

呼吸治療器濾材性能探討(二)

**The study on filtration efficiency of  
breathing system filters for mechanical  
ventilator(II)**

研究主持人：陳春萬、萬國華

計畫主辦單位：行政院勞工委員會勞工安全衛生研究所

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行政院勞工委員會勞工安全衛生研究所  
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## 摘要

勞工安全衛生研究所過去研究顯示，不管是咳嗽和打噴嚏時或是一般呼吸狀況下，人員呼氣時都可能產生微粒，呼出微粒量隨著潮氣容積增加而增加。勞研所另外也研究證明，使用呼吸器之病患排氣也會產生微粒，但二種呼吸器模式(壓力控制模式與容積控制模式)下的病患所呼出之微粒，分佈並沒有明顯差異，濃度最高粒徑在  $0.3\sim 1.0\ \mu\text{m}$ ，濃度範圍在  $0.001\sim 0.098\ \text{particles/mL}$ ，在呼吸器管路吐氣端安裝的有摺式和靜電式二種過濾濾材，過濾效果相當。對於使用呼吸器病患排出之微粒中若含有病菌，醫護人員更應該注意，因此研究採用生物氣膠採樣器，評估不同呼吸器類型，不同呼吸條件下微粒與病菌產生情形。另依據次定結果及文獻相關措施，提出預防感染措施建議，提供醫護人員參考。

人體在不同的呼吸活動下的呼氣微粒粒徑與濃度變化均不相同，過去有關呼氣微粒的研究以健康人爲主要研究對象，極少研究探討使用機械換氣輔助呼吸病患之呼氣微粒及呼氣細菌濃度分佈變化，因此本研究選取臺灣中部某醫學中心的呼吸加護病房內使用機械換氣輔助呼吸的病患做爲研究對象，以微粒分徑儀和八階氣膠衝擊器評估病患呼氣中的微粒和細菌之粒徑與濃度變化；另外也在呼吸加護病房內進行空氣採樣，以瞭解醫院室內空氣品質的變化。

研究發現使用機械換氣輔助呼吸病患呼氣中的微粒分佈主要爲  $0.5\sim 3.5\ \mu\text{m}$ ，呼氣微粒濃度範圍介於  $0.001\sim 0.949\ \text{particles/mL}$  之間，與第一年類似。在病患呼氣細菌的檢出率方面，細菌檢出率爲  $0\%\sim 28.6\%$ 、革蘭氏陽性細菌和革蘭氏陰性細菌的檢出率分別爲  $64.3\%\sim 78.6\%$  和  $28.6\%\sim 71.4\%$ ；在呼氣細菌濃度分佈方面，總細菌平均濃度爲  $0\sim 406.3\ \text{CFU/m}^3$ 、革蘭氏陽性細菌的平均濃度爲  $177.1\sim 562.5\ \text{CFU/m}^3$  和革蘭氏陰性細菌的平均濃度爲  $270.8\sim 625.0\ \text{CFU/m}^3$ 。在呼吸加護病房的空氣品質變化方面，室內二氧化碳濃度範圍爲  $872\sim 1,266\ \text{ppm}$ ，空氣中絕大多

數的微粒主要是  $PM_{10}$ ，空氣中的細菌以 1.1-2.09  $\mu m$  粒徑的濃度最高，其中總細菌濃度為 164.2~3,135.4 CFU/m<sup>3</sup>，而革蘭氏陽性細菌和革蘭氏陰性細菌的濃度分別為 66.1~2,089.5 CFU/m<sup>3</sup> 和 23.5~2,089.5 CFU/m<sup>3</sup>。此外，呼吸加護病房的會客人數與室內溫度、細菌濃度之間有顯著的正相關，且環境溫度會影響細菌的生長。而測試使用過之呼吸器末端之高效率濾材過濾器，雖然經過多次高溫滅菌鍋處理，效率仍無變化，現階段醫院使用管理過濾器之模式應屬適當。

關鍵詞：機械換氣、呼氣微粒、呼氣細菌、室內空氣品質、呼吸加護病房

# Abstract

The results of previous studies carried out by Taiwan's Institute of Occupational Safety and Health (IOSH) indicate that breath particles are exhaled when people cough, sneeze, or simply breathe, and that the amount of the exhaled breath particles increases along with increases in tidal volume. IOSH research has proven that mechanically ventilated patients also exhale particles. The highest concentrations of particles were in the sizes of 0.3-1  $\mu\text{m}$ . No significant differences in exhaled particle concentrations (0.001-0.098 particles/mL) of different sizes were found between the pressure control mode and volume control mode of mechanical ventilation. Nor were there any significant differences in filtration efficiency between pleated hydrophobic filters and electrostatic filters. The particle size and concentration distributions of exhaled bacteria in mechanically ventilated patients with different ventilators and mode settings were evaluated using a bioaerosol sampler. The risk of infection for healthcare workers in intensive care units was evaluated, and recommendations for preventive measures were made.

Particle sizes and concentrations in the exhaled breath of humans vary with respiratory activity. Previous studies focused on exhaled breath particles from healthy individuals, and so far few studies have been carried out to evaluate the distributions of exhaled particles and exhaled bacterial concentrations from mechanically ventilated patients. Therefore, this study recruited mechanically ventilated patients in the respiratory intensive care unit of a medical center in central Taiwan. The particle size and concentration distributions of exhaled particles and bacteria from the mechanically ventilated patients were evaluated by using an optical particle analyzer and an eight-stage bioaerosol impactor, respectively. The indoor air quality of the

respiratory intensive care unit was also evaluated.

The results of this study indicated that the sizes of particles exhaled from mechanically ventilated patients were mostly in the range of 0.5-3.5  $\mu\text{m}$ , with particle concentrations ranging between 0.001 particles/mL and 0.949 particles/mL. The detected rates of total bacteria and gram-positive and gram-negative bacteria from exhaled breath were 0-28.6%, 64.3-78.6%, and 28.6-71.4%, respectively. The total bacteria concentration in breath exhaled by mechanically ventilated patients ranged from 0 CFU/m<sup>3</sup> to 406.3 CFU/m<sup>3</sup>, and the levels of gram-positive bacteria and gram-negative bacteria were 177.1-562.5 CFU/m<sup>3</sup> and 270.8-625.0 CFU/m<sup>3</sup>, respectively. In addition, indoor carbon dioxide concentrations were found to range between 872 ppm to 1,266 ppm. Most of the particles in the air were 1  $\mu\text{m}$  or smaller in size. Bacteria in sizes of 1.1-2.09  $\mu\text{m}$  comprised the highest concentration in the air of the respiratory intensive unit, and airborne bacterial concentrations ranged from 164.2 CFU/m<sup>3</sup> to 3,135.4 CFU/m<sup>3</sup>. The concentrations of airborne bacteria were 66.1-2,089.5 CFU/m<sup>3</sup> for gram-positive bacteria and 23.5-2,089.5 CFU/m<sup>3</sup> for gram-negative bacteria. The number of persons visiting patients was positively associated with air temperature and bacterial concentration, and bacterial growth was affected by air temperature. The performance of used high-efficiency particulate air (HEPA) apparatus was the same as that of new apparatus in this study; even multiple sterilizations of the HEPA apparatus did not affect its efficiency.

**Key Words:** Mechanical ventilation, exhaled particle, exhaled bacteria, indoor air quality, respiratory intensive care unit