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- Abstract -

Air concentration and particle size distribution of  
wood dust during wood-working processes

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Wood dust is created when machines are used to cut or shape wood materials. Industries of high risk of wood dust exposure are sawmills, dimension mills, furniture industries, and carpenters, etc. Health effects associated with wood dust exposure includes dermatitis, allergic respiratory effects and cancer. Health effects of wood dust are mainly depend on the concentration, dust size and exposure time. This study were carried out to evaluate the concentration and particle size distribution of wood dust during working processes. The subjects of this study were 53 workers exposed to wood dust in 7 furniture factories and 5 musical instruments, and 5 sawmill factories.

The average total wood dust concentrations measured by personal cascade impactor were  $1.82 \pm 2.31 \text{mg/m}^3$  in primary manufacture,  $3.59 \pm 1.72 \text{mg/m}^3$  in secondary manufacture,  $5.09 \pm 1.46 \text{mg/m}^3$  in sanding operation. Mass median diameters of hardwoods dust were  $3.36 \mu\text{m}$  in primary manufacture,

$4.25 \mu\text{m}$  in secondary manufacture,  $4.21 \mu\text{m}$  in sanding operation. softwoods dust were  $3.39 \mu\text{m}$  in primary manufacture,  $4.34 \mu\text{m}$  in secondary manufacture. Particle size distributions showed a nearly the same pattern in each working processes. The sample concentration of all hardwood dust exceeded the Threshold Limit Value(TLV) and 20.8% of the softwood dust exceeded the Threshold Limit Value. The range of size distribution were 0.5-  $10 \mu\text{m}$  in the soft and hardwood dust. The respirable dust of soft and hardwood took up 59% and above. Therefore new threshold limit value for wood dust should be needed in Korea. Also, it should be done for various studies on health effects related to occupational exposure of wood dust.

**Key words** : Hardwood dust, Softwood dust, Mass median diameter, Cascade impactor, Size distribution, Respirable dust

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I. (National Institute for Occupational Safety and Health, NIOSH)

가

(aerodynamic diameter)

100 $\mu$ m 가

가 (American Conference of Governmental Industrial Hygienists, ACGIH)

(inhalable), (thoracic), (respirable)

100 $\mu$ m , 10 $\mu$ m .

가 , ACGIH

4.0 $\mu$ m (ACGIH, 1996). 가 , 1.0mg/m<sup>3</sup>, 5.0mg/m<sup>3</sup>

80-90% 가 15 $\mu$ m (Imbus Dyson, 1987). (cellulose), (semicellulose) (lignin) 33 2 ‘ (glycosides), (quinones), (tannins), (terpenes), 1994 (aldehydes), (coumarins) 가 (hardwoods) (softwoods) 5.0mg/m<sup>3</sup> 가 (broad leaves) (beech), 가 (oak), 가 (mahogany), (maple), (1996) (walnut), (western red cedar) (needle like leaves) (fir), (pine) 37mm closed-face cassette (inhalable particle mass, IPM)

( , ) (threshold limits value-time weighted average, TLV-TWA) 1.0mg/m<sup>3</sup>, 5.0mg/m<sup>3</sup> . Scheeper (1995)

, A1 가 (ACGIH, 1996),

. Pisaniello (1991) 가

가

가

, 가

가

1

- 1.5m . 1998 3

4 가 20 , 가

40 8

200 - 300

## II.

(personal cascade impactor, model No. 296, Andersen, USA)

1. (Andersen sampler, model AN-200, Sibata)

7 가 5

가

, 5

53

가

가 , 가

가

(nozzle)

가

가 , 가

1

4

. 가

6

(slot)

5, 6

12

가

(medium density

(cut-point diameter,

fiberboard, MDF)

(particle

$\mu\text{m}$ ) Table 2 .

board, PB)

(wenge),

가

(ebony), ,

(particle bounce)

34mm

Mylar (Sierra Model C- 290- MY)

24

0.01mg

(meranti)

가

(Mettler AE 240, Switzerland) 3

(Table 1).

. 6

34mm, 5 $\mu\text{m}$  pore

2.

polyvinylchloride(PVC)

(personal air sampler, Gilian,

1)

USA)

(primary flow-

가

calibrator, Gilian, USA)

Table 1. Classification and quantity of woods by type of factory

Factory		Number of employees	Type of wood	Quantity(m <sup>3</sup> /year)	
				Hardwood	Softwood
Furniture making	A	778	MDF*, PB	441	5,195
	B	138	Oak <sup>☆</sup> , Meranti*, Maple <sup>☆</sup> , Beech <sup>☆</sup> , Bubinga*, Cherry <sup>☆</sup> MDF*	4,800	7,440
	C	200	Meranti*, PB, MDF	4,000	8,500
	D	650	MDF, PB	350	5,100
	E	236	Ebony <sup>☆</sup> , Wenge <sup>☆</sup> , Parosa <sup>☆</sup> , Madica*, Taun*, MDF	80	2,130
	F	76	MDF*, PB	.	1,150
	G	75	MDF, PB	.	1,850
Musical instruments (guitar)	A	2193	Ash <sup>☆</sup> , Rosewood <sup>☆</sup> , Walnut <sup>☆</sup> , Cherry <sup>☆</sup> , Spruce <sup>☆</sup> , Beech <sup>☆</sup> , Oak <sup>☆</sup> , Maple <sup>☆</sup> , Basswood <sup>☆</sup> , Alder <sup>☆</sup> , Meranti*, Nyatoh*, Teak*,	14,400	21,600
	B	56	Elder*, Basswood <sup>☆</sup> , Maple <sup>☆</sup> , MDF	.	.
	C	50	Maple <sup>☆</sup> *, Elder*, Rosewood <sup>☆</sup> , Basewood*, MDF	76	608
	D	257	Maple <sup>☆</sup> *, Basewood*, Wenge <sup>☆</sup> , MDF	702	19,278
	E	46	Maple <sup>☆</sup> , Rosewood <sup>☆</sup>	800	.
Sawmill	A	86	Meranti*, Pine*	.	8,000
	B	13	Pine*	.	2,100
	C	146	Spruce <sup>☆</sup> , MDF, PB, Poplar <sup>☆</sup> , Cherry <sup>☆</sup> , Maple <sup>☆</sup> , Meranti*	.	.
	D	24	Capas <sup>☆</sup> , Malas <sup>☆</sup> , Bukilar <sup>☆</sup> , Pine*	3,600	2,400
	E	19	Pine*, Wenge <sup>☆</sup> , Meranti*	4,500	10,500

☆, hardwood; \*, softwood; MDF, medium density fiberboard; PB, particle board.

2.0 ℓ/min

8

(Ø

3

80mm)

Table 3

Table 2. Design parameter and cut-point diameters of the personal cascade impactor

Stage	Nozzle			Slot length (cm)	Cut- Point diameter( $\mu\text{m}$ )
	Shape	No.	Width(cm) Diameter(cm)		
1	slot	6	0.0813	0.953	9.8
2	slot	6	0.0432	0.953	6.0
3	slot	6	0.0254	0.953	3.5
4	slot	6	0.0173	0.480	1.55
5	round	12		0.0457	0.93
6	round	12		0.0318	0.52
Back- up filter					0

Table 3. Design parameter and cut-point diameters of the area cascade sampler

Stage	Orifice diameter (cm)	No. of orifice	Cut- point diameter( $\mu\text{m}$ )
0	0.1587	400	11 or more
1	0.1181	400	7.00- 11
2	0.0914	400	4.70- 7.0
3	0.0711	400	3.30- 4.7
4	0.0533	400	2.10- 3.3
5	0.0342	400	1.10- 2.1
6	0.0254	400	0.65- 1.1
7	0.0254	210	0.43- 0.65
Back- up filter			043 or less

(mass median diameter, MMD)

1

III.

2)

1.

(非母數) 1)

(Wilcoxon) (順位合)

(Kruskal- Wallis)

(cumulative 가

particle size distribution)

50% 10 $\mu\text{m}$  , 4.0 $\mu\text{m}$

Table 4. Air concentration of hardwoods and softwoods dust by working process

unit; mg/ m <sup>3</sup>					
Process	No. of samples	Type	Inhalable	Thoracic	Respirable
Primary manufacture	3	Hardwoods	4.74(1.10)	1.55(1.07)	3.19(1.14)
	12	Softwoods	1.54(2.87)	0.50(3.65*)	1.04(2.10)
	.	Mixed woods	.	.	.
Secondary manufacture	6	Hardwoods	3.56(1.88)	1.42(1.57)	2.14(2.20)
	12	Softwoods	3.76(2.23)	1.54(2.45)	2.20(2.01)
	12	Mixed woods	2.72(2.51)	0.96(2.20)	1.76(2.82)
Sanding	2	Hardwoods	5.91(1.31)	2.11(1.23)	3.80(1.40)
	.	Softwoods	.	.	.
	6	Mixed woods	4.50(2.61)	1.25(3.41)	3.25(1.82)

GM(GSD); geometric mean(geometric standard deviation), \*, P<0.05.

Table 5. Air concentration of hardwoods and softwoods dust by working process (area sampling)

unit; mg/ m <sup>3</sup>					
Process	No. of samples	Type	Inhalable	Thoracic	Respirable
Primary manufacture	1	Hardwoods	8.72	2.50	3.78
	4	Softwoods	5.24(1.62)	1.13(1.44)	1.23(1.31)
	.	Mixed woods	.	.	.
Secondary manufacture	1	Hardwoods	6.19	1.92	3.14
	3	Softwoods	9.37(1.51)	2.17(1.31)	2.17(1.41)
	6	Mixed woods	8.84(2.29)	2.09(2.57)	2.87(1.94)

GM(GSD); geometric mean(geometric standard deviation)

3, 4 가 가  
 가 6.0 - 14.7 $\mu$ m 5 (P>0.05).  
 가 5.9 $\mu$ m 가 3.19 $\pm$   
 . 1.14mg/ m<sup>3</sup>, 가 2.14 $\pm$ 2.20mg/ m<sup>3</sup>,  
 3.80 $\pm$ 1.40mg/ m<sup>3</sup> 가  
 (Table 4). 가 가 (P>0.05).  
 1.55 $\pm$ 1.07mg/ m<sup>3</sup>, 가 1.42 $\pm$ 1.57 가  
 mg/ m<sup>3</sup>, 2.11 $\pm$ 1.23mg/ m<sup>3</sup> 67%, 가 60%, 64%

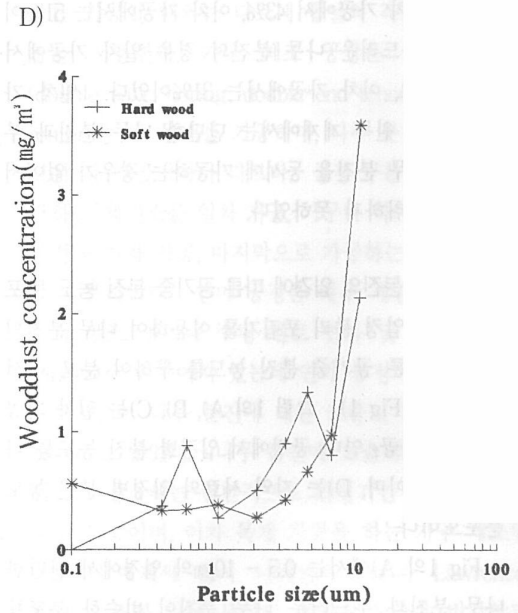
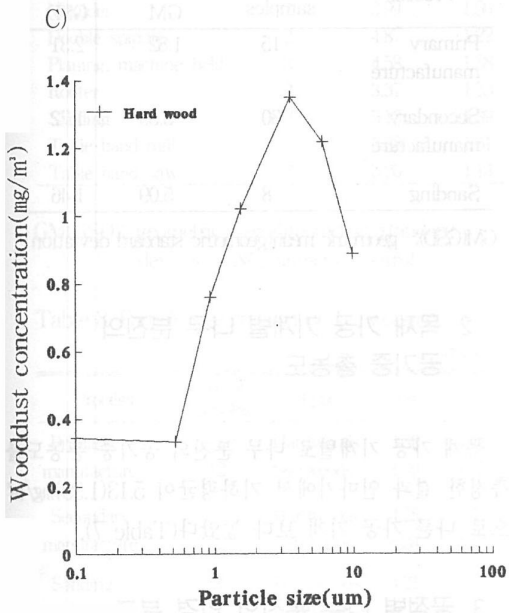
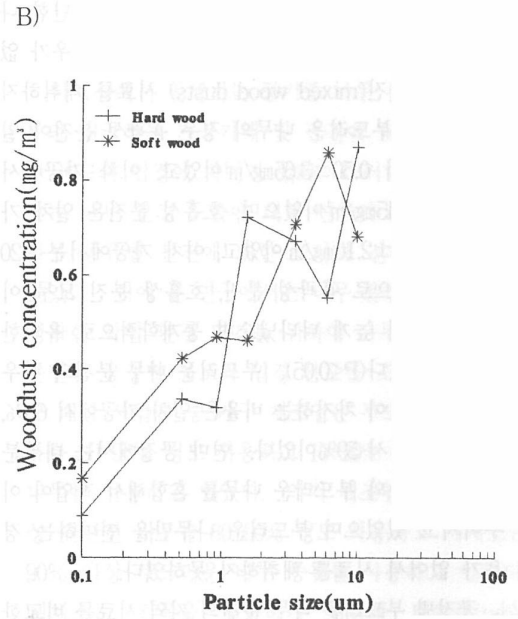
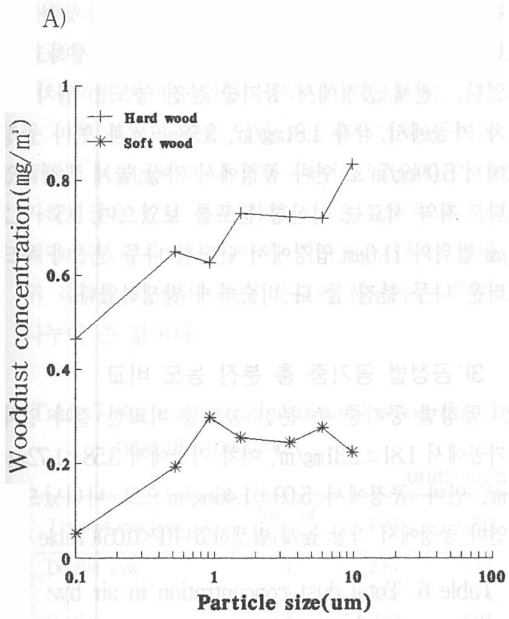


Fig 1. Distribution of dust concentration in air by process.

- A) Primary manufacture      B) Secondary manufacture  
 C) Sanding                      D) Area sampling

가 (mixed wood dusts) 가 0.5 - 5 $\mu$ m  
 가 0.50 $\pm$ 3.65mg/m<sup>3</sup>, 가 1.81mg/m<sup>3</sup>, 3.58mg/m<sup>3</sup>  
 가 1.54 $\pm$ 2.45mg/m<sup>3</sup>, 가 5.09mg/m<sup>3</sup> 가  
 가 1.04 $\pm$ 2.10mg/m<sup>3</sup>, 가 2.20  $\mu$ m 11.0 $\mu$ m, 0.5 - 1.2  
 $\pm$ 2.01mg/m<sup>3</sup>, 가  
 가 (P<0.05). 3)  
 가 59%, 가 68%,  
 가 1.81 $\pm$ 2.31mg/m<sup>3</sup>, 가 3.58 $\pm$ 1.72mg/m<sup>3</sup>  
 m<sup>3</sup>, 5.09 $\pm$ 1.46mg/m<sup>3</sup>  
 가 (P<0.05)(Table 6).

Table 6. Total dust concentration in air by working process

Process	No. of samples	Dust concentration unit; mg/ m <sup>3</sup>	
		GM	GSD
Primary manufacture	15	1.82	2.31
Secondary manufacture	30	3.59	1.72
Sanding	8	5.09	1.46

GM(GSD); geometric mean(geometric standard deviation)

가 (P>0.05)(Table5).  
 가 43%, 가 51%  
 29%, 가 31% 가  
 가 가

2) 가  
 (Fig 1). 1 A), B), C) 가  
 가 , 가  
 , D) 5.13(1.39)mg/m<sup>3</sup>  
 가 (Table 7).

Fig 1 A) 0.5 - 10 $\mu$ m  
 , B) 1.6 - 10 $\mu$ m  
 . C) (Fig 2)



가 4.25μm, 4.21μm, 3.36μm, 가  
 (P>0.05)(Table 8).  
 가 3.39μm, 가  
 4.34μm (P>0.05).  
 50%  
 ,  
 15.9%

IV.

가  
 가  
 80-90% 10-20%  
 80-90%  
 90%  
 (table  
 band saw), (table band mill),  
 , 가  
 가 가  
 . 가  
 (double saw, boring, double-end tenoner, moulder,  
 router ) 가 ,  
 가  
 가 , 가  
 가 , 가

Table 7. Air concentration of total wood-dust by type of machine

unit; mg/ m <sup>3</sup>			
Type of machine	No. of samples	GM	GSD
Double saw	4	3.87	1.17
NC	6	2.08	1.74
Cutting	3	2.63	1.94
Boring	2	5.12	1.34
Double-end tenoner	3	3.61	1.91
Angular	2	4.60	1.25
Moulder	2	3.99	1.59
Double spindle	2	4.87	1.22
Planing, machine-held	3	4.58	1.38
Router	2	3.37	1.23
Sanding	8	5.13	1.39
Table band mill	5	3.38	1.51
Table band saw	5	3.20	1.14

GM(GSD); geometric mean(geometric standard deviation) NC, numeric control.

Table 8. Particle size distribution by working process

unit; μm				
Process	No. of samples	Type	GM	GSD
Primary manufacture	3	Hardwoods	3.36	5.33
	12	Softwoods	3.39	3.62
Secondary manufacture	6	Hardwoods	4.25	3.43
	12	Softwoods	4.34	4.59
Sanding	2	Hardwoods	4.21	3.24
		Softwoods	·	·
Area sampling	2	Hardwoods	5.71	5.97
	7	Softwoods	7.69	7.17

GM(GSD); geometric mean(geometric standard deviation)

(hand sander)  
 가  
 , 가 가  
 (Bean Lawrence, 1991).  
 (Liou , 1996).

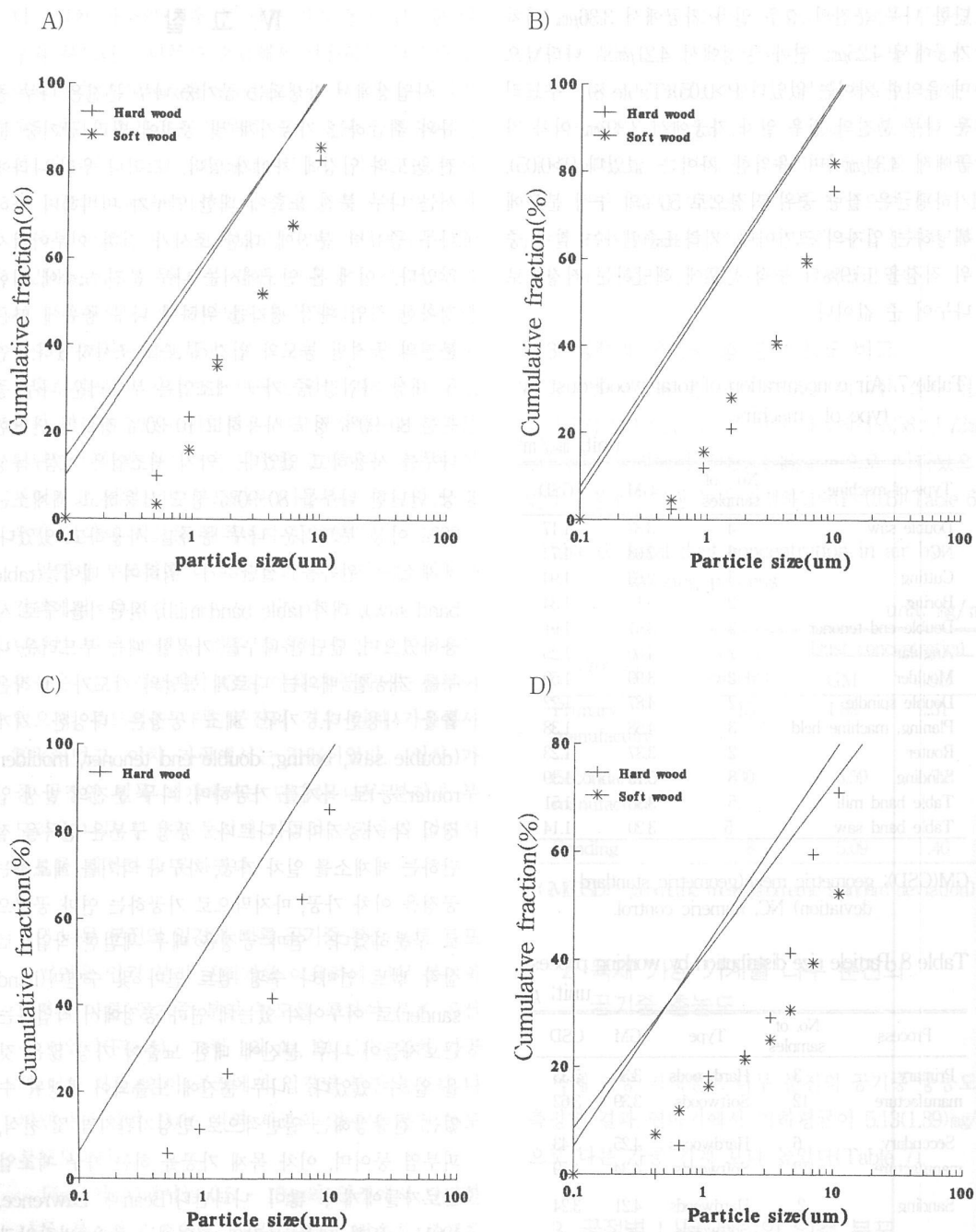


Fig 2. Cumulative particle size distribution by process.

- A) Primary manufacture
- B) Secondary manufacture
- C) Sanding
- D) Area sampling

가 (Imbus Dyson, 1987). , 가 , 가 가 가 1.81mg/m<sup>3</sup>, 3.58mg/m<sup>3</sup>, 5.09mg/m<sup>3</sup> 가 (nasal adenocarcinoma) . Teschke (1994) 가 (Nylander Dement, 1993). 가 가 가 가 가 가 (Nylander Dement, 1993). Pisaniello (1991) 가 가 가 2.5mg/m<sup>3</sup>, 3.9 mg/m<sup>3</sup> 3.2mg/m<sup>3</sup> , Scheeper (1995) 가 59- 68% 60- 67% , 가 1.32- 4.14mg/m<sup>3</sup> 가 4.74mg/m<sup>3</sup>, 1.54mg/m<sup>3</sup> . Pisaniello (1991) 가 18.7 (cells) , μm , 19.0μm 가 2 가 4.25μm, 4.34μm . 가 3.56mg/m<sup>3</sup>, 16- 19μm 3.76mg/m<sup>3</sup> 4.21μm . (1994) 가 9.14μm, 9.12μm, 9.83μm . Pisaniello (1991) (Thorpe Brown, 1995), 78% 가 1.0mg/m<sup>3</sup> 5.0 mg/m<sup>3</sup> 16% 가 5.0 mg/m<sup>3</sup> 가 180- 220 20.8% 가 mesh가 60% , 59%

11 가 , 가  
 (1.0mg/ m<sup>3</sup>) , 0.50mg/ m<sup>3</sup>, 1.54mg/ m<sup>3</sup> ,  
 24 20.8% 가 (5.0mg/ m<sup>3</sup>) 1.04mg/ m<sup>3</sup>, 2.20mg/ m<sup>3</sup>  
 (p<0.05).

59% 2. 가

가 가 가 0.5- 10 $\mu$ m 가  
 가 가 가 1.6- 10 $\mu$ m ,

가

가

3.5- 5.0 $\mu$ m

9.8 $\mu$ m

가

9.8 $\mu$ m

0.5- 5.0 $\mu$ m

가

1.81mg/ m<sup>3</sup>, 가 3.58mg/ m<sup>3</sup>,

5.09mg/ m<sup>3</sup> 가

3. 가

가

5.13mg/ m<sup>3</sup> 가

4.

## V.

가

3.36 $\mu$ m,

가

가 4.25 $\mu$ m,

4.21 $\mu$ m ,

가 , 가

3.39 $\mu$ m, 4.34 $\mu$ m

가

가

20.8%가

1.

0.5- 10 $\mu$ m ,

59% .

1.55mg/ m<sup>3</sup>, 가 1.42mg/ m<sup>3</sup>,

2.11mg/ m<sup>3</sup> 가

가

가가

3.19mg/ m<sup>3</sup>, 가

2.14mg/ m<sup>3</sup>,

가

가

3.80mg/ m<sup>3</sup>

(p>0.05).

가

가가

33 2 ‘

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