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Bacteriological Quality, Physicochemical Properties and Pollution Load Index of Water from Dams and Rivers in Zamfara State, Nigeria

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Abstract

The physicochemical properties of water from four dams and four selected rivers in Anka and Maru LGAs were analyzed during the wet and dry seasons using standard analytical methods. The influence of season was studied on the microbial load of the different dams and rivers. The pollution load index was also calculated using the standard method. The result revealed marked variation and non-uniform distribution of all the physicochemical parameters from the wet season to the dry season. pH (ranged from 7.35± 1.37 - 7.87±1.17), EC (ranged from 123± 1.11 - 163±2.03), TSS (ranged from 69.34± 1.12 – 94.64±1.04), TDS (ranged from 189.67± 0.41 – 265.32±0.77), SO_4 Cl and Turbidity (ranged from 7.77± 0.37 - 19.93±1.72) have values that fall below the EPA standard permissible limits for drinking water with exception of turbidity with values above the regulated limit. The Total Viable Count (TVC), Total Coliform Count (TCC), and the most probable number (MPN) were analyzed for both wet and dry seasons, the results showed that average TVC ranged from 3.30 $X10^5$ to 8.9 $X10^5$ while average TCC ranged from 191 to 1635 and MPN ranged from 35 to 80 in the wet season while it ranged from 25 to 67 during the dry season. This situation suggests heavy presence of microorganism during the wet season more than the dry and accumulated more in the dams. Microorganism such as *Enterobacter aerogenes*, *Salmonella enteritidis*, *Shigella dysenteriae*, *Proteus vulgaris*, *Enterobacter cloace*, *Escherichia coli* were isolated and result revealed that they are present in varying percentage degrees in the rivers where it ranged from 89.68 to 99.98% and it ranged from 82.89 to 92.89% in the dams. This suggests that the dams are more polluted. The pollution load index (PLI) was calculated and the results showed that the dams have PLI which ranged from 0.205 to 0.691 and the rivers have PLI values which ranged from 1.385 to 4.426. this suggest that the water sources have varying degrees of pollution status and generally have values greater than the permissible limit.

Key words: physicochemical, seasonal variation, bacteriological, dams and rivers, pollution load index.

Introduction

The quality of drinking water has now become a very important topic on the global stage, especially in developing African countries including Nigeria. The health risks associated with water contact activities like fishing, mining

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and boating include being infected with harmful disease-causing bacteria, which may be detrimental to health [1]. Water is said to be one of the driving factors involved in the reproduction and transfer of human-associated bacteria [2]. Hence, Safe water is a fundamental human right which when contaminated with pathogenic bacteria, it might lead to a high detrimental public health concern [3]. Environmental pollution by toxic heavy metals does not only elicit concern in the metropolitan cities but also in remote and rural communities where anthropogenic activities are taking place. Contamination of the environment usually result from industrial activities, such as mining, electroplating, gas exhaust, energy and fuel production, fertilizer and pesticides application, and generation of municipal waste [4]. Gold mining processing have been the main sources of heavy metal contamination in the environment [5]. [6], [7]. The uncontrolled dissemination of waste effluents to large water bodies has negatively affected both water quality and aquatic life [4]. During the processing of the ores for gold, poisonous substances such as oxides and sulphides of heavy metals are released into the environment [1]. Hence, most of the water sources, particularly in Zamfara State are gradually becoming polluted due to the addition of these foreign materials from the environment.

Certain environmental conditions such as salinity, pH, and water hardness can play an important factor in heavy metals accumulation up to toxic concentrations in the living organism and cause ecological damage [9]. Thus, heavy metals acquired through the food chain as a result of pollution are potential chemical hazards that threaten consumers [8].

Nearly a year has passed since WHO classified the global resurgence of cholera as a grade 3 emergency. Report from NCDC in Nigeria agrees with WHO report which reveals that Between January and August 2023, there were over 3000 suspected cases of cholera in Nigeria. The most affected state was Zamfara state with 787 cases and about 108 deaths (WHO External report published january11, 2024).

pH measures the level of acidity or alkalinity of the water sample. Practically, every phase of water treatment such as softening, precipitation, coagulation, disinfection and corrosion are pH dependent [10]. High or low pH values in a river have been reported to affect aquatic life and alter toxicity of other pollutant in one form or the other [11].

Electrical conductivity is influenced by the presence of dissolved salts such as sodium chloride and potassium chloride which produce ion that migrate is solution and then generates electric current. High conductivity may lead to lowering the aesthetic value of the water by giving mineral taste to the water [12].

The chloride: content in water is another important factor for water quality analysis [13]. Excess chlorides in water are usually taken as index of pollution. The mining, sewage water and industrial effluents are rich in chloride and hence the discharge of these wastes result in high chloride level in the rivers [14].

Alkalinity: The presence of hydroxides, carbonate and bicarbonate in natural water cause alkalinity. Alkalinity is defined by [13], as a measure of the ability of water samples to neutralize strong acids to an arbitrary pH indicator end-point. Change in carbonates and bicarbonates also depend upon release of CO_2 through respiration of living organisms [15].

Total Suspended Solid: These are discrete particles that can be measured by filtering the sample through appropriate filters. The magnitude of these solids depends on the type of filter (paper or sintered glass) use, the pore size, the physical nature and the size of the particles [16], [10]. Increase in suspended solids in water is proportional to the increase in the extent of pollution and also account for odour and colour [4]. The materials deposited on the filter are the principal factors affecting separation of suspended solid from dissolve solid.

Total dissolved solid: Total dissolved solids are due to soluble materials. This refers to the portion of total solid that pass through the filter and is expressed in mg/l [10]. Water with high dissolved solid is generally of inferior palatability and may induce unfavorable physiological reactions in the consumer [16],[10]. High concentration of dissolved solid in water is also responsible for hardness, turbidity, odour, taste, colour and alkalinity [16]. The maximum permissible concentration of TDS is 500mg/L in potable water.

Turbidity: Turbidity: Is a measure of the loss of transparency of a solution. Turbidity is the cloudiness of water caused by a variety of particles and is another key parameter in drinking water analysis [5]. It is also related to the content of diseases causing organism in water, which may come from soil runoff. The presence of colloidal solid gives water a cloudy appearance which reduces its transparency. The standard recommended maximum turbidity limit, set by WHO and NDWQS, for drinking water is 5 Nephelometric turbidity units (NTU) [5], [17]. With the recent report from NCDC in Nigeria and WHO which shows that between January and December 2023, there were over 3000 suspected cases of cholera in Nigeria, with Zamfara state being the most affected with 787 cases and about 108 deaths, coupled with the massive displacement of people from the villages with Crowded living conditions in temporary shelters, often with poor hygiene facilities, increase the likelihood of disease spreading, the most recent in Talata Mafara. In the light of the above it is therefore urgent and necessary to carry out this research.

Objective of the research:

The objectives of this research work are to determine physico-chemical parameters (pH, conductivity, total dissolved solids, total suspended solids, alkalinity, chloride, turbidity, sulphate) and microbial assessment (TCC, TVC and MPN) for wet and dry seasons of the water bodies and compare results obtained with international standards.

Materials and Methods

Sample area and Sampling Points: Zamfara State is located in the North Western Zone of

Nigeria between Latitude 110 40′ E and Longitudes 700 25′ E at an altitude of 420 m. The dams are located in Gusau LGA (Gusau dam) Kaura -Namoda, and Maru LGA, Tsafe dam, Talata Mafara and rivers are located in Anka LGA of the state, they are Abare, Sunke and Bagega which are contaminated with lead poisoning coming from extensive gold mining in those villages.

Sample Collection and Analysis of Physicochemical Properties: Sample collection: Water samples from the different dams and rivers were collected at three different points in a location to form a composite water solution. The sterile sampling bottle with a rope tied around the neck was dipped into the water source; water was allowed to flow into the bottle and closed immediately. The samples were carried in a covered ice bag container and were immediately transported and analyzed in the laboratory not more than 1 hour [14].

Determination of pH. A pH meter standardized with different pH values of 4, 7, and 9 in buffer solution, was used to determine the pH of the samples. Fifty ml of each of the samples was introduced into test tubes. The standardized pH meter was inserted into the samples to obtain the pH. The determination was carried out in duplicates and the average values of the original water samples were obtained [18].

Total suspended Solids by Gravimetric Method: A known amount of the water sample was filtered through a pre- weighed filter paper. The filter paper was then dried between 103˚C and 105˚C [19]. Total suspended solid (TSS) was determined by using the following formula:

$$\text{Total Suspended Solids (TSS) mg/l} = \frac{(A-B)\times 10^3}{C}$$

Where A = weight of filter plus solids (g); B = weight of filter (g); C = volume of sample filtered (ml).

Turbidity by Nephelometric Method (turbidity meter): The water sample was gently agitated until air bubbles disappeared from the water sample. About 100 ml of the agitated sample was then transferred into a cell and the turbidity was measured directly from the meter display [19].

The turbidity meter was initially calibrated with a turbidity standard reagent before any sample reading was taken.

Microbiological analysis

Determination of Most Probable Number (MPN): This was done to confirm whether or not the water contained lactose-fermenting, gas-producing bacteria. twelve McCartney bottles containing sterile MacConkey broth and inverted Durham tubes in a 4-4-4 tube regimen was set for each sample according to the size of the water sample, i.e. 10 ml, 1 ml and 0.1 ml respectively. For the 10 ml sample, double strength MacConkey broth was used, 0.1 ml water sample was dispersed into

each bottle (1, 2, 3,4); 1 ml in each bottle (5, 6, 7and 8) and 10 ml (9, 10, 11 and 12). After inoculation, the bottles were corked and incubated at 37°C for 24 hours for gas production and lactose fermentation. Production of gas in the Durham tubes and colour change from red to yellow (acid production) confirmed the presence of coliform in the samples [14].

Confirmatory Test for Coliform Bacteria: This test was used for differentiating the coliform from non-coliform ones. The EMB agar was inoculated with culture from previous positive bottles with gas production for 37 °C for 24 hours. Observation for coliform colonies plates, If E. coli is present, the colonies appear green with a metallic sheen while Colonies of Enterobacter aerogenes, if present, appear purple and tend to coalesce. These observations on the EMB plate give a positive confirmatory test for coliforms [14].

Completed Test for Coliform Bacteria: A confirmed coliform colony from the confirmatory test plate was used to inoculate a tube of lactose broth with Durham tube and nutrient agar slant. Both the slant and tube were incubated at 44 °C for 48 hours. Lactose broth culture was observed for gas production [14].

Characterization and Identification of Bacterial Isolates: Characterization and identification of bacterial isolates was based on the biochemical tests and the Microbact Identification System. The Microbact biochemical identification kit was used for the identification of Gram-negative bacteria; 24E set which can identify both oxidasepositive and oxidase-negative bacteria was used.

For the identification procedure, an 18 - 24 hours culture of the isolates was prepared on nutrient agar and 0.85% normal saline solution was also prepared and dispensed into McCartney bottles and 1-4 colonies from the young culture of the bacterial isolates was then picked and emulsified into the 5 ml of the sterile normal saline prepared and shaken thoroughly to form a homogenous suspension. Using a sterile pipette, 4 drops from this emulsified suspension was added aseptically into each well. After inoculation, wells 1, 2, 3, 20 and 24 were overlaid with mineral oil for oxidasenegative organisms while wells 1, 2, 3 and 24 were overlaid with mineral oil for oxidase-positive organisms and afterwards incubation was done for according to Oxoid kit instructions [20].

The results were read as stated in the kit manual after which the octal and nine digits code was run on the identification software to get the most probable identity of the Gram-negative bacteria.

Result and Discussion

Table 1: Physicochemical parameters of water from dams in selected LGAs During wet and dry seasons

Location	pH	EC	Cl	TUR.	TSS	TDS	ALK.	SO_4
GUSAU	7.67±0.13	125±0.13	15.84±0.37	7.87±0.67	69.34±1.12	198.56±0.92	11.77±0.97	9.65±0.09
KAURA-NAMODA	7.69±1.13	123±1.11	13.33±0.29	7.77±0.37	78.67±0.23	189.67±0.41	13.98±0.07	9.34±0.76
TSAFE	7.35±1.37	156±1.57	16.32±1.32	7.97±0.77	86.34±0.19	231.69±0.87	16.51±0.47	13.89±0.32
T/MAFARA	7.73±2.11	145±0.11	15.67±0.67	7.94±1.07	80.17±0.97	243.72±0.31	17.89±0.09	16.46±0.12
DRY SEASON								
GUSAU	7.84±1.41	161±1.41	19.32±0.31	13.87±1.97	76.56±0.67	211.23±0.98	14.34±0.05	13.34±0.04
KAURA-NAMODA	7.77±0.77	157±2.13	18.43±1.33	18.79±1.19	84.78±0.37	224.91±0.63	18.61±0.08	15.12±0.08
TSAFE	7.44±2.62	158±0.71	19.87±0.79	17.97±1.43	89.47±0.87	247.73±0.91	19.87±0.11	17.91±0.65
T/MAFARA	7.87±1.17	163±2.03	19.99±1.17	19.93±1.72	94.84±1.04	265.32±0.77	18.95±0.05	17.99±0.08

Results are mean ± standard deviation

Table 2: Physicochemical parameters of water from river tributaries in selected LGAs During wet and dry seasons

location	pH	EC	Cl	TUR.	TSS	TDS	ALK.	SO_4
MARU	7.74±0.93	250±0.13	27.89±0.31	130.87±0.27	132.34±0.14	310.56±0.92	19.57±0.37	17.65±0.79
ABARE	7.78±0.32	318±0.17	32.31±0.29	507.11±0.32	521.67±0.03	545.67±0.41	24.08±0.26	24.34±0.76
SUNKE	7.65±0.77	280±0.59	31.38±0.32	431.97±0.97	398.34±0.59	368.69±0.17	21.51±0.77	21.89±0.36
BAGEGA	7.74±1.16	300±0.17	30.77±0.69	362.44±0.27	380.17±0.95	366.72±0.33	20.89±0.49	19.46±0.12
DRY SEASON								
MARU	7.86±1.48	270±0.41	29.64±0.31	179.87±1.97	143.56±0.77	318.23±0.48	21.34±0.15	19.34±0.49
ABARE	7.87±0.73	330±0.13	36.49±0.93	560.79±0.19	540.78±0.83	568.91±0.63	26.61±0.38	26.12±0.37
SUNKE	7.99±0.62	319±0.71	32.86±0.78	453.97±0.43	410.47±0.97	377.73±0.06	22.87±0.15	22.91±0.52
BAGEGA	7.98±1.11	334±0.03	31.19±0.17	374.93±1.12	404.84±0.09	374.32±0.76	23.95±0.15	21.99±0.38

Results are mean ± standard deviation

The pH of the water bodies in these studies showed that it ranged from 7.35±1.37 in Tsafe dam during the wet season to 7.87±1.17 for Maru dam during the dry season. While the pH values are not significantly different from that of the rivers (Table 1 and 2). The pH of aquatic environment can be upset by added acid or alkali from waste water. The maximum pH value recorded in this study is lower than 8.22, and 8.1 reported in similar water bodies in Nigeria [21]

and [22]. The lower values recorded during the wet season as against the dry season might be due to deposition of some organic matter into the water bodies from run-off. Partial decomposition of this organic matter by bacteria and fungi has been recognized to produce various organic acids that are capable of lowering the pH of aqueous solution [23].

The pH of all the locations was within the 6.0 and 9.5 WHO and USEPA standard limits for drinking water. Abare River recorded the highest conductivity value which could be as a result of the mining activities and other mineral exploitation done using the river water since it is close to mining sites. Generally, values from this study showed that Bagega, Sunke and Abare rivers contained relatively high amounts of dissolved ions than the dams. The values recorded in this study was however lower than 852.38 us/cm reported by [21] in Warri coastal rivers. Water conductivity values measured for the dry seasons were higher than for the wet seasons. This may be attributable to excessive evaporation of water from the dam during the dry season, which might have consequently increased the concentration of dissolved salts. The turbidity values of all the four dams' Gusau, Kaura-Namoda, Tsafe and Talata Mafara studied in this work are low when compared to the four rivers (Maru, Bagega, Sunke and Abare rivers). Kaura-Namoda dam recorded the lowest turbidity value while Abare River recorded the highest mean turbidity level. This Result from Table 2 revealed that the rivers were quite turbid when compared to the value of 16.7 NTU reported by [11]. It should be noted that mean turbidity values for the dams and river water samples in this work were higher than the stated permissible limit of 5.0 NTU for drinking water [24], [25].

The remarkable high turbidity in this work may be unregulated mining, agriculture and other human anthropogenic activities around the rivers and dams. Results of this study showed that, the levels of TSS in the entire sampling locations exceeded the World Health Organization (WHO) permissible limit of 50 mg/l for the protection of fisheries and aquatic life [26].

Higher TSS concentrations in this work may be attributed to discharges from use of the river/dam for mining, agricultural and domestic purposes. TDS is very important to water quality when it concerns domestic uses and has been listed by the EPA as a secondary ground water and drinking water contaminants [27]. The secondary contaminant causes aesthetic, technical, and cosmetic effects. Water high in total dissolved solids may have an unpleasant taste, odour, colour and may have a laxative effect beyond the tolerance level [25].

TDS levels recorded in this work were below the WHO guideline of 1000 mg/l for the protection of fisheries and aquatic life and for domestic Water supply. Excess chlorides in water are usually taken as index of pollution. The mining, sewage water and industrial effluents are rich in chloride

and hence the discharge of these wastes result in high chloride level in the rivers, this is in accordance to the work of [28]. Chloride is a ubiquitous aqueous anion in all natural waters, the concentrations varying widely and reaching a maximum in sea water. Natural levels in rivers and other fresh waters are usually in the range of 15 - 35 mg/l Cl, this is similar to what was recorded in this study, and much below the permissible drinking water standard of less than 250 mg/l stated by [25], [29].

Sulphates exist in nearly all natural waters, the concentrations varying according to the nature of the terrain through which they flow. No health-based guideline is proposed for sulphate level, but its presence in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect especially with the presence of magnesium and sodium.

Sulphate concentrations recorded in this work revealed Seasonal variation effect since concentrations recorded in the dry season is higher than those of the wet Season for both the dams and the rivers. Generally, the result obtained in this study for all the dams and rivers were lower than the 100mg/l and 200mg/l of Nigeria and WHO [29] tolerance limits respectively.

Table 3: Total viable count (TVC) Cful/ml of bacteria in water samples for wet and dry season

Name	Dry Season X 10^5	Wet Season X 10^5	Average X 10^5
Gusau Dam	2.5	4.1	3.30
Kaura-Namoda Dam	4.5	5.2	4.85
Tsafe Dam	6.1	6.6	6.35
T/Mafara Dam	4.7	5.4	5.05
Maru river	7.2	8.3	7.75
Abare river	8.4	9.4	8.90
Sunke river	7.5	8.4	7.95
Bagega river	6.8	7.6	7.20

One way factor (ANOVA) showed that there is no significant difference across the mean value (p= 0.85).

Table 4: Total Coliform count (TCC) Cful/100ml of bacteria in water samples for wet and dry season

Name	Dry Season	Wet Season	Average
Gusau Dam	251	131	191[a]
Kaura-Namoda Dam	450	386	418[b]
Tsafe Dam	621	611	616[b]
T/Mafara Dam	1200	1140	1170[c]
Maru river	720	845	783[b]
Abare river	1700	1570	1635[d]
Sunke river	1190	1122	1156[c]
Bagega river	1350	1310	1330[c]

Tukeys HSD test showed that mean values with similar alphabet are not significantly different (p= 0.05)

Table 5: MPN Determination using multiple Tube for water sample in the dry and wet season

MPN/100ml Name	Season	
	Wet	**Dry**
Gusau dam	35	25
Kaura – Namoda dam	42	31
Tsafe dam	39	28
T/Mafara dam	60	47
Maru river	43	33
Abare river	80	67
Sunke river	67	50
Bagega river	45	35

Table 6: Isolates Identification

Percentage composition %		
Name of Microorganism	Composite solution of water Dams	Composite solution of water Rivers
Enterobacter aerogenes	87.90	97.99
Salmonella enteritidis	88.94	98.98
Shigella dysenteriae	89.62	89.68
Proteus vulgaris	91.82	97.87
Enterobacter cloace	82.89	94.69
Escherichia coli	92.89	99.98

Result are mean values obtained.

Microbiological Analysis of the Water Samples: the total bacterial count is a reflection of the general purity of the water samples analysed. In all the dams, the total plate count obtained during the wet season were generally higher than those obtained in the dry seasons attributable to influx through runoff of microorganisms originating from vegetation decay, municipal sewage, garbage, domestic and faecal waste [30]. While those obtained from the rivers were generally higher than those of dams.

This situation suggests that the rivers are more polluted. [20] in their study on the bacteriological assessment of some selected streams reported that the total viable plate counts of twelve different samples of Mogaji streams in Ilorin, Kwara State ranged between 6.4×10^6 - 2.38×10^7cful/ml. This implied that the total viable counts were consistently high at all the sites sampled for the study. The MPN values for the wet seasons were higher than for the dry seasons; this may be due to run-offs, dead material in water and the more favourable low temperature during the Wet season. This is also in agreement with the work of [31] which reported that faecal bacteria could enter natural water from variety of sources.

[13] also explained that animal slurry or sewage sludge to land with subsequent run-off would also increase bacteria counts in water. Shigella sp. obtained in this study for both dams and rivers were also obtained in similar research conducted by [32] in a research work on phenotypic and genotypic characterization of *Shigella spp*. with reference to its virulence genes and antibiogram

analysis from river Narmada isolating different species of Shigella from the river. [20] also isolated Shigella sp. in similar research on the characterization of Shigella sp. from river catchments in the North West province of South Africa. E. coli obtained in this study was also reported in similar research by [33] from different sources including river water. [34] also reported the isolation of *Proteus sp*., *Enterobacter aerogenes*, *E. coli*, from water samples used for domestic purposes in the South-Western part of Nigeria which is similar to those obtained in this study.

Table 7: Heavy metal contamination factor (CF) and pollution load index PLI in water for both wet and dry season.

season ⟶	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	PLI Wet	PLI Dry
Location	Zn	Zn	Cd	Cd	Cr	Cr	Pb	Pb	Fe	Fe		
GUSAU DAM	0.005	0.007	0.380	14.74	0.236	0.688	0.945	1.438	0.204	0.206	0.321	1.515
KAURA/NAMODA	0.002	0.003	0.440	7.425	0.061	0.169	0.544	2.190	0.121	0.124	0.248	1.385
TSAFE DAM	0.001	0.002	0.450	3.453	0.028	1.094	0.606	1.602	0.113	0.118	0.205	1.443
T/MAFARA DAM	0.006	0.009	0.780	11.65	0.238	0.689	0.947	1.439	0.108	0.112	0.324	1.526
MARU	0.006	0.039	0.670	7.560	0.222	1.976	1.106	2.376	0.112	0.124	0.691	4.426
ABARE	0.002	0.035	0.250	8.512	0.268	1.956	1.956	3.310	0.104	0.144	0.435	3.027
SUNKE	0.029	0.046	0.510	7.441	0.131	0.816	0.816	2.438	0.093	0.103	0.610	2.394
BAGEGA	0.025	0.035	0.670	7.562	0.132	0.817	0.818	2.442	0.110	0.162	0.610	2.412

In this study, the WHO [24] guidelines value for drinking water quality were selected as the background level for the calculation of contamination factors (CF) of the water samples. The contamination levels may be classified based on their intensities on a scale of 1 to 6 (0=none, 1=none to medium, 2=moderate, 3= moderately strong, 4= strongly polluted, 5= strong to very strong and 6= very strong) [35] and [36]. The pollution load index (PLI) was obtained as a concentration factor of each metal with respect to the background values in the samples. Pollution load index value close to one indicates metal pollution loads near the background level and values above one indicates sample pollution [37].

Conclusion

The physicochemical parameters of the dams and rivers water samples revealed a relatively fresh water environment with low chemical pollution burden. However, high turbidity, total suspended solid and total dissolved solids of the river water compared with drinking water standards were recorded. Seasonal variations were also recorded for the water sample, where there was a general high value for the dry season and particular with the river water.

Microbial burden of the dams and rivers was also high compared to recommended standards by WHO and USEPA for drinking water, thus constituting a serious hazard to the public health as their presence is indicative of a possible presence of micro-organism associated with water borne diseases. The pollution level of all the water bodies studied using the contamination factor and pollution load index, which revealed that all the sample location has suffered from metal pollution.

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