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Interferences of Adding High Salts Content Matrices to Cadmium Using Flame Atomic Absorption Spectrometry (FAAS) in Aqua Solution

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Abstract: ***The effects of sodium chloride, Sodium dodecyl sulfate, and disodium ethylene diamine tetra acidic acid salts on the absorbance signal of cadmium element using flame atomic absorption spectroscopy (FAAS) were investigated. The absorbance signals were obtained for the analyte and the analyte in the matrix. The comparison of the obtained data with the thermochemical and physical properties of the matrix and the analyte led to conclusions about the interference mechanisms that affect the sensitivity, selectivity, and resolution of the analyte.***

Keywords: FAAS, Matrices, Interferences, Cadmium, Analyte, Absorption, Heavy metals

1. Introduction

Heavy metals are considered highly inorganic contaminants; which cannot be destroyed (Mohammadi et al.2010). Cadmium is one of the most toxic heavy metals for living organisms even in very small concentrations (Adamczyk & Grabarczyk 2019; Guyo et al.2015.; Mohammadi et al.2010). It is classified as a nonessential element in (IIB) group of the periodic table (Suquila et al., 2019). Cadmium is most often found combined with other elements, which produces compounds such as cadmium sulfate, cadmium chloride, cadmium oxide, and its metal ores in nature (Jiang et al.2020). Cadmium is used in the production of pigments, rubber, plastic batteries, fertilizers, and metal containers. However, it leads to the release of a large amount of cadmium into the ecosystem every year (Buyukpınar 2021). Also, cadmium is generated from the hydrometallurgical processing of metals such as lead, copper, and zinc as a byproduct (Golbedaghi et al.2012). The severe toxicity of this metal is a consequence of cumulative effects and long half - life which is between one and four decades (Bakırdere 2013). According to the FAO - WHO Expert Committee on Food Additives, Cd daily intake from all sources should not exceed 1 - 1.2 µg kg - 1 body mass (Gisele et al.2004). Long - term exposure to cadmium causes severe damage to the liver, kidney, lung, immune, and central nervous systems, as well as anemia, hypertension, osteoporosis, fertility disorders, proteinuria, and even cancer. (Haryanto et al.2023; Buyukpınar 2021; El Rasafi et al.2021;)

Atomic absorption spectrometry (AAS) is a widely used analytical technique for the determination of trace elements in various samples (Gisele et al.2004; Golbedaghiet al.2012) due to its good selectivity, specificity, easy operation, low cost, and high sample throughput. (Inse & Akman 2004). However, the accurate quantification of target elements can be influenced by the presence of interfering substances in the sample matrix, WHICH can include matrix components inherent to the sample, such as salts, complexing agents, surfactants, organic compounds, and matrix impurities. These matrix components can exhibit spectral overlap with the absorption lines of the target element, leading to spectral interference in the measurement. This spectral interference can result in decreased sensitivity, inaccurate quantification, or even false positives or negatives. Matrix substances may also chemically react with the analyte element, forming stable complexes or compounds that alter their atomic state or physical properties. These chemical interferences can affect the atomization or excitation process, resulting in signal suppression or enhancement. In addition, matrix components can influence the physical behavior of the sample during atomization, such as changes in volatility, viscosity, or surface tension. These alterations can impact the efficiency of atomization and the transport of analyte atoms to the light path, leading to signal variations. As a result, matrix effects can significantly impact AAS measurements, affecting sensitivity, precision, accuracy, and selectivity (ALP 2012; Christian et al.2014).

However, sodium chloride has been reported to have interference in either flame or graphite furnace atomic spectrometric determination of heavy metals Cd. sodium chloride was reported to have a distinctively suppressive effect on the Cd signal and influence the accuracy of the analysis (BEKTAS et al.1989; Byrne et al.1992). other studies investigated the effect of anionic sodium dodecyl sulfate surfactant (SDS) on heavy metals including Cd absorption by AAS was found that the SDS enhances the absorption signal as well as suppresses the interferences (Furukawa et al.2019). The effect of EDTA ligand on the absorption of cadmium using atomic absorption spectrometry has been investigated by Sun et al. They found that the presence of EDTA as interference reduces the adsorption signal of cadmium ions (Sun et al.2022).

Apparatus and reagents

contrAA® 300 atomic absorption spectrometer equipped with deuterium background correction and cadmium hollow cathode lamp was used for absorbance measurements, under the following conditions: wavelength: 228.8 nm; nm; lamp current: 8 mA; flame: air/acetylene. The burner height and the acetylene flow rate were adjusted to achieve the maximum absorbance signal, during aspirating the analyte solution.

All the chemicals and reagents were in high - purity grade and all solutions were prepared with deionized water.100 ppm stock solution of cadmium solution, sodium chloride, potassium chloride, disodium ethylene diamine tetra acidic acid (Na_2EDTA), Sodium dodecyl sulfate (SDS), and nitric acid (99%) were purchased from Sigma - Aldrich.

Sample preparation

The standard cadmium solutions with concentrations of 0.1 ppm and 1 ppm were prepared from 100 ppm cadmium stock solution. Stock matrix solutions of 100 ppm were prepared from analytical reagent grade NaCI, Na_2EDTA, and SDS. All test solutions were diluted to 1g/l, 2g/l, 4g/l, 6g/l, 8g/l, and 10g/l concentrations with distilled, deionized water immediately before use.

2. Results and Discussion

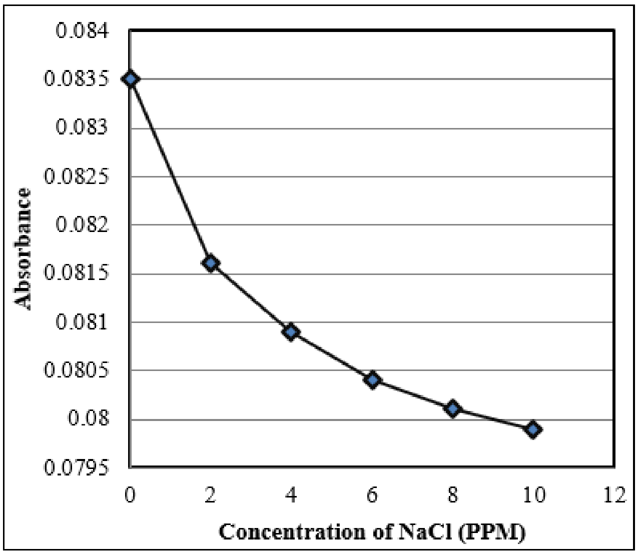

Figure 1: The effect of NaCL on absorbance signal of cadmium

The interference effect of different concentrations NaCl at a range 0 - 10 g/l on the determination of 1 ppm of Cadmium is shown in Figure 1. The absorbance signal of Cadmium gradually decreased at elevated concentrations of NaCl. One of the possible causes of suppression in the cadmium atomic absorption signal due to a vapor - phase interference caused by the formation of cadmium chloride which is not completely dissociated reducing the number of free Cd atoms during atomization subsequent absorption of cadmium. In addition, NaCl can alter the flame characteristics and atomization efficiency in the AAS instrument. Changes in the flame composition, flame temperature, or vaporization behavior can affect the atomization and subsequent absorption of cadmium. These matrix effects can lead to a decrease in the AAS signal of cadmium (Bektas et al.1989 Byrne et al.1992). Another possible mechanism is the occlusion of the analyte in microcrystals of the chloride matrix. As a result, the AAS signal of cadmium decreases. (Byrne et al.1992). Sodium has a lower ionization energy compared to cadmium. When NaCl is introduced into the flame, the sodium atoms can easily be ionized, leading to an increase in the flame temperature. Higher flame temperature can cause thermal excitation and ionization of cadmium atoms, reducing the absorption signal. Additionally, the increased flame temperature can also promote the formation of stable cadmium compounds, hindering the atomization process and decreasing the AAS signal. As a consequence, the AAS signal of cadmium is suppressed or reduced due to the presence of NaCl (Hisashi and Nello 1968).

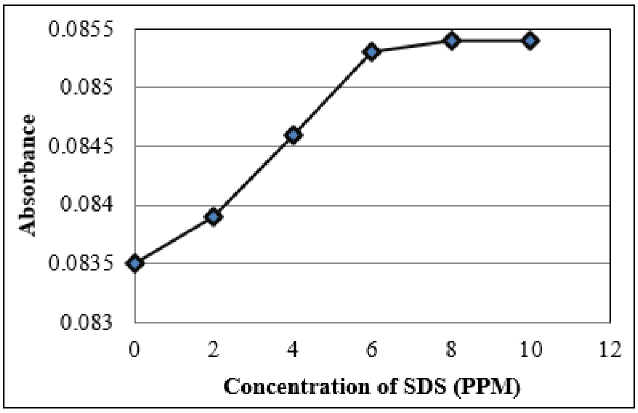

Figure 2: The effect of SDS on the absorbance signal of Cadmium

Figure 2 shows that the absorbance of 1 ppm cadmium increased as the concentration of SDS increased until 6g/l compared with the absorbance from cadmium alone in aqueous solution which was 0.084. After that, no significant increase in absorbance was recorded. This enhancement in absorbance may be due to the ability of SDS as a surfactant to decrease the surface tension of aqueous solution which can stimulate the generation of small droplets during the aspiration and nebulization process, causing in greater efficiency in flame processes and therefore greater sensitivity (Ruiz et al.1993; Kornahrens et al.1982; Michiko and Seinosuke 1980).

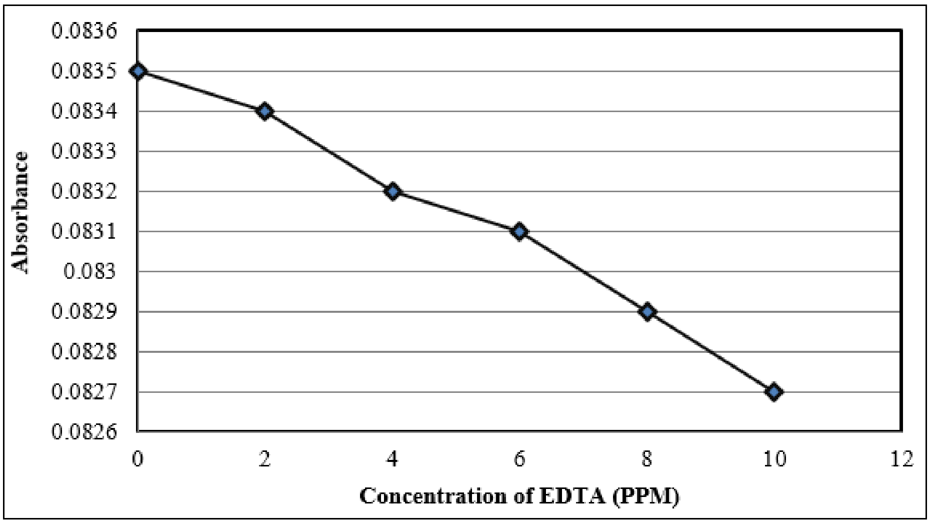

Figure 3: The effect of Na_2EDTA on the absorbance signal of cadmium

The effect of the concentration of EDTA in the range of 0–10 g/mL on the Cd (II) absorption was also investigated and the results are given in Figure 3. It was found that the no significant reduction of Cadmium absorbance signal when an elevated concentration of EDTA. The most common reason is that increasing the concentration of EDTA will increase the formation of Cd - EDTA complexes and decrease the concentration of free cadmium ions available for absorption. in addition, the Cd –EDTA complex is easily decomposed in the flame and gives free cd atoms this explains the slight decrease in the absorbance signal of cd (Mostafa 1996).

3. Conclusion

Interferences in FAAS, when adding salts such as sodium chloride and disodium ethylene diamine tetra acidic acid or surfactants like Sodium dodecyl sulfate to the cadmium were given different signal responses. The signal of Cd from the sample with different concentrations of NaCl reduces the number of free Cd atoms during atomization due to the form of cadmium chloride. In addition, NaCl at high concentration levels might decrease the efficiency of the flame. The signal of cadmium increased as the concentration of SDS. This enhancement in absorbance might refer ability of SDS as a surfactant to decrease the surface tension of aqueous solution which can stimulate the generation of small droplets during the aspiration and nebulization process, causing in greater efficiency in flame processes and therefore greater sensitivity. The effect of the concentration of Na_2EDTA in on the absorption. It was found that the no significant reduction of Cadmium absorbance signal when increasing the concentration levels of Na_2EDTA. The reason is that increasing the concentration of EDTA will increase the formation of Cd - EDTA complexes and decrease the concentration of free cadmium ions available for absorption. in addition, and the Cd –EDTA complex is easily decomposed in the flame and gives free Cd atoms this explains the slight decrease in the absorbance signal of Cd.

Finally, it is clear the chemical interferences due to adding these species lead to chemical interference effects on the formation of free cadmium atoms by either increasing or decreasing the signal using FAAS

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