Physico - Chemical Quality of Ground Water from Shallow Wells in Galambi and Environs, Bauchi State, Northern Nigeria

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ABSTRACT

Physico-chemical characteristics of ground water from shallow wells in Galambi and its environ in Bauchi State, Northern Nigeria, were evaluated. A total of fifteen shallow well water samples were randomly collected and analyzed for an assessment of its potability and suitability for domestic purposes. Results obtained indicate that the ground water is slightly acidic to moderately alkaline (5.70< P^H <8.10), hard to very hard, (124.7 – 256 mg/l), colourless, and odorless. Conductivity, HCO_3^{2-}, CO_3^{2-}, NO_3^{2-}, SO_4^{2-}, and PO_4^{3-} are generally within WHO permissible levels for potable water. However, heavy metals like copper, iron, and lead are of higher concentrations than WHO standards for drinking water. Consequently, relevant treatment procedures are strongly recommended to reduce concentrations of Fe, Cu and Pb in the water so as to minimize the risks/concerns that they may pose to human health within and around the study area. The plot of the average constituents of the ground water in a Piper Trilinear diagram shows that the water is potable and can be classified as alkaline earth water type with higher alkaline proportion (Ca – Mg – Na) and predominantly HCO_3^- water, as well as normal alkaline earth water type (Ca – Mg) with predominantly HCO_3^- water.

INTRODUCTION

Next to air as a major support substance to all lives is water. It generally comprises both surface water (streams, rivers, ponds, lakes, seas and oceans) and groundwater (water that accumulates underground). Ground water is commonly derived from both shallow wells (hand-dug wells) and deeper wells (boreholes drilled with rotary drilling rigs and pumped out to surface with a submersible pump) for consumption[1]. In Nigeria, a significant percentage of rural and urban dwellers depend mainly on ground water sources for their daily water requirements. Todd[2] observed that the quality of ground water is as essential to life as its quantity. The quality of any drinking water (surface or subsurface) is determined by its physical, chemical and microbiological characteristics. The study area is located at about 38km along Bauchi – Gombe road. It falls within longitudes 10^o 06’ and 10^o 15’E and latitudes 10^o 05’ and 10^o 20’N (Fig.1a & b). The total area covered by this study is approximately 42km^2.The area is drained mainly by River Gongola which rises from Jos Plateau and drains into the Niger – Benue system.

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Almost all the streams in the area are dried up in the dry season of every year. Surface water becomes rare during the dry season, with minimal supply from river Gongola. The inhabitants in the area constitute an estimated population of about 3,638 persons comprising 2,786 males and 852 females[3] and depend largely on groundwater supply from the hand-dug shallow wells in the absence of any deep borehole. Approximately 28 hand-dug wells exist in the study area out of which 15 were duly sampled in this work. The only borehole located in this area could not be sampled because it has stopped functioning for some years. Drinking water supply could be said to be a major problem in this area especially in the dry season. The aim of this study is to evaluate the suitability of groundwater in the area for drinking. The area of study comprises linear settlements distributed unevenly along the Bauchi – Yankari road including Dindima, Galambi, Angwan Sarki, Sabon Kaura, Sharuwa, Dadin Kowa, Kela Mai Kudi, Kela Mai Lowo, Ruga, and Tudun Gambo I and II.

The area is underlain by the Precambrian Basement Complex rocks of northcentral Nigeria. Charnockites are the dominant granitic rocks with

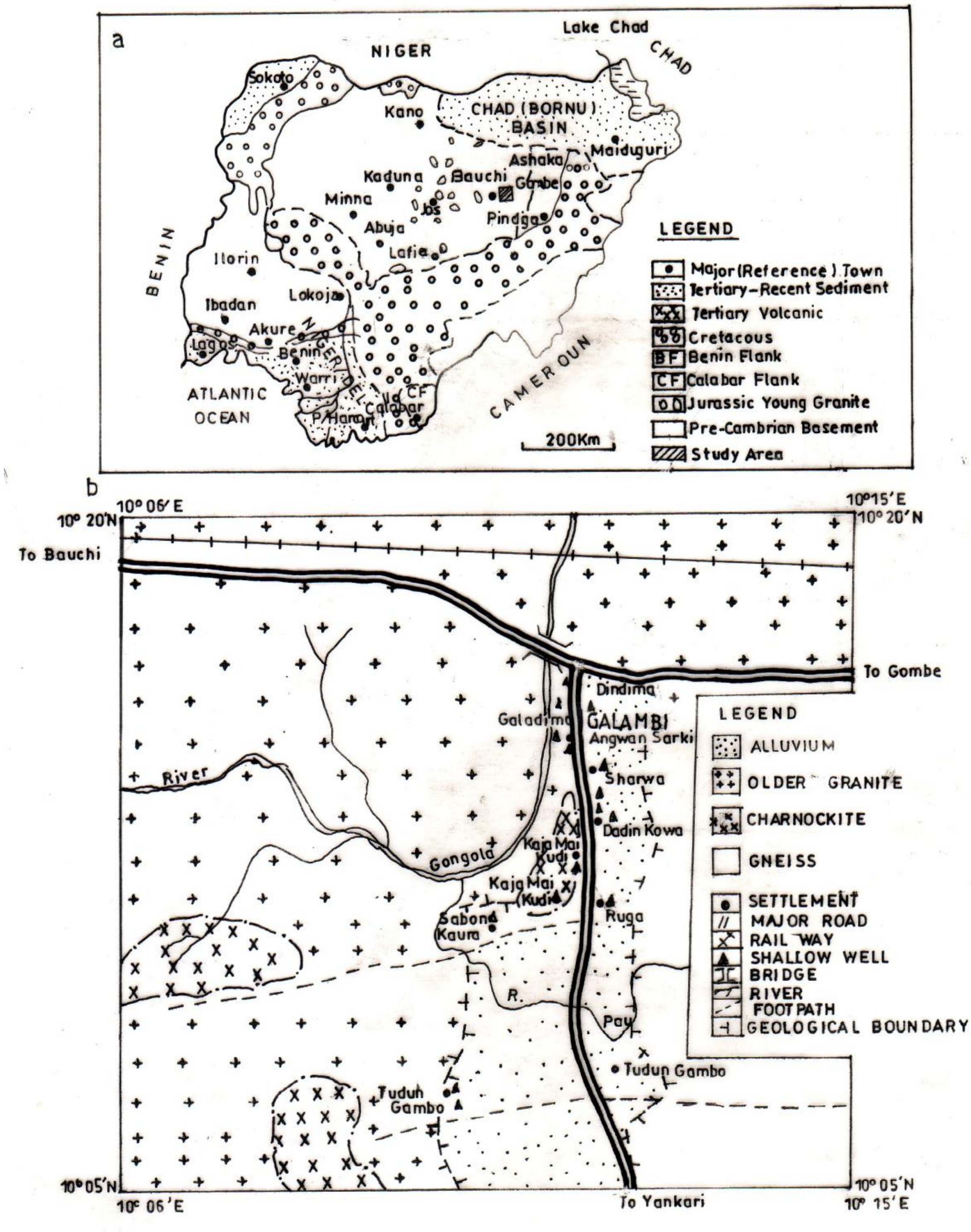

Fig 1: Map of the Study Area: a) sketch geological map of Nigeria showing Bauchi area of study. b) geological map of Galambi area showing the study well locations.

gneisses forming the minor rock types (Fig 2). A fresh specimen of the charnockites observed in the field appears deep-green in colour and pink to light brown when it is weathered. The geology of Bauchi area and environs has been well documented by a good number of authors[4-14] . Charnockitic rocks are the dominant rock type in the area and are characterized by their dark greenish to greenish-grey appearance. Olarewaju[13] noted that the cause of this diagnostic appearance lies principally in the feldspars which are dark greenish and moderately translucent, contrasting with the pale, whitish to reddish, opaque, chalky appearance typical of the feldspars in the granitic and amphibolite facies (metamorphic) rocks. Post-crystallization deformation texture is shown by the alignment of the large microperthitic K-feldspars observed in some outcrops of the charnockites in the area.

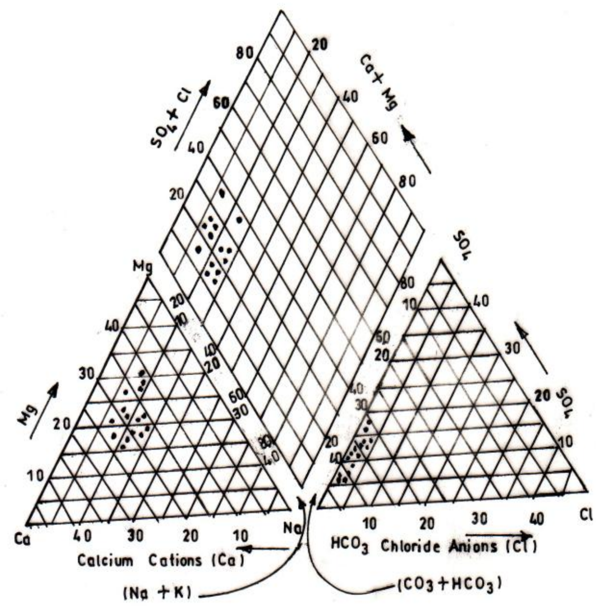

Fig. 2: Plots of Piper trilinear diagram for ground water in the Galambi area. (After Piper, 1944)

EXPERIMENTAL

Sampling

Fifteen water samples from different shallow wells within the area were collected in clean, white plastic containers and acidified with concentrated nitric acid to minimize contamination from walls of the container and decaying effect of any organic content. For each sample; effort was always made to collect water from a depth similar to that at which the inhabitants fetch for their domestic purposes. All the samples were subjected to analysis in the laboratory within 24 hours.

Analyses

The measurements of pH, total dissolved solids (TDS), temperature and electrical conductivity (EC) were carried out at respective well sites immediately the sample was drawn from the wells. Colour and odor were determined by direct observations of the water samples. Chemical parameters such as Na^+, K^+, Ca^{2+}, Mg^{2+} Fe^{2+}, Pb^{2+} and Cu^{2+} were analyzed using an atomic absorption spectrophotometer (AAS), Perkin Elmer model 290B, at the Nigerian Mining Corporation (NMC), Jos, whereas, Cl^- , SO_4^{2-}, NO_3^{2-}, CaO_3^{2-}, PO_4^{2-} , and HCO_3^{2-} were evaluated using titrimetric, colorimetric and gravimetric methods in the Department of Chemistry Laboratory, Federal University of Technology (FUT), Minna. Total hardness (Ht) and TDS were determined using titration method. All the analyses were carried out in strict accordance with standard procedures[15]. Ht for each of the samples was determined from the results of the hydrochemical analysis. Ht is usually expressed as the equivalent of calcium carbonate. Thus,

$$Ht\ (CaCO_3) = 2.5\ [Ca^{2+}] + 4.1\ [Mg^{2+}]$$

where 2.5, 4.1 are the ratios $CaCO_3$/Ca, $CaCO_3$/Mg, in equivalent weights, and Ht, Ca and Mg measured in mg/l.

pH Measurements

In this study, a portable pH meter was used and the standardization done with buffer solutions prepared at room temperature. The pH of water samples was measured directly in the field.

Electrical Conductivity

In this study, conductivity meter, Philips model 5013, was used for direct measurements in the water samples.

RESULTS AND DISCUSSION

The physico-chemical constituents of the groundwater obtained from the study area are presented in Table 1. The pH measurements indicate the acidity or alkalinity of a solution / water. It is a direct measurement of hydrogen or hydroxyl ion activity. It can be measured by two main methods; (i) indicator paper and (ii) electronic probe. These methods can be used for water or soil pH. The pH of all the samples averagely indicates a range of 5.70 - 7.80; this is within the permissible level[16] for drinking water. However, it implies a moderately acidic to slightly alkaline water. These pH values also compare favourably with those obtained for ground water within other Basement Complex localities in Nigeria [17].

Conductivity

Conductivity is the measure of the current carried by electrolytes ionic concentration in solution. An average electrical conductivity value in the water samples is 200µS/cm, which falls within the permissible level[16]. This also correlates with moderately high concentrations of the measured cations (Na^+, Ca^{2+}, Mg^{2+}, K^+) and the anions (Cl^-, SO_4^{2-}, NO_3^{2-} PO_4^{2-}, CO_3^{2-} and HCO_3^-) in the water.

Table 1: Results of Chemical Characteristics of shallow-wells Water in the study area.

Sample	Ca^{2+} (mg/l)	Mg^{+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Fe^{2+} (mg/l)	HCO_3^{2-} (mg/l)	Cl^{-} (mg/l)	SO_4^{2-} (mg/l)	NO_3^{2-} (mg/l)	PO_4^{2-} (mg/l)	Pb^{2+} (mg/l)	Cu^{2+} (mg/l)	CO_3^{2-} (mg/l)	PH	TEMP (°C)	EC (µS/cm) x 100	TDS (mg/l)	Total Hardness(mg/l)
Sw 1	22.00	17.00	16.00	6.52	1.13	61.20	0.06	16.00	2.50	7.00	1.12	1.89	1.43	5.83	28	1.5	350	124.2
Sw 2	18.00	31.00	13.00	5.60	2.26	57.20	1.08	7.40	3.90	11.40	4.18	3.12	1.69	6.00	28	3.9	300	172.1
Sw 3	27.00	29.00	12.00	4.50	1.81	31.20	0.08	10.20	6.60	15.00	1.85	1.16	1.21	5.93	28	0.8	230	186.4
Sw4	34.00	20.00	1.80	17.50	1.29	27.20	0.70	13.00	5.60	5.60	1.88	1.87	1.74	5.75	30	0.5	220	167.0
Sw5	31.00	34.00	11.10	15.25	1.60	47.20	0.63	13.40	5.00	7.40	1.02	1.33	1.85	5.70	28	0.3	210	216.9
Sw6	29.00	16.00	11.00	11.00	1.37	65.20	0.01	10.40	6.60	10.80	0.65	1.24	2.17	5.75	27	1.0	240	138.2
Sw7	45.00	35.00	21.50	23.50	3.88	113.2	2.20	28.20	10.40	22.40	3.81	3.33	3.28	6.60	28	8.9	350	250.0
Sw 8	30.00	21.00	15.50	9.75	1.26	35.20	0.73	20.00	4.60	10.20	1.10	1.25	2.01	7.70	27	2.5	270	161.1
Sw 9	40.00	19.00	16.00	9.25	2.25	65.20	0.80	7.20	3.90	7.60	0.99	1.18	0.90	7.35	28	4.8	320	177.9
Sw10	43.00	21.00	9.50	13.50	1.19	59.20	1.25	11.40	5.20	5.80	1.13	2.34	1.64	6.20	27	11.0	360	193.6
Sw11	46.00	32.00	17.00	12.80	2.08	51.20	1.33	15.00	5.00	6.40	0.87	1.62	1.16	6.30	27	24.0	380	246.2
Sw12	42.00	20.00	15.50	12.50	1.43	81.20	1.12	13.20	6.20	10.00	0.95	1.50	1.80	7.80	28	2.5	280	187.0
Sw13	26.00	18.00	17.50	11.25	1.22	43.20	1.22	15.20	4.80	9.00	1.21	1.48	1.53	7.25	28	4.5	310	138.8
Sw14	33.00	24.00	9.00	8.50	1.11	73.20	1.36	18.00	2.30	6.20	1.37	1.22	1.66	7.60	27	3.0	301	180.9
Sw15	21.00	30.00	13.00	8.00	1.20	43.20	1.29	16.20	7.40	11.40	1.28	1.31	1.96	6.60	28	6.8	330	175.5

Total hardness

Total hardness ranges between 124.7 - 256.0 mg/l (Table 2) and therefore falls below the WHO[16] maximum permissible level (500 mg/l) for drinking water. Furthermore, based on Hem's[18] water hardness classification, 53% of the water is hard whereas the remaining 47% is very hard (Table 3). Consequently, the water hardness in the study area could be described as a range from hard to very hard water.

Temperature

An average temperature value of 27°C was obtained for the study area.

Iron

Iron (Fe^{3+}) concentration values obtained from the study ranged between 1.11 and 3.88 mg/l. These values are higher than WHO maximum permissible level of 1.0 mg/l. Iron poses aesthetic problems rather than health problems. Such aesthetic concerns could be undesirable taste or/and staining of laundry and plumbing materials. However, the results of the study fall almost within the range of 1.0 – 2.0 mg/l of iron as observed in most ground water within areas of the Basement Complex of Nigeria[19]. Ezeigbo[20] observed that probably the most characteristic parameter of ground water in Nigeria is the relatively high iron content.

Copper

Average Cu^{2+} concentration in the studied water is in the range of 1.16–3.33 mg/l. The permissible limit by WHO[16] is 0.05–1.0 mg/l for potable water. Considerable Cu^{2+} concentration in humans is known essentially for aiding proper functioning of many important body enzymes. However, excessive Cu^{2+} levels in drinking water are risky to humans as it may cause genetic disorders, acute gastro-intestinal problems, anemia, and bone demineralization in children.

Lead

Lead (Pb^{2+}) concentration in the groundwater of the study area ranged between 0.65 and 3.81 mg/l. These concentrations are quite higher than WHO[16] maximum permissible limit for drinking water, hence it might pose a serious concern to the human population in the area. WHO[16] noted that high levels of lead in drinking water is generally toxic to both the central and peripheral nervous systems of humans thereby causing neurological and behavioral disabilities which could cause many other health related complications.

Table 2: Physio-chemical quality of ground water samples of the study area compared with WHO (1993) standards for drinking water.

Physio-chemical parameter	**Range of values obtained from study area**	**WHO (1993) Standards**	
		Recommended Level	**Maximum Permissible Level**
Colour	Colour Less	25	-
Odor	none	3, inoffensive	-
Temperature	27-30	-	-
pH	5.7-7.8	6.5-8.5	6.5-9
Conductivity (ms/cm)	0.3-24.0	-	250
TDS (Mg/l)	380-210	500	1500
Total iron (mg/l)	1.11-3.88	0.03	1.0
Pb2+ (mg/l)	0.65-3.81	0.05	0.1
Cu^{2+} (mg/l)	1.16-3.33	1.0	1.5
Ca^{2+} (mg/l)	18.0-46.0	75	200
Mg^{2+} (mg/l)	16.0-35.0	50	150
Na^{+} (mg/l)	1.8-21.5	-	-
K^{+} (mg/l)	4.5-23.5	-	200
SO_4^{2-} (mg/l)	7.2-28.2	200	400
NO_3^{-} (mg/l)	2.3-10.4	-	50
CO_3^{2-} (mg/l)	0.9-3.28	67	110
PO_4^{2-} (mg/l)	5.6-22.4	-	-
HCO_3^{-} (mg/l)	27.2-113.2	-	500
Cl^{-} (mg/l)	0.01-2.2	200	500
Total Hardness(mg/l)	124.7-256.0	100	500

Table 3: Distribution of the Samples into categories of Hardness. (After Hem[18], 1970)

Hardness($Ca+MgCO_3$) (mg/l)	**No. of Samples in range**	**Water classification**	**(%) Samples**
0 -60	-------	Soft water	-------
61-120	-------	Moderately hard	-------
121- 180	8	Hard	53
>180	7	Very hard	47

Alkaline earth metals

Among the known alkaline/alkaline earth metals, only Na^{2+}, Mg^{2+}, Ca^{2+} and K^{+} concentrations in groundwater of the area were measured. A range of concentrations of Na^{2+} (1.8 – 21.5 mg/l), Ca^{2+} (18.0 – 46.0 mg/l), Mg^{2+} (16.0 – 35.0 mg/l) and K^{+} (4.5 – 23.5 mg/l) are obtained for water in the area. WHO[16] has recommended maximum concentrations of 50 mg/l for Mg^{2+}, 75 mg/1 for Ca^{2+} and 200 mg/l for K^{+} in potable water. The low concentrations of these cations in the water samples could be attributed to the low levels of these elements in the rock types within the study area. The results generally indicate a potable quality of water in the study area. The anions evaluated in the groundwater samples of the area are $C1^{-}$, SO_4^{2-}, NO_3^{2-}, PO_4^{2-}, HCO_3 and CO_3^{2-} . Values obtained for the area indicate the levels Cl^{-} (0.01–22 mg/l); SO_4^{2-} (7.2–28.2 mg/l); NO_3^{-} (2.3–10.4 mg/l); PO_4^{2-} (5.6 – 22.4 mg/l); HCO_3^{-} (22.2–113.2 mg/l) and CO_3^{2-} (0.9–3.28 mg/l) respectively; WHO guidelines provide the acceptable limits $C1^{-}$

(500 mg/l); SO_4^{2-}(400 mg/l); NO_3^- (50 mg/l); HCO_3^- (500 mg/l) and CO_3^{2-} (110 mg/l) for these anions.

Characterization of Groundwater Types in the area

Plots of the physico-chemical parameters of the studied groundwater on the Piper[21] trilinear diagram (Fig. 2), based on Furtak and Langguth[22] classification schemes identify two water types, namely

(i). Earth alkaline water type with higher alkaline proportion (Ca-Mg-(Na)) and predominantly HCO_3^- water. This is an indication of cations exchange water, which shows that there is more HCO_3^- than available alkaline earth metal ions Ca^{2+} and Mg^{2+} in equivalent concentrations[24]. This water type constitutes about sixty percent (60%) in the study area.

(ii). Normal earth alkaline water type (Ca-Mg) and predominantly HCO_3^- water. The chemistry of this water type is mostly controlled by precipitation, dissociation of carbonic acid and to a lesser extent by weathering, dissolution and base exchange. Forty percent (40%) of the groundwater belongs to this water type. According to Amadi[17], this water type is typical of the Nigerian Basement Complex terrains with limited mixing, perhaps reflecting a primary stage of evolution of its groundwater system.

CONCLUSION

The chemistry of the basement rock types in Galambi and environs has significant effects on the groundwater quality most especially the shallow Basement aquifers in the weathered horizon, which serve as the major source of groundwater supply in the study area. Fifteen groundwater samples from Galambi and environs studied show that the water is odorless, colourless, and hard to very hard, moderately alkaline to slightly acidic; with the following two water types: Ca-Mg-(Na)-HCO_3 and Ca-Mg-HCO_3. More importantly, the groundwater also reveals higher concentrations of total iron, copper and lead, which are of higher values than the WHO permissible limits, thus raising concerns about its potability. From this study, the results obtained have therefore provided useful information in understanding the ground water quality and characteristics in the area. Hence the groundwater in the study area could not be said to be quite potable. Consequently, it is suggested and strongly recommended that deep boreholes tapping the fractured basement aquifers rather than the weathered horizons should be exploited as sources of drinking water in this area after quality analysis. Equally, relevant treatment measures should be adopted to reduce or mitigate the negative implications of these trace elements concentrations in the shallow wells in the area.

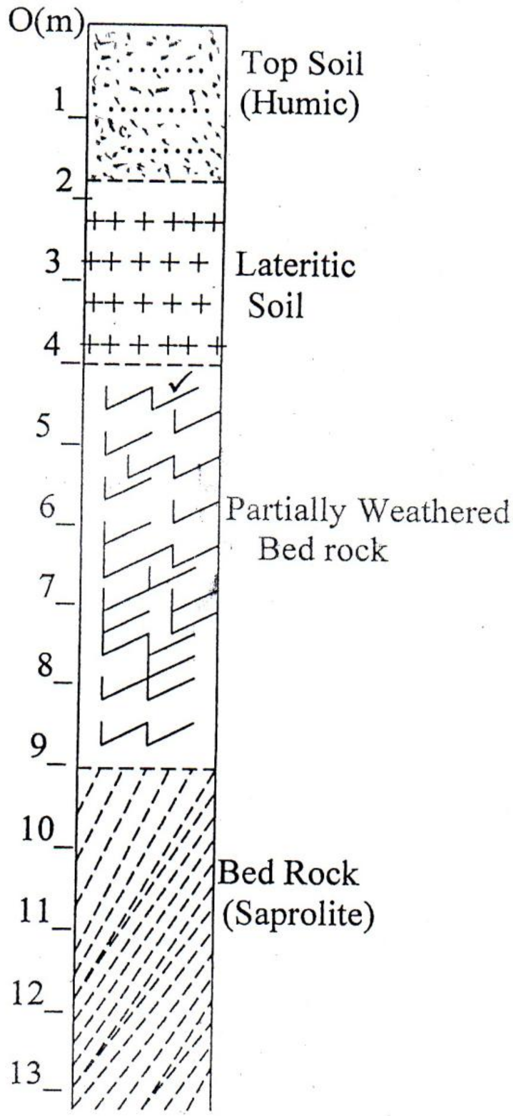

Fig. 3: Cross- section of typical borehole profile at Didima in Galambi area. Groundwater is tapped mainly from the weathered basement (saprolites) in the area.

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