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Determination of Heavy Metal Concentrations in Water Samples Obtained From Lake Afdera, Upper and Lower Dobi Areas, Afar Regional State, Ethiopia

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Abstract: *Heavy metals are environmentally stable, toxic and tend to accumulate in human beings causing chronic adverse effects on human health. This study was aimed to determine the level of six heavy metal contents in water samples. These water samples were taken from Lake Afdera, lower and upper Dobi (Elidar District) groundwater sites of Afar regional state, Ethiopia. For this study, eight water samples were collected from each three locations. Samples were mixed and one representative sample was taken from each site. All the samples were analyzed for six heavy metals namely; Pb, Cu, Mn, Ni, Zn and Cd, using standard procedures and inductively coupled plasma optical emission spectrometer (ICP-OES).The heavy metals concentrations in the Lake water and groundwater samples of Lake Afdera and upper Dobi (Elidar District) sites decreased in the sequence: Ni>Cu>Mn>Pb and for lower Dobi (Elidar District) site Ni>Mn>Cu>Pb respectively. From the results, Nickel was recorded with the highest mean value of 1.99 mg/L from upper Dobi (Elidar District) site, Lead concentration with mean value of 0.017 mg/L was found to be the lowest from lower Dobi (Elidar District) site, while concentrations of Zinc and Cadmium were found below method of detection limits. The results were compared within the permissible limit of world health organization standards.*

Keywords: *Lake water, Ground water, Heavy metals, ICP-OES.*

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I. Introduction

Metals are electropositive and are natural constituents of rocks, soils, sediments, and water. They are abundant in nature with atomic number below 40 and readily available as soluble species. However, some of which are virtually unavailable due to the low solubility of their hydroxides. From the view of environmental pollution, metals may be classified according to three criteria such as noncritical (Na, Mg, Fe, K, Ca, Al, Sr, Li, Rb), toxic but very insoluble or very rare (Ti, Hf, Zr, W, Ta, Ga, La, Os, Ir, Ru, Ba, Rh), and very toxic and relatively accessible (Be, Co, Ni, Cu, Zn, Sn, Cr, As, Se, Te, Ag, Cd, Hg, Tl, Pb, Sb, Bi)[1]. Very toxic heavy metals are environmentally stable and non-biodegradable, toxic to the living things and tend to accumulate in plants and animals causing persistent adverse effects on human healthiness[2]. Some of known serious effects of heavy metal include damaged mental and central nervous function and lower energy level. They also cause irregularity in blood composition, badly affect vital organs such as kidneys and liver. The long-term exposure of these metals result in physical, muscular, and neurological degenerative processes that cause Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis[3]. The sources of heavy metals are natural as they are components of the lithosphere and are released into the environment through volcanism[4], leached from rock weathering, soil erosion, dissolution of water-soluble salts according to their geochemical mobility[5] and coal, natural gas, and paper[6] or anthropogenic sources such as, municipal wastewater, manufacturing industries, and agricultural activities[7].

Heavy metals are introduced to the environment through a variety of sources such as combustion of fossil fuels, extraction, agricultural runoff, transportation[2], waste discharges[8], leachate from solid waste disposal sites. Heavy metals are priority toxic pollutants that severely limit the beneficial use of water for domestic and industrial application[9]. Frequent use of heavy metal contaminated water by human beings or animal directly exposes to unsafe and toxic mineral materials[10].

Once a metal is taken, it would be distributed in tissues and organs. Excretion typically occurs primarily through the kidneys and digestive tract, but metals tend to persist in some storage sites like the liver, bones, and kidneys, for years or decades because of their non-biodegradable nature and long biological half-lives. Most of the heavy metals pose extreme toxicity because of their solubility in water. Even low concentrations of heavy metals have damaging effects to man and animals because there is no good mechanism

for their elimination from the body. Therefore, the accumulation of low concentrations of these toxic metals in the human body poses direct or indirect health impacts in the long run[10, 11, 12].

Due to the fact that water containing heavy metal ions, is one of the main exposure routes for human body, as well as it is harvested from Lake and groundwater which contains various harmful elements, the evaluation of heavy metal levels in water is a growing concern in studies throughout the world. The FAO/WHO has also set safe limits of heavy metal elements in water because of their possible consequent health risks[13]. However, no investigations have been done in Ethiopia particularly in Afar national regional state at Afdera Lake, upper and lower Dobi (Elidar District) sites where the main source of Ethiopian salt is located. This is distributed for the daily consumption all over the country.

Therefore, it is essential to monitor the levels of heavy metals in water used by the local community. Thus, in this study among known heavy metals, an attempt was made to determine the levels of six heavy metals namely; Cadmium (Cd), Lead (Pb), Nickel (Ni), Zinc (Zn), Copper (Cu) and Manganese (Mn) in water sample obtained from Afdera Lake, upper and lower Dobi (Elidar District) sites.

II. Materials and Methods

2.1 Reagents and Chemicals

Analytical grade reagents (BDH Lab. Supplies, England) were used. Triply distilled water was used for all dilutions throughout the study. All polyethylene plastic containers were first cleaned by distilled water and soaked in 10% (v/v) nitric acid for 24 h and rinsed with deionized water prior to use. HCl 37% (England), HNO_3 (69%, England), H_2O_2 (30%, England) were used for microwave digestion.

2.2 Instrumentation

All digestion works were carried out by using microwave (Horiba, France.). And digested solutions of the concentration of the metal ions were analyzed by Agilent 5100 SVDV ICP- optical emission spectrometer (USA). The instrument was operated under conditions provided in Table 1.

Table 1: Working parameters used for the determination of the six heavy metal elements by ICP-OES

R/No	Instrument	Setting
1.	Read time (s)	20 sec
2.	Replicates	2
3.	Sample uptake delay	0 sec
4.	Stabilization time	10
5.	Rinse time	3 sec
6.	RF power (kW)	1.4
7.	Nebulizer flow (L/min)	Default (0.70)
8.	Plasma flow (L/min)	Default (12.0)
9.	Aux flow (L/min)	Default (1.0)

2.3 Sampling site

Water samples were collected from Afdera Lake, upper and lower Dobi (Elidar District) groundwater areas, Afar regional state, Ethiopia respectively (Figure 1, Figure 2, and Figure 3). The location of each sample sites is shown in Table 2.

Table 2: Latitude and Longitude of each sample sites.

Afdera_Site

FID	Shape *	ID	Latitude	Longitude
0	Point	1	13.285743	40.860971
1	Point	2	13.277042	40.860759
2	Point	3	13.271393	40.859997
3	Point	4	13.25687	40.861064
4	Point	5	13.2245	40.874915
5	Point	6	13.219654	40.873942
6	Point	7	13.20887	40.873773
7	Point	8	13.194241	40.880548

Elidar District(Dobi_Upper)

FID	Shape *	ID	Latitude	Longitude
0	Point	1	11.906305	41.652381
1	Point	2	11.907772	41.657276
2	Point	3	11.882744	41.694883
3	Point	4	11.883568	41.704316
4	Point	5	11.884232	41.706065
5	Point	6	11.881371	41.709871
6	Point	7	11.88235	41.710539
7	Point	8	11.881739	41.707524

Elidar_District(Dobi_Lower)

FID	Shape *	ID	Latitude	Longitude
0	Point	1	11.81496	41.762751
1	Point	2	11.810809	41.766039
2	Point	3	11.805464	41.783036
3	Point	4	11.841373	41.742889
4	Point	5	11.852429	41.723717
5	Point	6	11.857724	41.718492
6	Point	7	11.865814	41.705909
7	Point	8	11.870295	41.71328

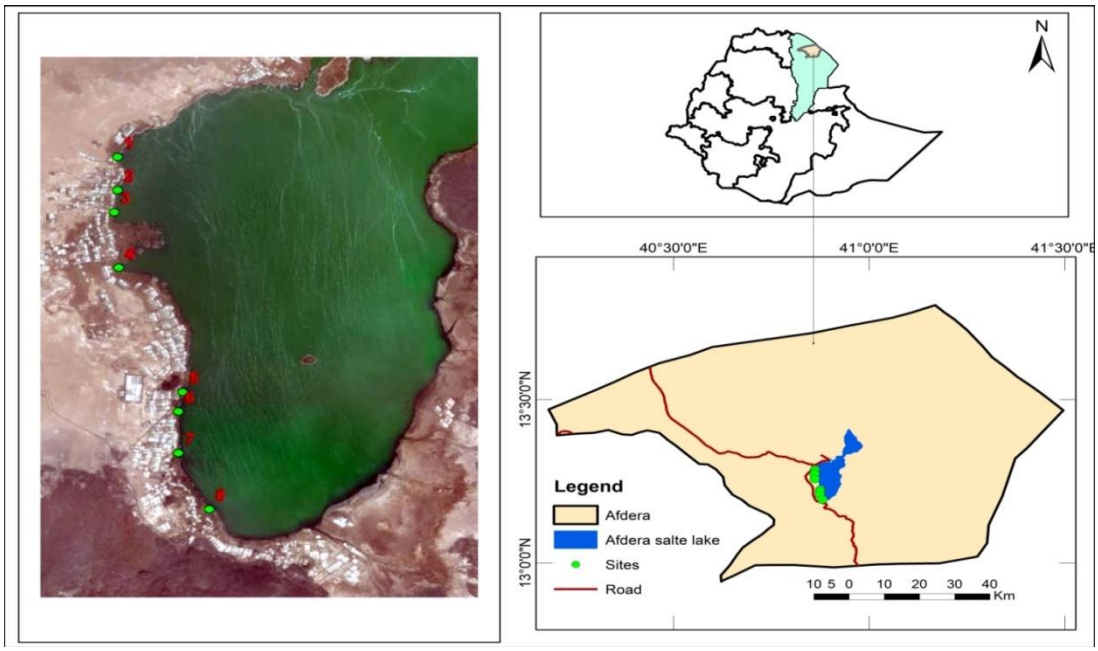


Figure 1: Afdera Lake sample site.

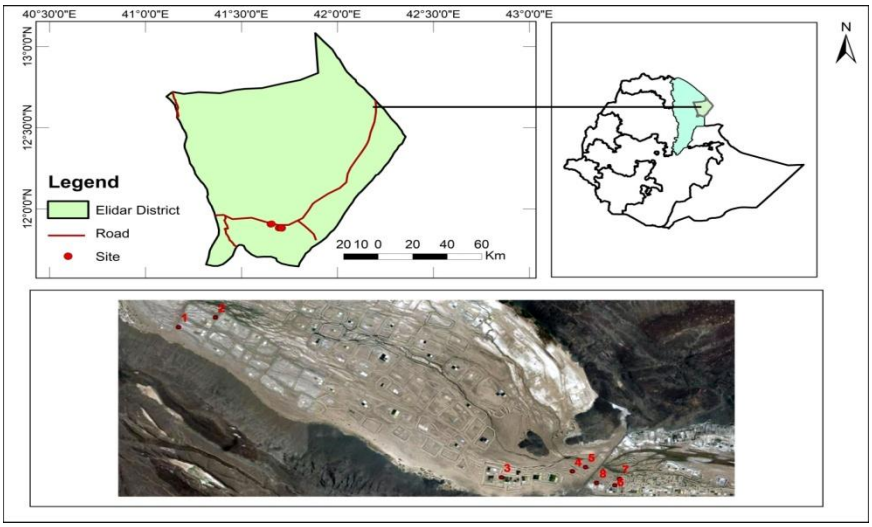


Figure 2: Upper Dobi (Elidar district) sample site.

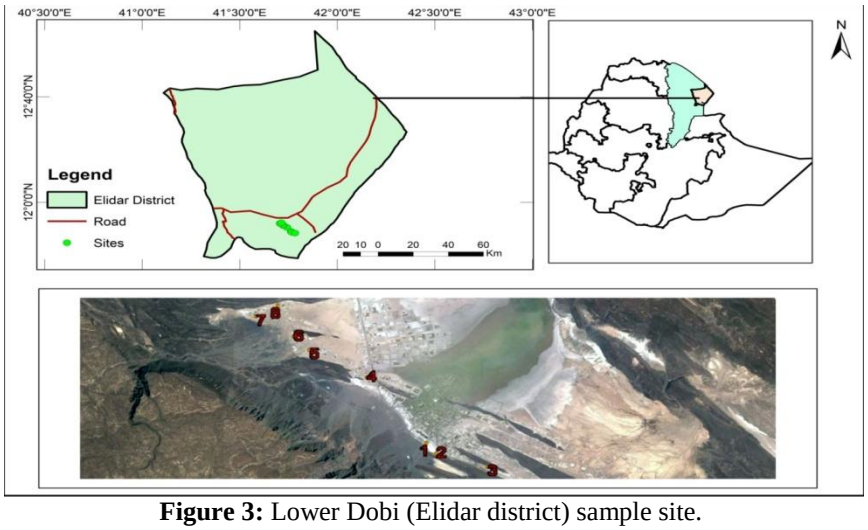


Figure 3: Lower Dobi (Elidar district) sample site.

2.4 *Sample Collection and Preparation*

Eight water samples were taken from each surface of the Lake Afdera, upper and lower Dobi (Elidar District) groundwater using one liter acid-leached polythene bottles. About 0.5L of each water samples, were taken at each sampling site, all the samples from each sampling site were mixed thoroughly by shaking and 1L representative sample from each three sampling sites were taken. Samples were acidified with nitric acid immediately on arrival to the laboratory and kept at 4^0C until analysis. For analysis, a 50 mL filtered aliquot of water samples were digested with 10 mL of concentrated HNO_3 at 80^oC for 1 h until a clear solution was observed[5]. After cooling, the digested samples were filtered using Buchner funnels and the filtrate was diluted to 100 mL with distill water. The final solutions were used for the elements analysis namely Cd, Pb, Cu, Zn, Mn, and Ni, by inductively coupled plasma optical emission spectrometer.

III. Results and Discussion

From the study sites highest heavy metal concentration was found in Dobi (Elidar District) upper site for nickel (1.99 ppm), Lead concentration with mean value of 0.017 mg/L was the lowest from lower Dobi (Elidar District) site while concentrations of Zinc and Cadmium were found below method of detection in the water samples.Comparison of heavy metal concentrations among the samples and WHO standard are given in Table 3.

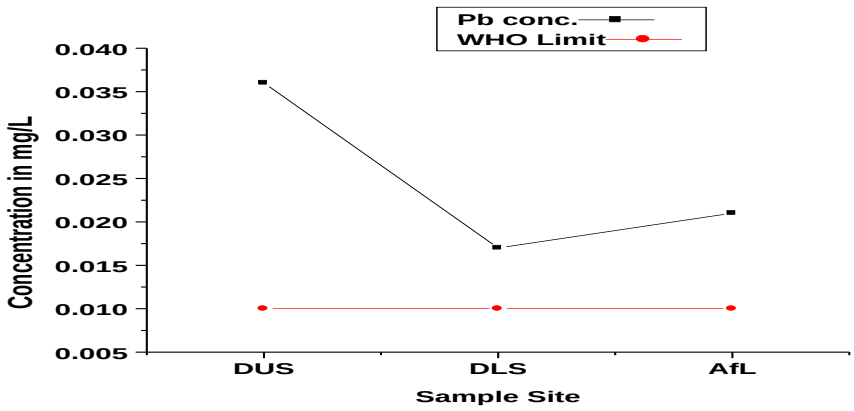
Table 3: Concentration (mg/L) of heavy metals in water from Dobi (Elidar District) upper (DUS), Dobi (Elidar District) lower (DUL) and Afdera Lake (AfL).

S.No	Elements	Concentrations (mg/L)			WHO permissible limits (mg/L)
		DUS	DLS	AfL	
1.	Pb	0.036 ± 0.01	0.017 ± 0.01	0.021 ± 0.01	0.01
2.	Cu	0.618 ± 0.10	0.38 ± 0.03	0.81 ± 0.05	2
3.	Mn	0.59 ± 0.03	0.42 ± 0.02	0.58 ± 0.02	0.1
4.	Ni	1.99 ± 0.24	1.03 ± 0.08	1.33 ± 0.16	0.07
5.	Cd	<MDL	<MDL	<MDL	0.003
6.	Zn	<MDL	<MDL	<MDL	0.01

<MDL = Method detection limit

3.1 Lead

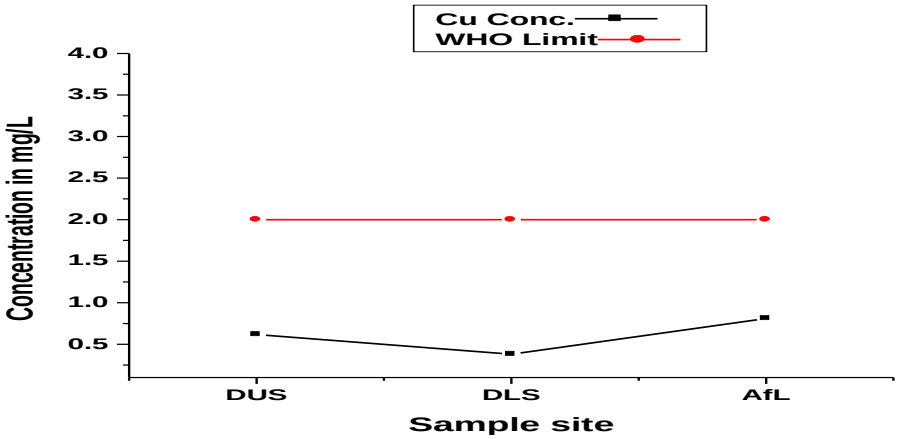
As shown from the result, the mean concentration of lead in the water samples from the Lake Afdera was 0.021 ± 0.01 mg/L, upper Dobi (Elidar District) groundwater 0.036 ± 0.01 mg/L and lower Dobi (Elidar District) groundwater 0.017 ± 0.01 mg/L. The permitted level of Lead in water is 0.01 mg/L according to the world health organization standards. But in this study the lead content in the entire three sites is above the permissible limit. Hence, this heavy metal affects human health when it is drunk by the local community. Lead is higher toxic metal and its concentration in water has been increased mainly through anthropogenic activities such as gasoline exhausts, smelter emission, peeling paint, etc[14]. And human being is exposed to Lead through the intake of contaminated food and drinking water, and by the inhalation of particulate lead in ambient air.This toxic metal may cause kidney disease, nervous disorder, Neurological effects in infants and children, Carcinogenicity, Mutagenicity, and Gonadal dysfunction in men when it is above the permitted limits[15].The comparison levels of Lead concentration with WHO standard is shown Graph-1.



Graph.1: Mean concentration of Lead in samples compared with WHO limit

3.2 Copper

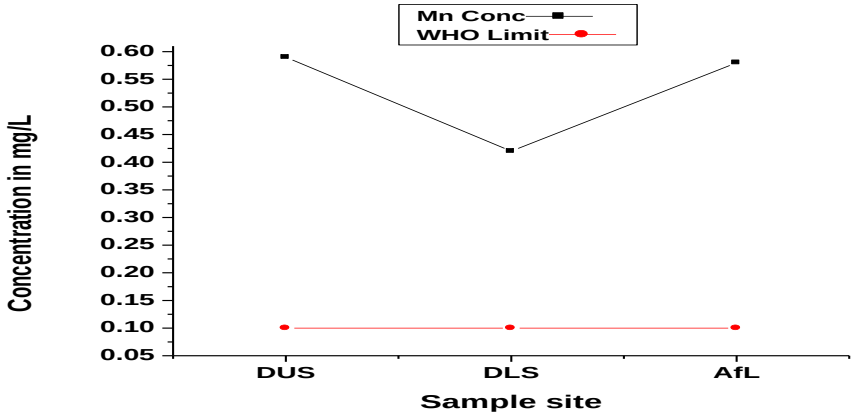
The level of dissolved Copper concentration in water samples ranges from 0.81 ± 0.05 mg/L to 0.38 ± 0.03 mg/L found from Afdera Lake and Dobi (Elidar District) groundwater. The permissible limit of copper in water is 2 mg/L, which is below the permitted levels presented by the world health organization. Therefore, Copper could not be health problem for a consumer. Though Copper is not a cumulative systemic poison, large dose is harmful and might cause central nervous system disorder, liver damage, kidney damage, failure of pigmentation of hair and effects on iron metabolism[16]. The comparison levels of Copper concentration with WHO standard is shown Graph-2.



Graph.2: Mean concentration of Copper in samples compared with WHO limit

3.3 Manganese

Manganese heavy metal content in water samples are 0.59 ± 0.03 mg/L, 0.58 ± 0.02 mg/L and 0.42 ± 0.02 mg/L Afdera Lake, upper Dobi (Elidar District) and lower Dobi (Elidar District) respectively. The values are above the permitted limit recommended by international water quality standards (WHO) 0.1 mg/L. The mean concentration of Manganese in the three sample sites were above the standard limit. Manganese is an essential element for humans and animals when it is below the permissible limit but hasan adverse neurological effect (e.g. tremor, gait disorders) following extended exposure to very high levels in drinking water[13]. Since Manganese concentration was above the permissible limit in the three sites, it could be source of health problem for human. The comparison levels of Manganese concentration with WHO standard is shown Graph-3.

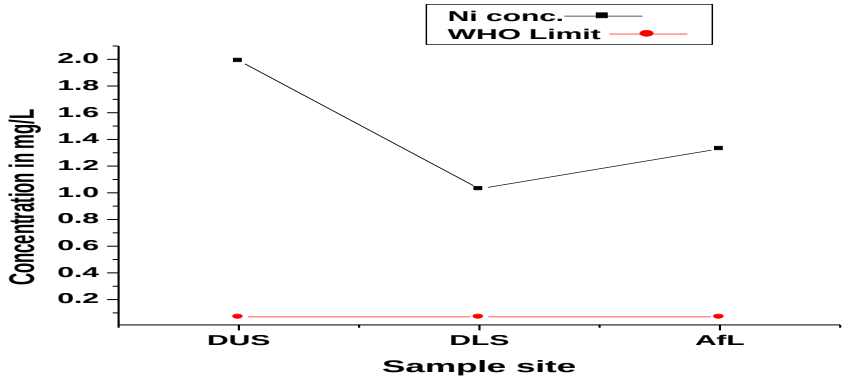


Graph.3: Mean concentration of Manganese in samples compared with WHO limit

3.4 Nickel

In the study, Nickel concentration was found in the whole sample that had been analyzed by inductively coupled plasma spectrometer. Nickel was detected in every sample site with values 1.99 ± 0.24 mg/L at Dobi upper (Elidar District), 1.33 ± 0.16 mg/L at Afdera and 1.03 ± 0.08 mg/L Dobi lower (Elidar District) in decreasing order. And mean concentration is above the permissible level (0.07 mg/L) as recommended by world

health organization[13]. Nickel compounds can cause a variety of adverse effects on human health such as vomiting, diarrhea, giddiness, lassitude, headache, shortness of breath, Skin irritation and hypersensitivity[17]. Therefore, drinking water containing Nickel metal is one of the main sources of exposure for human being. The comparison levels of nickel concentration with WHO standard is shown in Graph-4.



Graph.4: Mean concentration of Nickel in samples compared with WHO limit

3.5 ***Cadmium and Zinc***

The concentration of cadmium and zinc was found below the method of detection limit. So the local community could not be affected by these heavy metals.

IV. Conclusion

Inductively coupled plasma optical emission spectrometer is used for determination of these six heavy metals up to trace level. In overall the study areas the concentrations of Nickel, Manganese and Lead in Afdera, upper and lower Dobi (Elidar District) sites are at higher concentration above the permitted limit presented by world health organization. Meanwhile, concentration of Copper was found to be below the standard limit. Moreover, the levels of Cadmium and Zinc were found to be below the method of detection limit. The high value of heavy metal contaminants indicates that the lake water and groundwater is not safe and should not be used for domestic purposes. Therefore, all stake holders (federal, regional and zonal) water resources and environmental department should set up periodical monitoring of the water quality which is thus required to assess the condition of water body and immediate steps should be taken to check the anthropogenic activity around the lake and groundwater. This will be helpful in saving the lake and groundwater from heavy metal pollution.

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