Voltammetry Determination Of Some Trace Elements In Tap Water Samples Of Jeddah Area In The Kingdom Of Saudi Arabia

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Abstract: The estimation of Pb, Cd, Cu, Zn, Fe, Se concentration in the tap water of Jeddah in Kingdom Of Saudi Arabia city was accomplished using electrochemical methods. The obtained results were lower than the average range of these elements in the maximum concentration as they were allowed to be by The World Health Organization (WHO). [Journal of American Science 2010;6(10):1026-1032]. (ISSN: 1545-1003).

Keywords: tap water; voltammetry; Saudi; trace elements.

1. Introduction

Electrochemical methods, especially anodic stripping voltammetry (ASV), are still recognized as the most convenient techniques for measuring trace heavy metals in various samples of environmental clinical and industrial origin contaminated water samples. Due to the capability of pre-concentrating analysis at/in the surface of the working electrode, ASV allows quantification of heavy metals down to a microgram or even nanogram per liter concentration level (Guzsvány et al., 2010 and Sonthalia et al., 2004).

A simple, fast and sensitive method has been developed for environmental water analysis using differential pulse stripping voltammetry (DPSV) performed on a hanging mercury drop electrode (HMDE) (Demetriades et al., 2004 and He Y et al., 2007).

Cadmium is a toxic and carcinogenic metal. The primary sources of cadmium exposure are cigarette smoke, food intake (shellfish, offal and certain vegetables), and ambient air, particularly in urban areas and in the vicinity of industrial settings, (Zhang et al., 2009). Inorganic lead is certainly the most extensively studied of all toxic agents. Toxic effects may occur in the central and peripheral nervous systems, blood, kidney, and cardiovascular, endocrine and immune systems, gastrointestinal tract, and male reproduction. Lead causes increase of blood pressure, (Skerfving and Bergdahl 2007 and Dragoe et al., 2006). Copper is a vital and toxic for many biological systems, so that its determination in water samples is warranted by the narrow window of concentration between essentiality and toxicity. It can be easily released from silicates, sulfites and oxides after some physical and chemical weathering and then transferred by water into soil and sediments (Faraji et al., 2009). Epidemiologic studies and case reports have shown that chronic exposure to selenium compounds is associated with several adverse health effects in humans. An early toxic effect of selenium is on endocrine function, and on the metabolism of growth hormone and insulin-like growth factor-1 (Vinceti et al., 2001). Polyvinyl chloride and iron pipe materials differentially impacted manganese deposition within a drinking water distribution system that experiences black water problems because it receives soluble manganese from a surface water reservoir that undergoes biogeochemical cycling of manganese, (Cerrato et al., 2006 and Lieu et al., 2001). Zinc (Zn) is environmentally ubiquitous and essential for life; one estimate suggests 20% of the world's population is at risk of Zn deficiency. Manifestations include abortion, teratology, prematurity, retarded growth and development, low immunity, poor healing, dermatitis, low physical work capacity, abnormal neuropsychological functions, and other abnormalities (Harold et al., 2007).

In this research, the estimation of Pb, Cd, Cu, Zn, Fe, Se concentrations in the tap water of Jeddah city in Kingdom Of Saudi Arabia were accomplished using voltammetry techniques.

2. Materials and methods

Gathering samples

Tap water samples were chosen from the tap water of Jeddah city for one-year. The northern districts of the city of Jeddah (Al- Bawadi, Al-Safa, Al-Zahra,Al-Hamra, Al-Rawda, Al-nwzha, Al-Rabwa, Al-Faisalia, Al-Basatin, Al-Marwa) The media districts of the city of Jeddah (Al-Bagdadia, Al-shargia**,** Al-Bagdadia Al-garbia, Al-rehap, Al-rhwise**,** Al-azizia, Al-kandra, Al-swhifa**,** Al-matar

algadim, Bani malik, Al-shrafia). The south districts of the city of Jeddah (Albalad, Alsabil, Alhindawih, Alkacikia, Madain Al-fahad, Alnwzla aliamania, Aleskan aljanobi,Algoraiat,Goizah,Hart almazlum).

The apparatus used in the study

The concentration of trace elements were measured by Polargraph instrumental 746 VA trace analyzer with 747 VA stand or from Metrohm company.

Sample preparation

Immediately, upon taking the water sample, filter it through a micro-filter (0.45µm). The filtrates and filters with residues are treated separately. Acidify the filtrates, per litre, with 1 ml conc. HNO3. The pH value of the acidified filtrates should lie between 1.7 and 2.0. If not, more acid must be added.

Organic matter often interferes with voltammetric determinations and therefore, sample solutions usually have to be digested (Van den Berg , 1984).

Voltammetric determination of zinc, cadmium, lead and copper

The concentration is determined by standard addition Zn, Cd, Pb, Cu are determined on the HMDE by anodic stripping voltammetry (ASV).

Reagents

All the used reagents must be of the purest quality possible (analytical grade).
Only ultrapure water should be used.
Sodium hydroxide solution, w (NaOH)=30 %
Acetic acid, w (CH3COOH) = 100 % KCl,
Standard solutions:
(Zn^{2+}) = 10 mg/L
(Cd^{2+}) = 0.1 mg/L
(Pb^{2+}) = 0.5 mg/L
(Cu^{2+}) = 2.5 mg/L
Diluted solutions are prepared using [HNO3] = 0.014 mol/L.

Analysis

Measuring solution:
10 mL (diluted) sample +1 mL KCl-sodium acetate solution, the pH of the solution should to 4.6 ± 0.2. The voltammogram is recorded with the following parameters:
Working electrode HMDE
Drop Size 4
Stirrer/RDE 2000 rpm
Measurement mode DP
Purge time 300 s
Pulse amplitude 0.05 V
Deposition potential - 1.15 V
Deposition time 90 s
Equilibration time 10 s
Start potential - 1.15 V
End potential 0.05 V
Voltage step 0.006 V
Voltage step time 0.1 s
Sweep rate 0.06 V/s
Peak potential (Zn) - 0.98 V
Peak potential (Cd) - 0.56 V
Peak potential (Pb) - 0.38 V
Peak potential (Cu) - 0.10 V

Voltammetric determination of selenium

Cathodic Stripping voltammetry (CSV) enables selenium to be determined in mass down to
(Se(IV)) = concentrations 0.3 µg/L.

Reagents

All of the used reagents must be of purest quality possible (p.a.). Only high purity water should be used.
- Sulphuric acid,w(H_2SO4) = 96%
- Nitric acid, w(HNO_3) = 65%
- Sodium hydroxide solution, w(NaOH) = 30%
- Ammonium sulphate
- Na_2EDTA dihydrate,
- Cu standard stock solution: (Cu) = 1.0 g/L
- Se standard stock solution: (Se(IV)) = 1.0 g/L.

Analysis of Se

Measuring solution:
10 mL (diluted) sample or digestion solution
+ 3.3 g ammonium sulphate
+ 1 mL EDTA solution
+ 1 mL Cu solution
Adjust the pH value of the solution with sulphuric acid to pH 2.2 ± 0.1, allow to cool.
The voltammogram is recorded with the following parameters:
working electrode HMDE
stirrer speed 2000 rpm
drop size 4
mode DP
purge time 300 s
deposition potential -0.4 V
deposition time 90 s
equilibration time 10 s
pulse amplitude 0.08 V
start potential -0.45 V
end potential -0.85 V
voltage step 0.004 V
voltage step time 0.1 s
sweep rate 0.04 V/s
peak potential Se -0.65 V(Papoff et al.,1998)

Adsorptive stripping voltammetry method for determination of Iron

Theory

Triethanolamine forms a complex with iron; the formation of this complex prevents the precipitation of iron in the alkaline electrolyte used. The signal obtained during the measurement shows the reduction of iron (III) to iron (II). $Fe^{3+} + e^{-} \rightarrow Fe^{2+}$ The potassium bromate contained in the supporting electrolyte then oxidizes Fe2+ back to Fe3+, which means that it is again available for reduction. In this way, a much higher iron concentration is simulated than is actually present. This catalytic enhancement leads to considerably larger signals. As this method is a direct voltammetric determination and not an adsorptive stripping voltammetry method, increasing the sensitivity by deposition of Fe triethanolamine complex and subsequent stripping is impossible.

Reagents

- Sodium hydroxide, w(NaOH) = 30%,
- Triethanolamine. w(C6H15NO3) 98%
- Potassium bromate . $KBrO_3$
- Fe3+ standard stock solution, β(Fe3+) = 1 g/L
- Ultrapure water type 1

(electrical resistivity > 18.2 MΩ·cm, TOC < 10 ppb)

- Nitric acid, w(HNO3) = 65%
- Citric acid anhydrous, w(C6H8O7) = 99.5%,

Voltammetric parameters

Working electrode HMDE
Stirrer speed (rpm) 2000
Mode DP
Purge time 300 s
Equilibration time 5 s
Pulse amplitude 0.05 V
Start potential -0.75 V
End potential -1.2 V
Voltage step 0.006 V
Voltage step time 0.5 s
Sweep rate 0.012 V/s
Peak potential Fe(total) -0.96 V.

Determination

Measuring solution

10 mL sample
+ 2 mL supporting electrolyte
pH = 12.3(Henze and Neeb,1986).

3. Results and discussion

Anodic stripping voltammetry (ASV) is an established method for trace metal ion analysis in contaminated water samples (Sonthalia et al.,2004).

A simple, fast and sensitive method has been developed for environmental water analysis by using differential pulse stripping voltammetry (DPSV) performed on a hanging mercury drop electrode (HMDE) (Yi He et al., 2007).

The estimation of Pb, Cd, Cu ,Zn ,Fe, Se concentrations in the tap water of Jeddah city in Kingdom Of Saudi Arabia was accomplished using voltammetry techniques. It is clear from Figure 1. Voltammogram of trace elements (Cu, Pb, Cd, Zn) in Tap water (voltage(V) with the current(A)), that the highest concentration is of Zn element in all Tap water that is under the study , then Cu element concentration then Pb element concentration and finally Cd .

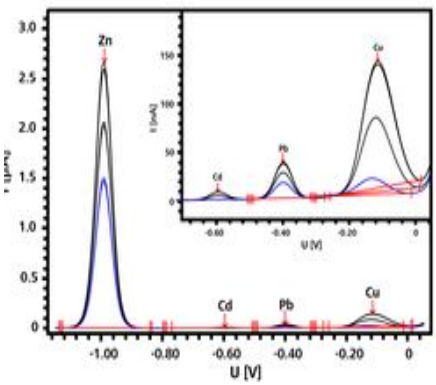

Figure 1. Voltammogram of the trace elements (Cu,Pb,Cd,Zn) in Tap water.

Also, it is shown from Figure 2.that, Voltammogram of Fe element in Tap water that Peak at potential of Fe (total) is = -0.96 V, while Figure 3. clear Plot of concentration (g/l) and current (A) Fe element in Tap water .

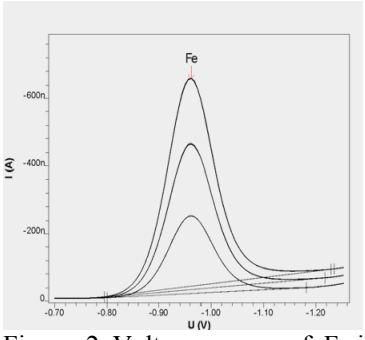

Figure 2. Voltammogram of Fe in Tap water.

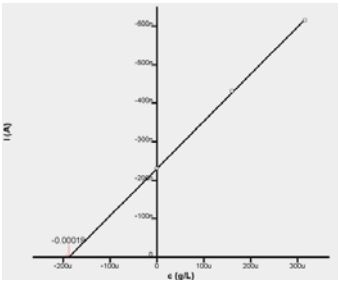

Figure 3. Plot of concentration and current Fe element in Tap water.

Figure 4. Voltammogram of Se element in Tap water, shows that peak potential of Se = -0.65 V , and Figure 5. Plot of concentration (µ/l) and current (nA) Se element in Tap water.

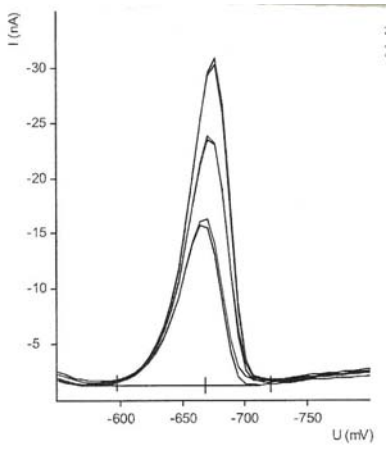

Figure 4. Voltammogram of Se element

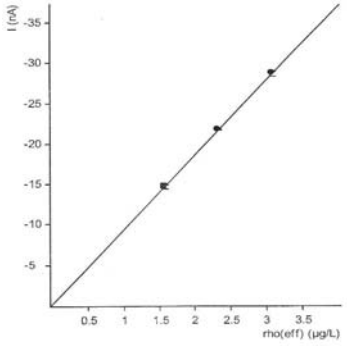

Figure 5. Plot of concentration (µ/l) and current (nA) Se element in Tap water.

Table1. Concentrations of essential trace elements in northern of Jeddah

Dist.	Concentrations of trace elements in ppm ± S.D.		
	Fe	Cu	Zn
Al-Basatin	0.007± 0.0041	0.0301± 0.0044	0.065±0 .0633
Al-nwzha	0.010± 0.0042	0.0311± 0.0043	0.018±0 .0632
Al- Bawadi	0.017± 0.0040	0.0321± 0.0041	0.0456± 0.0631
Al-Faisalia	0.008± 0.0038	0.0324± 0.0040	0.1411± 0.0629
Al-Rabwa	0.009± 0.0037	0.0357± 0.0042	0.1235± 0.0628
Al-Marwa	0.001± 0.0039	0.0368± 0.0045	0.1365± 0.0627
Al-Hamra	0.011± 0.0035	0.0387± 0.0046	0.1536± 0.0626
Al-Rawda	0.010± 0.0034	0.0398± 0.0043	0.1687± 0.0623
Al-Zahra	0.012± 0.0033	0.0411± 0.0041	0.1869± 0.0622
Al- Safa	0.013± 0.0032	0.0423± 0.0047	0.2134± 0.0621

Table (1) shows that the concentration of essential elements which is under studies in the Tap water for the chosen the northern districts of the city of Jeddah. They have been analyzed using SPSS program, at significant ($p<0.01$).

The highest concentration was found with Fe noticed from the table is (0.017ppm) in Al- Bawadi district Taps water, while Al-Marwa district has the lower concentration it reached (0.001ppm); the order is:

Al- Bawadi > Al- Safa >Al-Zahra > Al-Hamra > Al-Rawda and Al-nwzha >Al-Rabwa>Al-Faisalia > Al-Basatin >Al-Marwa.

Also the study showed that the highest concentration Cu was in Al- safa Tap water (0.0423ppm) then lowest is in Al-Basatin Tap water (0.0301ppm).

The study approved that the highest concentration of Zn was (0.2134ppm) in Al- safa Tap water then Finally Al-nwzha Taps water where the concentration reached to (0.018ppm).

Table 2. Concentrations of toxic trace elements in northern of Jeddah

Dist.	Concentrations of trace elements in ppm ± S.D.		
	Se	Pb	Cd
Al-Basatin	0.0011± 0.0018	0.022±0 .00623	0.0031± 0.00076
Al-nwzha	0.0016± 0.0017	0.023±0 .00638	0.0026± 0.00075
Al-Bawadi	0.0066± 0.0016	0.0241± 0.0069	0.0028± 0.00073
Al-Faisalia	0.0045± 0.0015	0.0252± 0.0068	0.0029± 0.00072
Al-Rabwa	0.0056± 0.0014	0.0261± 0.0066	0.0012± 0.00077
Al-Marwa	0.0023± 0.0013	0.0273± 0.0067	0.0014± 0.00066
Al-Hamra	0.0032± 0.0012	0.0321± 0.0065	0.0011± 0.00056
Al-Rawda	0.0021± 0.0011	0.0353± 0.0061	0.0022± 0.00046
Al-Zahra	0.0022± 0.0010	0.0376± 0.0064	0.0021± 0.00036
Al- Safa	0.0023± 0.0013	0.0389± 0.0063	0.0013± 0.00082

Table 2. Shows, the concentrations of toxic trace elements in northern of Jeddah. The study approved that the highest concentration of Se was found in Al- Bawadi Taps water, which reached (0.0066ppm), while in Al-Basatin Tap water was the last and , reached (0.0011ppm).

The study approved that, the highest concentration of Pb was (0.0389ppm) in Al- safa Taps water then Al-Zahra Taps water (0.0376ppm), then Al-Rawda Taps water reached to (0.0353ppm) after that Al-Hamra Taps water reached to (0.0321ppm), then Al-Marwa Taps water reached to (0.0273ppm). Finally, Al-Basatin Taps water where the concentration reached to (0.022ppm).

The highest concentration was found with Cd noticed from the table is (0.0031ppm) in Al-Basatin district Tap water, while Al-Hamra district has the lower concentration it reached (0.0011ppm).

1.Al-Bagdadia Al-shargia**. 2**. Al-Bagdadia Al-garbia **3**. Al-rehap. **4**.Al-rhwise**. 5**.Al-azizia. **6**.Al-kandra. **7**.Al-swhifa**.8**.Al-matar algadim. **9**.Bani malik. **10**.Al-shrafia.

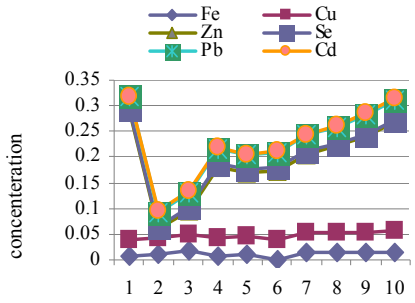

Figure 6. Concentrations of trace elements in Tap water in media of Jeddah Dist.

Figure 6. clarified the differences between Trace's element concentration in Tap water in media of Jeddah. So that it can be seen in:

1. Al-Bagdadia Al-shargia Taps water, the concentration of Fe element is found (0.0071ppm) where the concentration of Cu element reached to (0.0302ppm). Zn reached (0.2541ppm), following that Se element it reached (0.0022ppm). Pb reached to (0.0231ppm), following that, Cd element where it reached (0.0032ppm).
2. Al-Bagdadia Al-garbia Taps water concerning Fe ; it was (0.0110ppm) following that Se within (0.0018ppm) after that Zn within (0.0181ppm) then Pb within (0.0312ppm) after that Cu with in (0.0313ppm) following Cd within (0.0036ppm).
3. Al-rehap Taps water; in that the concentration Fe was within (0.0172ppm),while it was in concentration Pb element within (0.0301ppm).
4. Al-rhwise Taps water; it was the lowest concentration Cd element within (0.0039ppm), and the highest concentration Zn within (0.1412ppm).
5. Al-azizia Taps water concerning Fe within (0.0093ppm) and Pb concentration reached to (0.0278ppm) while the lowest concentration was in Cd element where it reached to (0.0022ppm) and the highest concentration was Zn element within (0.1238ppm).
6. Al-kandra Taps water; was the concentration of Fe element within (0.0012ppm), and the highest concentration of Zn within (0.1368ppm).
7. Al-swhifa Taps water; in that the highest concentration Zn was within (0.1538ppm) ,and it was lower in concentration Cd element within (0.0021ppm).
8. Al-matar algadim Taps water concerning Fe within (0.0130ppm) and Pb concentration reached to (0.0327ppm) while the lowest concentration was in Cd element where it reached to (0.0022ppm) and the

highest concentration was Zn element within (0.1689ppm).

9. Bani malik Taps water concerning Cd; it was the lowest concentration within (0.0023ppm) following that Se within (0.0032ppm) after that Fe within (0.0124ppm) Then Pb within (0.0376ppm) after that Cu with in (0.0413ppm) following that Zn within (0.1879ppm).

10. Al-shrafia Taps water; in that the highest concentration Zn was within (0.2144ppm) ,and it was lower in concentration Cd element within (0.0024ppm).

Table 3. Concentrations of essential trace elements in Tap water of south of Jeddah

Dist.	Concentrations of trace elements in ppm ± S.D.		
	Fe	Cu	Zn
Albalad	0.0072± 0.0044	0.0312± 0.1080	0.2542± 0.0713
Alsabil	0.0114± 0.0043	0.0323± 0.1070	0.0182± 0.0711
Alhindawiah	0.0175± 0.0042	0.0334± 0.1060	0.0459± 0.0712
Alkacikia	0.0086± 0.0039	0.0335± 0.1071	0.1414± 0.0709
Madain Al-fahad	0.0096± 0.0038	0.0369± 0.1076	0.1239± 0.0708
Alnwzla aliamania	0.0013± 0.0041	0.0368± 0.1079	0.1368± 0.0707
Aleskan aljanobi	0.0170± 0.0038	0.0378± 0.1075	0.1539± 0.0711
Algoraiat	0.0130± 0.0036	0.0500± 0.1074	0.1711± 0.0711
Goizah	0.0126± 0.0037	0.0423± 0.1077	0.1889± 0.0709
Hart almazlum	0.0138± 0.0039	0.0424± 0.1078	0.2145± 0.0712

Table 3.showed concenterations of essential trace elements in Tap water of south of Jeddah . The study approved that the highest concentration of Fe was (0.0175ppm) in Alhindawiah Tap water. also showed that the highest concentration of Cu was (0.0500ppm) in Algoraiat Tap water. The highest concentration was found with Zn noticed from the table is (0.2542ppm) in Albalad district Tap water.

Table 4. Concentrations of toxic trace elements in Tap water of south of Jeddah

Dist.	Concentrations of trace elements in ppm ± S.D.		
	Se	Pb	Cd
Albalad	0.0025± 0.0015	0.0232± 0.0047	0.0042± 0.0011
Alsabil	0.0019± 0.0015	0.0313± 0.0048	0.0046± 0.0010
Alhindawiah	0.0069± 0.0016	0.0302± 0.0046	0.0040± 0.0010
Alkacikia	0.0046± 0.0015	0.0299± 0.0047	0.0049± 0.0011
Madain Al-fahad	0.0068± 0.0016	0.0288± 0.0048	0.0023± 0.0009
Alnwzla aliamania	0.0046± 0.0015	0.0289± 0.0047	0.0019± 0.0006
Aleskan aljanobi	0.0045± 0.0016	0.0317± 0.0048	0.0022± 0.0008
Algoraiat	0.0036± 0.0015	0.0329± 0.0047	0.0023± 0.0009
Goizah	0.0036± 0.0016	0.0379± 0.0046	0.0024± 0.0011
Hart almazlum	0.0044± 0.0014	0.0399± 0.0045	0.0025± 0.0008

Table 4 studies concentrations of toxic trace elements in Tap water of south of Jeddah

The study showed that the highest concentration Se was (0.0069ppm) in Alhindawiah Tap water.

The study approved that the highest concentration of Pb was (0.0399ppm) in Hart almazlum Tap water.

The highest concentration was found with Cd noticed from the table is (0.0049ppm) in Alkacikia district Tap water.

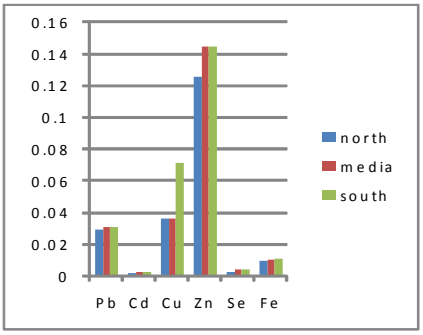

Figure 7. Mean concentration of trace elements in Tap water of Jeddah

Also it is clarified from the Figure 7. mean concentration of trace elements in Tap water of Jeddah dist

1. South Jeddah Taps water, the highest mean concentration Pb element is found, that it reached to (0.0314ppm) .
2. North Jeddah Taps water concerning Cd; it was the lowest mean concentration within (0.0020ppm).
3. South Jeddah Taps water; in that the highest mean concentration Cu was within (0.0717ppm) ,and it was lower in mean concentration Zn element within (0.0301ppm) in north Jeddah Tap water.
4. South Jeddah Tap water, the highest mean concentration Se element is found, that it reached to (0.0043ppm), also the highest mean concentration Fe element is found in South Jeddah Tap water, which it reached to (0.0112ppm).

The obtained results were lower than the average range of these elements in the maximum concentration as they were allowed to be by The World Health Organization (WHO).

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