN/2 represents potential electrode spacing. This whole process in VES station 1 was repeated about the 43 VES stations.

**Table 1: Field Data for VES 3**

AB/2	MN/2	Resistivity ( $\Omega$ m)	IP(ms)	SP(mv)
1	0.5	18.302	3.29	0.106
2	0.5	36.416	12.3	0.105
3	0.5	56.872	33.5	0.106
4	0.5	87.278	45.7	0.108
6	0.5	152.55	99.2	0.11
7	0.5	200.11	137	0.112
8	0.5	248.66	177	0.113
10	0.5	512.78	174	0.112
10	2.5	126.64	65.1	90.128
12	2.5	152.88	88.6	0.136
14	2.5	55.645	5.38	0.124
15	2.5	56.367	4.19	85.838
17	2.5	64.535	7.74	56.346
20	2.5	93.077	8.28	94.114
25	2.5	83.988	5.64	91.959
30	2.5	87.026	7.38	87.416
40	2.5	105.97	15.2	77.891
50	2.5	174.27	3.87	70.314
50	7.5	505.85	9.42	18.272
60	7.5	154.21	9.79	39.426
70	7.5	151	18.1	3.69
100	7.5	940.93	95.7	4.237
120	7.5	623.39	53.1	67.614
150	7.5	303.37	6.46	83.227
170	7.5	652.64	14.4	80.354
200	7.5	599.08	6.07	80.387

The groundwater and soil samples collected from the study area were taken to laboratory for analyses in accordance with standard methods prescribed by [18]. The following are the parameters determined; pH, total dissolved solids (TDS), color, Turbidity, electrical conductivity, odour.

**3.2 Data Analysis**

For this study, the data obtained from the vertical electrical sounding (VES) using the Schlumberger electrode where systematically processed and interpreted to reveal the geoelectric characteristics of the subsurface layers.

### 3.3 Resistivity Data

Apparent resistivity data were plotted against AB/2 using ipi2win. The same software were used to model the subsurface parameter carrying the measured apparent resistivity values. These parameters include  $\rho$ , h, d and number of layers.

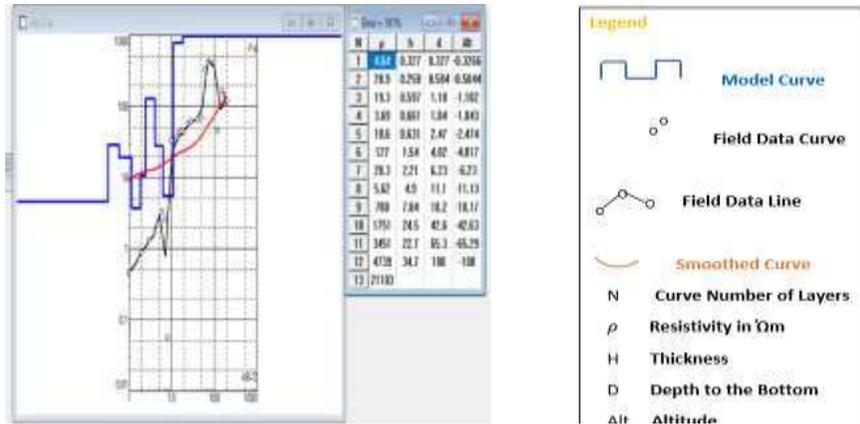


Figure 2 Digitized Model of Interpreted VES 3

IP and SP data were also obtained and, tabulated in Microsoft excel and plotted against spacing. Later were gridded using Surfer 16 software the contour maps were also generated using the software. The Data for IP and SP plotted using Microsoft Excel for VES 3 is below

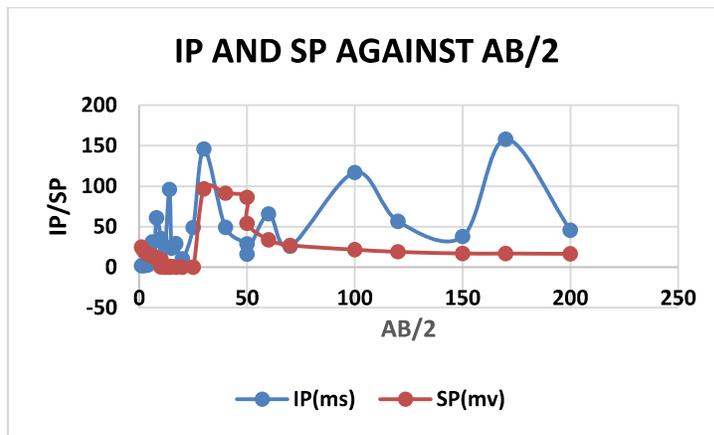


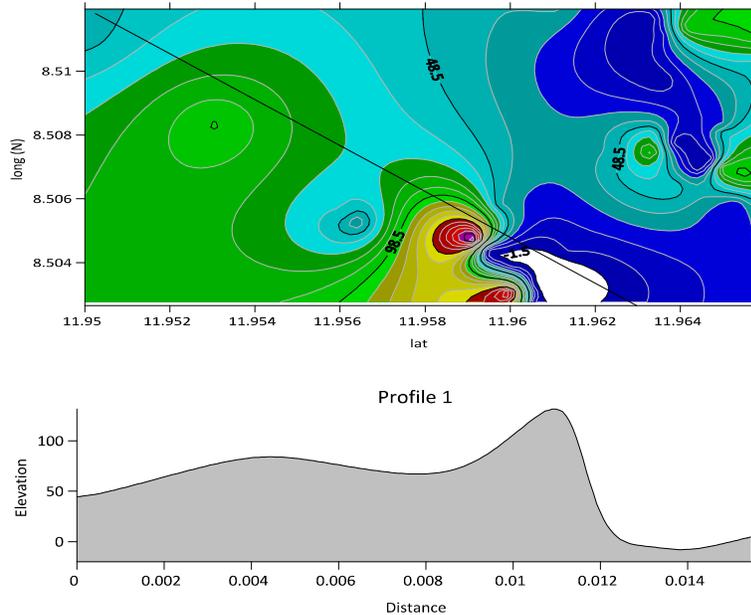
Figure 3. IP and SP Graph for VES 3

## 4. RESULT AND DISCUSSION

The interpolated maximum depth to the top of fresh basement complex rocks derived from the deepest depth with resistivity greater than  $70\Omega m$  was inputted alongside the corresponding coordinates for each point. The data was gridded and contoured to generate the spatial variation of fresh basement complex rock topography underneath the study area using surfer version 16 as shown in figure 4. figure 4 also carried out the cross section (profile) taken along direction. This direction aligns with region with greatest depth to the top pf basement rocks.

Reviewing the map the location with greatest depth (218m) at a region levelled A followed by B (188m) can be identified. Other region with appreciable depths over the rest the area are

locations C, D, E, F each of the depth about 108m. Table 1 has given the coordinates for the various region

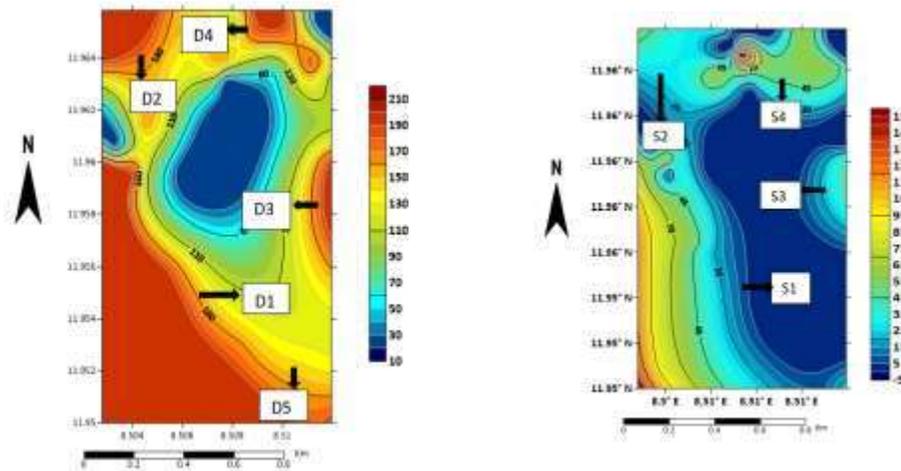


**Figure 4: Depth to the top of fresh basement complex rock**

#### 4.2 Induced polarization interpretation

The interpolated depths for the IP for locations with maximum values of IP and greater depth were plotted alongside corresponding by geographic coordinates in the surfer software as shown in the surfer software as shown in figure 5.

Consider figure 5 the location with greater depth to fresh basement complex rocks were identified as D1(170m), D2(190m), D3(170m), D4(250m) and D5(190m). The meta data for the point is given table 5.

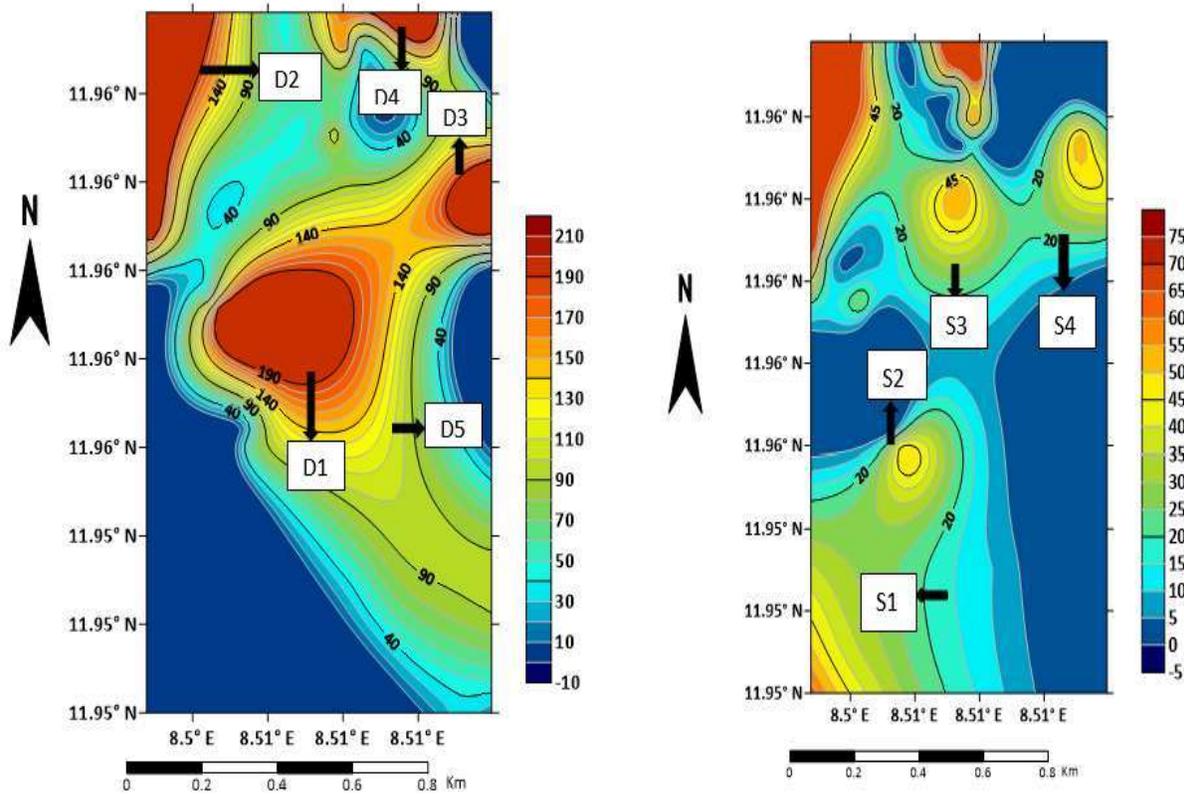


**Figure 5: Depth of fresh basement complex rocks topography using IP**

Four locations with variations of shallow depths were shown from the above plots were ranged from 15m and above as were shown on the legend. S1 shows a very shallow depths which correspond to low thickness, S2 and S3 revealed a second shallow depth as demonstrated on the map and S4 is the third shallow depth at 35m to 55m.

**4.3 Spontaneous Polarization Data Interpretation**

Locations with highest SP values and corresponding largest AB/2 spacings were interplotted for each VES-SP plot/graphs. These depths alongside the corresponding VES coordinates were keyed into surfer software, gridded using method and plotted as contoured as maps. The locations/areas with greatest depth over the region where identified as S1(125m), S2(85m), S3(75m), S4 (159m), S5(75m) and S6(85m). the detailed spatial information of the identified points are given in table 1.



**Figure 6: Depth of Fresh Basement Complex Rocks Topography using IP**

The distribution of IP shallow depths were presented in the figure above. Four locations with varying SP shallow depths were arranged in order of increasing their depths as S1<S2<S3<S4 which shows a regions with low groundwater occurrence and low aquifer thickness. Furthermore, the regions were exposed to low groundwater movement.

**4.4 Physico-Chemical Analyses**

A total of twelve (12) samples of water and soil were obtained at some strategic points. Six of the samples are water, four obtained are underground water, two are waste water. Also, the soil is six samples also two of them are from dumping site area outside but very near to

the survey area. The PH, Total dissolved solids (TDS), Dissolved oxygen (DO), Total suspended solids, Biochemical Oxygen Demand were analyzed.

The results of the water and soil sample collected where show in table 4.

**Table 2 Analyses of Water and Soil Sample**

Sample ID	PH	TSD PPM	DO mg/L	BOD mg/L	TSS mg/L
Sample A	6.6	387	5.2	5.2 – 3.8 =1.4	65
Sample B	6.8	389	5.6	5.6 – 4.6 =1.0	50
Sample C	6.2	299	4.8	4.8 – 4.0 =0.8	72
Sample D	5.8	719	6.0	6.0 – 5.1 =0.9	35
Sample E	6.4	837	5.6	5.6 – 4.2 =1.4	44
Sample F	6.9	430	5.0	5.0 – 3.2 =1.8	80
Soil A	6.6	157	4.7	4.7 – 2.4 =2.3	
Soil B	7.5	45	7.1	7.1 – 5.9 =1.2	
Soil C	6.8	254	6.5	6.5 – 5.3 =1.2	
Soil D	7.6	49	6.2	6.2 – 5.1 =1.1	
Soil E	7.4	32	6.2	6.2 – 4.9 =1.3	
Soil F	8.2	117	6.1	6.1 – 4.7 =1.4	

The following Parameters were examined in this analysis. The results are compared with standard limits from [18].

**Table 3: Analyzed water sample compared with standard limits**

Parameter	WHO/FEPA Standard	Observations
pH	6.5 – 8.5	Sample D (5.8) and C (6.2) are <b>below standard</b> , indicating acidity.
TDS (mg/L)	1000 mg/L max	All samples are within limits. However, Sample E (837) and D (719) show <b>elevated levels</b> , which might indicate pollution.
DO (mg/L)	≥5 mg/L (desirable)	Sample C (4.8) is <b>low</b> , implying possible organic pollution. Others are acceptable.
BOD (mg/L)	≤3 mg/L (natural water)	All samples exceed 0.8–1.8 mg/L, indicating <b>moderate organic pollution</b> .
TSS (mg/L)	≤30 mg/L (desirable)	Samples C (72), F (80), A (65), and B (50) have <b>elevated TSS</b> , indicating possible <b>siltation or pollution</b> .

These results indicates that Contamination suspected in samples C, D, E, and F, with low pH (acidic), high TDS, and elevated BOD and TSS.

For the soil sample;

**Table 4: Analyzed soil sample compared with standard limits**

Parameter	Observations
Ph	Soil D (7.6) and F (8.2) are slightly alkaline. Others are within range.
TDS	Soil C (254), A (157), and F (117) show high TDS, indicating salt accumulation or contamination.
DO & BOD	BOD values >1.5 mg/L (Soil A – 2.3) suggest biodegradable organic pollution. Others are moderate (1.1–1.4).

Soil A and C show potential contamination by salts and organics. Slight alkalinity in Soil F may affect nutrient availability.

## 5. DISCUSSION

Using resistivity values  $>70 \Omega\text{m}$ , the interpolated depth to the top of the fresh basement complex rocks was mapped (Figure 5), with the deepest areas occurring at: Location A: 218 m, Location B: 188 m, Locations C, D, E, F:  $\sim 108$  m. These deep-seated zones, especially A and B, indicate significant aquifer thickness and are optimal for groundwater development due to their capacity for groundwater accumulation and natural protection from surface contaminants. Aquifer-bearing zones lie between 8–30 m, characterized by moderate resistivity values (31–44.5  $\Omega\text{m}$ ). Fresh basement is detected beyond 56 m with resistivity up to 598  $\Omega\text{m}$ , confirming the base of water bearing formations. Layers show alternating sand and clay materials, suggesting partially confined aquifers. Recommended drilling depth: 30–50 m to access reliable groundwater zones while avoiding unproductive basement penetration.

For induced polarization the deep basement depths are at: D1, D2, D3, D5: 170–190m D4: 250m (deepest, strongest aquifer potential)

These depths support high groundwater storage capacity and reduced contamination risk, as thicker unsaturated zones buffer surface pollutants.

The spontaneous polarization identifies deep flow paths at S1 (125 m), S2 & S6 (85 m), S4 (159 m). therefore, shallow basement zones (e.g., S2, S3, shallow VES layers) correlate with Samples C and D, which exhibit acidic pH, low DO, and high TDS/TSS, confirming vulnerability to contamination. Also, Deep basement areas (A, D4, S4) align with samples of better quality, indicating protective layering against pollutant infiltration.

## CONCLUSION

The integration of VES, IP, and SP techniques with physicochemical analysis provided a comprehensive evaluation of groundwater potential and contamination risks in Sharada Industrial Area. From the study, deeper basement zones (e.g., A, D4, S4) offer the most promising and protected aquifer systems, ideal for sustainable groundwater extraction. Shallow basement zones, particularly those near industrial activities, are more vulnerable to contamination, as supported by poor water quality in Samples C, D, E, and F. Geoelectrical and IP/SP techniques are effective for identifying safe groundwater abstraction zones and understanding subsurface flow patterns. The physicochemical parameters generally meet WHO/FEPA standards, but elevated TDS, TSS, and low pH in specific samples indicate localized pollution likely from industrial sources.

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