Assessment of effects of abattoir activities on Groundwater Quality in part of Keffi, North Central Nigeria

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Abstract

Animal residues, faeces, blood among other wastes are generated from abattoir activities in Keffi town and disposed within the vicinity. These wastes give the environment an unaesthetic look and attract disease causing organisms which can find way into groundwater. Geological mapping, geophysical survey, chemical and microbiological examination of hand-dug well waters have been carried out across the study area. Geological mapping reveals the occurrence of 3 major rock units; migmatites, schist and phyllite with intrusions of pegmatite, quartz and aplite veins. Geophysical survey (Vertical Electrical Sounding, VES) indicates an irregular weathering front with depth to bedrock that ranges between 9.54m to 33.65m. Twenty three (23) water samples from hand-dug wells were analyzed during the wet season and nine (9) samples during the dry season for pH, Conductivity, TDS, Ca^{2+}, Mg^{2+}, K^+, Na^+, NO_3, HCO_3^-, Cl^-, SO_4^{2-} and Fe^{2+}. Concentration of these parameters when compared with their corresponding standard values of Nigerian Standard for Drinking Water Quality (NIS-554:2007) and World Health Organization (WHO, 2011) revealed that the well waters are somewhat safe for consumption. However, microbiological study reveals the presence of bacteria and organic pollution in the water. Also abattoir activities was seen to have influenced the levels/concentrations of TDS, conductivity, Ca^{2+}, K^+, NO_3, SO_4^{2-}, $Fe^{2+}$and coliform count.

Keywords: geology, hydrogeology, pollution, abattoir, water quality

Introduction

Water is the life blood of the environment and one of the most essential needs of human beings. Of all water available on earth, groundwater is known to be the most abundant source of potable water and the safest water supply for domestic, agricultural and industrial use as it is less susceptible to pollution, relatively cheaper to access once favorable spots are located and takes a shorter time to develop than other sources. However, the provision of potable water is perhaps the most difficult problem facing many developing countries including Nigeria today.

Water though generally not scarce in the study area (Keffi town) because of the pipeborne water supply from Mada Water Works about 60km north of the town, recent shortage of supply have compelled residents to explore groundwater resources to supplement the public supply. Keffi town has two abattoirs; the central abattoir which is about the oldest industry in the town dates more than a century old and a smaller one

(Yan Awaki) whose slaughter activities started about 10years ago (Sarkin Pawa, 2011). Pipe-borne water from the Keffi reservoir does not adequately supply the abattoir areas, hence groundwater through wells and boreholes serve as the main source of water supply for the residents of the area. A lot of wastes are generated from the abattoir activities and this includes faeces, residues and blood among others.

In the central abattoir, the wastes are disposed within the vicinity as government has not provided any waste disposal land. What distinguishes the central from the small abattoir is that in the later, the slaughtered goats are roasted using old tyres and petrol flames which pollute the air and add to the waste while the generated wastes are dumped in a nearby stream. These wastes give the immediate environment an unaesthetic look, foul odour, attract flies and disease causing organisms. This study aims at assessing the effects of the abattoir activities on groundwater quality in part of Keffi.

Materials and methods

The study area which is a portion of Keffi is located between longitudes 07^{0} 51' 30" and 07^{0} 53' 30" and latitudes 08^{0} 50' 30" and 08^{0} 52' 00" thus covering an area of about 10km^{2} (Figure 1).

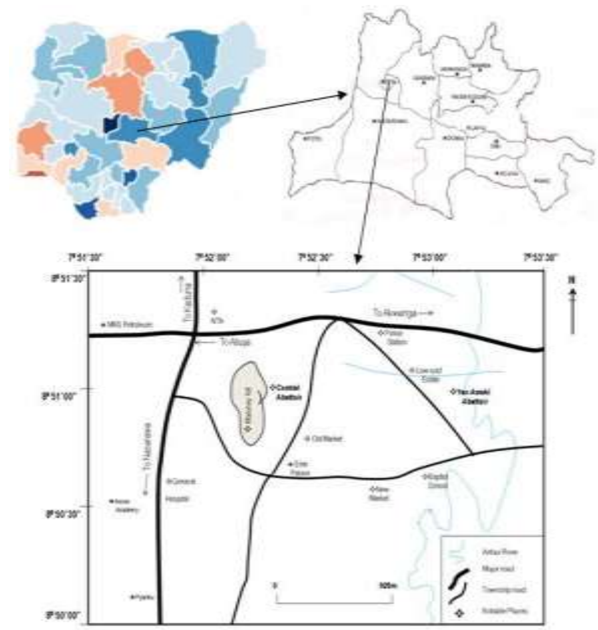

Figure 1: Location map of the study area

Rainfall in Keffi is moderately heavy, ranging from 1200 – 2000mm being on the windward side of the Jos Plateau (NIMET, 2005).The area is characterized by wet and dry seasons. The wet season covers the period from May to September while the dry season covers the period between October and April of each year. The monthly average temperature rises to 39^{0}C and may fall to 17^{0}C during the harmattan period.

The vegetation is that of Guinea or moist Savannah characterized by thick vegetation, tall grasses and trees but which have largely been altered by human activities such as tree falling and forest fires, only open forest and grassland are left (in Obaje *et al.*,2005).

The area is drained mainly by Antau River with many other streams which are tributaries of the Antau River that flows north – south dropping gently from the northern hill ranges. The following stages were adopted for this study:

a. Field studies which included reconnaissance survey, detailed geological mapping, geophysical survey where 8 Vertical Electrical Soundings were taken, sampling of water from 23 hand-dug wells during both wet and dry seasons, water level measurements in the wells on monthly basis and in-situ tests of physical parameters (taste, odour, pH, EC, Temperature and TDS) of the water samples (Figure 2).

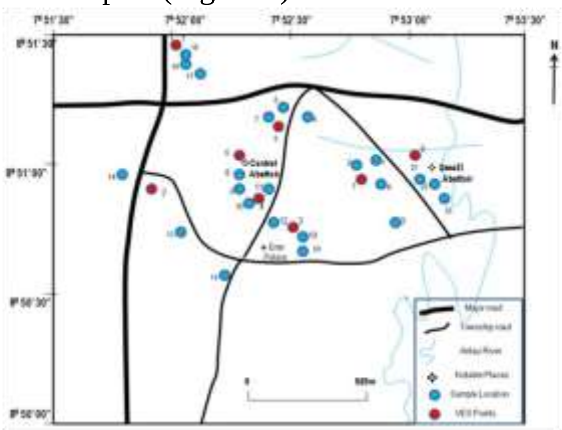

Figure 2: Sampling and VES points

b. Laboratory analysis for determination of the concentrations of major cations; Calcium (Ca^{2+}) Magnesium (Mg^{2+}), Potassium (K^+), Sodium (Na^+) and anions; Nitrate (NO_3), Bicarbonate (HCO_3^-), Chloride (Cl^-), Sulphate (SO_4^2) and Iron (Fe^{2+}). Microbiological parameters determined include coliform count, Escherichia coli, Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD).

A portable Martini instrument Mi 806 with sensitive probe was used for measuring temperature, pH, electrical conductivity and Total Dissolved Solids. The water samples were analyzed following procedures as recommended by ASTM (1999), APHA (2005) and EPA (1996). EDTA Titrimetric method was employed to determine Ca^{2+} and Mg^{2+} concentrations, turbidimetric method was used for SO_4^{2-}, flame photometry for K^+ and Na^+, argentomeric method for Cl^-, Cadmium Reduction Method for NO_3, phenanthroline method for Fe^{2+}, total coliforms and Escherichia coli by membrane filtration technique and Chemical Oxygen Demand by dichromate digestion method.

Results and Discussion

Geology

Geological mapping of the study area (part of Keffi sheet 208NE) which covers about 10km^2 was conducted on a scale of 1:850 (Figure 3). The area is characterized by near surface outcrops of underlying basement rocks and shallow overburden. Migmatites, schist and phyllites with intrusions of pegmatites, quartz and aplite veins are well exposed in the study area. The study area can also be divided into two hydrogeological units namely; aquiferous zone within the weathered overburden overlying the basement rocks and the aquiferous zone within the intense fracture joint system in the partially weathered basement.

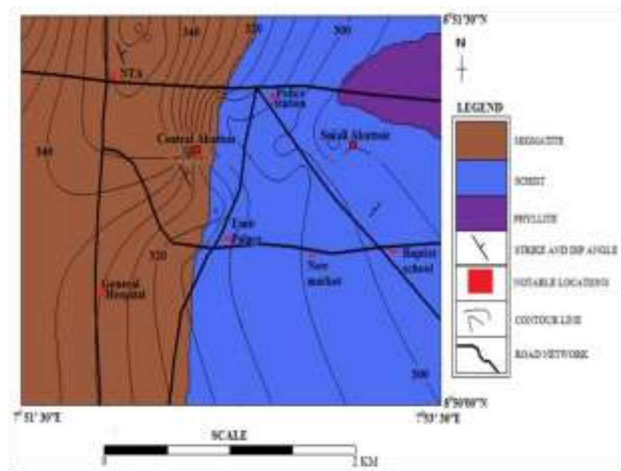

Figure 3: Geological map of part of Keffi

Geophysical Survey

Resistivity method of geophysical survey using ABEM terrameter was conducted to determine the thickness of regolith and depth to bedrock within the study area. The

Schlumberger array method was employed and a total of 8 Vertical Electrical Sounding (VES) was made each to cover an area with cluster of wells (Figure 4). Typically, three geo-electric layers are indicated with exception of VES 1 which has up to four layers. From the surface, there is a low resistivity with relatively thick layer of top soil (mean thickness 5.82m) which corresponds with the water table. This is followed by a high resistivity layer of variable thickness, the weathered zone, the base of which ranges between 3.94m and 23.76m, (mean thickness 15.07m). The geoelectric layer terminates at the bedrock which is marked by a sharp rise in the resistivity with thickness to infinity. The depth to bedrock corresponds to the base of the weathered zone which varies between 3.94m and 23.76m with a mean of 15.07m.

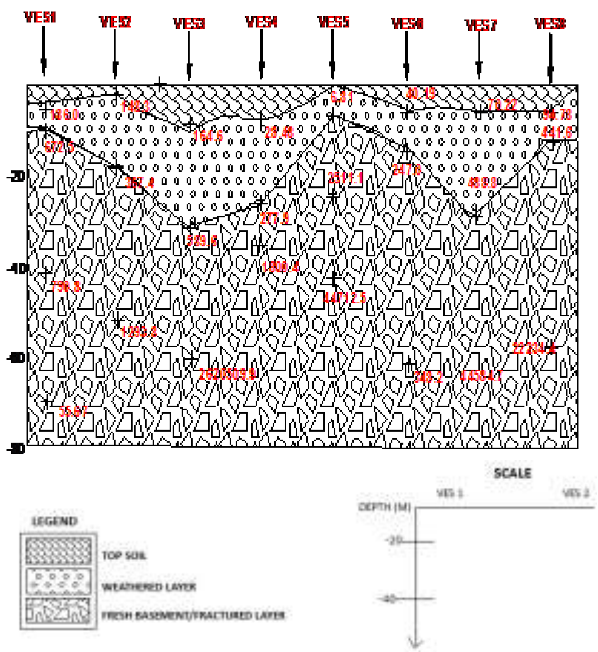

Figure 4: Geo-electric section of VES 1 to VES 8

Hydrogeology

A total of 23 hand-dug wells were identified in the study area and their water levels were measured on a monthly basis. The data obtained from this inventory was used to plot the groundwater flow network (Figure 5). It reveals that wells on the western part of the study area which lies on higher altitudes are within the divergent zone where groundwater moves in all directions but mostly to the eastern part.

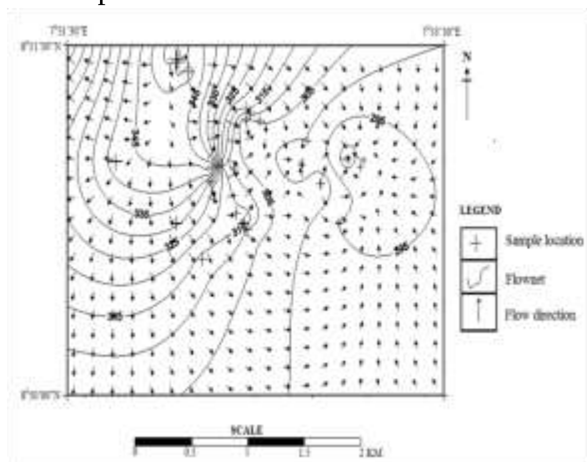

Figure 5: Groundwater flow direction

The small abattoir located in the northeastern part of the study area lies on lower altitude forming a convergent zone where groundwater meets from various points and this explains the high water level in wells (KW21, KW22 and KW23) around the area. This implies that contaminants if present in wells around the central abattoir can move or spread to other areas while at the small abattoir area, contaminants will be restricted and may not move away from the source. The sampling was done during the peak of wet season (August to October) and during the peak of dry season (December) in order to record the effect of dilution that occurs during the wet season (Figure 2). The wells with high water levels above sea level are located in areas of high altitude and most of them (W05, W07, W08, W09, W10, W11, W13, W14, W15, W16, W17 and W18) are in areas underlain by migmatite rocks. The Vertical Electrical

Sounding result of VES1, VES 2, VES 3 and to some extend VES 4, indicated shallow bedrock depth and thin layer of weathered regolith in areas of high altitude. Most wells (W08, W09, W11, W13 and W14) in these areas have high water levels below ground level and hence can be said to be fracture controlled. Few wells underlined by rocks of schistose lithology have high water levels below ground level (W21, W22 and W23) and are located close to the small abattoir (Yan Awaki). This is an indication that migmatites in the study area are more water bearing than the schistose rocks as the former weathered regolith are more permeable than the fine-grained residual of the latter.

Physical parameter pH level in the groundwater of the study area is low (acidic) in the western part and high in the north-eastern part. The values are high around the small abattoir and increases northward while Figure 6 shows that pH is high (alkaline) in the western and northeastern part of the study area during the dry season and the south-eastern part still remaining low (acidic). The values around both abattoirs are moderate and this indicates that the pH may not likely be attributed to the abattoir effect but geological and other environmental effects. The map in Figure 7 shows that electrical conductivity rises sharply from both abattoirs and peak around the centre of the study area. Figure 8 depicts a similar situation except that electrical conductivity is lower around the smaller abattoir in the dry season. Both maps were able to show the effect of abattoir activities on the groundwater as it raises the level of electrical conductivity. Temperature ranges between 26.6^{0}C to 29.2^{0}C during the wet season. The dry season recorded lower values which ranged between 23.1^{0}C to 27.2^{0}C and this might not be unconnected with the cold harmatan experienced during the period of sampling. Total dissolved solids (TDS) as indicated by Figure 9 are somewhat influenced by the abattoir activities as it sharply increases around the two abattoir areas and peaks close to the central abattoir. During the dry season, only the central abattoir is seen to have influenced TDS concentration of the groundwater where it rises to the peak.

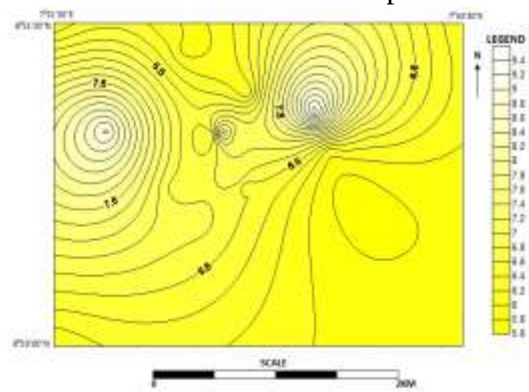

Figure 6: pH level in the groundwater during Dry season

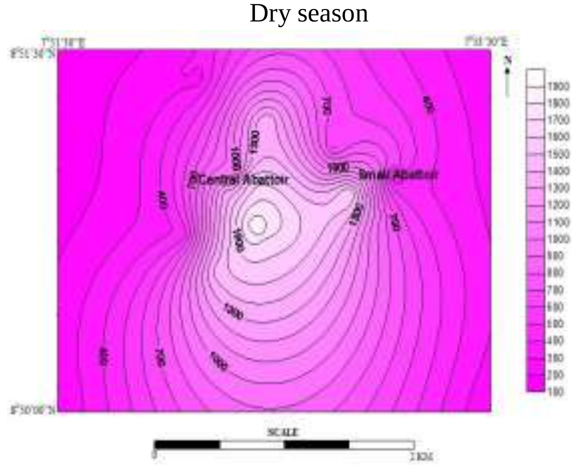

Figure 7: Electrical conductivity (EC) in the groundwater during wet season

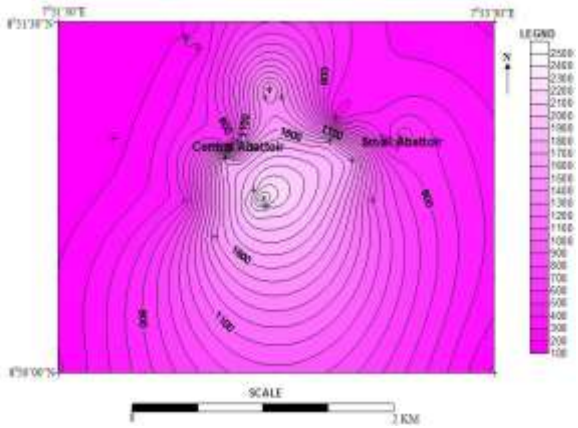

Figure 8: Electrical conductivity (EC) in the groundwater during dry season

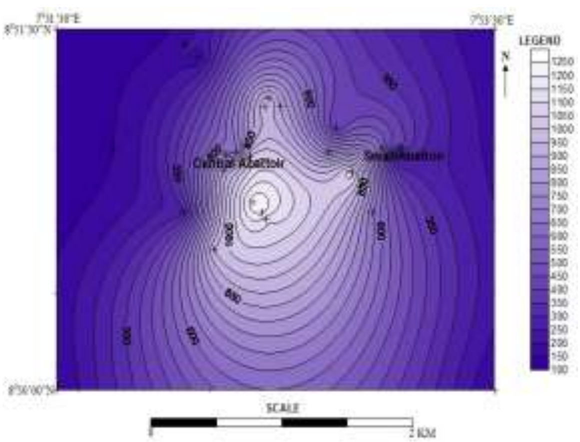

Figure 9: TDS concentration in groundwater during wet season

Chemical parameter

Figure 10 shows that calcium concentration is higher around the small abattoir and might have been influenced by dumping/burning of animal bones, tusk and blood going on in the abattoir. The map in Figure 11 shows that magnesium concentration is higher around the centre of the study area. It also shows that the central abattoir area has higher concentration of magnesium than the small abattoir area. Abattoir activities are likely not to have any influence of magnesium concentration on the groundwater of the study area. The map in Figure 12 clearly shows the influence of abattoir activities on the groundwater, as concentration of sodium around the two abattoir areas is higher than in other parts of the study area.

Figure 13 above shows high concentration of potassium around the small abattoir and another high concentration in the southwestern part of the study area. The small abattoir has a cattle market attached to it which as a result produces many cattle faeces that serve as manure or fertilizer and again potassium is present in the tissues of all animals. This can lead to conclusion that the cattle market together with the small abattoir has influenced the concentration of potassium in the groundwater of the area. Chloride concentration is high in the tested water samples. Two samples (KW12 and KW20) have values (277.2mg/L and 375.1mg/L respectively) above the Nigerian permissible limit of 250mg/L while eight samples KW04 (228.3mg/L), KW05 (203.8), KW07 (228.3mg/L), KW10 (236.5mg/L), KW12 (277.2mg/L), KW18 (236.5mg/L), KW19 (228.3mg/L) and KW20 (375.1mg/L) have chloride concentrations above WHO 200mg/L maximum permissible limit. From the result, it is observed that wells with depths greater than 6 meters have higher chloride concentrations than shallower wells. The figure above shows that the abattoir activities have no effect on the chloride concentration of groundwater in the study area. The influence is likely from septic system discharges. Figure 14 shows clearly the influence of abattoir activities on the nitrate concentration of the groundwater. Nitrate concentration is higher around the two abattoirs especially the central abattoir than in any other part of the study area. Figure 15 shows in clarity the influence of activities of the small abattoir on sulphate concentration in groundwater of the study area which saw it rise to the peak, while the central abattoir has shown has no effect on the groundwater. It is clear from Figure 16 that the abattoir activities have no effect on the bicarbonate concentration of the groundwater as both abattoir areas have low concentrations. Table 4 shows the high concentration of iron in groundwater around the small abattoir where as very low concentrations are recorded around the central abattoir. This shows that the small abattoir activities have effect as regard to iron concentration in the groundwater.

Microbiological Parameter

The maximum permissible limits (both Nigerian and WHO standards) for coliform count and Escherichia coli in drinking water are 10 cfu/100mL and 0 cfu/100mL respectively. All the samples have high coliform count above the permissible limit indicating poor sanitary condition in the whole of the study area (Table 6). A total of eight samples (KW08, KW10, KW14, KW18, KW19, KW21, KW22 and KW23) have no trace of faecal contamination (E. coli) while the remaining samples have varying degree of the contamination. Samples KW03 and KW17 have very high count of faecal contaminations of 19 cfu/100mL each.

Seven samples that were obtained from wells very close to both the central and small abattoirs either have low faecal contamination or none at all. Samples KW08, KW10, KW21, KW22 and KW23 have no faecal contamination while samples KW09 and KW11 have 1 and 2 counts respectively indicating a better sanitary condition around the abattoirs.

The result of dry season analysis (Table 7) shows the presence of coliform bacteria above the permissible limit in all the water samples. In samples KW03 and KW07 there were decrease in the number of coliforms present against that recorded in the wet season while for samples KW08, KW09, KW10 and KW11 (wells closest to the central abattoir) there was soar in the number of coliforms present. Samples KW21, KW22 and KW23 maintained the same number of coliforms found in the wet season thereby unaffected by dilution of the wet season.

High faecal contamination recorded in samples KW03 and KW17 (19cfu/100mL each) in the wet season have drastically reduced in the dry season to 3cfu/100mL and 6cfu/100mL respectively. Samples KW08, KW21 and KW23 have maintained no trace of faecal contamination while sample KW09 had little increase in the contamination. Samples KW10 and KW22 which had no trace of the contamination in the wet season recorded 3cfu/100mL and 1cfu/100mL respectively in the dry season.

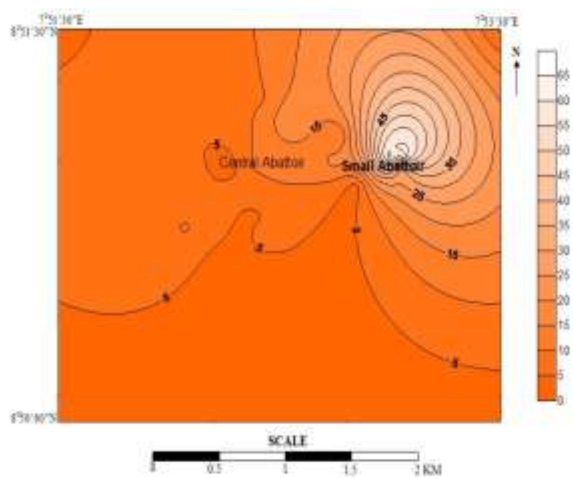

Figure 10: Calcium concentration in groundwater

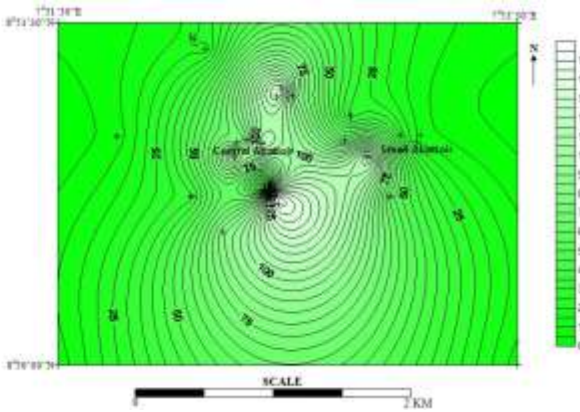

Figure 11: Magnesium concentration in groundwater

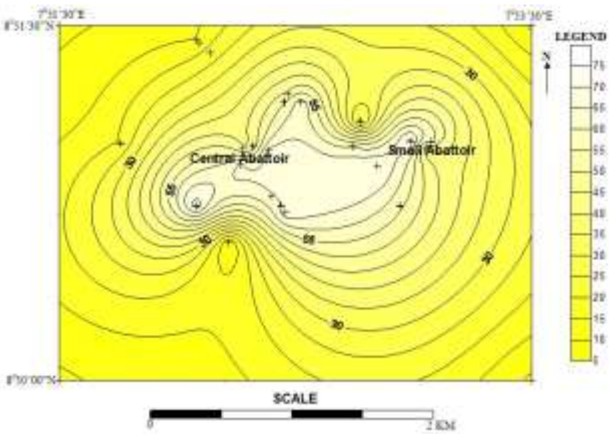

Figure 12: Sodium concentration in groundwater

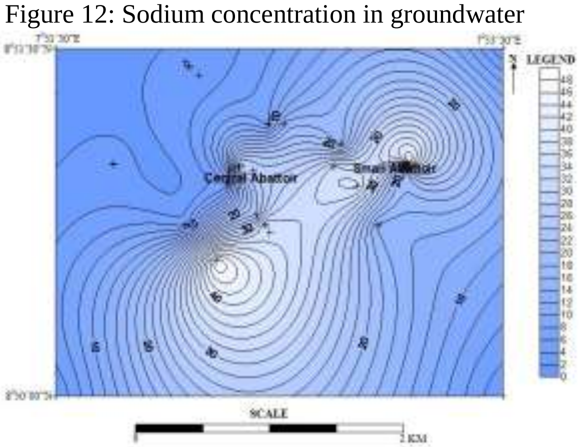

Figure 13: Potassium concentration in groundwater

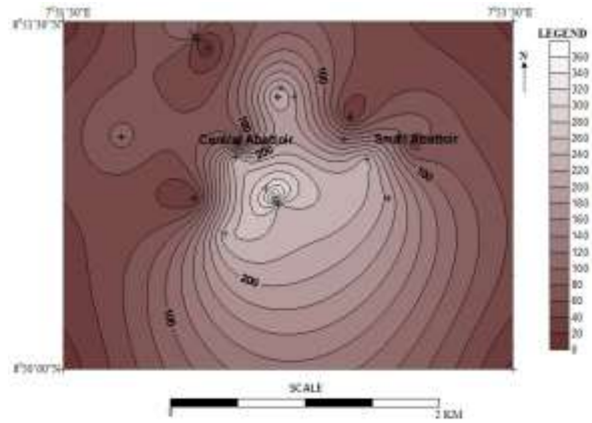

Figure 14: Chloride concentration in groundwater

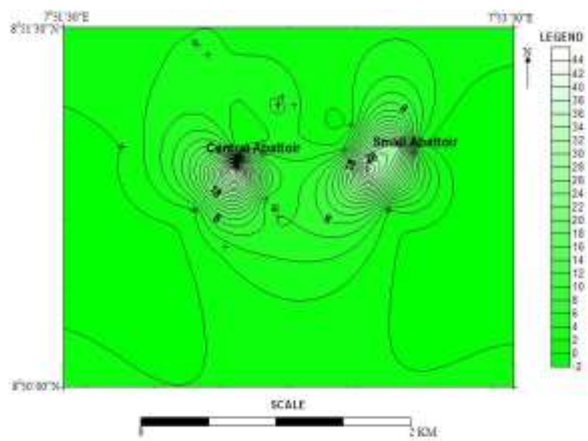

Figure 15: Nitrate concentration in groundwater

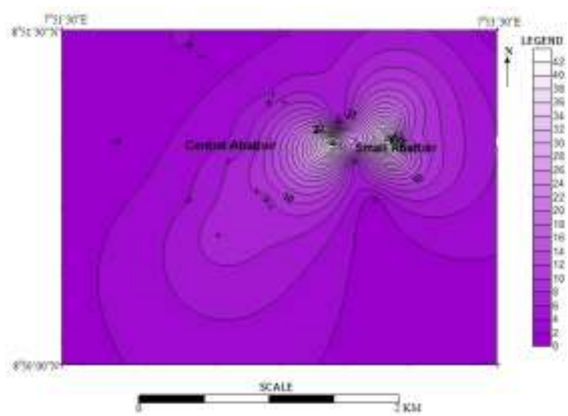

Figure 16: Sulphate concentration in groundwater

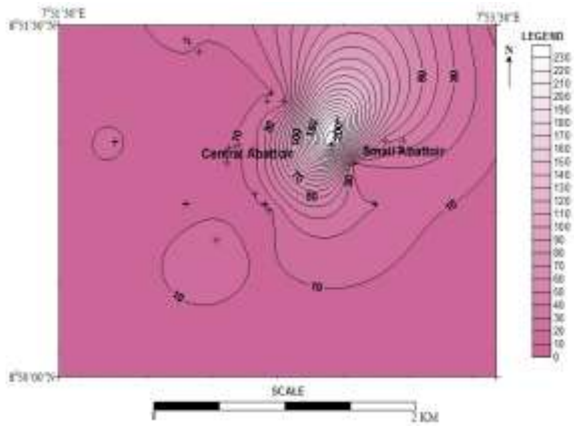

Figure 17: Bicarbonate concentration in groundwater

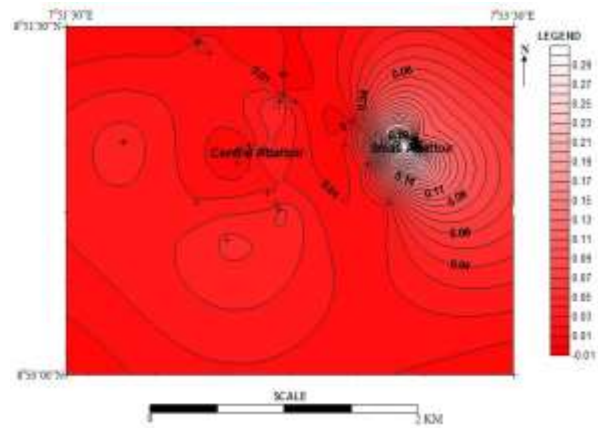

Figure 18: Iron concentration in groundwater

Table 1: Water levels in wells from May – December 2011

WELL NO.	WELL DEPTHS (m) bgl	AVERAGE MONTHLY WATER LEVEL ABOVE SEA LEVEL (m)							
		MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
KW01	5.0	300.2	298.9	301.2	301.3	301.5	301.3	297.6	297.5
KW02	3.75	295.2	295.7	296.4	296.6	296.6	296.1	294.3	294.3
KW03	9.0	295.2	294.2	294.8	294.9	295.7	294.9	294.4	294.2
KW04	3.6	304.4	303.6	305.0	305.4	305.8	305.5	304.7	304.4
KW05	5.10	314.0	313.9	314.2	314.0	314.8	314.0	-	314.4
KW06	6.45	305.1	303.7	307.1	308.4	308.6	308.2	303.8	303.7
KW07	8.0	299.5	296.8	299.7	300.3	301.4	301.0	298.2	297.1
KW08	4.10	311.2	312.9	313.4	313.5	313.7	313.4	310.3	310.0
KW09	3.61	347.4	350.4	350.6	350.7	350.9	350.6	350.1	349.4
KW10	6.21	325.9	325.8	326.5	327.9	330.8	327.0	325.8	325.9
KW11	6.0	-	306.6	311.0	311.3	311.4	311.2	307.6	306.2
KW12	8.10	315.4	314.9	315.0	316.8	316.2	316.8	315.1	315.0
KW13	2.0	331.0	331.1	331.4	331.5	331.5	331.4	330.4	330.1
KW14	5.0	342.9	342.5	343.1	343.5	343.5	343.3	342.6	339.8
KW15	5.50	360.8	360.83	361.1	361.7	361.5	361.1	360.8	360.6
KW16	4.50	342.7	342.8	343.0	343.4	343.2	343.1	342.8	342.8
KW17	4.0	352.6	352.1	352.3	353.4	354.2	353.1	352.9	351.9
KW18	7.50	312.8	312.7	313.8	314.3	314.5	313.9	313.0	309.0
KW19	7.50	307.3	306.7	308.1	309.0	309.2	309.1	308.3	304.7
KW20	7.75	322.4	320.3	322.7	323.8	324.2	324.0	323.5	319.8
KW21	4.50	-	-	-	-	-	294.3	294.0	293.9
KW22	4.0	-	-	-	-	-	286.4	286.0	285.9
KW23	4.50	-	-	-	-	-	293.4	292.7	292.5

Table 2: Physical Test Result (in-situ) of water samples during the wet season

Sample No	Taste	Odour	pH	Electrical conductivity(μS/cm)	Temp (°C)	TDS (mg/l)
KW01	Na	Cement	11.07	587	28.2	393.3
KW02	Tasteless	Odourless	6.67	1049	27.8	702.8
KW03	Bitter	Odourless	6.04	980	27.9	656.6
KW04	Tasteless	Odourless	6.40	1635	28.2	1095.5
KW05	Clay	Earth	6.23	1388	28.5	930
KW06	Tasteless	Odourless	7.03	1255	27.9	840.9
KW07	Bitter	Mud	6.11	1403	29.2	940
KW08	Na	Stinking	6.58	916	27.1	613.7
KW09	Bitter	Odourless	6.26	1015	27.6	680.1
KW10	Bitter	Odourless	6.40	1303	27.5	873
KW11	Bitter	Odourless	7.05	1510	27.8	1011.7
KW12	Na	Grassy	6.68	1849	27.4	1238.8
KW13	Bitter	Grassy	6.88	425	26.6	284.8
KW14	Bitter	Odourless	5.91	221	26.7	148.1
KW15	Tasteless	Odourless	6.41	246	27.3	164.8
KW16	Tasteless	Odourless	6.14	376	27.6	251.9
KW17	Tasteless	Odourless	6.33	219	27.5	146.1
KW18	Tasteless	Odourless	6.64	1419	27.9	950.7
KW19	Tasteless	Odourless	6.62	1656	27.3	1109.5
KW20	Tasteless	Odourless	6.57	1826	28.0	1223.3
KW21	Tasteless	Odourless	8.08	283	27.5	189.6
KW22	Bitter	Odourless	8.93	818	27.2	548.1
KW23	Tasteless	Odourless	8.66	610	27.2	408.7

Table 3: Physical Test Result of water samples during the dry season

Sample No.	Taste	Odour	pH	Electrical conductivity(µS/cm)	Temp (°C)	TDS (mg/l)
KW01	Bitter	Cement	9.39	252	23.7	131.2
KW02	Tasteless	Odourless	7.49	1599	23.4	799.3
KW03	Bitter	Odourless	5.70	1005	23.9	522.7
KW04	Tasteless	Odourless	6.06	1633	26.2	821.4
KW05	Clay	Earth	6.27	1660	26.8	844
KW06	Tasteless	Odourless	6.94	1411	24.9	712.8
KW07	Bitter	Mud	6.03	1517	27.0	759.8
KW08	Na	Stinking	7.97	808	23.1	541.4
KW09	Bitter	Odourless	6.39	481	26.7	322.3
KW10	Bitter	Odourless	6.61	1707	24.8	1143.7
KW11	Bitter	Odourless	7.11	1582	24.2	1059.9
KW12	Na	Odourless	6.96	2008	25.5	1012
KW13	Bitter	Odourless	6.71	466	24.7	222
KW14	Bitter	Odourless	9.09	170	25.7	118.6
KW15	Tasteless	Odourless	6.07	183	26.7	119
KW16	Tasteless	Odourless	6.17	369	24.8	185.5
KW17	Tasteless	Odourless	5.87	254	25.5	121.3
KW18	Tasteless	Odourless	6.90	1480	26.8	744.4
KW19	Tasteless	Odourless	6.62	2073	27.2	1039.2
KW20	Tasteless	Odourless	6.43	2531	27.0	136.7
KW21	Tasteless	Odourless	6.41	426	26.3	285.4
KW22	Bitter	Odourless	6.71	468	24.4	313.6
KW23	Tasteless	Odourless	6.57	699	24.9	468.3

Table 4: Summary of Result of Chemical Analysis (dry season)

Sample no.	Parameters (mg/l)								
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^{-}	SO_4^{2-}	HCO_3^{-}	Fe^{2+}
KW03	38.1	47.2	79.3	21.4	212.6	4.8	0.9	19.2	0.08
KW08	65.6	20.4	83.0	39.0	148.9	27.7	38.7	33.7	0.14
KW09	36.5	10.7	58.0	12.0	114.6	20.6	13.0	9.9	0.06
KW10	72.9	71.1	143.0	8.0	436.5	39.8	88.1	11.0	0.14
KW11	33.4	214.4	101.0	12.0	253.1	28.2	76.3	10.2	0.07
KW17	20.9	23.1	20.0	11.5	61.7	12.2	1.4	7.4	0.12
KW21	38.5	34.3	37.0	19.0	62.5	9.1	31.0	27.0	0.16
KW22	29.2	37.4	38.0	18.0	56.6	7.6	44.1	31.3	0.08
KW23	27.1	17.2	60.0	42.0	169.7	6.7	19.4	14.7	0.00
NIS 554:2007	-	**0.2**	**200**	-	**250**	**50**	**100**	-	**0.3**
WHO, 2011	**75**	**30**	**200**	**12**	**200**	**25**	**200**	**250**	**0.1**

Table 5: Summary of Result of Chemical Analysis (wet season)

Sample no.	Parameters (mg/l)								
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^{-}	SO_4^{2-}	HCO_3^{-}	Fe^{2+}
KW01	10.4	27.8	22.5	16.7	16.3	0.53	2.8	205.5	0.00
KW02	16.8	57.1	60.5	34.8	122.3	3.76	44.0	229.0	0.01
KW03	8.8	58.1	56.0	15.4	195.7	1.59	0.9	21.0	0.023
KW04	3.24	122.5	69.5	36.8	228.3	36.48	3.5	13.5	0.032
KW05	10.4	126.4	51.0	8.71	203.8	3.23	4.4	9.0	0.00
KW06	19.2	83.0	63.0	16.7	187.5	2.70	7.0	11.5	0.01
KW07	12.8	124.4	54.5	7.37	228.3	5.36	5.1	13.5	0.045
KW08	7.2	77.6	46.0	29.5	97.8	4.25	5.2	13.5	0.01
KW09	2.4	70.3	46.0	12.7	71.2	0.00	4.3	6.0	0.00
KW10	5.6	108.3	66.0	5.36	236.5	42.90	6.0	5.0	0.00
KW11	10.4	118.1	66.5	26.8	171.2	3.76	7.4	12.5	0.032
KW12	4.0	11.2	64.0	24.1	277.2	5.36	8.3	10.5	0.021
KW13	10.4	33.18	73.0	5.36	16.3	1.60	3.9	6.0	0.021
KW14	8.8	7.32	20.5	2.66	89.7	0.00	0.5	11.0	0.037
KW15	7.2	17.1	15.0	2.68	106.0	2.12	2.4	12.0	0.00
KW16	4.8	23.4	17.0	4.69	16.3	2.70	1.2	14.0	0.03
KW17	5.6	16.1	22.0	2.68	8.15	2.12	1.4	7.0	0.012
KW18	2.4	83.9	9.5	48.2	236.5	2.92	7.5	16.0	0.043
KW19	6.4	147.4	68.5	34.4	228.3	6.42	7.5	6.5	0.044
KW20	8.0	151.3	64.5	36.8	375.1	3.23	6.9	12.5	0.02
KW21	28.1	14.1	40.5	16.0	35.5	10.3	27.0	35.5	0.29
KW22	61.7	28.1	72.9	35.2	106.4	27.9	43.1	42.9	0.30

KW23	60.1	14.3	56.7	42.6	97.5	0.53	12.0	37.0	0.11
NIS 554:2007	**-**	**0.2**	**200**	**-**	**250**	**50**	**100**	**-**	**0.3**
WHO:2011	**75**	**30**	**200**	**12**	**200**	**25**	**200**	**250**	**0.1**

Table 6: Result of Microbiological analysis (wet season)

Sample no.	**Parameters (cfu/100mL)**	
	Total coliform count	Escherichia coli
KW01	23	6
KW02	27	1
KW03	44	19
KW04	32	1
KW05	43	8
KW06	28	1
KW07	19	1
KW08	13	0
KW09	32	1
KW10	24	0
KW11	43	2
KW12	29	1
KW13	37	2
KW14	19	0
KW15	21	1
KW16	34	2
KW17	41	19

KW18	18	0
KW19	14	0
KW20	34	3
KW21	41	0
KW22	44	0
KW23	32	0
NIS:2007	**10**	**0**
WHO, 2011	**10**	**0**

Table 7: Result of microbiological analysis (dry season)

Sample no.	**Parameters**			
	Total coliform count (cfu/100mL)	Escherichia coli (cfu/100mL)	Chemical Oxygen Demand (COD) (mg/L)	Biochemical Oxygen Demand (BOD) (mg/L)
KW03	40	3	18	11
KW08	31	0	33	13
KW09	51	2	47	19
KW010	67	3	84	34
KW011	61	1	74	30
KW017	34	6	13	09
KW021	41	0	54	22
KW022	44	1	53	21
KW023	32	0	34	14

NIS 554:2007	**10**	**0**	**-**	**-**
WHO, 2011	**10**	**0**	**-**	**-**

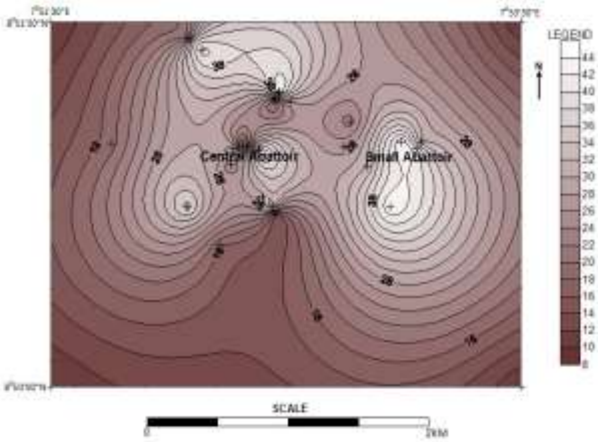

Figure 19: Coliform bacteria concentration in groundwater

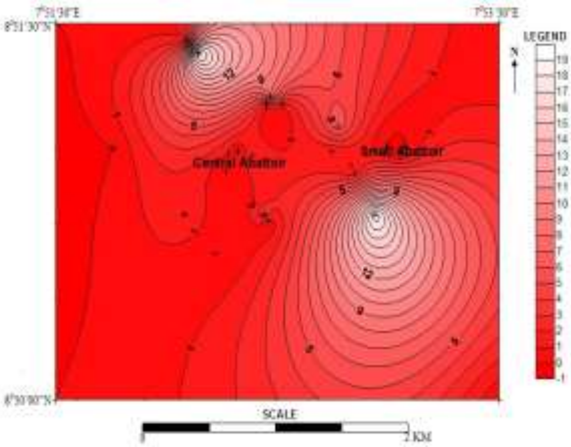

Figure 20: Escherichia coli concentration

Conclusion

The study is on the effect of abattoir activities on the groundwater of part of Keffi, North-central Nigeria using geological, geophysical, hydrogeological, geochemical and microbiological baseline data and the following conclusions were derived:

1. Geologically, the study area is characterized by three (3) major outcrops; migmatite, schist and phyllites with intrusions of pegmatite, quartz and aplite veins.

2. Geophysical investigation result revealed the existence of three (3) geo-electric layers and irregular weathering front with depth to bedrock that ranges between 9.54m to 33.65m.
3. Water levels in the wells have positive correlation with amount of rainfall in any particular month and that migmatite rocks are more water bearing than schistose rocks of the study area.
4. The results of the physical, chemical and microbiological parameters tests during the wet and dry seasons when compared with water quality standards provided by Nigerian Industrial Standard (NIS 554:2007) and World Health Organisation (WHO, 2011) showed that a number of individual samples have some parameters with high concentrations above the maximum permissible limits and as such considered not safe for human consumption. Also dilution effect was visible as all the parameters recorded higher values during the dry season with the exception of magnesium and Escherichia coli only.
5. Effect of the abattoir on groundwater was well established using a contour map of the concentrations of the various parameters. It was seen that the abattoir activities influenced the levels/concentrations of Electrical conductivity, total dissolved solids (TDS), calcium, sodium, potassium, nitrate, sulphate, iron and coliform count and that the smaller abattoir has greater effect on groundwater than the central abattoir. There was also high organic pollution around the abattoirs as revealed by Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) tests conducted.

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