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Research Article

SORPTION SPECTROSCOPIC METHOD FOR THE DETERMINATION OF CHROMIUM (III) IONS

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ABSTRACT

The presence of chromium in the environment poses a potential mutagenic hazard to all animal and plant life, including humans. Methods have been proposed for detecting the formation of chromium, isolating it, and recovering it from contaminated environmental samples. The permissible limits of chromium in environmental samples such as industrial waste, workplace particles, plants, aquatic animals, and food samples have been studied. A suitable organic reagent has been selected. A sorption spectroscopic method has been developed for the determination of chromium (III) in industrial effluents. An optimal sorbent has been selected for the chosen organic reagent. A method for immobilization was developed, and immobilization was carried out with the selected carrier. The pH dependence of the complex formation between chromium (III) and the organic reagent was studied. The structure of the complex formed with the immobilized Nitrozo-R reagent was confirmed by scanning electron microscopy (SEM) and X-ray fluorescence spectroscopy.

KEYWORDS

Sorption-spectroscopy, immobilization, nitroso-R-salt, chromium, organic reagents, PPA fiber.

INTRODUCTION

Chromium exists in various forms in the environment, and its toxicity levels vary accordingly. In its hexavalent form, chromium is highly soluble in water. This property allows it to easily contaminate water bodies and become bioavailable to humans by reacting with cellular components. Long-term exposure to chromium in humans can lead to a range of serious health issues, including microcytic anemia, damage to mitochondrial and blood cell DNA, which in turn can cause carcinogenicity, occupational asthma, heightened sensitivity of the respiratory system, and inflammatory diseases of the nose and eyes. Pollution is not only endemic but also propagated through other branches of the natural environment, such as the food chain and transportation systems. Numerous studies are ongoing to reduce the levels of chromium contamination in the environment. [1-2]

The recommended daily intake of chromium is 35 µg for men and 25 µg for women. However, for individuals over the age of 50, it is advised to reduce the daily dose to 30 µg for men and 25 µg for women. [3]

Excess chromium in the form of industrially used chromates poses significant health risks due to its accumulation in the body. Its toxicity can result in skin irritation, allergic reactions, and even cancer. Prolonged exposure to chromium can lead to the development of conditions such as digestive disorders, nausea, vomiting, abdominal pain, diarrhea, dehydration, impaired kidney function, cardiovascular dysfunction (including blood pressure fluctuations and arrhythmias), and deterioration of the nervous system. This includes symptoms like irritability, anxiety, depression, headaches, impaired motor coordination, memory loss, sleep disturbances, vision problems, damage to the liver and kidneys, and hormonal imbalances. [4]

For decades, river sediments exposed to manganese-laden wastewater have been found to contain not only numerous microorganisms but also organic and inorganic substances. To effectively treat wastewater containing chromium (Cr) and extract Cr from water and sediments, the sorption mechanisms of Cr ions in wastewater from chromium mining areas have been studied. This research aims to provide guidelines for managing and recovering Cr from river sediments in chromium mining regions, as well as to offer a better understanding of the sorption and desorption mechanisms. [5]

Currently, various organic reagents are being used to detect heavy and toxic metal ions in wastewater and industrial effluent. There are numerous methods available for detecting chromium (III) ions. In this study, an organic reagent containing a nitroso group, specifically nitroso-R-salt, was used for the detection of chromium (III) ions.

Selection of the Optimal Carrier

Table 1

Fiber	A Before Immobilization	A, After Immobilization	ΔA
PPA	0,553	0,295	0,298
PPD	0,553	0,433	0,12
PPF	0,553	0,387	0,166
SMA-1	0,553	0,424	0,129

SMA-2	0,553	0,490	0,063
SMA-3	0,553	0,465	0,088

Various carriers were selected for immobilization. To prepare them for immobilization, they were converted into their chloride form. For this, 0.2000 g of each carrier was weighed using an analytical balance and immersed in 50.0 mL of 0.1 M HCl for 1 hour. They were then washed 2-3 times with distilled water. The carriers that transitioned into the chloride form were immersed in the nitroso-R-salt reagent, and the optimal carrier was selected. Based on the results presented in Table 1, PPA fiber was chosen as the optimal carrier.

The spectra of the organic reagent and complex compounds are described in Figure 1.

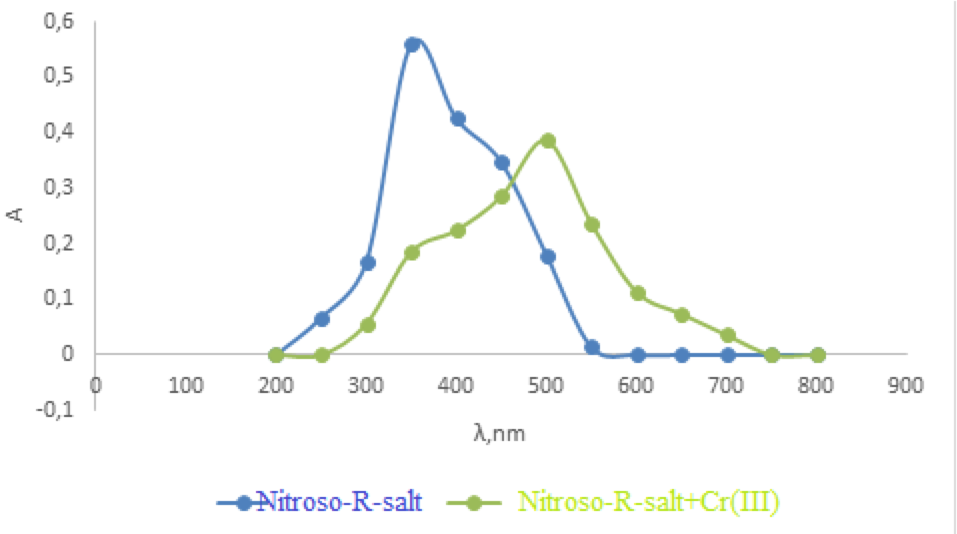

Figure 1. Spectra of Nitrozo-R-salt and its complexes with Cr(III) ions

The presence of the complex formed between immobilized PPA fiber and Cr(III) ions can be explained by the diffraction patterns in the analysis from the scanning electron microscopy (SEM) detector, which show a signal characteristic of chromium ions. The analysis results are presented in Figure 2.

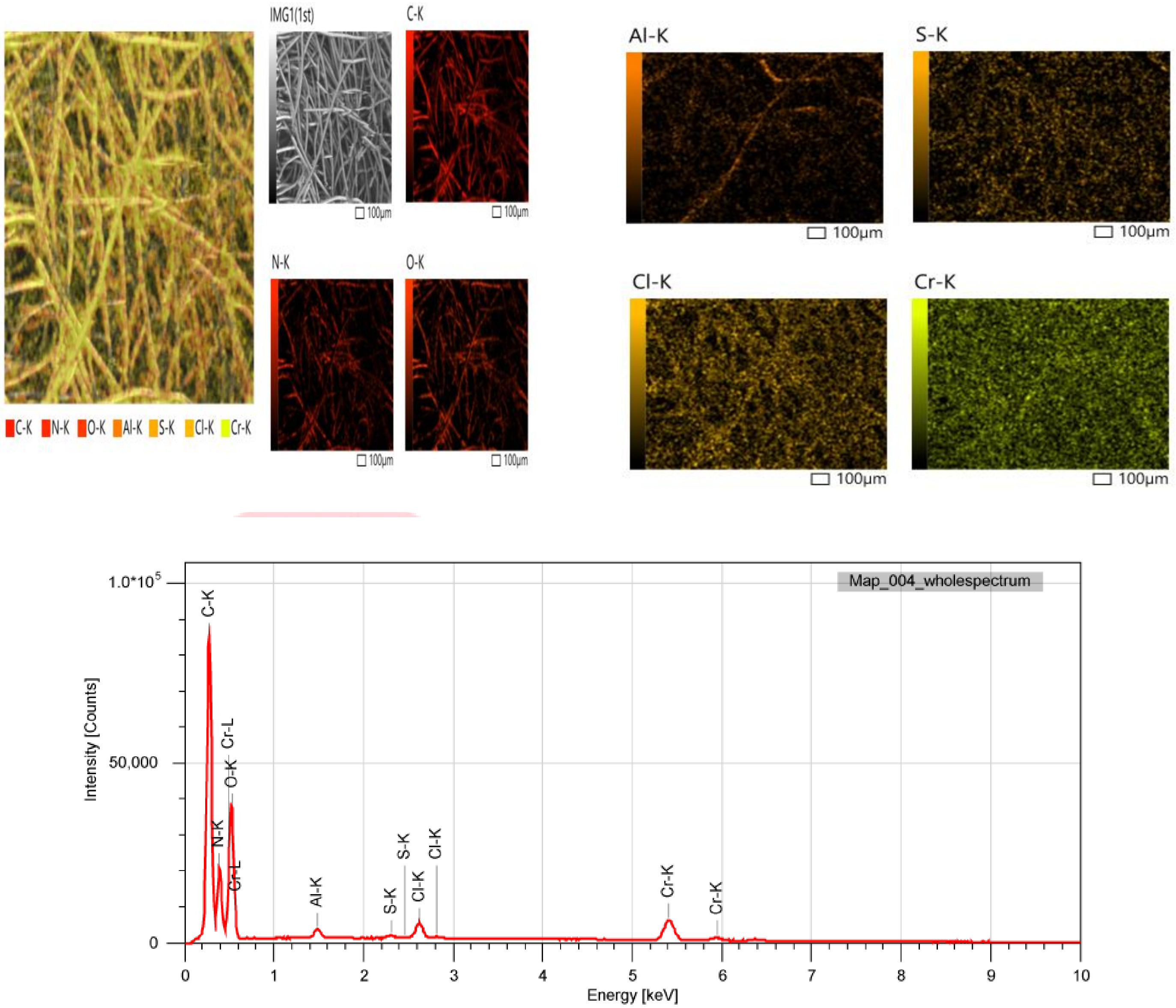

Figure 2. Complex formed by Cr(III) ions with nitroso-R-salt immobilized on PPA fiber

Table 2

SEM Analysis Results of the Complex Formed by Cr(III) Ions with Nitrozo-R-salt Immobilized on PPA Fiber

Element	Nitroso-R-salt + PPA		Nitroso-R-salt + PPA +Cr(III)	
	Masa%	Atom%	Masa%	Atom%
C	36.15±0.03	42.54±0.03	35.76±0.03	43.81±0.03
N	26.98±0.07	27.23±0.07	25.15±0.06	26.42±0.07
O	32.69±0.07	28.88±0.06	29.06±0.06	26.73±0.06
Al	0.35±0.00	0.18±0.00	0.34±0.00	0.18±0.00

S	0.13±0.00	0.06±0.00	0.13±0.00	0.06±0.00
Cl	0.79±0.01	0.32±0.00	0.75±0.01	0.31±0.00
Cr	2.90±0.01	0.79±0.00	8.81±0.32	2.49±0.09

According to the analysis results, the presence of Cr(III) ions in the immobilized PPA fiber complex formed with the metal ion indicates the selectivity and efficiency of the developed method. The structure of the immobilized complex was studied using X-ray fluorescence. The composition of the complex formed by Cr(III) ions with the immobilized nitroso-R-salt reagent was analyzed through X-ray fluorescence.

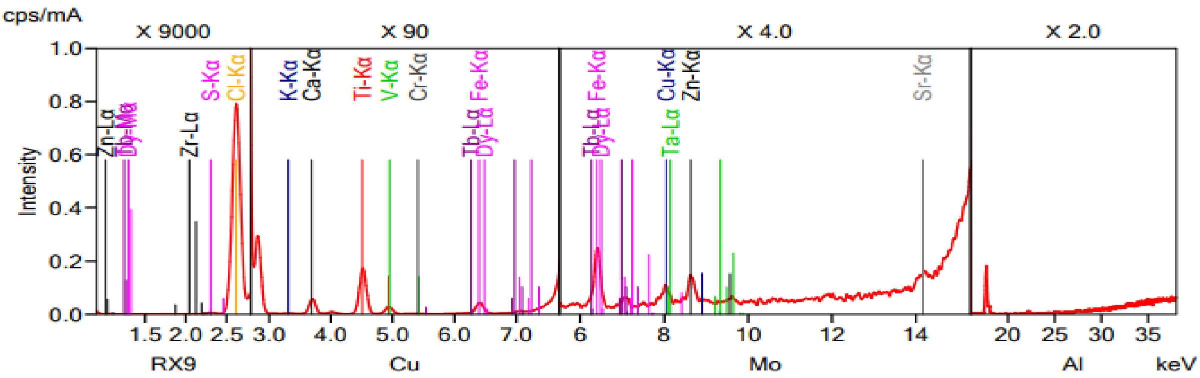

Figure 3. Immobilized Nitrozo-R-salt

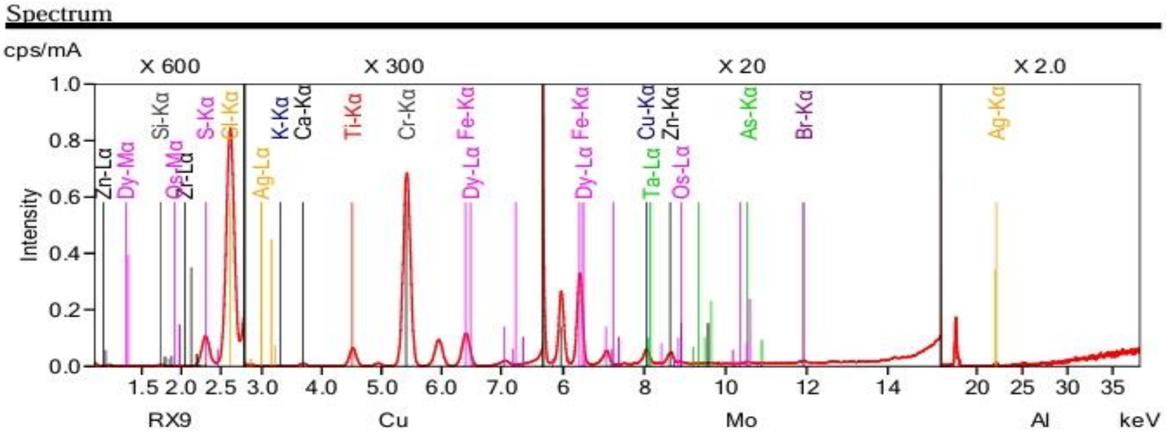

Figure 4. Complex formed by immobilized Nitrozo-R-salt and Cr(III) ions

Based on the results obtained from the X-ray fluorescence analysis of the complex formed by Cr(III) ions with the nitroso-R-salt reagent, it was proven that the complex was indeed formed. The optimal conditions for detection (pH = 3-4, t = 15 min, T = 25°C) were selected.

It can be concluded that the toxic properties of heavy metals on the health of living organisms are negative, and this requires constant environmental monitoring as well as ongoing control over the composition of wastewater and waste from industrial enterprises and other industrial facilities. Furthermore, it has been proven that there is a need to develop new modern analytical methods for detecting heavy metals in waste and wastewater. The method developed in this study will help to achieve the goal of increasing the detection rate while reducing the emissions of pollutants during the analysis of concentrations in chromium industries.

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