Volume 5 No.9, September 2015 ISSN 2224-3577
International Journal of Science and Technology

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Groundwater Quality Assessment in Akoko South East Area of Ondo State, Nigeria

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ABSTRACT

Water samples from 11 wells representing one shallow well each in the eleven electoral wards of Akoko South East Local Government Area (AKSE) of Ondo State, Nigeria were collected to assess the quality of groundwater in the area. During sample collection, well physical conditions such as diameter, presence of lining, apron and cap/cover, and proximity to source of pollution (e.g. septic tank), were observed. The samples were collected the same day and thereafter taken to the laboratory for physico-chemical and bacteriological analyses. The results showed that many of the wells were neither properly lined nor provided with cover/cap thus exposing them to both runoff and base-flow contamination from nearby pollution sources. Physico-chemical parameters of the samples were within acceptable limits for drinking purposes, nevertheless, the levels of turbidity, EC and TDS, hardness and Fe+ in some samples in the area were high. However, the presence of coliforms in all the samples generally suggested microbial contamination which rendered their consumption without treatment unsafe. Thus, the paper recommended amongst others, strict adherence to standard methods of well construction, good sanitary measures, treatment of water before consumption and good physical planning in the local government area.

Keywords: *Groundwater quality, shallow well, contamination, coliform, treatment*

1. INTRODUCTION

Groundwater from shallow and deep (borehole) wells has become the major source of potable water in most semi-urban and rural areas of Nigeria. This is especially so because, aside its assumed low susceptibility to pollution [1-4], the method is a readily available and reliable but cheap source of domestic water supply. For instance, Eduvie [5] stated that groundwater is usually preferred to surface water because it is available in most areas, potable without treatment and of low cost technologies. As a result of the foregoing, governments and individuals in Nigeria have explored groundwater in forms of shallow and deep wells for the supply of potable water. The use of the method became more pronounced especially during the last fifteen years in a way to meet the Millennium Development Goals (MDGs) of potable water supply target in the [6]. However, there is spatial variation of groundwater quality based on the type of geological formation in an area, exposure to pollution sources and method of abstraction amongst other factors [7, 8]. Consequently, there is the need for the assessment of the quality of groundwater at local scales in the country for safety purpose.

The quality of groundwater is a measure of its wholesomeness. This means that such water should not contain any physico-chemical and microbial substances in amounts that are harmful when consumed by man. Thus any source of water for human consumption must conform to the quality control guidelines set by both international and national agencies such as the World Health Organization (WHO) and the Nigerian Industrial Standard (NIS), respectively. This is necessary to avoid the negative health implications of the consumption of such water [9-11]. Studies have shown that many health challenges such as mortality, morbidity and poverty are consequences of consumption of water from unwholesome sources [12-14]. In addition, about 80% of the diseases causing deaths in developing countries are contracted through the consumption of polluted water [15]. Naturally, groundwater is usually of high quality, but as a result of urbanization, indiscriminate siting of septic tanks and pit latrines, refuse dumps and mining activities, the quality of many ground water resources has been degraded [16]. For this reason, there is the need to continuously assess the quality of water from this source, especially in areas where people depend solely on it.

The supply of potable water in Akoko South East Local Government Area (AKSE) is majorly from groundwater. This is because, none of the six towns in the area is at present connected to pipe borne water supply. Therefore, the people of the area have been relying on either boreholes and/ shallow wells for their domestic water supply. However, a recent study [6] has shown that over 50% of the boreholes are currently not functioning in Akoko Area, thereby increasing the use of shallow well, which is more affordable, as a veritable source of domestic water supply. Although there are few streams and rivers in the area, they hardly last for a few weeks during the dry season owing to the fact that the area receives less rain

Volume 5 No.9, September 2015 ISSN 2224-3577
International Journal of Science and Technology

http://www.ejournalofsciences.org

during the raining season. However, consumption of water from the shallow wells is usually without any prior treatment in the area. This is in spite of the prevalence of the use of open refuse dump and toilet system in virtually all the towns. In addition, many of the shallow wells were sited without due consideration to the location of pollution sources such as septic tanks within the neighbourhood. All these suggest that groundwater resource in the area may be highly susceptible to leachate contamination and becomes polluted. Although many studies have been conducted elsewhere to assess the quality of groundwater in the state and beyond [e.g. 17-22], none has been carried out in the present study area. Hence, the need for thorough appraisal of groundwater quality in the local government area becomes imperative. Therefore, the aim of this paper was to carry out an assessment of groundwater quality in Akoko South East Local Government Area of Ondo State, Nigeria.

2. MATERIALS AND METHODS

2.1 The Study Area

The study area, AKSE (Figure 1), is located North-East of Ondo State and Southwestern Nigeria. The area falls within Latitude $7^{0}25'$ N and Longitude $5^{0}54'$ E of the equator. The headquarters of the local government is in Isua with other five major towns- Ipe, Ifira, Epinmi, Ipesi and Sosan. With a population figure of 82,443 [23], it covers an area of about 530 km² occupying a generally undulating terrain with an altitude ranging between 270 m and 2750 m above sea level [24]. The climate is tropical with two distinct seasons- the dry and wet seasons. The wet season begins in April and ends in October or occasionally early November while the dry season is usually between November and April. As a result of its location in the guinea savannah transition zone, the local government like most other parts of Akoko receives less rainfall in comparison with other parts of the state with an annual average ranging between 1480 mm and 2500 mm, relative humidity of 60-85 % and temperature of between 280 and 320 [25]. The vegetation of the area is made up of both the rainforest and guinea savannah type characterized by light forests, shrubs and scattered cultivation with different plants and trees which may reach a height of 5 m and even more. The people of the local government area are predominantly farmers, specializing in cassava, yam and cereal production, while a few of them are artisans.

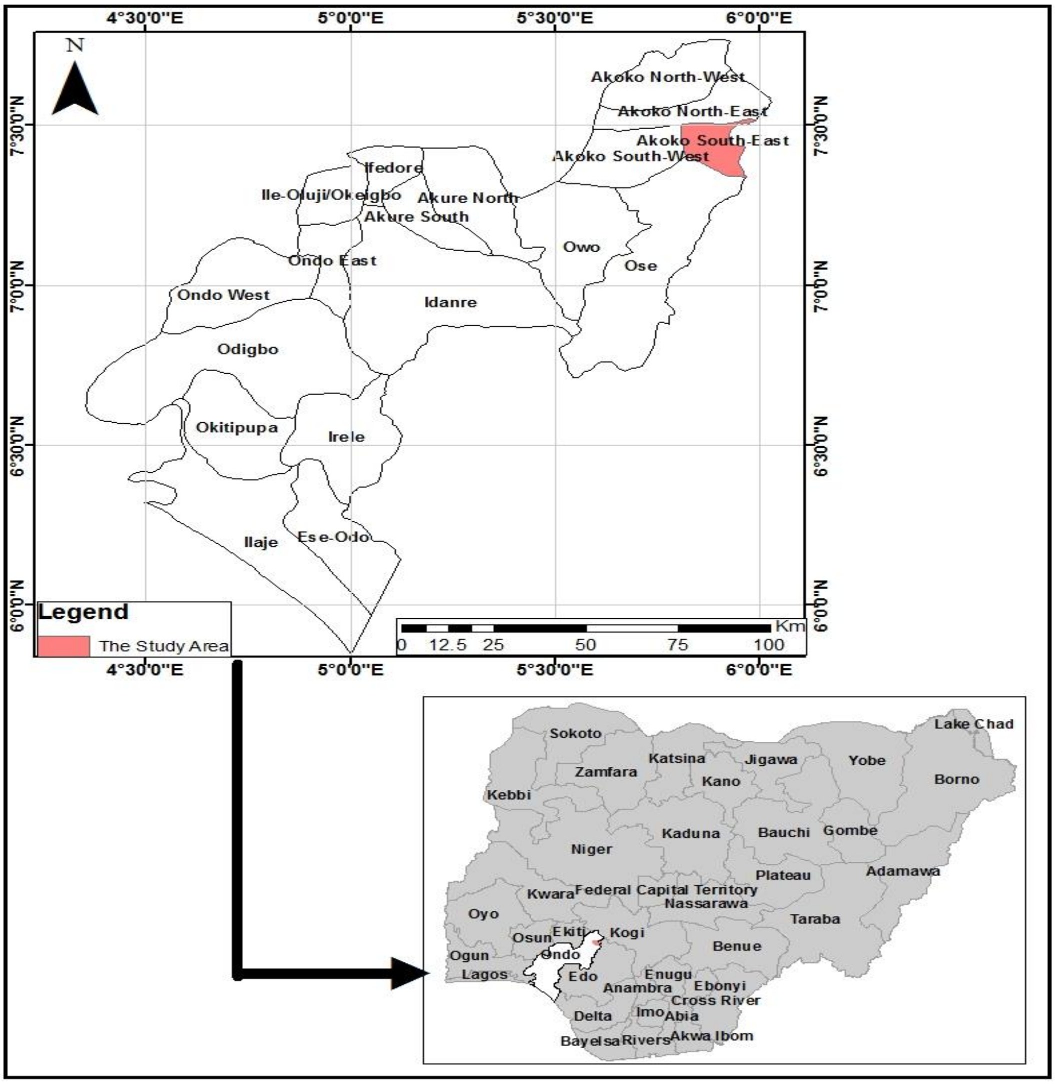

Figure 1: Map of Ondo State of Nigeria showing the location of the study area

2.1. Methods

In this study, one shallow well each was selected in each of the eleven (11) electoral wards in the local government area upon which groundwater quality assessment was based. Water samples were collected from the selected shallow wells in plastic bottles sterilized to prevent their pre-occupation by microorganisms before sample collection. A newly purchased and also sterilized plastic fetcher was used to draw water from the shallow wells, immediately poured into the plastic bottles, labelled and tightly covered with the lid. Physical conditions of the shallow wells such as depth, diameter, presence of lining, apron and cap/cover, and proximity to source of pollution (e.g. septic tank), were also observed. Where feasible, efforts were made to determine the age of the wells through oral interviews of the landlords of the houses where the well were located. All water samples were collected the same day and kept in a refrigerator for about 24 hours before they were taken to the laboratory for physico-chemical and bacteriological analyses.

3. RESULTS AND DISCUSSION

3.1 Physical Conditions of Wells

It was generally observed that most of the shallow wells were not properly lined (Table 1). For instance, out of the 11 wells, only two (2) representing about 18.2% had concrete lining, four (4) signifying 36.4% had their wall plastered while the remaining five (5), about 45.4% had their walls neither lined nor plastered. Water Aid [26] stated that wells without adequate lining have high tendency to silting-up and collapse. In addition, [27] observed that wells without adequate lining were more prone to contamination from underground pollution such as septic tanks, pit toilets and polluted streams/river as a result of base-flows. This suggests that over 80% of the wells are highly susceptible to underground pollution depending on their proximity to pollution sources. Similarly, it was also observed that most of the wells were without headwall/apron and good cover/cap; while the two wells which were lined had concrete apron and cap, two out of the four plastered wells had brick apron with steel caps while the other two in this group had apron but, were covered with iron sheets/planks. All the five wells without lining had neither apron nor good cap; at best they were either covered with planks or iron sheets. This condition also suggests that at least 50% of the wells were opened to surface contaminants due to water infiltration from polluted land surfaces such as dumpsites and fuel spillage.

Table 1: Physical conditions of the selected shallow wells in the study area

Sample	Location	Type of lining	Apron/Head well	Well cap/cover	Proximity to pollution source	Diameter (m)	Depth (m)	Age (yrs)
W1	Sabo, Epinmi	none	none	planks/iron sheets	polluted stream	0.91	4.57	21
W2	Iseu. Epinmi	plastered	bricks	steel	none	0.76	3.65	25
W3	Isowo, Ifira	none	none	planks/iron sheets	none	0.91	4.57	18
W4	St. James, Ipe	concrete	concrete	concrete/steel	none	0.76	4.57	16
W5	Uba, Ipe	plastered	bricks	planks/iron sheets	none	0.76	3.65	21
W6	Ukuba, Ipesi	none	none	planks/iron sheets	refuse dump	0.91	3.96	22
W7	Eben. Pry Schl., Isua	concrete	concrete	concrete/steel	none	0.76	3.65	23
W8	Irobo, Isua	plastered	bricks	steel	none	0.76	4.57	25
W9	Izo, Isua	none	none	planks/iron sheets	refuse dump	0.91	3.65	23
W10	Eti-ose, Isua	plastered	bricks	planks/iron sheets	polluted river/refuse dump	0.76	3.04	25
W11	St. Andrew Schl., Sosan	none	none	planks	refuse dump	0.91	3.65	20

3.2. Physico-chemical Analysis of Shallow Well Water

The results of the physico-chemical analysis (Table 2) of groundwater quality showed that all the parameters tested fall within the permissible set limits [28, 29]. The pH values of the samples are generally within the permissible limit of 6.5-8.5 apart from wells W1, W8 and W11 which were slightly alkaline. The slight acidic nature of samples W3 and W5 could be attributed to their exposure to surface runoff (wells not being properly covered) from the spraying of herbicides which has become a common practice in the area recently. However, alkalinity in water samples has the potentials to alter the ability of other pollutants to cause toxicity [30]. High pH values may also affect the solubility and bioavailability of other substances (heavy metals) in water [31]. In line with the pH values, the well water samples were also moderately alkaline (values ranges between 45 mg/l and 85 mg/l) and capable of buffering any sudden change in pH. Nevertheless, the values are within the permissible limits of both WHO and NIS. Although there is currently no health implication for poor alkalinity in water, moderate alkalinity encourages the growth of aquatic life.

In terms of turbidity, the samples are also within the permissible limits, with only samples W1, W6 and W11 being slightly turbid. This situation may have been caused by the deposition of clay particles in the wells. Turbidity does not have direct health implication, but there may be other consequences [28] such as interference with water treatment, rejection by the consumers and staining of clothes and household fittings. Electrical conductivity (EC) is related to alkalinity and therefore followed the same pattern amongst the samples. Although they are relatively high in W1 and W3, the values are within the limits set by WHO and NIS indicating low level of dissolved solids [32].

Total dissolved solids (TSS) followed the same pattern of EC and are below 1000 mg/l and 500 mg/l set by WHO and NIS, respectively. However, their relatively high values in W1, W7 and W11 may be due to exposure to surface runoff and environmental pollution. The total suspended solids (TSS) of the well samples ranged between 20 and 115 mg/l. There are no limits set by both WHO and NIS for this parameter, yet high TSS can lead to high total solids in water. Consumption of such water without treatment could be dangerous to human health as high TSS which has the tendency to shield harmful microorganisms may be caused by the influx of run-off into wells [30].

Total hardness of water was higher in W1, W2, W6 and W6 than the NIS limits, but lower than WHO standard. Water hardness is usually as a result of dissolution of minerals containing multivalent metal ions in water. Studies [e.g. [33] have shown that regular consumption of hard water can have a lowering effect on the rate of cardiovascular disease. Nevertheless, the major negative effects of the use of hard water include wastage of soap, gray staining of washed clothes and scaling of pipes. Except in three instances where dissolved oxygen is less than 5 mg/l, indicating a slight anaerobic condition, other samples conformed to the required limits. This may have been caused by the presence of certain microorganisms in the samples which might have used the oxygen molecules for aerobic respiration. However, higher values (≥ 0.5) of dissolved oxygen in some samples showed their suitability for irrigation and other agricultural purposes [34].

The primary source of sodium in ground water is from the release of soluble products during the weathering of plagioclase feldspars [35]. However, the concentrations of sodium ion in the samples are relatively low when compared to the WHO and NIS limits of 200 mg/l. Excessive consumption of sodium in drinking water may lead to gastro-vascular problems in infants and high blood pressure in adults [36]. Both magnesium and calcium ions concentrations are within the permissible limits for all samples. No specific adverse health effects have been attributed to the consumption of the two ions in drinking water, but their presence in water is objectionable given their ability to cause hardness of water. However, the slightly high values of the two parameters in W1 and W11 may have been as a result of the type of rock found in the study area.

For sulphate, it is a non-toxic anion that is present in natural water, yet health challenges like catharsis, dehydration and gastrointestinal irritation have been linked with it when concentration is above 500 mg/l [37]. In the present study, the concentrations of the ion obtained are generally lower than set limits except in W1 and W11 where the values are higher that the NIS limit. The sources of sulphate in underground water may be rocks, geological formation and others [32]; in addition, inflow of runoff from organic fuel polluted surfaces within the vicinity may have caused the high sulphate concentration in the two samples. The concentrations of nitrate ion in the wells also fall within the permissible level, but relatively high in few instances. High concentration of nitrates in some of the wells may have been caused by runoff from agricultural fields and refuse dumps, leaking septic tanks and animal wastes. Consumption of water polluted with nitrates ion can lead to such health problems as methemoglobinemia in infants less than six months, diarrhea and respiratory diseases [38].

All the samples showed relatively low chloride ions residual, except in W1, W2, W10 and W11 which are relatively high but still permissible. High chloride in surface and groundwater may arise from both natural and anthropogenic sources such as run-off containing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds [39]. Although chloride seems not to pose any health hazard, however, given that chloride ions are non-cumulative toxins [40], continuous consumption of an excessive amount of the ion can lead to some health hazard [39]. Excess chloride in water impacts bad tastes and may indicate contamination from urine and sewage. Lastly, apart from W1, W8 and W11, the water samples in the area were characterised by low iron concentrations and fell within the WHO and NIS maximum acceptable limits for drinking and domestic water. Iron is naturally found widely in soils and is a constituent of many ground waters, however, excess iron residual in water may cause taste, odour problem

Volume 5 No.9, September 2015 ISSN 2224-3577
International Journal of Science and Technology

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and reddish colouration of water thereby leading to staining of pipes, toilet and kitchen facilities and clothes.

Statistical analysis of the physico-chemical parameters (Table 3) also showed that the range of all parameters conformed to the limits set by both WHO and NIS. Nevertheless, some of the parameters (e.g. EC, TSS, hardness and chloride) showed high deviation from the mean indicating that there are clear differences in the level of pollution amongst the samples. In addition, the pattern of the coefficient of variation (CV) also indicated that all the examined parameters with the exception of TSS, hardness and chloride are homogenous. This tends to suggest that apart from the three parameters, others could be safely monitored through a continuous testing of any of the wells used in this study.

Table 2: Physico-chemical and bacteriological parameters of the shallow wells in the study area

Parameters	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	WHO	NIS
pH	8.94	6.81	6.63	7.14	6.65	6.83	6.91	8.72	6.81	6.72	8.61	6.5-8.5	6.5-8.5
Alkalinity (mg/l)	85	55	60	45	70	83	47	72	64	75	82	80-120	100
Turbidity (NTU)	4.53	3.22	2.20	2.13	2.10	4.14	2.10	3.82	2.10	3.10	4.10	0-5	0-5
Electrical Conductivity (EC) (µS/cm)	335	275	346	214	155	288	218	269	212	246	285	400	1000
Total Dissolved Solids (TDS) (mg/l)	350	274	172	152	214	318	121	220	151	235	326	1000	500
Total Suspended Solid (TSS) (mg/l)	115	60	45	38	20	86	35	65	25	35	82	-	-
Hardness (mg/l)	255.5	168.9	105.2	79.9	65.8	240.5	72.4	93.5	70.2	116.4	238.4	500	150
Dissolved Oxygen (O2-) (mg/l)	4.24	5.31	5.71	5.41	7.80	4.41	5.91	5.10	6.42	7.5	4.57	-	-
Sodium (Na^+) (mg/l)	123.3	76.2	40.4	35.4	28.3	77.5	28.3	82.4	29.4	81.5	103.4	200	200
Magnesium (Mg^{2+}) (mg/l)	0.25	0.14	0.18	0.11	0.16	0.20	0.12	0.21	0.14	0.16	0.28	200	0.2
Calcium (Ca^{2+}) (mg/l)	110.4	28.4	63.5	62.5	54.2	25.4	70.2	90.6	80.5	115.5	120.2	75-200	300
Sulphate (SO_4^{2-}) (mg/l)	140.3	85.2	42.5	35.0	48.5	85.5	58.2	69.3	62.5	78.5	125.5	250	100
Nitrate (NO_3^-) (mg/l)	30.5	25.6	23.2	24.1	13.2	44.1	27.1	25.0	21.1	32.2	40.8	50	50
Chloride (mg/l)	130.1	120.0	40.5	62.5	41.0	30.5	28.0	40.0	80.5	162.0	118.0	250	250
Iron (Fe^{2+}) (mg/l)	0.23	0.10	0.18	0.10	0.20	0.20	0.15	0.25	0.18	0.13	0.24	0.3	0.2
Feacal Coliform (cfu/100ml)	20	05	13	06	17	13	05	04	18	22	19	0	0
Total Coliform (cfu/100ml)	28	12	24	12	26	25	13	10	28	30	32	0	0

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Table 3: Descriptive statistics of the shallow well sample parameters

Parameter	Range	Mean	SD	CV (%)
pH	6.63 - 8.94	7.34	0.88	11.96
Alkalinity (mg/l)	85 - 45	67.09	13.45	20.04
Turbidity (NTU)	4.53 - 2.10	3.05	0.92	30.29
Electrical Conductivity (µS/cm)	346 - 155	258.45	54.03	20.91
Total Dissolved Solids (mg/l)	350 - 121	230.27	74.62	32.40
Total Suspended Solid (mg/l)	115 - 25	55.09	28.17	51.13
Dissolved Oxygen (mg/l)	7.80 - 4.41	5.67	1.12	19.80
Hardness (mg/l)	255.5 - 65.8	136.97	71.57	52.25
Sodium (mg/l)	123.3 - 28.3	64.19	31.86	49.63
Magnesium (mg/l)	0.28 - 0.11	0.27	0.30	28.77
Calcium (mg/l)	120.2 - 25.4	74.67	31.02	41.54
Sulphate (mg/l)	140.3 - 35.0	75.55	31.43	41.61
Nitrate (mg/l)	40.5 - 13.2	27.90	8.35	29.94
Chloride (mg/l)	162.0 - 28.0	77.55	45.07	58.12
Iron (mg/l)	0.25 - 0.10	0.18	0.05	29.21

3.3 Bacteriological Analysis of Shallow Well Water

The results of the bacteriological analysis showed that all the wells were contaminated with both faecal coliform and total coliform (Table 2). The general standard is that water for domestic uses should not contain any of the substances as their presence suggests possible pollution by either human or animal wastes. This is because, the presence of coliform in water indicates the possibility of the presence of disease organisms [18]. Adetunde et al. [17] observed that locating shallow wells at closed proximity to septic tanks, refuse dumps and the defecation of domestic animals around the vicinity of such wells could lead to feacal pollution of water from such sources. Given the fact that free range system, open refuse dump and toilet system are common practice in the entire towns in the study area, the level of faecal contamination of the wells may be explicable. Similarly, poor town planning in the area may have also contributed to a situation where households construct wells close to the septic tank of their neighbours. However, studies have shown that many groundwater sources in the rural areas of Nigeria are commonly contaminated with coliform bacteria [41, 17]. Nevertheless, consumption of such water can lead to some water-borne diseases such as diarrhea, typhoid and hepatitis.

5. CONCLUSION

The results of this study have shown that the quality of the majority of the shallow wells water in AKSE are generally good for domestic uses, however, with minimum treatment. Most of the physicochemical parameters of the samples were within acceptable limits for drinking purposes. Nonetheless, the high levels of turbidity, EC and TDS, hardness and Fe+ in some samples in the area, though within the permissible limits, called for concern. Thus, these parameters should be continuously monitored because of their possible threats to health at higher concentrations. Nevertheless, the presence of coliforms in all the samples generally called to question their suitability for domestic uses. Although the presence of coliform in a water sample may not necessarily pose any danger of diseases infestation when consumed, it is definitely a sign of poor sanitary system in the environment where the wells are constructed. To this end, we suggest that wells should be properly completed with concrete walls, apron and covered to reduce the effects of runoff and base-flow from polluted environment. In addition, there is also the need to abolish open waste dump and toilet systems in the area. Similarly, enforcement of good physical planning will help to forestall a situation whereby wells in certain households are situated close to the septic tank of neighbours. Regular treatment of well water before consumption and public awareness campaign are also recommended to ensure safe water use in the area. It is also suggested that more deep wells (boreholes) should be provided in the local government area so that the people can depend less on shallow wells. However, this recommendation may be premature as the outcome of our next study which hopes to compare the quality of the two sources of groundwater will determine its propriety.

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International Journal of Science and Technology

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