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RESEARCH ARTICLE

Comparative Bacteriological and Heavy Metal Toxicity Evaluation of Groundwater Wells Proximal to Pollution Receiving Streams in Ondo City, Nigeria

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Abstract:

Background:

Groundwater is the main and easily accessible source of water supply. Aside its over-exploitation problems, groundwater has undergone quality challenges-owing to its proximity to pollution sources.

Methods and Materials:

This study assessed the quality of hand-dug wells situated close to the pollution receiving streams in the Ondo City. Thirty water samples; from fifteen hand-dug wells and fifteen closely associated streams across the city were collected for the study. Physico-chemical, microbial and heavy metals parameters were comparatively analyzed in stream and groundwater samples to assess percolation impact on groundwater quality. Studies were carried out in wet and dry seasons.

Results:

The results obtained from the wells water show that beside temperature and $_{P}$H, the mean values of other physicochemical parameters like turbidity (111.47 NTU & 68.77 NTU/), total dissolved solid (474.6 mg/l & 68.77mg/l), and electrical conductivity (822.31 µS/cm & 816.79 µS/cm) in both season respectively were above the World Health Organisation (WHO) highest desirable limits. The highest total coliform (T.col) recorded at 11,200 (cfu/100ml) and 11,300 (cfu/100ml) and Faecal coliform at 8,400 (cfu/100ml) and 12,100 (cfu/100ml) for dry and rainy seasons respectively. Highest level of aluminium, cadmium, lead, and chromium concentrations in well water at 1.632mg/l, 0.820mg/l, 0.079mg/l and 0.079mg/l recorded in the rainy season exceeded WHO's recommendations. Pearson Correlation analysis between well and stream in the dry season shows positive correlation for all water parameters, with strong significance in $_{P}$H, turbidity, faecal coliform and chromium concentration (0.544, 0.914, 0.414 &0.597) respectively. Similarly, in the rainy season, both well and stream had positive correlations for most parameter tested with significances in turbidity, electrical conductivity, total dissolved solid and cadmium concentration (0.708, 0.775, 0.766&0.655) respectively.

Conclusion:

The major outcome of this research revealed most water samples (well and stream) failed quality assessments. The positive correlations between wells and polluted stream parameters suggested that distance contributed significantly to well contaminations.

Keywords: Groundwater, Correlation, Percolation, Coliform, Heavy metals, Lead.

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1. INTRODUCTION

In Nigeria, as most developing nations, clean portable water continues to remain one of the significant requirements of Mankind. The importance of water and the increasing need to access it has made humans to seek every cheap and economical ways to obtain it [1]. Of the known sources of water, surface water (streams, ponds) and groundwater (hand dug wells, boreholes) remain the two major natural sources in which water is globally abstracted [2, 3]. And of these two major sources, groundwater is reportedly the most trustable source of water available to developing population. Groundwater also account for a global daily dependence from an approximated 1.5 billion human population with over 50 fifty percent of rural and urban population still seeking water from

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hand dug wells and boreholes, many of which has been reported unsafe [4 - 6]

A survey by Majuru *et al*. estimated that 65 million Nigerians had no access to safe water. Many disease outbreaks in rural Nigeria like Cholera, Salmonellosis, and Diarrhoea have been greatly linked to poor water quality.

Owing to the human population explosion and its resultant effect on water demands, the challenge of achieving acceptable water quality is still on the increase. The use of water for agricultural activities, indiscriminate pesticide and agro allied use; and unguarded disposal of industrial wastes can also impact the safety of groundwater available to developing populations. Additionally, due to the sanitation inadequacies; well sited around poor sewage systems, pit latrines and waste dumps have also been reported to affect the physical, chemical and microbial integrity of wells sited close to them [7]. According to the different safe drinking standards, drinking water must not contain feacal contaminants. But earlier studies have reported an approximately 1.8 billion people that are globally affected by feacally contaminated drinking water [8]. More so, there is a rising trend of groundwater contamination with heavy metals, especially in rapidly industrialized communities, with poor environmental monitoring systems. Underground water in such areas can be highly prone to metal leachates, with many of these metals being reported to predispose varying diseases and health disorders.

Even though government agencies are saddle with responsibility of providing safe water for the populace and accordingly managing potential threats to water quality [9], the deficiency of this necessitates for effective monitoring of groundwater available to communities. Ondo city is the second largest community in the Ondo state, Southwestern Nigeria. The sole water source for people in this area is groundwater. Owing to the financial limitations, most residents make use of shallow dug wells. These wells are often deliberately sited close to streams and ponds in order to have access to water all year round. Just like its water, inadequacy of effective sanitation systems in this city still exists. This study intends to assess the physico-chemical, microbial and heavy metals contamination of some selected hand dug wells and closely associated streams and evaluate the possible interaction between them.

2. MATERIALS AND METHODS

2.1. Study Area

This study was carried out in Ondo city, which is the second largest community in Ondo State, Nigeria. The city lies between 7.088923^o N and 4.7990935^{o}E. It is located at about 300 km northeast of Lagos and 45 km west of Akure. Ondo city falls within the humid tropical region with two distinct seasons, the rainy season, which usually runs from March to October, and dry season, from November to March. Ondo is continually growing in human population and has no effective municipal pipe borne water supply.

2.1.1. Sampling Point Selection

Thirty (30) water samples were collected from fifteen (15) wells and fifteen (15) stream points close to each sampled wells across Ondo city (Fig. **1**) Samples were collected in two seasons; Dry season samples were collected in the month of February, 2017 while the rainy season samples were collected in the month of June, 2017. Water samples from the two sources (well and stream) and seasons were taken for comparative analysis.

The coordinates of wells at the different study sites and their associated streams were used in generating map of the area. The core sites that were mapped are Ojojo, Ebido, Iluyemi, Olorunsola, Gani Fawehinmi, Lisaluwa, Irewole, Ogbodu, Sabo, Yemoja, Losunla, Oke gbogi, Bethlehem, Odojomu and Oke Odunwo. The locations of the wells illustrated on the map (Fig. **2**) show a random but well spanned distribution of the sampled wells across the city.

2.1.2. Collection of Samples

For well samples, sterile 50ml bottles (attached with a clean bob) were carefully lowered with a string inside the wells for water collection. To collect streams samples, sterile bottles were gently submerged in each of the streams to collect water. Samples were collected in triplicate, properly screw capped and transported to the laboratory in ice box, in order to maintain the microbial population and were processed for microbial presence within 24 hours according to the International guideline [10]

2.2. Physico-chemical Analysis

Physicochemical parameters like Temperature, pH, Turbidity, Total Dissolved solids and Electrical Conductivity were measured following appropriate water measuring apparatus.

2.2.1. Heavy Metal Analysis

The heavy metals screened were Aluminium (Al), Cadmium (Cd), Lead (Pb) and Chromium (Cr). The analysis was carried out using a furnace Atomic Absorption Spectrophotometer.

2.3. Microbial Analysis

2.3.1. Test for Total coliform

0.1ml of water was plated in a petri dish containing MacConkey agar as the growth medium. It was then incubated at 37°C for 24hrs after which the observed colonies were counted and result expressed as cfu/ml. This experiment was carried out in three replicates for each well water sample. Same was carried out for the stream water sample. The appearance of a pink to dark red colonies indicated the presence of coliforms [11]

2.3.2. Test for Faecal coliform

0.1ml of well water was inoculated into plates containing Eosin-Methylene Blue (EMB) agar and was then incubated for 24 hours at 44°C; this was replicated three times for each well water sample. Same experiment was carried out for the stream water samples. Bacterial colonies were counted to obtain the viable cell count. Differential colour range, from green metallic sheen to pinkish and creamy colouration was used in identifying specific faecal coliform growth [11].

Fig. (1). Section of some sampled wells with accompanying streams.

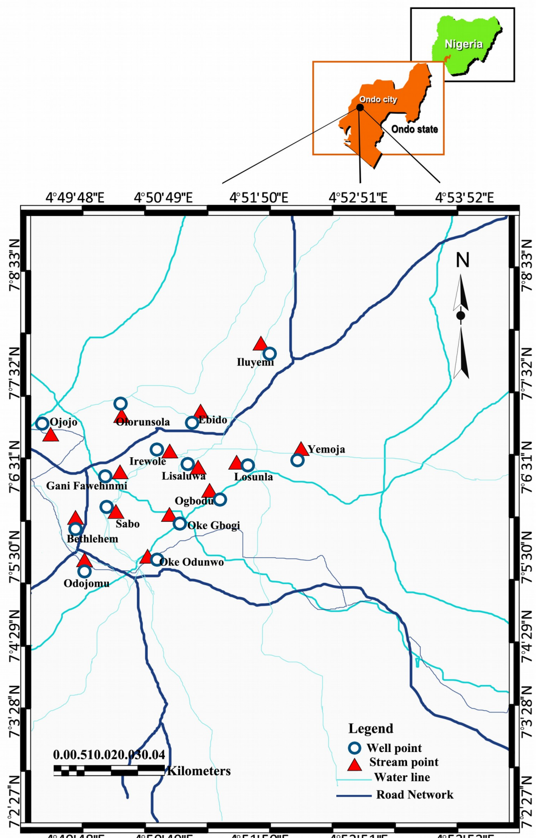

Fig. (2). Map of the study area showing the location of sampled wells and associated stream points in Ondo city.

2.4. Statistical Analyses of Data

T-test was used to compare physicochemical parameters and coliform counts for rainy and dry season. A correlation analysis was carried out to establish the degree of relationship between all parameters measured in the streams and wells. All analyses were carried out using Statistical Package for Social Sciences (SPSS) version 21.0.

3. RESULTS

Results recorded from the study show (Tables **1**) that all hand dug wells tested had coliform contaminations higher that the WHO permissible limits. Also, most of the physico-chemical parameters and heavy metal measured were higher than the permissible limits.

3.1. Difference in Well Water Parameters Between Dry and Rainy Seasons

The differences in parameter concentrations across well water showed only temperature and faecal coliform counts to have significant differences between the wet and dry season. The concentration of Cd, Pb, Cr and pH were not significantly different ($p>0.05$) amongst well waters during dry and rainy season (Table **2**).

3.2. Difference in Stream Water Parameters Between Dry and Rainy Seasons

From Table **3**, the differences in Temp, EC, TDS, Al, Pb and Cr concentrations were significantly different ($P \leq 0.05$) during both season while pH, turbidity, Total coliform, Faecal coliform, Cd were not significantly different from one another amongst well waters during dry and rainy season.

3.3. Difference in Water Parameters Between Stream and Wells in Dry Season

The differences recorded in the concentrations between streams and wells in the rainy seasons are shown. In all, the pH, Faecal coliform, Cd, Pb, Cr concentrations were significantly different ($P \leq 0.05$) while Temperature, Turbidity, EC, TDS, Total coliform and Al contents were not of significant different between streams and wells in dry season (Table **4**).

Table 1. Seasonal variation of quality parameters of well water and comparison with WHO standards

PARAMETER	DRY SEASON Min Max Mean±SE			RAINY SEASON Min Max Mean±SE			HD	MP
Temperature (°C)	27.1	31.0	29.1±0.32	23.9	27.4	29.5±0.36	-	-
pH	5.5*	7.6	6.8±0.13	6.00	8.10*	7.6±0.18	7.0-8.9	6.5-9.5
Turbidity (NTU)	0.61	508*	111.47±45.94	5.10*	512*	68.77±20.91	< 1	5
Electrical Conductivity(μs/cm)	601	1110*	822.31±35.65	498	1342*	816.79±37.87	900	1200
Total Dissolved Solid(mg/l)	383*	823*	474.6±18.50	279*	751*	364.2±18.85	0	500
Total coliform (x10^4 cfu/ml)	1.08*	1.12*	0.69±0.69	1.0*	1.13*	0.79±0.47	0	0
Faecal coliform (x10^{4}cfu/ml)	0.23*	0.84*	0.51±0.27	0.48*	1.21*	0.80±0.37	0	0
Aluminium	0.046*	0.210*	0.102±0.013	0.009*	1.632*	0.146±0.028	0	0.05
Cadmium	0.000	0.031*	0.010±0.003	0.000	0.820*	0.063±0.018	0	0.003
Lead	0.002*	0.046*	0.016±0.003	0.000	0.079*	0.067±0.020	0	0.01
Chromium	0.000	0.048*	0.027±0.006	0.000	0.079*	0.081±0.021	0	0.05

MIN=Minimum, MAX=Maximum, SE=Standard Error, WHO=World Health Organisation *Values higher than WHO Standard

Table 2. Independent sample T-test for difference in concentration of well water parameters between dry and rainy seasons.

PARAMETER	PAIR	MEAN±SE	N	SD	df	TCalc	Sig(2-tailed)	RMKS
Temperature (°C)	Dry season Rainy season	29.1±0.32 25.4±0.30	15 15	1.23 1.15	14 14	8.294	0.000	**S**
pH	Dry season Rainy season	6.8±0.13 6.9±0.15	15 15	0.51 0.59	14 14	-0.89	0.381	**NS**
Turbidity (NTU)	Dry season Rainy season	111.5±45.94 120.9±45.79	15 15	177.91 177.35	14 14	-0.146	0.885	NS
EC (μs/cm)	Dry season Rainy season	822.31±35.65 792.20±55.22	15 15	138.06 213.89	14 14	0.458	0.650	NS
TDS (mg/l)	Dry season Rainy season	474.6±18.50 444.9±30.50	15 15	71.65 118.13	14 14	0.833	0.412	NS
Total coliform(x10^4 cfu/ml)	Dry season Rainy season	5.8±0.79 6.9±0.69	15 15	3.05 2.67	14 14	-1.115	0.274	NS
Faecal coliform(x10^4 cfu/ml)	Dry season Rainy season	5.1±0.148 7.9±0.59	15 15	1.87 2.28	14 14	-3.769	0.001	S
Aluminium (mg/l)	Dry season Rainy season	0.102±0.013 0.153±0.027	15 15	0.05 0.11	14 14	-1.709	0.099	NS
Cadmium (mg/l)	Dry season Rainy season	0.001±0.003 0.014±0.005	15 15	0.12 0.02	14 14	-0.616	0.543	NS

(Table 2) contd.....

PARAMETER	PAIR	MEAN±SE	N	SD	df	TCalc	Sig(2-tailed)	RMKS
Lead (mg/l)	Dry season Rainy season	0.016±0.003 0.016±0.005	15 15	0.11 0.02	14 14	0.055	0.956	NS
Chromium (mg/l)	Dry season Rainy season	0.021±0.005 0.029±0.006	15 15	0.02 0.02	14 14	-1.045	0.305	NS

N=Number of Samples SD=Standard Deviation df=Degree of freedom t calc=Calculated t-value Sig (2-tailed)=Significance of 2 tailed test, RMKS=Remarks EC=Electrical Conductivity, TDS=Total Dissolved Solids, Total coliform=Total coliform count, Faecal coliform=Faecal coliform count, S=Significant, NS=Not Significant

Table 3. Independent sample T-test for difference in concentration of stream water parameters between dry and rainy seasons

PARAMETER	PAIR	MEAN±SE	N	SD	df	TCalc	Sig(2-tailed)	RMKS
Temperature (^{o}C)	Dry season Rainy season	29.5±0.36 26.7±0.24	15 15	1.39 0.92	14 14	6.536	0.000	**S**
pH	Dry season Rainy season	7.6±0.18 7.4±0.16	15 15	0.69 0.64	14 14	1.015	0.319	NS
Turbidity (NTU)	Dry season Rainy season	68.77±20.91 111.35±33.86	15 15	81.01 131.14	14 14	-1.070	0.294	NS
EC (µs/cm)	Dry season Rainy season	816.79±37.87 651.40±33.70	15 15	146.65 130.52	14 14	3.263	0.003	S
TDS (mg/l)	Dry season Rainy season	477.1±24.39 364.2±18.85	15 15	94.46 73.02	14 14	3.662	0.001	S
Total coliform(x10^4 cfu/ml)	Dry season Rainy season	8.6±1.54 7.9±0.47	15 15	5.97 1.84	14 14	0.430	0.673	NS
Faecal coliform(x10^4 cfu/ml)	Dry season Rainy season	7.8±0.70 9.3±0.47	15 15	2.69 1.82	14 14	-1.787	0.085	NS
Aluminium (mg/l)	Dry season Rainy season	0.146±0.028 0.535±0.129	15 15	0.11 0.50	14 14	-2.951	-2.951	S
Cadmium (mg/l)	Dry season Rainy season	0.063±0.018 0.252±0.100	15 15	0.07 0.39	14 14	-1.853	0.084	NS
Lead (mg/l)	Dry season Rainy season	0.067±0.020 0.518±0.167	15 15	0.08 0.52	14 14	-2.680	0.018	S
Chromium (mg/l)	Dry season Rainy season	0.081±0.021 0.372±0.121	15 15	0.08 0.37	14 14	-2.378	0.031	S

N=Number of Samples SD=Standard Deviation df=Degree of freedom t calc=Calculated t value Sig (2-tailed)=Significance of 2 tailed test RMKS=Remarks EC=Electrical Conductivity TDS=Total Dissolved Solids Total coliform=Total coliform count Faecal coliform=Faecal coliform count S=Significant NS=Not Significant

Table 4. Paired sample T-test for difference in concentration of water parameters between streams and wells in dry season.

PARAMETER	PAIR	MEAN±SE	N	SD	df	TCalc	Sig(2-tailed)	RMKS
Temperature (^{o}C)	Well water Stream water	29.1±0.32 29.5±0.36	15 15	1.23 1.39	14 14	-1.049	0.312	NS
pH	Well water Stream water	6.8±0.13 7.6±0.18	15 15	0.51 0.69	14 14	-5.655	0.000	S
Turbidity (NTU)	Well water Stream water	111.47±45.94 68.77±20.91	15 15	177.91 81.01	14 14	1.518	0.151	NS
EC (µs/cm)	Well water Stream water	822.31±35.65 816.79±37.87	15 15	138.06 146.65	14 14	0.137	0.893	NS
TDS (mg/l)	Well water Stream water	474.6±18.50 477.1±24.39	15 15	71.65 94.46	14 14	-0.110	0.914	NS
Total coliform(x10^4 cfu/ml)	Well water Stream water	5.8±0.44 6.1±0.59	15 15	2.98 3.97	14 14	-0.560	0.578	NS
Faecal coliform(x10^4 cfu/ml)	Well water Stream water	5.1±0.27 8.0±0.37	15 15	1.83 2.46	14 14	-8.359	0.000	S
Aluminium (mg/l)	Well water Stream water	0.102±0.013 0.146±0.028	15 15	0.05 0.11	14 14	-1.615	0.129	NS
Cadmium (mg/l)	Well water Stream water	0.010±0.003 0.063±0.018	15 15	0.01 0.07	14 14	-3.009	0.009	S

(Table 4) contd.....

PARAMETER	PAIR	MEAN±SE	N	SD	df	TCalc	Sig(2-tailed)	RMKS
Lead (mg/l)	Well water Stream water	0.016±0.003 0.067±0.020	15 15	0.01 0.08	14 14	-2.582	0.022	S
Chromium (mg/l)	Well water Stream water	0.021±0.005 0.081±0.021	15 15	0.02 0.08	14 14	-3.255	0.006	S

N=Number of Samples **SD**=Standard Deviation **df**=Degree of freedom **t calc**=Calculated t value **Sig (2-tailed)**=Significance of 2 tailed test **RMKS**=Remarks **EC**=Electrical Conductivity **TDS**=Total Dissolved Solids, **Total coliform**=Total coliform count, **Faecal coliform**=Faecal coliform count, **S**=Significant, **NS**=Not Significant

Table 5. Paired sample T-test for difference in concentration of water parameters between streams and wells in rainy season.

PARAMETER	PAIR	MEAN±SE	N	SD	df	TCalc	Sig(2-tailed)	RMKS
Temperature (^{o}C)	Well water Stream water	25.5±0.30 26.7±0.24	15 15	1.14 0.92	14 14	-3.885	0.002	**S**
pH	Well water Stream water	6.9±0.15 7.4±0.16	15 15	0.59 0.64	14 14	-2.563	0.023	S
Turbidity (NTU)	Well water Stream water	111.35±33.86 68.77±20.91	15 15	131.14 81.01	14 14	1.765	0.099	NS
EC (µs/cm)	Well water Stream water	792.2±55.22 651.40±33.70	15 15	213.89 130.52	14 14	3.902	0.002	S
TDS (mg/l)	Well water Stream water	444.9±30.50 364.2±18.85	15 15	118.13 73.02	14 14	4.010	0.001	S
Total coliform(x10^{4} cfu/ml)	Well water Stream water	6.9±0.69 7.9±0.47	15 15	2.67 1.84	14 14	-2.356	0.034	S
Faecal coliform(x10^{4} cfu/ml)	Well water Stream water	7.9±0.59 9.3±0.47	15 15	2.29 1.82	14 14	-3.029	0.009	S
Aluminium (mg/l)	Well water Stream water	0.153±0.028 0.535±0.129	15 15	0.11 0.50	14 14	-2.930	0.011	S
Cadmium (mg/l)	Well water Stream water	0.014±0.005 0.252±0.100	15 15	0.02 0.39	14 14	-2.454	0.028	S
Lead (mg/l)	Well water Stream water	0.016±0.005 0.518±0.167	15 15	0.02 0.65	14 14	-3.043	0.009	S
Chromium (mg/l)	Well water Stream water	0.027±0.006 0.372±0.121	15 15	0.02 0.47	14 14	-2.899	0.012	S

N=Number of Samples **SD**=Standard Deviation **df**=Degree of freedom **tcalc**=Calculated t value **Sig (2-tailed)**=Significance of 2 tailed test **RMKS**=Remarks **EC**=Electrical Conductivity **TDS**=Total Dissolved Solids **Total coliform**=Total coliform count **Faecal coliform**=Faecal coliform count **S**=Significant **NS**=Not Signifi

3.4. Difference in water parameters between streams and wells in rainy season

Differences in concentrations between stream and wells in rainy seasons showed that aside turbidity, all water parameters were significantly different ($p<0.05$) between well and streams during the rainy season (Table **5**).

3.5. Correlation of water parameters between streams and wells in dry season

Water parameters between streams and wells in dry season (Table **6**) showed that pH, Turbidity Cr conc. and faecal coliform counts of streams in dry season positively and significantly correlated with wells at $P<0.05$. The Temperature, EC, TDS, Total coliform, Al, Cd and Pb levels of stream also positively correlated with wells, though not significant at $P>0.05$ (Table **6**)

3.6. Correlation of water parameters between streams and wells in rainy season

In the rainy season, the Turbidity, EC, TDS, and Cd, of streams positively and significantly correlated with well water at $P<0.05$. Temperature, pH, Al, Pb, were also positive but not significant. Conversely, the Total coliform and faecal coliform counts were negatively correlated between stream and wells respectively $p>0.05$ (Table **7**).

Table 6. Correlation of water parameters between streams and wells in dry season.

PARAMETER	PAIR	MEAN±SE	N	SD	df	PEARSON CORRE LATION	Sig(2-tailed)	RMKS
Temperature (^{o}C)	Well water Stream water	29.1±0.32 29.5±0.36	15 15	1.23 1.39	14 14	0.236	0.398	**NS**
pH	Well water Stream water	6.8±0.13 7.6±0.18	15 15	0.51 0.69	14 14	0.544	0.036	S
Turbidity (NTU)	Well water Stream water	111.47±45.94 68.77±20.91	15 15	177.91 81.01	14 14	0.914	0.000	**S**

(Table 6) contd.....

PARAMETER	PAIR	MEAN±SE	N	SD	df	PEARSON CORRELATION	Sig(2-tailed)	RMKS
EC (µs/cm)	Well water Stream water	822.31±35.65 816.79±37.87	15 15	138.06 146.65	14 14	0.398	0.141	NS
TDS (mg/l)	Well water Stream water	474.6±18.50 477.1±24.39	15 15	71.65 94.46	14 14	0.446	0.095	NS
Total coliform($x10^4$ cfu/ml)	Well water Stream water	5.8±0.44 6.1±0.59	15 15	2.98 3.97	14 14	0.217	0.153	NS
Faecal coliform($x10^4$ cfu/ml)	Well water Stream water	5.1±0.27 8.0±0.37	15 15	1.83 2.46	14 14	0.414	0.005	S
Aluminium (mg/l)	Well water Stream water	0.102±0.013 0.146±0.028	15 15	0.05 0.11	14 14	0.243	0.383	NS
Cadmium (mg/l)	Well water Stream water	0.010±0.003 0.063±0.018	15 15	0.01 0.07	14 14	0.361	0.187	NS
Lead (mg/l)	Well water Stream water	0.016±0.003 0.067±0.020	15 15	0.01 0.08	14 14	0.221	0.429	NS
Chromium (mg/l)	Well water Stream water	0.021±0.005 0.081±0.021	15 15	0.02 0.08	14 14	0.597	0.019	S

N=Number of Samples **SD**=Standard Deviation **df**=Degree of freedom **t calc**=Calculated t value **Sig (2-tailed)**=Significance of 2 tailed test **RMKS**=Remarks **EC**=Electrical Conductivity **TDS**=Total Dissolved Solids **Total coliform**=Total coliform count **Faecal coliform**=Faecal coliform count **S**=Significant **NS=**Not Significant

Table 7. Correlation of water parameters between streams and wells in rainy season.

PARAMETER	PAIR	MEAN±SE	N	SD	df	PEARSON CORRELATION	Sig(2-tailed)	RMKS
Temperature (°C)	Well water Stream water	25.5±0.30 26.7±0.24	15 15	1.14 0.92	14 14	0.299	0.279	NS
pH	Well water Stream water	6.9±0.15 7.4±0.16	15 15	0.59 0.64	14 14	0.398	0.142	NS
Turbidity (NTU)	Well water Stream water	111.35±33.86 68.77±20.91	15 15	131.14 81.01	14 14	0.708	0.003	**S**
EC (µs/cm)	Well water Stream water	792.2±55.22 651.40±33.70	15 15	213.89 130.52	14 14	0.775	0.001	S
TDS (mg/l)	Well water Stream water	444.9±30.50 364.2±18.85	15 15	118.13 73.02	14 14	0.766	0.001	S
Total coliform($x10^4$ cfu/ml)	Well water Stream water	6.9±0.69 7.9±0.47	15 15	2.67 1.84	14 14	-0.821	0.000	S
Faecal coliform($x10^4$ cfu/ml)	Well water Stream water	7.9±0.59 9.3±0.47	15 15	2.29 1.82	14 14	-0.680	0.005	S
Aluminium (mg/l)	Well water Stream water	0.153±0.028 0.535±0.129	15 15	0.11 0.50	14 14	0.047	0.868	NS
Cadmium (mg/l)	Well water Stream water	0.014±0.005 0.252±0.100	15 15	0.02 0.39	14 14	0.655	0.008	S
Lead (mg/l)	Well water Stream water	0.016±0.005 0.518±0.167	15 15	0.02 0.65	14 14	0.434	0.106	NS
Chromium (mg/l)	Well water Stream water	0.027±0.006 0.372±0.121	15 15	0.02 0.47	14 14	-0.408	0.131	NS

N=Number of Samples **SD**=Standard Deviation **df**=Degree of freedom **t calc**=Calculated t value **Sig (2-tailed)**=Significance of 2 tailed test **RMKS**=Remarks **EC**=Electrical Conductivity **TDS**=Total Dissolved Solids **Total coliform**=Total coliform count **Faecal coliform**=Faecal coliform count **S**=Significant **NS=**Not Significant

4. DISCUSSION

Generally, the study revealed that the water from wells in Ondo city contained high coliform bacteria. These coliform counts were higher than the WHO standard which stated that coliforms or faecal coliform must not be detectable in any 100ml of drinking water [12]. Similar studies also recorded high values for Total coliform counts in various groundwater wells [13, 14]. The mean faecal coliform count of the wells in this study was generally higher in the rainy season (12.10×10^4 cfu/ml) than in the dry season (8.40×10^4cfu/ml). attributed to excess rainwater that infiltrates and percolates the soil which could facilitate microbes transport.[15]. In another reported work of [16], the impacts of leaking sewers on urban groundwater produce a potential risk for soil and groundwater contamination. Beside the proximity of understudied wells to polluted streams, various other factors such as well depth, prevailing weather condition, orientation of wells to sewage pit, well properties and nature of well-site could have facilitated the migration and entrance of faecal contaminants from streams into well water.

The Pearson correlation matrix of well water and associated streams for most of the parameter tested were positive during the dry and rainy season. The total and faecal coliform counts correlation of well to streams during the dry season were also positive but not significant. This result conforms to the observations [17, 19] that reported a positive correlation between well distance and bacterial counts of well water samples; thus, suggesting the closeness of polluted stream as a factor for well contamination.

Contrarily, the rainy season correlation of the faecal coliform count to the distances between wells and streams was negative, which is in agreement with another work [20] which did not find any association between the bacteriological quality of dug-well and distance to the nearest pollution source probably due to the season of the year in which the study was conducted. However, the low significant negative correlation recorded in the rainy season with respect to total and faecal coliform contamination may be a result of increasingly high water activity which might have led to constant disengagement of bacterial adhesion and proliferation as against the dry season's lesser water activity and warmer temperature that aid bacterial growth. Some other factors such as underlying rocks and seepage propensity, or other edaphic factors could also contribute to well water contamination [19].

Additionally, most of the wells recorded a mean value of metal presence that is higher than both desirable and permissible limits. This high metal contamination may be attributed largely to the disposal of batteries, lead-based paints and other industries based wastes into the streams which could have seeped into wells. The positive correlations of heavy metal contaminants recorded between stream water and well water also corroborates the findings of other studies [21] and [22].

CONCLUSION

Findings from this research revealed that most wells studied in Ondo city failed quality standards measured. Positive correlations of well and streams parameters also suggest reasonable levels of influence, which associated polluted streams exerted on the groundwater tested. The primary treatment of water by boiling, filtering before use for drinking, cooking and washing should also be encouraged. In addition to this, there should be restrictions on the disposal of domestic solid wastes on water bodies and stream whether close or far from hand dug wells.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The authors confirm that the data supporting the findings of this study are available within the article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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