PHYSICO-CHEMICAL AND BACTERIOLOGICAL ANALYSIS OF GROUNDWATER QUALITY IN UPPER KUBANNI RIVER BASIN ZARIA, NIGERIA

BY

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ABSTRACT

This study analyzed the Physico-chemical and Bacteriological characteristics of groundwater in Upper Kubanni River Basin Zaria, Nigeria. Eight samples were purposively selected and analyzed in the laboratory; out of this, four were taken from shallow wells and four from boreholes. The parameters assessed include colour, odour, taste, pH, total hardness, dissolved oxygen (DO), total dissolved solids (TDS), chlorine (cl^-), nitrate, phosphate, lead (Pb), chromium (Cr), Iron (Fe), magnesium (Mg) and coliform count. Land use land cover (LULC) analysis was carried out using GIS techniques to determine the different land use within the study area. Findings of the study show some level of variability between borehole and shallow well water quality. Shallow wells were more contaminated than boreholes. The results for Physico-chemical and Bacteriological properties of groundwater were compared with WHO and NSDWQ set standards. It shows that the water samples were slightly acidic with few within acceptable limits. TDS, hardness, Mg, Fe, Pb and Cr were above WHO and NSDWQ limits from both borehole and shallow wells. For the LULC analysis, it shows that cultivation is the major land use in upper Kubanni. It was also established that there is a relationship between groundwater quality and cultivation due to higher amount of coliform in shallow wells within upper Kubanni. Due to high concentration of Physico-chemical contaminants in both borehole and shallow wells alongside with higher amount of total coliform in shallow wells; this study concludes that groundwater across the study area is not safe for direct consumption. Appropriate water treatment techniques such as boiling, addition of lime due to high harness, chlorination and filtration are recommended prior to domestic usage in order to reduce the spread of water borne diseases.

Key words: Drainage basin, Groundwater, Land Use Land Cover, Upper Kubanni

INTRODUCTION

Historically, human civilization first began along a region of several important river valleys; this is because human settlements require natural resources to cover their needs for shelter, food and water. People chose to live close to rivers because it is an attractive factor; it is needed for domestic and agricultural water supply as well as for navigation purposes. Most plants and animal life cluster along a river because water is one of the basic requirements for existence. A river influences human activities in the area of fishing, hunting and farming for their livelihood. However, groundwater quality may be impacted with increase in population and emergence of new settlements around the river valley which serves as potential sources of groundwater pollution through indiscriminate waste disposal as a result of industrial, commercial and agricultural activities (Davie, 2002; Christopherson, 2005; Saadu and Ali, 2016).

A river usually develops from the availability of adequate supply of water and a slope which the water will flow to initiate the process of its formation. Adequate supply of water is usually provided by precipitation which is mainly in the form of rainfall or snow. The flow of this water across the earth, in response to gravity, results in runoff, which occurs when precipitation exceeds evaporation and transpiration, combined with infiltration rate and groundwater storage. It is from the flow of this run off, coupled with fluvial processes that a river is gradually formed (Clement, 2005).

Groundwater is the cheapest and accessible source of fresh water in most developing countries especially in Africa where surface water quality has been tampered with through pollution (Soladoye, 2014). Water can be polluted by introduction of harmful elements and compounds or through the release of microorganisms into water bodies which alters its physical and chemical properties by changing the taste, smell and or colour of the water (Butu and Iguisi, 2012).Contaminants introduced by man may be from septic tanks, areas where fertilizer, pesticides, or herbicides are used or stored, landfills and unauthorized dumpsites (Adebo and Adetoyinbo, 2009; Iguisi and Butu, 2012; Samuel, 2013).

Some groundwater contaminants can also originate from natural source. The types and concentrations of natural impurities depend on the nature of the geological material through which the groundwater moves and the quality of the recharge water. Groundwater moving through sedimentary rocks and soils may pick up a wide range of compounds such as magnesium, calcium and chlorides. The effect of these natural sources of groundwater contaminants depends on their type and concentrations (Butu, 2012).

Upper Kubanni River is prone to groundwater contamination due to intense anthropogenic activities such as cultivation, construction, quarrying and sand mining. There is agglomeration of settlements across the whole length of the Kubanni River. The land surrounding the river is utilized for different purposes at different stages of the river. All rivers occur in three stages of development and each stage has a unique set of characteristics that makes it different from other stages (Iwena, 2015). A number of studies have been conducted on groundwater quality upstream of the Kubanni River basin; for example Samuel (2013), Okpanachi, Sawa and Yusuf (2015) as well as Ahmed, Jamilu and Ibrahim (2016). The difference between previous studies and this study is that the present study assessed the physical, chemical and bacteriological characteristics of groundwater from both borehole and shallow wells comparing them with the World Health Organisation (WHO, 2011) and Nigerian Standard for Drinking Water Quality (Standards Organisation of Nigeria [SON], 2007). It also employed GIS technique to determine the different activities taking place within Upper Kubanni and relate them with groundwater quality.

THE STUDY AREA

The Kubanni Drainage Basin is located in Zaria, Nigeria. The Kubanni River takes its source from the Kampagi Hills in Biye, near Shika in Zaria. The Kubanni River flows southward and covers a total length of 21km where it empties itself into the Galma River. The Drainage Basin is within Latitudes 11° 05' -11° 10' N and Longitudes 7° 36' -7°45' E (Figure 1).

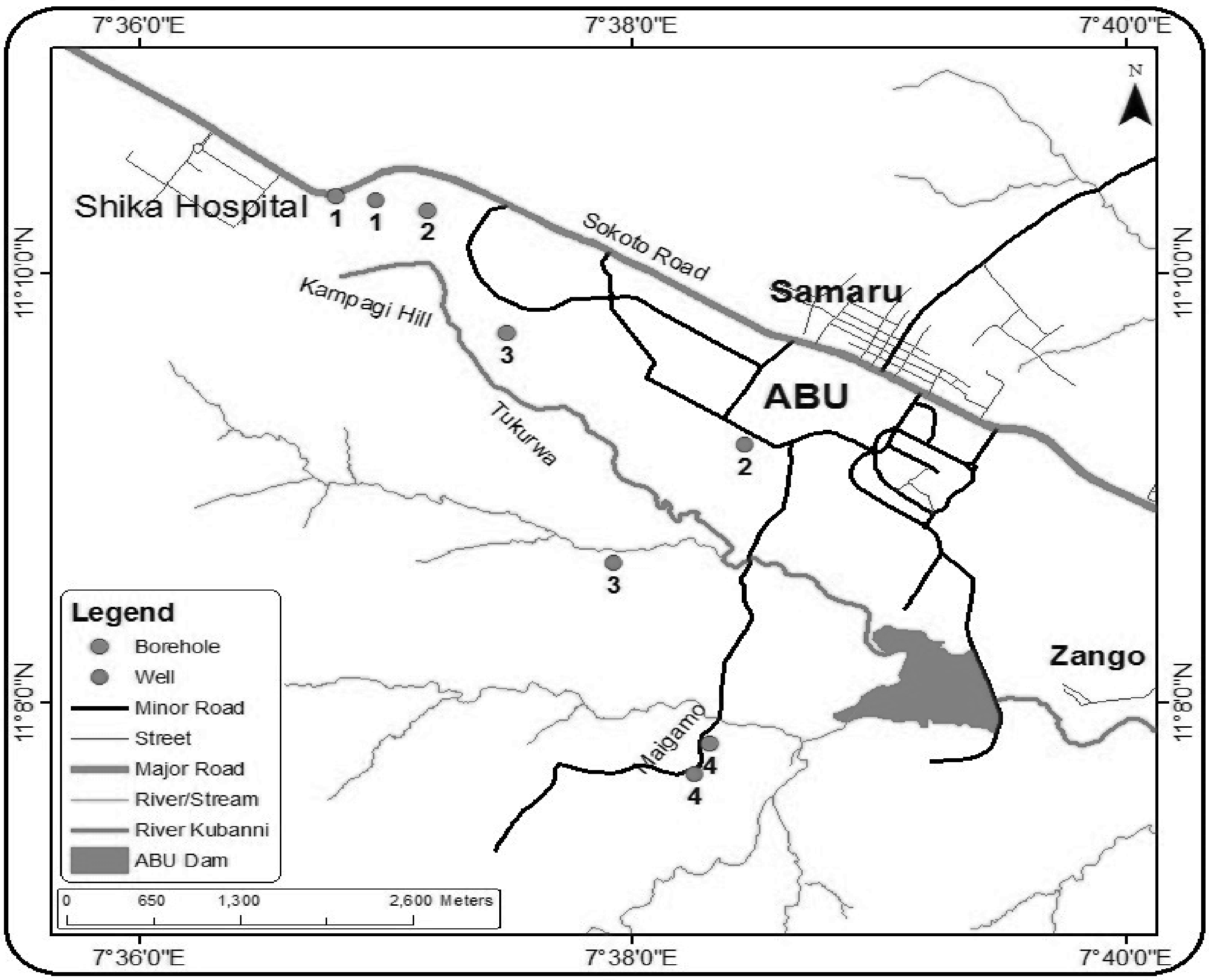

Figure 1: Study area and Sampling Locations
Source: Adapted and modified from the administrative map of Kaduna.

The River is seasonal and was dammed by the Ahmadu Bello University authority in 1973 at about 7.25km from source to provide water to the University Community (Iguisi, Funtua and Obamuwe, 2001; Yusuf, 2009). The area lies within the tropical wet and dry climatic zone. There exist two different seasons, the wet and dry season respectively. These seasons are dictated and controlled by the Inter Tropical Convergence Zone (ITCZ), which is in turn dictated and controlled by the movement and dominance of two air masses; the continental air mass and the maritime air mass. The mean annual rainfall is about 1100mm with an average intensity of 80mm/hr. Most of the rain comes in form of convectional rainfall (Ahmed et al., 2016).

The Zaria region is primarily underlain by the Basement Complex Rocks. The region is an area within the Zaria plain, a dissected part of the Zaria – Kano portions, an extensive peneplain, which had developed on crystalline metamorphic rock, and believed to be overlain by wind drift sediments (Wright and McCurry, 1970; Bello, 1973)

MATERIALS AND METHODS

The data used for the study include the physical parameter such as colour, odour, taste, and Total Dissolved Solids (TDS); chemical parameters include pH, total hardness, dissolved oxygen (DO), chlorine (cl^-), nitrate, phosphate, lead (Pb), chromium (Cr), Iron (Fe), and magnesium (Mg) while bacteriological parameter is the total coliform count. The sampling techniques used for this study is purposive. The choice for purposive sampling is to enable the researcher to take water samples from groundwater sources (shallow and deep wells) close to the upper course of the River. Eight samples were therefore used for the purpose of this study; four from shallow wells and four from boreholes. The water samples were collected in clean and sterile plastic bottles (750 ml). The sample bottles were initially washed after which they were rinsed with methylated spirit and finally with a portion of the water sample before collecting the samples.

All samples were tightly sealed and immediately taken to the Water Resources and Environmental Engineering and the Agronomy laboratories, Ahmadu Bello University, Zaria for analysis using standard laboratory procedures. The LULC was characterized using Earth Resource Development Assessment System (ERDAS) Imagine 9.2 through a supervised classification method (maximum likelihood algorithm). This technique was adopted due to its high level accuracy and reliability in handling spatial data. It enabled the researcher to generate classes based on the actual LULC themes present within the study area.

RESULTS AND DISCUSSION

Physico-chemical and Bacteriological Characteristics of Groundwater within Upper Kubanni

The Physical, chemical and bacteriological characteristics of borehole and shallow wells within Upper Kubanni are presented in Tables 1, 2 and 3 respectively.

Table 1: Physical Characteristics of Groundwater within Upper Kubanni

S/N	Parameters	Groundwater Sources							
		B1	B2	B3	B4	SW1	SW2	SW3	SW4
1	Odour	UO	UO	UO	UO	UO	UO	UO	UO
2	Taste	UO	UO	UO	UO	UO	UO	UO	UO
3	Colour	5	5	5	5	5	5	5	5
4	TDS	3240	190	130	460	880	250	320	846

Source: Laboratory Analysis, 2018
B= Borehole, SW= Shallow wells, UO= Unobjectionable

The result for physical parameters in Table 1 shows that all samples from both borehole and shallow wells in upper Kubanni were tasteless, colourless and odourless while TDS recorded highest in borehole and shallow well at sampling locations 1 when compared to other samples.

This is perhaps due to faulty design and completion of the borehole and the land use within. Except for borehole sampling location 1, it is clear that the shallow wells have higher TDS values as observed by Okpanachi, Sawa and Yusuf (2015).

Table 2: Chemical Characteristics of Groundwater within Upper Kubanni

S/N	Parameters	Groundwater Sources							
		B1	B2	B3	B4	SW1	SW2	SW3	SW4
1	pH	5.8	6.3	6.6	6.4	6.3	6.6	6.6	6.4
2	DO	1.7	1.7	3.40	1.7	1.7	2.70	2.50	1.90
3	BOD	0.70	1.30	1.70	0.20	0.70	1.80	1.40	0.90
4	Hardness	5050.91	191.94	141.69	141.69	676.75	222.22	202.02	626.24
5	Calcium	80.97	90.94	50.78	52.63	283.39	68.82	101.21	161.94
6	Chlorine	0.03	0.1	0.2	0.04	0.2	0.03	0.2	0.1
7	Phosphate	0.05	0.01	0.01	0.01	0.05	0.01	0.05	0.02
8	Nitrate	1.20	0.01	0.02	0.01	2.20	0.03	0.02	1.90
9	Magnesium	18.78	5.56	5.56	6.26	4.87	3.48	4.17	4.87
10	Iron	1.60	0.80	0.80	1.20	0.80	0.80	0.80	0.80
11	Lead	0.448	0.793	1.253	0.793	2.172	0.448	0.908	0.563
12	Chromium	0.618	0.618	0.506	0.169	0.393	0.281	0.169	ND

Source: Laboratory Analysis, 2018 ND= Not detected

The results for chemical parameters as shown in Table 2 indicate that there is a very little variation in the pH where borehole recorded the lowest value at sampling location 1. It also shows that all the samples are slightly acidic since they are close to the neutral level. The further away from the 6.5 minimum limit, the more acidic the water (Ali, Imam and Abdulkadir, 2012). Highest values for total hardness and Mg were also observed in borehole 1.The high level of hardness is due to geological formation. Total hardness is an important criterion for ascertaining the suitability of water for domestic, drinking and many industrial uses (Mostafa et al., 2013; Ayodele, 2018). Hardness of water for domestic use relates mainly to its reaction with soap. The use of the groundwater for domestic purposes may therefore lead to soap wastage or more soap requirement for washing. According to WHO (2011), high concentration of magnesium increases hardness and gives an unpleasant taste to drinking water. Also, the presence of lead and chromium is risky especially in shallow well 1 for the former and boreholes 1 and 2 for the latter.

Table 3: Bacteriological Characteristics of Groundwater within Upper Kubanni

S/N	Parameters	Groundwater Sources							
		UB1	UB2	UB3	UB4	UW1	UW2	UW3	UW4
1	COLIFORM	0	0	0	0	25	23	18	14

Source: Laboratory Analysis, 2018

The result for bacteriological analysis in Table 3 shows that borehole water within upper Kubanni is free from coliform. This implies that the borehole within this area is of good bacteriological quality as indicated by zero coliform. For the shallow wells, it shows that all the samples contain potential pathogenic organisms as observed from the coliform count result in Table 3. The absence of coliform in borehole water could be due to the depth of the water table. According to Efe (2008), the longer the distance traveled by water through soil formation the cleaner it becomes; this explains why borehole water within upper Kubanni is of better quality than shallow wells. The presence of coliform in shallow well water calls for concern.

Comparing Groundwater in Upper Kubanni with the WHO and NSDWQ standards

Groundwater from both borehole and shallow wells within the study area were compared with the WHO and NSDWQ standards in Tables 4, 5, and 6 respectively.

Table 4: Physical Parameters and the WHO/NSDWQ standard

S/N	Parameters (mg/l)	Groundwater Sources B1	B2	B3	B4	SW1	SW2	SW3	SW4	WHO (2011)	NSDWQ (2007)
1	Odour	UO	UO	UO	UO	UO	UO	UO	UO		
2	Taste	UO	UO	UO	UO	UO	UO	UO	UO		
3	Colour	5	5	5	5	5	5	5	5	5	5
4	TDS	3240*	190	130	460	880*	250	320	846*	500	500

Source: Laboratory Analysis, 2018 * = beyond WHO/NSDWQ limits
B= Borehole, SW= Shallow wells, UO= Unobjectionable

Table 4 shows that all the physical parameters (taste, odour and colour) analyzed for borehole and shallow wells within upper Kubanni fall within the World Health Organization (WHO) and National Standard for Drinking Water Quality (NSDWQ) limits except for TDS which recorded higher value than the WHO and NSDWQ standards in some cases. The borehole sampling point which recorded higher TDS value is location 1 while for shallow wells, sampling locations 1 and 4 were above the WHO and NSDWQ limits. Higher values for TDS could be attributed to intensive cultivation within the study area and also the nature of the soil. High TDS causes gastro intestinal irritation, affects the efficiency of hot water heaters, and it is unsuitable for many industrial uses (Abdullahi, 2017).

For the chemical parameters, the pH value for borehole in all the samples except for location 3 were below the WHO and NSDWQ set standards. For the shallow wells, pH values sampling locations 1 and 4 were also below the WHO and NSDWQ set standards. This means that the water samples within upper Kubanni is slightly acidic. According to Mohsin, Safdar, Asghar and Jamal (2013), water with low pH indirectly affects human health, since it can increase metal leaching from pipes and fixtures such as copper and lead thereby making it toxic. Except for borehole sampling location 3, the DO values were within the permissible limit while the BOD values were all within limits.

Table 5: Chemical Parameters and the WHO/NSDWQ standards

S/N	Parameters	Groundwater Sources									
		B1	**B2**	**B3**	**B4**	**SW1**	**SW2**	**SW3**	**SW4**	**WHO (2011) Standard**	**NSDWQ (2007) Standard**
1	pH	5.8*	6.3*	6.6	6.4*	6.3*	6.6	6.6	6.4*	6.5-8.5	6.5-8.5
2	DO	1.7	1.7	3.40	1.7	1.7	2.70	2.50	1.90	3	3
3	BOD	0.70	1.30	1.70	0.20	0.70	1.80	1.40	0.90	0.8-5.0	0.8-5.0
4	Hardness	5051**	192	142	141.1	677**	222.2	202	626.2**	150	400
5	Calcium	81	91	51	53	283**	69	101.2	162	10-200	10-200
6	Chlorine	0.03	0.1	0.2	0.04	0.2	0.03	0.2	0.1	0.20	0.20
7	Phosphate	0.05	0.01	0.01	0.01	0.05	0.01	0.05	0.02	200	250
8	Nitrate	1.20	0.01	0.02	0.01	2.20	0.03	0.02	1.90	25	50
9	Magnesium	19**	7	6	6.2	5	4	4.2	5	10	10
10	Iron	1.60**	0.80**	0.80**	1.20**	0.80**	0.80**	0.80**	0.80**	0.3	0.3
11	Lead	0.5**	0.8**	1.3**	0.89**	2.2**	0.4**	0.9**	0.6*	0.05	0.01
12	Chromium	0.6**	0.6**	0.5**	0.2**	0.4**	0.3**	0.2**	ND	0.05	0.05

Source: Laboratory Analysis, 2018 *= below WHO/NSDWQ limits ** = beyond limits

Total hardness was also found to exceed both the WHO and NSDWQ water quality standards in borehole and shallow well at location 1 and locations 1 and 4 respectively. This could be attributed to geologic and environmental factors. According to WHO (2011), water containing hardness level above 500mg/l is considered to be very hard. This means that wastage of soap during cleaning and scale formation on hot water boilers will be encountered due to high level of hardness in the water.

All the heavy metals analyzed have exceeded both WHO and NSDWQ limits in all the samples from both borehole and shallow wells except Mg which is found beyond the limit only in borehole at location 1. The reason for high concentration of heavy metals is due to the geology, nature of the soil and land use within the study area. This observation agreed with the reports of Adebo and Adetoyinbo (2009), which observed higher concentration of heavy metals in borehole above the WHO limits which they attributed it to geological and environmental factors. Staining effect of white materials such as plumbing fixtures will be encountered due to heavy metal concentration such as Fe, Mg, Cr and Pb which are above the WHO and NSDWQ limits. Excess of iron makes water to change from colourless to brownish black which becomes objectionable to consumers (Bello, 2011). Also, iron concentration in water above 200mg/l can be toxic to human health.

Table 6: Bacteriological Parameters and the WHO/NSDWQ standards

S/N	Parameters (mg/l)	Groundwater Sources UB1	UB2	UB3	UB4	UW1	UW2	UW3	UW4	WHO (2011)	NSDWQ (2007)
1	COLIFORM	0	0	0	0	25	23	18	14	0	10

Source: Laboratory Analysis, 2018

The result for bacteriological analysis in Table 6 revealed that all samples analyzed for borehole within upper Kubanni are free from pathogenic bacteria. This is in agreement with the findings of Yaya and Okafor (2010) which revealed that coliform count in borehole (deep well) satisfy the permissible level prescribed for drinking water. However, for shallow wells, it shows that the wells within the study area contains high amount of total Coliforms. The source of total coliform bacteria in shallow wells is due to intensive use of manure during farming operations. The main sources of bacteriological contamination of groundwater are microorganisms from human or animal excreta and their presence indicates the fecal pollution of groundwater (Mostafa et al., 2013; Josiah, Nwangwu, Akpanyung and Dike, 2014).

From the WHO standard, it is stated that potable drinking water should contain zero coliform while the NSDWQ gives a minimum of 10cfu/100ml. Diarrhea accounts for 80% of all diseases and over one third of deaths in developing countries which are caused by the patients' consumption of contaminated water (Ali, Mohamadou, and Saidou, 2010). This means that shallow well water within upper Kubanni is not suitable for direct consumption based on the comparison with the WHO and NSDWQ standards for drinking water. Effective water treatment technique should be used so as to reduce the prevalence rate of water borne diseases like typhoid fever, cholera and diarrhea in children. It can also be concluded that shallow wells are more contaminated than boreholes within the study area. This could be due to the difference in the depth of the water table between shallow wells and boreholes. This is similar with the findings of Okpanachi et al. (2015), who observed that shallow wells were more contaminated than the deep wells which they attributed to the effect of solid dumpsites.

LULC Characterization of Upper Kubanni River Basin

The LULC classification as characterized in Table 7 shows that cultivation is the dominant land use practice within upper Kubanni. According to Mostafa et al. (2013), agricultural activities increase nitrate content in groundwater. Intensive use of manure is associated with bacterial contamination from animal waste. Fertilizer application can also affect groundwater quality by increasing nitrate and phosphates level.

Table 7: LULC Characterization of upper Kubanni River Basin

LULC	Upper (Hectare)	%
Built up	166.7	5
Water	70.0	2
Farmland	1441.2	42
Forest	435.8	13
Bare land	1066.8	31
Fadama/wetland	190.1	6
ABU Quarters	32.6	1
Total	3403.2	100

Source: Authors' Analysis, 2018

Relationship between Groundwater Quality and LULC

A careful observation of Table 7 shows that the major land use in upper Kubanni is cultivation which covered 42% of the total land uses. This means that higher coliform bacteria observed in shallow wells above the WHO and NSDWQ limits in the study area originated from animal excreta (manure) and fertilizer application which are common practices within upper Kubanni. Jamilu et al. (2016) viewed agriculture as a significant non-point source of groundwater contamination. Therefore, upper Kubanni is prone to groundwater contamination from agricultural activities such as fertilizer and manure application, spray of chemicals such as herbicides, pesticides, etc. This is evident from the result of bacteriological analysis of groundwater presented in Tables 3 and 6 indicating that shallow wells within upper Kubanni are contaminated by coliform. High amount of coliform in shallow wells within upper Kubanni which originated from farming activities explains the relationship between groundwater quality and land use in the study area.

CONCLUSION

Results of this study for the analysis of the Physico-chemical and bacteriological characteristics of groundwater in upper Kubanni river basin revealed that there were considerable deviations from both WHO and NSDWQ set standards. This shows clearly that the samples, especially from the shallow wells do not satisfy the drinking water standards. The LULC analysis shows that cultivation (farming) is the major land use in upper Kubanni. It was also established that there is a relationship between groundwater quality and cultivation due to higher amount of coliforms in shallow wells within the study area. Due to high concentration of chemical contaminants in both borehole and shallow wells across the study area alongside with higher amount of total coliform in shallow wells within upper Kubanni; this study concludes that groundwater across the study area is not safe for direct consumption.

Based on the findings of this study;

i. Appropriate water softening technique is recommended such as addition of soda ash or lime and also the use of iron exchange for reducing hardness level across the study area.

ii. Iron removal through appropriate method such as aeration coupled with filtration is recommended.

iii. Shallow well water should be effectively treated by disinfection or distillation so that bacteria and other harmful disease causing microorganism can be eliminated.

iv. Government and relevant authorities should make policies and laws to control the use of fertilizer and manure so as to reduce the rate of groundwater contamination caused by farming activities.

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