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# APPLICATION OF RAPID DETECTION TECHNOLOGY IN FOOD HEAVY METALS

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**Abstract:** The problems of chemical contamination, microbial contamination and adulteration in food have attracted widespread attention around the world. Heavy metal contamination in chemical contamination poses a huge threat to food safety. Traditional heavy metal detection technology is time-consuming and cannot meet current needs. Fast, convenient and accurate analysis and detection technology has become the future development trend. The article summarizes the current research and development of rapid detection technology for heavy metals in food, briefly points out the problems existing in the research process, focuses on demonstrating the importance of new materials in promoting the development of rapid detection technology, and looks forward to its future research directions.
**Keywords:** Food safety; Heavy metals; Rapid detection; Immunoassay; Electrochemical sensor

## 1 INTRODUCTION

Food safety has become a global topic. Frequent food safety incidents in the world have caused huge economic losses and caused many diseases and even deaths [1-2]. Food safety mainly involves the following aspects: chemical pollutants, microbial contamination and food adulteration, among which heavy metals are one of the main chemical pollutants [3]. Heavy metals mainly include lead, cadmium, mercury, arsenic, zinc, nickel, copper and other elements [4], all of which can have negative effects on the human kidney, liver, nervous and cardiovascular systems [5]. Lead ranks first among the six heavy metal pollutants [6]; in 1972, the United Nations Food and Agriculture Organization and the World Health Organization gave priority to defining cadmium as a food contaminant, and Ranked first among the 12 dangerous toxic substances proposed by the United Nations Environment Program in 1974 [7]; Mercury elements can be converted into methylmercury, a more toxic form that harms human health [8]; Inorganic arsenic and arsenic are present in food Organic arsenic, inorganic arsenic and their compounds have been defined as major carcinogens [9]. Therefore, the determination of heavy metal content in food is essential.

The traditional method of detecting heavy metals mainly relies on spectroscopy with large instruments [10], which can accurately measure the content of heavy metals in food. However, the sample pre-processing steps are cumbersome, the detection time is relatively long, the equipment is expensive, and there are many experimental consumables, so it is limited to the laboratory. Analysis and detection are difficult for other occasions, especially on-site detection [11]. Compared with traditional detection technology, heavy metal rapid detection technology has significant advantages: first, it can achieve rapid and accurate analysis of multiple elements; second, the equipment is small and easy to transport [12], which is convenient, fast and economical, and is suitable for heavy metals in food On-site detection of contaminants. This article reviews the latest applications of food heavy metal rapid detection technology in recent years from six aspects: chemical colorimetry, enzyme inhibition method, immunoassay, electrochemical sensor, biological barcode and information technology, focusing on the application of new materials in various rapid detection.

## 2 RAPID DETECTION TECHNOLOGY OF HEAVY METALS IN FOOD

### 2.1 Chemical Colorimetry

Chemical colorimetry refers to a specific chemical color reaction between the substance to be measured and a specific chemical reagent on the test paper. Qualitative or semi-quantitative detection can be achieved through color comparison. Li Qin et al. [13] used self-made cadmium test paper as a carrier, added ascorbic acid and potassium iodide to potatoes, adjusted the pH with sulfuric acid, and quickly determined the harmful heavy metal cadmium content in potatoes by comparing it with a standard color guide. However, traditional chemical colorimetric methods have disadvantages such as low sensitivity and being suitable for a single sample. The combination of new materials and chemical colorimetric technology has greatly reduced the detection limit, improved detection sensitivity, and successfully achieved on-site rapid detection of heavy metals in food. Wu et al. [14] combined colorimetry with microfluidic paper chip technology to rapidly detect Cu2+ in drinking water, with a detection limit as low as 0.340 μmol/L. Cao et al. [15] established a portable colorimetric rapid detection method for Cu2+ in drinking water based on natural food pigment-red beet pigment and a smartphone. Under alkaline conditions, red beet pigment selectively reacts with Cu2+ through redox reaction and chelation, thereby changing the color of the solution from purple to orange-red. Smartphones based on Android systems can realize visual detection of Cu2+ with a linear range Reaching 4 ~ 20 μmol/L, the detection limit is 0.84 μmol/L. Huang et al. [16] used non-noble metal nanozymes to achieve rapid detection of Hg2+ in food. The integrated system based on biocompatible nanozyme CS-MoSe2 NS and a smartphone can achieve rapid on-site detection of Hg2+ within 15 minutes, with a detection limit of 8.4 nmol/L. The combination of new technologies such as chip technology and smart equipment with colorimetric methods makes the heavy metal detection process more convenient and faster, and the detection results are intuitive, making it more suitable for rapid screening of on-site batch samples. However, there are also hydrophobic materials (colorimetric paper chips) , nanozymes and other new materials have shortcomings such as high research and development costs, lack of reproducibility and accuracy of test results. In the future, scholars will conduct in-depth research on the composition of colorimetric paper, enzyme synthesis, and improving the reliability of results.

### 2.2 Enzyme Inhibition Method

The principle of detecting heavy metals by enzyme inhibition method is that heavy metal ions combine with the thiol or methyl mercapto group that forms the active center of the enzyme, causing the reaction system to change in color, pH, conductivity, absorbance, etc., and the heavy metal content is measured through these variables. At present, various enzymes such as urease, glucose oxidase, phosphatase, and protease have been used to detect heavy metals in food, and detection technologies include biosensors, enzyme reactors, etc. Da Silva et al. [17] developed a new type of glucose oxidase electrochemical biosensor with high sensitivity, low detection limit, good reproducibility, stability and selectivity, and was successfully used to detect Hg2+, Trace detection of Cd2 + and Pb2 +. Lukyanenko et al. [18] used a handheld enzymatic luminescence biosensor to achieve rapid detection of Cu2+ in drinking water. The detection system is based on a thermally stable silicon photomultiplier (SiPM), consisting of a handheld photometer and a microfluidic chip. The detection limit for copper sulfate is 2.5 mg/L.

The enzyme inhibition method is simple and convenient, but it is mostly used for environmental sample detection, and there are relatively few reports on its use in food testing. Future research should focus on developing enzyme sources that are specific and stable for multiple heavy metals, optimizing pre-treatment methods, reducing interference from complex sample matrices, improving the extraction rate of heavy metals in food, and increasing the use of enzyme inhibition methods in food testing. research in the field.

### 2.3 Immunoassay Technology

#### *2.3.1 ELISA*

ELISA is an immunoassay method that uses enzymes as markers and has been used to detect a variety of heavy metal contaminants in food. The method is fast, sensitive, simple, and suitable for on-site detection [19]. Xu et al. [20] used ELISA method to detect Pb2+ in drinking water, food and seed samples based on self-made monoclonal antibodies. The detection limit reached 0.7 ng/mL and the recovery rate was 82.1% to 108.3%. Hao Dailing et al. [21] established indirect and direct competition ELISA detection methods for Cu2+ in food based on the prepared heavy metal copper monoclonal antibody. The two methods have good sensitivity, detection limit and linear range.

The ELISA method is currently developing rapidly, with short detection time, easy operation, and low cost. However, there are still problems in the research process such as environmental pollution from sample pretreatment, preparation of new chelating agents, and the urgent need to enhance antibody specificity [19].

#### *2.3.2 Colloidal gold immunochromatography test paper method*

Colloidal gold immunochromatography (gold immune-chromato-graphic assay, GICA) is a qualitative or semi-quantitative immunoassay technology using colloidal gold as a label. Liu Meichen et al. [22] and Zhao Xiaoxu et al. [23] respectively used colloidal gold immunochromatographic test paper method to achieve rapid quantitative detection of Pb2+ in brown rice and dairy products, and the detection results were consistent with the AAS method. This method is simple and easy to operate, and can be used for on-site rapid preliminary screening of various substances such as veterinary drugs, antibiotics, pesticide residues, heavy metals, toxins, etc. in food [24]. However, the disadvantages of the colloidal gold immune test paper method are that the test results are unreliable and have poor stability. How to apply new materials to improve the sensitivity, accuracy and stability of the test results will be the focus of future research.

#### *2.3.3 Chemiluminescence immunoassay*

Chemiluminescence immunoassay has fast analysis speed, high sensitivity, wide linear range, simple equipment, and good response to a variety of complex compounds, and has been widely used in food analysis [25]. Xu et al. [20] used chemiluminescence enzyme immunoassay to detect Pb2+ in food, with a low detection limit (0.1 ng/mL) and a high recovery rate (80.1% to 98.8%).

Based on chemiluminescence technology, electrochemiluminescence technology (elec-trochemiluminescence, ECL) has gradually developed. This technology integrates electrochemical analysis technology and chemiluminescence technology. The principle is that under a certain excitation voltage, unstable intermediate substances will be produced on the electrode surface. The unstable intermediates react with each other or with other substances in the system to produce light radiation. Phenomenon, the generated photons are received by optical instruments and converted into emission spectra for trace analysis of substances. This technology has good selectivity, high sensitivity, good reproducibility, low detection limit, and wide response range. It has become a research hotspot in the field of food safety and quality testing.

In the 1960s, scholars began to study electrochemiluminescence. The development of electronic technology and the emergence of high-sensitivity photoelectric sensors provide powerful tools for the study of electrochemiluminescence technology. In the 1980s, electrochemiluminescence technology entered the application stage. High-performance liquid chromatography (HPLC) and capillary electrophoresis (CE) rely on electrochemiluminescence analysis technology and flow injection analysis (FIA) technology to improve the reproducibility and stability of optical signals sex. The electrochemiluminescence of ruthenium terpyridine was one of the important discoveries of this period. After the 1990s, electrochemiluminescence equipment, electrode materials, and optical signal transmission materials have further developed, and the application scope of electrochemical analysis has expanded to immune analysis, drug analysis, biologically active substances, and in vivo analysis. At present, electrochemiluminescence systems are mainly divided into inorganic, organic and semiconductor nanomaterial systems, namely quantum dot systems.

Because quantum systems have the characteristics of good stability, tunable emission, good biocompatibility, and low toxicity, researchers have combined quantum dot technology and electrochemiluminescence technology to develop a variety of sensing devices for food detection. Enhanced detection sensitivity and specificity. Feng et al. [26] combined MIL-53(Al)@CdTe with electrochemiluminescence to achieve rapid detection of Hg2+ and Pb2+. The two heavy metal ion aptamer sensors have low detection limits and can be used in actual samples such as fish and shrimp. Detection of heavy metal content. Electrochemiluminescence technology can also be combined with microfluidic technology for food heavy metal detection. Disposable microfluidic polymer chip or paper chip technology is low-cost and easy to operate. The sample preprocessing and separation process is completed on the chip, directly through a mobile phone or the naked eye. The detection results can be obtained immediately. The disadvantage of microfluidic devices is lower sensitivity, which is attributed to less sample volume and reagent consumption [27].

Electrochemiluminescence technology has obvious advantages, but it still has shortcomings in detection specificity, sensitivity, and multi-component collaborative detection. In the future, this technology will continue to be combined with nanomaterials, and some nanomaterials can be used as emission sources for electrochemiluminescence. At the same time, we will continue to use the surface plasmon resonance, good conductivity and magnetism of nanomaterials to design new electrochemical luminescence sensors; on the other hand, we will explore combinations with other technologies to improve detection results.

### 2.4 Electrochemical Sensors

Biosensors enable rapid, economical, and high-throughput analysis of heavy metal contaminants in food and the environment. The principle of this technology is that after the sample is identified by the biometric element, it is converted into a measurable signal by a signal converter. The principle of electrochemical sensors is similar to that of biosensors. They are based on measuring the electrochemical properties of substances, or converting chemical signals of substances into electrical signals for measurement. Electrochemical sensors usually consist of two parts. One part is a sensor that can selectively identify the substance to be measured, and the other part is a signal conversion device that converts the signal from one form to another.

Electrochemical technology has been developed for a long time. Due to its high efficiency, portability and high sensitivity, it has been used in many fields such as biomedicine, environmental testing, food testing and analysis. New materials have pushed the development of electrochemical sensors into a new stage, providing many new methods for sensor design. Zhang et al. [28] developed an economical and practical electrochemical platform to detect Cd2+, Pb2+, and Hg2+ in orange juice and apple juice. The information terminal of this platform only requires a smartphone and a homemade voltage regulator as an electrochemical analysis tool. The sensitivity and accuracy of the detection results are good. Yu Yali et al. [29] successfully developed an electrochemical sensor with a self-assembled gold electrode based on the T-Hg-T model for detecting Hg2+ in fish. When the Hg2+ concentration is 1 to 104 nmol/L, the linearity is good (R2=0.997 ), the detection limit is low (0.5 nmol/L). Yu et al. [30] used dandelion-shaped copper oxide nanospheres decorated with gold nanoparticles as the modified material of the sensor, and used the T-Hg-T structure to trigger a hybridization chain reaction for signal amplification to measure Hg2+, and achieved satisfactory results. Wang et al. [31] developed a new Cd2+ electrochemical aptasensor based on graphene/graphitic carbon silicon nitride nanocomposite material, which has good selectivity, low detection limit (0.337 nmol/L), high sensitivity and linearity. Wide range (1 ~ 1 000 nmol/L).

The test performance of electrochemical sensors based on nanomaterial modification has been significantly improved, opening up a new channel for the detection of heavy metals in food. However, there are still problems in the research and promotion process such as relatively high cost, complex preparation process of nanomaterials, low reuse rate, weak combination of nanomaterials and electrodes, large detection equipment, low degree of automation, and low degree of marketization. Therefore, future research will be improved in the following aspects: first, synthesis of new nanomaterials with good electrochemical properties, high stability, and strong interaction; second, portability and automation of detection equipment; third, commercialization and integration of new sensors applied to actual testing.

### 2.5 Biological Barcoding Technology

Biological barcoding technology is a new molecular biology amplification technology that uses oligonucleotides as target identifiers for protein and nucleic acid detection. Gold nanoparticles (AuNPs) are used as biological barcode carriers to detect target molecules [32]. In 2003, Nam et al. [33] proposed nanoparticles based on biological barcodes for the first time, which can detect proteins extremely sensitively. After that, a large number of related research appeared in the fields of clinical drugs and basic life sciences [34]. Biological barcoding technology for food heavy metal detection started late and had a small scope. Until 2008, Shen et al. [35] based on deoxyribonucleic acid (DNA) electrochemical sensors, used biological barcoding technology to enhance the signal and reduce the detection limit ( 1 nmol/L), improving sensitivity and successfully detecting heavy metal lead in food.

Biological barcoding technology has broad prospects, but this technology is still immature and has drawbacks that cannot be ignored, one of which is the preparation of monoclonal antibodies. Monoclonal antibodies on the market are very expensive, and for small molecules like heavy metals, it is very difficult to prepare antibodies. Antibodies are indispensable substances for biological barcoding technology. How to reduce the cost of antibodies is currently a problem that needs to be solved. Another significant disadvantage is that biological barcode detection requires DNA amplification before electrophoresis or chip detection. The problem of expensive equipment limits the practical application of this method. Compared with other rapid testing methods, there are fewer literature reports on biological barcoding technology in food testing. The biggest reason may be that the testing cost is high.

### 2.6 Information Technology

At present, the development of information technology has reached a new level, and big data, cloud computing, Internet of Things and artificial intelligence have been applied to food safety supervision. It is inevitable to generate a large amount of data in almost all social fields. Applying big data to the field of food safety is very necessary to establish a food safety system. Currently, there are many examples of using big data. For example, large chain restaurants collect the transportation temperature, shelf life and quality indicators of food to ensure that relevant food can be quickly recalled from the restaurant when problems arise. The cloud computing center is a huge data information reception, security assessment, early warning and storage system. It can evaluate the safety of food and calculate the corresponding food safety level. E-waste contains potential environmental pollutants such as heavy metals and industrial compounds , and large amounts of e-waste will contaminate the environment, water and food. Cloud computing networks can be expanded by providing computing services to remote areas, thereby reducing the generation of e-waste.

Based on big data and cloud computing, the Internet of Things emerged as the times require. The Internet of Things can obtain original information about food ingredients and achieve real-time tracking. Technologies related to health, environment, and food can also be integrated through the Internet of Things to solve global health problems. Big data is the driving force behind the development of artificial intelligence (AI). As a new technology, artificial intelligence accelerates the process of collecting data through computer technology to simulate human thinking. Food supervision and testing can take advantage of the unique analytical calculation and self-learning capabilities of artificial intelligence. Researchers have developed an intelligent cloud platform embedded with intelligent algorithms to predict the sensory properties of food. An infrared spectrometer platform can also be used to detect allergic substances to ensure production line safety [36]. Jia et al. [37] designed a wearable camera containing a miniature camera and a motion sensor. This camera can automatically adjust the field of view of the captured image, and the accuracy of detecting various indicators of food and beverages is 91.5% and 86.4%. There are relatively few reports on the use of artificial intelligence for heavy metal detection in food, and this will definitely become the direction of future research.

The fourth industrial revolution marked by artificial intelligence will affect the reconstruction of the world economic order. The application of artificial intelligence in the field of food safety will be the direction of future food supervision. On the one hand, artificial intelligence can strengthen the supervision of food market order; on the other hand, artificial intelligence will help solve consumers' needs for high-quality and safe food.

## 3 CONCLUSION

Food safety is a major public security issue faced by all countries in the world that affects national stability and social harmony. Especially in recent years, food safety incidents have occurred frequently around the world, the safety situation is severe, and the overall food safety situation is not optimistic. Rapid detection technology for heavy metals in food has developed rapidly, but there are still the following problems. First, some rapid detection equipment has low sensitivity and poor stability, making it difficult to meet the accuracy and precision requirements of actual sample detection; second, the pre-processing steps are generally cumbersome and matrix interference is serious. ; Third, the rapid inspection equipment is relatively large and difficult to carry around. In the future, food heavy metal rapid testing technology will develop in the direction of increased sensitivity, shortened time, improved selectivity, portable and modularized testing equipment, which will make it easier for testing personnel to carry out work at any time and play an effective preventive role in food testing. Ensure food safety. In addition, novel analytical methods and the application of new functional materials will continue to become research hotspots in the field of food heavy metal detection. Combining biological barcoding technology with other technologies to improve detection sensitivity and convenience will be one of the research directions.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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