ESTIMATION OF HEAVY METALS IN THE GROUNDWATER OF SELECTED AREAS FROM AL-DHALIA DISTRICT, AL-DHALIA GOV., YEMEN

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Received: 17 April 2020 / Accepted: 18 September 2020 / Published online: 30 September 2020

Abstract

In this research, the level of heavy metals Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Lead (Pb) and Zinc (Zn) in groundwater in selected areas in the region of Al-Dhalia district, Al-Dhalia Governorate, Yemen. Sixteen groundwater samples were collected from the study area included 9 artesian wells samples and 7 of hand-dug wells, and analyzed for the presence of heavy metals using Atomic Absorption Spectrophotometer (AAS). The results of the analysis showed that the concentrations of Pb, Mn and Cu in most of the studied samples have exceeded the Yemeni and WHO standards for drinking water, while the concentrations of Fe, Cd, Cr and Zn in most of the studied samples were low and fall within the optimum specifications for local and WHO drinking water.

Keywords: Toxic metals, Groundwater, Al-Dhalia Governorate, Yemen.

1. Introduction

Today heavy metals pollution of the groundwater is one of the serious environmental problems. Groundwater pollution is one of the most important environmental problems in the present world where metal pollution has major concern due to its high toxicity even at low concentration [1,2]. Heavy metals enter in groundwater from variety of sources; it can either be natural or anthropogenic [3,4]. Usually in natural environments, the concentration of the metals is very low and is mostly derived from the minerals and the weathering of geological formations and soils of that area [5,6]. Main anthropogenic sources of heavy metal pollution are mining, disposal of untreated and partially treated effluents as well as metals from different industries such as pharmaceutical products and indiscriminate use of heavy metal containing fertilizer and pesticides in agricultural fields [7-10]. In Yemen, which is witnessing remarkable development in various development fields, most of the newly industrial, agricultural and commercial projects of origin did not take into account the circumstances and specificity of the local environments in which they are established, so these activities became an environmental burden resulting in pollution of water, soil and air (due to the lack of application of laws, and regulations related to environmental protection). As well as, the increase in the population also constitutes an environmental pressure resulting in the exacerbation of the phenomenon of environmental pollution. In the Al-Dhalia district, Al-Dhalia governorate, wastewater is collected from different parts of the city to its center through a layer that is characterized by its penetration of these collected waters. When the rains fall, a large part of this waste is moved with the flow of torrents to different places, where there are many water wells beside the stream, “these wells are used by residents for drinking or human use”. Due to the lack of sewage stations and the result of the discharge of waste to the places where the torrents run, which leads to the transfer and leakage of pollutants to the surface and ground water. As well as, this districts from the agricultural areas, where it uses a lot of pesticides and fertilizers agricultural indiscriminately. These pollutants a will be transferred to the groundwater with the flow of rain or it may leak through the soil to reach the groundwater that feeds the water of the wells, some of which are used for drinking in the study area. According to Al-Amry et al., [11] about 71% of the water used for the drinking purpose.

The importance of this study comes as a result of the lack of periodic chemical analyzes. Therefore, through this study, we are trying to contribute to knowing the extent of pollution with some heavy elements in the water of some...
wells, finding conclusions and suggesting appropriate solutions for that.

1.1 Spatial and temporal limits of the study area

From the administrative point of view, the study area is located in Al-Dhalia district, Al-Dhalia governorate which determines the spatial location of Al-Dhalia governorate in the southern part of the central region of the Republic of Yemen. Where (astronomically) geography is confined between the latitudes 13 °, 30 ° - 14 °, 15 °, north of the equator, and longitudes 44 °, 10 ° - 44 °, 48 ° east of Greenwich (Fig. 1). The spatial limits of the study area from which well water was sampled are in the range of the southern area of Al-Dhalia dist. The pelvic area of the study area is estimated according to the sources of runoff of surface and ground water at about 86 square kilometers, which represents 24.9% of the total area of Al-Dhalia governorate, which amounts to about 345 square kilometers [12,13].

Figure 1: showing the location of the groundwater wells from which the study samples were taken in Al-Dhalia dist., Al-Dhalia governorate

Al-Dhalia governorate is bordered to the north by Al-Bayda governorate, to the east by parts of Al-Bayda and Lahj governorates, to the south by parts of Lahj and Taiz governorate, to the west by Ibb governorate, and the capital of Al-Dhalia governorate is Al-Dhalia city [12,13].

2. Experimental Section

2.1 Positioning

Initially, the purpose of going to the study area (Al-Dhalia Directorate) was in September (2014), for determining the location of the wells to be studied, and how close is it to the sewage? It was only a cluster of rural villages or the city of Al-Dhalia. Sixteen sites were identified for the wells to be studied. 5 located in the city of Al-Dhalia "characterized by its proximity to sewage water", while the other wells (eleven wells) are located in rural villages and far from the city of Al-Dhalia and there is no gathering of any wastewater, but it is located on the course of torrents Coming from the city. At each Location the coordinates were taken using a GPS (Tables 1 and 2).

2.2 Sampling and analysis

Water samples were collected using 0.75-liter polyethylene bottles and acidified with nitric acid to a pH below 2 to minimize precipitation and adsorption on container walls, and kept at a temperature of 4 °C to stop the precipitation of important metals before the commencement of the analysis [14]. To ensure the collection of representative water samples from the borehole and dug-wells, large quantity of water from were pumped out or bailout for at least thirty minutes to remove water from bore storage in the case of the borehole and the dug wells before sampling. This was done to obtain water coming directly from the aquifer. All chemicals used were of analytical reagent grade. All the plastic and glass-ware used were soaked overnight in 10% nitric acid, rinsed with distilled water, and finally with Millipore water before use. pH meter and the electrode of conductivity meter (Model: EUTECH INSTRUMENTS PC510).

2.3 Statistical processing of data

Statistical analysis was done for all samples by SPSS Program and origin 7.5.

3. Results and Discussion

In the present study, metals such as Cd, Cr, Cu, Fe, Mn, Pb and Zn were considered. Heavy metal concentrations of groundwater samples, the guideline values for drinking water as specified by the WHO (2011) [15] and Yemen’s Ministry of Water and Environment (YMWE, 1999) [16] are summarized in (Tables 3&4).

3.1 Cadmium (Cd)

Cadmium level varies from 0.0014 to 0.0049 mg/L in four locations (25% of the samples analyzed), which are above the WHO maximum admissible limit of Cd in drinking water (0.003 mg/L) [15], but all the samples analyzed were found to comply the maximum admissible limits (0.005 mg/L) for Yemeni specifications [16] (Tables 3&4).

Cadmium is a natural element in the earth’s crust. An acute exposure to significantly higher cadmium levels can lead to a variety of negative health effects including Diarrhea, Vomiting, fever, lungs damage, muscle pain [17,18].

Cadmium is highly toxic and responsible for several cases of poisoning through food. Small quantities of cadmium cause adverse changes in the arteries of human kidney. It replaces zinc biochemically and causes high blood pressures, kidney damage etc. [19]. It interferes with enzymes and causes a painful disease called Itai-itai [20].

The main sources of cadmium are industrial activities; the metal is widely used in electroplating, pigments, plastics, stabilizers and battery industries [21]. Another important
source of Cd emission is the production of artificial phosphate fertilizers [22]. The presence of cadmium is likely due to human activities (sometime-unrequired chemicals are used in agriculture process, municipal waste, runoff from waste batteries and paints).

### 3.2 Chromium (Cr)

The amount of chromium present in water samples have been illustrated in (Table 3). In this study, the concentration of chromium of most studied water samples were found to be within the permitted limits set (0.05 mg/L) by WHO [15] and Yemeni Standards [16], with the exception of two samples which are above the WHO [15] and Yemeni standards [16], this constituted 12.5% of the samples analyzed (Table 4). Chromium level in the well samples was low and close to each other with the exception of three samples which were of high level, the reason may be due to the temperature of exposed pipes exposed to sunlight daily in addition to most of the studied water wells have a high temperature and therefore it could be another reason for corrosion of pipes and a change in the concentrations of heavy metals, including chromium in the water of distribution networks [23], Discharge from steel and pulp mills; erosion of natural deposits [24].

Generally, the natural content of chromium in drinking water is very low ranging from 10 to 50 μg/L, except for the regions with substantial chromium deposits [25]. Chromium in excess amounts can be toxic especially in the hexavalent form. Sub chronic and chronic exposure to
chromic acid can cause dermatitis and ulceration of the skin. Long-term exposure can cause kidney, liver, circulatory and nerve tissue damages. Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high level of chromium [26,27].

3.3 Copper (Cu)

The total concentrations of copper in the studied samples in ground water are listed in (Table 3). The concentrations of copper in the studied samples were ranged between 0.04 to 9.09 (mg/L). Of all the samples analyzed, 37.5% and 68.75% contain copper level above WHO [15] (2 mg/L) and Yemeni Standards (1 mg/L) [16], respectively (Table 4). Copper compounds are used as or in fungicides, algacides, insecticides and wood preservatives and in electroplating, azo dye manufacture, engraving, lithography, petroleum refining and pyrotechnics. Copper compounds can be added to fertilizers and animal feeds as a nutrient to support plant and animal growth [28-30]. Copper compounds are also used as food additives (e.g., nutrient and/or coloring agent) [28,31]. Recent studies have delineated the threshold for the effects of copper in drinking-water on the gastrointestinal tract, but there is still some uncertainty regarding the long-term effects of copper on sensitive populations, such as carriers of the gene for Wilson disease and other metabolic disorders of copper homeostasis [15].

3.4 Iron (Fe)

Table (3) shows that the iron element concentrations of the studied samples. The range of concentration of iron in all the studied samples is 0.01 to 2.40 mg/L, the highest concentration of 2.40 mg/L was found in sample 16. The second, third and fourth highest concentrations of 0.43, 0.40 and 0.38 mg/L was found in samples 14, 1 and 15, respectively. However, the Fe values (It was found in four samples (1, 14, 15 and 16) were higher than the maximum admissible limit for WHO (0.3 mg/L) [14], and sample 16 were above the maximum admissible limit by Yemeni Standards (1 mg/L) [16].

In general, of all the samples analyzed, 25% and 62.5% contain iron level were higher than the maximum admissible limit by WHO (0.3 mg/L) [15] and Yemeni standards (1 mg/L) [16], respectively (Table 4).

3.5 Manganese (Mn)

Table (3) shows that manganese level in the studied samples ranged between (0.10 mg/L) as a minimum in the samples 14 and 15, and (1.40 mg/L) as a maximum in sample 4. Most of the studied samples were of highest level of manganese, and this increase is likely to be contaminated with wastewater for wells near the city. As for the wells water in Al-Sailah, the reason may be due to the temperature of exposed pipes exposed to sunlight daily in addition to most of the studied water wells have a high temperature and therefore it could be another reason for corrosion of pipes and a change in the concentrations of heavy metals, including manganese in the water of distribution networks [23]. Manganese is naturally occurring in many surface water and groundwater sources, particularly in anaerobic or low oxidation conditions and this is the most important source for drinking-water. Manganese occurs naturally in many food sources, and the greatest exposure to manganese is usually from food [15]. Manganese is a mineral that naturally occurs in rocks and soil, but human activities are much responsible for underground water pollution by this element [17].

From figure (3.3) we can see that manganese level in samples 9, 12, 14, 15, 16 were within the MAL of WHO (0.4 mg/L) [15] and Yemeni specifications (0.2 mg/L) [16] except for the sample12. However, the rest of the samples were found to be lower than the permissible limits of Yemeni [16] and WHO specifications [15].

In general, of all the samples analyzed, 68.75% and 62.5% contain manganese level were higher than the maximum admissible limit by Yemeni Standards (0.2 mg/L) [16] and WHO (0.4 mg/L) [15], respectively (Table 4).

3.6 Lead (Pb)

The results of lead (Pb) analysis of 16 samples of well water ground are shown in Table 3. The range of concentration of lead in all the studied samples is 0.16 to 0.89 mg/L. The highest concentration of 0.89 mg/L was found in sample 10, while the lowest concentration of 0.16 mg/L in sample 13. The concentrations of Pb in in all studied samples were higher than the maximum admissible limit (0.01mg/L) for WHO [15] and Yemeni standards [16] (Table 4). A lead level in all studied samples was high, and some samples recorded results of ten times the limit allowed in drinking water. Anthropogenic activities (urban, industrial and agricultural activities) play an influential role in the presence of lead, as wastewater is the main reason of increasing lead level in wells located in the Al-Dhalia city. While the water well, located at Al-Sailah, the increase in lead may be due to the quality of the rocks through which this water passes, as well as due to the temperature of exposed pipes exposed to sunlight daily in addition to the high temperature of some wells, which can be Cause corrosion of pipes [23]. The amount of lead dissolved from the plumbing system depends on several factors, including pH, temperature, water hardness and standing time of the water, with soft, acidic water being the most plumb solvent [15]. According to Gowd and Govil[32] mostly used in the manufacture of lead acid storage batteries. Lead is also released from smelting, motor vehicle exhaust fumes and from corrosion of lead pipe work. There are too many source that introduce lead in atmosphere such as industrial waste, household paint, and vehicle exhausts [33].
The maximum acceptable concentration results are of concern as lead is a poisonous metal that can damage nervous connections (especially in young children’s) and cause blood and brain disorders. One of the most important and serious biochemical effects of lead is its interference with haemo synthesis, which leads to hematological damage [34,35].

### 3.7 Zinc (Zn)

Results show a range between non-detected and 0.07 mg/L of zinc (Table 3). All the samples were noted to be lower than the maximum permissible limit of drinking water for WHO [15] and Yemeni standards [16] (Tables 3&4). Zinc level is low in groundwater due to its weak solubility in water with moderate acidity. Zinc is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes. The diet is normally the principal source of zinc. Although levels of zinc in surface water and groundwater normally do not exceed 0.01 and 0.05 mg/l, respectively, concentrations in tap water can be much higher as a result of dissolution of zinc from pipes [15].

### 4. Conclusions

According to the maximum admissible limit (MAL) of drinking water by WHO and Yemeni Standards:
- The concentration of Pb was more than the MAL in the all wells water.
- More than 60 % contain Mn level were higher than the admissible limit.

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**Table 3**: Results of Heavy Metals Analysis (mean ± SD; mg/L) in the Studied Well Water

| S. No. | Cd       | Cr        | Cu          | Fe        | Mn       | Pb       | Zn       |
|--------|----------|-----------|-------------|-----------|----------|----------|----------|
| 1      | 0.0018±0.0007 | 0.060±0.0040 | 9.09±0.36   | 0.40±0.040 | 1.20±0.08 | 0.37±0.01 | 0.05±0.006 |
| 2      | 0.0029±0.0007 | 0.051±0.0031 | 7.06±0.27   | 0.10±0.010 | 0.70±0.06 | 0.29±0.012 | 0.01±0.002 |
| 3      | 0.0014±0.0004 | 0.014±0.0035 | 6.05±0.18   | 0.06±0.002 | 0.59±0.05 | 0.18±0.026 | 0.04±0.005 |
| 4      | 0.0049±0.0009 | 0.008±0.0007 | 7.57±0.31   | 0.04±0.003 | 1.40±0.09 | 0.28±0.021 | BDL      |
| 5      | 0.0029±0.0008 | 0.041±0.0030 | 3.52±0.12   | 0.01±0.002 | 0.59±0.05 | 0.22±0.017 | 0.01±0.002 |
| 6      | 0.0020±0.0005 | 0.001±0.0003 | 1.37±0.04   | 0.18±0.025 | 0.70±0.07 | 0.19±0.021 | 0.07±0.007 |
| 7      | 0.0014±0.0003 | BDL*       | 0.06±0.02   | 0.08±0.005 | 0.49±0.04 | 0.52±0.029 | 0.01±0.004 |
| 8      | 0.0021±0.0004 | 0.001±0.0002 | 0.04±0.02   | 0.08±0.005 | 0.90±0.07 | 0.88±0.02  | 0.02±0.003 |
| 9      | 0.0020±0.0005 | 0.003±0.0003 | 1.46±0.05   | 0.21±0.035 | 0.19±0.02 | 0.30±0.006 | BDL      |
| 10     | 0.0020±0.0005 | 0.006±0.0005 | 3.07±0.09   | 0.01±0.001 | 1.00±0.08 | 0.89±0.085 | 0.01±0.002 |
| 11     | 0.0039±0.0008 | BDL*       | 0.07±0.03   | 0.09±0.006 | 0.71±0.06 | 0.81±0.051 | 0.02±0.005 |
| 12     | 0.0029±0.0008 | 0.019±0.0025 | 0.06±0.03   | 0.21±0.031 | 0.39±0.03 | 0.72±0.040 | 0.02±0.005 |
| 13     | 0.0039±0.0007 | 0.003±0.0003 | 0.21±0.04   | 0.02±0.002 | 1.20±0.07 | 0.16±0.006 | BDL      |
| 14     | 0.0039±0.0007 | 0.001±0.0002 | 1.20±0.04   | 0.43±0.035 | 0.10±0.01 | 0.17±0.017 | 0.01±0.002 |
| 15     | 0.0029±0.0009 | 0.002±0.0003 | 1.80±0.06   | 0.38±0.030 | 0.10±0.01 | 0.18±0.006 | BDL      |
| 16     | 0.0020±0.0006 | BDL*       | 1.70±0.05   | 2.40±0.10  | 0.19±0.02 | 0.18±0.01 | BDL*     |
| L.S.D  | 0.00004   | 0.000127   | 0.01031     | 0.00226   | 0.00389   | 0.0021    | 0.00024  |
| Ranges | 0.0014±0.0049 | BDL-0.06   | 0.04-9.09   | 0.01-2.40  | 0.10-1.40  | 0.16-0.89  | BDL-0.07  |
| WHO [15]| 0.003     | 0.05       | 2           | 0.3       | 0.4       | 0.01       | 3        |
| YMWE[16]| 0.005     | 0.05       | 1           | 1         | 0.2       | 0.01       | 5        |

BDL*: below detection limit of the method

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**Table 4**: Percentage of samples, which comply with WHO [15] and Yemeni Standards [16], maximum admissible limit (MAL) of different drinking water parameters.

| Metal | Percent of samples more than WHO [15] | Percent of samples more than YMWE [16] |
|-------|--------------------------------------|--------------------------------------|
|       | No. of samples       | %   | No. of samples | %   |
| Cd    | 4                    | 25% | Nil           | Nil |
| Cr    | 2                    | 12.5% | 2 | 12.5% |
| Cu    | 6                    | 37.5% | 11 | 68.75% |
| Fe    | 4                    | 25% | 1 | 6.25% |
| Mn    | 11                   | 68.75% | 12 | 75% |
| Pb    | 16                   | 100% | 16 | 100% |
| Zn    | Nil                  | Nil | Nil           | Nil |

The maximum acceptable concentration results are of concern as lead is a poisonous metal that can damage nervous connections (especially in young children’s) and cause blood and brain disorders. One of the most important and serious biochemical effects of lead is its interference with haemo synthesis, which leads to hematological damage [34,35].

According to the maximum admissible limit (MAL) of drinking water by WHO and Yemeni Standards:
- The concentration of Pb was more than the MAL in the all wells water.
- More than 60 % contain Mn level were higher than the admissible limit.
37.5% and 68.75% contain copper level above WHO and YS, respectively.
Cd and Fe levels were exceeded WHO value (25% of samples analyzed).
12.5% of samples analyzed contain Cr level were higher than the MAL by WHO and Yemeni standards.
Levels of zinc in all of the studied samples were low the optimal specifications of local and WHO.

Recommendations

- The study recommends accelerating the study of the sewage networks project for the major city of Al-Dhalia, which is expected to be connected to the neighboring cities during the coming years, and to develop engineering designs in line with modern methods of wastewater treatment.
- Performing chemical analyzes of heavy elements periodically to identify the level of their accumulation in water, especially for drinking.
- Water is of great importance; therefore, continuous guidelines and instructions must be put in place to reduce its consumption, pay attention to the purity of drinking water and keep its sources away from the places of pollution.
- The municipality shall set up modern technical specifications for cesspits, preventing household wastewater from seeping into aquifers, and requiring cesspits to siphon the water of those pits into basins that are prepared to receive them at the new station site.
- The study recommends the concerned authorities (official and private) to avoid using excessive fertilizers and pesticides, especially in the areas near the wells.

References

[1] Momodu M.A., Anyakora C.A (2010). Heavy metal contamination of ground water: the Surulere case study. Res J Environ Earth Sci 2:39–43.
[2] Maravecchio J.E., Botte S.E., Freije R.H. (2007). Heavy metals, major metals, trace elements. Handbook of water analysis. CRC Press, London.
[3] Reza R, Singh G. (2010). Assessment of heavy metal contamination and its indexing approach for river water. Int J Environ Sci Tech 7(4):785–792.
[4] Adaikpoh E.O., Nwajei G.E., Ogala J.E. (2005). Heavy metals concentrations in coal and sediments from River Ekulu in Enugu, coal city of Nigeria. J ApplSci Environ Manag 9(3):5–8.
[5] Karbassi A.R., Amirnezhad R. (2004). Geochemistry of heavy metals and sedimentation rate in a bay adjacent to the Caspian Sea. Int J Environ Sci Tech 1(3):191–198.
[6] Reiners WA, Marks R.H., Vitousek P.M. (1975). Heavy metals in subalpine soils of New Hampshire. Oikos 26:264.
[7] Nouri J, Mahvi A.H, Jahed G.R, Babaei A.A. (2008). Regional distribution pattern of groundwater heavy metals resulting from agricultural activities. Environ Geo 55(6):1337–1343.
[8] Karbassi A.R, Monavari S.M, NabiBidhendi G,R, Nouri J, Nematpour K. (2008). Metal pollution assessment of sediment and water in the Shur River. Environ Monit Assess 147(13):107–116.
[9] Ammann A.A., Michalke B., Schramel P. (2002). Speciation of heavy metals in environmental water by ion chromatography coupled to ICP-MS. Anal BioanalChem 372(3):448–452.
[10] Hatje V., Bidone E.D., Maddock J.L. (1998). Estimation of the natural and anthropogenic components of heavy metal fluxes in fresh water Sinos river, Rio Grande do Sul state, South Brazil. Environ Tech 19(5):483–487.
[11] Al-Amry A. S., Habtoor A. and Qatan A. (2020). Hydrogeochemical characterization and environmental impact of fluoride contamination in groundwater from Al-Dhalia basin, Yemen, Electronic Journal of University of Aden for Basic and Applied Sciences (EJUA-BA), Vol. 1 No. 1:30-38.
[12] Baabad M. A. (2014). An analytical study of the environmental medium of the catha edulis (Forskal) in Al-Husain District, Al-Dhalia Gov., Master Thesis, Faculty of Aden, University of Aden, Yemen.
[13] The Comprehensive Directory of Al-Dhalia governorate: https://www.yemenna.com/index.php?go=guide&op=show&link=dalea
[14] APHA (1992). Standard methods for the examination of water and wastewater, 18th edition, American Public Health Association.
[15] WHO (2011). Guidelines for drinking water quality, Fourth edition. World Health Organization, Geneva. ISBN: 978 92 4 154815 1.
[16] YMWE (1999). Yemen’s Ministry of Water and Environment. Guidelines for drinking water quality. Sana’a, Republic of Yemen.
[17] Jamshaid M., Khan A.A., Ahmed K., Saleem M. (2018). Heavy metal in drinking water its effect on human health and its treatment techniques - a review, International Journal of Biosciences, 12 (4):223-240, http://dx.doi.org/10.12692/jib/12.4.223-240
[18] Nordberg G.F. (2004). Cadmium and health in the 21st century-historical remarks and trends for the future. BioMetals 17(5):485–489.

[19] Rajappa, B., Manjappa, S. & Puttaiah, E.T. (2010). Monitoring of heavy metal concentration in groundwater of Hakinaka Taluk, India. Contemporary Engineering Sciences, 3(4):183-190.

[20] Gebrekidan M. and Samuel Z. (2011). Concentration of Heavy Metals in Drinking Water from Urban Areas of the Tigray Region, Northern Ethiopia. MEJS. 3(1):105-121, ISSN:2220-184X

[21] Nassef, M., Hannigan, R., EL Sayed, K.A & Tahawy, M.S.E.I. (2006). Determination of some heavy metals in the environment of Sadat industrial city. Proceeding of the 2nd Environmental Physics Conference, Cairo University, Egypt, pp. 145-152.

[22] Saleh, Sh. M. K. and Alberkani, A. A. Assessment of metal contamination in deposited dust of the industrial area and some streets in Aden City, Yemen. J of Nat. and Appl. Sci, (in press).

[23] BarhianS. A. (2001). A study of the extent of pollution of some drinking water sources with heavy metals in Hadramout Governorate, Uni. of Aden J. of Nat. Applied Sci., 5 (2): 271-286.

[24] Joseph C., Eric Pearce, P. G., Jack W. (2018). Water Chemistry, Technical Learning Collage, Water Chemistry Copyright 1/1/2018©TLC (928) 468-0665.

[25] Jayana, B.L., Prasai, T., Singh, A. & Yami, K.D. (2009). Assessment of drinking water quality of madhyapur-thimi and study of antibiotic sensitivity against bacterial isolates. Nepal J of Sci and Tech, 10:167-172.

[26] Pandey, J., Shubhashish, K & Pandey, R. (2010). Heavy metal contamination of Ganga River at Varanasi in relation to atmospheric deposition. Tropical Ecology, 51(2):365-373.

[27] Hanaa, M., Eweida, A. & Farag, A. (2000). Heavy metals in drinking water and their environmental impact on human health. International Conference on Environmental Hazards Mitigation, Cairo University, Egypt, pp. 542-556.

[28] WHO (2004). Copper in Drinking water, Background document for development of WHO Guidelines for Drinking-water Quality, WHO/SDE/WSH/03.04/88 English only.

[29] ATSDR (2002). Toxicological profile for copper (draft for public comment). Atlanta, GA, US Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry (Subcontract No. ATSDR-205-1999-00024).

[30] Landner L., Lindestrom L. (1999). Copper in society and in the environment. Vasteras, Swedish Environmental Research Group (MFG) (SCDA S-721 88).

[31] US FDA (1994). Code of Federal Regulations. Vol. 21. Food and Drugs Part 182, Substances Generally Recognized as Safe, pp. 399–418, and Part 184, Direct Food Substances Affirmed as Generally Regarded as Safe, pp. 418–432. Rockville, MD, US Food and Drug Administration.

[32] Gowd S.S. and Govil P.K. (2008). Distribution of heavy metals in surface water of Ranipet industrial area in Tamil Nadu, India. Environ Monit Assess 136:197–207.

[33] Nadeem-ul-Haq, Arain M.A., Haque Z., Badar N., Mughal N. (2009). Drinking water contamination by chromium and lead in industrial lands of Karachi. J of Pakistan Medical Asso. 59(5), 270–274.

[34] Ehi-Eromosele C.O. and Okiei W.O (2012). Resources and Environment, 2(3):82-86 DOI :10.5923/j.re.20120203.01.

[35] Chaitali V. Mohod, Jayashree D. (2013). Review of heavy metals in drinking water and their effect on human health, Int J of Innovative Res in Sci, Engineering and Tech., 2(7): 2992-2996.
مقالة بحثية

تقرير الفحوات الثقيلة في المياه الجوفية لمناطق مختارة من مديرية الصالح، محافظة الضالع، الجمهورية اليمنية

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استلم في: 17 أبريل 2020 / قبل في: 18 سبتمبر 2020 / تنشر في: 30 سبتمبر 2020

الفحص

في هذا البحث تم دراسة مستوى تراکم بعض الفحوات الثقيلة الكادميوم (Cd)، الكروم (Cr)، الحديد (Fe)، المنغنيز (Mn)، النحاس (Cu)، الزنك (Zn)، الرصاص (Pb) في المياه الجوفية من مناطق مختارة في مديرية الضالع، محافظة الضالع. وذلك بجمع العينات من 16 بنرا شملت 9 من الآبار الارتوازية و 7 من الآبار المحفرة يدويًا، ومن ثم التحليل باستخدام جهاز طيف الامتصاص الذري. بينت نتائج التحليل ارتفاع تراکم عناصر الرصاص (Pb) والمنغنيز (Mn) والمنغنيز (Mn) والكروم (Cr) في معظم العينات، بينما تراکم عناصر الحديد (Fe) والكاربيوم (Cd) والزنك (Zn) لمياه الشرب، بينما تراکم عناصر الحديد (Fe) والكربيوم (Cd) والزنك (Zn) لمياه الشرب. الصحة العالمية (WHO) للظاهرة المدروسة كانت منخفضة وتفوق ضمن الحد الأدنى للمواصفات المحلية ومنظمة الصحة العالمية لفيض الشرب.

الكلمات الرئيسية: الفحوات الثقيلة، المياه الجوفية، محافظة الضالع، اليمن.