บันทึกข้อความ

ส่วนราชการ ภาควิชาวิศวกรรมเคมี คณะวิศวกรรมศาสตร์ ทร.3343
ที่ ศบ. 0529.8/3 วันที่ 30 กันยายน 2553
เรื่อง ขออนุมัติคัดมอบแทนการพิมพ์ในโครงการวิชาการระดับชาติ เรื่อง "การกรองอนามัยการละอองทางอากาศใน
อาคารจากกระบวนการสีขาวด้วยแผ่นกรองไนโตรไพรอิซีน"

เรียน รองคณบดีฝ่ายวิจัยและบริการวิชาการ สำนักงานภาควิชาวิศวกรรมเคมี

อ้างอิงประกาศนับที่ 40/2550 ประกาศ ณ วันที่ 22 สิงหาคม 2550 คณะวิศวกรรมศาสตร์
เรื่อง "หลักเกณฑ์การจ่ายค่าตอบแทนการศึกษาพิมพ์ผลงานวิจัยวารสารวิชาการ คณะวิศวกรรมศาสตร์ มหาวิทยาลัย
กhoaวิทยา" ตามความถ้วนแล้วนั้น

เมื่อจากบทความทางวิชาการของผู้ช่วยศาสตราจารย์ ดร.วิทยา สนองรามา และผู้ช่วยศาสตราจารย์
ดร.สมคุณ สนองรามา ได้รับการตีพิมพ์ในวารสารวิชาการระดับชาติ เรื่อง "การกรองอนามัยการละอองทางอากาศใน
อาคารจากกระบวนการสีขาวด้วยแผ่นกรองไนโตรไพรอิซีน Filtration of Indoor Air Particulate Matter from Rice
Milling Process by Silk Fibroin Fiber" ได้รับการตีพิมพ์ในวารสารวิชาการระดับชาติ ว.วิศวกรรมศาสตร์เวทมนทไทย
(สวท.) ฉบับที่ 24 ฉบับที่ 2: หน้า 9-16 (2553) พฤศจิกายน–ธันวาคม 2553

ดังนั้น ภาควิชาวิศวกรรมเคมี จึงขอให้ขออนุมัติคัดมอบแทนการพิมพ์ผลงานในวารสารวิชาการ
ในเรื่องดังกล่าว

จึงเรียนมาเพื่อโปรดพิจารณา

(ผู้ช่วยศาสตราจารย์ ดร.วิทยา สนองรามา)
อาจารย์ประจาภาควิชาวิศวกรรมเคมี

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(ลายมือ)

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FRACTION FORM FOR ACADEMIC WORK

Title “Filtration of Indoor Air Particulate Matter form Rice Milling Process by Silk Fibroin Fiber การกรองอนุภาคค์สารของอากาศภายในอาคารจากกระบวนการผลิตผ้าด้ายผินกระดองไนโตรีน”
- ได้รับการพิพมพ์ในวารสารวิชาการกรมสิ่งแวดล้อมไทย ปีที่ 24 ฉบับที่ 2: หน้า 9-16 พฤศจิกายน - สิงหาคม (2553)

Collaborative work only 3 person:

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<td>2. Wipada Sanongraj</td>
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<td>3. Sompop Sanongraj</td>
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<td>4. Bovornlak Oonkhanond</td>
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ลงนามรับรองข้อมูล

(ผู้ช่วยศาสตราจารย์ ดร.วิภัตตา สนองเรณูร์)
ผู้รับผิดชอบบทความ (Corresponding Author)

* หมายเหตุ: ข้างล่าง ผู้ช่วยศาสตราจารย์ ดร.สมภพ สนองเรณูร์ มอบอำนาจให้ผู้ช่วยศาสตราจารย์ ดร.วิภัตตา สนองเรณูร์ ในการเป็นต้นแบบผังการพิมพ์ ของข้างล่างและส่วนผลงานวิชาการในตารางข้างด้าน

(ผู้ช่วยศาสตราจารย์ ดร.สมภพ สนองเรณูร์)
Filtration of Indoor Air Particulate Matter from Rice Milling Process by Silk Fibroin Fiber

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Abstract

The main objective of this research is to investigate the potential usage of the silk fibroin (SF) fiber for removing rice mill particulate matter (PM). The SF fiber was prepared by de-gumming silk cocoons with 0.5 wt % Na₂CO₃ alkaline solutions. Two sets of experiment were conducted to investigate the effects of initial PM concentration and air flow rate on the removal efficiency. Rice bran collected from a local rice mill in Ubonratchathani province was used as an indoor air contaminant in this work. The morphology and physical properties of silk fibroin (SF) fiber were analyzed. The SEM revealed the deposition of PM on the used fiber. The PM removal efficiencies of 72.29 ± 3.03% and 39.33 ± 1.99% were obtained when using the initial PM concentration of 0.040 mg/m³ and 0.020 mg/m³ for PM₁₀ and PM₁₅, respectively, at the air flow rate of 5 L/min. When the initial concentrations of PM₁₀ and PM₁₅ were increased to 2 and 5 times of the original concentrations, the PM removal efficiencies were 51.25 ± 4.33% and 53.02 ± 0.40% for PM₁₀ and 44.57 ± 5.78% and 47.80 ± 0.96% for PM₁₅, respectively. In addition, the SF fiber costs about three times less than the Whatman No.1 (a commercial fiber). Therefore, the SF fiber could be applied as an alternative material for indoor air treatment.

Keywords: filtration; indoor air contaminant; particulate matter; silk fibroin fiber
Introduction

Filtration is a relatively economical and efficient method for improving indoor air quality. The traditional technologies of filtration for removing indoor air particulates include high-efficiency particulate air filter (HEPA), electronic air cleaners, ion generators etc. Filter is an important component in filtration [1, 2]. One of fibrous filters is silk fibroin (SF) fiber from silkworm. Silk fibers from Bombyx mori silkworm, which have a very long history of use as textile materials in China, attracted many researchers in the fundamental science research and application research fields in recent years [3, 4]. Silk fiber is a natural protein fiber, having two primary components, fibroin and sericin. Silk fibroin is the major component, which accounts for about 70% of novel silk fibers, and sericin is another kind of silk protein, which accounts for about 30% of silk fibers [3]. Recently, SF fiber from silkworm (e.g., Bombyx mori) has been explored to exploit the properties of this protein as biomaterial [5, 6], bath preparations and pharmaceuticals due to its excellent characters as textile fiber. Moreover, the natural silk fiber is one of the strongest and toughest materials mainly because of the dominance of well orientated β-sheet structures of protein chains [7, 8]. The silk fibroin can be easily obtained using silk alkaline solution. Briefly, silk cocoons of Bombyx mori were degummed with 0.5 wt% Na₂CO₃ solution and washed with deionized water to remove the sericin [9, 10].

Indoor air quality has received immense attention in the early 1990s because of higher level of pollutants in indoor air environment as compared to outdoor air environment [11]. Usually, people spend 80-90% of their time indoors resulting in higher risk from indoor air pollutants. Indoor environments can cause important effects on human health and work efficiency [12]. In 1995, USEPA identified indoor air pollution is one of the top environmental risk [13]. Indoor air pollutants consist of biological contaminants, chemical contaminants and particulates depending on air pollutant sources [14].

Particulate matter or PM, is a mixture of microscopic solids or liquid droplets suspended in air. The constituent particles typically vary in size,
composition and origin [15]. Particles of less than 10 μm in diameter are often referred to as "inhalable" in terms of PM₁₀ (<10 μm in mean aerodynamic diameter). The "fine particle" is also often referred as PM₂.₅ (<2.5 μm in diameter) [16]. Particle exposure can lead to a variety of health effects such as headaches, runny nose, cancer, and respiratory diseases [17] depending on long-term or short-term particle exposures [18]. One of the major sources of indoor air particles is rice mills particularly from a rice milling process. Suwanno et al. [19] found that the PM concentrations in rice mills in Ubonratchathani province, Thailand, were 0.1170 mg/m³ and 0.0366 mg/m³ for total dust and respirable dust, respectively.

The aim of this study is to investigate the ability of silk fibroin as a fiber for filtration of particulate matter in indoor air. The SF fiber was synthesized from cocoons of the Bombyx mori silkworm. Cocoons were degummed with sodium carbonate (Na₂CO₃) solution. Rice bran was selected as a particle pollutant because it is mainly found in a rice mill process. Thus, in this work the SF was used as bio-filtration fiber for particulate removal, and the cost comparison between SF fiber and Whatman No.1 was also studied.

Experimental Procedure

Preparation of Bombyx mori silk fibroin

Cocoons of the Bombyx mori silkworm were collected from a local farm (Ubonratchathani province, Thailand). They were dried in sunlight and then cut into small pieces of approximately 1 mm x 1 mm dimensions. They were degummed by boiling them in an aqueous solution of 0.5% (w/w) Na₂CO₃ solution at 90°C for 60 min to remove all traces of sericin for complete degumming of the shells. The cocoon pieces were subsequently washed thoroughly in distilled water and dried briefly for 3 hr in a vacuum oven at 80°C.

Silk fibroin fiber characterization

Scanning electron microscope (SEM) analysis and BJH nitrogen adsorption technique

SEM characterization was performed by using a Jeol JSM-5410LV microscope at an acceleration voltage of 15kV. SF fiber samples for SEM were sputter-coated with a thin gold layer under rarefied Argon atmosphere. Physical properties of SF fiber samples were examined using Autosorb-1(AS1Win Version 1.50). Nitrogen gas was utilized as an adsorbate gas. The BJH method was applied for specific surface area, specific pore volume, and pore size analysis [20].

The reactor and measurement

As shown in Fig. 1, a glass room with the dimensions of 78 L was used as a reactor in this study. The temperature and relative humidity were continuously monitored by Hygrometer monitor (Model TECPEL 550). In all sets of experiment, temperature and relative humidity ranged from 25-30°C and 65-70%, respectively. Rice bran from a local rice mill in Ubonratchathani province was used as indoor air contaminant. Four mixing small fans were installed in the room to ensure adequate mixing of rice bran particulate matter in air. Rice bran was added from the top of the room and allowed to reach equilibrium. The initial concentration was controlled to be 0.040 ± 0.005 mg/m³ and 0.020 ± 0.005 mg/m³ for PM₁₀ and PM₂.₅, respectively. The SF filter was placed inside the filter holder with the diameter of 33 mm. Then, it was connected with the room and an aerosol personal pump (Fig. 1). The PM pollutants in the room were pumped through the SF filter using an aerosol personal pump. The air flow rate was varied from 3, 4, and 5 L/min. The PM concentration was continuously measured for 8 hr by a Side Pak Personal Aerosol Monitor (AM510) with impactor PM₂.₅ and PM₁₀. The interval time was set at 10 seconds.
Results and Discussions

Fiber morphology

Fig. 2a) shows the SEM of SF fibers before PM filtration. SEM micrographs revealed the fibrous morphology of the SF fiber. An average diameter of the SF fiber was estimated to be approximately 10 μm. The images of the SF fiber after PM filtration were depicted in Fig. 2b). SEM images revealed the deposition of fine particle on the SF fiber. Therefore, it could be concluded that PM pollutants were adhered onto the SF fiber. Consequently, the SF fiber may be used as an alternative material for PM filtration. The physical properties of the SF fiber were analyzed using the BJH technique and were reported in Table 1. From the results, the SF fiber has the specific surface area and pore volume of 62.325 ± 7.149 m²/g and 0.0332 ± 0.004 cc/g, respectively. The pore size of the SF fiber was estimated to be 24.665 ± 0.007 Å and was classified as mesopore.

SF Filtration

Two sets of experiment were conducted to observe the filtration of PM₁₀ and PM₂₅ using the SF fiber. Initial concentrations of PM₁₀ and PM₂₅ were maintained at about 0.040 ± 0.005 mg/m³ and 0.020 ± 0.005 mg/m³, respectively. These concentrations were achieved by controlling the amount of rice bran added into the room. As seen in Fig. 3a) the initial PM₁₀ concentration reached equilibrium at around 3 hr. The similar result was observed for initial PM₂₅ concentration as shown in Fig. 3b). Then the treatment of PM was performed using the different air flow rate of 3, 4, and 5 L/min.

The PM₁₀ removal efficiency at the air flow rate of 5, 4, and 3 L/min is shown in Fig. 3a). As seen from the figure, the PM₁₀ concentration decreased rapidly during the initial period of treatment. PM₁₀ concentration decreased from 0.039 mg/m³ to 0.011 mg/m³ after the treatment period of 4 hr when using the air flow rate of 5 L/min. Also PM₁₀ concentration decreased from 0.038 mg/m³ to 0.017 mg/m³ and from 0.037 mg/m³ to 0.020 mg/m³ when using the air flow rate of 4 L/min and 3 L/min, respectively, after the treatment period of 4 hrs. After the 4th hour of treatment, the PM₁₀ concentration tends to reach equilibrium. The results also showed that the PM₁₀ removal efficiency increased with the air flow rate. This may be due to the higher the air flow rate, the more particles pumped from the room to the filter. The highest PM₁₀ removal efficiency of 72.29 ± 3.03% was obtained when using the air flow rate of 5 L/min.

The PM₂₅ removal efficiency at the air flow rate of 5, 4, and 3 L/min is shown in Fig. 3b) As seen from
Fig. 2 The morphologies of the SF fiber (a.) before filtration and (b.) after filtration at magnifications 1) 500X, 2) 1000X 3) 1500X and 4) 2000X

Table 1 BJH analysis of SF fiber

<table>
<thead>
<tr>
<th>Sample</th>
<th>Specific surface area (m²/g)</th>
<th>Specific pore volume (cc/g)</th>
<th>Pore size (Å)</th>
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</thead>
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<tr>
<td>1</td>
<td>67.380</td>
<td>0.036</td>
<td>24.660</td>
</tr>
<tr>
<td>2</td>
<td>57.270</td>
<td>0.031</td>
<td>24.670</td>
</tr>
<tr>
<td>Average</td>
<td>62.325±7.149</td>
<td>0.033±0.004</td>
<td>24.665±0.007</td>
</tr>
</tbody>
</table>

Table 2 PM removal efficiencies of SF filtration

<table>
<thead>
<tr>
<th>Types of PM</th>
<th>PM removal efficiency at air flow rate</th>
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<tr>
<td></td>
<td>5 L/min</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>72.29 ± 3.03%</td>
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<tr>
<td>PM₂₅</td>
<td>39.33 ± 1.99%</td>
</tr>
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</table>

Fig. 3 PM concentrations before and after treatment at air flow rate of 3, 4, and 5 L/min a) PM₁₀ (initial concentration of 0.040 mg/m³), b) PM₂₅ (initial concentration of 0.020 mg/m³)
the figure, PM$_{2.5}$ concentration decreased from 0.023 mg/m$^3$ to 0.015 mg/m$^3$ after the treatment period of 3 hrs. when using the air flow rate of 5 L/min. Also PM$_{2.5}$ concentration decreased from 0.022 mg/m$^3$ to 0.015 mg/m$^3$ and from 0.024 mg/m$^3$ to 0.016 mg/m$^3$ when using the air flow rate of 4 L/min and 3 L/min, respectively after the treatment period of 3 hrs. Then PM$_{2.5}$ concentration tends to reach equilibrium for all experiments. Similar to the above, the PM$_{1.0}$ removal efficiency increased with the air flow rate. The highest removal efficiency of 39.33 ± 1.99% was obtained when using the air flow rate of 5 L/min. Table 3 show the PM removal. When the initial PM concentrations were varied to 2 and 5 times of the original ones, the PM$_{1.0}$ removal efficiencies were 51.25 ± 4.33% and 53.02 ± 0.40%, respectively. PM$_{2.5}$ removal efficiencies were 44.57 ± 5.78% and 47.80 ± 0.96%, respectively. Cost comparison between the Whatman No.1 and the SF fibers is shown in Table 4. The results show that the SF fiber has less cost than the Whatman No.1 filter paper.

![Graph](image)

**Fig. 4** PM concentrations before and after treatment at air flow rate of 5 L/min a) PM$_{1.0}$ b) PM$_{2.5}$ (Co = initial concentration of PM)

**Table 3** PM removal efficiencies at low rate of 5 L/min

<table>
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<th>Types of PM</th>
<th>PM removal efficiency at initial concentration</th>
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<tr>
<td>PM$_{1.0}$</td>
<td>0.040 mg/m$^3$</td>
</tr>
<tr>
<td></td>
<td>72.29 ± 0.303%</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>0.020 mg/m$^3$</td>
</tr>
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<td></td>
<td>38.93 ± 2.56%</td>
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**Table 4** Cost comparison of the Whatman No.1 and the SF fiber

<table>
<thead>
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<th>Types of fiber</th>
<th>Price (Baht/Pack $^*$)</th>
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<tr>
<td>Whatman No.1 $^a$</td>
<td>178.00</td>
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<tr>
<td>Silk fibrin $^b$</td>
<td>61.25</td>
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</table>

$^a$ Unit of sale in pack of 100.

$^b$ Whatman Grade No.1 filter paper of 5.5 cm in diameter size.
Conclusion

The SF fiber was readily synthesized using the Na$_2$CO$_3$ solution. The SEM images revealed the deposition of fine particle on the fiber. The BJH analysis showed that most of pore sizes of the SF fiber were mesopores. The removal efficiency of the SF fiber increased with an increase of an air flow rate. The results showed that the highest removal efficiencies of 72.29 ± 3.03% and 39.33 ± 1.99% were obtained for PM$_{10}$ and PM$_{2.5}$, respectively when using 5 L/min of air flow rate. The initial PM concentration was varied to 2 and 5 times of the initial concentrations. PM$_{10}$ removal efficiencies were 51.25 ± 4.33% and 53.02 ± 0.40%, respectively. PM$_{2.5}$ removal efficiencies were 44.57 ± 5.78% and 47.80 ± 0.96%, respectively. The SF fiber could be applied as an alternative material for removing particulate matter in indoor air.

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References


