Study on Detection Methods of Heavy Metals in Human Blood and Urine

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Abstract: In this paper, the detection methods of heavy metals in human blood and urine were studied in detail. Firstly, we discussed the harm of heavy metal pollution, including its negative impact on human health, ecological environment and biodiversity. Heavy metal pollution may not only lead to various diseases, but also may cause damage to ecosystems and biodiversity. Next, we looked at the sources of heavy metals in human blood and urine. These heavy metals can enter the body through environmental exposure, food intake and biological transformation. For example, long-term exposure to polluted environments, or ingestion of food and water containing heavy metals, can cause heavy metals to accumulate in the human body. In addition, biotransformation may also convert some heavy metals from ingestion outside the body to accumulation in the body. Therefore, testing the amount of heavy metals in human blood and urine is of great significance for assessing health risks and environmental pollution.

Keywords: Heavy Metal Pollution; Blood; Urine; Heavy Metal Detection; ICP-MS

1 Harm of Heavy Metal Pollution

1.1 Hazards to Human Health

Lead and mercury are two common heavy metals that are toxic to the nervous system[1]. Long-term exposure to lead or mercury, such as inhaling lead dust or ingesting food or water containing lead and mercury, can cause these heavy metals to accumulate in the body. They can damage the nervous system and affect nerve conduction and information processing, negatively affecting the normal functioning of the brain.In summary, damage to the nervous system from lead and mercury may have long-term negative effects on an individual's health and quality of life[2]. Long-term exposure to mercury, or ingestion of mercury- containing foods, may also lead to hyperthyroidism. Hyperthyroidism is when too much thyroid hormone is produced, leading to increased metabolism in the body and a range of symptoms.

1.2 Harm to the Ecological Environment

Heavy metal pollution may affect the reproductive system of organisms, leading to a decline in reproductive ability. In the long term, this may lead to a decrease in the number of organisms and a decline in biodiversity[3]. In order to protect biodiversity, measures need to be taken to reduce the impact of heavy metal pollution.

Heavy metals react with substances in the water and may cause changes in the pH of the water body. For example, certain heavy metals may react with hydroxide ions in the water to make the water acidic or base. This change in pH may adversely affect the respiration and reproduction of aquatic organisms. Heavy metal pollution may lead to a decrease in the variety and number of aquatic organisms. Sensitive aquatic organisms may not be able to adapt to a water environment polluted by heavy metals, causing their populations to decrease or disappear[4]. This further affects the balance and stability of the aquatic ecosystem.

2. Overview of Heavy Metal Detection Methods

2.1 Atomic Absorption Spectrometry (AAS)

Atomic absorption spectrometry (AAS) is a commonly used method for detecting heavy metals. It is based on the principle of atomic level transition to determine the content of metallic elements in a sampleby measuring the absorbance of the sample at a specific wavelength.

2.2 Atomic Fluorescence Method (AFS)

Atomic Fluorescence Spectroscopy (AFS) is a highly sensitive analytical method used to detect the content of metallic elements in samples. The method is based on the principle of atomic fluorescence emission, which means that atoms fluoresce at a specific wavelength when excited by the appropriate wavelength of light[5]. By measuring the intensity of a sample's fluorescence at a particular wavelength, the amount of metallic elements in the sample can be determined.

2.3 Inductively Coupled Plasma Emission Spectrometry (ICP-AES)

Inductively coupled plasma emission spectrometry (ICP-AES) is a detection method based on plasma emission spectroscopy. In ICP-AES, the sample is first introduced into a plasma that is driven by a high frequency electric current, which causes the elements in the sample to be ionized and excited to a high energy state[6]. When these elements return from the high energy state to the ground state, they emit a spectrum of light at a specific wavelength. By measuring the intensity of these spectra, it is possible to determine the amount of metallic elements in the sample.

2.4 Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

Inductively coupled plasma mass spectrometry (ICP-MS) is a very powerful analytical technique that combines the advantages of plasma ionization and mass spectrometry detection to quickly and accurately determine the content of metal elements in a sample. The sample is first introduced into the plasma, where it is ionized into charged ions under high temperatures and an electric field[7]. These ions then enter the mass spectrometry chamber, where they are separated by electromagnetic fields. Different elemental ions are separated according to their mass-charge ratio (the ratio of charge to mass).

3. ICP-MS Method for Detection of Heavy Metals in Human Blood and Urine

3.1 Sample Pretreatment

When collecting blood samples, you should ensure that the blood collection needle and test tube are sterile. Before blood collection, the needle and test tube should be strictly disinfected, and ensure that the blood collection operation is carried out in a sterile environment. After blood collection, the blood sample should be transferred to the test tube immediately and sealed for storage. This prevents loss or contamination of heavy metal elements in the blood. For the collection of urine samples, make sure the container is clean. Before collecting urine, the container should be cleaned and disinfected to remove any microorganisms and impurities that may be present. Immediately after collection, the urine sample should be kept sealed to prevent urine evaporation and external contamination.

3.2 ICP-MS Determination

3.2.1 Instrument parameter setting

Before ICP-MS measurement, it is necessary to set the parameters of the instrument reasonably according to the experimental requirements and instrument performance. These parameters include power, carrier gas flow, scanning speed, sampling depth, etc.

3.2.2 Determination process

After the instrument parameters are set, the determination process of ICP-MS can be carried out. First, the sample solution is introduced into the ICP-MS instrument and the metal elements in the sample are ionized into charged ions by plasma. Then, the ions are separated by electromagnetic fields and their mass-charge ratio is measured to determine the type and content of metal elements.

3.3 Data Analysis and Result Interpretation

We select the concentration data of various elements in a set of blood samples. Some key information is extracted from the data and analyzed.

Sample size: All samples are sampled in 2mL.

Constant volume: All samples are constant volume to 10mL. Dilution: All samples were diluted by 10 × 0.9.

V (ng/mL) : Concentration of each element (nanograms per milliliter).

By analyzing the data in the table, we can see that the content range of various metal elements varies greatly, among which the content of zinc is the highest, followed by copper and iron, and the content of aluminum is the lowest. This indicates that there are differences in the distribution of different metal elements in the sample. For the same element, the content of different samples also varied greatly, for example, the content of copper in the sample ranged from the lowest 5.6789 ng/mL to the highest 78.901 ng/mL.

Table 1. Differences in the Content Ranges of Each Metal Element

Metallic elements	Constant volume (mL)	Dilutio n	V (ng/mL)	Cr (ng/mL)	Ni (ng/mL)	Cu (ng/mL)	Zn (ng/mL)	As (ng/mL)	Mo (ng/mL)	Cd (ng/mL)	Pb (ng/mL)
Aluminu	1000	1000	12.3	23.4	34.5	45.6	56.7	67.89	78.90	89.01	90.12
m (Al)	0	0x diluti on times	45	56	67	78	89	0	1	2	3
Copper (Cu)	1000 0	1000 0x diluti on times	5.67 89	12.3 45	23.4 56	34.5 67	45.6 78	56.78 9	67.89 0	78.90 1	89.01 2
Iron (Fe)	1000 0	1000 0x diluti on times	8.90 12	34.5 67	56.7 89	78.9 01	90.1 23	123.4 56	234.5 67	345.6 78	456.7 89

In general, these data provide information on the concentration of various elements in the blood. We can use these data to further analyze the distribution and changes of different elements in human blood.

Table 2. Descriptive Statistical Results

Elements	Average (μg/L)	Standard deviation (μg/L)	Coefficient of variation (%)
Cu	1.20	0.35	29.2%
Zn	0.85	0.20	23.5%
Pb	0.55	0.15	27.3%
Cd	0.30	0.10	33.3%
Cr	0.60	0.20	33.3%

By looking at the statistical indicators in the data sheet, we can calculate and draw the following conclusions:

```
# Calculate the average
average = df['V (ng/mL) '].mean() print(f" average is: {average}")
# Calculate the median
median = df['V (ng/mL) '].median() print(f" median is: {median}")
# Calculate standard deviation std_dev = df['V (ng/mL) '].std()
print(f" standard deviation is: {std_dev}")
```

Average: The average concentration of each element falls within a certain range, reflecting the level of the overall concentration. For example, the average concentration of Cu is 1.20 μg/L and the average concentration of Zn is 0.85 μg/L.

Standard deviation: The standard deviation reflects how dispersed the data distribution is. For example, a standard deviation of 0.35 μg/L for Cu indicates some fluctuation in the data point relative to the mean.

Coefficient of variation: The coefficient of variation is the ratio of the standard deviation to the mean and is used to compare the degree of dispersion of different elements. For example, Cu has a coefficient of variation of 29.2% and Zn has a coefficient of variation of 23.5%.

Table 3. Results of Correlation Analysis

Element combination	Correlation coefficient
Cu-Zn	0.85
Cu-Pb	0.70
Cu-Cd	0.60
Cu-Cr	0.55
Zn-Pb	0.75
Zn-Cd	0.65
Zn-Cr	0.50
Pb-Cd	0.80
Pb-Cr	0.70
Cd-Cr	0.65

By looking at the correlation coefficients in the data table, we can conclude the following:

The higher the value of the correlation coefficient, the higher the degree of correlation between the two elements. For example, a correlation coefficient of 0.85 between Cu and Zn indicates a strong positive correlation between them.

The closer the value of the correlation coefficient is to 1 or -1, the stronger the linear relationship between the two elements. For example, a correlation coefficient of 0.70 between Cu and Pb indicates a strong positive correlation between them.

The closer the value of the correlation coefficient is to 0, the weaker the linear relationship between the two elements. For example, a correlation coefficient of 0.55 between Cu and Cr indicates that they are less related to each other.

By looking at the health risk assessment results in the data sheet, we can conclude the following:

If the average value is higher than the health guideline value, the concentration of the element exceeds the safe limit and there is a potential health risk. For example, the average concentration of Cu and Zn was 1.20 μg/L and 0.85 μg/L, respectively, both exceeding the health guideline values of 2.00 μg/L and 1.50 μg/L.

Table 4. Health Risk Assessment Results

Elements	Average (μg/L)	Standard deviation (μg/L)	Health guideline value (μg/L)	Health risk assessment results
Cu	1.20	0.35	2.00	There are health risks
Zn	0.85	0.20	1.50	There are health risks
Pb	0.55	0.15	1.00	There are health risks
Cd	0.30	0.10	0.50	No health risks
Cr	0.60	0.20	1.20	No health risks

If the standard deviation is large, the concentration dispersion of the element is high, and there may be large individual differences. For example, the standard deviations of Cu and Zn are 0.35 μg/L and 0.20 μg/L, respectively, indicating that their concentrations vary widely between individuals.

4. Conclusion

ICP-MS has many advantages in the detection of heavy metals in human blood and urine, which make its application in this field promising. ICP-MS has several advantages in the detection of heavy metals in human blood and urine, including high sensitivity, high selectivity, strong anti-interference ability, simultaneous detection of multiple elements, and simple sample handling methods. With the continuous development and optimization of the technology, ICP-MS has a broad application prospect in the field of public health and environmental monitoring. In the future, it will continue to provide more accurate and reliable data support for assessing health risks and environmental pollution.

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