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SORPTION-SPECTROSCOPIC DETERMINATION OF CHROME (III) IONS FROM ENVIRONMENTAL OBJECTS

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Abstract

The permissible environmental limit values were studied, and an optimal organic reagent was selected. A sorption spectroscopic method for the determination of chromium (III) ions in industrial wastewater was developed. A suitable sorbent for the selected organic reagent was chosen. The immobilization methodology was developed and implemented. Immobilization was carried out using the selected carrier. The pH dependence of the formation of the complex between the organic reagent and chromium (III) ion was studied. The structure of the complex formed by the immobilized nitroso-R-salt reagent and the mechanism of reagent immobilization onto the fiber were confirmed using Scanning Electron Microscope (SEM) and X-ray fluorescence.

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

Introduction

The presence of hexavalent chromium in the environment poses a potential mutagenic risk to all living organisms, including humans. Over the last few decades, numerous physicochemical and biochemical mechanisms have been discovered for detecting chromium formation, isolating it, and recovering it from contaminated environmental samples. This review addresses the detection of chromium species in various environmental samples, including industrial waste, workplace dust, plants, aquatic animals, and food samples. It discusses both physical, chemical, and biological analysis methods, with particular focus on extraction/recovery techniques. The goal of this article is to provide an understanding of the advances in this field that can be applied from laboratory to industrial levels [1].

Chromium occurs in various forms in the environment, and its toxicity levels vary accordingly. In its hexavalent state, chromium is highly soluble in water. This allows it to easily contaminate water bodies and become bioavailable, reacting with cellular components, which makes it a significant health risk for humans. Long-term exposure to chromium leads to several severe health conditions, including microcytic anemia, damage to mitochondria, and the DNA of blood cells. These effects can result in carcinogenicity, occupational asthma, heightened sensitivity of the respiratory system, and inflammatory diseases of the nose and eyes. Chromium pollution spreads not only at endemic levels but also through other environmental pathways, such as food chains and transportation systems. Numerous studies are ongoing to reduce the levels of chromium pollution in the environment [2].

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

Excessive amounts of chromates, commonly used in industry, accumulate in the body and pose serious health risks. Their toxicity includes symptoms like skin irritation, allergic reactions, and even cancer. Long-term exposure to chromium compounds can lead to digestive issues, nausea, vomiting, abdominal pain, diarrhea, dehydration, kidney dysfunction, cardiovascular dysfunction (changes in blood pressure, arrhythmia), deterioration of the nervous system, anxiety, depression, headaches, coordination problems, memory loss, sleep disturbances, vision problems, and liver and kidney damage. Hormonal imbalances are also a common effect of prolonged exposure [4].

For many years, river sediments exposed to manganese-rich effluents have contained not only numerous microorganisms but also organic and inorganic substances. The effective treatment of chromium-containing wastewater and the extraction of chromium from water and sediment have been studied using sorption mechanisms. This research aims to provide guidelines for managing and recovering chromium from river sediments in chromium extraction areas, enhancing the understanding of the sorption and desorption mechanisms involved [5].

Currently, various organic reagents are used to detect heavy and toxic metal ions in wastewater and industrial effluents. Many methods are available for detecting chromium (III) ions. In this study, the organic reagent nitrozo-R-salt, which contains a nitrozo group, was used to detect 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

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Various carriers were selected to determine the optimal immobilized carrier. To prepare these carriers for immobilization, they were converted into their chloride form. For this purpose, 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. Afterward, the carriers were washed 2–3 times with distilled water. The carriers, which were converted into their chloride forms, were then treated with the nitrozo-R-salt reagent to identify the optimal carrier. Based on the results presented in Table 1, PPA fiber was chosen as the optimal carrier.

The spectral descriptions of the organic reagent and complex compounds are provided in Figure 1.

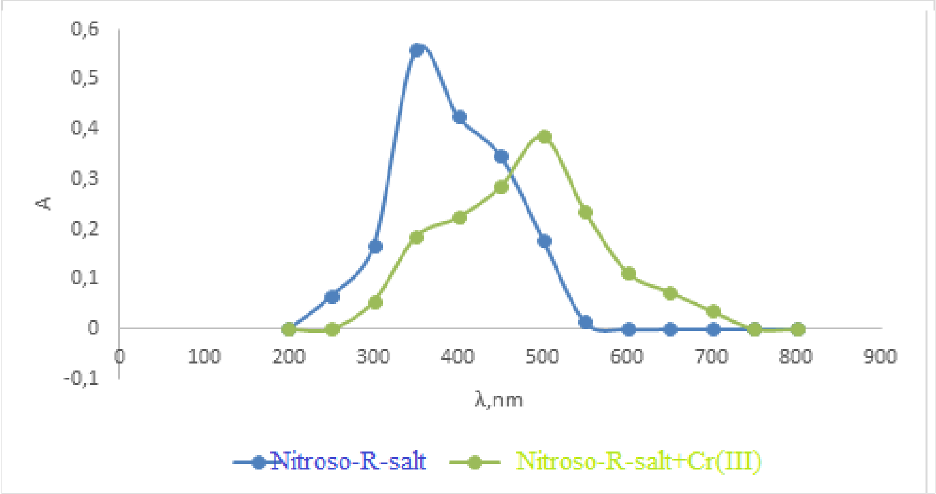
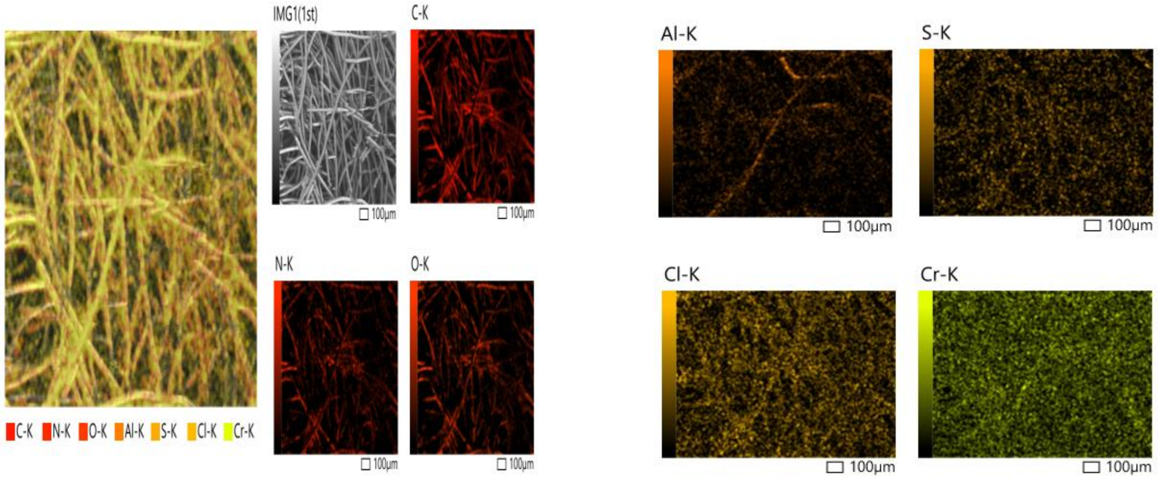


Figure 1. Spectra of Nitrozo-R-salt and its complexes with Cr(III) ions

The presence of the complex formed by the immobilized PPA fiber with Cr(III) ions can be explained by the characteristic signal of chromium ions observed in the diffractograms of the scanning electron microscopy (SEM) analysis detector. The analysis results are presented in Figure 2.



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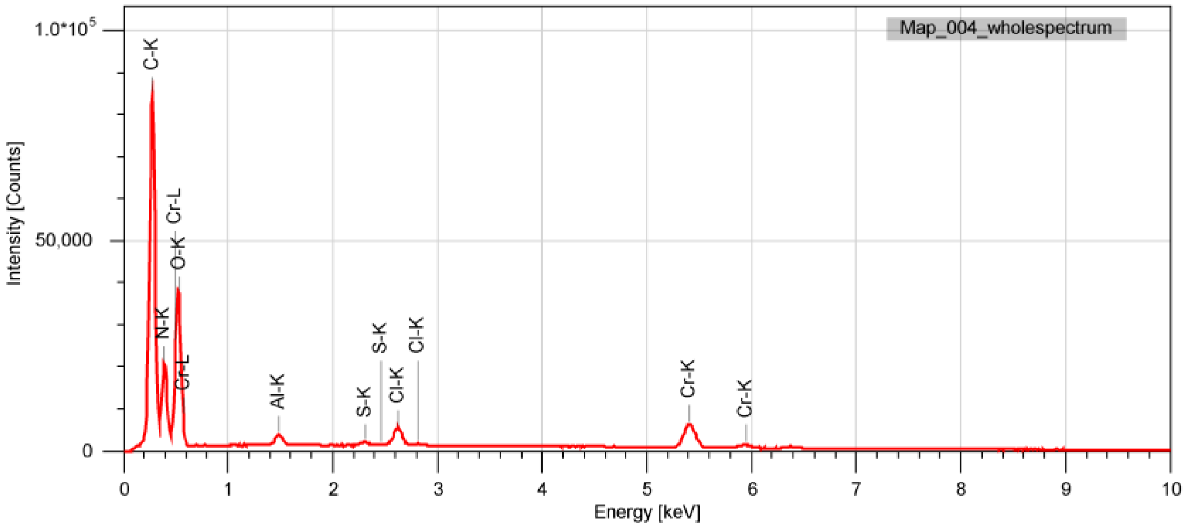

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Figure 2. Complex formed by Cr(III) ions with nitroso-R-salt immobilized on PPA fiber

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

The analysis results indicate the presence of Cr(III) ions in the immobilized PPA fiber that formed a complex with the metal ion. This confirms the selectivity and effectiveness of the developed method.

The structure of the immobilized complex was studied through X-ray fluorescence (XRF). The composition of the complex formed by Cr(III) ions and the immobilized nitrozo-R-salt reagent was investigated using XRF analysis.

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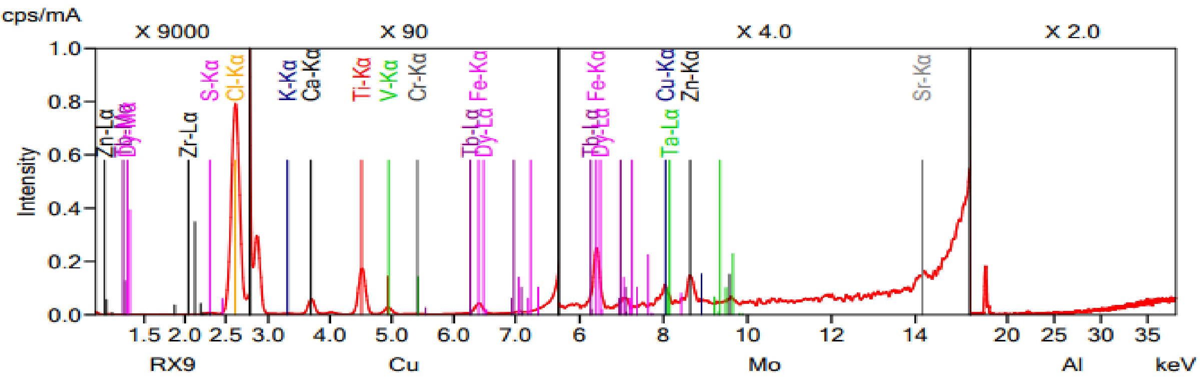

Figure 3. Immobilized Nitrozo-R-salt

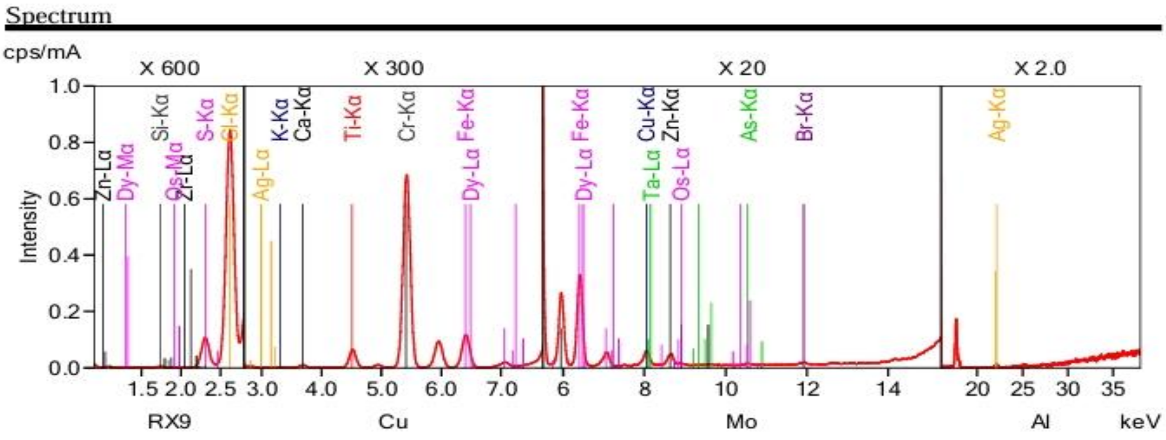

Figure 4. Complex formed by immobilized Nitrozo-R-salt and Cr(III) ions

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.

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