Detection Methods of Mercury and Lead Ions

Yixuan Xiao *

Guangdong Country Garden School, Guangdong, China

* Corresponding Author Email: 201004010121@stu.swmu.edu.cn

Abstract. Heavy metals ions are substances that can cause irreversible damage to the human body. These elements are often contained in raw materials and equipment in industrial production. These heavy metal ions, especially lead and mercury ions, can cause serious diseases when they enter the human body. Therefore, in order to avoid the excessive accumulation of mercury and lead ions in human body, it is very important to detect the heavy metal ions in products. The inductively coupled plasma mass spectrometry (ICP-MS) for detecting mercury ions has been discussed in this work. In addition, electrochemical sensor which used to detect mercury ions was also introduced in this work. As for detection of lead ions, flame atomic absorption spectrometery (FAAS) and anodic stripping voltammetry (ASV) were discussed respectively. This work will promote the understanding of lead and mercury ions detection. At the same time, more research on portable and inexpensive detection methods has become a focus of future research.

Keywords: Mercury, lead, detection method.

1. Introduction

In people's daily life, the body usually absorbs heavy metals in a certain way. People are not aware of this, which leads to the occurrence of many diseases [1]. The most common route is through foods such as seafood (cephalopods predominate), vegetables (spinach has the highest content). The main reason why these foods contain heavy metal ions is related to the heavy metals contained in water sources. Based on the food chain of organisms, organisms higher up the food chain tend to ingest more toxins. Similar to this, when a body of water is at its primary level and the human body is at a higher level, it indicates that the heavy metal ions in the food that people eat come from water. Skin penetration is yet another entry point into the body. Heavy metals in cosmetics may enter the human body through this method. These harmful ingredients may come from eye shadow, blush, contouring and other cosmetics. Heavy metals are often added to makeup products to increase the product's affinity and make it easier to adhere to surface skin. For example, preservatives are also a kind of coordination. In addition, powder plays the most obvious role in cosmetics because the color of the product comes from it. However, during the production process, factors such as unclean impurities may lead to excessive heavy metals.

These heavy metals that may cause harm to the human body include Pb, Cd, Hg. . . Metals such as chromium and nickel have been shown to produce both acute and long-term toxicity in both people and other creatures, also have even been linked to the formation of cancer. If these heavy metals exceed the standard, they usually have a very bad effect on the nervous system, and usually cause irreversible damage to the human hematopoietic system, lung function, and kidneys [2]. It can be seen that it is particularly important to carry out strict heavy metal detection on products that the human body comes into contact with daily. This article will describe two common heavy metal ions: mercury and lead, and how can human detect these ions.

2. Various kinds of Heavy metal ions detection means

2.1. Detection of Mercury

2.1.1. Inductively coupled plasma mass spectrometry (ICP-MS)

With the straightforward operation of ICP-MS, one can locate components at low concentrations. Yong Fang, Yushi Pan et al. mentioned a research that used ICP-MS to detect mercury and arsenic

ions in rice flour simultaneously [3]. According to the report, 7700×ICP-MS-Aglient USA is use in the detection of Hg and As. The chromatographic column of the Aglient 1260 HPLC (reverse-phase C18 column) is concatenate to the nebulizer putting a perfluoro alkoxy. The addition of methanol advanced the sensitivity of the identification of ions from heavy metal. The literature indicates that the strength of Hg ion and as ion increases obviously when methanol is added. In addition, pH also effects the judment of the ions. Data shows when the pH value is lower than 6, Hg and as ions baseline are confound. Meanwhile the change of pH value has an effect on the data image. When the pH was less than 7.1 after the test, the combination of DMA peaks and MMA peaks resulted in a more chaotic image shape for Hg. So, the two heavy metal ions can be distinguished by this method [3]. During the experiment X seriesII ICP-MS determine the isotopes of metal or metalloids (53Cr, 75As, 202Hg). previously using microwave assisted digest to dispose the sample. GO@SiO_2 column used to separating and identifying the element of different chemical forms by HPLC. Distinguish the elemental speciation of Hg ions eg. Methyl mercuric, phenylmercuric, and hg (II) ions. The column by using Ammonium acetate as mobile phase. Can determine phenylmercuric ions from the others. Due to the robust high performance fluid chromatography employing ICP-MS is the ideal solution due to the interface features such as adequate repeatability, and sensitivity [4].

2.1.2. Plastic based disposable electrochemical sensor

Because the traditional spectral detection technology equipment cost too expensive, researchers are exploring more convenient and affordable testing methods. According to the report of Wan Wang and colleagues, a plastic based disposable electrochemical sensor was designed to test mercury ions. When it is combined with disposable plastic electrochemical sensors, the cost was reduced. Because the use of this method of equipment, energy consumption is far lower than the traditional method. By the report, this study describes the electrochemical technique concurrent measurement of lead, arsenic, and mercury ions using gold-sputtered polymer probes. Au sputtering on PET slice for 30mA current lasting 80s.When the plastic based disposable electrochemical sensor is applied to the experiment, the results show that the data meet the lowest point of the corresponding calibration curve. This means that the method can be used in the actual test [5].

2.2. Detection of Lead

2.2.1. Flame atomic absorption spectrometery (FAAS)

The widely use of FAAS is largely due to its simplicity and reliability. The method of detection of FAAS requires the sample to be converted into a mist by nebuilzer. Because of high-temperature, the chemical bond of the sample break to form a free atomic state [6]. Whereafter an element-specific hollow cathode lamp will emit light source the metal ions absorb light from it. The Beer-Lambert law is commonly used to measureing chemicals. The principle declaring that a substance's absorbance is directly correlated to its concentration. As it is shown in formula (1), a linear relationship between the two variables could be observed [7]. In the formula A stands for absorbance, ε represent the absorption by the species that are attenuating, ℓ means the optical path length and c indicate the attenuating species concentration. In FAAS, a solution that does not contain any metal ions is usually tested first. The solution is then tested separately at the in-proportion concentration to form a standard calibration curve when the curve conforms to the Beer-Lambert Law it set up. When the calibration curve is available, the unknown sample can be measured.

$$A = \varepsilon \ell c \tag{1}$$

Hussain Ullah et al. reported the detection of Pb (II) by using the Perkin Elmer 400 flame atomic spectrophotometer. The as-prepared sample contained multiple metal ions, such as lead (II) and copper (II). This indicated that this detection method can detect lead ions selectively in complex environments. The standard deviation of three independent measurements is used to improve the readings as necessary. The flame type used in this experiment is Air-acetylene, and the wavelength

is 283.31nm [8]. Mohammad Behbahani, Parmoon Ghareh Hassanlou et al. According to the report, flame atomic absorption spectrometer (AA680) use Air-acetylene. The presence of metal ions is related to pH, and extraction recovery get lower when pH is greater than 7, and also decreases when pH is less than 7. The data show that the most suitable pH value is 7, at which time cadmium and lead ions in the sample can be extracted well.

2.2.2. Anodic stripping voltammetry (ASV)

Metals and some chemical and organic components can be found using the electrochemical method known as ASV. Its ability to distinguish the oxidation state and the sensitivity of the sample to analysis the sample. Mounira Dali et al. The technology of lead and cadmium simultaneous detection utilizing ASV-based biosensors is introduced in this article. This article may detect metal ions using acidic buffers of various concentrations, calculate the limit of quantitation through experiments, and determine the quantity by voltammograms. The LOQ value can then be determined by linear comparison because the current is proportionate to the concentration. Because the method in this article has a lower limit of quantitation (LOQ) than conventional electrochemical methods, it can be utilized with lower amounts of heavy metal ions and still produce useful findings [9]. There are several steps to follow; Firstly, is the sample preparation, dissolve the cosmetic product into solvent as well as strong acid solutions in order to release heavy metal ions. Secondly, prepare the electrode. The most common material of the electrode is mercury film, and the shape are often plan or disk. It is important to polish and clean the electrode before the experiment. After that placing the sample into the electrochemical cell with working, auxiliary and reference electrode. The metal ions have been oxidize scanning the working electrode to obtain the peak in the current signal. Final steps is to analyse the data obtained, the concentration of the heavy metal ions is calculated using the current signal, The ratio of area to height depends on how concentrated the desired elements are. Metal ions exist in many forms in the natural environment. Form complexes with other molecules (most present in the form of granular minerals). Other metal oxides or minerals have metal attached to them. In the case of lead ions, it mainly binds to hemoglobin in the blood [10].

3. Conclusion

Excessive lead or mercury ions can cause damage to the human nervous system. Therefore, it is necessary to detect these heavy metal ions quantitatively. There are various detection methods for lead and mercury ions. However, the detection of these two ions is greatly influenced by the pH value. In the data analysis phase of these characterization methods, the unique properties of elemental ions are utilized for analysis. Usually, the unique peak position and height represent the type and content of the ion.

This work focuses on the detection of mercury and lead ions. The detection of mercury by ICP-MS was introduced in this article. This detection method strongly relies on instrument equipment. In addition, plastic based disposable electrochemical sensor methods for detecting mercury ions was also introduced. As for detection of lead ions, FAAS and ASV were introduced. This work will help to understand of lead ion detection and mercury ion detection. New portable and simple detection methods should be explored in the future.

References

[1] Bocca Beatrice, Pino Anna, Alimonti Alessandro, Forte Giovanni. Toxic metals contained in cosmetics: A status report. Regulatory Toxicology and Pharmacology, 2014, 68 (3): 447 - 467.

[2] Mahurpawar Manju. Effects of heavy metals on human health. Int J Res Granthaalayah, 2015, 530 (516): 1 - 7.

[3] Fang Yong, Pan Yushi, Li Peng, Xue Mei, Pei Fei, Yang Wenjian, Ma Ning, Hu Qiuhu. Simultaneous determination of arsenic and mercury species in rice by ion-pairing reversed phase chromatography with inductively coupled plasma mass spectrometry. Food Chemistry, 2016, 213: 609 – 615.

[4] Cheng HeYong, Zhang Wenwen, Wang Yuanchao, Liu Jinhua. Graphene oxide as a stationary phase for speciation of inorganic and organic species of mercury, arsenic and selenium using HPLC with ICP-MS detection. Microchimica Acta, 2018, 185 (9): 1 - 8.

[5] Wang Wan, Bao Ning, Yuan Wenfeng, Si Nianpeng, Bai Hua, Li HaiYu, Zhang Qing. Simultaneous determination of lead, arsenic, and mercury in cosmetics using a plastic based disposable electrochemical sensor. Microchemical Journal, 2019, 148: 240 - 247.

[6] Huang Jen-Yi, Li Xu, Zhou Weibiao. Safety assessment of nanocomposite for food packaging application. Trends in Food Science & Technology, 2015, 45 (2): 187 - 199.

[7] Agarwal Avinash Kumar, Gupta Tarun, Kothari Abhishek. Particulate emissions from biodiesel vs diesel fuelled compression ignition engine. Renewable and Sustainable Energy Reviews, 2011, 15 (6): 3278 - 3300.

[8] Ullah Hussain, Noreen Shamsa, Fozia, Rehman Ali, Waseem Amir, Zubair Shumaila, Adnan Muhammad, Ahmad Ijaz. Comparative study of heavy metals content in cosmetic products of different countries marketed in Khyber Pakhtunkhwa, Pakistan. Arabian Journal of Chemistry, 2017, 10 (1): 10 - 18.

[9] Dali Mounira, Zinoubi Khaoula, Chrouda Amani, Abderrahmane Sihem, Cherrad Semcheddine, Jaffrezic-Renault N. A biosensor based on fungal soil biomass for electrochemical detection of lead (II) and cadmium (II) by differential pulse anodic stripping voltammetry. Journal of Electroanalytical Chemistry, 2018, 813: 9 - 19.

[10] Borrill Alexandra, Reily Nicole E, Macpherson Julie. V. Addressing the Practicalities of Anodic Stripping Voltammetry for Heavy Metal Detection: A Tutorial Review. The Analyst, 2019, 144: 6834.