THE IMPACT OF INJECTION WELLS ON GROUNDWATER QUALITY IN THE GOVERNMENT RESERVED AREA OF BENIN CITY, SOUTHERN NIGERIA.

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Abstract

Injection wells, in this case, are sinkholes that are dug and constructed to control flooding. This research encompasses investigations of groundwater to determine the impact of injection wells on the quality and to ascertain the levels of inorganic chemicals and microbial contaminants. Thirteen water samples were collected from the area of study, consisting of ten (10) from boreholes and three (3) from the injection wells. The water samples collected were taken to the Laboratory for physicochemical analyses using the Atomic Absorption Spectrophotometer (AAS). Some of the parameters analyzed were pH, TDS, hardness, and heavy metals. The biological parameter mainly includes coliform count. The result of the analysis indicated that whereas the groundwater contains low levels of inorganic chemical contaminants (except for Lead which has values for both boreholes and injection wells that are above permissible limits when compared to the SON and WHO standards), the coliform count and pH were high. It is therefore recommended that the practice of the use of injection wells to control flooding in the study area or anywhere should be discouraged to reduce the chances of leachates percolating into the water table, and instead a better alternative should be the construction of proper drainage routes/systems in the study area.

Keywords: Injection wells, boreholes, coliform counts, physicochemical

1.0 INTRODUCTION

Groundwater is the most widely valuable natural resource in the world. It is known to occur within the earth's sediments, rocks, or sand formations. The occurrence and distribution of this natural resource are restricted to some geological formations and structures called aquifers. An aquifer is explained as a subsurface formation that is capable of storing and transmitting water at a pace fast enough to provide sufficient quantity to wells (Fetter, 2007). The presence of water in a formation does not in any way imply that the water quality is good enough for domestic consumption, except that the formation is properly sealed by a non-porous formation. The quality of groundwater that is ingested by humans and animals is very important. Water quality is determined by the solutes and gases dissolved in the water, as well as the matter suspended in and floating on the water. Water quality is a consequence of the natural physical and chemical state of the water as well as any alterations that may have occurred as a consequence of human activity. The usefulness of water for a particular purpose is determined by the quality. If human activity alters the natural water quality so that it is no longer fit for the use for which it had previously been suited, the water is said to be polluted or contaminated. Water pollution is defined as the presence in groundwater of toxic chemicals and biological agents that exceed what is naturally found in the water and may pose a threat to human health and/or the environment (Environmental Pollution Centers, 2021).

Contamination denotes impairment of water quality by chemical or bacterial pollutants to a degree above the acceptable limit but not necessarily enough to create immediate hazards to public health. The attenuation of a pollutant as it enters and moves through the ground occurs as a result of biological, chemical, and physical processes. Hence, the self-cleansing capacity of a soil or rock aquifer system depends on the physical and chemical attributes of the pollutant, the nature of the soil or rock comprising the aquifer, and how the pollutant enters the ground. In general, the concentration of a pollutant decreases as the distance it has travelled through increases. However, the slow rate of travel of pollutants in underground strata means that a case of pollution may go undetected for many years. The form of pollutants is an important factor concerning its susceptibility to the various purifying processes. For instance, pollutants that are soluble, such as fertilizers and some industrial wastes, cannot be removed by filtration. Metal solutions may not be susceptible to biological action. Solids, on the other hand, are amenable to filtration, provided that the transmission media are not coarse-grained, fractured, or cavernous. Karst or cavernous limestone areas pose particular problems in this respect. Insoluble liquids such as hydrocarbons are generally transmitted through porous media, although some fraction may be retained in the media. Usually, however, the most dangerous forms of groundwater pollution are those that are miscible with water in the aquifer.

Concentrated sources of pollution are most undesirable because the self-cleansing ability of ground in that area is likely to be exceeded. As a result, the raw pollutant may be able to enter an aquifer and travel some considerable distance from the source before being reduced to a negligible concentration. A much greater hazard exists when the pollutant is introduced into an aquifer beneath the soil horizon since the powerful purifying processes that take place within the soil are bypassed and attenuation of the pollutant is reduced. This is most critical when the pollutant is added directly to the zone of saturation because, in most soils and rocks, the horizontal component and permeability usually is much greater than the vertical one. Consequently, a pollutant can then travel a much greater distance before significant attenuation occurs. It generally is assumed that bacteria move at a maximum rate of about two-thirds of the water velocity. Since most groundwater only moves at the rate of a few meters per year, the distances travelled by bacteria are usually quite small and, in general, it is unusual for bacteria to spread more than 33 m from the source of the pollution. However, Brown et al. (1972) suggested that viruses are capable of spreading over distances that exceed 250 m, although 20 to 30 m may be a more typical figure. Of course, in porous gravel, cavernous limestone or fissured rock, bacteria and viruses may spread over distances measured in kilometers.

Groundwater quality in a region is largely determined by natural processes such as lithology, groundwater speed, and quality of reloaded water, the interaction of water with soil components and rock, and interaction with other types of aquifers. It is also affected by anthropogenic activities such as agriculture, industry, urban development and increasing exploitation of water resources and atmospheric input (Helena et al. 2002; Chan 2001). The widespread use of chemical and organic pesticides or herbicides is another possible source of groundwater contamination (World Health Organization, 2006).

Previous studies have shown possible contamination of groundwater in Benin City. Imeokparia and Offor (1992) observed high levels of iron (Fe), lead (Pb), nickel (Ni), manganese (Mn), and copper (Cu) in Ogba and Ikpoba Rivers in Benin City. Imasuen and Omorogieva (2013) established that the increasing population in the metropolitan town of Benin City has a direct impact on the heavy metal concentration in the environment. Omorogieva and Andre-Obayanju (2020) concluded that leachates were the source of groundwater pollution in Ikhueniro area of Benin City. This is probably because Benin City is seating on the Benin formation of the Niger Delta which is made up of continental flood plain sands and alluvial deposits (Short and Stauble, 1967).

Isokpehi *et al*, (2019) working on microorganisms association in gymnasium centers in Lokoja reported that Staphylococcus aureus causes hospital and opportunistic infections while some Bacillus sp. are resistant to disinfection and can thrive in most environments due to their spore formation. These bacterial species are considered to be non-pathogenic but have occasionally been isolated from cases of conjunctivitis, meningitis, pneumonia, and sepsis (Brooks et al., 2010).

The area of study been an urbanized one has ample boreholes (with average depths to water is about 44 meters) and the presence of three (3) known injection wells (with depths somewhat over 22 meters) having injection fluids that might be a threat to the quality of the groundwater in the area. Based on the aforesaid, water samples were collected from boreholes surrounding the injection wells, with the nearest and farthest boreholes having a distance of 171 meters and 1.7 kilometers respectively from an injection well.

This research, therefore, aims to investigate the levels of inorganic chemicals and microbial pollutants in the boreholes within the Government Reserved Area (G.R.A), metropolitan city of Benin, Southern Nigeria, to ascertain if it is potable while also investigating the role of injection wells in the contamination of groundwater of this area.

2.0 MATERIALS AND METHOD

The methods involve three (3) stages, which are:

3.1 Field Work / Sample Collection

The fieldwork was carried out within the area of study which is the Government Reserved Area (G.R.A), Benin City, and is specifically bounded by latitudes 6º17’52’’N, 6º19’18’’N and longitudes

5º36’26’’E, 6º36’05’’E. Benin City is underlain by sedimentary Benin Formation described in Short and Stauble (1967).

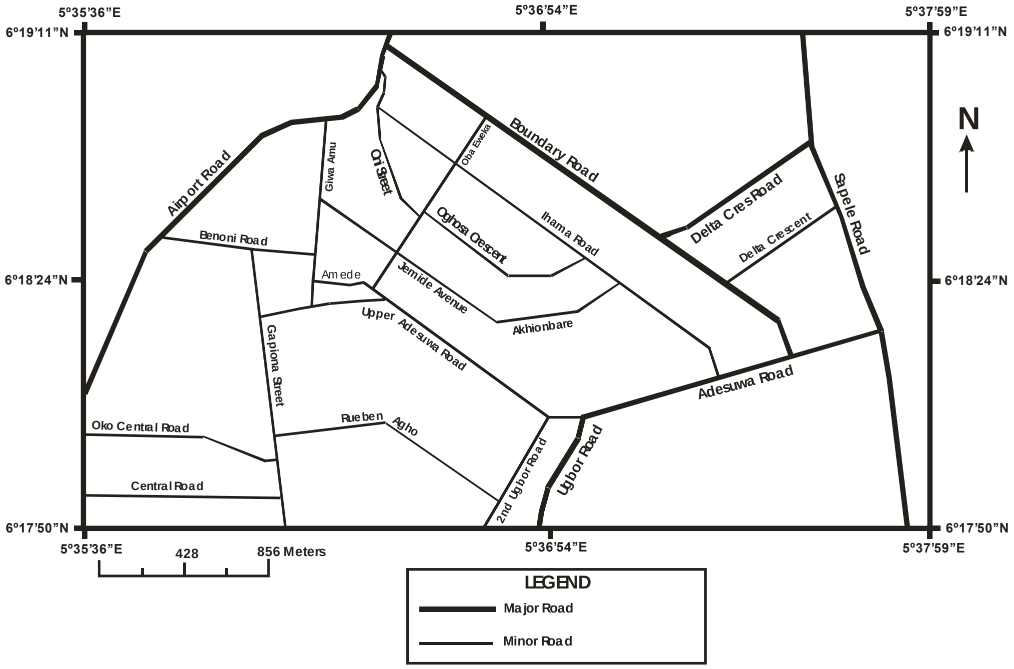


Figure 1: Study Area and Accessibility Map

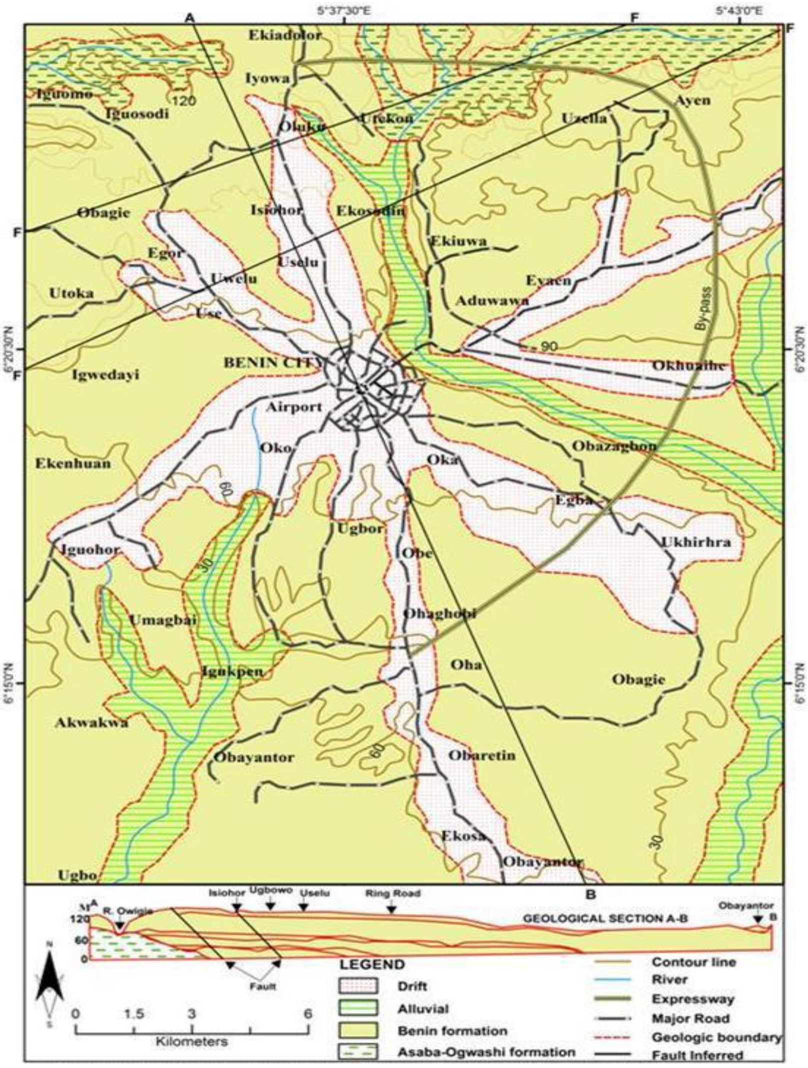


Figure 2: Geological Map of Benin City and Environs (Akujieze, 2014)

A total of thirteen (13) water samples were collected, consisting of ten (10) water samples from ten (10) boreholes and three water samples from three (3) injection wells. These were properly labelled and sent to the laboratory for analysis.

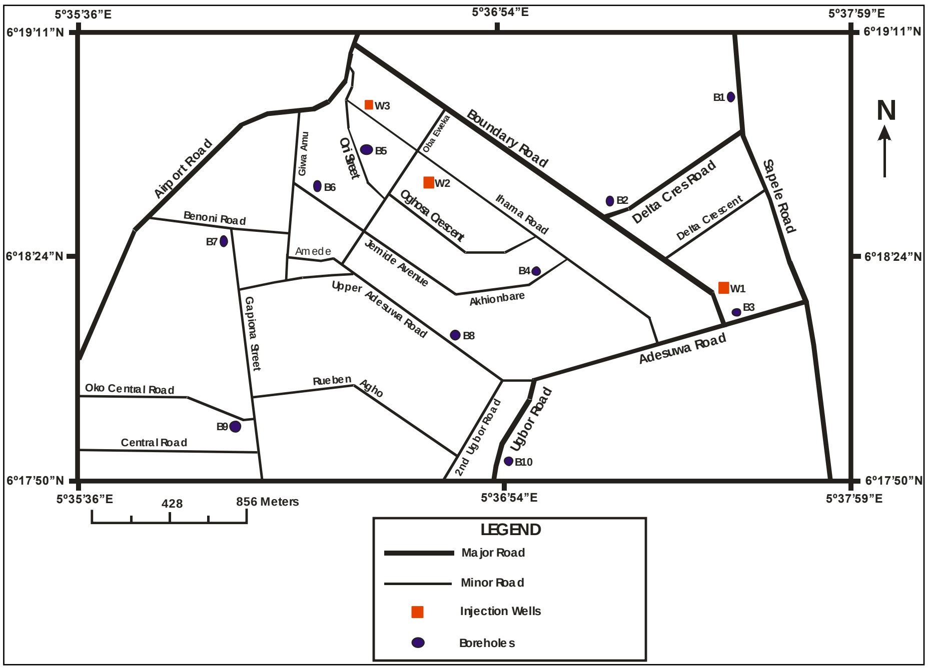


Figure 3: Map of Sample Locations

The water samples collected were analyzed at Benin-Owena River Basin/University of Benin Joint Analytical Research Laboratory. Representative water samples collected in plastic containers were subjected to series of laboratory analyses which include determination of metals for water samples using Atomic Absorption Spectrophotometer, Physicochemical analysis, and standard methods for the examination of water and wastewater samples.

RESULTS

Interpretation is done with the data obtained from the analysis carried out. Inferences were made on the concentration of certain parameters as compared to the World Health Organization (WHO) and Standard Organization of Nigeria (SON) standards were arrived at.

Also, the values for selected parameters such as TDS, pH, coliform count, iron, etc. are placed on the sample location map and then contoured, to attain an Isochem Map. It is a map that connects or joins places of the same or equal chemical characteristics. The isocherm map is also known as the concentration map, and it is used to know the spread of the concentration of the selected parameter in the area of study.

Table I: Selected chemical properties of the water samples

PARAMETER	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BH10	W 11	W
pH	6.0	5.2	5.6	4.5	4.2	3.7	3.9	3.9	3.9	4.0	6.0	6
Colour (Pt. Co)	0	0	0	9	0	0	0	0	0	0	513	3
Conductivity (µS/cm)	70	10	40	40	60	40	50	30	30	30	30	2
Suspended Solid	2	3	1	6	1	4	0	3	2	2	145	1
Total Dissolved Solids	37.1	5.3	21.2	21.2	31.8	21.2	26.5	15.9	15.9	15.9	15.9	1
Turbidity (NTU)	0	2	0	0	0	0	0	0	0	0	226	1
Chloride	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	2
Sulphate	4	1	7	3	1	3	3	3	2	2	54	4
Nitrate	9.6	3.1	12.0	6.2	3.1	6.2	12.0	12.0	12.0	6.2	12.8	7
Bicarbonate	0	0	0	0	0	0	0	0	0	0	0	0
Carbonate	0	0	0	0	0	0	0	0	0	0	0	0
Hardness	8	8	12	12	20	10	12	6	8	8	36	2
Calcium	2.80	1.60	1.60	3.21	7.21	1.60	4.0	1.60	2.40	1.60	13.63	9
Magnesium	0.49	0.97	1.95	0.97	0.49	1.46	0.49	0.49	0.49	0.97	0.49	0
Lead	0.029	0.016	0.023	0.043	0.052	0.032	0.018	0.023	0.015	0.033	1.212	1
Iron	0.176	0.172	0.216	0.416	0.127	0.118	0.246	0.154	0.276	0.186	0.342	2
Copper	0.056	0.029	0.038	0.022	0.025	0.066	0.028	ND	0.019	0.072	0.158	0
Sodium	5.40	5.812	5.440	5.540	4.441	4.620	6.620	4.360	3.680	5.360	10.530	8
Chromium	0.004	0.002	0.001	0.002	0.002	0.003	0.001	0.003	0.001	0.002	0.117	0
Zinc	0.326	0.113	0.132	0.127	0.108	0.223	0.142	0.247	0.141	0.136	4.223	4
Coliform	1.6×10^{4}	7.5×10^{3}	2.1×10^{4}	8.0×10^{3}	5.2×10^{3}	2.0×10^{3}	8.0×10^{3}	5.2×10^{3}	2.0×10^{3}	3.1×10^{3}	2.2×10^{4}	2 0
Ecoli	0	0	0	0	0	0	0	0	0	0	0	0

*All units are in mg/l except otherwise mentioned.

BH – Borehole
W – Well
SON – Standard Organisation of Nigeria
WHO – World Health Organisation

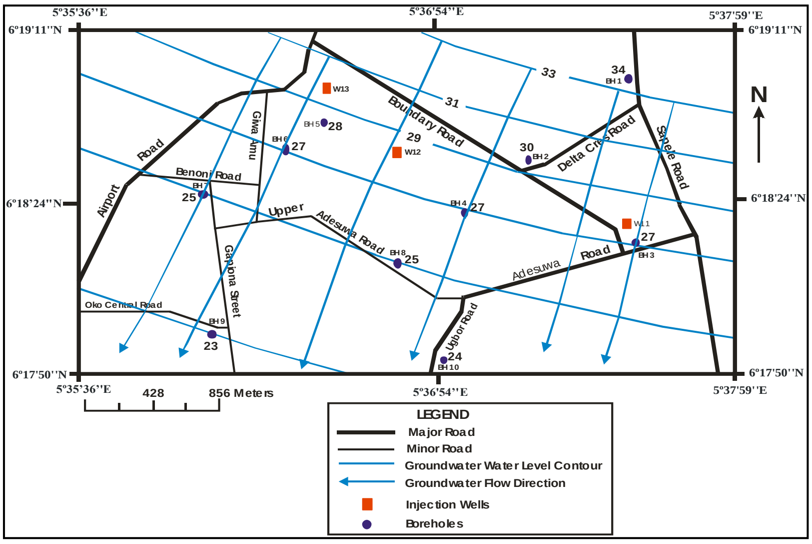


Figure 4: Water Level Contour Map of the Study Area

The above water level contour map of the study area shows that the groundwater flow direction is South – West.

3.0 DISCUSSIONS

pH

Figure 5 been synchronized with the water level contour map illustrates the gradual decrease in pH values of boreholes due South-West, away from the Injection wells, as indicated in Figure 6 which shows that the pH values of the water samples from the boreholes and injection wells are within permissible limits when compared to the SON and WHO standards. The pH values of the water samples from the boreholes ranged from 3.7 to 6.0, with a mean value of 4.49 indicating acidic water. The pH values of the water samples from the injection wells ranges from 6.0 to 6.4, with a mean value of 6.2 indicating slightly acidic water. The injection wells may have affected the pH of the groundwater as the boreholes with high pH values are those close to the injection wells, and the boreholes with low pH values are those that are far away from the injection wells.

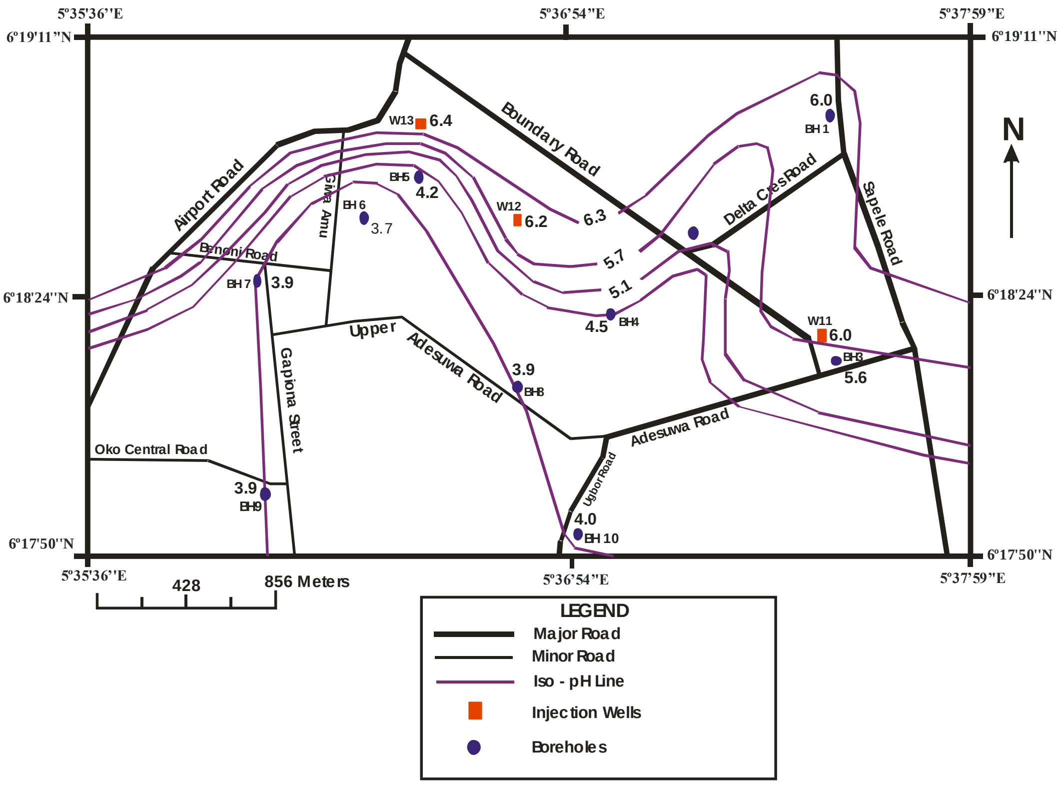


Figure 5: Concentration Map for pH Parameter

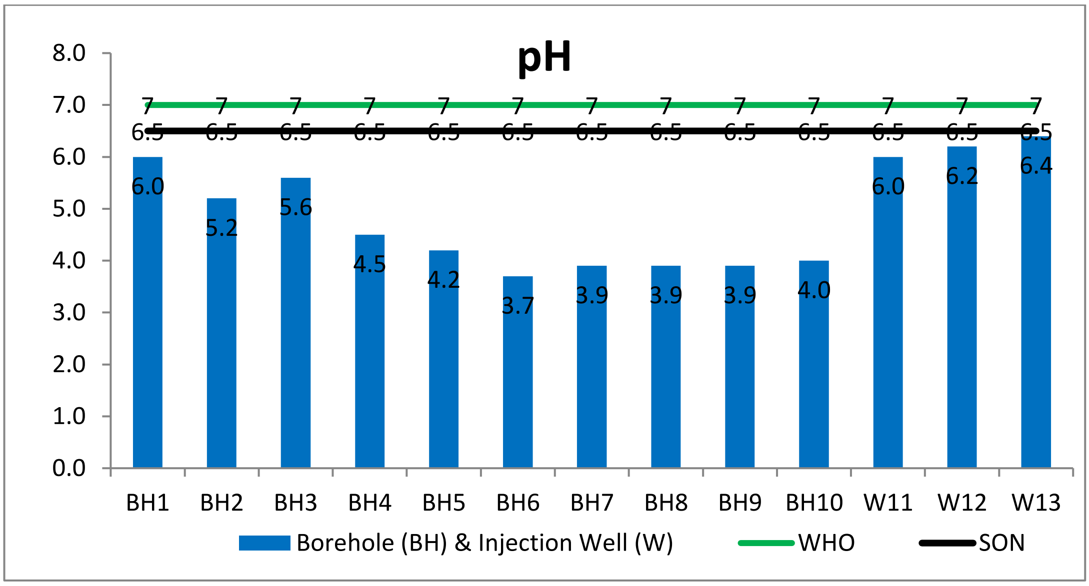
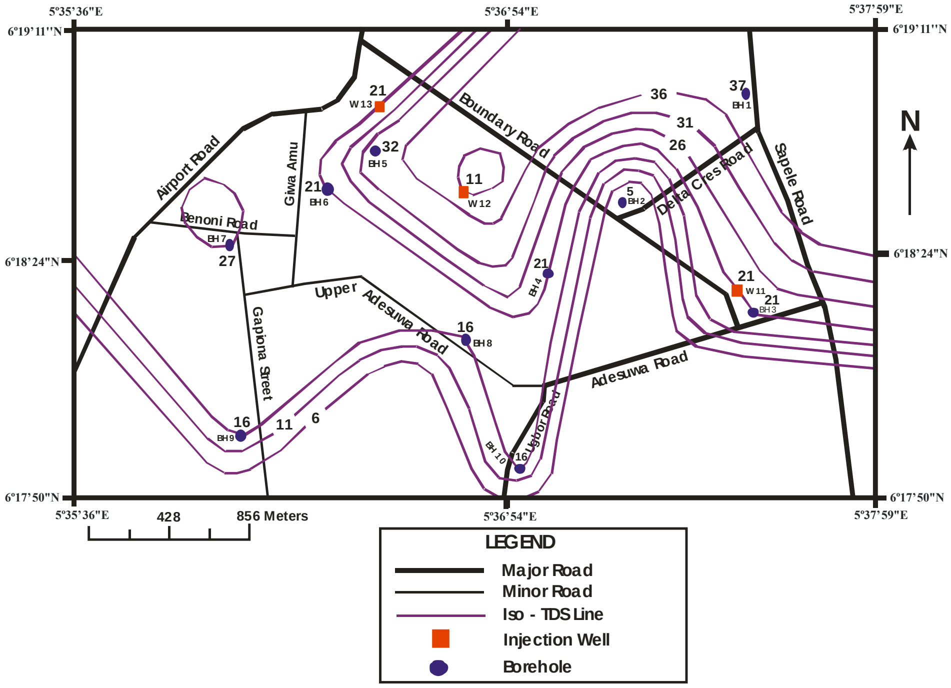


Figure 6: Bar Chart showing the pH Reading

Total Dissolved Solid

The total dissolved solids (TDS) observed in the different samples are shown in Figure 8. The results show that the TDS values of the water samples from the boreholes and injection wells are within permissible limits when compared to the SON and WHO standards. The TDS values of the water samples from the boreholes range from 5.3 mg/l to 37.1 mg/l, with a mean value of 21.2 mg/l. The TDS values of the water samples from the injection wells ranges from 10.6 mg/l to 21.2, with a mean value of 15.9 mg/l. (state the SON and WHO levels)



Figures 7: Concentration Map for Total Dissolved Solid Parameter

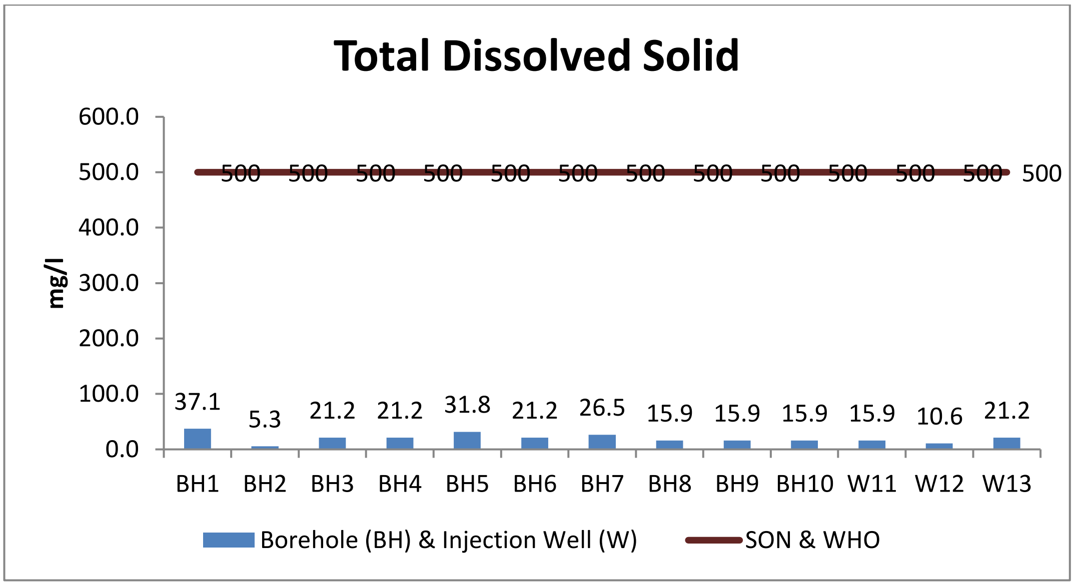


Figure 8: Bar Chart of Total Dissolved Solid Reading

Turbidity

The turbidity test revealed that water samples from the boreholes have very low turbidity (Figure 9). However, BH 2 showed a reasonable level of turbidity although within acceptable limits according to SON and WHO standards. The injection wells, on the other hand, are turbid, whose values range from 162 NTU to 226 NTU, with a mean value of 191.3, which is above permissible limits when compared to the SON and WHO standards and may be attributed to the dissolved inorganic chemicals present in the injection fluid.

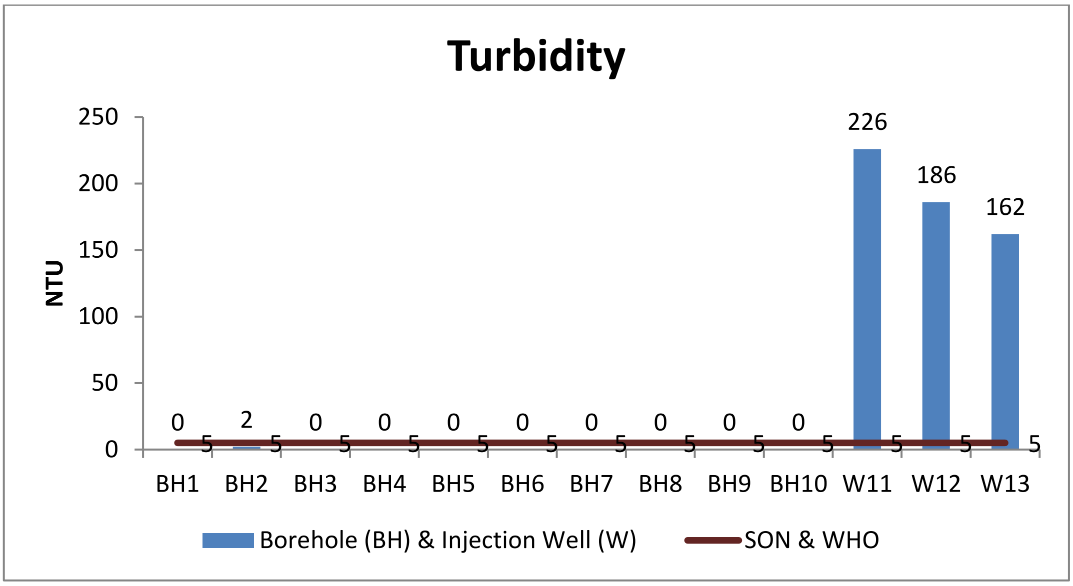


Figure 9:Bar Chart showing Turbidity Reading

Sulphate

The sulphate levels detected in the water samples are shown in Figure 10. The sulphate values of the water samples from the boreholes and injection well are within permissible limits when compared to the SON and WHO standards with average differences of 97 mg/l and 247 mg/l respectively. The sulphate values of the water samples from the boreholes range from 1 mg/l to 7 mg/l, with a mean value of 2.9 mg/l. The sulphate values of the water samples from the injection wells ranges from 45 mg/l to 54 mg/l, with a mean value of 49 mg/l.

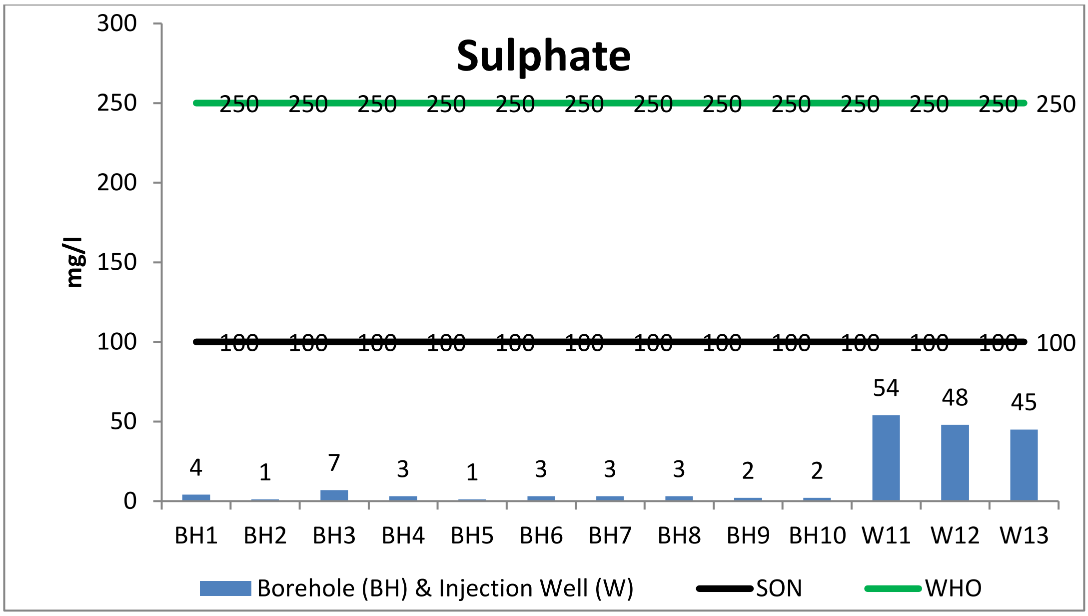


Figure 10: Bar Chart of Sulphate Reading

Nitrate

Figure 12 shows that the nitrate values of the water samples from the boreholes and injection wells are within permissible limits when compared to the SON and WHO standards. The nitrate values of the water samples from the boreholes range from 3.1 mg/l to 12 mg/l, with a mean value of 8.2 mg/l. The nitrate values of the water samples from the injection wells ranges from 6.9 mg/l to 12.8 mg/l, with a mean value of 9.1 mg/l.

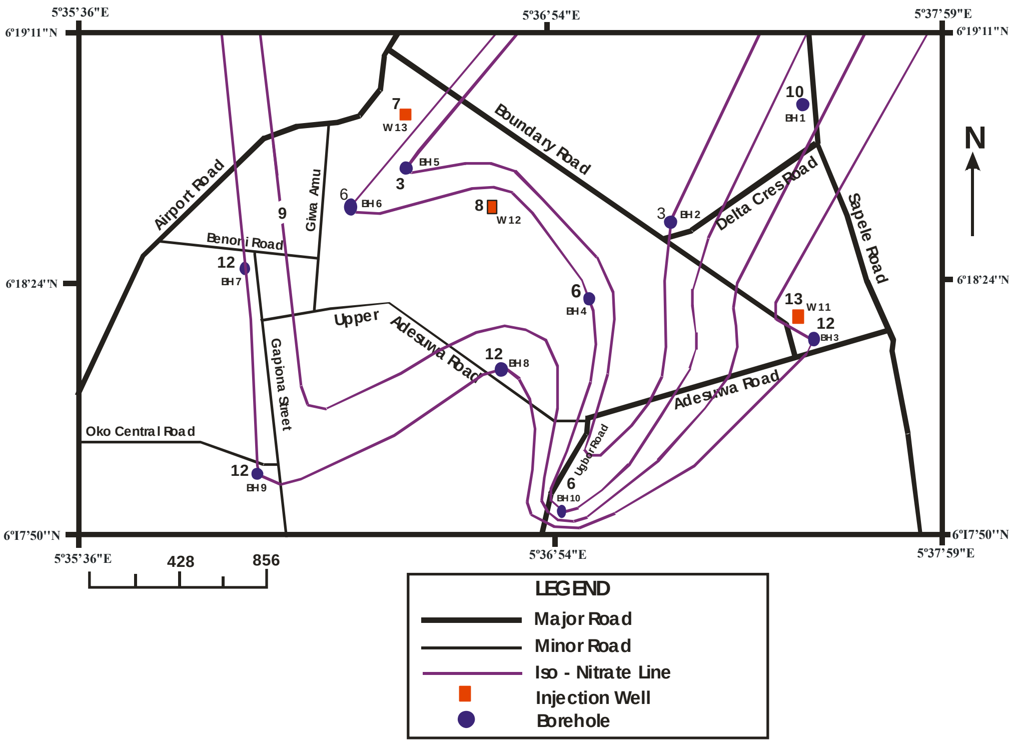


Figure 11: Concentration Map for Nitrate Parameter

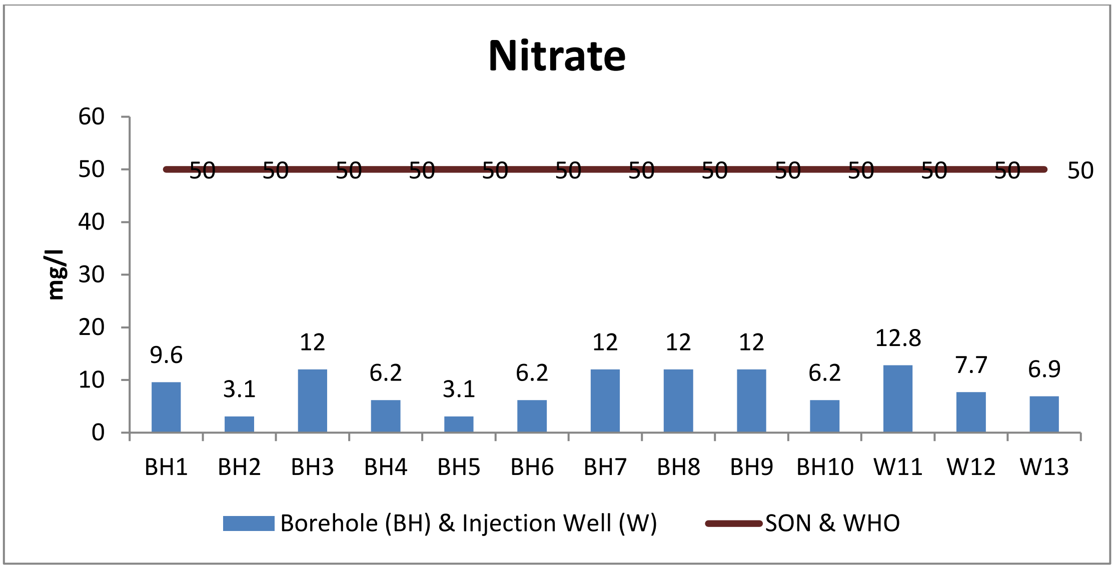


Figure 12: Bar Chart of Nitrate Reading

Hardness

Figure 14 shows that the hardness values of the water samples from the boreholes and injection wells are within permissible limits when compared to the SON and WHO standards. The hardness values of the water samples from the boreholes range from 6 mg/l to 20 mg/l, with a mean value of 10.4 mg/l. The hardness values of the water samples from the injection wells ranges from 26 mg/l to 38 mg/l, with a mean value of 33.3 mg/l. The injection wells may have affected the hardness of the groundwater as the boreholes closer to them (BH 3, BH 4, and BH 5) possess high hardness values, compared to others, and the hardness values gradually decrease southwest, away from the injection wells (Figure 13).

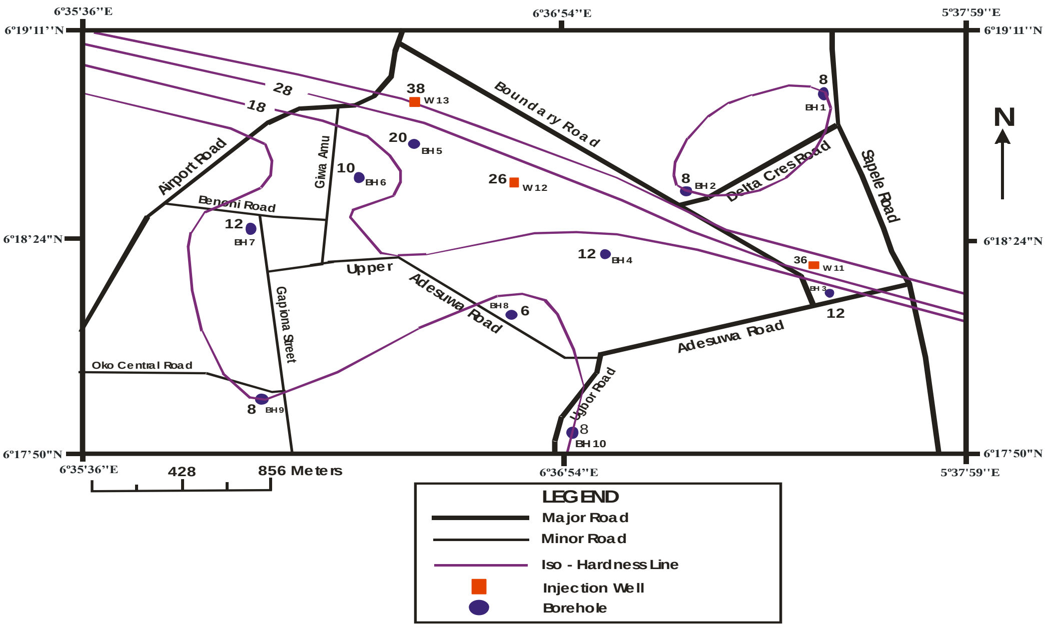


Figure 13:Concentration Map for Hardness Parameter

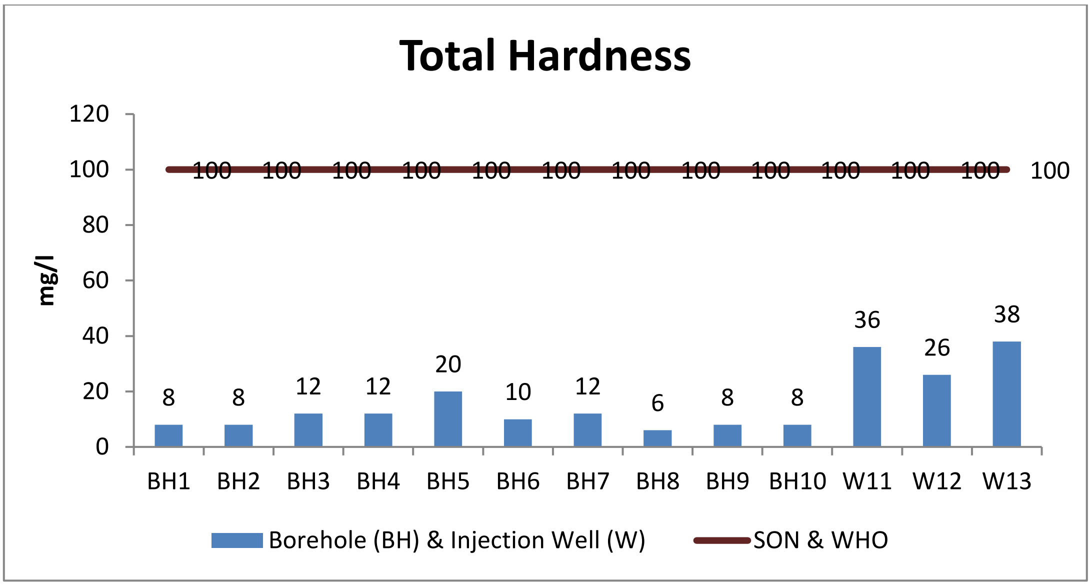


Figure 14:Bar Chart of Total Hardness Reading

Lead

Figure 15 shows that the lead values for the water samples from the boreholes are above permissible limits (except BH 2, 7, and 9) when compared to the SON and WHO standards, and the same goes for that of the injection wells, which are all above permissible limits. The high lead value of the injection wells can be attributed to the presence of a paint industry and mechanic workshops (gasoline, and engine oil) within the study area, as lead is part of the raw materials for manufacturing paint. The lead values of the water samples from the boreholes range from 0.015 mg/l to 0.052mg/l, with a mean value of 0.0335 mg/l. The lead values of the water samples from the injection wells ranges from 1.212 mg/l to 2.113 mg/l, with a mean value of 1.6625 mg/l.

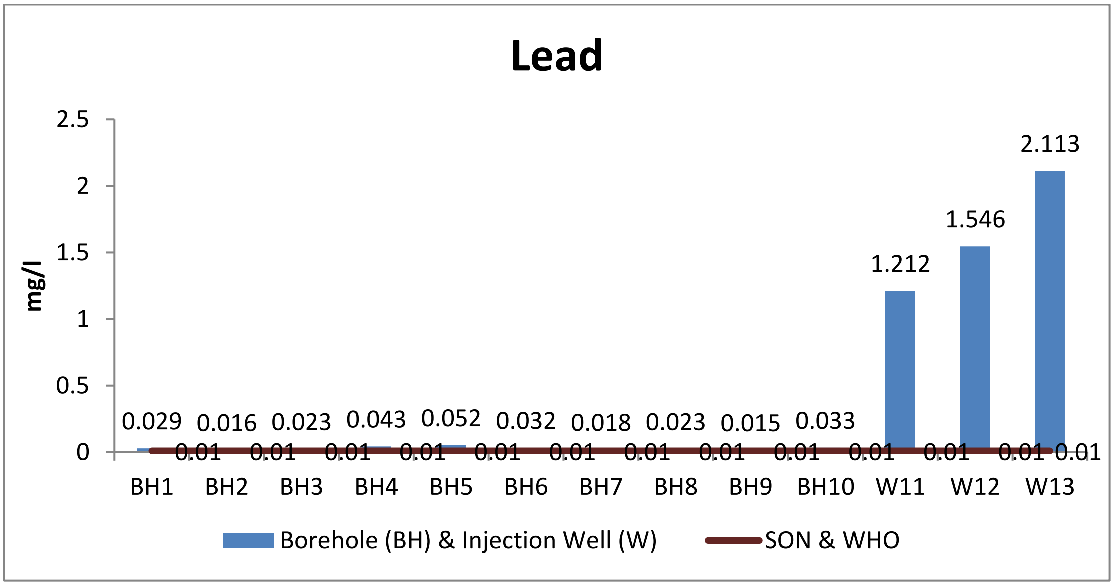


Figure 15: Bar Chart showing Lead Reading

Iron

Figure 17 shows that the iron values for the water samples from the boreholes (except BH 4) are within permissible limits when compared with the SON and WHO standards, and that of the injection wells are above permissible limits. The high iron values of the injection wells can be attributed to the presence of mechanic and welding workshops within the study area. The iron values of the water samples from the boreholes range from 0.11 mg/l to 0.41 mg/l, with a mean value of 0.203 mg/l. The iron values of the water samples from the injection wells ranges from 0.34 mg/l to 2.15 mg/l, with a mean value of 1.44 mg/l.

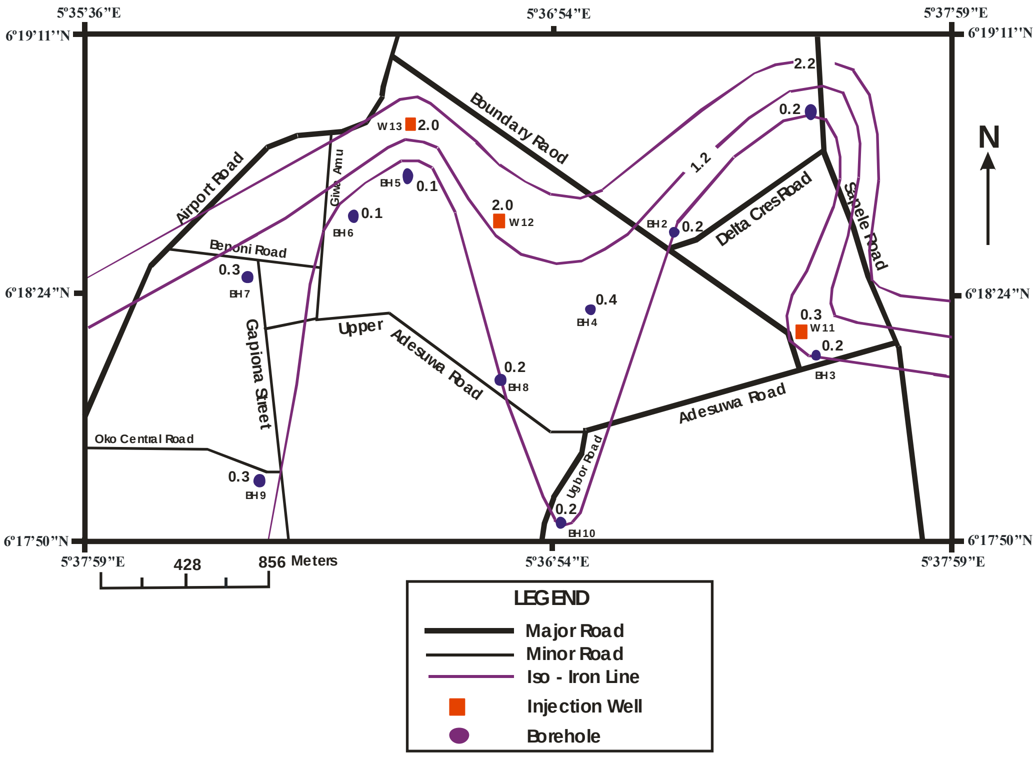


Figure 16: Concentration Map for Iron Parameter

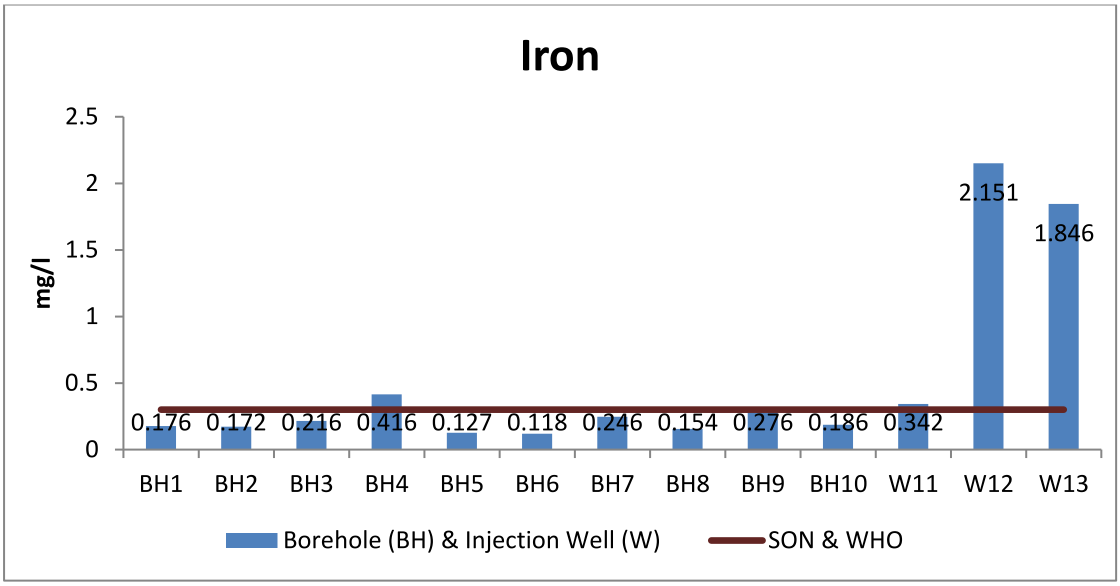


Figure 17: Bar Chart of Iron Reading

Chromium

Figure 18shows that the chromium values of the water samples from the boreholes are within permissible limits when compared to the SON and WHO standards, and that of the injection wells (except W12) is above the SON and WHO limits. The chromium values of the water samples from the boreholes range from 0.001 mg/l to 0.004 mg/l, with a mean value of 0.0021 mg/l. The chromium values of the water samples from the injection wells ranges from 0.014 mg/l to 0.117 mg/l, with a mean value of 0.081 mg/l. The high value of copper in W1 and W3 may result from the disposal of combusted engine oil.

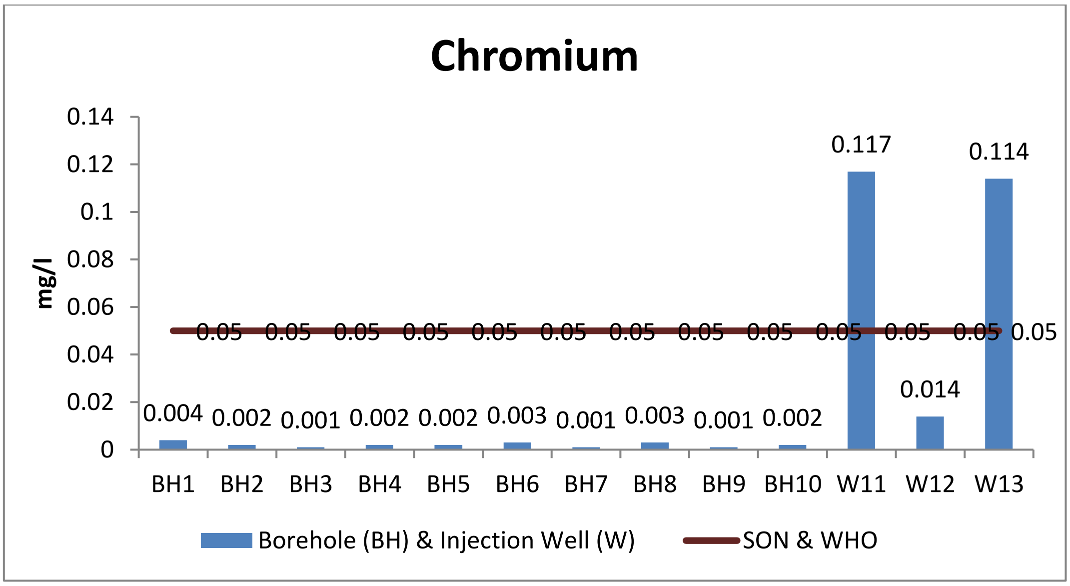


Figure 18: Bar Chart of Chromium Reading

Zinc

Figure 19shows that the zinc values of the water samples from the boreholes are within permissible limits when compared to the SON and WHO standards and that of the injection wells are above the SON and WHO limits. The zinc values of the water samples from the boreholes range from 0.10 mg/l to 0.32 mg/l, with a mean value of 0.16 mg/l. The zinc values of the water samples from the injection wells ranges from 3.14 mg/l to 4.62 mg/l, with a mean value of 3.99 mg/l. The high value of zinc in W1, W2, and W3 can be attributed to the improper disposal of zinc-containing waste from welding workshops and electrical utilities.

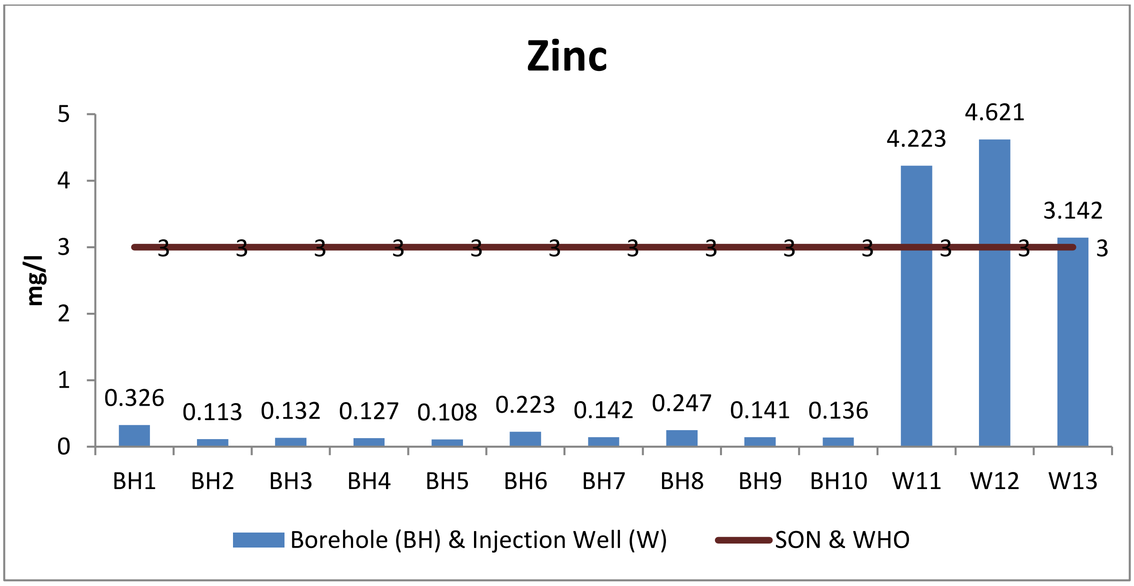


Figure19: Bar Chart showing Zinc Reading

Coliform

Figure 21 shows that the coliform count values of the water samples from the boreholes and injection wells are above permissible limits when compared to the SON and WHO standards, as the standards have zero (0) tolerance for coliforms. The coliform count values of the water samples from the boreholes range from 2,000 (2.0×10^3) mg/l to 21,000 (2.1×10^4) mg/l, with a mean value of 7,760 (7.76×10^3) mg/l. The coliform count values of the water samples from the injection wells ranges from 18,000 (1.8×10^4) mg/l to 22,000 (2.2×10^4) mg/l, with a mean value of 20,000(2.0×10^4) mg/l.

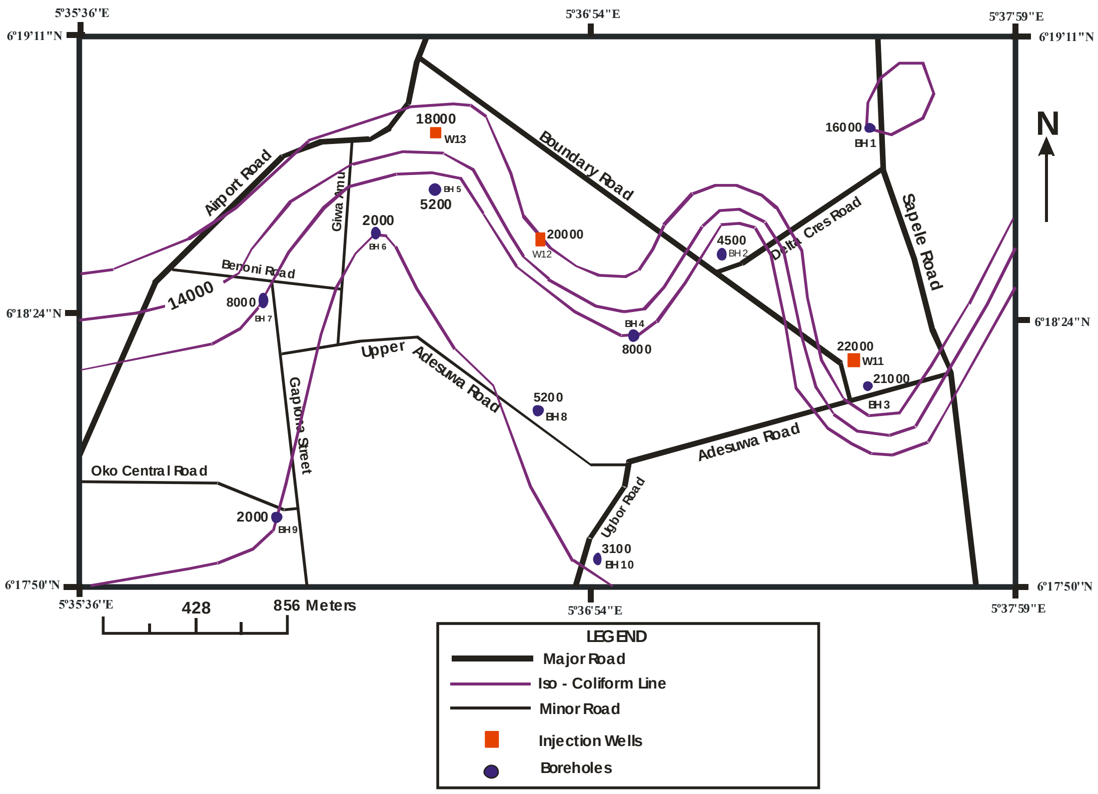


Figure 20: Concentration Map for Coliform Count Parameter

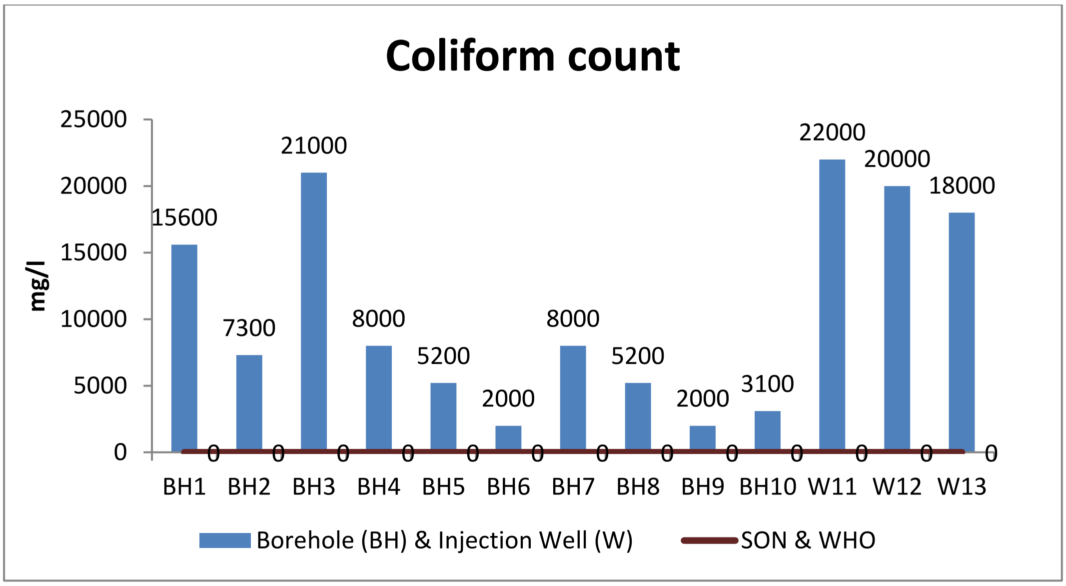


Figure 21: Bar Chart of Coliform Count

4.0 CONCLUSIONS

In conclusion, from the results obtained in this study, it was observed that the values of all the parameters of the water samples from the boreholes are within permissible limits when compared to the standards of the WHO and SON. Exceptions are with the concentrations of Lead (BH 1, 3, 4, 5, 6, 8, 10), Iron (BH 4), and Coliform Count which are above the WHO and SON Standards. Hence this indicates that the groundwater of the study area has relatively low levels of inorganic chemicals, but the value projections of Lead and the presence of Coliforms in the groundwater serve as a threat to human life.

The injection wells have a significant impact on the groundwater quality of the area, for certain parameters such as pH, Lead, and Coliform Count. As indicated by the concentration maps and bar charts of the pH and coliform parameter, the values for these parameters are relatively high for the boreholes close (an average of 422 meters) to the injection wells, and they tend to reduce relatively southwest, away from the injection wells. Hence, the impact of the injection wells on the groundwater quality of the area, for pH and Coliform Count. It is therefore recommended that the practice of the use of injection wells to control flooding in the study area or anywhere should be discouraged to reduce the chances of leachates percolating into the water table, and instead a better alternative should be the construction of proper drainage routes/systems in the study area.

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