Assessing Respirator Protection Factor with Novel Personal Devices

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Background

Respirators are worn by medical professionals, emergency responders, construction workers and industrial workers to reduce their inhalation exposure to aerosols.

A fit test is performed when a respirator is initially assigned to a worker to assess the protection that the respirator provides.

Quantitative fit testing is often conducted using the TSI PortaCount®, a bench-top device that uses a condensation particle counting (CPC) system to measure the particle concentration inside and outside of the respirator.

Currently there is no personal device that can measure protection factors while the respirator is in use. Such devices would be valuable to identify individual worker protection factors while on the job.

Objective

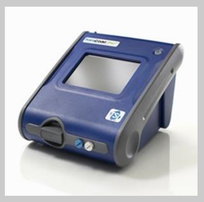
Evaluate two new, compact and personal dual-channel optical and CPC-based particle counters (DC-OPC and DC-CPC) that enable real-time respirator fit evaluation while performing specific occupational tasks

Methods

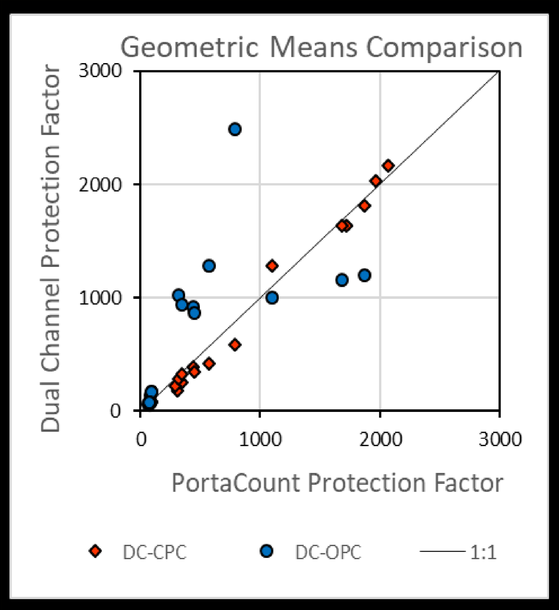
- Multi-Purpose Respirator (3M 65021HA1-C) with P100 organic vapor cartridges was donned by subject.
- Concentrations inside and outside the respirator were measured simultaneously using the DC-OPC (0.3 µm channel), DC-CPC and Portacount (in real-time mode). The respirator interior was sampled by all three sensors connected to a single port on the mask.
- Three trials were run for each test. Test environments included salt, incense and normal ambient conditions. Target protection factors of 75, 100, 300, 500 and 1000 were simulated.
- During testing, three OSHA accepted activities for determining the fit factor were executed including normal breathing, deep breathing and moving the head side to side. Each exercise was performed for 60 seconds.

Test subject donning the respirator. The port on the subject's left is plugged while the port on the subject's right has two Y connectors for consistent sampling from inside the respirator.

Instruments used to count particles are listed and described below. The devices vary in functional range, principle of operation, size, weight and the number of channels.

	PortaCount	Dual-Channel Condensation Particle Counter (DC-CPC)	Dual-Channel Optical Particle Counter (DC-OPC)
Principle of operation	Alcohol-based condensation particle counting	Water-based condensation particle counting	Optical particle counting
Size	17 x 22 x 24 cm	13 x 11 x 6.4 cm	15 x 9.4 x 5.1 cm
Weight	5 lbs	1.7 lbs	1.0 lb
Lower size cutoff	~15 nm	~7.5 nm	~300 nm
Number of channels	1	2	2
Flow rate per channel	0.35 Lpm	0.5 Lpm	0.5 Lpm
Picture			

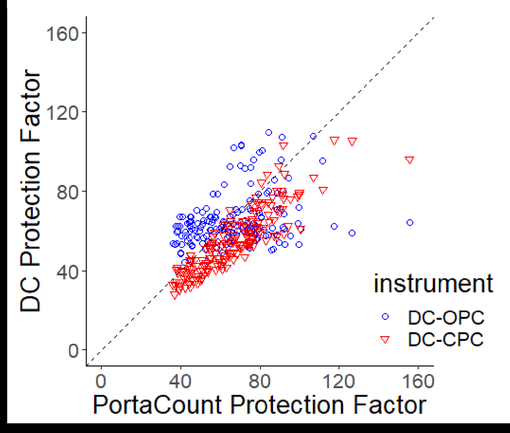
Results



Overall geometric mean protection factor measured with the dual channel instruments relative to that measured with the PortaCount

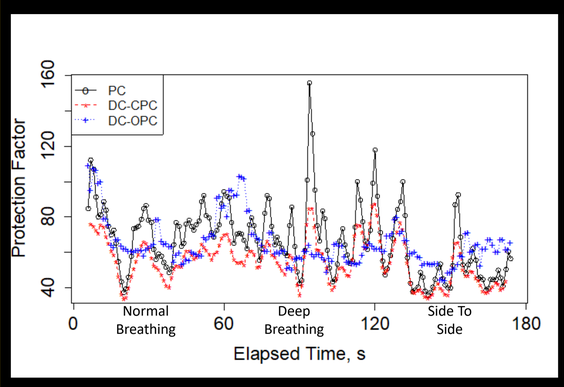
- Protection factors for the **DC-CPC (red)** follow 1:1 line closely; suggests that this instrument is accurate over a wide range.
- Protection factors from the **DC-OPC (blue)** show scattered results, deviating from the PortaCount at target protection factors higher than ~100.

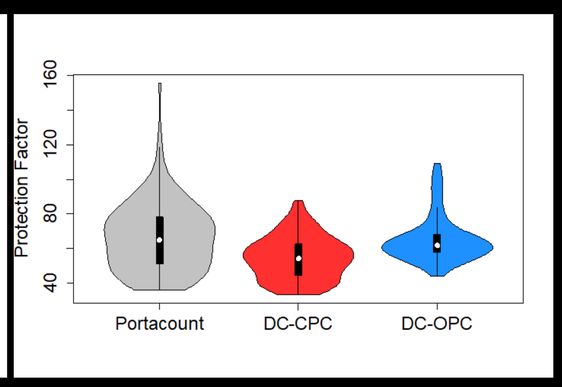
Correlations for a target protection factor of 75; DC-CPC $R^2 = 0.84$ DC-OPC $R^2 = 0.11$



Second-by-second protection factors

- The plot on the right shows results from one run, in which the ambient concentration of incense was ~24,000 /cm^3 and the target protection factor was 75. The R^2 value for the DC-CPC is 0.84 while that for the DC-OPC is 0.11.
- The bottom plots show the second-by-second data (left) and additional statistical distribution information (right) for this run.
- For this low target protection factor (PF=75), both dual-channel instrument measurements are relatively consistent with the PortaCount.





Conclusions

- The DC-CPC correlates well with the PortaCount over a large range of protection factors, ambient concentrations and aerosol types, even on a second-by-second basis
- The DC-OPC has a limited functional range in ambient concentrations between ~10,000 and ~40,000 /cm^3 for protection factors less than ~100
- Further evaluation is needed before these devices should be used to assess real-time protection factors in the occupational setting

Future Work

Continue to characterize dual channel devices for measuring protection factors:

- Additional CPC and OPC performance evaluation and protection factor benchmarking
- Measuring protection factors in specific ambient occupational environments
- Measuring protection factors for specific activities

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