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Developing polyamide nanofiltration membranes for treating radioactive waste effluents: a review

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The treatment of radioactive waste effluents has become increasingly critical with the global expansion of nuclear energy. Conventional methods, such as ion exchange, evaporation, and chemical precipitation, are effective but often limited by high energy requirements and secondary waste generation. Polyamide-based nanofiltration (NF) membranes offer a promising alternative due to their high selectivity, lower operational pressure, and scalability. However, these membranes exhibit vulnerability to gamma irradiation present in low- and intermediate-level radioactive waste (LILW), leading to structural degradation, reduced salt rejection, and diminished water permeability.

This review synthesizes recent advancements in the development of radiation-resistant polyamide NF membranes for nuclear wastewater treatment. Key strategies include surface functionalization with polyethyleneimine (PEI), the incorporation of Prussian Blue and graphene oxide, and the spray coating of titania nanosheets. These modifications have achieved enhanced rejection rates for radionuclides such as Co^{2+}, Sr^{2+}, and Cs^{+}, with values reaching up to 99.5% while preserving or improving water flux. Furthermore, uranium removal efficiencies have demonstrated strong pH and ionic dependency, with rejection rates ranging from 4% to 98%.

Despite these improvements, challenges remain in addressing fouling, maintaining long-term structural integrity under radiation exposure, and achieving consistent rejection of monovalent radionuclides. Future directions emphasize the need for hybrid membranes that integrate adsorption and separation functions, as well as real wastewater validations under operational conditions.

In conclusion, polyamide NF membranes hold significant potential as core components in next-generation radioactive effluent treatment systems, aligning with the goals of sustainable and safe nuclear energy deployment.

Technical Track

Fuel Cycle and Waste Management

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