Personal Respiratory Protective Devices: Efficacy of Millipore and Whatman Filters

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Abstract

A Millipore filter with 0.22 μm pore size and a Whatman grade 1 filter with > 11 μm particle retention were used to capture laser smoke particle mimic atmospheric suspended particulate matter. The experiment was conducted at the Department of Otolaryngology in Ramathibodi Hospital from April 1996 to October 1997. The laser smoke particle evacuator with rotameter created an air flow rate of 15 l/min through the filters. The mean and standard deviation of the laser smoke particle count under high power optical microscope in a 10 Millipore filter and a 10 Whatman filter were 411,327.6 +/-13,325.0 and 290,453.0 +/-28,409.8 respectively, 29.4 per cent different. Laser smoke particle size distribution in both filters under eyepiece micrometer was: 1 to 10 μm in Millipore (99.0%) and in Whatman (96.2%), 1 to 5 μm in Millipore (77.1%) and in Whatman (77.6%), no laser smoke particle larger than 17 μm was detected. The Millipore filter ruptured when the air flow rate was greater than 15 l/min. The Whatman filter was suitable for evaluating filtration efficacy of various personal respiratory protective devices in a high air flow rate condition.

Key word : Filter, Suspended Particulate Matter, Laser Smoke Particle, Prevention

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Suspended particulate matter amount in a high air-polluted area is about 3 times above the standard level in Thailand according to WHO criteria[1,2]. Laser smoke particles create particle amount and size distribution similar to that of atmospheric suspended particulate matter. A single pulse mode of carbon dioxide laser was selected due its availability in clinical usage and it is easier to control proper particle concentration. The filtration efficacy of a Millipore filter with 0.22 μm pore size and a Whatman grade 1 filter with > 11 μm particle retention for laser smoke particle were compared[3]. A Millipore filter is a membranous, homogenous, very thin filter with 2 focal levels which is suitable for particle counting under an optical microscope. A Whatman filter is a fibrous filter

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with 10 focal levels under optical microscope, is easier to handle and cheaper[4,5]. The amount and size distribution of laser smoke particles were examined with a high power optical microscope and eyepiece micrometer[6]. A Millpore filter is very fragile and ruptures with an air flow rate above 15 l/min so a Whatman filter was modified for a higher air flow rate situation for evaluating the efficacy of different personal respiratory protective devices such as filters with intranasal, hollow, cylindrical, medical grade and silicone stent[7-10]. Suspended particulate matter can penetrate a facial mask or leak around the facial seal[11-13].

MATERIAL AND METHOD

The experiment was conducted at the Otolaryngology Department in Ramathibodi Hospital from April 1996 to October 1997. Each 10 Millipore filter (GS-filter type, Millipore Corporation, Bedford, Massachusetts 01750 U.S.A.) had a pore size of 0.22 μm. Each 10 Whatman filter (grade 1, Whatman Group, U.S.A.) had a pore size for particle retention of >11 μm. Each filter diameter was 1.3 cm with 1.1 cm active filtration diameter and a 0.9507 cm^2 cross -sectional area. The filter adapter was composed of two hollow plastic cylindrical tubes. The inner filter adapter had a 1.3 cm outer diameter and a 1.1 cm inner diameter. The outer filter adapter had a 1.6 cm outer diameter and a 1.3 cm inner diameter with a circular 0.2 cm thickness ridge in the middle part. Each filter was fitted to the ridge and sealed by the inner adapter which was applied to the outer adapter lumen. The filter adapter length was 6.0 cm. (Fig. 1) A carbon dioxide laser (Sharplan model 1060, Laser Industries Ltd, Tel Aviv, Israel.) with 5 shots of single mode, 10 W, 0.2 s duration was used for each filter. A laser smoke particle evacuator (Xplume, Sharplan, model 100, Laser Industries Ltd, Tel Aviv, Israel.) with a rotameter (MFV-6, Aalborg instruments, Monsey, New York, U.S.A.) created an air flow rate of 15 l/min through each filter for 1 min. A rotameter was calibrated by a standard flowmeter (Puratan-Bernett FT, series D, pressure compensated flow meter, CSA standard, U.S.A.). The rotameter was connected between the laser smoke particle evacuator and the filter adaptor. A 3 x 3 x 3 cm plastic box was used to confine laser smoke particles. One 1.4 cm diameter hole at the top of the box was for the filter adapter inlet and the other 1.4 cm diameter hole at one side of the box was for the laser handpiece. The specimen for laser evaporization was put inside the box. (Fig. 1). The particles in each filter material were counted for 10 fields with a 10 x 40 optical microscope (Olympus ECB, Olympus Optical Co, Ltd. 2 chrome, Hatagaza, Shibuya, Tokyo, Japan.) Total laser smoke particle count in each filter was the particle amount in 10 fields multiplied by 70.1308. The size distribution was examined with an eyepiece micrometer (Model WHK 10X/20L, Olympus, Tokyo, Japan).

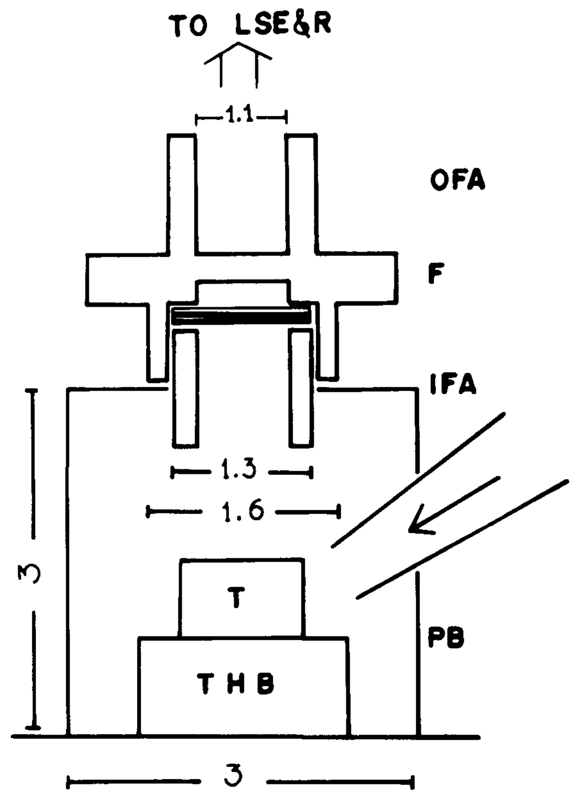

Fig. 1. Diagram of Millipore or Whatman filter (F) with inner filter adapter (IFA) and outer filter adapter (OFA) attached to plastic box (PB) ; tissue (T) for laser evapolization was on tissue holder block (THB) ; big arrow was air flow to laser smoke particle evacuater and rotameter (LSE&R); small arrow was laser beam through the handpiece. The number was in cm.

RESULT

Laser smoke particle distribution in both filter types was homogenous. The Millipore filter

Table 1. Laser smoke particle count in Millipore and Whatman filter.

Filter No.	laser smoke particle count in filter * Millipore	Whatman
1	359,913	243,745
2	412,675	244,388
3	454,253	264,018
4	444,159	285,537
5	458,089	294,103
6	428,547	296,353
7	440,979	299,090
8	342,984	312,269
9	362,583	330,273
10	409,094	334,749
Mean +/- S.D.	411,327.6+/-13,325.0	290,453.0+/-28,409.8

* Millipore and Whatman were counted for 2 and 10 focal levels respectively. Each filter was counted in 10 fields under 10 x 40 optical microscope and multiplied by 70.1308 to get the total laser smoke particle

Table 2. The laser smoke particle size distribution in Millipore and Whatman filter.

particle size (um)	Millipore particle count *	%	Whatman particle count *	%
1	148	14.5	260	25.1
2	211	20.7	197	19.1
3	156	15.3	149	14.4
4	179	17.6	118	11.4
5	92	9.0	79	7.6
6	133	13.0	99	9.6
7	13	1.3	7	0.7
8	55	5.4	54	5.2
9	5	0.5	4	0.4
10	17	1.7	28	2.7
11	-	-	1	0.1
12	9	0.9	15	0.5
13	-	-	-	-
14	1	0.1	9	0.8
15	-	-	-	-
16	-	-	6	0.6
17	-	-	8	0.8
Total	1,019	100.0	1,034	100.0

* laser smoke particle count and size estimation were done under a 10 x 40 optical microscope and eyepiece micrometer; each Millipore and Whatman filter had 2 and 10 focal levels respectively

got the maximum particle amount from the laser evaporative field. The mean and standard deviations of the laser smoke particle count in the Millipore and Whatman filter were 411,327.6 +/- 13,325.0 and 290,453.0 +/- 28,409.8 respectively with a difference of 29.4 per cent. Laser smoke particle concentration in the plastic box that was captured by the Millipore and Whatman filter was 0.78 million particles/cu ft or 27 particles /cu cm and 0.55 million particles /cu ft or 19 particles / cu cm respectively (Table 1). The laser smoke particle size distribution in the Millipore and Whatman filter was similar. The particle size of 1 to 10 µm in the Millipore filter was 99.0 per cent and in the Whatman filter it was 96.2 per cent. The size of 1 to 5 µm the in Millipore filter was 77.1 per cent and in the Whatman filter it was 77.6 per cent. No particle size larger than 17 µm was detected. A particle size smaller than 1 µm could not be differentiated under a high power optical microscope (Table 2). The histogram of the laser smoke particle size distribution pattern in both filter types was not significantly different (Fig. 2).

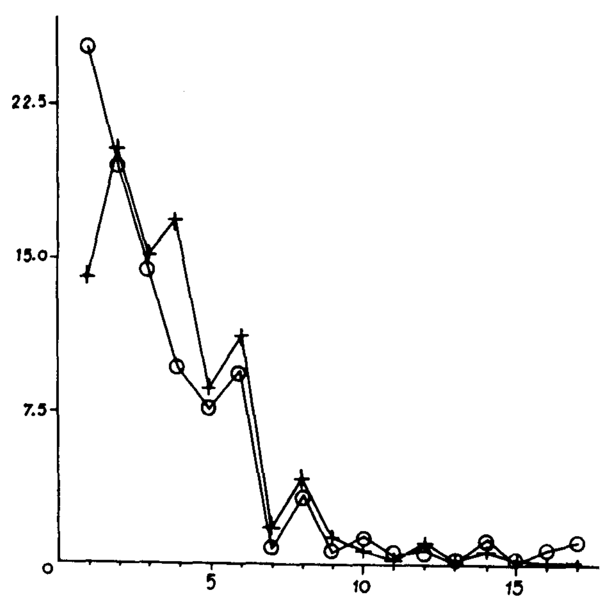

Fig. 2. Histogram of laser smoke particle size distribution retention in Millipore (+) and Whatman (O) filter; Y-axis was percentage of laser smoke particle retention and X-axis was laser smoke particle size in micrometer.

DISCUSSION

The filtration capabillity of Millipore and Whatman filters was applied to estimate the filtration efficacy of a personal respiratory protective device such as intranasal, hollow, cylindrical, medical grade, silicone stent with filters in humans(14-

16). The laser smoke particle was used as a source of atmospheric suspended particulate matter. A single pulse mode of a carbon dioxide laser created a suitable particle amount and size distribution. A Millipore filter is supposed to get the maximum particle amount from a laser evaporative field. The percentage difference of the laser smoke particle retention in both filter types was used to estimate the real particle amount from the laser evaporative procedure[17]. A Whatman filter is popular in air pollution monitoring, it is not fragile and is easier to handle. The air flow rate of 15 l/min through each filter is within the human sedetary work load when compared with that of 30 l/min during a moderate work load[18]. A Millipore filter ruptured while the Whatman filter tolerated an air flow rate of higher than 15 l/min.

The size distribution of laser smoke particles in both filter types was not significantly different. The particle size range of 1 to 10 μm was the most predominant size range in both filter materials. The particle size range of 1 to 5 μm was "respirable particulate" for the human respiratory tract[19,20]. The industrial hygienist concern is often focused on the 0.5 μm to 10 μm size range because a large amount of particle mass enters the human respiratory system from within these size ranges[21-23]. The U.S. Environmental Protection Agency has tentatively defined "inhalable particulate" as particles having an aerodynamic diameter less than 15 um. A cut-off size of 10 μm is with consideration [24-26]. In a heavily air-polluted area, the total and small particle suspended particulate matter amount increases dramatically[27]. The unsampled aerosol may range from about 0.001 μm to about 100 μm in particle size. Particles smaller than about half the wave length of visible light (0.4-0.7 μm) are generally invisible by optical means[28].

SUMMARY

The Millipore and Whatman filters were studied for their filtration capability for laser smoke particle retention. Laser smoke particles had a particle amount and size distribution like that of atmospheric suspended particulate matter in a high air-polluted area. The particle retention in Millipore filter was 29.4 per cent greater than that of the Whatman filter and was used as maximum particle amount from the laser evaporative field. The particle size distribution in both filter types was similar. Due to the fragility of the Millipore filter, the Whatman filter was suitable for an air flow rate greater than 15 l/min. The filtration efficacy of various personal respiratory protective devices such as intranasal, hollow, cylindrical, medical grade, silicone stent with filters should be compared with a Whatman filter.

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เครื่องป้องกันระบบทางเดินหายใจส่วนบุคคล : ประสิทธิภาพของแผ่นกรองมิลลิพอร์และวัตแมน

*ครรชิตเทพ ตันเผ่าพงษ์, พ.บ.**

การใช้แผ่นกรอง Millipore ที่มีขนาดช่องกรอง 0.22 ไมโครเมตร และแผ่นกรอง Whatman เกรด 1 ที่กรองขนาดวัสดุซึ่งใหญ่กว่า 11 ไมโครเมตร สำหรับกรองฝุ่นละอองจากการยิงคาร์บอนไดอ๊อกไซด์เลเซอร์เพื่อใช้แทนฝุ่นละอองในบรรยากาศ โดยทดลองที่ภาควิชาโสต นาสิก ลาริงซ์วิทยา คณะแพทยศาสตร์ โรงพยาบาลรามาธิบดี ระหว่างเดือนเมษายน พ.ศ. 2539 ถึงเดือนตุลาคม พ.ศ. 2540 เครื่องดูดฝุ่นละอองจากการยิงเลเซอร์ทำให้ปริมาตรของอากาศที่ไหลผ่านแผ่นกรองแต่ละชนิดเท่ากับ 15 ลิตรต่อนาทีโดยควบคุมด้วย rotameter ค่าเฉลี่ยและค่าเบี่ยงเบนมาตรฐานของฝุ่นละอองจากการยิงเลเซอร์โดยการตรวจด้วยกล้องจุลทรรศน์กำลังขยายสูงในแผ่นกรอง Millipore และ Whatman อย่างละ 10 แผ่น เท่ากับ 411,327.6 +/-13,325.0 และ 290,453.0 +/-28,409.8 ตามลำดับ มีค่าแตกต่างกันร้อยละ 29.4 ขนาดของฝุ่นในแผ่นกรองทั้งสองชนิดไม่แตกต่างกันมากเมื่อวัดด้วย eyepiece micrometer โดยพบฝุ่นขนาด 1 ถึง 10 ไมโครเมตรในแผ่นกรอง Millipore ร้อยละ 99.0 และใน Whatman ร้อยละ 96.2 พบฝุ่นขนาด 1 ถึง 5 ไมโครเมตรในแผ่นกรอง Millipore ร้อยละ 77.1 และใน Whatman ร้อยละ 77.6 แต่ไม่พบฝุ่นที่มีขนาดใหญ่กว่า 17 ไมโครเมตร แผ่นกรอง Whatman สามารถใช้กับปริมาตรการไหลของอากาศซึ่งผ่านแผ่นกรองมากกว่า 15 ลิตรต่อนาที ในขณะที่แผ่นกรอง Millipore จะฉีกขาด ผลการทดลองนี้จะนำไปตรวจสอบประสิทธิภาพของเครื่องป้องกันระบบทางเดินหายใจส่วนบุคคล

คำสำคัญ : ฝุ่น, แผ่นกรอง, เลเซอร์, การป้องกัน

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