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Validation and application of adsorption breakthrough models for the chemical filters used in the make-up air unit (MAU) of a cleanroom

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ABSTRACT

The dynamic adsorption capacity calculated from the breakthrough curves progressively decreased with the increases in the face velocity, suggesting that the effect of intraparticle diffusion and possibly the rate of adsorption as the rate-limiting mechanism were increasingly more profound for a chemical filter-type adsorber configuration. The Yoon–Nelson model generally matched well with the experimental breakthrough curved for breakthrough fraction less than 50%. However, the proportionality constant in the Yoon–Nelson model needed modification through the method from which the mass transfer coefficient (k_v) in the Wheeler–Jonas equation is determined. Subsequently, a series of breakthrough curves for the hypothetical toluene concentrations and face velocities simulating realistic operating conditions was generated, and their validity was verified against the adsorption capacity predicted by the Dubinin–Radushkevich isotherm equation. The useful life of a chemical filter could henceforth be estimated with confidence using the breakthrough curves predicted by the modified Yoon–Nelson model.

1. Introduction

Control of indoor air quality has been recognized as an area of research and practical interests due to its implication of health (occupants' welfare) and productivity (workers' safety and product yield). Major strategies for the control of indoor pollutants include source control, enclosure and ventilation at the source, as well as dilution and displacement ventilation [1]. In principle, the source control method restricts potentially harmful pollutant emissions, such as the volatile organic compounds (VOCs) and formaldehyde emissions from furnishings. Enclosure and ventilation at the source control pollutants generated by the activity of building occupants typically use local extractors, cooker, or range hoods to remove these pollutants at the source. Dilution and displacement ventilation are used for diluting and removing residual pollution from unavoidable contaminant sources, such as odors and CO_2 emissions generated by building occupants. In addition to these methods, filtration methods have been developed to remove gaseous-phase chemical pollutants using gas adsorption and chemical gas filters.

One of the special applications of chemical gas filters is the control of air molecular contaminant (AMC) in "cleanroom" settings which are designed to meet the stringent cleanliness requirement during product manufacturing, most notably the microelectronics device fabrication [2–5]. The control of organic AMCs is increasingly critical to the product yield and reliability as the degree of integration of microelectronic devices increases. In such cleanroom settings, the AMC sources generally fall into two categories: internal and external [6]. Some internal sources could be chemicals used in the manufacturing process, accidental spills, and off-gassing of cleanroom components. External sources vary significantly with plant location, its vicinity to traffics, and building design. In general, outside pollutants are removed from the make-up air unit (MAU), whereas indoor-generated contaminants are removed from the recirculating air handling units (AHU). Chemical filtration equipment installed in MAU systems are typically designed to control SO_x, NO_x, O_3, VOCs, and some site-specific

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