Determination of Trace Lead and Cadmium in Canned Soft Drinks in Syria

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Introduction: Soft drinks are highly consumed in Syria due to their preferable taste, advertisement, and lack of awareness about their harmful effects on the human body. Heavy-metal contamination is one of the top problems associated with the soft drinks industry. In this study, the levels of heavy metals (lead [Pb] and cadmium [Cd]) in carbonated and noncarbonated canned soft drinks in the Syrian market were investigated. The leaching of Pb and Cd in canned drinks was also investigated under different storage conditions.

Materials and Methods: Soft drink samples were collected from the Damascus market. The samples were prepared using microwave digestion. All samples were analyzed using the developed and validated atomic absorption spectroscopy (AAS) method.

Results and Discussion: All studied samples at all stages of the study were free of Cd. The mean concentration of Pb ranged between 13.76 and 42.12 ppb. Our results showed that the levels of Cd and Pb were in the allowed limits according to Syrian Specification (1992/47) and the Food and Drug Administration (FDA) limits. There is no leaching of Pb and Cd in all studied samples under different storage conditions over 1 year of study.

Conclusion: The results of this study showed that all samples are following good manufacturing procedure (GMP) and safe to be consumed by costumers.

Keywords: Cadmium, heavy metals, lead, soft drink, Syria

INTRODUCTION

Soft drinks can be described as nonalcoholic, sweetened, low-pH, water-based, often flavorful, colorful, and containing a quantity of fruit juice, fruit pulp, or other natural ingredients. These drinks are usually kept in metal cans, glass bottles, or tetra pack carton containers.[1,2] They are highly consumed due to their hydration effect, taste, and providing the body with the necessary amount of sugar and essential salts.[3] However, consuming high amounts of soft drinks could have adverse impacts on human health starting with increase the chance of tooth decay to obesity and metabolomic disease such as diabetics. Another adverse effect of soft drink consumption is the high possibility of consumer exposure to heavy-metal contamination. High levels of toxic heavy metals have been reported in soft drinks.[4-10] The sources of heavy metals in soft drinks include fruits, water, sweeteners, flavor agents, coloring dyes, or manufacturing procedures. Toxic heavy metals such as lead (Pb) and cadmium (Cd) have serious harmful effects on the human body. Pb is a well-known toxic metal causing acute and chronic toxicity by affecting the central nervous, hematopoietic, hepatic, and renal system producing serious disorders.[11] The main mechanism of Pb toxicity is the ability of Pb to deactivate antioxidant enzymes (especially those containing sulfhydryl groups), which cause an oxidative stress due to the inability of the body to readily detoxify the reactive intermediates or to repair the resulting damage.[12] In 2010, the Food and Drug Administration (FDA) confirmed that the presence of Pb in juices in percentage more than 50 ppb leads to serious health effects.

Access this article online

Quick Response Code:

Website: www.jspbsonline.org

DOI: 10.4103/jpbs.JPBS_357_19

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How to cite this article: Alkhatib R, Ataie M. Determination of trace lead and cadmium in canned soft drinks in Syria. J Pharm Bioall Sci 2020;12:344-50.
problems, so this value shall not be exceeded,[13] whereas the value of Pb should not exceed 0.025/kg body weight according to Syrian standards.[14]

Continuous exposure to Cd affects the kidney and could progress clinical renal complications, which may lead to renal failure. Cd toxicity is mainly due to its ability to replace other essential ions such as zinc, magnesium, and calcium in human enzymes leading to inactivation of these enzymes.[15] No safe value of Cd was recommended by the Syrian standard[14] or FDA[13] which means the soft drinks should be free of Cd, whereas the permissible value of Cd in soft drinks in the UK was 1 ppb.[16]

In Syria, soft drinks are highly consumed by all community components especially children.[17] Although many studies have shown that Middle East Area including Syria has high pollution with heavy metals including soil,[18,19] fruits,[20] water,[21-23] air,[24] and the Mediterranean Sea,[25] there are no studies showing the levels of heavy metals in the Syrian-marketed soft drinks. Thus, the aims of this study were to evaluate the concentrations of Pb and Cd in soft drinks available in the Syrian market and to compare their levels with the permitted levels published by regulatory authorities and other available studies in Middle East Area. For this purpose, a new accurate graphite furnace atomic absorption spectroscopy (GFAAS) method coupled to microwave digestion method was used.

MATERIALS AND METHODS

Carbonated and noncarbonated soft drink samples were collected from Damascus’s local market. To avoid the variation in sample storage conditions before metal analysis, all samples were chosen with less than 1-week manufacturing date. A total of 249 samples were collected containing different types of fruits, namely orange, apple, pineapple, mango, strawberry, cola, and red grapes as they are highly consumed. Two sources of samples were considered, which are local and nonlocal manufacturers. Table 1 shows the cods given to all types of samples in this study.

All glasswares used in this study were of Grade A including volumetric flasks, beakers, and measuring cylinders. Glasswares were soaked in 5% nitric acid for 3h followed by washing with deionized water, then dried before use.

Sample preparation

To obtain the highest recovery of trace elements, two methods of sample digestion were applied and compared in terms of recovery and repeatability. Those methods are microwave digestion and wet digestion methods.

Three samples of noncarbonated drinks R1, R2, and R3, and three samples of carbonated drinks M1, M2, and M3 were used for the comparison of the study. Pb 10 µg/L was added to each sample, then the digestion method was applied and the obtained samples were analyzed and the recovery of each metal was calculated and compared using \( t \) test.

For microwave digestion method, sample preparation was carried out using microwave digestion system (Multiwave 3000, Anton Paar, Graz, Austria). 5 g of each samples were weighted carefully and transferred into polytetrafluoroethylene (PTFE) vessels, and a mixture of 3 mL of nitric acid 65% and 2 mL of H\(_2\)O\(_2\) 30% was added. The thermal program applied for sample digestion is presented in Table 2.

In the wet digestion method, a mixture of 65% nitric acid and 30% oxygen water (2:1) was used as a digestion solution. 5 mL of digestion solution was added to 5 g of each sample and placed in a digestion vessel under a fume hood. The mixture was heated up to 130°C for 5h until the digestion was completed.

Following completion of the digestion, the samples were left closed for 2h until complete cooling to room temperature. The entire content of each vessel was

| Taste | Noncarbonated drinks | Carbonated drinks |
|-------|-----------------------|-------------------|
| Local company | Nonlocal company | Local company | Nonlocal company |
| Red grape | GA | GB | – | – |
| Mango | MA | MB | – | – |
| Pineapple | PA | PB | – | – |
| Orange | OA | OB | OY | OZ |
| Apple | AA | AB | AY | AZ |
| Strawberry | – | – | SY | SZ |
| Cola | – | – | CY | CZ |
| Sugar free cola | – | – | DY | DZ |
filtered and transferred into a 25-mL volumetric flask and the volume was brought up to the mark using deionized water.

An adequate detection method of trace elemental analysis with its corresponding sample digestion/preparation is highly required for such study. Therefore, our study has been designed to develop, optimize, and validate a comprehensive process of analysis for determining toxic metals, namely Cd and Pb in soft drinks. Elemental analysis was performed using AAS (Model Zeenit 700p, Analytik Jena, Germany). Cd and Pb quantifications were performed by GFAAS. GFAAS conditions were studied and optimized for the highest recovery of Cd and Pb, as shown in Table 3.

Primary stock standard solutions for each metal Cd and Pb with a concentration of 1000 ppb were prepared by weighing 1 g of metal standard (1000 ppm) into a 1-L volumetric flask and diluting it to the mark by deionized water. This stock solution was used for the preparation of standard solutions for calibration purposes by serial v/v dilution with deionized water.

Method development and validation were studied using different analytical parameters such as limit of detection (LOD), limit of quantification (LOQ), linearity (coefficient of correlation), recovery, and precision.[26]

**Limit of detection and limit of quantification**

LOD is the lowest concentration of analyte that can be detected and distinguished from the blank. The LOQ is the lowest concentration that can be detected with a suitable level of accuracy and precision.

**Linearity**

Linearity of an analytical method is the capability of the technique to obtain results that are directly proportional to the concentration of analyte in the sample (within the range). The calibration range was studied for low standard concentration in accordance with the aim of this study to detect trace concentrations of toxic metals. The criteria for the standard curve are the coefficient of correlation, which should be more than 0.990. In this study, calibration curve was initiated before each analysis of each element to check the linearity of the method.

**Accuracy**

The accuracy of measurement is the level of closeness with the actual value. Accuracy of the method was checked by measuring the recovery of two spiked Quality Control (QC) standard solutions in various concentrations prepared within the analytical working range for each element.

The preparations were performed by serial v/v dilution from the primary stock standards of 1000 ppm for each element. The recovery percentages of the QC standards were calculated as follows:

$$\% \text{ Recovery} = \left( \frac{\text{measured value}}{\text{prepared value}} \right) \times 100. \quad \text{(Equation 1)}$$

**Precision**

The precision of measurement system or reproducibility is the degrees of variation of repeated measurements under unchanged conditions. The precision of the results was indicated from the values of standard deviation (SD) and relative standard deviation (RSD) of the QC measurements.[26] RSD is measured using the following equation:

$$\% \text{ RSD} = \left( \frac{\text{SD}}{\text{mean}} \right) \times 100. \quad \text{(Equation 2)}$$

**RESULTS**

**Digestion method optimization**

Table 4 shows the recovery and repeatability results of both digestion methods.

Recovery percentages of Pb for wet digestion and microwave digestion were varied between 101.20%–104.28% and 98.70%–101.28%, respectively. Statistically the application of Student’s $t$ test indicated that there were no significant differences between the recovery results for both methods of all elements for wet digestion on a hot plate and microwave digestion at a 95% confidence level. However, lesser SD was observed by the microwave digestion method showing significantly higher repeatability. In addition, microwave digestion is

| Table 2: Microwave thermal program |
|-----------------------------------|
| **Step** | 1 | 2 | 3 |
| Temperature (°C) | 160 | 190 | – |
| Ramp (min) | 10 | 10 | |
| Hold (s) | 10 | 20 | 15 |

| Table 3: Graphite furnace atomic absorption spectrometry conditions |
|---------------------------------------------------------------|
| **Metal** | **Wavelength (nm)** | **Ashing temperature (°C)** | **Atomization temperature (°C)** |
| Pb | 283.3 | 900 | 1500 |
| Cd | 228.8 | 800 | 1300 |

Pb = lead, Cd = cadmium
a time-saver method as compared to the wet method. Therefore, the microwave digestion method was applied for entire sample preparation in our study.

**Development and validation of atomic absorption spectroscopy analytical method**

To obtain accurate results, the method of analysis of both elements was developed and validated for the low standard range. The sensitivity of the method was optimized to detect and quantify very low concentrations of Pb and Cd. Therefore, the LOD was 0.43 and 0.147 ppb for Pb and Cd, respectively, whereas the LOQ was 1.29 and 0.44 ppb for Pb and Cd, respectively. With such low LOQ, the linear range for Pb was set to the range of 0.5–45 ppb for Pb and 0.1–5 ppb for Cd. Figure 1A and B shows the linear standard curve for Pb and Cd, respectively.

Both metals showed an excellent coefficient of determinations using GFAAS and low values of LOD and LOQ which showed the sensitivity of the method. Table 5 summarizes the typical parameters of the calibration curve such as linear ranges, $R^2$ coefficient of determination, standard concentration, and absorbance for Cd and Pb measured by the developed GFAAS methods.

**Accuracy and precision**

Accuracy was studied by the recovery calculation of three QC samples, whereas precision was measured by calculating the RSD% value for repeated measurement of QC samples. The results are presented in Table 6.

The results obtained for Cd and Pb analysis by GFAAS in QC samples showed excellent levels of accuracy and precision within the acceptable requirements specified by International Council for Harmonization (ICH) guidelines.[26]

The developed methods were used for the analysis of Pb and Cd in carbonated and noncarbonated soft drinks in the Syrian market and the leaching of both metals in canned soft drinks under different storage conditions. The results showed the absence of Cd in all studied samples, which are in accordance with Syrian and World health regulations. However, Pb was found in all studied samples in concentrations that ranged between 13.76 and 42.12 ppb. Pb concentrations are presented in Table 7.

Heavy-metal leaching in canned soft drinks was studied over 1 year under two different storage conditions. Cd did not appear in all studied samples under both storage conditions, whereas Pb was presented in all studied samples. Table 8 shows the levels of Pb in studied samples over the study period.

**DISCUSSION**

Sample preparation technique has a vital role in the analysis of heavy metals due to the importance of cleanup and good recovery. In our study, we compared

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**Table 4: Recovery and repeatability results of both digestion methods**

| Sample | Added value (µg/L) | Measured conc. (µg/L) (±SD) | %R | RSD | %R | RSD |
|--------|-------------------|-----------------------------|----|-----|----|-----|
| R1     | 10                | 10.03 (+0.08)               | 100.34 | 0.79 | 10.42 (+0.11) | 104.24 | 1.06 |
| R2     | 10                | 9.89 (+0.09)                | 98.92 | 0.91 | 10.43 (+0.12) | 104.27 | 1.18 |
| R3     | 10                | 9.87 (+0.08)                | 98.70 | 0.85 | 10.43 (+0.11) | 104.28 | 1.08 |
| M1     | 10                | 10.13 (+0.09)               | 101.28 | 0.89 | 10.23 (+0.10) | 102.28 | 1.02 |
| M2     | 10                | 9.97 (+0.07)                | 99.70 | 0.74 | 10.22 (+0.11) | 102.17 | 1.12 |
| M3     | 10                | 10.06 (+0.08)               | 100.56 | 0.84 | 10.12 (+0.12) | 101.20 | 1.17 |

SD = standard deviation, RSD = relative standard deviation
two methods that are the wet digestion method and the microwave digestion method. We found that the microwave method is faster, safer, and better in terms of recovery and repeatability. Many methods have been used for sample preparation including dry ashing method,[7,27] wet digestion method,[5] and microwave digestion method.

### Table 5: Linear ranges, \( R^2 \), standard concentration and absorbance for cadmium and lead measured by graphite furnace atomic absorption spectrometry

| Metal | Standard concentration (µg/L) | Absorbance   | Coefficient of determination \( (R^2) \) |
|-------|-----------------------------|--------------|---------------------------------|
| Cd    | 0.1                         | 0.0094       | 0.997                           |
|       | 0.5                         | 0.0453       |                                 |
|       | 1                           | 0.1113       |                                 |
|       | 2                           | 0.2463       |                                 |
|       | 4                           | 0.4381       |                                 |
|       | 5                           | 0.5151       |                                 |
| Pb    | 0.5                         | 0.00329      | 0.999                           |
|       | 2                           | 0.0131       |                                 |
|       | 5                           | 0.0237       |                                 |
|       | 15                          | 0.0424       |                                 |
|       | 30                          | 0.0834       |                                 |
|       | 45                          | 0.113        |                                 |

Pb = lead, Cd = cadmium

### Table 6: Accuracy and precision results

| Metal | Sample ID | Prepared conc. (µg/L) | Measured conc. (µg/L) (±SD) | % Recovery | % Precision |
|-------|-----------|-----------------------|-----------------------------|------------|-------------|
| Pb    | QC 1      | 5                     | 4.99 (±0.04)                | 99.92      | 0.76        |
|       | QC 2      | 10                    | 9.87 (±0.08)                | 98.70      | 0.81        |
|       | QC 3      | 30                    | 30.06 (±0.25)               | 100.2      | 0.83        |
| Cd    | QC 1      | 0.5                   | 0.51 (±0.01)                | 102        | 1.9         |
|       | QC 2      | 1                     | 0.995 (±0.05)               | 99.5       | 0.4         |
|       | QC 3      | 3                     | 2.99 (±0.02)                | 99.7       | 0.72        |

Pb = lead, Cd = cadmium, SD = standard deviation

### Table 7: Lead concentrations found in canned soft drinks

| Local company | Noncarbonated drinks | Carbonated drinks |
|---------------|----------------------|-------------------|
| Nonlocal company | GA 28.89             | OY 17.63          |
| MA 24.16      |                     | AY 15.83          |
| PA 21.25      |                     | SY 18.49          |
| OA 21.85      |                     | CY 16.45          |
| AA 32.72      |                     | DY 16.84          |
| GB 24.16      |                     | AZ 15.75          |
| MB 21.03      |                     | SZ 16.25          |
| PB 22.42      |                     | CZ 15.67          |
| OB 23.51      |                     | DZ 13.66          |

### Table 8: Lead concentrations in canned soft drinks stored under two different conditions

| Storage conditions | Controlled temperature | Noncontrolled temperature |
|--------------------|-------------------------|----------------------------|
| Period (month)     | 0 3 6 9 12              | 0 3 6 9 12                 |
| GA                 | 28.89 29.18 27.75 28.76 29.36 28.89 29.19 28.56 31.22 30.89 |
| MA                 | 24.16 24.17 24.67 23.88 24.08 24.16 24.71 24.34 23.59 25.45 |
| PA                 | 21.25 21.15 21.21 21.54 20.90 21.25 21.57 21.93 22.39 23.38 |
| OA                 | 21.85 21.97 21.22 22.56 22.28 22.85 21.95 22.15 22.25 22.91 |
| AA                 | 32.72 32.45 32.76 33.18 31.71 32.72 32.58 32.73 32.72 32.86 |
| YA                 | 15.84 16.23 15.82 16.17 15.68 15.84 15.41 15.71 15.43 15.89 |
| YC                 | 16.32 16.66 16.50 16.08 15.61 16.32 16.58 16.82 17.46 16.89 |
digestion method. The microwave digestion method is preferable to the wet digestion method due to many factors, such as it minimizes acid amount, reduces metal loss, reduces time consumption, and is better for operator health. On the contrary, many instruments and techniques were used for the analysis of heavy metals in soft drinks including AAS, ICP-MS, and inductively coupled plasma optical emission spectrometry (ICP-OES). In our study, we have used GFAAS technique due to its ability to detect low traces of metals, suitability for Pb and Cd analysis, and relatively low cost of operation.

In our study, Cd concentration was below the detection limit in all samples all over the study. This is in consistent with the Syrian Standard No. (1992/47), which specified that drinks should be free of Cd. This result is also in agreement with other studies as Cd was reported to be below the detection limit in all studied samples in the Nigerian market. However, another Nigerian study reported the presence of Cd in some fruit juice drinks. This may be because samples studied were juice samples containing 80% of natural fruit juice, which is one of the main sources of heavy-metal contamination, whereas in our study the natural fruit juice content does not exceed 30% maximum. The absence of Cd in all samples indicates the good manufacturing procedure (GMP) compliance and ensures a nonpolluted source of water, fruit, and other ingredient used in soft drink manufacturing.

Pb has been found in all studied samples in concentrations ranged between 13.76 and 42.12, which is below the permitted limit specified in Syrian Standard No. (1992/47) and FDA standards. The study also showed a higher Pb concentration in noncarbonated soft drinks compared to carbonated drinks. The possible sources of Pb in soft drinks are the fruits, water, contamination during the manufacturing process, and soft drink minor ingredients such as flavors, sweeteners, and coloring dyes. Fruits are the main source of contamination in noncarbonated soft drinks as they represent 30% of their content. The fruit could be contaminated by heavy metals due to many reasons that involve contaminated soil, water, fertilizer, and pesticides. Fruits contamination with a high content of heavy metals has been reported in the Middle East as well as soil contamination. High heavy metal levels were also reported in river and groundwater and fertilizers. Our results were in accordance with many studies performed in the Middle East and reported low Pb concentrations in soft drinks using other techniques such as ICP-OES and ICP-MS. Our study also found no significant leaching of heavy metals in canned soft drinks over 1 year of storage under controlled and noncontrolled conditions. This result is in accordance with other recent studies, which shows the compatibility of used cans for soft drinks manufacturing.

**CONCLUSION**

In conclusion, soft drinks in the Syrian market are safe for human consumption as they are not contaminated by heavy metals especially Cd and Pb. However, although the Pb concentrations are in the permissible limits, we recommend using free of contamination sources for the production of soft drinks. We advise costumers to reduce daily soft drink consumption as heavy metals could accumulate in their body over time and cause harmful effects and diseases. Also, soft drinks contain high sugar content, which lead to obesity and diabetics over noncontrolled consumption.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**REFERENCES**

1. Jorge K. SOFT DRINKS | Chemical Composition, in Encyclopedia of Food Sciences and Nutrition (Second Edition), B. Caballero, Editor. Oxford: Academic Press; 2003. p. 5346-52.
2. Ashurt PR. Chemistry and technology of soft drinks and fruit juices. Blackwell Publishing; 2005.
3. Shachman M. The soft drinks companion: a technical handbook for the beverage industry. CRC Press LLC; 2004.
4. Williams AB, Ayejuyo OO, Ogunyale AF. Trace heavy metals composition of some Nigerian beverages and food drinks. Food Chem 1999;66:275-9.
5. Ogwumike CM, Ayeweh CMA, Ojo MF, Tella OO. Trace heavy metals composition of some Nigerian beverages and food drinks. Food Addit Contam Part B Surveill 2015;2:384-90.
6. Godwill EA, Jane IC, Scholastica IU, Marcellus U, Eugene AL, Gloria OA. Determination of some soft drink constituents and contamination by some heavy metals in Nigeria. Toxicol Rep 2015;2:384-90.
7. Bingöl M, Yentür G, Er B, Öktem AB. Determination of some heavy metal levels in soft drinks from Turkey using ICP/OES method. Czech J Food Sci 2010;28:213-16.
8. Onianwa PC, Adetola IG, Iwegbue CMA, Ojo MF, Tella OO. Trace heavy metals composition in some Nigerian beverages and food drinks. Food Chem 1999;66:275-9.
9. Ofori H, Owusu M, Anyebuno G. Heavy metal analysis of fruit juice and soft drinks bought from retail market in Accra, Ghana. JSRR 2013;4:423-8.
10. Hadiani MR, Derfooli-Manesh S, Shoebi S, Ziarati P, Mousavi Khaneghah A. Trace elements and heavy metals in mineral and bottled drinking waters on the Iranian market. Food Addit Contam Part B Surveill 2015;8:18-24.
11. Alkhathib and Ataie: Determination of trace Pb and Cd in canned soft drinks in Syria
12. Flora SJS, Pachauri V, Saxena G. Arsenic, cadmium and lead: reproductive and developmental toxicology. London, UK: Academic Press; 2011.
13. U.S. Food & Drug Administration (FDA). Low levels of lead in juice products. 2010.
14. Syrian Standard Specification. Specification of non-alcoholic soft water. The Syrian Arab Organization For Standardization & Metrology, Ministry of Industry in Syria. First Amendment S. s. 47/1992.
15. Jamieson D. Saving sulfur. nature genetics. 2002;31(3):228-30.
16. Ysart G, Miller P, Crews H, Robb P, Baxter M, L’Argy CD, et al. Dietary exposure estimates of 30 elements from the UK Total Diet Study. Food Addit Contam. 1999;16(9):391-403.
17. Musaiger A, Kalam F. Dietary habits and lifestyle among adolescents in Damascus, Syria. Ann Agric Environ Med 2014;21:416-9.
18. Möller A, Müller HW, Abdullah A, Abdelgawad G, Utermann J. Urban soil pollution in Damascus, Syria: concentrations and patterns of heavy metals in the soils of the Damascus Ghouta. Geoderma 2005;124:63-71.
19. Al Obaidy AHM, Al Mashhadi AA. Heavy metal contaminations in urban soil within Baghdad city, Iraq. J Environ Prot 2013;4:72.
20. Ibraheen LH, Abed SA. Accumulation detection of some heavy metals in some types of fruits in the local market of Al-Diwaniyah city, Iraq. Rasayan J Chem 2007;10:339-43.
21. Zakhem BA, Hafez R. Heavy metal pollution index for groundwater quality assessment in Damascus Oasis, Syria. Environ Earth Sci 2015;73:6591-600.
22. Hassan S, Schmieder K, Böcker R. Spatial patterns of submerged macrophytes and heavy metals in the hypertrophic, contaminated, shallow reservoir Lake Qattineh/Syria. Limnologica 2010;40:54-60.
23. Batayneh AT. Heavy metals in water springs of the Yarmouk Basin, North Jordan and their potentiality in health risk assessment. Int J Phys Sci 2010;5:997-1003.
24. Al-Masri MS, Al-Kharfan K, Al-Shamali K. Speciation of Pb, Cu and Zn determined by sequential extraction for identification of air pollution sources in Syria. Atmos Environ 2006;40:753-61.
25. Othman I, Al-Masri MS, Al-Rayyes AH. Sedimentation rates and pollution history of the Eastern Mediterranean Sea: Syrian coast. Sci Total Environ 2000;248:27-35.
26. ICH topic Q2 (R1). Validation of analytical procedures: text and methodology. London, UK: European Medicines Agency; 2005.
27. Jorhem L. Determination of metals in foodstuffs by atomic absorption spectrophotometry after dry ashing: NMKL interlaboratory study of lead, cadmium, zinc, copper, iron, chromium, and nickel. J AOAC Int 1993;76:798-813.
28. Bizzi CA, Pedrotti MF, Silva JS, Barin JS, Nóbrega JA, Flores EMM. Microwave-assisted digestion methods: towards greener approaches for plasma-based analytical techniques. J Anal At Spectrom 2017;32:1448-66.
29. Al-Mudhaf HF, Alzaid HM, Abu-Shady AI. Study of trace and heavy metals content of soft drinks in the state of Kuwait. Int J Eng Res Appl 2016;6:1-6.
30. Abdel-Rahman GN, Ahmed MB, Sabry BA, Ali SS. Heavy metals content in some non-alcoholic beverages (carbonated drinks, flavoured yogurt drinks, and juice drinks) of the Egyptian markets. Toxicol Rep 2019;6:210-14.
31. Al Attar L, Al-Oudat M, Shamali K, Abdul Ghany B, Kanakri S. Case study: heavy metals and fluoride contents in the materials of Syrian phosphate industry and in the vicinity of phosphogypsum piles. Environ Technol 2012;33:143-52.