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Comparative analysis of heavy metals in groundwater around Sharada and Bompai industrial areas, Kano Metropolis, Nigeria

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Abstract
There is a frequent release of effluents and toxic chemicals in Sharada and Bompai Industrial areas which pollutes the major sources of groundwater in the area, hence the need to undertake the comparisons. A total number of 40 samples were collected from both industrial areas using standard methods. The samples were analysed for heavy metals such as As, Cd, Cr, Cu, Co, Ni and Pb using Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-OES). The data was analysed using ANOVA in SPSS environment and Heavy Metal Pollution Index (HPI) assessment. Results of correlation of the level of heavy metals between the industrial areas indicated that only cadmium, Copper and Cobalt are significant at 0.05 level with P-values 0.0041, <.0001 and <.0001 respectively. Results of correlation of the level of heavy metals with season shows that only Cupper is significant at 0.05 level P-value 0.0021. The interaction correlation (between heavy metals, sites and seasons) indicated that only Copper and Cobalt are significant at 0.05 and 0.01 with P-value 0.0007 and <.0001 respectively. This shows that Sharada and Bompai industrial areas has the highest HPI in dry season of 439.17 and 302.96 respectively which are all above acceptable limit of 100. Result for suitability rating indicated that all the areas were contaminated with all the heavy metals except for cobalt. It is concluded that there is high level of contamination (HPI) in groundwater of the both areas, therefore need for treatment.

1. Introduction
Water is a necessity for the survival of any living organism and humans on the earth surface, it plays a fundamental role in sustaining any living and non-living organisms [1, 2]. Water quality deterioration is becoming increasingly important in the world due to the human activities which are at increase [3]. Access to safe water is a basic human need and a key factor in the development and sustainability of human societies therefore, there is a need to access facilities and services for the safe disposal of human waste as a basic sanitation which is very important in order to prevent contamination of water resources and exposure to diseases. Larger percentage of the world population rely on boreholes to exploit groundwater [1]. Groundwater in industrial areas is bound to contamination depending of effluents discharge. Industrial effluents contain appreciable amounts of both inorganic and organic chemicals and their byproducts which are capable of polluting surface and groundwater [4]. Urban groundwater can easily be contaminated from a range of sources and if it happened there is increase in abstraction rates it

may lead to locally reduced water quality and falling water levels [5]. In Nigeria, the rate of urbanisation characterised by high population concentration, increasing industrial and agricultural activities coupled with environmental pollution/degradation and indiscriminate disposal of all kinds of wastes are perceived to pose serious pollution threats with all its concomitant health hazards on groundwater quality especially in urban areas [6, 7]. This concern has attracted overwhelming attention of researchers in different parts of Nigerian urban areas. In Nigeria despite governments and NGOs efforts to increase access to safe groundwater in urban and rural areas, the most vulnerable people still rely on inadequate sources of deteriorating quality [5].

Groundwater is often regarded as the most important segment of an improved water supply as it is often more reliable than surface water, less vulnerable to pollution and therefore less expensive to treat, and more resilient to climate variability [8,9]. Groundwater is one of the main sources of water in Kano state like in the other parts of the globe and it is used extensively for domestic, industrial as well as agricultural purposes, uncensored human activities in developing countries including Nigeria contributes immensely to the poor quality of groundwater. The problem of water quality is much more acute in areas which are densely populated with localized industries. Peculiarly, groundwater can also be contaminated by naturally occurring sources such as Arsenic, Iron and Manganese which are dissolved and can later be found in high concentrations in the water. The quality of groundwater depends on the management of anthropogenic discharges as well as the normal physiochemical characteristics of the catchment areas [10, 11].

Heavy metals are dangerous because they tend to accumulate in the body. Bioaccumulation results when there is an increase in the concentration of a chemical in a biological organism over time, compared to the natural concentration of chemicals in the environment. Heavy metals may enter a water supply system from industrial and household wastes, or acidic rain resulting in the breakdown of soils and releasing heavy metals into streams, lakes, rivers, and groundwater [12, 13]. Groundwater exploration is becoming more apparent due to rapid urbanization as well as increase in population which leads to the excessive dependence on groundwater. In the study location (Sharada and Bompai), there are industries such as Tanneries, Ginneries, Foam Industries, Pharmaceutical industries, Plastic industries among others which discharges toxic effluents that pollutes surface water.

In the study areas (Sharada and Bompai), there are industries such as Tanneries, Ginneries, Foam Industries, Pharmaceutical industries, Plastic industries among others which discharges toxic effluents that pollutes surface water. Evidences are common in Salanta and Jakara River in which the colour and odour of the water are highly affected. Also many studies like that of [14], [15], [16] studied surface water quality in Sharada and Challawa indicated that the surface water is polluted but they did not investigate the level of heavy metals in groundwater. Since surface water and groundwater are either directly or indirectly related therefore, the need to investigate the level of these heavy metals in groundwater of the area. Many studies examined the levels of some metals in water sources in the areas of Sharada and Challawa respectively but did not cover the whole of Sharada and did not compare the results with other industrial areas. For instant Imam [14] assessed the concentrations of heavy metals in the surface water of Bompai-Jakara drainage basinand discovered that all of the elements analysed were above acceptable limits. [17] analysed the effect of Industrial waste discharge on River Challawa and Tamburawa old water treatment plant, located downstream of the effluent discharge points. Likewise, [15] conducted a study at Sharada Industrial Estate with the aim of characterising the physicochemical parameters of wells water in phase III of Sharada Industrial Estate and discovered that parameters are within tolerable limits. The study looked at physiochemical and not heavy metals in particular and not in comparison with another area. [18] reported that in the downstream section of Challawa river natural process of silicate mineral and anthropogenic influences are the major common sources of groundwater pollution. However, despite these studies on heavy metals in groundwater in Kano State, it can be seen that most of the studies conducted on heavy metals were outside the study area. Even the studies conducted around the study area were centred in a particular area, or focusing on surface water only and none of the studies compare the level of heavy metals in the two major industrial areas, and assessed both boreholes and hand-dug wells which is the major sources of water in the area. Therefore the aim of the study was to compare levels of the selected heavy metals in groundwater sources of Sharada and Bompai industrial areas and relate the Heavy metal pollution index with standards for effective potable water supply.

2. Material and Methods

2.1. The Study Area

The study areas are within Kano metropolis which lies between latitude 11º51ˈ N to 12º6ˈ N and longitude 8º23ˈE to 8º38ˈE. Kano Metropolis bordered by Minjibir LGA on the North east and Gezawa LGA to the East, while Dawakin Kudu LGA to the South East, Madobi and Tofa LGAs to the South West [19]. The study covers Sharada and Bompai industrial areas which covers Dala, Fagge, Gwale, Kano Municipal, Nassarawa, Tarauni, and parts of Kumbotso and Ungogo Local Government Areas (LGA) of Kano Metropolis respectively (Figure 1 & 2). The dominant geology of the area is Basement Complex Rocks of Precambrian era. The geology underlying parts of Kano State is the basement complex and consisting of variety of metamorphic and igneous rocks ranging in age from Precambrian to Jurassic.

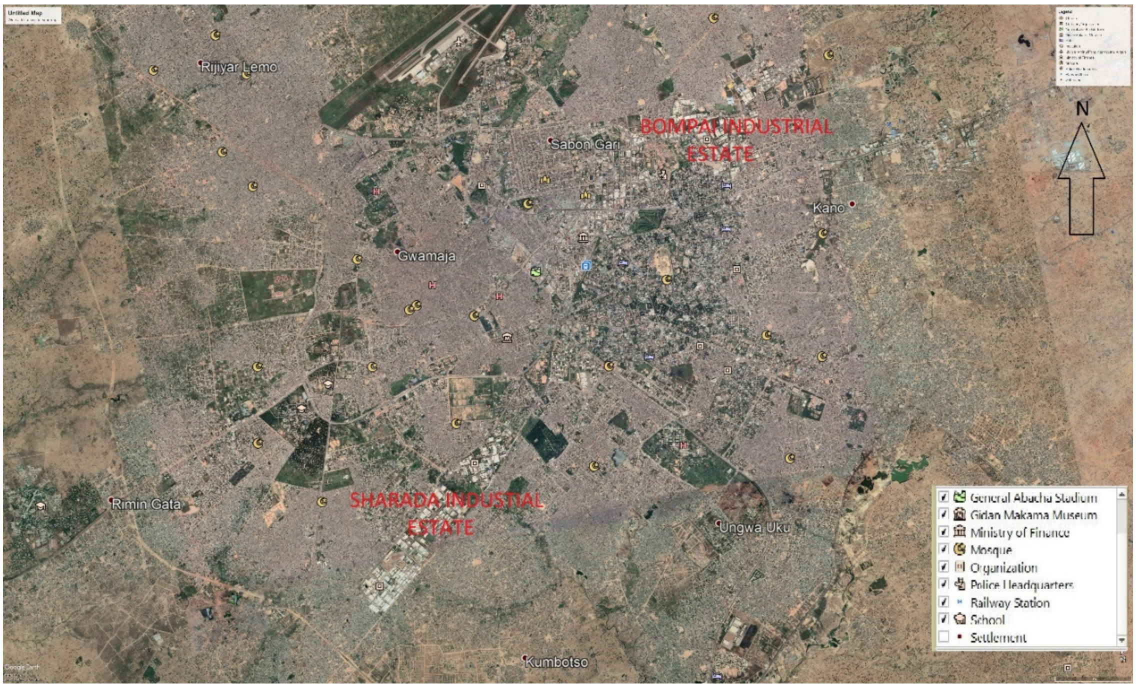

Figure 1 Aerial View of the Study Sites
Source Downloaded from Google Earth on 5th, January, 2021.

Metamorphic rocks are migmatite, gneiss, schist and some quartzite which have been deformed structurally into antiforms, synforms and down faulted blocks [1]. The geology of the area and relief may have an indirect influence on ground water quality of the area. The climate of Kano is described as

Aw by Koppen, with both annual and seasonal variability's...wet years and dry years may record between 850 and 750mm [20]. The climate of Kano state is characterized by four seasons which are dictated by the movement of ITD that control north easterlies and south west easterlies.

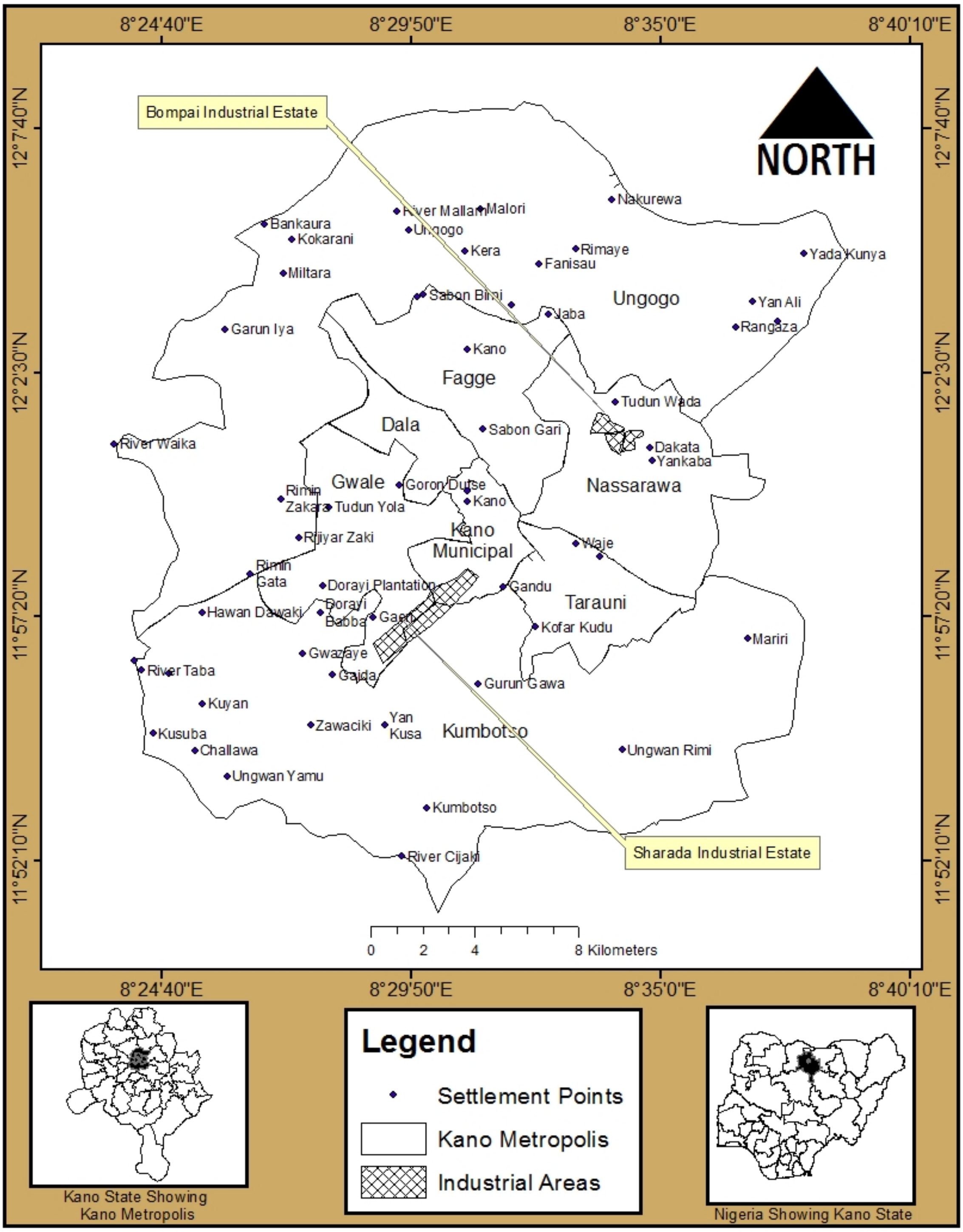

Figure 2 Part of Kano Metropolis showing the study Locations

The dominant soil of the area is Eutric-Cambisol soil according to the World Reference Base for Soil Resources, (WRB). The vegetation of Kano State is the semi-arid savannah. The Sudan Savannah is sandwiched by the Sahel Savannah in the north and the Guinea Savannah in the south. The average altitude of Kano metropolis is 472 meters above sea level. Drainage of the area is influenced by the relief of the area. The study area is drained by the two major River; River Jakara and River Kano. The Jakara

River is the largest drainage network in Kano Metropolis [21]. The drainage density of the area affects groundwater quality.

2.2 Sampling techniques

Reconnaissance survey of the study area was conducted in April 2018. It was during this reconnaissance visit that the researcher was able to plan the actual field work in terms of sampling and methods that was adopted during the field work. According to [22], Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms. Types of industries and their associated heavy metals were acquired during reconnaissance survey.

The areas selected are Sharada and Bompai industrial areas both located in Kano Municipal and Nassarawa Local Government Areas respectively. Because the area where the sample is taken is quite extensive, Quantum Geographical Information System (QGIS) was used to divide the area into grids (36 Squares) and in each square, 1 well and or borehole was randomly selected for sampling in the study area as adopted by [23, 24].

2.3 Water Samples Collection

Water samples were collected in both rainy and dry season in sequence. A total number of 40 water samples were collected in both Sharada and Bompai which were placed in an acid washed plastic bottles for storage and further analysis. The samples were taken in 100 ml bottles covered in black polythene bags to avoid unpredictable changes in characteristic as recommended by the standard procedures. The collected samples were filtered (Whatman no. 42), preserved with concentrated, ultra-high-purity nitric acid (HNO3) (Suprapur Merck, Germany) and kept at a temperature of 4 °C for further analysis.

2.4 Laboratory Techniques

Laboratory tests were processed and analysed both qualitatively and quantitatively. Sample digestion followed Briggs method (using multi-element reagent), the analysis adopted US EPA Standard Operating Procedure for groundwater sampling. The samples were placed in an Advanced Microwave Digestion System machine to be digested then placed in to the ICP-OES machine (Inductively Coupled Plasma-Atomic Emission Spectrometry) which was already programmed to analyse the level of concentration of each of the required metals.

2.5 Data Analysis

For successful analysis of the results, the set of 7 heavy metals were chosen because these were the established water pollutants and their concentrations in the water samples were measurable. The level of concentration of heavy metals on seasonal bases and the mean level of heavy metals were assessed using the Heavy Metal Pollution Index (HPI) as adopted from [25] Data on difference between water quality parameters for both seasons were analysed using one way ANOVA as adopted from [26]. Overall mean values of the parameters were compared with WHO, E.U and SON standards for drinking water quality using simple comparison as adopted from [27].

3. Results and Discussion

Arsenic result showed that there was highly significant effect (<.0001) of the sampling sites and season on arsenic concentration. The highest mean value of arsenic (Table 1) was found in Sharada while the least value was found in Bompai. For the seasonal effect maximum concentration was obtained during the dry season. Despite this, there was no significant interaction effect between sites and season.

Table 1 Correlation Analysis showing Level of Significance.

Industrial Sites	As (ppm)	Cd (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Co (ppm)	Cr (ppm)
Bompai	0.970b	0.177a	0.206a	0.157a	0.191	-0.306b	0.165
Sharada	1.237a	0.075b	-0.026b	-0.285b	0.159	0.064a	0.120
p-value	<0.001	0.0041*	<.0001*	<.0001	0.107	<.0001*	0.339
SE±	0.0320	0.024	0.035		0.014	0.022	0.033
Seasons							
Dry	1.322a	0.147	0.168a	-0.163b	0.225a	-0.138	0.115
Wet	0.885b	0.106	0.012b	0.035a	0.125b	-0.104	0.171
p-value	<0.001	0.238	0.0021*	<.0001	<.0001	0.280	0.235
SE±	0.0320	0.024	0.035		0.014	0.022	0.033
Interaction							
Sites x Season							
p-value	0.259	0.172	0.0007*	0.214	0.635	<.0001**	0.142
SE±	0.045	0.034	0.049	0.029	0.02	0.031	0.047

**correlation is significant at the 0.01 level (2-tailed)
*correlation is significant at the 0.05(2-tailed)
Source: Data Analysis, 2019.

The result for Cadmium represented in the table showed that there was a high significant effect ($p < 0.0001$) of the sampling sites and season on cadmium concentration. The highest mean value of cadmium (Table 1) was found in Bompai while the least value was in Sharada. For the seasonal effect, maximum level of concentration was found during dry season. Cadmium concentration is highest in Bompai as a result of the presence of paint industries present in the area. Despite this, there was no significant interaction between sites and season. This is substantiated by the findings of [28] Pollution site or industrial areas have great influence on surface and groundwater quality in El kolea city (Agadir, Morocco)

Copper was found to be higher in Bompai Industrial area during the dry season with a significant effect of <0.001. There is a significance difference interaction between site and season. These findings are similar to that of [29, 30] where by Copper concentrations were higher during dry season and have a significant difference between site and seasons.

For Nickel the result shows high concentrations in Bompai industrial area during the rainy season with a significant effect of (0.001). Some areas show that the presence of Nickel in water is within the permissible limit and in other areas, the concentration is below the permissible limits. But despite this, there was no significant interaction effect between sites and season. The result is similar to the findings of [29], where Nickel is showed to be higher during wet season but with no significant effect between site and season.

Finding on Lead indicated high concentrations in both Sharada and Bompai especially during dry season. This is as a result of presence of foam and textiles industries, plastic and pesticides industries. The highest mean value was found in Bompai (Table 2). The maximum concentration in terms of seasonal effect was found during the dry season. There was no significant interaction effect between sites and season. The result showed highest mean value of cobalt concentration in Sharada (Table 2) while the least value was found in Bompai industrial area. For seasonal effect, maximum concentration was found during the dry season. There was significant interaction effect between sites and season and this as a result of the effluents been discharged from the Sharada category of industries which are mainly Plastics, Tannery and insecticide industries in the areas. The findings of these results are similar to that of [29] were Cobalt concentration is high during winter season and in both water, soil and plant.

The result showed the highest mean value of chromium (Table 2) was found in Bompai while the least value was found in Sharada. For seasonal effect, maximum concentration was found during the wet season. Despite this there was no significant effect between sites and season. The finding of these result is contrary to the findings of [29] where by Chromium concentration is seen to have a significant effect on site and season. The result of the ratings (Table 2) had shown that the threshold for arsenic based on WHO, EU and SON of standards for Bompai (wet and dry) and Sharda (wet and dry) are all above the standard permissible limits for drinking water. From the result of the ratings (Table 2) had shown that the threshold for cadmium based on WHO, EU and SON standards for Bompai (Wet), Bompai (dry), Sharada (wet), Sharada (dry) are all above the standard permissible limit for drinking water.

Table 2 Correlation Analysis showing Level of Significance.

S/N	Heavy metal	BOMPAI WET	BOMPAI DRY	SHARADA WET	SHARADA DRY	WHO	EU	SON
1	Arsenic	0.79	1.16	0.99	1.48	0.01	0.01	0.01
2	Cadmium	0.13	0.22	0.44	0.07	0.003	0.005	0.003
3	Copper	0.04	0.37	-0.02	-0.03	0.003	0.002	1
4	Nickel	0.27	0.04	-0.20	-0.37	0.07	0.02	0.02
5	Lead	0.14	0.25	0.11	0.20	0.01	0.025	0.01
6	Cobalt	-0.22	-0.39	0.01	0.12	0.05	0.05	0.05
7	Chromium	0.16	0.17	0.18	0.06	0.05	0.05	0.05

Source Data analysis, 2019, [31], [32] and [33]

The result of the ratings (Table 2) had shown that the threshold for Copper based on WHO, SON and EU standards for Bompai (Wet), Bompai (dry), Sharada (wet) and Sharada (dry) is uncontaminated are within the permissible limits of drinking water. The result of the ratings (Table 2) had shown that the threshold for Nickel based on WHO standards for Bompai (Wet) is above the permissible limit for drinking water, Bompai (dry) is within the standards for drinking water, Sharada (wet) and Sharada (dry) is uncontaminated are all within the permissible limits for drinking water. This result is supported by the findings of [34] that all the parameters are within the limit except for Fe in groundwater around waste dump sites in Warri, Nigeria. The result of the ratings (Table 2) had shown that the threshold for Lead based on WHO, EU and SON standards for drinking water for Bompai (Wet), Bompai (dry), Sharada (wet) and Sharada (dry) are all above the permissible limit for drinking water. The result of the ratings for Cobalt contamination in drinking water (Table 3) had shown that the threshold for Cobalt based on WHO and EU standards all the sites and seasons are below the standard permissible limits for drinking water apart from Sharada (dry) which is above the limit for drinking water. The result of the ratings (Table 2) had shown that the threshold for Chromium based on WHO, EU and SON standards for Bompai (Wet), Bompai (dry), Sharada (wet) and Sharada (dry) are all above the standard permissible limits for drinking water. The result (Table 3) indicates that the contents of studied heavy metals in all the sampling points are high above the maximum permissible limits for drinking water. The results are compared to HPI values which are calculated as an index of risk. HPI values are an important indicator of water pollution by heavy metals. The mean value of HPI in Bompai wet season is 302.96 and that indicates high level of contamination since the critical pollution index above 100 is considered not potable.

Table 3 HPI for Bompai Wet.

Heavy metal (ppm)	Mean Conc. (Mi)	Highest permitted value for drinking water (Si)	Desirable Maximum Value (Ii)	Unit Weightage Wi=1/Si	Sub-index Qi	Wi * Qi
Arsenic (As)	0.79	0.01	0.5	2.00	159.98	318.87
Cadmium (Cd)	0.13	0.003	0.05	20.00	270.21	5404.26
Lead (Pb)	0.14	0.01	0.1	10.00	666.66	1444.44
Copper (Cu)	0.04	2	3	0.33	196.00	65.33
Nickel (Ni)	0.27	0.07	0.1	10.00	666.67	6666.67
Chromium (Cr)	0.16	0.05	0.5	2.00	24.44	48.89
Cobalt (Co)	-0.22	0.002	0.5	2.00	44.58	89.16

$\Sigma W_i = 46.33$, $\Sigma Q_i W_i = 14326.91$, HPI = 302.96.

The result of Bompai dry season (Table 4) shows the contents of studied heavy metals in all the sampling points are high above the maximum permissible limits for drinking water. The results are compared to HPI values which are calculated as an index of risk. HPI values are an important indicator of water pollution by heavy metals. The mean value of HPI in Bompai dry season is 294.28 and indicates high level of contamination since the critical pollution index above 100 is considered not potable. This is supported by the assertion of [35] that groundwater that contain heavy metals and anions from industries pollute the water and rendered it not potable.

Table 4 HPI for Bompai Dry Season

Heavy metal (ppm)	Mean Conc. (Mi)	Highest permitted value for drinking water (Si)	Desirable Maximum Value (Ii)	Unit Weightage Wi=1/Si	Sub-index Qi	Wi * Qi
Arsenic (As)	1.16	0.01	0.5	2.00	234.69	469.39
Cadmium(Cd)	0.22	0.003	0.05	20.00	461.70	9234.04
Lead (Pb)	0.25	0.01	0.1	10.00	266.67	2666.67
Copper (Cu)	0.37	2	3	0.33	163.00	54.33
Nickel (Ni)	0.04	0.07	0.1	10.00	100.00	1000.00
Chromium(Cr)	0.17	0.05	0.5	2.00	26.67	53.33
Cobalt (Co)	-0.39	0.002	0.5	2.00	78.71	157.43

$\Sigma W_i = 46.33$, $\Sigma Q_i W_i = 14063.76$, HPI = 294.28.

The result of Sharada wet season (Table 5) indicates that the mean concentration levels of Arsenic, Cadmium, Lead and Cobalt in all the sampling points are high above the maximum permissible limits for drinking water while Copper, Nickel and Chromium have the desirable permitted values for drinking water. The results are compared to HPI values which are calculated as an index of risk. HPI values are an important indicator of water pollution by heavy metals. The mean value of HPI in Bompai wet season is 8.63 and that indicates low level of contamination since the critical pollution index above 100 it is considered not contaminated. The average for both seasons and all sampling sites is 74.082 which makes it to be portable. This is contrary to the findings of [36] in Tamil Nadu India that groundwater is highly deteriorated and unsuitable for drinking in premonsoon period due to evaporation.

Table 5 HPI for Sharada Wet. Season

Heavy metal (ppm)	Mean Conc. (Mi)	Highest permitted value for drinking water (Si)	Desirable Maximum Value (Ii)	Unit Weightage Wi=1/Si	Sub- index Qi	Wi * Qi
Arsenic (As)	0.99	0.01	0.5	2.00	200.00	400.00
Cadmium (Cd)	0.08	0.003	0.05	20.00	163.83	3276.60
Lead (Pb)	0.11	0.01	0.1	10.00	111.11	1111.11
Copper (Cu)	0.02	2	3	0.33	202.00	67.33
Nickel (Ni)	-0.2	0.07	0.1	10.00	900.00	9000.00
Chromium (Cr)	-0.18	0.05	0.5	2.00	28.89	57.78
Cobalt (Co)	0.01	0.002	0.5	2.00	1.61	3.21

$\Sigma W_i = 46.33$, $\Sigma Q_iW_i = 13916.03$, HPI = 8.63.

The result of Sharada dry season (Table 6) indicates that the mean concentration levels of Arsenic, Cadmium, Lead and Cobalt in all the sampling points are high above the maximum permissible limits for drinking water while Copper and Nickel have the desirable permitted values for drinking water while chromium is slightly higher than the maximum limit. The results are compared to HPI values which are calculated as an index of risk. HPI values are an important indicator of water pollution by heavy metals. The mean value of HPI in Sharada dry season is 439.78 and that indicates high level of contamination since the critical pollution index above 100 it is considered not potable. This result is substantiated by that of [37] at Sabke Reservoir in Daura Katsina state, Nigeria where the level of pollution is also high. It is also supported by [38, 39] that excessive heavy metals concentration like Pb, Zn, Cb and others resulted in diseased like anaemia.

Table 6 HPI for Sharada Dry

Heavy metal (ppm)	Mean Conc. (Mi)	Highest permitted value for drinking water (Si)	Desirable Maximum Value (Ii)	Unit Weightage Wi=1/Si	Sub- index Qi	Wi * Qi
Arsenic (As)	1.48	0.01	0.5	2.00	300.00	600
Cadmium (Cd)	0.07	0.003	0.05	20.00	142.55	2851.06
Lead (Pb)	0.2	0.01	0.1	10.00	211.11	2111.11
Copper (Cu)	-0.03	2	3	0.33	203.00	67.67
Nickel (Ni)	-0.37	0.07	0.1	10.00	1466.67	14666.67
Chromium (Cr)	0.06	0.05	0.5	2.00	2.22	4.44
Cobalt (Co)	0.12	0.002	0.5	2.00	23.69	47.39

$\Sigma W_i = 46.33$, $\Sigma Q_iW_i = 20348.34$, HPI = 439.17.

Conclusion

The analysis of heavy metals in groundwater quality has revealed variation in the mean value of the heavy metal parameters with season and sources in the study area. The result indicated significant interaction in Cu and Co between site and season but no significant difference in As, Ni, Pb, Cd and Cr based on sources and seasons. The relationship between the water quality parameters, groundwater sources and season indicated that the area appears to have common sources of pollution where Co highly correlated with Cu respectively with location and seasons. Furthermore, there is no water sample that perfectly meets up with the standards for drinking water quality. Therefore the findings of this study led to the conclusion that groundwater in Bompai Industrial area is more polluted due to high Heavy Metal Pollution Index (HPI) as a result of the geology of the area and the high number of tannery industries located in the area and therefore is not fit for human consumption without proper treatment.

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