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Mini Review

Rapid Screening Methods to Detect Lead and Cadmium in Textiles

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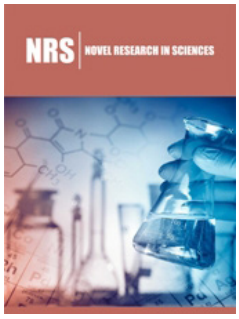

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Abstract

The detection of lead and cadmium is one of routine test items in the third party testing organization. Due to the quantity of positive samples is less than 1% in recent years, it is meaningful to develop rapid screening method to screen the positive samples. This review summarizes the progress of rapid screening methods of lead and cadmium, which includes the development of the pre-processing step and the detection step. With these rapid screening methods, it will save a lot of time and extraction reagent. Furthermore, the further study of the current research field is prospected in this review.

Keywords: Rapid screening methods; Lead and cadmium; Environment; Ecological textiles; Homogeneous samples; Chromogenic reaction

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Introduction

Lead and cadmium can cause serious health problems for human. The lead and cadmium in textiles mainly come from two ways: One way is absorption and enrichment of heavy metals in the environment during the plant fiber growing process. The other way is the post-processing of fabrics, such as dying and adding additive. Both the European Union and China have drawn up related regulations about the limit values of lead and cadmium in textiles. The thresholds of lead and cadmium for textiles depend on extraction condition and the product classifications, which have been identified in the standards such as the Standard 100 by the OEKO-TEX® [1], GB/T 18885-2020 Technical specifications of ecological textiles [2] and GB 31701-2015 Safety technical code for infants and children textile products [3], and so on. The specific limit values will not be elaborated here.

GB/T 30157-2013 Textiles-Determination of total content of lead and cadmium has been usually used to test the total content of lead and cadmium in textiles in the third party inspection agency in China [4]. The GB/T 17593.2-2007 Textiles-Determination of heavy metals-Part 2: Inductively coupled plasma atomic emission spectrometry is usually used to test the extractable content of lead and cadmium in textiles in the third party inspection agency in China [5]. Generally, the testing involves a three-step process: sample pretreatment, microwave digestion (solvent extraction), and instrumental determination. Large and precise instruments such as Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) are necessary for the instrumental determination. Although the results are reliable, the testing process is time-consuming and costs high. Therefore, the rapid screening methods to simplify the extraction process and replace the instrumental determination are highly needed.

Rapid Screening Methods

X-ray fluorescent method

X-Ray Fluorescent method (XRF) shows great application perspective as it is nondestructive, quick and low-cost. The testing principle is shown in Figure 1. This method has been applied to screen out lead and cadmium on the surface layer of the textiles. In the standard SN/T 4360-2015 Textile-Screening of heavy metals (Pb, Cd, Hg, Ni)-Energy dispersive X-ray fluorescence

spectrometric method, the limit detection of lead and cadmium is 50mg/kg [6]. Yongjie Hu et al. developed this method to determine the total heavy metal content was of children's textiles [7]. The results showed that the result using XRF is in good agreement with that of the current standard determination methods. Moreover, the detection limit of lead and cadmium is less than or equal to 5mg/kg, which satisfies the detection limit of children's textiles. However, XRF is suitable for homogeneous samples; the result will not be accurate if the sample is not homogeneous such as the mixture of different colors or materials.

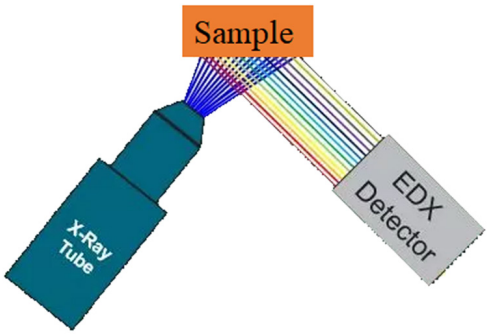

Figure 1: The principle of X-ray fluorescence spectrometer.

Colorimetric analysis

The basic principle of the method is that lead or cadmium reacts with chromogenic agents to identify the correlated heavy metal. The color range shows semi-quantitative results.

The main advantages of this method are:

a. Expensive instrument such as ICP-AES or XFR is not necessary so that the experiment is cheap.

b. The chromogenic reaction is quick and the chromogenic agents are diverse.

c. The chromogenic reaction is easy be processed into reagent kits. For example, the standard colorimetric plate for chromogenic reactions for the rapid determination of lead or cadmium is shown in Figure 2 [8].

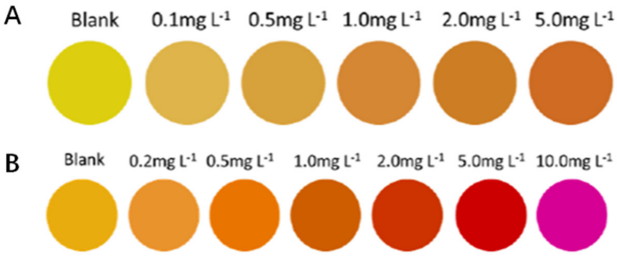

Figure 2: Cadmium (A) and lead (B) standard colorimetric plates.

Although cadmium and lead testing kits are user-friendly, the shortcomings is also obvious. Firstly, the sensitivity is not very high, and the result only stands for qualitative and semi-quantitative results. Secondly, it still needs pretreatment of textile samples such as acid digestion. Thirdly, the chromogenic agents is few specific to one specific kind of metal, so it will show false-positive test results in some cases. Therefore, combined chromogenic agents may be a good choice in the practice.

Biological colloidal gold technology

The colloidal gold technique is a technique that combines antigen-antibody immune reaction with colloidal gold labeling for antigen and antibody detection. The principle is schemed in Figure 3, The antigen labeled with colloidal gold is fixed on the conjugated pad. The antibody from the sample combines with the labeled antigen and flows to the testing line. The antibody from the sample captures with the lgM antibody on the testing line so that the labeled antigen gathers to show color. If the labeled antigen does not be captured by the antibody on the testing line, it will be captured by the antibody on the control line and show color [9]. It can quickly detect heavy metal ions qualitatively or semi-quantitatively, its operation is simple, fast, and highly specific. However, the development of colloidal gold technology has been hindered because this technology is very expensive and can only be used for qualitative and semi-quantitative results.

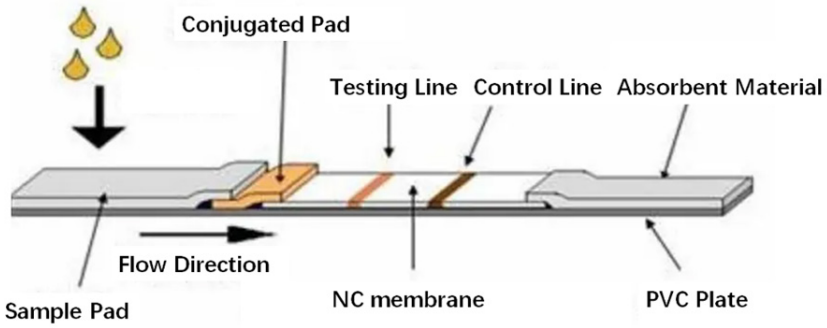

Figure 3: The testing process of colloidal gold test strips.

Conclusion and Prospect

XRF, colorimetric method, and biological colloidal gold technology for rapid screening method of lead and cadmium has showed great application prospect and attracted much attention, but there are still some shortcomings, respectively. XRF is only applicable for homogeneous samples of surface layer, and X-ray cannot attach the deep layer of the samples. If the coating layer is too thick and not homogeneous, the result will be incorrect. For

the colorimetric method, the sensitivity of reported chromogenic agents. The sensitivity of reported chromogenic agent is not high enough, and there is interference from other substances. Usually, qualitative or semi-quantitative screening testing is performed. It needs sample pretreatment using strong acid. For the biological colloidal gold method, the kit preparation is cumbersome and the cost is high. Moreover, the detection limit, the reproducibility and accuracy still need to be improved correspondingly. However, these rapid screening methods will get more and more applications with limited drawbacks.

Acknowledgement

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