International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Assessment of Some Heavy Metals in Groundwater of Awe and its Environs, Parts of North-Central Nigeria: Implications to Health

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Abstract

The study was conducted in Awe Local Government Area of Nasarawa State, parts of the Middle Benue Trough. The aim of the study was to assess the concentrations of some heavy metals in groundwater. Forty eight (48) groundwater samples (16 from wells, 4 from springs, and 28 from boreholes) were collected. Inductive Coupled Plasma Mass Spectrophotometer (ICPMS) was employed to determine the concentrations of these heavy metals in the collected groundwater samples. The study revealed that the concentrations of Ba, Cd, Co, Cr, Cu, Ni, Pb, U, and Zn in hand dug wells are within the WHO permissible limits for drinking water. However, in Azara the concentration of As in the well water is above the WHO permissible limit. Also, Mo concentration in a well water sample at Kanje is above WHO permissible limit. Strontium (Sr) concentration (0.131 – 1.711) in almost all the well water samples are above the WHO permissible limit (0.07 mg/l). Akiri and Awe springs have As, Ba, Cd, Co, Cr, Mo, Ni, Pb, and U concentrations above WHO permissible limits but the concentrations of these heavy metals in Kekura I and Anuku II springs are within the WHO permissible limits.

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The concentrations of As, Cd, Cr, Co, Mo, Ni, Pb and U in almost all the borehole water are within the WHO permissible limits with the exception of the artesian borehole at Tsohongari Awe I. The variation in the content of heavy metals in the groundwater may be associated with the geology (Asu River Group and Awe Formations) and also on the present of minerals such as As, Pb and Ba in the study area. Eighty - eight percent (88%) of groundwater found in the study area are fresh while brackish and saline water are six percent (6%) each using Sr. Ninety two percent (92%) of the groundwater in the study area are thermal water while only eight percentages (8%) are sub – thermal in nature based on temperature. The likely health challenges that the people using water from the two hot springs may encounter after long time exposure includes; skin disease, circulatory system and heart problems, cancer, bone fractures, hypertension, liver and kidney problems.

Keywords: Assessment; Heavy Metals; Groundwater; Middle Benue Trough; Health.

1. Introduction

One of the basic needs for human survival is drinking water [1]. Groundwater resource is a major source of freshwater. It is essential for reliable and economic provision of safe drinking water supplies in both the urban and rural environments for sustainable development of any economy. Groundwater includes water from boreholes, hand dug wells, hand pumps, and springs [2]. Demand for groundwater has been on the increase due to rapid growth in population as well as the accelerated pace of industrialization and urbanization in the last few decades' especially in developing countries like Nigeria. Rocks are broken down by weathering to form the soils in which crops and animals are raised. Groundwater moves through these porous and permeable rocks and soils as part of the water cycle [3]. Groundwater contamination and its management have become important because of far reaching impact on human health. Drinking water containing heavy metals above the maximum permissible limits cause potential risk to human health. Heavy metals in groundwater are generally dissolved in very minute quantities in most of the cases; its concentration is less than 1 mg/l [4,5]. Populations are exposed to heavy metals primarily through water consumption, but few heavy metals can be bioaccumulated in the human body. Many developing countries including Nigeria are faced with the challenge of reducing human exposure to heavy metals, mainly due to their limited economic capacities to use advanced technologies for heavy metal removal [6]. Heavy metals can disturb body's metabolic functions through various ways. Moreover, they may accumulate in vital body organs such as liver, heart, kidney, and brain disturbing normal biological functioning. Once heavy metals are within the organs, they block their vital activities in body. With the current era of growing technology, the concentration of heavy metals present in drinking water is still not within the recommended limits as set by the regulatory authorities in different countries of the world. Drinking water contaminated with heavy metals such as As, Cd, Ni, Hg, Cd, Zn, and Pb, is becoming a major health concern for public and health care professional [7]. There are some other heavy metals such as Pb and Hg which are not known to have any beneficial effects on human health but in fact are deleterious to human health if accumulated in body over time. A research was carried out by [8] on boreholes water in part of the Middle Benue Trough and it was discovered that the water was not contaminated by Mn, Zn, and Ni. Pb, Fe, Cu, and only Cr level in water was above [9] Standard. According to a survey conducted by [10], about 137 million people are exposure to As contaminated drinking water in more than 70 countries. According to WHO, the permissible limit of As concentration in drinking water is 0.01 mg/l, some countries like United States of America (USA) has also developed As concentration guidelines for drinking water because of the growing risk of health effects caused by As through exposure by drinking water [9]. In Bangladesh, because the levels of As in drinking water are much higher than the permissible limits of WHO and people are chronically exposed to this As contaminated drinking water that's why about 57 million people in Bangladesh are at risk for arsenicosis and other As induced health effects [11]. A study conducted on 150 patients in Bangladesh revealed that about 82% population was suffering from moderate or severe skin lesions [12]. The excess arsenic damages the skin, causes circulatory system problems and results in an increased risk of cancer [13]. In the United States of America in Fairbanks, Alaska the well water was found to be contaminated with As concentration exceeding up to 0.05 mg/l [9] value. Cadmium (Cd) is known to cause kidney diseases [14], “itai-itai” disease, Kobayashi [15] and is probably carcinogenic too. It effects cardio vascular system and may cause gastro intestinal upset, renal dysfunction, hypertension, growth inhibition, genetic defects and testicular tumors. High concentration of Cr in groundwater may cause ulceration of nasal septum and dermatitis (Singh and Bhayana, 1986). Copper (Cu) was an essential element in human metabolism and was considered to be non-toxic up to 0.05 mg/L concentration in drinking water [17, 18]. Elevated copper (Cu) level in drinking water may have a neurotoxic potential and can produce mental diseases such as Alzheimer [19]. In Pakistan, Pb concentration was found to be ranging from <0.001 to 4.7 mg/l in various areas in most of water samples and this concentration exceeds the permissible limit which is 0.01 mg/l a standard set by WHO for drinking water [9]. Some of water samples collected from Azad Jammu Kashmir Pearl valley showed Pb concentration ranging between 1.8 and 4.7 mg/l [20]. The possible sources of lead in groundwater of Western Uttar Pradesh, India [21] were diesel fuel consumed extensively in farm lands, discarded batteries, paint and leaded gasoline. Lead was also used in some pesticides such as lead arsenate. Pb is toxic to the central and peripheral nervous systems, including sub-encephalopathic neurological and behavioral effects. Its consumption in higher quantity may cause hearing loss, blood disorders, hypertension and eventually, it may prove to be fatal [17, 18]. Strontium (Sr) minerals are widely distributed through - out the earth and are released to the groundwater by the natural recrystallisation of rocks and weathering of rocks and soils [22]. Strontium in soil dissolves in water, so that it would be able to leach deeper into the ground and enter the groundwater. [23] Established that Sr content could be linked to various water types. They suggested Sr values of < 1.6 mg/L for fresh groundwater, 1.6 – 5.0 mg/L for brackish water, and >5.0 mg/L for saline groundwater in the coastal aquifers. Water and soil containing much Sr, on consumption often leads to fractures and osteodystrophy. Strontium is also known to have a pronounced rachitic effect [24]. Zinc (Zn) is an essential trace element found in virtually all kind of food and potable water in the form of either salt or organic complexes and is an essential and beneficial element in human as well as plant metabolism. Zinc deficiency may leads to dwarfism, dermatitis and loss of taste [13]. The groundwater temperature within Hit and surrounding area south of Kubaisa ranges between (27 – 34) ^{O}C and is classified as thermal water, while the groundwater temperature to the north, northeast and northwest of Kubaisa ranges between (22 – 26) ^{O}C and is classified as sub thermal water [25].

1.1. The Study Area

The study area is defined by Longitudes 9°0'0" - 9°20'0"E and Latitudes 8°0'0" - 8°30'0"N and is part of the Middle Benue Trough. Stratigraphy of the Cretaceous sediment fill of the Middle Benue Trough can be divided into six (6) depositional units. Geological map of the study area revealed five formations which include Asu

River Group, Awe- Keana, Ezeaku, Agwu Formations and newer basalt. The mineralizations of the Asu River Group are: quartz, feldspar, hematite, calcite, and copper. The Awe Formation lithostratigraphically consist of flaggy, whitish, medium to coarse grained, sometimes calcareous sandstones on the average about 30 cm in thickness and inter bedded with carbonaceous shales or clays from which brines issues copiously. Lithostratigraphically, the Keana formation is heavily current bedded, fine to very coarse, sometimes conglomeritic, at times indurated, gritty and arkosic. The oldest rock in the study area is the Asu River Group and the basalt is the youngest rock in the study area. The mineral contents of the basaltic rocks are plagioclase, pyroxene, olivine, iron ore and analcite.

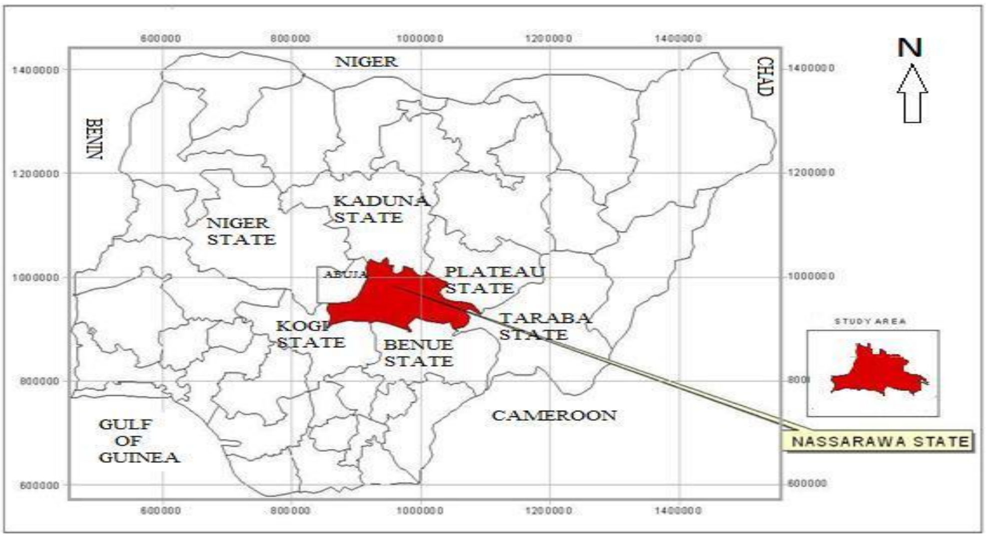

Figure 1: Location Map of the Study Area

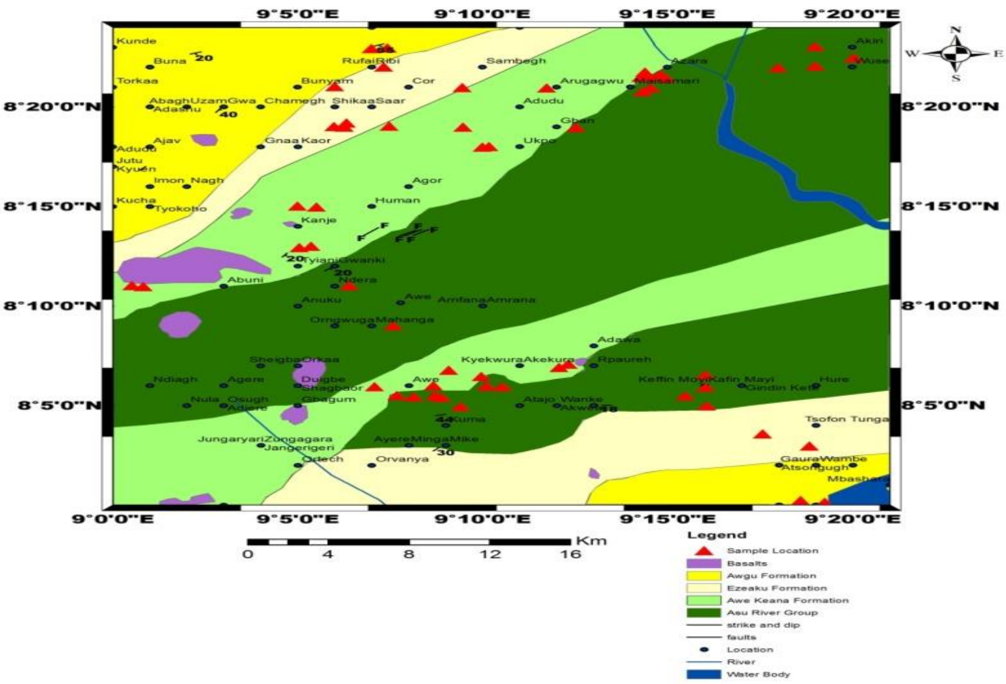

Figure 2: Geologic map of the study area showing rock types and location points

2. Materials and Methods

Forty-eight (48) groundwater were sampled from wells, boreholes, and springs using 250ml plastic bottles which were previously soaked in acidified water and washed. At each sampling point, the sample containers were further rinsed with the sampled water before sampling. One sample was collected at every sampling point and acidified with two (2) drops of concentrated hydrochloric acid for homogenization and prevention of absorption/adsorption of trace elements to the walls of the plastic container. At every sampling point, coordinates were taken using the Geographical Positioning System (GPS), GARMIN model. The water samples were transferred into 60mls plastic bottles and sent to ACME-Laboratories in Canada where Inductive Coupled Plasma Mass Spectrophotometer (ICPMS) was used for the analysis.

3. Results

The analytical results for the water sampled from wells, springs and boreholes in the study area are presented in table 1, table 2, and table 3 respectively.

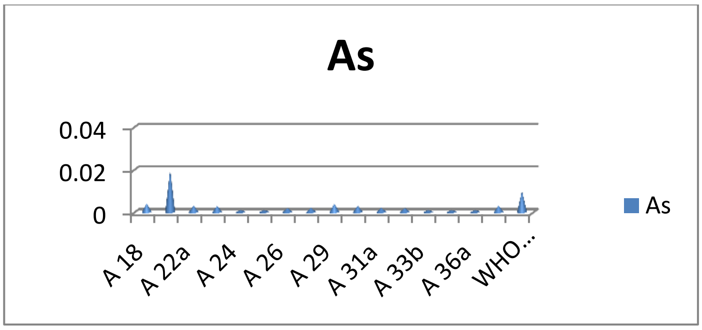

Figure 3.1: Concentration of As in well water samples of the study area

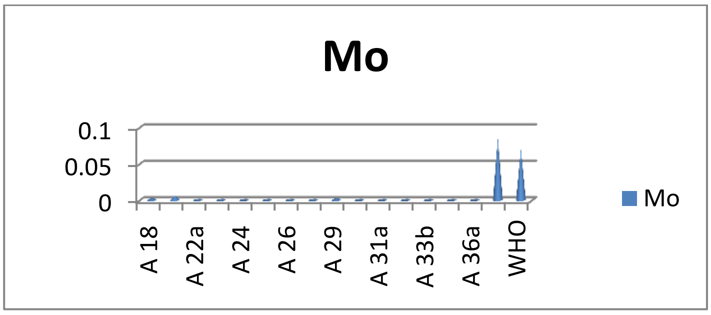

Figure 3.2: Concentration of Mo in well water samples of the study area

Table 1: Concentrations of some heavy metals (mg/l) in well water of the study area

Sample Identification symbol	Locations	Longitudes	Latitudes	Elevation (m)	Temp °C	As	Ba	Cd	Co	Cr	Cu	Mo	Ni	Pb	Sr	U	Zn
A 18	Azara (Angwa Wuje) I	9°14'4 9.5"	8°21'49.6"	111	29	0.004	0.295	0	0	0	0.001	0.003	0	0	1.194	0.002	0.001
A 19	Azara (Angwa Wuje) II	9°14'4 5.6"	8°21'45.3"	114	31	0.020	0.474	0	0	0	0.001	0.006	0.001	0	0.752	0.003	0.001
A 22a	Arugwagu I	9°12' 27.6"	8°21' 3.7"	135	26	0.003	0.342	0	0	0	0.002	0.001	0	0	1.405	0.009	0
A 22b	Arugwagu II	9°12' 27.2"	8°21' 2.8"	129	23	0.003	0.296	0	0	0	0.001	0.001	0	0	1.307	0.009	0
A 24	Agwan Eggon I	9°8'34.3"	8°6'5"	152	32	0.001	0.005	0	0	0.001	0.002	0	0.017	0	0.131	0.001	0.072
A 25	Agwan Eggon II	9°8'30.4"	8°6'7.5"	113	30	0.001	0.090	0	0	0.007	0.002	0.001	0	0	0.345	0.002	0.002
A 26	Agwan Eggon III	9°8'38.8"	8°5'3.5"	124	30	0.002	0.197	0	0	0.005	0.002	0.001	0	0	0.421	0	0.002
A 27	Angwan Mission	9°8'11.2"	8°6'10.6"	131	31	0.002	0.545	0	0	0.001	0.007	0.001	0.006	0.001	0.179	0.014	0.080
A 29	Tunga Sabo II	9°19'25.5"	7°59'55.5"	96	29	0.004	0.665	0	0.001	0.006	0.003	0.003	0	0	1.711	0	0.009
A 30a	Tsohon Tunga I	9°18'54.5"	8°3′42.9"	109	30	0.003	0.035	0	0	0.003	0.001	0	0	0	1.026	0	0.005
A 31a	Gidin Kade I	9°16'49.6"	8°6'17.6"	120	30	0.002	0.263	0	0	0.001	0.001	0	0	0	0.467	0	0.014
A 32b	Keffi Moyi II	9°16'0.3″	8°5'20.9″	140	31	0.002	0.479	0	0	0.001	0.003	0	0.002	0.	0.334	0	0.020
A 33b	Baure II	9°12'49.5″	8°7'31.7″	180	31	0.001	0.041	0	0.001	0.001	0.002	0	0.001	0	0.054	0	0.014
A 34b	Kekura II	9°10'42.1″	8°6'49.5″	151	33	0.001	0.030	0	0.001	0.001	0.001	0	0.001	0	0.023	0	0.010
A 36a	Anuku I	9°5'24.3″	8°15'30″	183	29	0.001	0.071	0	0	0.001	0.001	0	0	0	0.176	0	0.014
A 38a	Kanje I	9°5'24.8″	8°13'49.5″	173	32	0.003	0.210	0	0	0.009	0.001	0.085	0	0	0.433	0	0.001
WHO (2011)						0.01	0.7	0.003	0.05	0.05	0.05	0.07	0.02	0.01	0.07	0.03	3.00

Table 2: Concentrations of some heavy metals (mg/l) in spring water of the study area

Sample Identific-ation symbol	Locations	Longitudes	Latitudes	Elevation (m)	Temp°C	As	Ba	Cd	Co	Cr	Cu	Mo	Ni	Pb	Sr	U	Zn
A 13	Akiri spring	9°20′7.0”	8°22′52.0”		46	<3.00	15.248	<0.700	<0.300	<0.300	<0.080	<0.300	<0.300	<4.00	7.680	<3.00	<0.300
A 34a	Kekura I	9°10’30.1″	8°6’51.5″	144	33	0.001	0.046	0	0.002	0.001	0.001	0	0.002	0.00	0.027	0	0.008
A 35b	Awe spring	9°8’8.3″	8°5’3.8″	108	38	<3.00	3.683	<0.700	<0.300	<0.300	<0.080	<0.300	<0.300	<4.00	9.521	<3.00	<0.300
A 36b	Anuku II	9°5’18.7″	8°15’21.1″	172	29	0.002	0.071	0	0.003	0.001	0.004	0	0.002	0.002	0.070	0	0.041
WHO (2011)						0.01	0.7	0.003	0.05	0.05	0.05	0.07	0.02	0.01	0.07	0.03	3.00

Table 3: Concentrations of some heavy metals (mg/l) in borehole water of the study area

Sample Identification Symbol	Locations	Longitudes	Latitudes	Elevation (m)	Temp °C	As	Ba	Cd	Co	Cr	Cu	Mo	Ni	Pb	Sr	U	Zn
A 5	Shirka (Angwan Zaki)	9°6′22.9”	8°19’27.8	218	30	0.001	0.477	0.00	0	0.009	0	0.001	0	0.00	1.681	0	0.001
A 6	Shirka (Angwan MB)	9°6′21.7”	8°19’37.8	220	30	0.002	0.260	0.00	0	0.007	0.001	0.002	0	0.00	0.239	0	0.001
A 7	Shirka (Angwan Teacher)	9°6′21.4”	8°19′42.6”	225	30	0.001	0.300	0.00	0	0.008	0.001	0.002	0	0.00	0.252	0	0
A 9	Gidan Adudu II	9°9′15.4”	8°19′15.7”	182	30	0.001	0.080	0.00	0	0.018	0.001	0.001	0	0.00	0.153	0	0
A 10a	Wambai Ukpo I	9°10′44.2”	8°18′24.5”	180	31	0.001	0.081	0.00	0	0.017	0.001	0.002	0	0.00	0.085	0	0
A 10b	Wambai Ukpo II	9°10′46”	8°18′25.9”	177	30	0.001	0.037	0.00	0	0.014	0.001	0.002	0.001	0.00	0.024	0	0
A 11	Ingbien	9°12′00.6”	8°19′18.8”	154	30	0.001	0.029	0.00	0	0.010	0	0.027	0	0.00	0.030	0	0
A 14	Akiri town	9°19′45.7”	8°23′4.4”	114	31	0.002	0.296	0.00	0	0.004	0	0.001	0	0.00	0.115	0	0
A 15	Wuse town	9°18′35.4”	8°22′15.2”	107	31	0.003	0.503	0.00	0	0.014	0.001	0.004	0	0.00	0.932	0.002	0.001
A 16a	Azara (Rimi Sabo) I	9°14′ 55.8″	8°21’45.1”	116	31	0.003	0.263	0.00	0	0.011	0.001	0.004	0	0.00	0.544	0.003	0.001
A 16b	Azara (Rimi Sabo) II	9°14’ 54.4”	8°21’43.6”	116	30	0.003	0.645	0.00	0	0.005	0.002	0.002	0	0.00	0.833	0.002	0.007
A 17	Azara (Gidin Rimi)	9°14’ 58.3”	8°21’48.9”	109	26	0.015	1.508	0.00	0	0.020	0.001	0.004	0	0.00	2.054	0.002	0.001
A 20	Azara (Motor Park)	9°14’5 37.6”	8°21’37.9”		31	0.001	0.275	0.00	0	0.013	0.001	0.002	0	0.00	0.908	0.005	0
A 23	Sambegh	9°9’ 46.9”	8°21’ 41.9”	176	23	0.001	0.312	0.00	0	0.009	0.001	0	0	0.00	0.176	0	0
A 28	Tunga Sabo I	9°19’23.4”	8°0’0.1”	99	30	0.004	0.645	0.00	0	0.002	0.004	0	0	0.00	1.129	0.001	0.057
A 30b	Tsohon Tunga II	9°18’54.5”	8°3′42.9”	109	30	0.001	0.188	0.00	0	0.007	0.002	0.007	0	0.00	0.829	0.019	0.205

A 31b	Gidin Kade II	9°16’49.6”	8°6′17.6”	120	30	0.001	0.018	0.00	0	0.005	0.001	0.001	0	0.00	0.278	0	0.015
A 32a	Keffi Moyi I	9°16’8.3”	8°5′21.7”	147	31	0.002	0.766	0.00	0	0.003	0.001	0	0	0.00	0.621	0	0.007
A 33a	Baure I	9°12’21.2″	8°7’27.9″	191	33	0.001	0.030	0.00	0.001	0.001	0.040	0	0.001	0.005	0.022	0	0.035
A 34c	Kekura III	9°10’49.7″	8°6’48.6″	162	34	0.001	0.032	0.00	0	<0.001	0.008	0	0.001	0.001	0.025	0	0.014
A 35a	Tsohongari Awe I	9°7’46.1″	8°6’2.2″	124	40	<3.00	3.350	<0.700	<0.300	<0.300	<0.080	<0.300	<0.300	<4.00	8.729	<3.00	<0.300
A 37a	Abuni I	9°2’47.6″	8°11’23.12″	151	30	0.007	0.352	0.00	0	0.007	0.002	0.001	0	0.00	0.596	0	0.002
A 37b	Abuni II	9°2’49.1″	8°11’26.1″	149	30	0.009	0.618	0.00	0.001	0.005	0.003	0.007	0.002	0.00	1.539	0	0.001
A 38b	Kanje II	9°5’24.8″	8°13’49.5″	173	31	0.004	0.506	0.00	0	0.008	0.001	0.003	0	0.00	0.604	0.001	0.005
A 39	Undora	9°6’9″	8°11’22.1″	149	31	0.002	0.282	0.00	0	0.003	0.002	0	0	0.00	0.286	0	0.001
A 40	Mahanga	9°7’18.8″	8°9’2.7″	137	30	0.003	0.929	0.00	0	0.006	0.001	0	0	0.00	1.516	0	0.002
A 41	Awe police station	9°8’33.8″	8°6’49.9″	135	33	0.002	0.093	0.00	0	0.006	0.001	0.002	0	0.00	0.638	0.001	0.003
A 42	Awe Kufar Ademola	9°8’45.7″	8°6’27.3″	139	30	0.001	0.274	0.00	0.002	<0.001	0.007	0	0.002	0.001	0.138	0	0.023
WHO (2011)						0.01	0.7	0.003	0.05	0.05	0.05	0.07	0.02	0.01	0.07	0.03	3.00

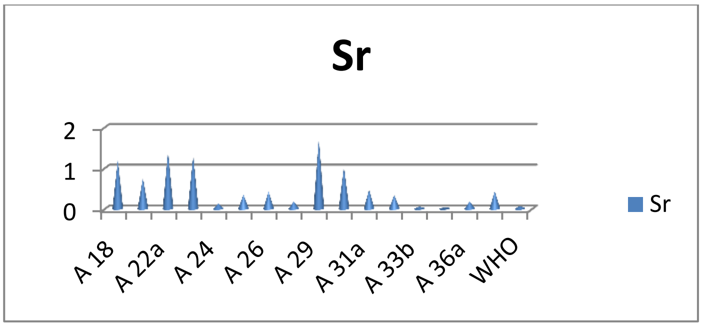

Figure 3.3: Concentration of Sr in well water samples of the study area

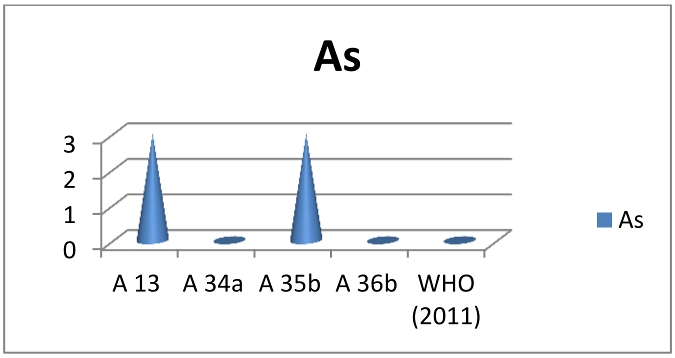

Figure 3.4: Concentration of As in spring water samples of the study area

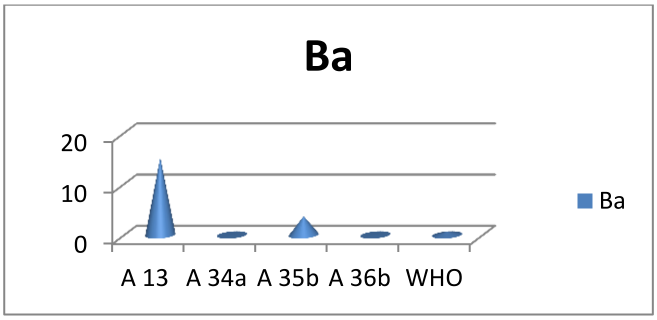

Figure 3.5: Concentration of Ba in spring water samples of the study area

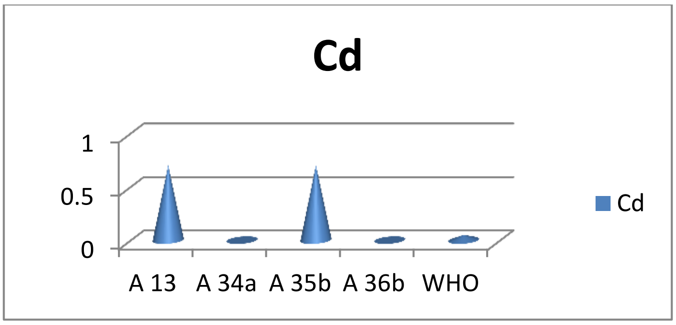

Figure 3.6: Concentration of Cd in spring water samples of the study area

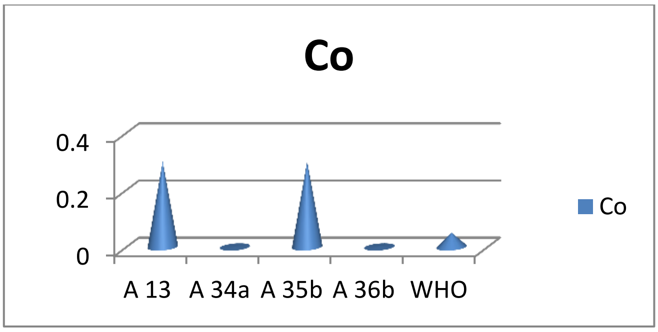

Figure 3.7: Concentration of Co in spring water samples of the study area

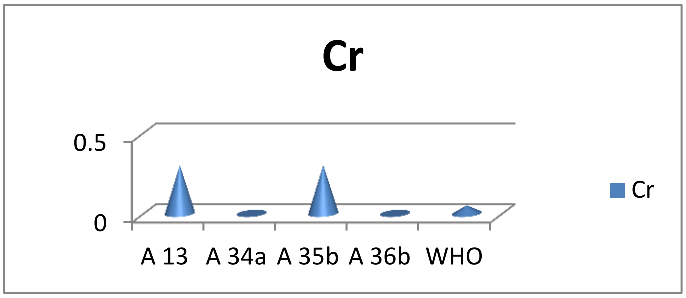

Figure 3.8: Concentration of Cr in spring water samples of the study area

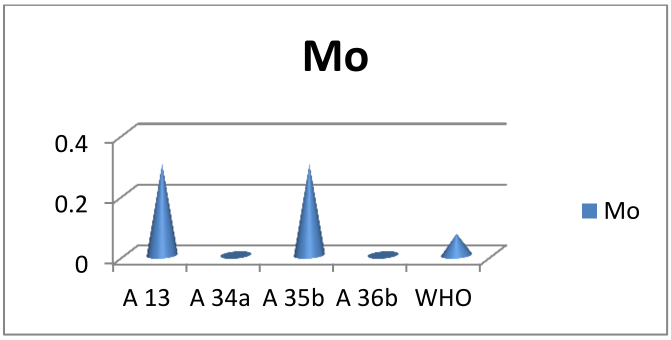

Figure 3.9: Concentration of Mo in spring water samples of the study area

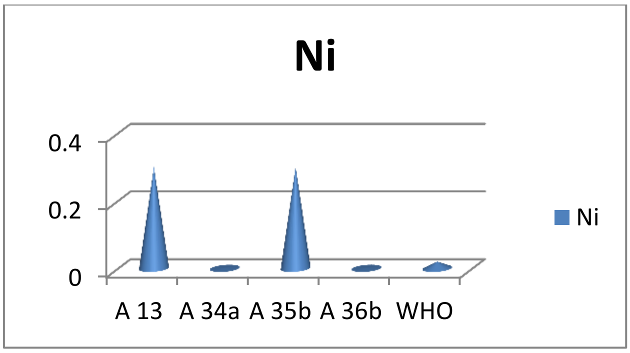

Figure 3.10: Concentration of Ni in spring water samples of the study area

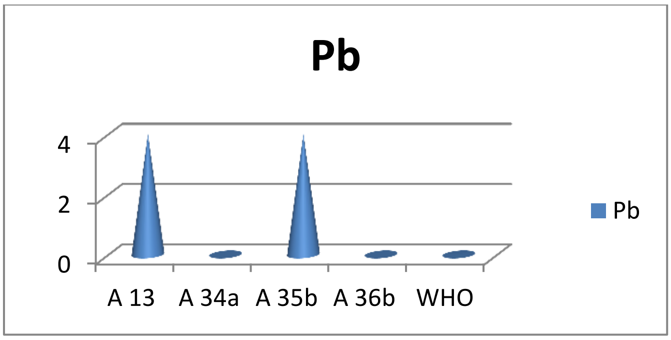

Figure 3.11: Concentration of Pb in spring water samples of the study area

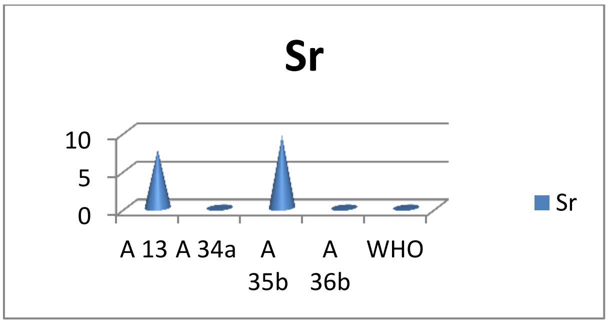

Figure 3.12: Concentration of Sr in spring water samples of the study area

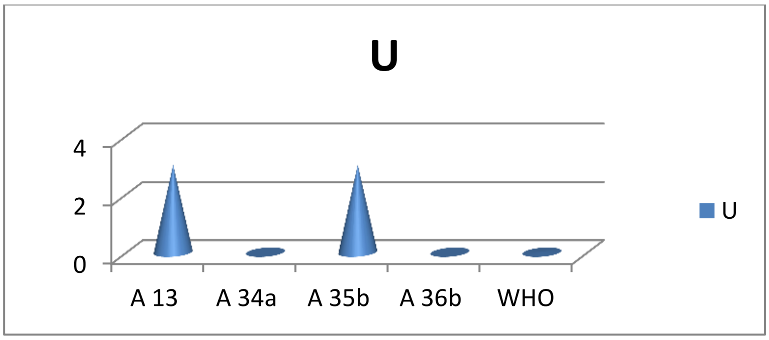

Figure 3.13: Concentration of U in spring water samples of the study area

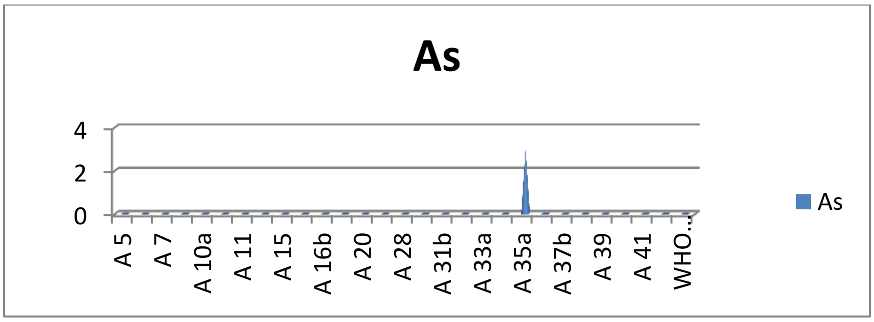

Figure 3.14: Concentration of As in borehole water samples of the study area

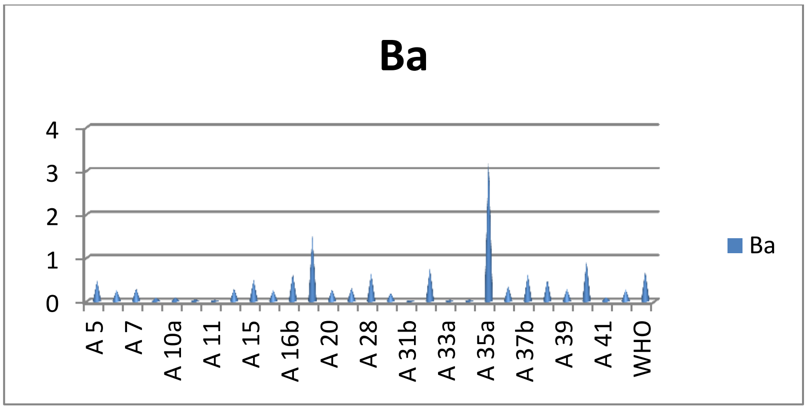

Figure 3.15: Concentration of Ba in borehole water samples of the study area

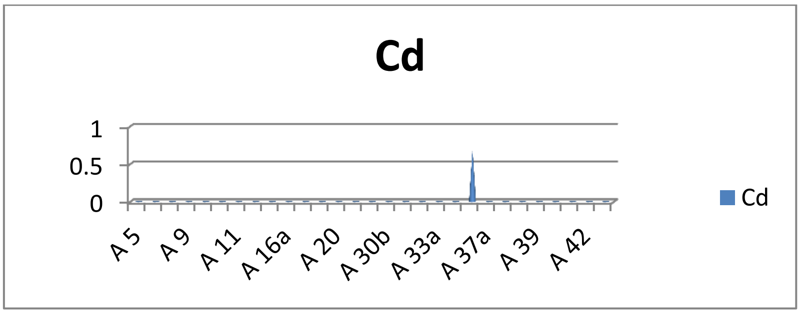

Figure 3.16: Concentration of Cd in borehole water samples of the study area

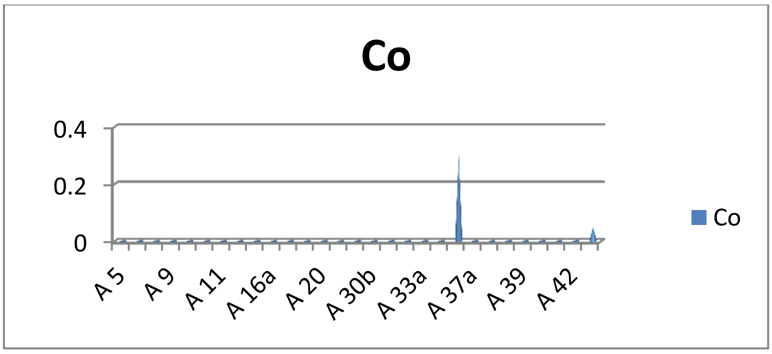

Figure 3.17: Concentration of Co in borehole water samples of the study area

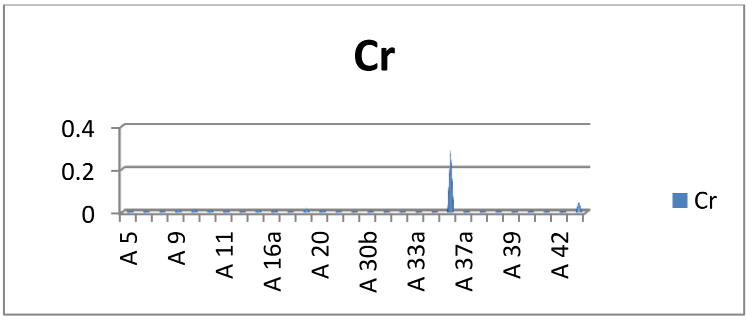

Figure 3.18: Concentration of Cr in borehole water samples of the study area

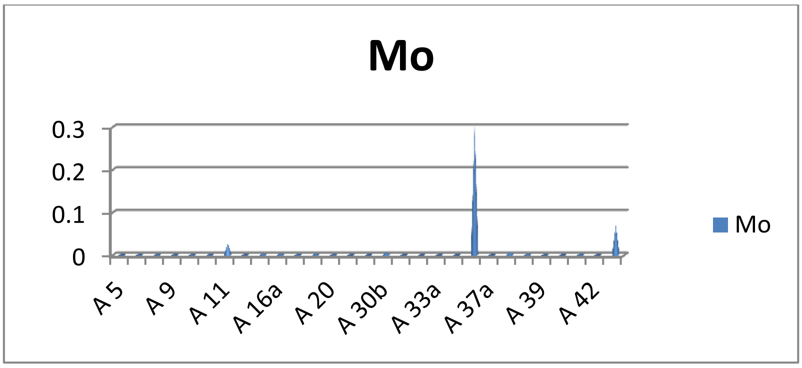

Figure 3.19: Concentration of Mo in borehole water samples of the study area

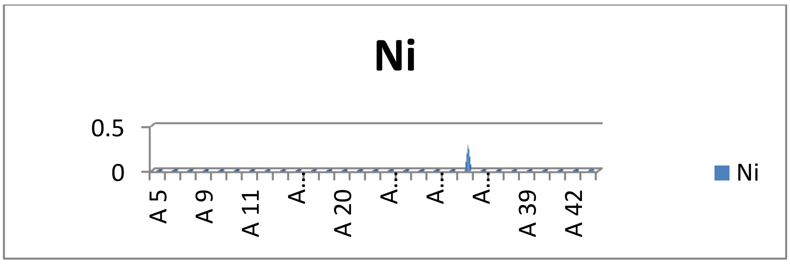

Figure 3.20: Concentration of Ni in borehole water samples of the study area

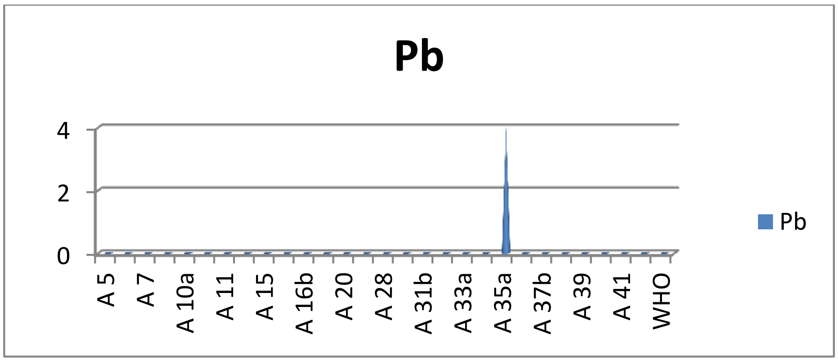

Figure 3.21: Concentration of Pb in borehole water samples of the study area

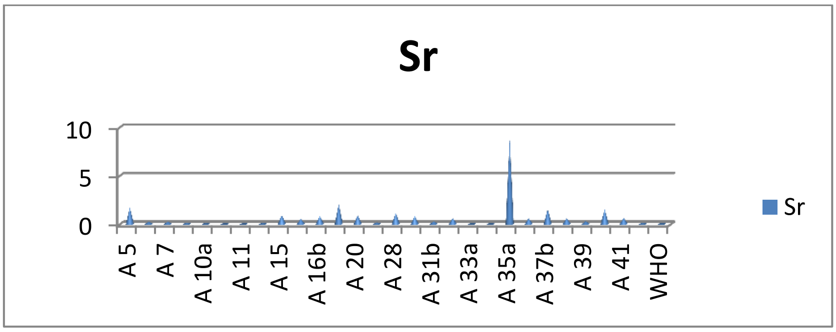

Figure 3.22: Concentration of Sr in borehole water samples of the study area

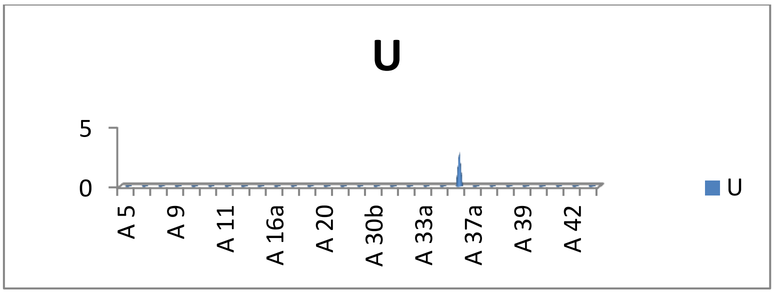

Figure 3.23: Concentration of U in borehole water samples of the study area

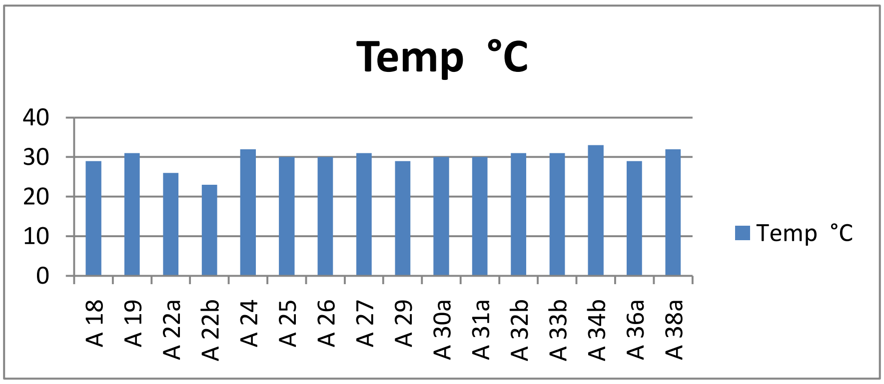

Figure 3.24: Temperature readings in the well water of the study area

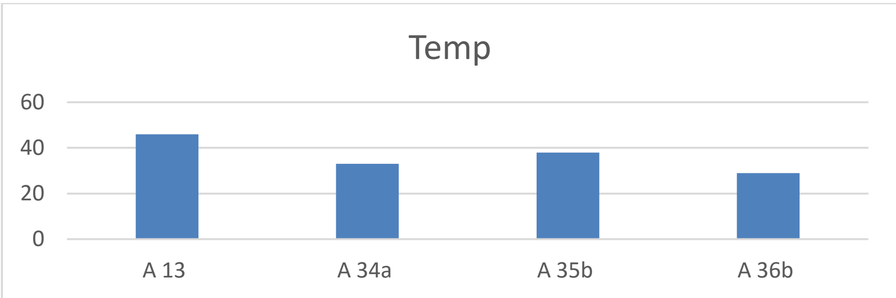

Figure 3.25: Temperature readings in the spring water of the study area

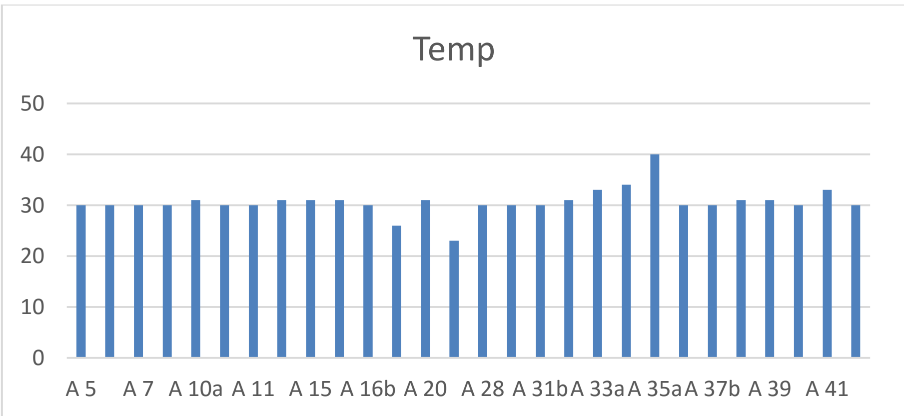

Figure 3.26: Temperature readings in the borehole water of the study area

3.1. Well Water

The concentrations of Ba, Cd, Co, Cr, Cu, Ni, Pb, U, and Zn are all within [9,] permissible limit for drinking water (table 1). The [9] permissible limit of As is 0.01 mg/l and the concentration of As in well water of the study area ranges from 0.001 to 0.020 mg/l. Only water from one well (A 19) has concentration above [9] permissible value (table 1 and figure 3.1). The concentration of As in water of the remaining fifteen wells are within WHO value (Figure 3.1). Inhabitants of the study area using water from A 19 well are likely to be affected by skin disease, circulatory system problems and cancer [13]. The concentration of Mo in fifteen water samples from wells in the study area are within WHO permissible limit with only one water sample (A 38a) with value (0.081 mg/l) which is above [9] permissible limit of (0.07 mg/l) as seen in table 1 and figure 3.2. Of all the heavy metals present in well water of the study area, Sr concentration in fourteen water samples have concentration (0.131 – 1.711 mg/l) which are above [9] permissible limit of 0.07 mg/l (table 1 and figure 3.3). Low level of Zn in all the well water can cause dwarfism, dermatitis and loss of taste. Consumption of water with high concentration of Sr leads to fractures and osteodystrophy, Sr is also known to have a pronounced rachitic effect [24], therefore people using the water from the fourteen wells that have high concentration of Sr are likely to be affected by the above diseases. Based on classification of water by [23] using Sr, only one of the well water sample (A 29) is brackish. The remaining fifteen well water samples are fresh water (table 1). None of the well water samples is saline. There are two types of water based on temperature values. Two of the well water samples are sub-thermal (A 22a, A 22b) while the remaining fourteen are thermal water [25] table 1 and figure 3.24.

3.2. Spring Water

Zinc (Zn) concentrations in all the spring water are within [9] permissible limit for drinking water (table 2). The concentrations of As, Ba, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sr, and U in the two hot springs of the study area (A 13 and A 35b) are above [9] permissible limits (figures 3.4 – 3.13). The inhabitants of this area using these two hot spring water for drinking are likely to be affected by these health challenges: damages of the skin, circulatory system problems, cancer, liver and kidney diseases, damage of the heart muscles, over-production of red blood cells or damage of the thyroid gland, hearing loss, blood disorders, hypertension and eventually, it may prove to be fatal [5, 13, 17, 18].Two of the spring water samples (A 13 and A 35b) are saline in nature and the other two spring are both fresh using the classification of water by [23]. None of the water sample is brackish (table 2). All the spring water are thermal water based on the work of [25], table 2 and figure 3.25.

3.3. Borehole Water

The concentrations of Zn in the entire borehole water samples is within [9] permissible limit (table 3). Only one borehole (A 35a) has high concentrations of As, Cd, Cr, Co, Cu, Mo, Ni, Pb and U above [9] permissible limits (table 3 and figures 3.14 – 3.23). Concentrations of Ba (0.080 - 3.350 mg/l) and Sr (0.002 – 8.729) are within [9] permissible limits in some of the borehole water samples and above in some. The inhabitants of the study area using this borehole water for drinking are likely to be affected with health problems associated high concentrations of these heavy metals [5, 13, 17, 18]. Samples A 5, A 17 are brackish in nature, sample A 35a is saline and the remaining twenty five samples are fresh water (table 3) and [23]. Water from A 17 and A 23 boreholes are sub - thermal water while the remaining borehole water are all thermal water based on temperature values in table 3 and figure 3.26.

4. Conclusion

Assessment of heavy metals in the groundwater of Awe and its environs showed that the distribution of As, Ba, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sr, U and Zn in most of the groundwater in the study area are within [9] permissible limits for drinking water. Akiri, and Tsohongari Awe II springs have concentrations of most these heavy metals above [9] permissible limits. Tsohongari Awe I artesian borehole also has concentrations of heavy metals similar to those of Akiri and Tsohongari Awe II springs. People living in the study area used the water in these hot springs and artesian borehole for drinking and bathing believing that they have healing power not knowing the long time effects on their health. Akiri spring is found on Asu River Group while Tsohongari Awe II springs and Tsohongari Awe I artesian borehole are found on Awe Formation. Eighty eight percentages (88%) of groundwater found in the study area are fresh water while brackish and saline water constituted six percent (6%) of the groundwater each. Ninety two percent (92%) of the groundwater in the study area are thermal water while only eight percent (8%) are sub – thermal in nature. Likely health challenges that will be encountered by the inhabitants of the study area if expose to these heavy metals for long time are: skin disease, circulatory system and heart problems, cancer, fractures, hypertension, liver and kidney problems.

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