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Perspective

Magnetic Silica MIPs Revolutionize Precise Neopterin Immune Biomarker Detection

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DESCRIPTION

Neopterin (NPT), a key indicator of immune system activation linked to infections, autoimmune diseases, and cancers. To overcome these limitations, researchers developed a system using magnetic silica-supported molecularly imprinted polymers (MIP-MS) combined with UV spectrophotometry. This technique enables selective, sensitive, and cost-effective detection of NPT in complex biological fluids (e.g., serum, cerebrospinal fluid). The MIPs are engineered to recognize and bind only NPT molecules, and the magnetic support allows for quick and easy sample separation.

Redefining biomarker detection through molecular imprinting

Neopterin is emerging as a critical biomarker in the realm of clinical diagnostics, primarily due to its association with immune system activation. Synthesized by monocytes and macrophages in response to interferon-gamma, NPT levels provide vital insight into immune status, particularly in pathological conditions such as viral infections, autoimmune disorders, and certain cancers. However, its clinical utility is often hindered by the limitations of conventional detection methods. High-Performance Liquid Chromatography (HPLC), ELISA, and even advanced techniques like SERS, though effective, can be costly, time-intensive, and environmentally unfriendly due to the use of organic solvents or radioactive substances.

In this context, a novel approach has been developed that integrates magnetic silica-supported Molecularly Imprinted Polymers (MIP-MS) with UV spectrophotometry. This method presents a transformative advancement for the selective extraction and quantification of NPT in biological samples. By capitalizing on the high specificity and reusability of MIPs, this technique not only enhances sensitivity but also ensures cost-effective and environmentally friendly diagnostics.

The synthesis of this MIP-MS composite follows a surface imprinting strategy, leveraging the structural and magnetic properties of magnetic silica Through precise engineering, a polymer layer is formed around the template molecule NPT creating highly selective recognition sites. These sites ensure that only molecules with a matching structure are retained during sample extraction. The combination of these molecular recognition sites with magnetic separation results in an efficient and robust system that can isolate NPT even in complex matrices like serum and cerebrospinal fluid.

Characterization techniques such as SEM, TEM, XRD, XPS, and VSM confirmed the successful fabrication of MIP-MS, with clear morphological and structural integrity. The adsorption kinetics aligned with a pseudo-second-order model, while the isotherm behavior fit the Langmuir model, indicating monolayer adsorption on homogenous binding sites. With an adsorption capacity of 98.3 mg/g and an imprinting factor of 4.77, the MIP-MS demonstrated excellent specificity toward NPT compared to non-imprinted polymers.

Moreover, this novel system showcased outstanding performance metrics. A wide linear detection ranges from 3 to 300 nM, an impressively low detection limit of 1.18 nM, and recovery rates between 97.6% and 100.4% all underscore its analytical robustness. The method's precision was further validated by a relative standard deviation of less than 5%, and its reusability was proven through consistent performance over ten adsorption-desorption cycles highlighting the method's practicality for routine clinical use.

Clinical and technological implications for the future

The integration of UV spectrophotometry with MIP-MS represents a substantial leap forward in clinical diagnostics, particularly for low-resource settings. Unlike techniques that demand highly skilled personnel or complex instrumentation, UV spectrophotometry is widely accessible and easy to operate. When combined with a selective sample preparation method such as MIP-based solid-phase extraction, it becomes a powerful yet practical tool for clinicians and researchers.

The key to this method's success lies in its synergy the molecular recognition precision of MIPs enhances selectivity, while the

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magnetic silica support ensures quick separation without centrifugation or filtration. This dramatically reduces analysis time and labor intensity. Furthermore, the use of environmentally safer solvents and reusable materials positions this technique as a sustainable alternative to traditional methods.

Applications of this platform extend far beyond NPT. The same design principles can be adapted to other biomarkers of diagnostic relevance, paving the way for a new class of selective, stable, and reusable sensors in biomedical analysis. Given the rising demand for point-of-care diagnostics and personalized medicine, such techniques offer scalable solutions that balance performance with affordability.

CONCLUSION

In summary, the development of a magnetic silica-supported molecularly imprinted polymer for the extraction and detection of neopterin *via* UV spectrophotometry addresses a critical need in the clinical diagnostic field. By overcoming the shortcomings of traditional methods, it offers a sensitive, rapid, and selective alternative for detecting immune system activity. With further validation and adaptation, this technique has the potential to revolutionize the monitoring of immune-mediated diseases and expand the accessibility of high-quality diagnostics worldwide.