2D Resistivity Imaging And Hydrochemical Analysis of Groundwater Contamination Induced By Abattoir Wastes at Atenda, Southwestern Nigeria

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Abstract: The extent of groundwater contamination induced by abattoir wastes and effluent at Atenda in Ogbomosho Nigeria was mapped using 2D electrical resistivity imaging and hydrochemical analysis. The area was mapped along four N - S traverses established around the abattoir wastes dump site using dipole-dipole array with the aid of Campus ohmega (Ω) Terrameter. Water samples were also collected from eight hand-dug wells in the vicinity of the abattoir and analyzed for temperature, pH, conductivity, color, Cl^-, Ca^{2+}, Mg^{2+}, Fe^{3+}, nitrate, nitrite, phosphate, calcium hardness, total hardness, total alkalinity, turbidity, and dissolved oxygen (DO). The resistivity survey results yielded low resistivity values below the waste dump site along traverse 2 and along traverses 3 and 4 which were established outside the waste dump site. Similarly, low resistivity values were observed along traverse 1 toward the abattoir waste dump site. Resistivity values increase with distance away from the abattoir waste dump site indicating reduction in amount of leachates away from the dump site. The results of the hydrochemical analysis also indicated the presence of contamination as established by the geophysical survey.
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1. Introduction

Abattoirs are generally known all over the world to pollute the environment either directly or indirectly (Adelegan, 2002; Osibanjo and Adie (2007)). This has mostly been in connection with the slaughtering processes and the means of disposing the generated wastes. Wastes generated by abattoirs include solid and liquid wastes (mostly paunch content, bones, horns, fecal components, slurry of suspended solids, fat, blood and soluble materials) (Sangodoyin *et al*. 1992; Bello and Odeyemi, 2009).

Depending on conditions like the age, rate of water infiltration, local geology, pH and climatic condition of an abattoir waste dump site, ground water may become contaminated if the chemical contaminants associated with this wastes dissolve in water, and percolated into the aquifer. One geophysical technique that has proven very useful in mapping the composition, structure and nature of the subsurface is electrical resistivity imaging. It has provided an appreciable tool for delineating the degree and extent of contamination owing to the resistivity contrast between the contamination zone and the immediate subsurface vicinity (Enikanselu, 2008). The technique is both fast, and economical in delineating ground water contamination, as well as other environmental issues. Though the technique is not used to directly detect contaminants, it is used in the imaging of the geological environment through which the contaminants move thereby allowing the detection and distribution of any possible contaminant. It is however, more effective to complement this geophysical technique with hydrochemical analysis (Kayabali *et al*., 1998; Olayinka and Olayiwola, 2000).

Groundwater contamination has been suspected in the hand-dug wells by the inhabitants in the vicinity of Atenda abattoir in Ogbomoso North Local Government area of Oyo State, Nigeria.

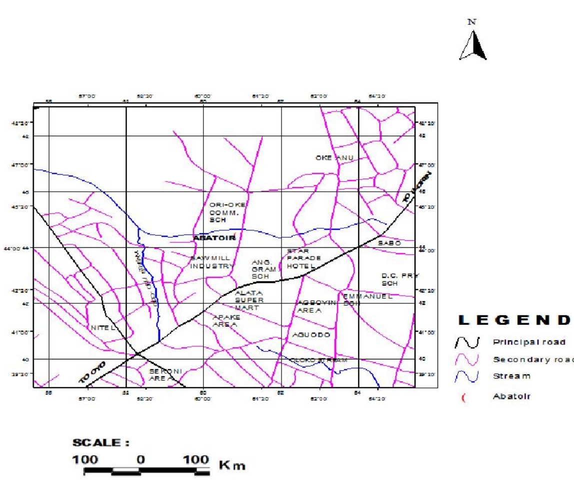

Figure 1.0: Location Map of the study area.

At Atenda abattoir like every other abattoir in Nigeria, wastes generated are directly disposed behind the slaughter house and the effluents are discharged through an outlet to the nearby stream. This has been the usual method of disposing this abattoir wastes right from its existence. The investigation carried out revealed that the Atenda abattoir had been in operation for more than twenty-eight years. Thus, some level of environmental impact is expected. This study was therefore carried out to trace or attribute the source of the contamination in the surrounding hand-dug wells (which constitute about 90% of water sources for domestic and irrigation purposes) of Atenda abattoir to the leachates emanating from this abattoir wastes and effluent.

2. Location of Study Area

The study area is located in Ogbomoso North Local Government Area of Oyo State, Southwestern Nigeria which lies between longitudes 04^{o}1’5741”E and 04^{o}14’534”E and latitudes 8^{o}8’693”N and 08^{o}08’712”N (Figure1.0). Ogbomoso covers an area of about 3600 square meters and has a seasonal climate characterized by two major seasons in a year (rainy/wet and dry season).

3. Methods and materials used for the study

3.1. Electrical Resistivity Imaging

In this study, dipole-dipole field array was employed. Data was acquired with the aid of Campus Ohmega (Ω) Terrameter along four traverses established in the N-S direction (Figure 2.0).

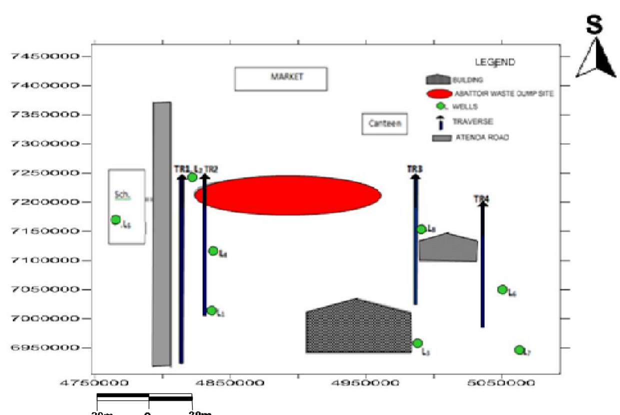

Figure: 2.0: Survey plan showing locations of sampled wells and Traverse lines.

An inter-electrode spacing of 5m was adopted while inter-dipole expansion factor (n) was varied from 1 to 5. The dipole-dipole data was inverted using the DIPRO software and the result was presented as pseudosections.

2.2 Hydrochemical Analysis:

Water samples were collected from eight hand-dug wells around the dumpsite all of which are approximately 5m deep and taken to the laboratory for hydrochemical analysis. The Samples were analyzed for temperature, color, PH, conductivity, chloride (Cl^-), iron (Fe^{3+}), nitrate (NO_3^-), calcium hardness, magnesium (Mg^{2+}), calcium(Ca^{2+}), total hardness, total alkalinity, nitrite (NO_2^-), turbidity and dissolved oxygen (DO). The methods and procedure of the analysis were those developed by the American Public Health Association (APHA, 1995, 2000) and Interpretation of the hydrochemical analysis was done by plotting various standard values of certain ion concentration against the sampled values.

4. Analysis and Discussion of Results

4.1 Resistivity Data

Figures 3.0, 4.0, 5.0 and 6.0 show the pseudosections generated along traverses 1, 2, 3, and 4 respectively.

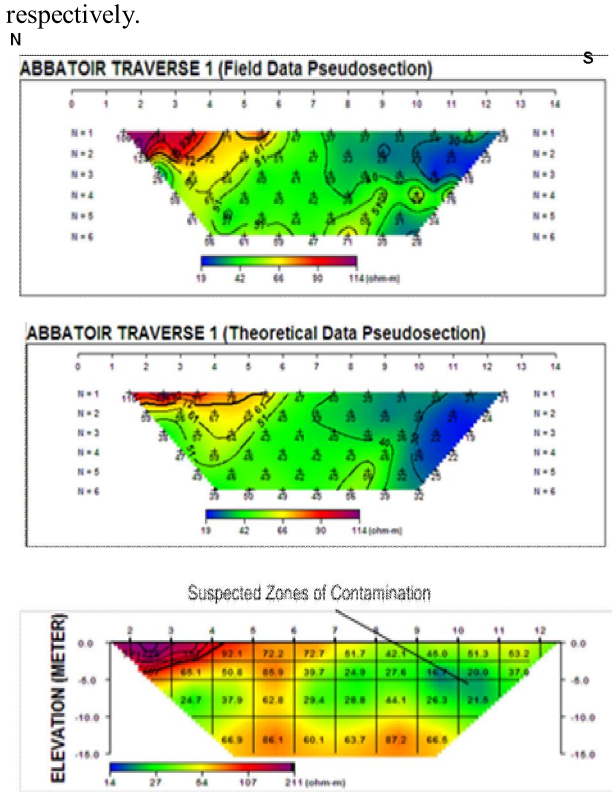

Figure 3.0: The inversion model along traverse one: (A) Field Data Pseudo section (B) Theoretical Data Pseudo section (C) 2-D resistivity structure.

The results for traverse one show resistivity values as high as 228Ωm near the surface from electrode positions 1 to 7, but at the electrode positions 8 to12, resistivity values were low with a significantly low resistivity value of about 16.7Ωm at a depth of about 4.5m toward the Southern portion of the traverse. Also at depth intervals between 10 and 15m, high resistivity values were observed in all the electrode positions.

The inversion model section for traverse two showed that resistivity values are generally low in all the electrode positions. At the electrode positions 2 to 4 in the northern portion of the traverse, resistivity values are significantly low to about 6.68Ωm. Similarly, significantly low resistivity values were observed at the electrode positions 5 to7 in the Southern portion of the traverse with the lowest value reading about 7.12Ωm.

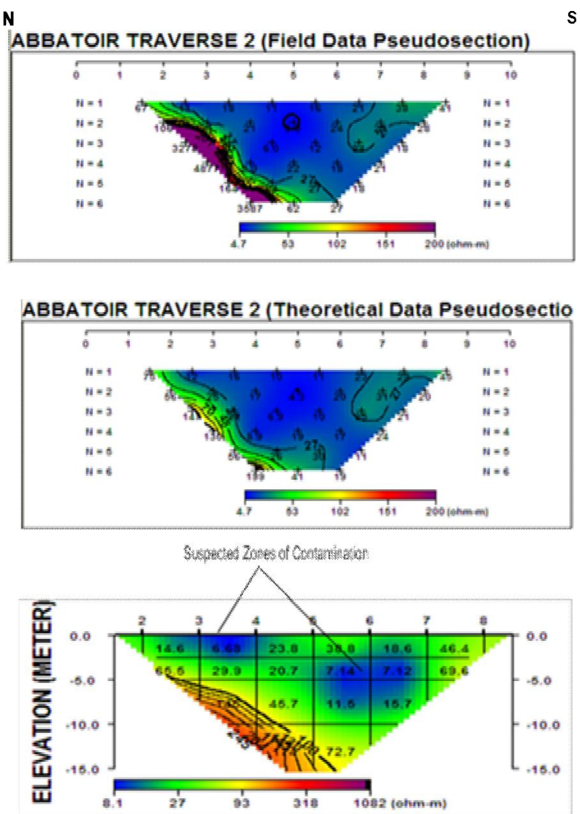

Figure 4.0: Inversion model sections for traverse Two: (A) Field Data Pseudo section (B) Theoretical Data Pseudo section (C) 2-D resistivity structure.

The result for traverse three show low resistivity values near the surface laterally in all the electrode positions. At the electrode positions 1 to3 in the northern end of the traverse, resistivity values are significantly low reading about 13.2Ωm. A significantly low resistivity values was also observed at the electrode positions 4 to 6 with the lowest value being 8.87Ωm. It was also observed that the resistivity values increase right from about 5.1m below the surface, showing a maximum value of 187Ωm at a depth of almost 15m in all the electrode positions.

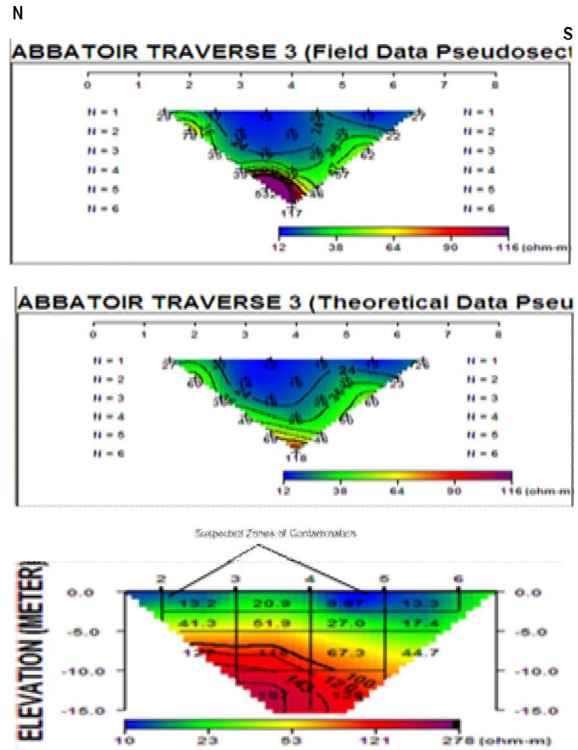

Figure 5.0: Inversion model sections for traverse Three: (A) Field Data Pseudo section (B) Theoretical Data Pseudo section (C) 2-D resistivity structure.

Figure 6.0 show high resistivity values at the electrode positions 1 to 6 toward the northern end of the traverse near the surface laterally to about 135Ωm. But at the electrode positions 6 to 8, significantly low resistivity values (29.2Ωm) were observed toward the Southern portion of the traverse. Furthermore, low resistivity values with depth were observed toward the Southern end of the traverse. These low values in resistivity further continue with depth toward the Northern end of the traverse. The low resistivity values observed at the electrode positions 8 to 12 on traverse one can be attributed to the presence of leachates emanating from the abattoir wastes dump site. While the high resistivity values observed at the electrode positions 1 to 7 toward the Northern end of the traverse may be associated with decrease in solute concentrations from the abattoir waste dump site. This showed that resistivity values of the pore-water increase with distance away from the abattoir waste dump site toward northern end of the traverse. The high resistivity values also observed at depth intervals between 10 and 15m may therefore be associated with zones unaffected by the abattoir wastes. An anomalously high resistivity value was also observed on the field data pseudo section between electrode positions 4 and 5 along traverse 4. This can be attributed to the presence of lateritic hard pan on that portion of the traverse values resulting in the highly conductive zones.

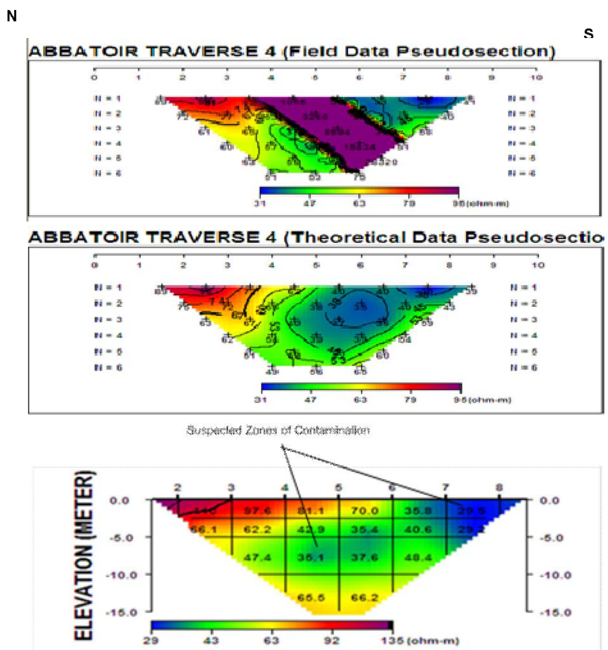

Figure 6.0: Inversion model sections for traverse 4; (A) field data pseudosection, (B) theoretical data pseudosection, and (C) 2D resistivity structure.

The significantly low resistivity values along traverse two may be due to presence of contamination emanating from the abattoir waste dump site and which have percolated through the subsurface and infiltrated the groundwater. These also indicate contaminant plumes with lateral extent of about 7.5m and 6m, and vertical extent of about 2.5m and 6m below the surface respectively. This is most likely the case because these highly conductive zones were observed directly below the abattoir wastes dump site along the traverse.

The significantly low resistivity values at electrode positions 1 to 3 and 4 to 6 along traverse three can also be associated with zones of contamination resulting from leachates emanating from the abattoir wastes dump site, with lateral extent of about 7m and 10m, and vertical extent of about 2.2m and 2.6m below the surface respectively. The increase in resistivity values in all the electrode positions right from about 5.1m below the surface with depth to a maximum value of about 187Ωm along traverse three can therefore be associated with zones unaffected by the leachates. The high resistivity values at the electrode positions 1 to 6 along traverse four may be associated with regions unaffected by the leachates, while the significantly low values in resistivity at the electrode positions 6 to 8 also along this traverse may be connected with the presence of leachates emanating from the abattoir wastes dump site. The presence of contamination resulting from the abattoir waste dump site might have therefore reduced the pore-water resistivity.

4.2: Comparison of 2D resistivity structure along all four traverses

A Comparison of the results obtained along the four traverses (Fig.7.0) further showed that the pore-water resistivity values increase with distance away from the abattoir waste dump site. This was mainly observed in traverses 1 and 4.

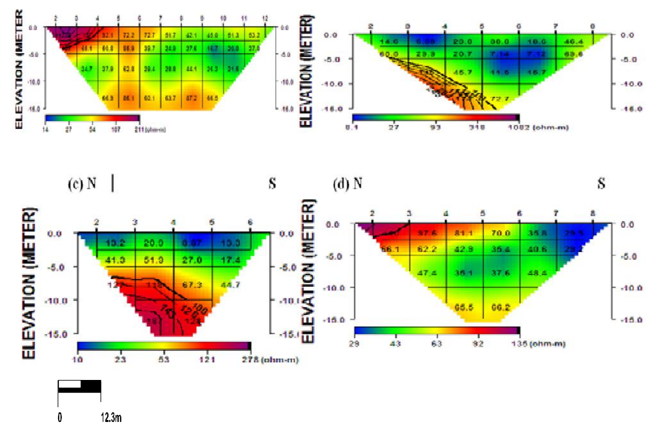

Figure 7.0: Comparison of 2D resistivity structure along all four traverses.

4.3 Hydrochemical Analysis

The results of the laboratory analyses of water samples obtained in the vicinity of the abattoir are shown in table 1.0.

Electrical Conductivity: The electrical conductivity values range between 543μS/cm and 136μS/cm. From this result, sample L_3 has the highest conductivity value and sample L1 has the lowest value. The higher the conductivity the higher the total dissolved solids (TDS) and the mineralization possibility of the groundwater. Therefore, wells L3, L4, and well L8 which have higher electrical conductivity than others can be attributed to their closeness to the abattoir wastes dump site. This high value obtained indicates a high possibility that the leachates from the abattoir wastes have polluted the ground water.

Turbidity: The turbidity varies across the analyzed samples with sample L_2 having the highest turbidity value of 34 PCU, followed by L_8 with a value of 21 PCU. Sample L_7 has the lowest turbidity value of 09 PCU. Generally, the turbidity values of analyzed samples are higher than the Nigeria Industrial Standard (NIS) limits. Turbidity is associated with suspended solids concentration. It has been observed that the size and concentrations of particles influenced the measurement of turbidity. In this study area, most of the surrounding wells tap their groundwater from the lateritic clays. These may have led to the high values of the suspended solids in the sampled waters and thereby increasing the turbidity.

PH: The pH for the sampled water lies within the standard NIS level of 6.5 – 8.5 with the exception of samples from wells L_6 and L_2 which are below the NIS limits. Migration of different cations and anions are influenced by different pH level. These pH values for the analyzed samples indicate that the water samples are acidic in nature. This acidic nature of the water may be due to the high presence of acidic materials in the subsurface that are emanating from the abattoir wastes and effluent into the surrounding wells.

Table 1.0 Summary of results obtained from water samples in comparison with Nigeria Industrial Standards (NIS) for drinking water.

Parameters determined	NIS Limits	Well L1	Well L2	Well L3	Well L4	Well L5	Well L6	Well L7	Well L8
Temperature	-	34	34	33	34	33	34	34	34
pH	6.5-8.5	6.65	6.49	6.59	6.68	6.66	6.25	6.73	6.62
Conductivity	-	136	242	543	376	240	193	301	308
Colour	5	85	90	72	84	68	64	54	70
Chloride	-	18	24.5	9.0	1.5	12	17.0	15.0	30.0
Iron3+	0.03	0.24	0.41	0.36	0.39	0.21	0.32	0.28	0.35
Nitrate	10	24	38	20	15.3	27	19	17	41
Calcium hardness	75	82.5	93.7	97.0	61.9	68	69	84	113.4
Magnesium	0.20	26.3	31.3	25	19	15	13	10	18
Calcium	75	27.5	31	32	24.7	22.6	26	28	37
Total hardness	100	110	125	128	86	100	92	115	224
Total Alk.	200	38	24	56	58	46	56	6.0	48
Nitrite	0.02	0.02	0.18	0.03	0.06	0.15	0.08	0.15	
Phosphate	100	15	28	16.9	24	22.6	16.4	10	26
Turbidity	5	22	34	19	20	15	12	09	21
DO	-	5	580	195	52	15	3	128	130

Chloride: Though there was no NIS desirable limit for laboratory analysis of chloride ion concentration, the concentration in samples vary appreciably from one another. Well L_8 has the highest value of Cl^- while L_7 has the lowest value. This variation in the chloride concentration of the surrounding wells may be due to the presence of NaCl and KCl from blood discharged into the effluent; salt from kitchen dishes in the canteens and salt used in skin processing (Lawal and Mahielbwala, 1992). The variation in their proportion in these surrounding wells can also be attributed to their relative closeness to the source of the contaminant.

Nitrate (NO_3^-): The trend of nitrate ion concentrations varied comparatively in the sampled wells. Sample L_8 has the highest concentration (41 mg/l), followed by sample L_2 with L7 having the lowest concentration of nitrate. All the samples have nitrate ion values higher than the Nigeria Industrial standard (NIS) desirable limit for nitrate. This high value in nitrate may be associated with the oxidation of other forms of nitrogen compounds like ammonia and nitrite to nitrates. These sources of nitrates are mainly from animal wastes and sewage systems. Therefore, the higher concentration observed in the wells closer to the abattoir may be due to their closeness to the abattoir wastes and effluent.

Nitrite: The nitrite concentrations observed in the sampled wells are above the NIS limit except for well L_1 which lies within the NIS limit. Well L_2 has the highest nitrite value while L_1 has the lowest. The source of nitrite is traceable to denitrification of nitrate (usually present in abattoir wastes and effluent) to nitrite. The higher concentration observed in some of the wells closer to the abattoir may be due to the leachates from the abattoir wastes percolating into the groundwater.

Iron (Fe^{3+}): The iron concentration in the wells sample varied comparatively. Sample L_2 has the highest iron concentration of 0.41 mg/l against the Nigeria Industrial standard of 0.03mg/l, while L_5 has the lowest concentration of iron. All the samples have ionic concentration above the Nigeria Industrial Standards (Table 1.0). The higher concentration of iron was found more in the sampled wells that are closer to the abattoir (e.g. L_2, L_3, and L_8). This may be as a result of iron contents in the abattoir wastes which may have percolated into the surrounding groundwater. This can also be due to the fact that these wells are tapping their ground water from the lateritic soils which contain more of iron rich mineral.

Calcium Hardness: The calcium hardness of the water samples vary appreciably from one well to another. Samples L_8 and L_3 have relatively high values of 113.4 and 97.0mg/l, and samples L_4, L_5 and L_6 have values below NIS recommended level.

Calcium: Generally the entire sampled wells have calcium concentration below the desirable level of NIS. This can be related to the wastewater mixing with fresh water. Although the concentration of the calcium ion in the sampled wells is lower than the NIS recommended level, there is a decrease in the trend away from the abattoir site.

Magnesium: All samples have high magnesium content as compared with NIS recommended limit. L_1 has the highest value of magnesium with value of 26.3mg/l, while L_7 has the lowest value of 10mg/l. The high magnesium content can be attributed to high clay content of the top soils in the vicinity of the abattoir. Another source may be from bones and horns of the carcasses.

Total Hardness: Generally, the total hardness is high relative to the NIS limit. Sample L_8 has the highest value of 224mg/l, and well L_5 has the exact desirable limit recommended by NIS. Generally, the trend is that sample L_8>L_3>L_2>L_7>L_1 >L5>L6>L4. Total hardness is as a result of the presence of Ca2+ and Mg2+ in the groundwater. This variation in total hardness may have resulted from the distance of each well from the abattoir wastes dump site. In contrary to the above, sample L_4 and L_6 have concentration below the NIS recommended level and this may be due to low concentration of Ca2+ and Mg2+ in the wells.

Total Alkalinity: The concentration of total alkalinity in the sampled wells is low compared to the NIS recommended limits. This shows that the ground water in the study area is acidic in nature and this can be attributed to acidic materials emanating from the abattoir wastes contaminating the surrounding wells in the vicinity of the study area.

Phosphate: Phosphate values ranged from 10 – 26 mg/l. Though these values are lower compared to the NIS limits, the trend shows that wells that are closer to the abattoir have higher values which could be due to the fact that much detergent is often used to wash the roasted carcass and this might have found its way to the groundwater through percolation. Other possible sources could be human activities requiring use of detergents.

4. Conclusion

In this work, the results of geoelectrical imaging and hydrochemical analysis for environmental impact of Atenda abattoir are presented. The resistivity survey results yielded low resistivity values below the waste dump site along traverses two, three and four. Similarly, low resistivity values were observed along traverse one. These low resistivity values were attributed to the presence of contamination as a result of the leachates emanating from the abattoir wastes dump site. Resistivity values increase with distance away from the abattoir waste dump site indicating reduction in amount of leachates away from the dump site. The results of hydrochemical analysis also agreed with the result of the geoelectrical imaging on the presence of contamination. The results of this study have established that the source of the contamination of the water in the surrounding wells in the vicinity of study area is the abattoir waste dump site. These have therefore demonstrated the effectiveness of integrated geophysical and hydrochemical analysis in environmental impact assessment.

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