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Chromium contents and some physicochemical parameters of groundwater in Odo-ona area of Ibadan, Nigeria

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Abstract

The assessment of groundwater quality is important to ascertain the level of contaminants, which have adverse effect on human health. The groundwater of Odo-ona area, Ibadan, Nigeria were studied for chromium (Cr) contents and other physico-chemical parameters. Cr contents were analysed using atomic absorption spectrophotometry technique while other physico-chemical parameters were determined using standard methods. The water samples were collected and analysed for Cr, pH, temperature, electrical conductivity, total dissolved solids (TDS), total alkalinity, sulphate, nitrate, phosphate and chloride. The results obtained were compared with the WHO guidelines or standards for drinking water. It was revealed that most of the parameters fall within the permissible limits of WHO except the Cr level, alkalinity and TDS, which were exceptionally higher than the acceptable range by WHO. This result renders the water not completely suitable for drinking to avoid health issues. It is thereby suggested that the groundwater in the study area be properly treated by appropriate technique before the water is used for domestic purposes. Also, regular monitoring of the groundwater quality in the study area is recommended so as to be aware of the level of contaminants and ensure precautionary measure. Further research should be conducted in the study area for other toxic metals and water quality parameters as well as the determination of the sources of groundwater contamination in the area.

Keywords: Groundwater, Chromium, WHO permissible limits, Physico-chemical parameters, Contamination.

Introduction

Water is vital resource require by living things for survival, but only 3% of the total available freshwater resources are found in rivers, lakes, and groundwater. Groundwater is the most suitable freshwater resource for human use since it contains only trace amounts of salts[1,2]. Groundwater is considered to be much more clean and free from contaminations than surface water such as river, pond, lake, etc. Unprecedented and unanticipated population, urbanization, unrestricted exploration guidelines, incorrect disposal of all types of wastes, and the use of chemical ingredients in agriculture all contribute to the infiltration of dangerous compounds into groundwater supplies, causing human health problems [2]. The availability of a clean drinkable water supply is one major factor that determines the development of a nation, and this is not obtainable in most African countries where more than 300 million people could not access clean water[1].

The problem of potable water for domestic purposes has been a global issue [3], and access to clean potable water and sanitation is one of the agenda of millennium development goals (MDG 6). More than half of the world's population now relies only on groundwater as a source of drinking water[4]. According to UNICEF, over 600 million people worldwide rely on unsanitary drinking water sources such as unprotected wells, springs, and surface water[5].

Globally, especially developing countries, groundwater is used as natural fresh water for domestic purposes as well as industrial and agricultural activities. Groundwater is regarded to be safe for drinking than surface water as the later is more exposed to contamination. Chromium is the most common contaminant in groundwater in all the toxic heavy metals through natural and anthropogenic sources (such as mining, steel and alloys production, paint manufacturing, dyeing, etc)[6]. Over 90% of freshwater resources is derived from groundwater which decrease gradually in Africa as the water require for domestic, agricultural and industrial purposes declines, which is largely due to population explosion, civilization, urbanization and industrialization[1].

Chromium naturally occurs in earth's crust with oxidation states ranges from II to VI. While chromium (III) is less harmful and causes little or no health concern, Chromium (VI) is highly toxic to human. Food is described by World Health Organization (WHO) as an important source of chromium in the body. Hexavalent form of chromium, Cr(VI) is corrosive and causes allergic reaction to the body. Chromium-induced allergic responses include significant skin redness and edema. Exposure to excessively high concentrations of chromium (VI) causes irritation, kidney damage, stomach discomfort, anemia, ulcer, asthma, cough, shortness of breath, wheezing, severe cardiovascular, respiratory problem and death[7-9]. Cr(VI) is described as a known human carcinogen through inhalation due to occupational exposure. The fate of Cr(VI) was proposed in human body during ingestion by three processes (a) passing through the compartment, (b) reduction to Cr(III) and (c) absorption into the body tissue. Chromium occurs naturally in the earth's crust (100mg kg^{-1}) and at elevated concentrations in mafic and ultramafic rock (200 and 2,400mg kg^{-1}, respectively) that occur near oceanic and continental plate margins as chromite ore ($FeCr_2O_4$), which is a complex of chromium, magnesium, aluminium and iron with different composition[10, 6]. Guo and coworkers[11] affirmed that generally Cr occurred predominantly as Cr(VI), which is more than 95% in aquifers associated with mafic and ultramafic formations. Cr(VI) was reported to has a high degree of environmental mobility and can come from both natural and manmade sources. The oxidation of Cr(III) to Cr(VI) occurs mostly in the presence of minerals containing Mn(III/IV) oxides such as birnessite, asbolane and lithiophorite. The occurrence of Mn oxides in the aquifer sediment appear to be the reason for oxidation and mobilization of Cr(VI) because these oxides readily initiate the oxidation under weakly acidic conditions[11]. The reduction of Cr(VI) to nontoxic Cr(III) is promoted in acidic environment and high organic content[12]. The stability of Cr(VI) increases especially at near neutral and alkaline pH. The low organic content and insufficient acidity to promote the reduction of Cr(VI) to Cr(III) give rise to persistence of Cr(VI) in water sources[12].

Cr(III) occurs naturally as environmentally stable and water-insoluble in environmental media. It is also an essential micronutrient with a recommended daily requirement of 50-200 µg/day. On the other hand, Cr(VI) is produced industrially (human activities) as chromite serves as main commercial form of Cr for industrial application. The indiscriminate disposal of chromite ore residues in open dumpsites leads to Cr contamination of groundwater bodies[6]. Compound of Cr(VI) are highly water-soluble and found as contaminant especially at neutral pH. There is tendency of Cr(VI) to reduce to Cr(III) at low pH and/or in the presence of certain organic compound. It has also been reported that higher pH values favour the oxidation while lower pH values favour reduction of Cr [6]. However, the reduction of Cr(VI) may not take place before it get to groundwater if the reduction capacity is low and also if the concentration in water is very high[13]. Cr(VI) concentrations in groundwater may be attributed to natural oxidation of geogenic Cr(VI) concentrations could exceed 50µg/L while higher Cr(VI) concentrations might be as a consequence of oxidation of naturally occurring Cr(VI) concentrations by anthropogenic activities such as the use of permanganate or persulfate[10].

The speciation of Cr in aqueous environment on some factors which include redox reaction, pH condition and organic matter. Cr(III) exists in aqueous solution as $[Cr(OH)]^{2+}$, $[Cr(OH)_2]^{+}$, $Cr(OH)_3$ (aq) and $[Cr(OH)_4]$, which give green colour to water. On the other hand, the most reactive and mobile Cr(VI) exists in aqueous solution as H_2CrO_4, $[HCrO_4]^{-}$ and $[CrO_4]^{2-}$ which gives a yellow colour to water especially at Cr(VI) level greater than 1µg/L [6]. Potential adverse effects of Cr exposure not only depends on the Cr form but also on the exposure route (ingestion, inhalation and dermal/skin contact), which also depends on the amount or dose. Natural inputs of Cr such as the atmosphere, soil, and water rock weathering, as well as anthropogenic impacts such as mining, land clearance, agriculture, acid precipitation, residential and industrial wastes; all influence physicochemical parameters of groundwater [1]. As a result, continuous monitoring of water quality levels is critical for measuring pollution levels, determining suitability for human use, as well as determining the possible harm to the ecosystem and ensuring the long-term management of these resources.

In Nigeria, many rural areas and parts of cities, groundwater is the only source of drinking water, which is accessed through hand-dug wells and boreholes, exposing a huge population to the risk of consuming contaminated water[2]. The major source of potable water for the residents of Odo-ona area of Ibadan, Nigeria is groundwater and the research has shown that no study has been carried out on the groundwater quality in the area. Hence, this study investigated the status of the groundwater in Odo-ona area of Ibadan, Nigeria with emphasis on the Cr contents and other physico-chemical parameters, and compare with the WHO permissible limits. This is important for the health implication of the population.

Materials and methods

Description of study area: Odo-ona area is located within Ibadan metropolis of longitudes 3°25´E– 3°35´E and latitudes 7°23´N– 7°31N. The mean annual rainfall of 1981.2 mm and has a mean annual temperature of 28.8ºC. The bedrock geology controls the drainage system, which has a distinctive dendritic pattern of structurally controlled streams and rivulets. During the wet season, from May to October, flash overland flow and drainage discharge are prevalent, helped by the surrounding terrain's hilly character[14].

Sample collection and analysis: Water samples were collected randomly from the hand-dug wells scattered around the study area during the rainy season in the month of July, 2017. This was done with the aid of plastic bucket in which a long rope was tied to one end. The bucket was used to make turbulence with the water inside the wells to ensure homogeneity before the water samples were collected into pre-cleaned sample containers after the containers were rinsed three times by each water samples. Two water samples were collected in a location (one for Cr analysis and the other for other physico-chemical determination). About 2mL concentrated nitric acid were added to each sample meant for Cr analysis to bring the pH < 2 in order to minimize precipitation and adsorption of the metal onto the container walls. The collected water samples were transported inside ice-chest to the laboratory and put inside freezer at -4ºC prior to analysis.

Digestion of water sample for Cr analysis was carried out by measuring 25mL of water sample into a beaker and 10mL concentrated acid was added. The mixture was put on hot plate until the solution reduced to about 5mL with intermittent shaking every 15 min. The mixture was removed from the hot plate and left to cool. It was then filtered into 50mL standard volumetric flask through Whatman No. 42 filter paper and made up to mark with distilled water. It was corked and thoroughly mixed before transferred into a pre-cleaned sample bottle before taking for atomic absorption spectrophotometer (AAS) Bulk scientific model for analysis. The digestion procedure was carried out for each water sample in duplicate. Blank sample was also prepared and determined while the other physico-chemical parameters were determined by standard analytical methods.

All glassware and sample materials used were previously washed thoroughly, and sterilized with 10% nitric acid solution for 48h and rinsed properly with distilled water. All the reagents used for analysis and instruments calibration were analytical reagent (AnalaR) grade and commercial BDH stock standards. The descriptive statistics was performed through MS Excel 2007.

Results and discussion

The values of chromium contents and other physico-chemical parameters were presented in Table-1. Chromium contents in the investigated groundwater from the studied area ranged from 0.108–0.287mg/L. The lowest Cr value was obtained in S7 while the highest Cr value was recorded in S9. The values of Cr recorded in all the water samples from the studied area were higher than the WHO permissible limit of 0.05mg/L. This results call for concern as the health of the population in the studied area is at risk.

Cr(VI) has corrosive properties and can trigger allergic reactions in the body.

pH is the degree of acidity or alkalinity of a solution. Actually, pH, which is regarded as one of the very vital and crucial water quality parameters in the water body system may has no direct health concerns on human but indirectly, it is the key parameter that bring about the considerable changes or alteration in other water quality parameters such as solubility of metal ions and survival of pathogen as well as all biochemical reaction[1,15]. The pH values in water sample from the present study ranged from 7.59 – 7.85. These results fell within the WHO's drinking water acceptable range of 6.5–8.5. The lowest pH value was found in S6 and the highest value was obtained in S3. The pH values obtained in the present study agreed with the values of 7.1 – 8.0 recorded in groundwater around Jalgaon district, Maharashtra, India[16].

The permissible limit for drinking water has not been set by WHO but generally cool water appear more soothing to drink than warm water. The temperature values of this study ranged between 28.00 and 30.00°C. Water temperature usually varies depending on the time of the day (ambience). Physical, chemical, and biological processes in water bodies are all influenced by temperature. High water temperature may enhance microorganism growth, taste, odour and colour of water[17]. This study temperature is similar to the temperature values of 28.00-30.00°C recorded in groundwater of an industrial area in India[18].

The dissolved oxygen decreases at increased water temperature[1]. Acidic water could cause irritation and stomach disorder and discomfort or upset and cause diarrhea as well as irritation to skin and eye, mucous membrane cell damage and acidosis[2].

Total dissolved solids (TDS) indicate the salinity behaviour of groundwater. It is a measure of inorganic salts in water. TDS are due to weathering of rocks, vegetable decay, and disposal of effluent. In this study, TDS values ranged from 2,600 – 23,800 mg/L in the water samples. The TDS values are found to be far above the WHO permissible limit of 500mg/L, though TDS around 1000mg/L can be recommended for drinking especially in the absence of alternate water source. The groundwater in the study area requires treatment before drinking. The TDS values obtained in this study were much higher than the values obtained from Bauchi metropolis in Nigeria[3], Kopargaon area in India[17], Konso area in southwestern Ethiopia [1] and Jalgaon district in India[16].

The tendency of water to carry an electric current is referred to as electrical conductivity, which is mostly determined by dissolved solids. The values of conductivity in this study ranged between 588 – 1193µS/cm. The lowest value was recorded in the water sample S8 and the highest was obtained in water sample S7. It was observed that only water sample S7 was above the WHO permissible limit of 1000µS/cm.

The ability of water to neutralize acids is measured as total alkalinity. Carbonates, bicarbonates, and hydroxides all contribute to the alkalinity of groundwater. The ranged of alkalinity values in the present study ranged between 260 – 738 mg/L, which were all above the WHO permissible limit of 150 mg/L and in the absence of alternate source of water, 600mg/L may be consider acceptable[1,16]. These values were almost similar to the values obtained from Jalgaon district, Maharashtra, India[16] but higher than values of 97.6 – 483.12 mg/L obtained from Konso area, southwestern Ethiopia[1].

Sulphate minerals occur widely in nature. Sulphate may be present in groundwater from leaching of sedimentary rocks and deposited as gypsum and some other minerals. The industrial wastes and domestic wastes also increase the concentration of sulphate[16]. The sulphate values in this study were between 19.90 and 37.60mg/L, which are within the WHO permissible limit of 250mg/L.

Nitrate occurs in groundwater through leaching of nitrate-rich materials such as sewage. Nitrate mostly come from industrial wastes, human and animal wastes, and fertilizer and chemical applications. The nitrate values ranged from 0.85 – 23.17mg/L in the present study. The values obtained were well below WHO permissible limit of 50mg/L.

Phosphates could be found in human and animal wastes, industrial wastes, phosphorus rich rock, detergent and fertilizers run off. The phosphate values in the investigated area varied from ND – 0.87mg/L. Phosphate content was not found in water sample S7. All the values obtained for phosphates in this study were below the 5mg/L specified by WHO as acceptable for drinking water. This result of phosphate is similar to the result obtained from Jalgaon district, India[16].

Chloride level in groundwater indicates sewage pollution. Chloride may be added to drinking water in a controlled proportion for health and sanitary reasons. The level could be increased by fertilizers contamination, human and animal wastes, salts and industrial pollution. The majority of the chloride content in groundwater is caused by ocean water and chloride-containing materials contamination[1]. The chloride level in the present study ranged from 9.17 – 32.86mg/L in the water sample investigated. These values were far below WHO recommended limit of 250mg/L for drinking water. The values were, however, higher than the values obtained in groundwater around Konso area, southwestern Ethiopia[1].

Conclusion

This study assessed physico-chemical characteristics, including chromium levels, in the groundwater of the Odo-ona region in Ibadan.

With the exception of Cr concentrations, alkalinity, and TDS, the majority of the parameters analyzed fall below the WHO permitted range.
Cr(VI) is a possible carcinogen that can cause a variety of chronic and acute illnesses. Before being used for domestic purposes, it is suggested that the groundwater be adequately treated.

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Table-1: Chromium level and other physico-chemical parameters of groundwater in Odo-ona area, Ibadan, Nigeria.

Sample	Cr (mg/L)	pH	Temp (°C)	TDS (mg/L)	Cond (µS/cm)	Alkalinity (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	Cl^- (mg/L)
S1	0.127±0.06	7.81±0.12	29.00±0.00	2800±566	737±0.23	436.8±0.01	28.7±0.18	12.14±0.18	0.49±0.02	24.25±0.08
S2	0.185±0.05	7.82±0.08	28.25±0.25	12200±100	829±0.41	530.4±0.02	37.6±0.08	17.08±0.10	0.49±0.10	19.76±0.03
S3	0.183±0.06	7.85±0.14	30.00±0.00	23000±283	744±0.15	509.6±0.05	33.2±0.57	22.11±0.15	0.68±0.02	21.32±0.04
S4	0.161±0.06	7.65±0.14	28.25±0.25	3800±268	731±1.01	520.0±0.02	24.8±0.18	18.96±0.06	0.62±0.02	10.95±0.10
S5	0.192±0.06	7.63±0.01	29.25±0.25	23800±566	795±0.98	457.6±0.03	25.7±0.21	21.02±0.11	0.87±0.01	32.86±0.12
S6	0.269±0.07	7.59±0.04	28.00±0.00	20400±101	621±0.75	364.0±0.04	19.9±0.16	13.28±0.12	0.80±0.03	28.71±0.28
S7	0.108±0.07	7.62±0.08	29.00±0.00	22200±102	1193±0.42	280.8±0.03	26.8±0.09	0.85±0.10	ND	9.17±0.08
S8	0.182±0.06	7.71±0.10	29.00±0.00	8800±131	588±1.12	561.6±0.02	22.64±0.11	17.99±0.12	0.62±0.02	19.17±0.20
S9	0.287±0.06	7.80±0.11	29.00±0.00	21400±566	877±0.36	738.4±0.01	22.79±0.20	18.71±0.09	1.11±0.02	12.18±0.08
S10	0.208±0.06	7.73±0.11	29.00±0.00	2600±100	865±0.42	260.0±0.03	26.39±0.11	23.17±0.08	0.37±0.01	13.75±0.11
WHO (2015)	0.05	6.5-8.5	-	500	1000	150	250	50	5	250

ND = Not detected

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