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Feasibility Study on Thermochemical Regeneration of TEDA-impregnated Activated Carbon for HVAC System

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1. Introduction

Nuclear power plant heating, ventilation and air conditioning (HVAC) systems utilize TEDA(Triethylenediamine)-impregnated activated carbon (AC) as a critical adsorbent to capture radioactive iodine species, such as methyl iodide (CH_3I). However AC filters are periodically replaced due to adsorption saturation and material degradation, and the resulting spent AC is managed as radioactive solid waste. AS of 2016, the cumulative volume of spent AC in Korea reached approximately 4,000 drums, with disposal costs estimated at 15.11 million KRW per drum [1]. This situation imposes significant economic and environmental burdens. Therefore, the thermochemical regeneration and reuse of spent AC have emerged as vital strategy for radioactive waste reduction. This study evaluated the feasibility of reusing thermochemically regenerated TEDA-impregnated AC through structural characterization and CH_3I adsorption performance evaluation.

2. Methods

Four types of AC samples were prepared sequentially from the raw material: Fresh AC (Sample 1), 5 wt% TEDA-impregnated AC (Sample 2), simulated spent and thermochemically regenerated AC from Sample 2 (Sample 3), and TEDA re-impregnated AC from Sample 3 (Sample 4). Textural properties were analyzed using N_2 adsorption at 77 K and CO_2 adsorption at 273 K to evaluate changes in surface area and micropore structure. Surface chemistry and thermal stability were characterized by X-ray photoelectron spectroscopy (XPS) and thermogravimetric analysis (TGA). Finally, CH_3I breakthrough tests were conducted at 30°C following the ASTM D3803 standard to verify the recovery of functional performance.

3. Results and Discussion

While TEDA impregnation initially resulted in a reduction of BET surface area due to partial pore blockage, the thermochemical regeneration process effectively restored the microporous structure of the spent AC. 77K N_2 adsorption results confirmed that the micropore structure and specific surface area were effectively restored by comparing Sample 1 (raw AC) with Sample 3 (pores cleaned by thermochemical treatment). The BET surface area was 1,178.9 m^2/g for Sample 1 and 1,119.4 m^2/g for Sample 3 to 95% for Sample 3 compared to Sample 1. In the case of impregnated samples, Sample 2 (fresh TEDA-AC) had a BET of 942.8 m^2/g, while Sample 4 (re-impregnated with TEDA after treatment) showed a BET of 980.9 m^2/g, a 4.03% increase relative to Sample 2. These results indicate that the application of TEDA, a polymer for adsorbing radioactive gas, decreases in the specific surface area compared to unimpregnated activated carbon due to the blockage of some pores.

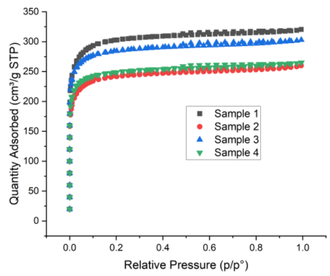

Fig. 1. Textural characterization of AC Samples by 77 K N_2 (Adsorption isotherms).

CH_3I Breakthrough tests conducted under an environment like ASTM D3803 revealed that the regenerated and re-impregnated AC exhibited adsorption behavior comparable to that of fresh TEDA-impregnated AC. These results demonstrate that the proposed regeneration process not only restores the physical pore structure but also recovers the chemical active sites necessary for effective iodine capture. Consequently, the regenerated AC meets the stringent performance requirements for nuclear air purification systems.

5. Conclusion

This study demonstrated that thermochemical regeneration followed by TEDA re-impregnation can effectively restore both the structural and adsorption properties of spent AC used in nuclear HVAC systems. The proposed regeneration strategy offers a practical approach to minimizing radioactive waste generation and enhancing the economic sustainability of nuclear power plant operation.

REFERENCES

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