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Research Article

Statistical Evaluation and Quality Analysis of Water Resources Around Quarry Site in Abuja Suburban Nigeria

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Abstract

Water resources occupy a vital position regarding the source of human hope for longevity and significant shortfalls on the strive towards sustainable development globally. Host communities to quarry companies without a water treatment plant are greatly affected by use of untreated water. This research highlights statistical evaluation and quality analysis of water resources around a quarry site in FCT Nigeria. The study engaged biological assay, physiological and chemical analysis to quantify contamination levels in the water resources and obtained data were subjected statistically using Pearson's Correlation, descriptive statistics, Levene's test for homogeneity and one–way analysis. The physiochemical analysis revealed the water resources to have high turbidity value in 58.3% of sampled population while nitrate concentration and electrical conductivity value were very low. The bioassay revealed presence of coliform bacteria in 100% of sampled population while thermotolerance count discovered disease-causing-pathogens in 41.7% of sampled population. Chemical analysis revealed that Pb, Cr, Ni and As were 91.7%, 83.3% 100% and 100% above recommended permissible limits for sampled population. These results suggests that water resources in this study is unsafe and holds a health-treat with regards to the contaminations inherent in them. Statistical evaluation revealed average positive linear relationship between heavy metal concentration suggesting close relationship of contamination source. Observed strong positive linear relationship between lead and copper, nickel and chromium as well as nickel and arsenic in the scatterplot depicts same source of contamination.

Keywords

Water Resource, Heavy Metal, Potable Water, Coliform Group, Contamination, NSDWQ

1. Introduction

In view of recent industrial advancement, population growth along and unchecked activities that contaminate water resources, potable water have classified under scarce commodity. Low standard water quality being made available to the public as potable water has its root in lack of proper sanitation systems, rapid urbanization and limited infrastructure [1-3]. According to Sukri *et al*., approximately 2.2 billion people worldwide lack access to potable water resulting to prevailing water-related diseases and greater risks for waterborne illnesses [4]. The resultant effects can be seen in abject degradation of communal health which leads to poverty and stifling of potentials for societal wellbeing which hinders economic growth. The World Health Organization (WHO) classified small portion of vast abundant Earth's water re-

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sources as potable water, implying a need to protect the available freshwater for domestic use [1, 5].

Moreover, rapid increase in population, economic and social activities in Africa is threatening available source of potable water via contamination. Nations have mechanisms in place to check influx of contaminants into water resources from socioeconomic activities but lack of necessary infrastructure still undermine every effort [2]. Contamination of water resources could be through natural or anthropogenic process such as mining, quarry, industrial effluents, pathogenic microorganisms, putrescible organic wastes and sediments [2-5]. Contaminated water is viewed to cause serious health and environmental challenges. Industrial effluents and wastes are paramount in contaminating the environment especially our water resources. Among several industrial contaminants in water bodies, heavy metals (HMs) are considered most dangerous to human health alongside coliform bacteria [6]. According to WHO report, the following HMs; arsenic (As), copper (Cu), mercury (Hg), nickel (Ni), cadmium (Cd), lead (Pb), and chromium (Cr) are considered most toxic to human wellbeing [7, 8]. The magnesium element is known to have adverse effect at certain concentration and could manifest as cardiovascular disease, stomach upset and distorted excretion [9]. Lead is a lethal element that is accredited with causing cancer. High concentration of lead in potable water has effect like; increased blood pressure, kidney damage, anemia, fatigue, irritability, digestive disorder, brain and nervous system damage among others which are prevalent for young children and women of child-bearing age. [10]. Copper causes liver and kidney malfunctioning, headaches, stomach cramps and skin irritation while nickel induce shortness of breath, nausea, vomiting, giddiness, lassitude and diarrhea in the body [11].

Hassan [3] studied metals distribution in the water bodies around a quarry site and found that the water resources in surrounding localities were polluted with cadmium, nickel and iron. Okafor and Njoku [12] in their study revealed that the concentration of lead, cadmium and iron were high in water resources within 0 – 50 m from quarry site and proposed that quarry activities have harmful effect to water and aquatic organisms residing in surrounding water bodies. According to the data they obtained, they suggested a treatment to water sources before domestic use to avoid ailments associated with water pollution. Georgaki and Charalambous [13] in their work concluded that regular interval checks with sufficient water sample population and data collation of targeted biological indicators of human health is recommended for communities. They opined that thorough examination of confounding factors which may affect the host communities to industries will provide important information on the effect of HM toxicity. The present study carried out analysis of water resources around a quarry site located in Karshi Road, Orozo, Abuja (FCT) Nigeria with the objectives of evaluating biological, chemical and physiological state of the water resources. The data obtained were statistically analyzed and discussed using descriptive and inferential analysis such as Pearson's Correlation and Levene's test for homogeneity of variance to correlate interdependence of the HMs. One–way analysis of variance was used to correlate relationships between HM concentration in the water samples in respect of health implications to the community.

2. Materials and Method

The study was carried out in the environs of a quarry site located in Karshi Road, Orozo, Abuja the Federal Capital Territory of Nigeria located between latitude 8.8211 °or 8 °49′ 16″ North and longitude 7.5538 ° or 7 ° 33′ 14″ East. Each water sample was collected within Karshi and Kaidi water resources not exceeding two [2] kilometers away from the quarry company which represented the total population for the study area and are listed below. Water sampling was done in the dry season of the year (October) using analytical method as described by Hassan [3] and the collected samples were preserved in prescribed method prior analysis.

2.1. Physicochemical Analysis of Water Samples

Determination of pH

The water sample pH values were determined using buffer standardized Hanna microprocessor pH meter at the point of collection.

Determination of conductivity and turbidity

The electrode of Jenway conductivity meter was calibrated using deionized water after which it was inserted into a 50 ml glassware containing the samples until a stable reading was obtained and recorded.

Determination of nitrate concentration

The nitrate concentration was determined using a 752M UV/Visible spectrometer after calibration using a sample with known wavelength.

2.2. Chemical Analysis of Water Samples

The determination of HM in water samples were done using an Atomic Absorption Spectrometer (AA32010) with respective lamps for each metal determination.

2.3. Bioassay of Water Samples

The membrane filtration of water samples was done using 50 ml of each sample and filter paper. Various nutrient solutions were prepared, sterilized in an autoclave and transferred into a Petri dish thereafter, the filtered bacteria with the filter paper were placed in the Petri dish. The setup was transferred to an incubator and incubated at varying temperature with time regarding the bacteria type and nature of culture media [14]. Total microbial counts were incubated at 25 – 37 ℃ for 24 hours, total coliform count was incubated at 37 ℃ for 48 hours while thermotolerance count were incubated at 44 ℃for

48 hours. The bacteria colonies were observed after incubation with hand magnifying glass and number of populated colonies recorded for each bacteria type and media culture.

2.4. Statistical Analysis

The data obtained were statistically analyzed using the Statistical Package for Social Sciences (SPSS 24) to study the descriptive statistics, homogeneity of variances and Pearson's correlation among HMs in water resources.

3. Results and Discussions

3.1. Physicochemical Analysis of Water Samples

The physicochemical properties of water resources examined in this work are recorded in Table 1 and discussed below.

pH of water

The pH value reveals ion concentration in water as a significant parameter in evaluating the safe condition of water resource. pH has a straight inverse relationship between H^+ ion concentration implying that an increase in H+ ion results a decrease in pH. Both WHO and Nigerian Standard for Drinking Water Quality (NSDWQ) recommends that the permissible limits for pH of potable water should be within the range 6.5 – 8.5. Water resources studied in this work were found to have values between 6.70 – 7.50 (Table 1) indicating safe values in view of recommended standards. This indicates that the HM concentrations in this study were not appreciable to affect the water pH since 100% of sampled points are in the neutral region.

Turbidity

Water turbidity is a degree of clarity which largely depends on the quantity of suspended solid matter representing colloidal substance which affect light emitting properties of water. The results measured for the different sampled point are presented in Table 1. The obtained value gives an insight on the extent of quarry dust and effluents settling in the water resources [12]. According to Yirdaw and Bamlaku (2016), high turbidity value impedes photosynthesis of water weeds which causes major distortion to the food-chain-web thereby distorting the ecosystem. Data obtained from the study area revealed 58.3% of sampled population as having turbidity level within the range 5.03 – 8.83 NTU while 41.7% were within recommended limits (1.79 – 4.71 NTU). Both WHO and NSDWQ recommends a maximum value of 5.00 NTU. This result showed that quarry activities had an effect on the turbidity through release of colloidal matter to the water resources. The quarry dust exhausted from quarry activities is known to alter water chemistry via absorption hence, obstructing sunlight passage and hindering photosynthesis. This adsorbed quarry dust might also disrupt normal groundwater movement thereby interrupting natural process of water-recharge [3].

Electrical Conductivity (EC)

Electrical conductivity test is a measure of conducting ion concentration that enhance passage of electric current through water. Generally, high amount of conducting ions represents inclusion of foreign ions as neutral-real water is reported as poor conductor of electricity while deionized water behaves as an insulator [8]. The NSDWQ acceptable maximum value for electric conduction of water is 1000 µS/cm but obtained values from sampled points in this study indicates low electrical conductivity in the range of 6.92 – 10.01 µS/cm. Similar values were reported by Okafor and Njoku [12] as they evaluated water resources around a quarry site in Ebonyi State Nigeria. This is an indication that quarry activities influenced ion concentration in the water resources through contributing of species which bonded and/or mopped up ions like Ca^{2+}, Mg^{2+}, SO_4^{2-} and the likes resulting to decreased electrical conductivity. This could be ascribed to an effect of sequestering and sedimentation of mobile ions in the water resources by dissolved quarry dust.

Nitrate concentration

Nitrate concentration in water resources is linked to leaching of inorganic fertilizers and nitrogen cycle processes which include bacterial oxidation and nitrogen fixation by leguminous plants. NSDWQ permissible limit is 50 mgL^{-1} and results obtained in this study ranged between 17.21 – 31.12 mgL^{-1} which is within acceptable limit for potable water. This implies 100% safety from sampled points which reveals that both human and quarry activities in this study had no negative effects regarding nitrate concentration in the water resources.

Table 1. *Values obtained for physiochemical and chemical analysis of water samples.*

Sample source	Nitrate (mg/L)	Turbidity (NTU)	pH	EC (µS/cm)	Mg (mg/L)	Pb (mg/L)	Cu (mg/L)	Ni (mg/L)	Cr (mg/L)	As (mg/L)
MCB	20.13	1.79	6.70	8.71	0.158	0.006	0.173	0.117	0.011	0.164
AHD	25.21	3.00	7.20	8.92	0.222	0.215	0.151	0.151	0.206	0.625
KQW	19.21	5.32	6.90	7.21	0.510	0.480	0.699	0.546	0.685	0.663
KQR	18.31	4.71	6.80	8.23	0.221	0.271	0.130	0.446	0.199	0.917

Sample source	Nitrate (mg/L)	Turbidity (NTU)	pH	EC (µS/cm)	Mg (mg/L)	Pb (mg/L)	Cu (mg/L)	Ni (mg/L)	Cr (mg/L)	As (mg/L)
KTB	20.23	5.03	6.70	9.32	0.080	0.098	0.308	0.052	0.010	0.362
KWW	30.11	8.83	6.90	6.92	0.959	0.108	0.082	0.130	0.121	0.052
KBS	24.25	6.21	7.30	7.21	0.628	0.204	0.109	0.077	0.198	0.121
KSP	21.11	5.88	7.50	8.88	0.258	0.031	0.216	0.244	0.426	0.082
KTS	31.12	4.71	6.90	9.21	0.159	0.013	0.315	0.355	0.095	0.142
KTW	18.93	5.03	6.70	9.31	0.391	0.178	0.403	0.209	0.307	0.078
QSS	17.21	5.35	6.80	10.01	0.173	0.351	0.527	0.061	0.086	0.101
QJS	25.14	2.37	6.90	8.75	0.238	0.186	0.449	0.147	0.277	0.113

3.2. Chemical Analysis

The results obtained for HM content in the sampled water resources recorded in Table 1 and discussed below.

Magnesium (Mg)

Magnesium element is abundant in water bodies and the earth crust with atomic weight and radii of 24.31 g/mol and 0.16 nm respectively. Magnesium is an essential micronutrient needed for proper functioning of living organisms in aquatic and terrestrial spheres. In humans, magnesium is present in bones, tissues and muscles [14-16]. In this study, all sampled points showed 100% permissible magnesium ion content with values ranging from 0.08 – 0.959 mgL^{-1} which are lower than NSDWQ acceptable limit of 20.0 mgL^{-1}. Similar results have been obtained by Hassan [3] in a study of water bodies carried out round a quarry site in Ogun State Nigeria. The low magnesium content recorded in this study suggests a situation where radical anions released through quarry activity as pollutant sipped into groundwater to mops ions via sequestering action. This agrees with the suggested reason for low electrical conductivity recorded in this study. According to the report by Division of Environmental and Community Health, Massachusetts, low levels of magnesium as found within this range is best for infants but can induce mild adverse effect on adults [16]. This adverse effect could manifest as cardiovascular disease, stomach upset and distorted excretion among the populace. The results also indicates that soft water is readily available within the area because magnesium ion causes water hardness.

Lead

Lead is one of the lethal elements to humans with atomic weight and radii of 207.19 g/mol and 0.175 nm respectively. According to World Health Organization [17], appreciable lead content in water leads to cancer, metabolism interference of Vitamin D functions, cerebral distorted development in infants and prolonged ingestion is lethal to the human nervous systems. The toxic effects of lead to humans have been reported as the reason why it is most tested HM fresh water sources [14]. In this study, results obtained showed that only 8.3% of sampled population were within permissible limit for lead content in water. The values recorded were in the range of 0.006 – 0.480 mgL^{-1} which implies that 91.7% of the sampled population were above NSDWQ permissible maximum limit of 0.01 mgL^{-1}. This brings the populace health under serious concern considering the lethal nature of lead. Similar findings have been reported by Hassan [3], an indication that quarry activities actually affects water resources within the vicinity by increasing the lead concentration.

Copper

Copper is abundant in nature with atomic weight and radii of 63.55 g/mol and 0.128 nm respectively. Copper is known as a micronutrient to living organisms but in humans, copper is required in low amounts to be healthy. The permissible NSDWQ limit for copper content in water is 1.0 mgL^{-1}. High amounts of copper in potable water gives it metallic taste and increase water hardness apart from its calamitous effect on washed fabrics. [5, 18]. In this study, obtained results showed 100% permissible copper content limit for the sampled points in the study area with values ranging between 0.082 – 0.699 mgL^{-1}. NSDWQ recommended standard from copper content in potable water is 1.0 mgL^{-1}. This suggests that the quarry activities had no adverse effect on populace health regarding copper ions concentration in water resources within the study area.

Chromium

Chromium is the 21st most abundant element in nature with atomic weight and radii of 51.996 g/mol and 0.130 nm respectively. Metallic chromium ion exists in stable forms as trivalent chromium and hexavalent chromium but the trivalent chromium when ingested is viewed medically to provide natural benefits such as an additive for diabetic treatment, essential micronutrient for body metabolism and enhances insulin activity [13]. Literature widely regards ingestion of hexavalent chromium as dangerous to human health. Hexavalent chromium is suspected be responsible for gastrointestinal and digestive dysfunctions in humans, urinary and reproductive impairment, respiratory and immune systems breakdown although not medically proven [13, 14]. In this present work, only 16.7% of the sampled points are within NSDWQ permissible limit for chromium content in water. The obtained values ranged from 0.010 – 0.685 mgL^{-1} which indicate that 83.3% of the population sampled in this study are above NSDWQ recommended limit of 0.05 mgL^{-1}. This suggests that the populace health is threatened within the study area especially the infants. The probable cause for increased chromium content in the water resources is suspected to come from corrosion of stainless steel pipes/equipment used in quarry activity.

Nickel

Nickel is abundant in nature with atomic weight and radii of 58.71 g/mol and 0.124 nm respectively. Literature search regards natural occurring nickel as probable source of cancer due to long-term accumulation in the body [14]. Nickel has been reported to be absorbed poorly by human body through food intake but a higher concentration can be delivered through water intake. However, absorbed nickel in human body is reported to be rapidly eliminated from serum through feces but in lesser extent through urine [11]. The population sampled in this study all surpassed the NSDWQ permissible limit of 0.02 mgL^{-1} with the recorded values ranging from 0.052 – 0.546 mgL^{-1}. This possesses a health concern for the populace especially the youth and infants. The probable cause for the high value of nickel concentration in the water could either be from corroded food packaging materials and corrosion of stainless steel or nickel materials.

Arsenic

Arsenic is a notoriously toxic metalloid with atomic weight and radii of 74.92 g/mol and 0.162 nm respectively. Arsenic occurs mostly in minerals in combination of sulphur and in high concentrations in underground water [19]. Arsenic is ingested mainly through food as organic component which is less harmful than the inorganic component found majorly in underground water. Exposure to certain concentrations of arsenic may result in stomach pain, nausea, vomiting, diarrhea, headaches, weakness and even death [17, 20]. The results obtained from this study revealed high arsenic content in all sampled water resources as against 0.01 mgL^{-1} NSDWQ permissible limit. The obtained values ranged from 0.052 – 0.917 mgL^{-1}. Omolara *et al.*, [9] reported that arsenic concentration in groundwater comes from dissolution of minerals from industrial effluents and smoke/dust particles from industrial processes. Quarry activities and indiscriminate domestic waste disposal could be responsible for the recorded arsenic concentration. Considering the arsenic concentration, the populace health is threatened especially the children and infants. This observation suggests an urgent need for water treatment plant to be sited in the community to safeguard the public health.

3.3. Biological Analysis

The bioassay was carried out by engaging the microbial, coliform and thermotolerance count to determine various levels of disease-causing pathogens in the water resources within the study area. Results obtained are recorded in Table 2. It can be deduced from the data in Table 2 that microbial activities are present in all sampled water which is not abnormal but the presence of coliform groups recorded in all sampled population is an indication of bacterial activities in them. It is observed that 91.7% of the sampled population were within safe NSDWQ permissible limit except for KTS with a total count of 11 groups. However, WHO recommends a zero count for safe drinking water. Thermotolerance which indicates the presence of resistant disease-causing bacteria has a recommended permissible limit of 0. Both WHO and NSDWQ documents that microbe groups found in this test is responsible for various infections in the body like; typhoid, urinary tract infections, bacteraemia, meningitis, diarrhea, acute renal failure and haemolytic anaemia [17, 19]. The results obtained in this study revealed thermotolerance coliform groups in 41.7% of the sampled population in values ranging from 1 – 3 groups. The observed result indicates that KTS having a total of 3 groups needs to be placed under state of emergency regarding potable water. Urgent action should be taken especially in KTS, AHD, QSS, QJS and KTW. The presence of the disease-causing pathogens is as a result of indiscriminate waste disposal, animal fecal contamination and indiscriminate defecation within the community.

Table 2. *Biological analysis of the water samples.*

Sample source	Total Microbial Count (CFU/ml)	Total Coliforms Count (CFU/ml)	Total Thermotolerance Count (CFU/ml)
MCB	63.0	04	00
AHD	58.0	05	01
KQW	77.0	08	00
KQR	62.0	06	00
KTB	82.0	06	00

Sample source	Total Microbial Count (CFU/ml)	Total Coliforms Count (CFU/ml)	Total Thermotolerance Count (CFU/ml)
KWW	92.0	02	00
KBS	98.0	03	00
KSP	76.0	04	00
KTS	44.0	11	03
KTW	78.0	09	02
QSS	93.0	07	02
QJS	87.0	07	01
NSDWQ limit	--	10	0

3.4. Statistical Analysis

Descriptive statistics

Descriptive statistics of variables reveals the minimum, maximum, mean and standard deviation of a population under study. The data obtained from this analysis are recorded in Table 3 for HMs observed in the water resources. As seen from the table, nickel had highest minimum occurrence value of 0.05 with standard deviation of 0.15142 and maximum occurrence value of 0.57 while magnesium recorded highest maximum occurrence value of 0.98 with standard deviation of 0.25133 and minimum occurrence value of 0.04. Lead had the lowest minimum occurrence value of 0.01 and lowest maximum occurrence value of 0.48 suggesting a deviation of occurrence with other HM. However, obtained values indicates that sources of the HMs are closely related or same considering its trend for maximum occurrences as well as minimum occurrences. The closer the values, the closer the occurrence of the HM to each other hence, the conclusion that the presence of HMs in the water resources are from related sources.

Table 3. *Descriptive statistics of HM content in water samples.*

	N	Minimum	Maximum	Mean	Std. Deviation
Magnesium (mg/L)	36	0.04	0.98	0.3292	0.25133
Lead (mg/L)	36	0.01	0.48	0.1756	0.13423
Copper (mg/L)	36	0.04	0.70	0.2985	0.18323
Nickel (mg/L)	36	0.05	0.57	0.2157	0.15142
Chromium (mg/L)	36	0.01	0.69	0.2145	0.18414
Arsenic (mg/L)	36	0.04	0.94	0.2894	0.28390
Valid N (listwise)	36				

Pearson's correlation

Pearson's correlation evaluates the linearity among variables to deduce any significance relationship. This carried out to determine whether there was linear relationship among HMs found in the various water resource studied. Obtained values for HM content in water samples are recorded in Table 4. A perusal of the table reveals a correlation between nickel and chromium ions which had the highest correlation value of 0.648 and its significant at level 0.01. This implies an average positive linear relationship between the metal ions indicating that their concentration increases together. This is finding is justified bearing the both nickel and chromium ion are products of corrosion of equipment/pipes deployed in service. This linear relationship of nickel and chromium is followed closely by nickel and arsenic with a value of 0.577 (sig. 0.000). This suggests a similar source of contamination for the HMs in the water resources which we ascribe to quarry activities in this study. Moreover, the correlation of lead and copper ions and lead and chromium ions are 0.572 (sig. 0.000) and 5.01 (sig. 0.002) respectively signifying close linear relationship with each other. The trend is same among other HMs as depicted in Table 4 suggesting average positive linear relationship with their occurrence.

Table 4. *Pearson's Correlation coefficient among HM content in water samples.*

		Mg (mg/L)	Pb (mg/L)	Cu (mg/L)	Ni (mg/L)	Cr (mg/L)	As (mg/L)
Mg (mg/L)	Pearson Correlation	1	0.212	-0.229	0.038	0.263	-0.181
	Sig. (2-tailed)		0.214	0.179	0.824	0.122	0.290
	N	36	36	36	36	36	36
Pb (mg/L)	Pearson Correlation	0.212	1	0.572**	0.363*	0.501**	0.481**
	Sig. (2-tailed)	0.214		0.000	0.029	0.002	0.003
	N	36	36	36	36	36	36
Cu (mg/L)	Pearson Correlation	-0.229	0.572**	1	0.344*	0.488**	0.028
	Sig. (2-tailed)	0.179	0.000		0.040	0.003	0.871
	N	36	36	36	36	36	36
Ni (mg/L)	Pearson Correlation	0.038	0.363*	0.344*	1	0.648**	0.577**
	Sig. (2-tailed)	0.824	0.029	0.040		0.000	0.000
	N	36	36	36	36	36	36
Cr (mg/L)	Pearson Correlation	0.263	0.501**	0.488**	0.648**	1	0.239
	Sig. (2-tailed)	0.122	0.002	0.003	0.000		0.160
	N	36	36	36	36	36	36
As (mg/L)	Pearson Correlation	-0.181	0.481**	0.028	0.577**	0.239	1
	Sig. (2-tailed)	0.290	0.003	0.871	0.000	0.160	
	N	36	36	36	36	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Levene's test of homogeneity of variances

An important assumption for conducting variance analysis is the assumption of constant variance among different levels of data analysis. The assumption of constant variance is tested on the HMs concentration in water resources using Levene's test and the obtained results are recorded in Table 5. A close study of the values revealed a clear trend of satisfaction of assumption across all the HMs groups since the significant levels were either unity or approach unity. This confirms the assumption that the contamination source of HMs in the water resources is closely related or same. The calculated mean value for magnesium (0.347) indicates that it might have different source (like agricultural activity) to outweigh the mean values of other tested HMs.

Table 5. *Levene's Test for homogeneity of variances for HM content in water samples.*

		Levene Statistic	df1	df2	Sig.
Mg (mg/L)	Based on Mean	0.347	11	24	0.964
	Based on Median	0.319	11	24	0.974
	Based on Median and with adjusted df	0.319	11	23.120	0.974

		Levene Statistic	df1	df2	Sig.
Pb (mg/L)	Based on trimmed mean	0.349	11	24	0.964
	Based on Mean	0.245	11	24	0.991
	Based on Median	0.265	11	24	0.987
	Based on Median and with adjusted df	0.265	11	24.000	0.987
	Based on trimmed mean	0.251	11	24	0.990
Cu (mg/L)	Based on Mean	0.273	11	24	0.986
	Based on Median	0.205	11	24	0.996
	Based on Median and with adjusted df	0.205	11	24.000	0.996
	Based on trimmed mean	0.272	11	24	0.986
Ni (mg/L)	Based on Mean	0.200	11	24	0.996
	Based on Median	0.083	11	24	1.000
	Based on Median and with adjusted df	0.083	11	24.000	1.000
	Based on trimmed mean	0.187	11	24	0.997
Cr (mg/L)	Based on Mean	0.220	11	24	0.994
	Based on Median	0.253	11	24	0.989
	Based on Median and with adjusted df	0.253	11	23.881	0.989
	Based on trimmed mean	0.225	11	24	0.993
As (mg/L)	Based on Mean	0.200	11	24	0.996
	Based on Median	0.083	11	24	1.000
	Based on Median and with adjusted df	0.083	11	24.000	1.000
	Based on trimmed mean	0.187	11	24	0.997

One–Way analysis of variance (ANOVA)

The One-Way analysis was carried out to ascertain if the source of contamination had effect on the concentration of HMs in the studied water resources. Results obtained from one-way analysis of variance are shown in Table 6. From the results, it is obvious that the concentration of HMs is not same among the sampled population of water resources. This is expected due to varying distance of sampled points from quarry site and/or anthropogenic activities surrounding each point. The distance of sampled point is a factor bearing the mobility of HM ions in solution. Arsenic has a highest F – value of 1646.454 with p – value of 0.000. The p–value obtained for all tested HM is less than 0.01 indicating that the null hypothesis of equal mean among sampled population of water resources is rejected. Hence, we conclude that based on the obtained data, the amount of each HM ion concentration depends on the location of sampled point within the study area. Similar conclusion can be drawn by observing the result trend of Partial correlation analysis computed below.

Table 6. *Result of the One – Way analysis of variance for HM content in water samples.*

		Sum of Squares	df	Mean Square	F	Sig.
Mg (mg/L)	Between Groups	2.204	11	0.200	700.309	0.000
	Within Groups	0.007	24	0.000		
	Total	2.211	35			
Pb (mg/L)	Between Groups	0.625	11	0.057	232.349	0.000

		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	0.006	24	0.000		
	Total	0.631	35			
	Between Groups	1.170	11	0.106	531.963	0.000
Cu (mg/L)	Within Groups	0.005	24	0.000		
	Total	1.175	35			
	Between Groups	0.799	11	0.073	466.785	0.000
NI (mg/L)	Within Groups	0.004	24	0.000		
	Total	0.802	35			
	Between Groups	1.181	11	0.107	424.643	0.000
Cr (mg/L)	Within Groups	0.006	24	0.000		
	Total	1.187	35			
	Between Groups	2.817	11	0.256	1646.454	0.000
As (mg/L)	Within Groups	0.004	24	0.000		
	Total	2.821	35			

Partial correlation analysis

Partial correlation analysis was carried out to determine the degree of linear relationships among HM concentration in sampled water resources in the study area. Table 7 below depicts partial correlations among tested HM in the study area. It can be deduced from Table 7 that magnesium had no any significant linear relationship with any of the HM considering that the partial correlation value in each case is less than 0.3 and its significant values are all greater than 0.05. this trend is observed across the studied HM and we conclude that the varying concentration for each HM is independent of the presence of other HMs. This is evidenced by the scatterplot matrix (Figure 1) showing similar trend on the inverse plot of each HM. The observed partial correlation values between lead and copper, nickel, chromium and arsenic are 0.617, 0.367, 0.501 and 0.590 respectively. Based on the result, we can conclude that there is evidence of mild positive linear relationship between lead and copper, chromium and arsenic at 5% level of significance, there was no suggestion of linearity between lead and nickel at below 5% level of significance. However, partial analysis suggests probable existence of significant positive linear relationship between copper and nickel (0.456, 0.006), copper and chromium (0.522, 0.002) statistically. Nickel on the other hand, had a positive average relationship with chromium (0.662, 0.000), nickel and arsenic (0.577, 0.000). Chromium did not exhibit any evidence of significant relationship with arsenic statistically. This indicates that though the HM might have a common source through which the water resources was contaminated, there was minimal HM concentration arising from other sources.

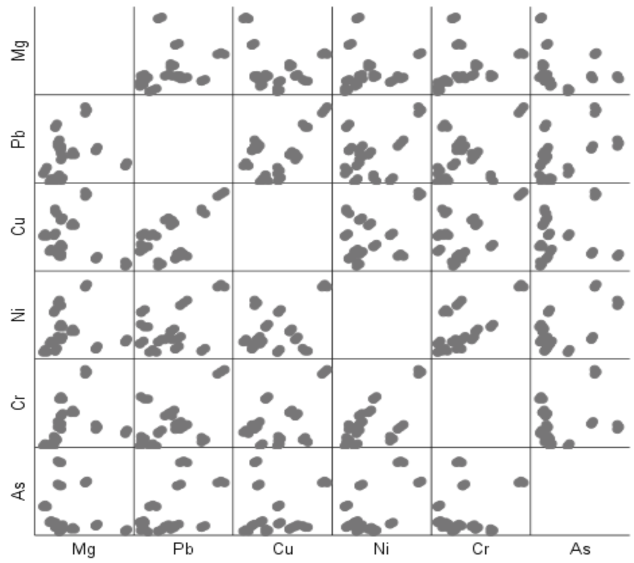

Figure 1. *Scatterplot Matrix showing relationships for HM content in water samples.*

Table 7. *Partial Correlation among the HMs.*

Control Variables		Mg (mg/L)	Pb (mg/L)	Cu (mg/L)	Ni (mg/L)	Cr (mg/L)	As (mg/L)
Mg (mg/L)	Correlation	1.000	0.212	-0.240	0.037	0.263	-0.237
	Significance (2-tailed)	.	0.221	0.165	0.833	0.127	0.171
	df	0	33	33	33	33	33
Pb (mg/L)	Correlation	0.212	1.000	0.617	0.367	0.501	0.590
	Significance (2-tailed)	0.221	.	0.000	0.030	0.002	0.000
	df	33	0	33	33	33	33
Cu (mg/L)	Correlation	-0.240	0.617	1.000	0.456	0.522	0.320
	Significance (2-tailed)	0.165	0.000	.	0.006	0.001	0.061
	df	33	33	0	33	33	33
Ni (mg/L)	Correlation	0.037	0.367	0.456	1.000	0.662	0.577
	Significance (2-tailed)	0.833	0.030	0.006	.	0.000	0.000
	df	33	33	33	0	33	33
Cr (mg/L)	Correlation	0.263	0.501	0.522	0.662	1.000	0.297
	Significance (2-tailed)	0.127	0.002	0.001	0.000	.	0.083
	df	33	33	33	33	0	33
As (mg/L)	Correlation	-0.237	0.590	0.320	0.577	0.297	1.000
	Significance (2-tailed)	0.171	0.000	0.061	0.000	0.083	.
	df	33	33	33	33	33	0

Scatterplot Matrix depicts pairwise relationships between variables to ascertain the strength of linearity among values [21]. Figure 1 shows pairwise dependencies among HMs in sampled water resources in the study area. According to Kononenko and Kukar [22], scatterplot Matrix does not provide complete visualization of the entire relationship between variables but it displays useful and important information regarding variables. As observed in the scatterplot, there is not any strong linear relationship between HM concentration. However, there are observed exceptions in the relationship between lead and copper, nickel and chromium as well as nickel and arsenic. The linearity observed could be ascribed to these HM having same source of contamination which is majorly corrosion of equipment/pipes deployed in service hence, the strong positive linear relationship.

3.5. Health Implication of Water Quality

The health of a community largely depends on the quality of their potable water sources and water borne illnesses from contaminated water are common health challenges in Africa. Potable water regulations by WHO and NSDWQ for a healthy society should be adhered to for a healthy society. As discussed in observed results, the sampled population water resources are not fit for potable water bearing that one or more parameter considered was above permissible limits for NSDWQ standards. As nations strive to meet sustainable development goal (SDG 6), water quality in the study area should be improved urgently. The present study reveals the water resources around the quarry site as unsafe and possess grave danger to the populace health especially children and infants. Urgently constructing water treatment plant with purifying systems like electrodialysis, reverse osmosis and ion exchange resins with disinfection unit should be considered in the study area. Furthermore, an enlightenment campaign should be carried out to sanitize the populace on indiscriminate defecation and improper waste disposal as these contributed to the presence of fecal coliform in the water resources. The negative health effects of such water resources should be made public and simple ways of purification should be engaged in the interim.

4. Conclusion

Consumption of contaminated water as potable water is the source of water-borne illnesses plaguing the nations. The short-term and long-term effects of HMs on human health cannot be overemphasized and should be taken seriously. Results obtained in this study revealed the presence of HMs like lead, nickel, arsenic and chromium to be above permissible limits in 91.7%, 100%, 100% and 83.3% of the sampled population. This indicates a situation that requires immediate remedy and treatment bearing the effect of these metals in the body. The physiochemical analysis revealed that turbidity value exceeded NSDWQ permissible limit in 66.7% of the sampled population. The bacteriological evaluation revealed coliform presence of in 100% of sampled population and thermotolerance coliform groups in 41.7% of the water resources confirming the unsafe state of the water resources. Statistical analysis deduced that prevalence of HMs like lead, nickel, arsenic and chromium in the water resources had no significant correlation with the smidgen of magnesium and copper. These contaminants were found to have positive linear relationship indicating a common source of contamination. It is concluded in this study that the quarry company had strong significant level regarding contamination of water resources.

Abbreviations

MCB	Borehole Tap-Water Near Kaidi Quarry Mosque (0.5km Away)
AHD	Army Post Service Housing Development Quarters Karshi (1.6km Away)
KQW	Quarry Company Main Water Point Kaidi (0km Away)
KQR	Quarry Company Residential Area Water Point Kaidi (0.5km Away)
KTB	Borehole Tap-Water Within Karshi Town (2km away)
KWW	Well-Water Near Market Within Karshi Town (2km Away)
KBS	Stream Water Point A Karshi Town (0.2km Away)
KSP	Stream Water Point B Karshi Town (2km Away)
KTS	Stream Water C Karshi Town (2km Away, Opposite Direction)
KTW	Karshi Town Well-Water (1.5km Away)
QSS	Stream Water Near Service Station, Quarry Junction (1km Away)
QJS	Stream Water Near Service Station, Quarry Junction (1.6km Away)

Author Contributions

Raphael Shadai Oguike: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – original draft, Writing – review & editing

Hamza Yusuf Adam: Data curation, Formal Analysis, Investigation, Validation, Software, Visualization

Omolara Oni: Funding acquisition, Investigation, Resources, Writing – review & editing

Sample Availability

Samples of the compounds are available from the author.

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Conflicts of Interest

The authors declare no conflicts of interest.

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