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화재용 방독면의 CO, HCl, HCN, SO_2 연소생성물 제거효율

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Gas Mask Removal Efficiency of CO, HCl, HCN, and SO_2 Gas Produced by Fire

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요 약

화재 시 발생하는 독성 가스인 CO, HCl, HCN, SO_2를 방독면에 의해 제거하는 효율은 화재로 인한 인명구조의 핵심 요소이다. 머리와 목끈이 없는 탄력있는 방독면은 전방을 주시할 수 있는 창, 탄력후드, 가스정화기와 공기 환풍구로 되어 있어서 화재 시 빠르고 쉽게 착용할 수 있다. 이 연구에서는 이러한 방독면의 CO, HCl, HCN, SO_2 제거 효율에 대한 연구를 진행하였다. 실험결과 CO 제거 효율은 최초 농도가 2505.0 ppm인 경우 3.5분 후에 99.99%였고, 8.5분 후에는 99.98%로 나타났다. 8.5분 후에는 CO 농도가 급격히 증가하는 특성을 보였다. HCl, HCN, SO_2에 대해서는 최초 농도가 각각 1003.0, 399.0, 100.3 ppm인 경우 20분 동안 제거 효율이 100%로 나타났다.

ABSTRACT

The removal efficiencies by elastic fire gas mask of toxic gases CO, HCl, HCN, and SO_2 produced by a fire have a key role in saving lives. The elastic fire gas mask comprises a visible window, elastic hood, gas purification canister, and air vent. It does not have hair or neck thongs, which makes it easy to use and put on quickly. This research examined the removal efficiency of toxic gases by such a mask. The removal efficiencies for CO with a background concentration of 2505.0 ppm were 99.99 and 99.98% after 3.5 and 8.5 min, respectively. The residual CO concentration was drastically increased after 8.5 min. The removal efficiencies for HCl, HCN, and SO_2 with background concentrations of 1003.0, 399.0, and 100.3 ppm, respectively, were 100% after 20 min.

Keywords : Fire gas mask, CO, SO_2, Removal efficiency

1. Introduction

Gas mask was fabricated for the first time by German military to protect from the gas attack of the England military in world war[1]. After that, the gas mask was used by fire officer during the fire suppression and by public in the subway in case of fire to prevent choke due to the toxic gasses. Fire produces CO, HCl, HCN, SO_2, and etc. The CO affects to the heart, and HCl affects to the skin and respiratory tract. Large amount of inhalation of high concentration HCl could be fatal. Toxication of HCN feels like a tightening the chest and dies with breathing difficulties. The SO_2 gives strong pain to the respiratory track and eyes and dies when one inhales large amount of SO_2[2,3].

Large number of investigations for the conventional gas mask were performed, including investigation of pretreatment layer, toxic gas adsorption layer, and ergonomic structure of the gas mask[4], study of the design for gas mask storage[5], research of gas mask design to fit to the face shape[6], investigation for the gas mask glasses[7], and investigation for the gas mask filter related with combustion gas[8]. However, there is lack of research for the fast and easy wearing method.

Since quick wearing a gas mask is important to escape

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from the fire, fast and easy wearing the gas mask is the subject in this research. Since it is made by high elastic material, it protects respiratory track at the same time with wearing the gas mask and enable to quickly escape from the fire and toxic gas. The CO gas is produced all flammable materials during the fire. The HCl and the HCN can be produced by silk, wool, nylon, polyacrylonitrile, polyurethane, polymelamine, polyurea, and polyvinylchloride during the fire[9]. The SO_2 is produced by petroleum, coal, gasoline, cigarette, and tree during the combustion. Therefore, it is necessary to test the removal ability of CO, HCl, HCN, and SO_2 to protect the people in case of fire.

2. Experimental

Fire gas mask is made by elastic materials, such as silicon, latex, rubber with elastic hood to protect the peoples head from the fire, window for visible forward direction, air vent for the person's exhale, and air purification canister to remove the CO, HCl, HCN, and SO_2 gas produced by fire as shown in Figure 1.

Air purification canister located in both side of the air vent is comprised with many inhaling holes, hosing for connection with elastic hood, non-woven fabric, first dustproof filter, activated carbon, second dustproof filter and removes CO, HCl, HCN, and SO_2 produced by fire.

The removal efficiencies of CO, HCl, HCN, and SO_2 gases for the fire gas were measured at 23 ^oC with 50% of relative humidity in the combustion toxicology laboratory. The standard gas concentrations were 2505.0, 1003.0, 399.0, and 103.0 ppm for CO, HCl, HCN, and SO_2, respectively. The gas concentrations were measured with ISO 19702:2006

Figure 1. The picture of an elastic fire gas mask.

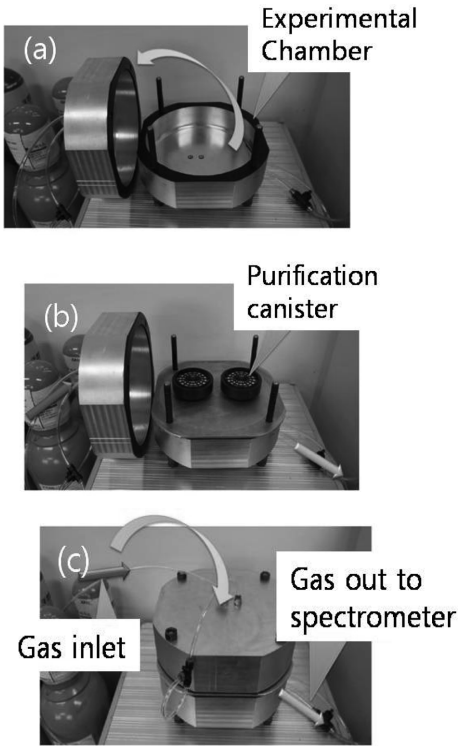

Figure 2. (a) before setting the gas purification canister, (b) after setting the gas purification canister, and (c) gas passing through the gas purification canister and go to the spectrometer.

(Toxicity testing of fire effluents-analysis of gases and vapors in fire effluents using FTIR technology)[10]. Figure 2 shows the measurement process. The gas cell path length, measurement mode, resolution, and number of scans were 10 m, absorbtion, 0.5 cm^{-1}, and 8 times. The wavenumber range of each gases were 2241~2040, 3085~2620, 3221~3378, and 1191~1108 cm^{-1} for CO, HCl, HCN, SO_2, respectively.

3. Results and Discussion

Kim et al.[11] reported for the development of secure refuge space by using existing restroom. In that case, toxic gas concentration would be key role to protect the person. The main purpose of this research is to measure the removal efficiency of the toxic gases including CO, HCl, HCN, SO_2 produced by fire. The toxic gas purification canister was comprised of filter, chemical adsorbent, CO catalyst and activated carbon. Cellulose based filter can adsorb toxic gases including SO_2, HF, HCl, CO_2, H_2S and HCHO and activated carbon can adsorb SO_2 and HCN gases[12-16].

The gas purification canister of fire gas mask was set to the test chamber, and the standard gasses with the

Table 1. Time Dependent Residual Gas Concentration of CO, HCl, HCN, and SO_2 Gasses

Test gas	Conc. (ppm)	Concentration with time (s ppm)						
CO	2505.0	s	209	505	801	1201	1249	1697
		ppm	0.3	0.4	30.3	187.8	201.5	263.3
HCl	1003.0	s	200	400	600	800	1000	1200
		ppm	0.0	0.0	0.0	0.0	0.0	0.0
HCN	399.0	s	200	400	600	800	1000	1200
		ppm	0.0	0.0	0.0	0.0	0.0	0.0
SO_2	100.3	s	200	400	600	800	1000	1200
		ppm	0.0	0.0	0.0	0.0	0.0	0.0

concentrations of 2505.0, 1003.0, 399.1, and 100.3 ppm for CO, HCl, HCN, and SO_2, respectively, were passed through the gas purification canister. The passed gases went to the ISO 19702:2006 FTIR spectrometer and measured the concentrations of the gases with the time. The time intervals for the CO gas concentration measurement were 209, 505, 801, 1201, and 1697 seconds. The time intervals of the other three gases including HCl, HCN and SO_2 were 200, 400, 600, 800, 1000 and 1200 seconds. Table 1 shows the resulting data.

The CO concentrations after 209, 505, 801, 1201, 1249 and 1697 seconds were 0.3, 0.4, 30.3, 187.8, 201.5 and 263.3 ppm, respectively. The removal efficiencies of the CO was 99.99% (0.3 ppm) and 99.98% after 209 and 505 seconds, respectively, with the background CO concentration of 2505.0 ppm. The residual CO concentration was increased drastically after 505 seconds, which indicated that the CO adsorbing material started partially saturate after 505 seconds with the background CO saturation of 2505.0 ppm as shown in Figure 3.

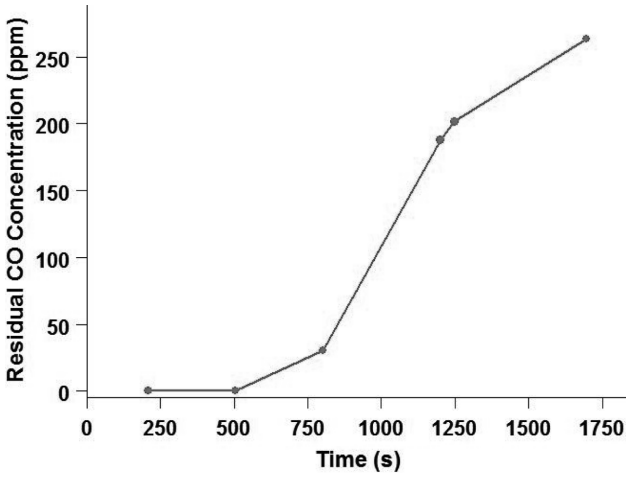

Figure 3. Time dependent residual CO concentration with the background CO concentration of 2505.0 ppm.

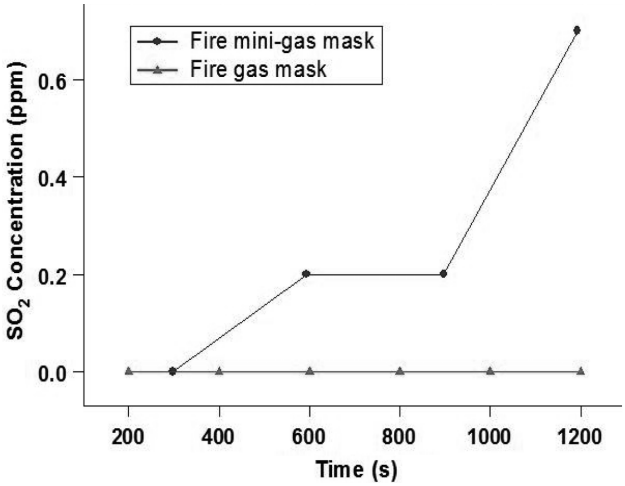

Figure 4. Comparison of the removal efficiency of SO_2 gas with the background SO_2 concentration of 100.3 ppm for fire gas mask and fire mini-gas mask.

Compared with the removal efficiency of CO with the background concentration of 2505.0 ppm, the HCl and HCN were completely removed for 20 min with the background concentrations of 1003.0 and 399.0 ppm, respectively. Therefore, the fire gas mask can protect people from HCl and HCN for 20 min with relatively large amount of HCl and HCN.

Figure 4 shows the comparison of SO_2 removal efficiency between fire gas mask and fire mini gas mask with the background concentration of 100.3 ppm. Although the fire mini gas mask has 0.2 and 0.7 ppm of residual SO_2 gas after 15 and 20 min, respectively, the fire gas mask completely removed SO_2 gas for 20 min. The fire gas mask completely removes HCl, HCN and SO_2 with the relatively large amount of background gas. To compare the fire gas mask and the fire mini-gas-mask, the removal efficiencies were compared in Figure 4. Although the fire mini-gas-mask is useful to quick evacuation in case of fire, it is desirable to use fire gas mask in case of large fire and long evacuation process instead of fire mini-gas-mask.

4. Conclusions

This research focused on the removal efficiency of CO, HCl, HCN, and SO_2 produced by fire for the elastic fire gas mask having no hair and neck thongs.

(1) The removal efficiencies for the CO with the background CO concentration of 2505.0 ppm were 99.99 and 99.98% after 3.5 and 8.5 min, respectively. The residual

CO concentration was drastically increased after 8.5 min.

(2) The removal efficiencies for HCl, HCN, and SO_2 with the background concentrations of 1003.0, 399.0, and 100.3 ppm, respectively, were 100% for 20 min.

References

1. K. J. Jang, “Fire and Biological War for Gas Mask”, Air Freshener Technology, Vol. 24, No. 3, p. 18 (2011).
2. M. C. Choi and B. S. Kim, “A Study on the Ways to Minimize Casualties through a Consideration of the CO Gas Generated During Combustion”, Journal of Korea Safety Management & Science, Vol. 15, No. 1, p. 136 (2013).
3. H. S. Kong, D. J. Kim, C. H. Bang, I. S. Bae, Y. S. Back, D. Y. Ahn, S. C. Woo, I. R. Jun, et al., “Fire Protection Theory”, Daegu: Yesmedia Ltd., pp. 1-19 (2014).
4. J. G. Won and J. S. Lee, “A Study on the Development of Portable Life Protective Mask”, Journal of the Korean Society of Urban Environment, Vol. 14. No. 2, pp. 145-153 (2014).
5. S. S. Park and H. S. Lee, “A Study of Problems with Design of Gasmask Storage Cabinets in Subway Stations”, Journal of Korea Design Knowledge Society, p. 126 (2011).
6. Y. J. Oh and S. J. Park, “The Facial Anthropometry with 3D Head Scanner Korean Gas Mask”, Proceedings of Conference, Korea CAD/CAM Review, p. 404 (2010).
7. J. Y. Lee, J. S. Park and W. Y. Jang, “Development of Gas-mask Spectacles”, Journal of Korean Ophthalmic Optics Society, Vol. 13, No. 4, pp. 9-12 (2008).
8. J. Y. Lee, J. H. Kim, Y. H. Kim and K. C. Jung, “A Study on Toxicity Evaluation of Combustion Gases Released from the Residental Container Fire Efficiency Test for the Fire Gas Mask Filters”, Journal of the Korean of Safety, Vol. 19, No. 4, p. 48 (2004).
9. M. C. Choi and B. S. Kim, “A Study on the Ways to Minimize Casualties through a Consideration of the CO Gas Generated During Combustion”, Journal of Korea Safety Management & Science, Vol. 15, No. 1, pp. 133-140 (2013).
10. ISO 19702:2006(en) Toxicity testing of fire effluents - Guide for analysis of gases and vapours in fire effluents using FTIR gas analysis.
11. J. S. Kim, H. J. Shin, J. Y. Kim and B. J. Park, “Development of Technology to Secure Refuge Space by Using Existing Restroom”, Korean J. Air-Conditioning Refrigeration Eng., Vol. 27, No. 1, pp. 24-30 (2015).
12. D. Sawifri and A. Lasryza, “Utilization of Coal Fly Ash as CO Gas Adsorbent”, International J. of Waste Resources, Vol. 2, pp. 13-15 (2012).
13. J. V. Romero, J. W. SmithH, B. M. Sullivan, L. M. Croll and J. R. Dahn, “SO_2 and NH_3 Gas Adsorption on a Ternary ZnO/CuO/$CuCl_2$ Impregnated Activated Carbon Evaluated Using Combinatorial Methods”, ACS Combinatorial Sci., Vol. 14, No. 1, pp. 31-37 (2012).
14. E. Barea, C. Montoro and J. A. R. Navarro, “Toxic Gas Removal-metal-organic Frameworks for the Capture and Degradation of Toxic Gases and Vapours”, Chem. Soc. Rev., Vol. 43, pp. 5419-5430 (2014).
15. B. J. Kim, H. Park and S. J. Park, “Toxic Gas Removal Behaviors of Porous Carbons in the Presence of Ag/Ni Bimetallic Clusters”, Vol. 29, No. 4, pp. 782-784 (2008).
16. S. V. Manyele, “Toxic Gas Absorber Design Considerations for Air Pollution Control in Process Industries”, Educ. Res. Rev., Vol. 3, No. 4, pp. 137-147 (2008).