Effect of Automobile Effluents on Groundwater Quality in Auto-Repair Site, Minna, Nigeria

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Abstract

Water samples from five groundwater sources which includes one borehole and four open wells within Keteren-Gwari automobile repair site, Minna, Niger State were analyzed to determine the effect of automobile effluents on groundwater quality in that area. Turbidity as well as the heavy metals (Ar, Cu, Ni and Pb) were at infinitesimal levels and could not be detected by the test means used during the analysis. The range of the remaining parameters tested for in the five samples includes pH (6.5-6.8), Total Hardness (11.6-13.4 mg/l), Conductivity (210-300 µs/cm), Sulphate (118-122 mg/l), Nitrate (0.12-0.18 mg/l), Cd (0.00-0.02 mg/l), Cr (0.00-0.02 mg/l), Fe (0.23-0.28 mg/l), Zn (0-2 mg/l), and Mn (0.1mg/l) were all within safe limits of the World Health Organization (WHO) Standard of pH (6.5-8.5), total hardness (100 mg/l), sulphate (200 mg/l), nitrate (50 mg/l), Cd (0.03 mg/l), Cr (0.05 mg/l), Fe (0.05-0.3 mg/l), Zn (5.0 mg/l), and Mn (0.5 mg/l) for drinking water and water meant for domestic use. It was also observed that water obtained from the borehole source had the least amount of contaminants detected in relation to that obtained from shallow open wells. Overall, consumption of water from the groundwater sources analyzed in this study would not pose any significant health problems as at the time of this study.

Keywords: Automobile effluents, Groundwater, Quality

1.   Introduction

The earth's liquid fresh water is found not in lakes and rivers, but stored underground in the aquifers (Young, 1992). These aquifers provide a valuable base-flow supplying water to rivers during periods of no rainfall. They are therefore, an essential resource that requires protection so that groundwater can continue to sustain the human race and the various eco-systems that depend on it. The contribution from ground water is vital; perhaps as many as two billion people worldwide depend directly upon aquifers for drinking water, and 40% of the world's food is produced by irrigated agriculture that relies largely on ground water. In the future, aquifer development will continue to be fundamental to economic development and reliable water supplies will be needed for domestic, industrial and irrigation purposes.

Nigeria with a land area of approximately 950,000 km^2. is richly endowed with diverse resources, however, there are staggering environmental problems manifested in various forms to present a grim of woes across the lengths and breaths of the nation. Pollution with other types of degradation such as erosion, loss of fertility and the continuing speed of urbanization are the major threat to the sustainability of soil resources in Nigeria (Bankole, 2005). Wide varieties of waste are dumped on soils. A dumpsite may consist of plastics, discarded cans, fins, pail and machine parts, dry cells, paints etc.

In addition, increased auto-mobile repairs/workshop activities in Nigeria due mainly to large inflow of used "Tokunbo" vehicles into the country in the late 1990s contributed markedly to the problem of groundwater contamination in most cities. Automobile used waste oil contain oxidation products, sediments, water and metallic particles resulting from machinery wears, organic and inorganic chemicals used in oil additives and metals that are present in fuel and transferred to the crankcase during combustion (EEA, 2007). Wear metals are formed in lube oils. Under the harsh conditions of temperature and pressure, the surface of the metal piece becomes slightly oxidized, forms salts with the degradation products of the oils and becomes soluble in the oil. The waste oil used for cleaning during services, metal scraps, waste tyres, used batteries etc. indiscriminately discarded on soils by artisans contaminates the soil and the water that makes its way through in to the underground water table. Percolation of leachates from these materials poses threats to underground water. While other sources of groundwater contamination have been well discussed, little is mentioned on the impact of automobile artisans on the eco-system.

The recognition of the pivotal role of ground water in human development is relatively recent and still patchy. The omission is understandable, water stored in the ground beneath our feet is invisible and so it's depletion or degradation due to contamination can proceed unnoticed, unlike rivers, lakes, reservoirs, where drying up or pollution rapidly becomes obvious and is reported. Thus we must determine which environmental process within the aquifer system can help to mitigate contamination, which environmental setting is more vulnerable, and how the resources can be managed to conserve them for future use. One of the characteristics of ground water is that pollution usually takes a very long time to appear in a water source, often decades or longer. In

consequence, it is technically difficult and expensive to clean up an aquifer once it is polluted (WHO, 1998). Sampat, (2000) reported that ground water pollution is pandemic and contaminants could be caused by either natural or human induced activities.

Auto mechanics are often ignorant on the implications of these contaminants on the soil. Antifreeze, waste oil, and deicer can cause significant rise in pollution levels of the ground water. Some major contributors to groundwater pollution include auto-mechanic repair site close to residential areas (EPA, 1994). The potential risk of groundwater contamination by activities of auto-repair sites can be very high. Waste fluids such as used engine oil, gear oil, hydraulics, coolants and other paint products can be characterized as hazardous when disposed indiscriminately. These fluids contain some chemical compounds which when sip gradually through the soil strata is capable of polluting and contaminating the water bearing formation. To this end, the study has the following objectives: to assess the ground quality from open wells and boreholes located within the auto-mechanic repair site and to determine the effect of automobile effluents on the groundwater quality.

1.1 Using Aquifer Vulnerability to Assess Pollution Risk.

Groundwater pollution risk can be illustrated as the interaction between two semi-independent factors (Custodio, 2002);:

1. The contaminant load that is applied to the surface environment as a result of human activity.
2. The natural pollution vulnerability of the aquifer.

The term aquifer pollution vulnerability is used to represent the intrinsic characteristics of the aquifer that determine whether it is likely to be affected by an imposed contaminant load. Vulnerability assessment is based on the potential contaminant attenuation capacity from the surface to the water table or to the aquifer in the case of semi-confined groundwater systems.

1.2 Factors that affect degree of groundwater pollution

1.2.1 Class of contaminants

Mobility and persistence are the key properties of a contaminant in its potential to contaminate groundwater. Mobility refers to the ease with which the contaminant is leached to the water-table. Non-mobile compounds tend to be retained in the soil as a result of sorption, cation exchange or precipitation processes. Mobile compounds degrade rapidly to simple non-toxic compounds.

1.2.2 Intensity of contamination

As the intensity of contamination increases, so the potential for groundwater contamination increases (UNEP, 2003). It is generally considered that at a low intensity of application, the soil zone is able effectively to eliminate and attenuate many contaminants, but that above a certain critical threshold a progressing greater percentage of the contaminant will be leached.

1.2.3 Mode of disposition

The mode of disposition refers to both the areal extent and where within the saturated- unsaturated profile the application is made. Diffuse or multipoint pollution sources produce widespread contamination of generally low concentration. Conversely, point source pollution produces localized contamination often of high concentration.

The soil layer is generally the most effective layer in attenuating contaminants. Thus, contaminants that by-pass this layer (for example, seepage from soakaways, drains and solid waste disposal pits or farm leaking underground tanks) may pose a more serious threat to groundwater than the contaminants applied directly to the surface.

2. Materials and Methods

2.1 Description of study area

Keteren-Gwari is located within Minna, the Niger state capital in Northern Nigeria. Its geographical coordinates are 9° 36′ N, 6° 33′ E. The automobile repair site was established about 27years ago. The total annual rainfall spreads over the month of April to October, with the highest amount in August. The average annual rainfall is about 1200mm and the mean annual temperature ranges between 29° C and 35°C during the dry season. The relief of the study area is similar to the topography of most of the Northern parts of Nigeria consisting of relatively flat lying land with some sparsely distributed hills.

2.2 Sample collection

Sampling bottles were carefully cleaned, sterilized and labeled. Groundwater sources in the area were located by enquiring from residents in the area. The labeled sampling bottles were then filled with water from one borehole and four wells within the study area. In the process, physical analysis of the water samples collected were tested for some parameters such as taste, odour, colour, and turbidity.

2.3   Materials for laboratory analysis

The equipment and materials used for this analysis ranges from complex computerized equipment to simple ones like the water containers. Some of the equipments used for testing the water samples include: Atomic absorption spectrophotometer, incubator, autoclaves, Bunsen-burner, inoculating loop, pH meter, Petri dishes, refrigerator, oven, desiccators, water containers, reagents and chemicals

2.3.1   Taste and odour

The taste of water is measured by flavour threshold test. In this test, the water sample to be tested is diluted with water free from any taste, to such an extent that the mixture of the water sample and the added water just becomes taste free. The volume of the water sample and that of the taste free water added for dilution are measured and the taste of the water is expressed in terms of Flavour Threshold Number (FTN) which represents the dilution ratio at which the water sample looses its taste. The FTN is computed as follows.

$$FTN = \frac{A-B}{A} \qquad\qquad (2.1)$$

where A = volume of water sample in ml, and
      B = volume of taste free water (or diluents) added in ml.

Equation 2.1 shows that the number of times the water is diluted to just make it taste free represents the flavour threshold number. Thus if diluting 25 ml of water sample 175 ml of taste free water is required to be added to make the water sample to just lose its taste, then the FTN will be eight. The odour of water is measured by threshold odour test. In this test, the water sample to be tested is diluted with odour free water to such an extent that the mixture of the water sample and the added water just becomes odour free. The volume of water sample and that of the odour free water added for dilution are measured and the odour of the water sample is expressed in terms of the Threshold Odour Number (TON) which represents the dilution ratio at which the water sample loses its odour. The TON is computed as follows

$$TON = \frac{A+B}{A} \qquad\qquad (2.2)$$

where:
    TON = Threshold Odour Number
    A = volume of water sample in ml, and
    B = volume of odour free water (or diluents) added in ml.

2.3.2   Colour

The colour in water is measured by platinum-cobalt method. In this method, colour is measured by visual comparison of water sample with the standard coloured water prepared by dissolving platinum-cobalt in distilled water. The intensity of colour is expressed on the platinum-cobalt scale as the number of colour units. On this scale, one unit of colour is the colour produced by 1mg of platinum-cobalt dissolved in 1litre of distilled water. The standard coloured waters of different colour units are prepared in the laboratory for being used for comparison. A simple instrument called the tintometer is used for comparing the water to be tested with the standard coloured water.

2.3.3   Turbidity

Turbidity was determined using a turbidmeter (Nephelometer). Turbidity measurement using this method is based on comparison of the intensity of light scattered by the water sample under defined condition with the intensity of light scattered by a standard reference suspension under the same conditions. The intensity of light scattered at right angles to the incident light using formazin polymer as the reference standard suspension was measured and computed as the turbidity.

2.4   Analysis of chemical parameters
2.4.1   Water pH

The pH value of each sample was measured using the pH meter. The pH meter was first calibrated, and then its electrode and surrounding area was rinsed with distilled water using the squeeze bottles and dried with soft tissue. A dry 100 ml beaky deep was filled to the 50 ml line with the water sample. The electrode was immersed

into the water. The sample was stirred once and then the displayed value was allowed to stabilize. The value was read and recorded and the same procedure was repeated for the other samples.
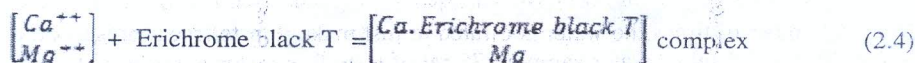
2.4.2 Electrical conductivity

A CMD 800 hydro check conductivity meter was used to determine the conductivity of the water sample. Before meaningful and repeatable measurement of conductivity was made, the setting for cell constant K and sample temperature was made for specific conductivity at 25°C. To view the cell constant K, μs (micro siemens) was switched on by key A was switched on and cell inserted into the test solution and reading displayed.

## 2.4.3 Measurement of hardness

The hardness of water is usually measured either by the soap solution test or the Versenate or ethylenediamine tetraacetic acid (EDTA) method. The EDTA method is considered to be more accurate. In this method, the total hardness is measured by titrating the water sample against EDTA or its sodium salt so as to form stable complex ions with the calcium or magnesium ions in water according to the following equation.

$$\begin{bmatrix} Ca^{++} \\ Mg^{++} \end{bmatrix} + EDTA = \begin{bmatrix} Ca.EDTA \\ Mg \end{bmatrix} \text{complex} \qquad (2.3)$$

In the titration, Erichrome black T (alcoholic solution of blue dye) is used as indicator to show when all the ions causing hardness have been complexed. The indicator, when added in a small amount to a sample of hard water, buffered to a pH value of about ten by ammonia buffer solution, combines with a few calcium or magnesium ions to form a weak complex wine red in colour according to the following equation

$$\begin{bmatrix} Ca^{++} \\ Mg^{++} \end{bmatrix} + \text{Erichrome black T} = \begin{bmatrix} Ca.Erichrome\ black\ T \\ Mg \end{bmatrix} \text{complex} \qquad (2.4)$$

This complex being unstable is quickly replaced by the $\begin{bmatrix} Ca.EDTA \\ Mg \end{bmatrix}$ complex as presented in equation 2.4. Erichrome black T is freed in this process as indicated by equation 2.5.

$$\begin{bmatrix} Ca.Erichrome\ black\ T \\ Mg \end{bmatrix} \text{complex} + EDTA = \begin{bmatrix} Ca.EDTA \\ Mg \end{bmatrix} \text{complex} + \text{Erichrome black T} \quad (2.5)$$
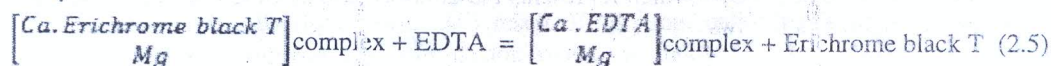
The wine-red colour is changed to distinct blue colour which indicates the end of titration. The total hardness of the water sample is given in mg/l or ppm by the following expression.

$$\text{Total hardness (mg/l or ppm)} = \frac{ml\ of\ EDTA\ used \times 100}{ml\ of\ water\ sample} \qquad (2.6)$$

2.4.4 Determination of chloride

A suitable portion of the sample was diluted to100 ml. 3 ml Al (OH)$_3$ suspension was added, mixed, left to settle, and then filtered. If sulfate, sulfide or sulfite is present, 1 ml H$_2$O$_2$ is added and stirred for about 1 minute. 1 ml K$_2$CrO$_4$ indicator solution is then added and titrated with standard AgNO$_3$ titrant to a pinkish yellow end point. It is important to be consistent in end point recognition.

2.4.5 Determination of nitrate

Two moles of NO$_3^-$ react with one mole of chromotropic acid to form a yellow reaction product, the absorbance of which is measured at 410nm. The method can be used to determine nitrate concentrations in the range 0.1 – 5 mg NO$_3^-$ - NL^{-1}. It is necessary to eliminate interference by nitrate, residual chlorine and certain oxidants which yield yellow colour when they react with chromotropic acid. Interference from residual chlorine and oxidizing agent can be eliminated by addition of sulfite. Urea eliminates nitrite interference by converting it to N$_2$ gas. Addition of antimony can mark up to 2000mg Cl$^-$ L^{-1}.

2.4.6 Determination of sulphate

While traces of sulphate occur universally in all types of waters, its content may be appreciably high in several saline waters showing an electrical conductivity (EC) higher than 1 ds/m at 25 °C. Sulphate can be determined gravimetrically, colorimetrically, turbidimetrically or titrimetrically. Here, the turbidimetric method is described.Sulphate content is determined by the extent of turbidity created by precipitated colloidal barium

sulphate suspension. Barium chloride solid crystals are added to ensure fine and stable suspension of $BaSO_4$ at a pH of about 4.8. This also eliminates interference from phosphate and silicate. This fine suspension of $BaSO_4$ is stabilized by gum acacia, and the degree of turbidity is measured with a turbidity meter or estimated spectrophotometrically at 440 mm.

3. Results and Discussion

The results of analysis for the water samples A,B,C,D and E are presented in Table 3.1,3.2,3.3 and 3.4 respectively. Sample A represents water collected from a borehole while samples B,C,D and E represents water collected from open wells within the study area.

3.1 Physical properties
3.1.1 pH

The range of pH values obtained from the test samples ranged from 6.5-6.8. Sample a have the least value of 6.5 and samples B and E have the highest value of 6.8. Values recorded were within stipulated WHO pH tolerance limit of between 6.5-8.5. Based on this, the pH of the water from all the sample sites would not adversely affect its use for domestic or recreational purposes.

3.1.2 Sulphate

Sulphate levels in all the water samples analysed varied from 118-122 mg/l. Sample A having the least value, 118 mg/l and sample C have the highest value, 122 mg/l. None of the water samples had sulphate level exceeding 200 mg/l which is the WHO maximum permissible level drinking water

3.1.3 Nitrate

Nitrate levels in the water samples ranged between 0.12 and 0.18 mg/l. Nitrate toxicity increases the risk of anemia in infants and pregnant women and formation of carcinogenic nitrosamines (Bush and Meyer, 1982). The WHO guideline for domestic water supply states limit of 3 mg/l for nitrate levels. None of the samples exceeded this limit thus. Nitrate concentration is not considered to pose a problem for domestic use of water from the sample sources.

3.1.4 Turbidity

Turbidity stems from the reduction of transparency due to the presence of particulate matter such as clay, silt, finely divided organic matter, plankton or other microscopic organisms. The colloidal materials provide adsorption sites for chemicals that may be harmfull to health or cause undesirable tastes or odours. Turbidity was infinitesimal and therefore not detected by test means carried out during the analysis.

3.1.5 Conductivity

Conductivity indicates the presence of dissolve solids and contaminants especially electrolytes but does not give information about specific chemical. Most drinking waters have conductivity measurement below 2000 µs/cm but the recommended value is 250 µs/cm. The values for conductivity in the test sample ranged from 210-300 µs/cm. Sample a recorded the lowest value of 210 µs/cm while sample B recorded the highest value of 300 µs/cm.

3.2 Heavy metal contents
3.2.1 Copper, arsenic, nickel and lead

Levels of the heavy metals listed i.e Cu, Ar, Ni and Pb in all the samples tested were infinitesimal and therefore could not be detected by test method used in the analysis of the samples. WHO permissible level for Cu, Ar, Ni an Pb in drinking water is 2.0 mg/l, 0.01 mg/l, and 0.01 mg/l respectively. Since these heavy metals were not detected, they do not pose any immediate threat to life.

3.2.2 Zinc.

Zinc levels in the water samples ranged between 0-2mg/l. it was not detected at all in sample A, and had the highest level 2mg/l in samples B,C and E. All of these values fall below the 5.0mg/l highest desirable level for zinc in drinking water (WHO, 1984).

3.2.3 Manganese.

Manganese level in all the water samples had a value of 0.01 mg/l. which is below the WHO standard of 0.5 mg/l maximum permissible level for manganese in potable water.

3.2.4 Iron

Values for iron in the water samples tested ranged between 0.23-0.28 mg/l. Sample a have the least value of 0.23 mg/l and sample E have the most of 0.28 mg/l. These values are in line with the WHO standard range of between 0.05-0.3 mg/l for iron in potable water.

3.2.5   Chromium

Chromium levels in the water samples ranged from 0mg/l in sample A to 0.02 mg/l in samples B and E. these values fall below the WHO maximum permissible value of 0.05 mg/l for chromium in drinking water. Primary use of water high in chromium could lead to adverse health effects such as renel disease and cancer (Salido and Jones, 1999).

3.3   Pollution prevention guide for auto-mobile repair shops

The potential risk to ground water contamination by effluents from automobile repair sites can be high. Often, the types of waste fluids that are used to clean parts, used motor oil, coolant, and other fluids can be characterized as hazardous and/or dangerous wastes. The waste fluids, if washed down a drain and into a motor vehicle waste disposal well, could pose a serious risk to human health if ground water were to become contaminated.

3.3.1   Solvents

Automobile repair shops typically use solvents in a variety of operations including parts cleaning, degreasing, and painting. Many of these solvents may be classified as hazardous waste, and may therefore require expensive treatment and/or disposal.

- Try to find one multi-purpose solvent that can serve a variety of uses, rather than having a different solvent for each operation. This will minimize the number of waste streams and increase the recycling potential of the spent solvent.
- Substitute less hazardous substitutes for solvent cleaners. Consider water based cleaners.
- Minimize the amount of cleaning solvents lost during drainage of cleaned parts; remove parts from the bath slowly to prevent spillage; install drip trays or racks near the bath for draining cleaned parts; return the drainage to the bath.

3.3.2   Oils

Use drip pans to catch lube oils for reuse; handle oils carefully to avoid spillage. Also contact a reputable recycler to collect your used oil.

3.3.3   Other wastes

- Use paint with higher solids content, or water based paints with no solvent, whenever possible.
- Collect all scrap metals and take it to a metal recycler.
- Consider recycling scrap tyres, it may be cost effective to contract with a tyre recycler, rather than send them to a landfill.

4.   Conclusions and Recommendations

4.1 .   Conclusions

Based the results obtained from the study area it could be concluded that the location (Keteren-Gwari Automobile Repair Site) has no trace or any significant effect on the ground water quality as at the time of this study. Therefore, domestic use of water from groundwater sources located within the study area, will not pose an immediate health risk to residents within the area.

4.2   Recommendations

The following recommendations were made;

1. Though not yet observed within the study area, mechanic workshops situated within residential areas are anthropogenic sources of heavy metals and other contaminants in soils that may pose serious threat to groundwater.
2. Environmental laws restricting indiscriminate dumping of automobile waste should be enforced and defaulters punished.
3. Stake holders involved in the use of auto-mechanic workshops need to be alerted of the impending dangers.

References

Akan, J. C. 2007. Studies on the Effect of Municipal Waste and Industrial Effluent on the Pollutant levels of River Challawa, Kano State. Research Journal of Applied Sciences Vol.2; 530-535,

Anonymous 1995. Analysis of Wear Metals and Additives in Lubricating Oils, Application Note.

Bankole, P.O., 2005. Information on Nigeria Environmental Profile. Federal Ministry of Environment, Mainframe Publishers, Nigeria

Custodio. E. 2002. Aquifer overexploitation: what does it mean? Hydrogeology Journal, Vol. 10, 254–277.

EEA., 2007, Progress in Managing of Contaminated Sites (CSI 015). European Environmental Agency. Assessment Published July 2005; Kongen, Ytov, 6 DK-1050, Denmark.

Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for zinc, Iron Manganese, and copper. Soil Sci. Soc. Am. J., 42: 421–448.

Ogugbaja, v . o. et al 2009. Study of the Level of Some Agricultural Pollutants in Soils and Water Leaf. Journal of Applied Sciences in Environmental Sanitation Volume 4, No 2: 71-78

Sampat, P. 2000. Deep trouble: the hidden threat of groundwater pollution. Worldwatch Paper, No. 154, (Washington DC: World watch Institute.)

U.S. EPA. Underground Injection Wells and Your Drinking Water: pamphlet. Office of Water. EPA 813-F-94-001; July 1994.

WHO. 1998. Guidelines for drinking-water quality. Second edition. Vol. 2 and Addendum to Vol. 2 (Geneva: WHO.)

Young, R. A. 1992. Managing aquifer over-exploitation: Economics and policies. 199–222 in Selected papers on overexploitation. Simmers, Villarroya and Rebollo (editors) (Hanover, Germany: IAH Heise.) Vol. 3.

Table 3.1 Result of Water Analysis for Sample A

S/No	Parameter	Unit	Measured Value	Standard Value (WHO)
1	pH	-	6.5	6.5-8.5
2	Total Hardness	mg/l	11.6	100
3	Turbidity	NTU	ND	5
4	Conductivity	µs/cm	210	-
5	Sulphate	mg/l	118	200
6	Nitrate	mg/l	0.12	50
7	Ar	mg/l	ND	0.01
8	Cd	mg/l	ND	0.03
9	Cr	mg/l	ND	0.05
10	Cu	mg/l	ND	2.0
11	Fe	mg/l	0.23	0.05-0.3
12	Ni	mg/l	ND	-
13	Pb	mg/l	ND	0.01
14	Zn	mg/l	ND	5.0
15	Mn	mg/l	0.01	0.5

S/No = Serial number, ND = Not Detected, WHO = World Health Organization,

Table 3.2 Result of Water Analysis for Sample C

S/No	Parameter	Unit	Measured Value	Standard Value (WHO)
1	pH	-	6.6	6.5-8.5
2	Total Hardness	mg/l	12.8	100
3	Turbidity	NTU	ND	5
4	Conductivity	µs/cm	288	-
5	Sulphate	mg/l	122	200
6	Nitrate	mg/l	0.14	3
7	Ar	mg/l	ND	0.01
8	Cd	mg/l	0.01	0.03
9	Cr	mg/l	0.02	0.05
10	Cu	mg/l	ND	2.0
11	Fe	mg/l	0.26	0.05-0.3
12	Ni	mg/l	ND	-
13	Pb	mg/l	ND	0.01
14	Zn	mg/l	2.0	5.0
15	Mn	mg/l	0.01	0.5

S/No = Serial number, ND = Not Detected, WHO = World Health Organization

Table 3.3 Result of Water Analysis for Sample D

S/No	Parameter	Unit	Measured Value	Standard Value (WHO)
1	pH	-	6.4	6.5-8.5
2	Total Hardness	mg/l	13.2	100
3	Turbidity	NTU	ND	5
4	Conductivity	µs/cm	284	-
5	Sulphate	mg/l	120	200
6	Nitrate	mg/l	0.16	3
7	Ar	mg/l	ND	0.01
8	Cd	mg/l	0.01	0.03
9	Cr	mg/l	0.01	0.05
10	Cu	mg/l	ND	2.0
11	Fe	mg/l	0.27	0.05-0.3
12	Ni	mg/l	ND	-
13	Pb	mg/l	ND	0.01
14	Zn	mg/l	1.0	5.0
15	Mn	mg/l	0.01	0.5

S/No = Serial number, ND = Not Detected, WHO = World Health Organization

Table 3.4 Result of Water Analysis for Sample E

S/No	Parameter	Unit	Measured Value	Standard Value (WHO)
1	pH	-	6.8	6.5-8.5
2	Total Hardness	mg/l	13.4	100
3	Turbidity	NTU	ND	5
4	Conductivity	µs/cm	290	-
5	Sulphate	mg/l	120	200
6	Nitrate	mg/l	0.18	3
7	Ar	mg/l	ND	0.01
8	Cd	mg/l	0.02	0.03
9	Cr	mg/l	0.01	0.05
10	Cu	mg/l	ND	2.0
11	Fe	mg/l	0.28	0.05-0.31
12	Ni	mg/l	ND	
13	Pb	mg/l	ND	0.01
14	Zn	mg/l	2.0	5.0
15	Mn	mg/l	0.01	0.5

S/No = Serial number, ND = Not Detected, WHO = World Health Organization