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Investigating the Decline in Water Quality from Point of Source (P.O.S) To Point of Use (P.O.U) around Awe to Ogbagba Community

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ABSTRACT
Surface water is vulnerable to water quality deterioration due to its open nature. This study looked to investigate the decline in the water quality of a stream water around Awe to Ogbagba in Oyo East Local Government Area of Oyo State, Nigeria, from its Point of Source (P.O.S) to its Point of Use (P.O.U).

Fifteen water quality parameters were looked at: pH, Colour, Odour, Turbidity, Electrical Conductivity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Alkalinity, Calcium Hardness, Total Hardness, Chloride, Nitrate, Iron, Total Coliform, and Escherichia Coli (E. Coli). Samples were taken at eight sampling points along the stream and tested. The results were compared with the Nigerian Standard for Drinking Water Quality (NSDWQ) and statistical analysis was done to obtain the Weighted Arithmetic Water Quality Index (WA-WQI).

The physico-chemical quality of the stream at all the sampling points was good. However, the bacteriological water quality was questionable. All sampling points but one had E. Coli values above the NSDWQ permissible level of zero (0).The unacceptable E. Coli levels were as a result of faecal contamination.

From the WA-WQI results, of all the eight sampling points, four had “Excellent” Water Quality Rating (WQR), one had a “Good” WQR, two had “Poor” WQI, and one had an “Unsuitable for Domestic Purpose” WQR.

Since the major cause of the water quality decline in the stream was faecal contamination, due to human and animal faeces; sanitary measures were encouraged to be put in place and water treatment was recommended.

Keywords: Water Quality, Stream, Water Quality Index, E. Coli, Faecal contamination.

I. INTRODUCTION

Water is an essential part of the environment (Uddin et al., 2021). It can be found in the different strata of the Earth in different forms – beneath the surface as groundwater, and on the surface as surface water (Simon & Adianimovie, 2022).A sufficient volume of water in both quantitative and qualitative capacity is required in order to adequately meet the needs of man (Folami et al., 2019).The bacteriological and physicochemical qualities of water, as well as their connections with one another, are all indicators of water quality. Therefore, they are deciding factors in water quality evaluation and analysis (Smitha & Shivashankar, 2013; Opaluwa et al., 2022).

Surface and groundwater resources are both heavily used natural resources that are today plagued by major pollution issues on a global scale. Compared to surface water, groundwater is typically not metered for use, which has resulted in extreme overuse. Surface water is normally metered, but it is more vulnerable to pollution from numerous sources. Compared to other sources of water, it is easiest to obtain surface water for man’s use, therefore, it is at the greatest risk of not only domestic, but other types of pollution (Tripathi & Singal, 2019).A very serious matter of sustainable development, the pollution of surface water poses a great risk to the health and well-being of man (Obiora-Okeke et al., 2022).

Populations that rely on surface water (rivers, streams, dams, etc.) are examples of those that use unimproved sources of drinking water. A quarter of the population in Nigeria (24%) relies on unimproved sources of water, some of which are unprotected dug wells (12%), surface water (11%), and unprotected springs (1%). Out of all these, surface water used for drinking that is usually obtained from water bodies such as lakes, streams, rivers, canals, ponds, agricultural irrigation supplies and dams poses the greatest risk to man's health. Because surface water is bottom-tier and highly detrimental compared to other water supply service levels, the WHO/UNICEF JMP Services Ladder does not consider homes that get the water they consume straight from it to have any form of service whatsoever. Surface water as a source of water supply is seventeen (17) times more likely to be utilised by rural dwellers (17 percent) compared to urban residents (1 percent) (Federal Ministry of Water Resources et al., 2020).

Escherichia coli (E. coli) is the suggested marker for faecal pollution - a serious threat to the health and well-being of man. It helps in establishing data for properly managed water supply systems. WHO guidelines state that the drinking water supply for a home must be free of E. coli, or have no thermotolerant coliform producing units per 100 milliliters of water, in order to be declared safe for consumption. Cities usually have a lower level of thermotolerant pollution at Point of Source (P.O.S) and Point of Use (P.O.U) compared to rural regions (Federal Ministry of Water Resources et al., 2020).

The problem this study addresses is the problem of surface water (stream) quality decline in a rural region from the Point of Source (P.O.S) to the Point of Use (P.O.U). In the study area, the quality of such an unimproved source of water, specifically the bacteriological quality, is in question and therefore needs to be assessed and analysed. Typical solutions that could be employed to address this problem of water quality decline include preventive sanitary measures and water treatment methods, especially disinfection, to inactivate the bacteriological contaminant present in the water. One unusual method that was suggested in this study is bacterial inoculation/immunity.

The goal of this research work is the assessment of the water quality of stream water in the study area for drinking purpose.The aim was achieved through the following objectives:

i. Carrying out a survey of the stream site conditions and stream water haulage pattern in the rural communities the stream passes through;
ii. Taking grab samples of water from the stream at each sampling point, from the Point of Source (P.O.S) to the Point of Use (P.O.U);
iii. Carrying out standard laboratory tests on the collected samples; and
iv. Comparison of the results obtained with the Nigerian Standard for Drinking Water Quality (NSDWQ) and statistical analysis of the results using Weighted Arithmetic Water Quality Index (WA-WQI).

Study area

The study area is the Awe to Ogbaba rural settlement located in Oyo Town, specifically in the Oyo East Local Government Area of Oyo State, Nigeria as shown in Fig 1. below. This particular Local Government Area was created under military rule in December, 1996, after the defunct Oyo Divisional Council was split into three parts namely, Atiba, Oyo West and Oyo East. At the moment, according to the allocation of geographical zones and categorisation in Oyo State, it is part of the local government councils that constitute Zone 4 (Oyo regions). It shares borders with Afijio, Atiba and Ogo-Oluwa Local Government Areas southward, northward and eastward respectively (Chibueze et al., 2021).

The map of the study area is shown in Fig 2. below, where:
S.P. 1: The source of the stream at Awe community.
S.P. 2: The sampling point of the stream around a fish pond area at Awe community.
S.P. 3: The sampling point of the stream just after the fish pond area at Awe community.
S.P. 4: The sampling point of the stream at Oniyere community (Oniyere Stream).
S.P. 5: The sampling point of the stream at Awusan community (Awusan Stream).
S.P. 6: The sampling point of the stream at Ajagba community (Ajagba Stream).
S.P. 7: Another sampling point of the stream at Ajagba community (Alapata Stream).
S.P. 8: The sampling point of the stream at Ogbagba community (Ogbagba Stream).

As shown in Fig 2., the stream being studied spans from S.P. 1 (Sampling Point 1), which is the source of the stream at Awe to S.P. 8 (Sampling Point 8), which is the final sampling point of the stream, with intermediate sampling points at different locations. The total stream length under study is 12,852.46m.

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Fig 1. Map of Oyo state showing the study local government area (Chibueze et al., 2021)

Fig 2. Map of study area (Google, n.d.)

II. DATA AND METHODS

A survey of the stream site conditions in the study area was done through physical observation and conducting interviews with some community members. The socio-economic data of the three communities within the study area being served by the stream was obtained by interviewing the members of those communities and also

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administering questionnaires through random sampling. The water haulage pattern of the people living in these three communities was determined by interviewing some of the elders there, through physical observation of the people as they fetched water, and also by administering questionnaires through random sampling.

Sampling was done under clear weather conditions at the eight (8) sampling stations using labelled sampling bottles. 75cl plastic bottles were used for physical and chemical tests, while sterilised glass bottles were used for bacteriological tests. The grab samples were carefully obtained in order to get accurate test results. They were then stored properly and taken to the laboratory for tests within 24 hours.

After sampling, standard laboratory tests were carried out for physical, chemical and bacteriological assessment. Fifteen (15) parameters were tested for, namely: pH, Colour, Odour, Turbidity, Electrical Conductivity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Alkalinity, Calcium Hardness, Total Hardness, Chloride, Nitrate, Iron, Total Coliform, and Escherichia Coli (E. Coli).

After the laboratory tests were carried out on the water samples, the results of the different parameters were compared with the National Standard for Drinking Water Quality (NSDWQ) permissible levels (NSDWQ, 2015). Statistical analysis was also done using the Weighted Arithmetic Water Quality Index (WA-WQI) method to find the water quality indices of the water at the various sampling points. The analysis was done using the Microsoft Excel software package.

III. RESULTS AND DISCUSSION

The study area is predominantly agrarian with vast farmlands and a major part of the population engaging in crop farming. Apart from that, the stream that runs through the various communities serves as a source of water supply for fishing activities, with a number of fish ponds sited along the stream. The stream also serves as a source of water supply for the population living within the study area for their various domestic activities including drinking. Near the source of the stream, at Sampling Point 1, is a pile of animal dung which serves as manure for farming. Also close to Sampling Point 4 is another pile of animal dung. The stream mostly passes through bushes, trees and grasses, and sand which could help in the filtration of the water. Because of the open nature of the stream and the agricultural activities it supports, the quality of the stream water for drinking is at risk as pollution and contamination is inevitable. Therefore, the research was carried out to ascertain the quality of the water as it varied along the stream by taking samples at all eight (8) sampling points starting at the source, and checking to see at what points the water is of good drinking quality and the points it is not.

Table 1. below gives a summary of the results of the standard laboratory tests carried out on the water samples collected at all eight sampling points. The Nigerian Standard for Drinking Water Quality (NSDWQ) permissible limits for the test parameters are also included in the table. The comparison of the parameter values obtained from the test results at all sampling points with the NSDWQ standard values is shown from Fig 3. to Fig 16. below. It should be noted that NSDWQ standard values were not specified for Total Suspended Solids (TSS), Alkalinity and Calcium Hardness.

It can be seen from the results that all the physical parameters of pH, Colour, Odour, Turbidity, Electrical Conductivity (E.C), Total Dissolved Solids (TDS), and chemical parameters of Total Hardness, Chloride, Nitrate and Iron all fell within the NSDWQ permissible limits at all eight (8) sampling points, implying that the physico-chemical quality of the stream at all the sampling points is good. However, the bacteriological water quality (in terms of E. Coli present) is questionable. The NSDWQ permissible level for E.Coli in drinking water is zero (0). All sampling points had E. Coli values above this level except for Sampling Point 8 which had an acceptable value of zero (0). The worst E. Coli level was observed at Sampling Point 7, with a value of 965.

E. Coli is indicative of faecal contamination, which is due to human and animal wastes. The presence of unacceptable E. Coli levels in the stream at all but one sampling point may be due to humans defecating around the stream. It could also be from the faeces of cattle while they are at the stream with their nomadic herdsmen, trying to get some water to drink. It could also be due to the humongous pile of animal dung close to the source of the stream (S.P. 1) and near Sampling Point 4, which is meant to serve as manure. This may find its way into the stream and contaminate it bacteriologically.

Table 1. Laboratory test results and NSDWQ permissible limits

PARAMETER	S.P. 1	S.P. 2	S.P. 3	S.P. 4	S.P. 5	S.P. 6	S.P. 7	S.P. 8	NSDWQ
pH	8.2	7.08	7.34	7.55	7.13	7.06	6.90	6.97	6.5 - 8.5
Colour (TCU)	1.63	1.32	2.34	0.23	0.29	0.34	0.18	0.27	15
Odour	ODOURLESS / UNOBJECTIONABLE								
Turbidity (NTU)	1.92	3.89	1.66	1.22	1.65	1.58	1.07	1.50	5
E.C (μs/cm)	92.7	197.5	146.9	142.2	142.2	202	159.2	207	1000
TSS (mg/L)	1.25	2.08	1.31	0.12	0.23	0.18	0.22	0.15	N/A
TDS (mg/L)	106	213	117	225	185	196	101	211	500
Alkalinity (mg/L)	56	46	37	65	28	38	21	42	N/A
Total hardness (mg/CaCO$_3$)	126	138	124	115	102	84	120	140	150
Ca Hardness (mg/CaCO$_3$)	83	90	81	85	73	60	76	93	N/A
Chloride (mg/L)	35	42	49	21	17	23	15	20	250
Nitrate (as mg/L NO$_3$)	3.46	2.52	2.39	4.23	2.18	3.04	2.45	2.06	50
Iron (mg/L)	0.022	0.034	0.017	0.022	0.034	0.017	0.014	0.021	0.3
Total Coliform (MPN/100ml)	170	50	12	170	50	12	1600	9	10
E. Coli (MPN/100ml)	126	38	4	126	38	4	965	0	0

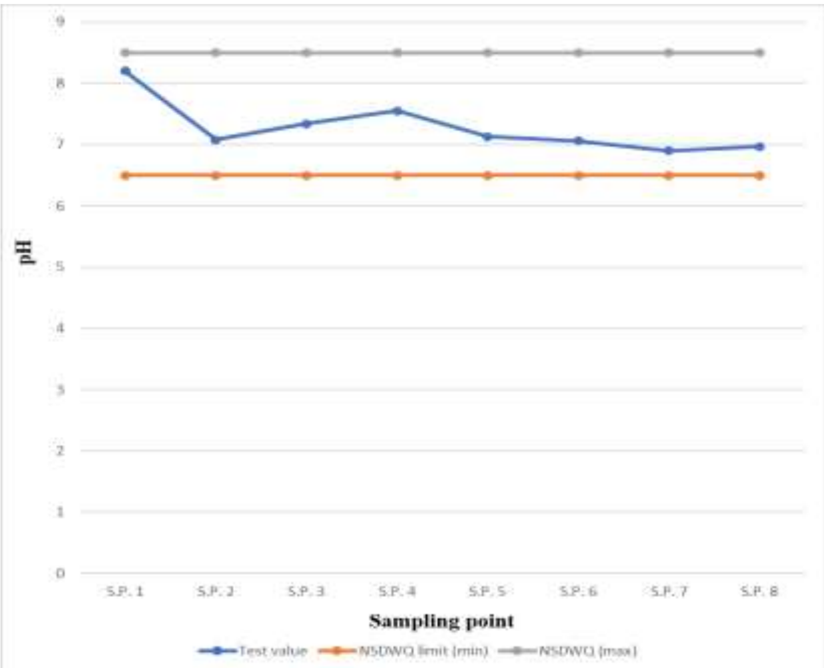

Fig 3. pH for all sampling points

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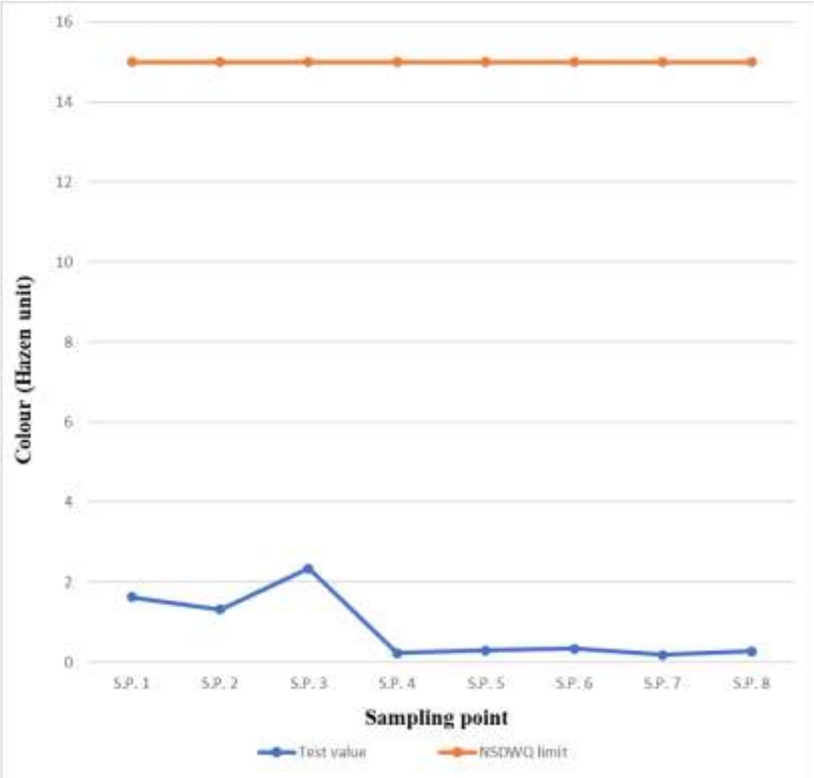

Fig 4. Colour for all sampling points

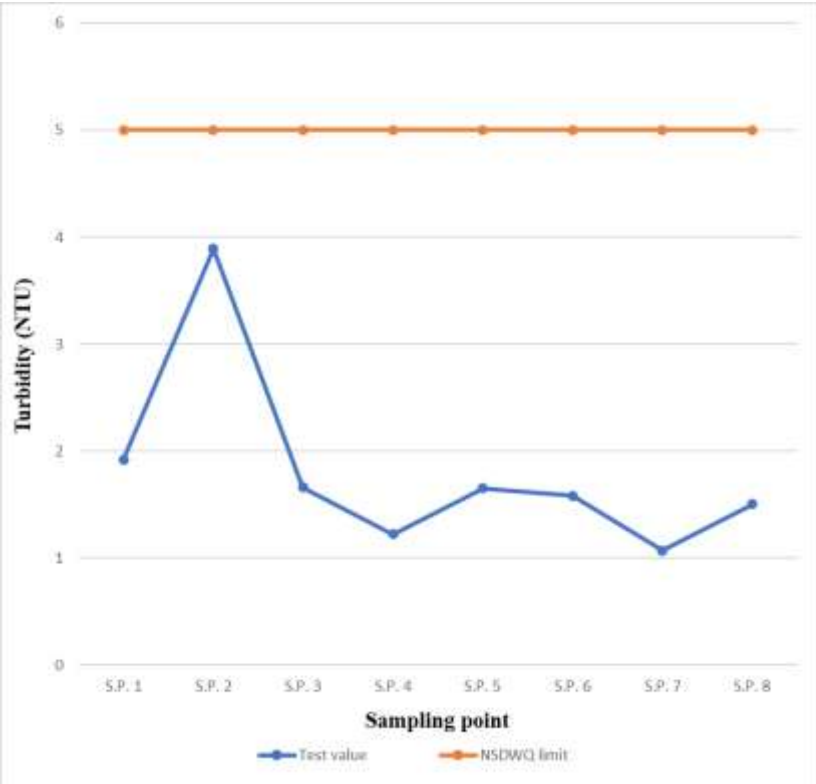

Fig 5. Turbidity for all sampling points

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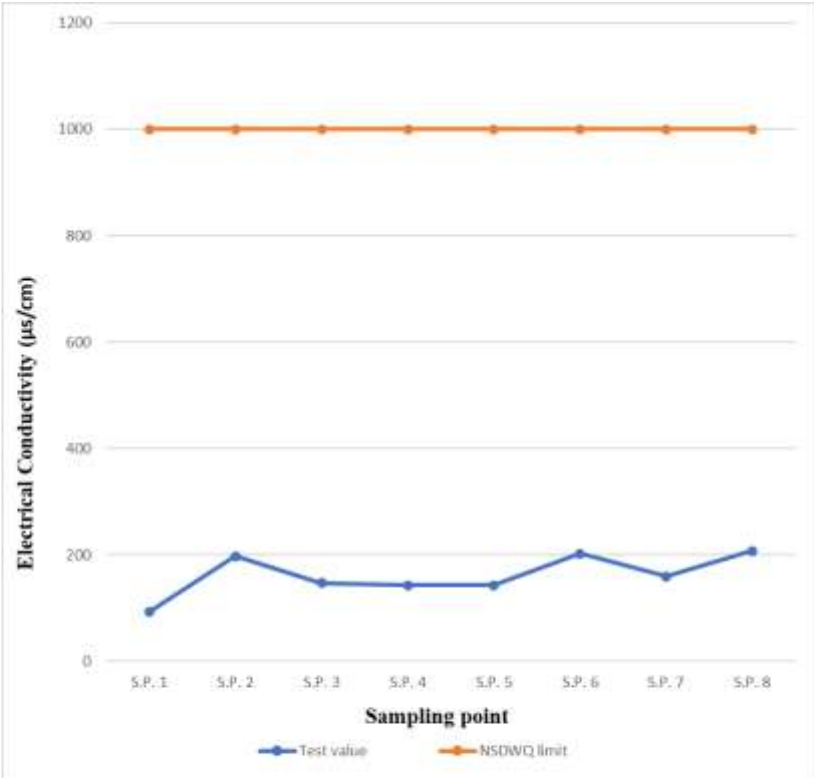

Fig 6. Electrical conductivity for all sampling points

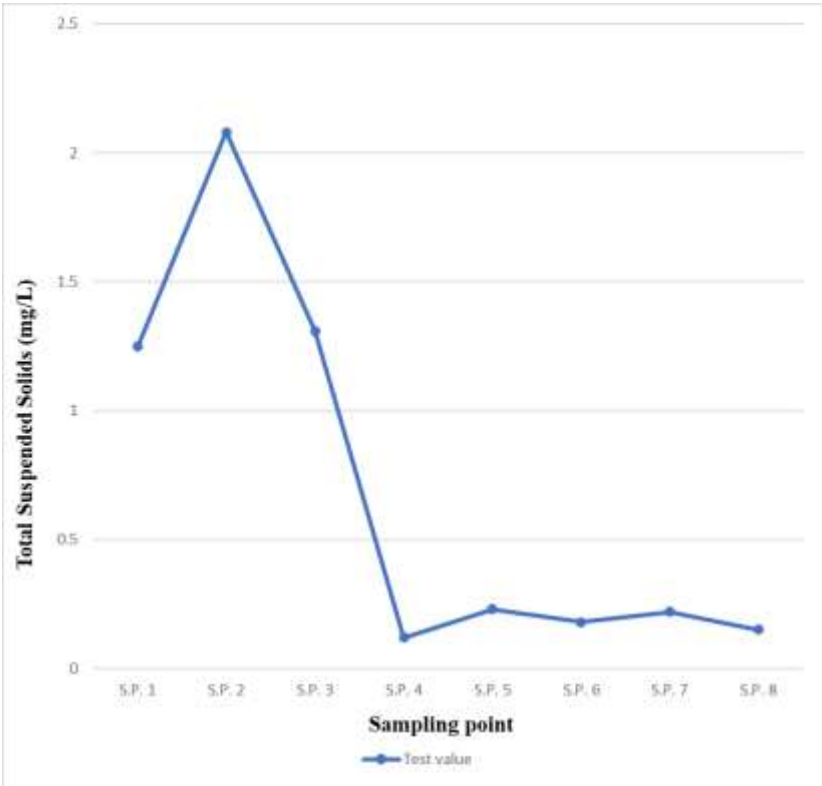

Fig 7. Total Suspended Solids for all sampling points

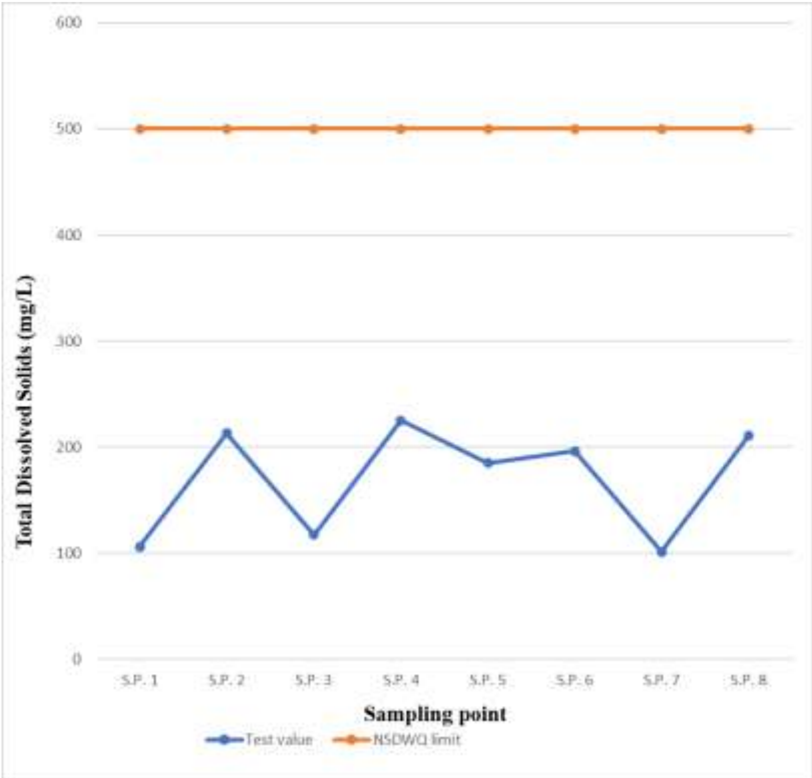

Fig 8. Total Dissolved Solids for all sampling points

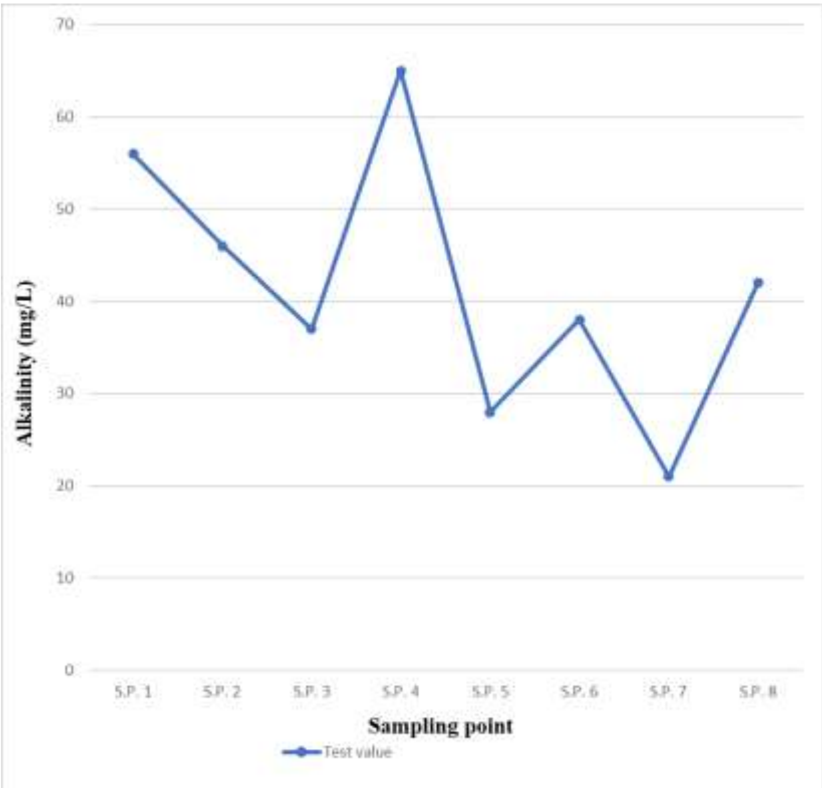

Fig 9. Alkalinity for all sampling points

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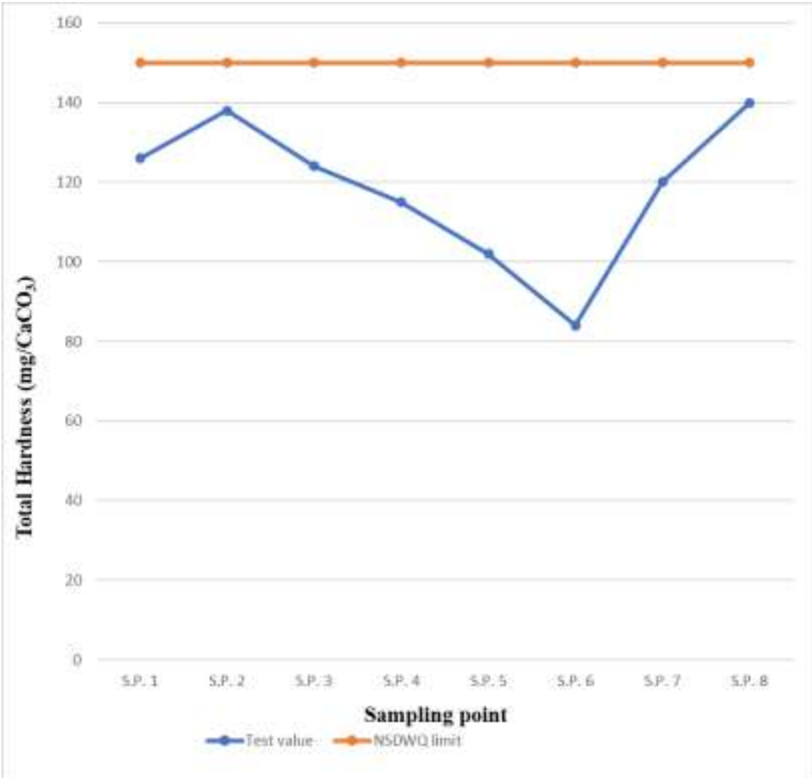

Fig 10. Total Hardness for all sampling points

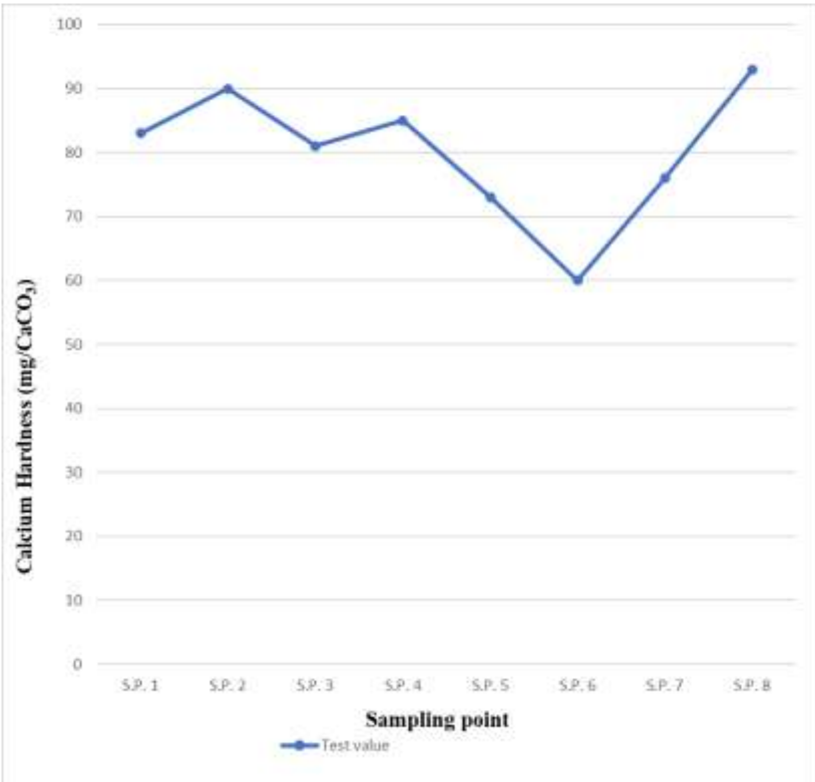

Fig 11. Calcium Hardness for all sampling points

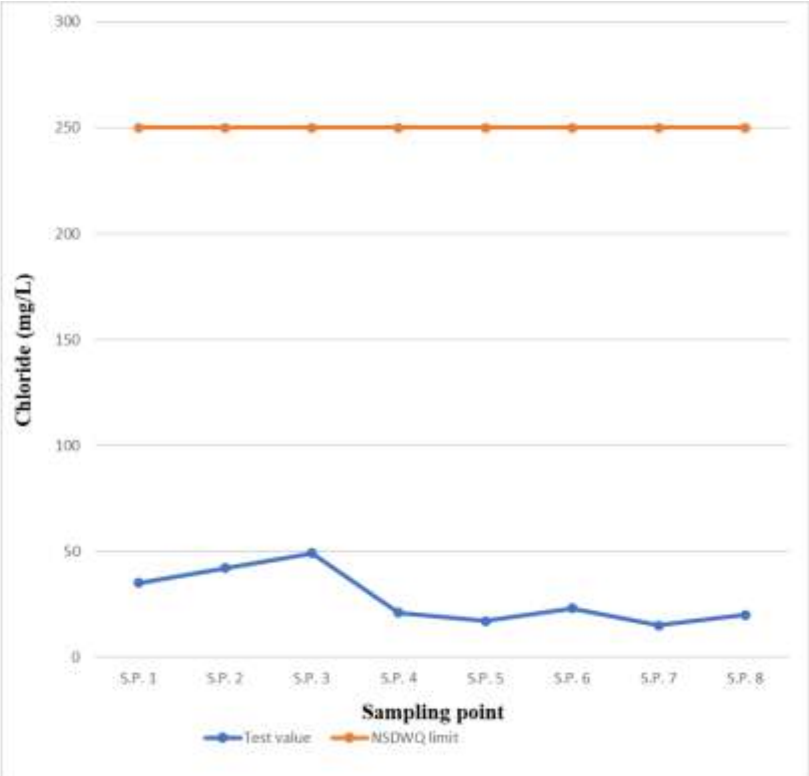

Fig 12. Chloride for all sampling points

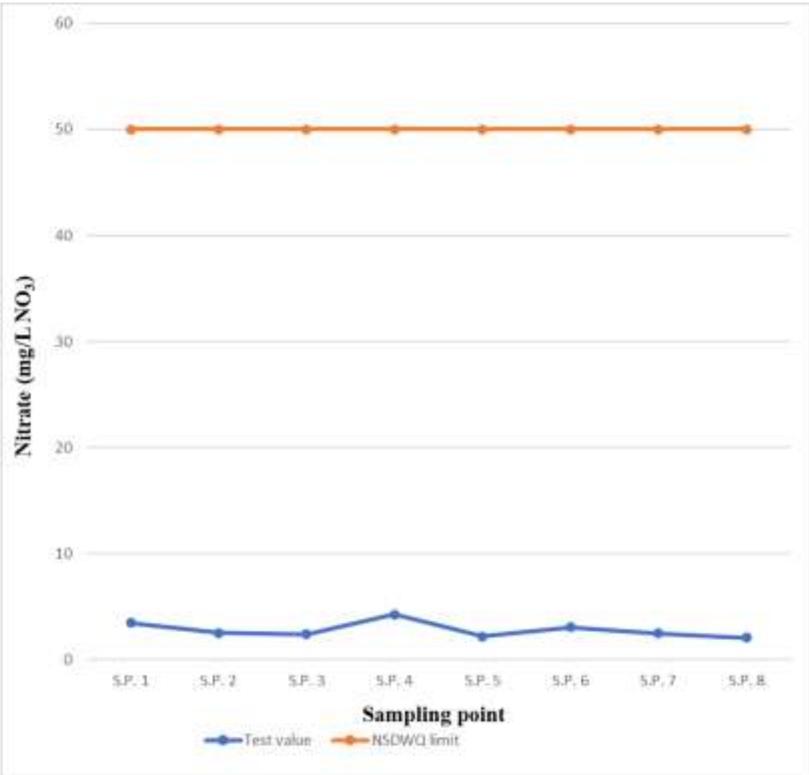

Fig 13. Nitrate for all sampling points

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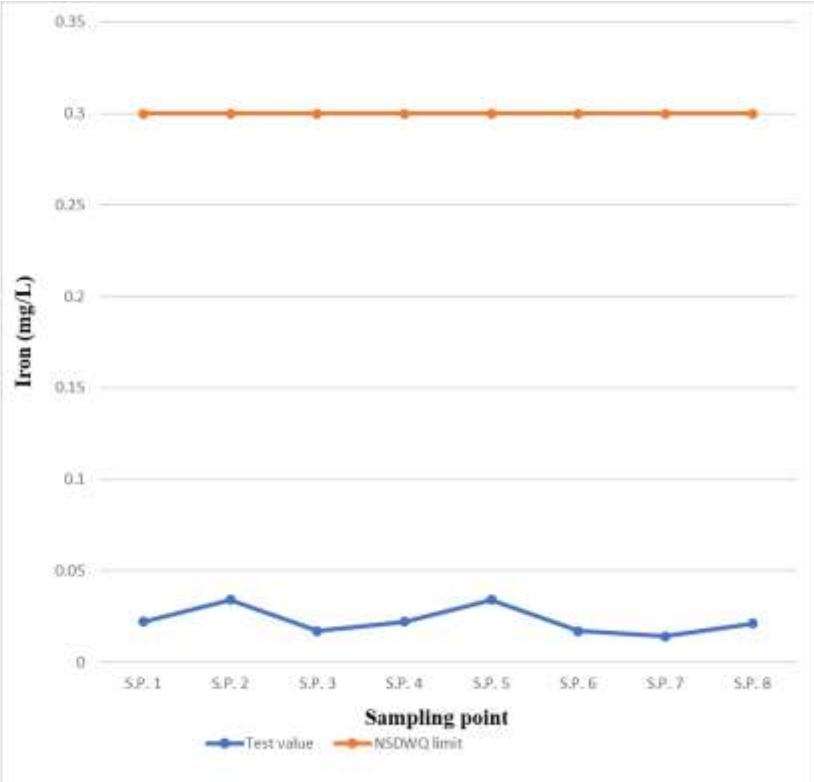

Fig 14. Iron for all sampling points

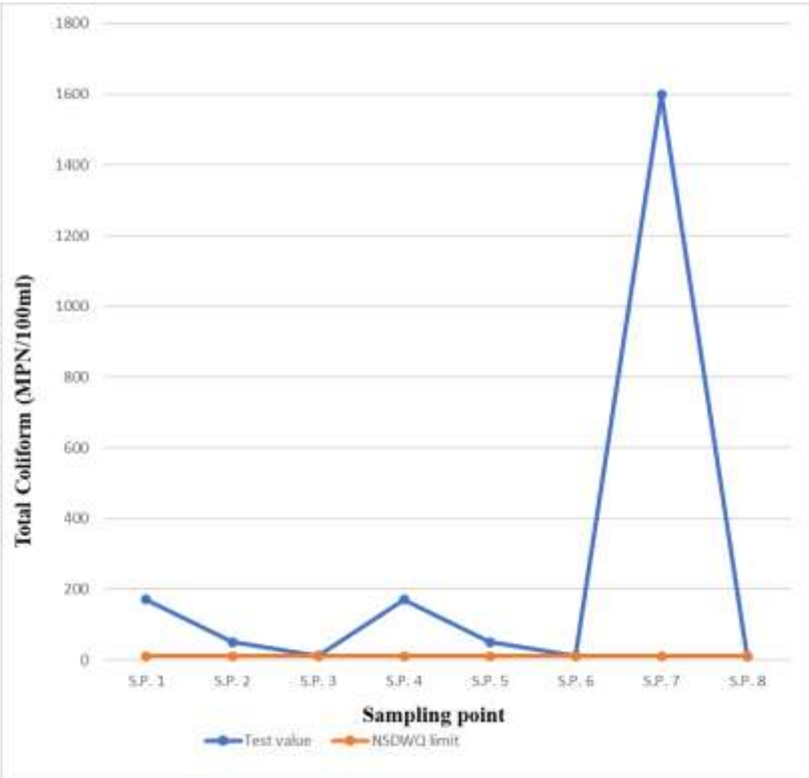

Fig 15. Total Coliform for all sampling points

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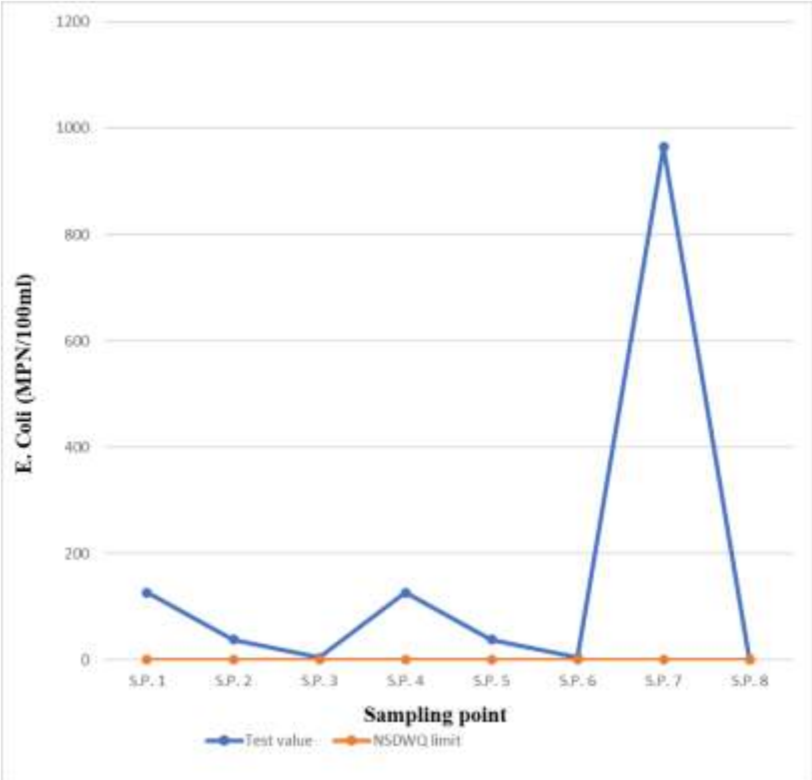

Fig 16. E. Coli for all sampling points

The laboratory test results were analysed using the Weighted Arithmetic Water Quality Index (WA-WQI) method. The parameters used were pH, Colour, Turbidity, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness, Chloride, Nitrate, Iron and Total Coliform. The steps involved in this method are (Nihalani & Meeruty, 2021):

Step 1. Data collection for various water quality parameters.

Step 2. Calculating constant K value using the formula shown in Eq.1. below:

$$K = \frac{1}{\Sigma(1/S_i)}$$ (Eq. 1.)

where Si is standard permissible for ith parameter.

Step 3. Calculating quality rating scale (Qi) for each parameter using Eq. 2. below:

$$Q_i = 100 \times \left(\frac{V_i - V0}{S_i - V0}\right)$$ (Eq. 2.)

where Vi is estimated concentration of ith parameter in the analysed water

V_0 is the ideal value of this parameter in pure water

$V_0 = 0$ (except pH = 7.0 and DO = 14.6 mg/l)

Step 4. Calculating unit weight (Wi) for individual water quality parameter using Eq. 3. below:

$$W_i = \frac{K}{S_i}$$ (Eq. 3.)

Step 5. Calculating water quality index using formula shown in Eq. 4. below:

$$WQI = \frac{\Sigma Q_i W_i}{\Sigma W_i}$$ (Eqn 4.)

Table 2. below shows the Water Quality Rating based on the WA-WQI, while Table 3. shows the results of the Weighted Arithmetic Water Quality Index analysis performed on the laboratory test results. The analysis is illustrated using Fig 17. below.

It can be seen from the analysis that the samples obtained at Sampling Point 3, Sampling Point 5, Sampling Point 6, and Sampling Point 8 all have “Excellent” water quality rating. The samples collected at Sampling Point 2, Sampling Point 4, and Sampling Point 7 have “Good”, “Poor”, and “Unsuitable” water quality ratings respectively. It can be seen that Sampling Point 6, with a WQI of 9.99 has the best lowest WQI, implying that it has the best drinking water quality, while Sampling Point 7, with a WQI of 420.60 has the highest WQI, implying that it has the worst water quality and is therefore unsuitable for drinking.

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At the source, the water has a "Poor" Water Quality Rating (WQR) with a WQI value of 55.32. This may be due to the presence of the manure from the animal dung located close to the source. On getting to Sampling Point 2 at a distance of 950.82m from the source, the water becomes better in quality with a "Good" WQR and a WQI value of 27.38. At a further distance of 417.84m from that point to Sampling Point 3, the water improves in quality again with an "Excellent" WQR and a WQI value of 10.91.

After travelling 2,929.55m from there, there is a decline in water quality as the water at Sampling Point 4 now has a "Poor" WQR and a WQI value of 53.11, which is similar to the quality at the source. This decline in water quality could also be as a result of another pile of manure from animal dung located close to the stream at that point which could have found its way into the stream to contaminate it. Travelling a further 3,633.56m, the water improves in quality at Sampling Point 5 with an "Excellent" WQR and a WQI value of 24.97. At a further distance of 1,036.65m to that point, the water becomes better in quality, still retaining the "Excellent" WQR and now with a lower WQI value of 9.99. At this Sampling Point 6, the stream records its lowest WQI value, meaning that it is at this point of the stream that the water quality is best.

Unfortunately, at a distance of 838.69m to that point, there is a serious decline in water quality as the water at Sampling Point 7 has an "Unsuitable" WQR with a WQI value of 420.60. This could be attributed to the high population pressure on the stream at that point, which could result in a large number of people defecating around the stream thereby contaminating it with faecal pollution and impairing its quality in the process.

Finally, moving a farther distance of 3,045.35m from there to the last Sampling Point, the water quality improves significantly as an "Excellent" WQR and a WQI value of 10.14 is recorded at that Sampling Point 8.

It can be observed that the decline in water quality is mainly due to faecal contamination coming from human and animal wastes being discharged around the affected areas.

Table 2. Water quality rating for WA-WQI method

WQI value	Grading	Water Quality Rating
0 – 25	A	Excellent
26 – 50	B	Good
51 – 75	C	Poor
76 – 100	D	Very poor
Above 100	E	Unsuitable for drinking purpose

Table 3. Water Quality Index (WQI) at all sampling points

SAMPLING POINT	WQI VALUE	GRADE	WATER QUALITY RATING
S.P. 1	55.32	C	POOR
S.P. 2	27.38	B	GOOD
S.P. 3	10.91	A	EXCELLENT
S.P. 4	53.11	C	POOR
S.P. 5	24.97	A	EXCELLENT
S.P. 6	9.99	A	EXCELLENT
S.P. 7	420.60	E	UNSUITABLE FOR DOMESTIC PURPOSE
S.P. 8	10.14	A	EXCELLENT

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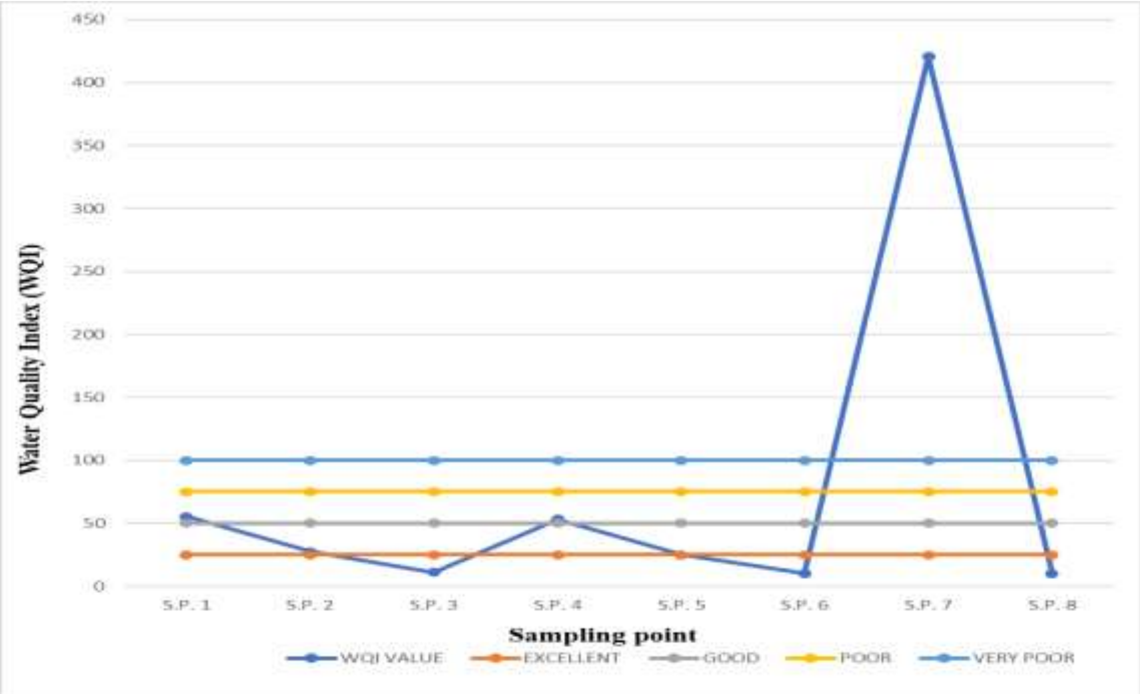

Fig 17. WQI of samples at all sampling points

IV. CONCLUSIONS AND RECOMMENDATIONS

From the results, the physical parameters of pH, Colour, Odour, Turbidity, Electrical Conductivity (E.C), Total Dissolved Solids (TDS), and chemical parameters of Total Hardness, Chloride, Nitrate and Iron all fell within the NSDWQ permissible limits at all eight (8) sampling points, implying that the physico-chemical quality of the stream at all the sampling points is good. However, the bacteriological water quality (in terms of E. Coli present) is questionable. The NSDWQ permissible level for E.Coli in drinking water is zero (0). All sampling points had E. Coli values above this level except for Sampling Point 8 which had an acceptable value of zero (0). The worst E. Coli level was observed at Sampling Point 7, with a value of 965.

E. Coli is indicative of faecal contamination, which is due to human and animal wastes. The presence of unacceptable E. Coli levels in the stream at all but one sampling point may be due to humans defecating around the stream. It could also be from the faeces of cattle while they are at the stream with their nomadic herdsmen, trying to get some water to drink. It could also be due to the humongous pile of animal dung (manure) close to the source of the stream and at another sampling point. This may find its way into the stream and contaminate it bacteriologically.

Also, from the Weighted Arithmetic Water Quality Index (WA-WQI) analysis, the samples obtained at Sampling Point 3, Sampling Point 5, Sampling Point 6, and Sampling Point 8 all have "Excellent" water quality rating. The samples collected at Sampling Point 2, Sampling Point 4, and Sampling Point 7 have "Good", "Poor", and "Unsuitable" water quality ratings respectively.It can be seen that Sampling Point 6, with a WQI of 9.99 has the best lowest WQI, implying that it has the best drinking water quality, while Sampling Point 7, with a WQI of 420.60 has the highest WQI, implying that it has the worst water quality and is therefore unsuitable for drinking. The "Poor" and "Unsuitable" water quality is as a result of the unacceptable E. Coli levels present at the affected sampling points.Escherichia Coli have been implicated in diseases suchas diarrhoea, Urinary Tract Infections (UTIs), respiratory illness, pneumonia, etc (Adesina et al., 2018). Therefore, appropriate measures need to be taken to prevent these outcomes in the rural communities in the study area.

From the results of the research work, the following recommendations are made to address the problem of faecal contamination of the stream water:

i. A law should be implemented regulating nomadic herdsmen from taking their cattle near the stream for drinking, as they usually contaminate the water with their faeces in the process.

ii. Sanitary lifestyle should be preached among the inhabitants of the communities in the study area in order to discourage unsanitary habits of urinating and defecating around the stream.

iii. The use of animal dung as manure around the stream should be discouraged.

iv. Water treatment, especially disinfection, should be carried out on the stream water before use, in order to inactivate the bacteriological contaminant present in the water and make it safe for drinking.

v. An unusual approach that may be explored is bacterial inoculation/immunity. From research, only a proportion of a given population may be susceptible to some pathogens, because immunity developed after an initial episode of infection or illness may provide lifelong protection. Examples include hepatitis A virus and rotaviruses. It is estimated that in developing countries, all children above the age of 5 years are immune to rotaviruses because of repeated exposure in the first years of life. This translates to an average of 17% of the population being susceptible to rotavirus illness (World Health Organisation, 2017). Therefore, the possibility of having the members of the affected rural communities within the study area take in the bacteriologically-contaminated water over time in order to develop immunity against the bacteria may be explored.

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