ANALYSIS OF HEAVY METAL IONS IN WASTEWATER

Miradxamova Gulyorxon O‘tkir kizi

Assistant, Tashkent State Technical University

named after I. Karimov, Olmaliq branch

Abstract: The present study examines the applicability of sorption-based methods combined with solid-phase immobilized reagents for the determination of toxic heavy metal ions in wastewater. Various sorbent materials, including polymer ion-exchange resins, naturally occurring minerals, and chemically modified nanoparticles, were employed to investigate metal uptake efficiency. Special emphasis was placed on the role of surface functional groups (–COOH, $–NH_2$, $–SO_3H$) in metal ion binding processes. Immobilization of organic chelating reagents within polymer supports resulted in a substantial enhancement of analytical sensitivity and selectivity. The developed approach enabled effective preconcentration and accurate determination of Cr(III), Cu(II), Mn(II), and Co(II) ions at trace concentration levels ranging from 10^{-5} to 10^{-6} mol/L. These findings highlight the practical significance of the proposed methodology for industrial wastewater monitoring, selective sorbent development, and the optimization of automated analytical techniques.

The occurrence of chromium and manganese ions in industrial wastewater is widespread and poses a considerable threat to environmental safety. Accurate detection and continuous control of Cr(III) and Mn(II) species remain challenging due to their variable oxidation behavior, coordination chemistry, and tendency to form stable aqueous complexes. Chromium predominantly exists in the trivalent state as strongly hydrated coordination compounds, whereas manganese is mainly present as Mn(II), characterized by high mobility and solubility in water. These chemical characteristics necessitate the use of selective reagents and tailored sorbent materials to ensure reliable and selective determination of these metal ions.

Sorption-based approaches provide an effective means for the selective separation and determination of Cr(III) and Mn(II) ions by exploiting differences in their physicochemical properties. The retention of metal ions on sorbent surfaces may occur through several mechanisms, including physical adsorption, ion-exchange interactions, and the formation of coordination or chelate complexes. Among these mechanisms, complex formation plays a dominant role in enhancing selectivity and sensitivity, particularly for transition metal ions with well-defined coordination behavior.

Sorbent materials functionalized with amino-containing groups exhibit strong affinity toward Cr(III) ions due to the ability of nitrogen donor atoms to form stable coordination bonds with trivalent chromium. These interactions lead to increased sorption capacity and improved analytical response, allowing efficient preconcentration of Cr(III) even at trace concentration levels. In contrast, Mn(II) ions demonstrate weaker binding interactions with amino-functionalized sorbents as a result of their lower complexation stability and higher hydration energy, which limits direct sorption-based detection.

To achieve selective differentiation between Cr(III) and Mn(II), the use of organic complex-forming reagents is required. Nitroso R-salt is a well-known chromogenic reagent capable of forming intensely colored chelate complexes with certain metal ions, exhibiting particularly high selectivity toward

Cr(III). When immobilized onto a solid support, nitroso R-salt retains its complexing ability while providing the advantages of solid-phase systems, including enhanced stability, reusability, and improved preconcentration efficiency.

The immobilized nitroso R-salt system enables sensitive photometric determination of Cr(III) at low concentration levels through the formation of a stable colored complex on the sorbent surface. Under optimized conditions, Mn(II) produces only weak or negligible coloration, which does not interfere with the analytical signal of Cr(III). This selective behavior allows accurate quantification of chromium in the presence of manganese, making the proposed approach highly suitable for the analysis of complex wastewater matrices.

The nitroso R-salt based sorption–spectrophotometric method is effective, sensitive, and selective for Cr(III) and Mn(II) determination in wastewater. Cr(III) forms stable chelates with high color intensity, while Mn(II) can be quantified after preconcentration. The immobilized sorbent reduces reagent consumption, simplifies analysis, and allows reuse.

References

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