Evaluation of Cleaning and Washing Processes for Cotton Fiber

Part V. Characterization of Dust Samples[1]

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ABSTRACT

Fine dusts in trash samples collected on Pneumafil filter during carding of washed cottons were separated into 20 to 38-μm and <20-μm fractions, their ash contents determined, and elemental analyses performed on the resulting inorganic residues. The quantity of fine dusts separated was affected by carding rate and the use of an electrostatic eliminator on the card. The lower the carding speed, the lower the fine dust content per bale. The electrostatic eliminator significantly increased the amount of fine dusts per bale even at the lowest carding speed. Ash contents varied with washing conditions, carding rate, and whether the electrostatic eliminator was employed. A wide variety of elements was present in the fine dusts, but unexpectedly high levels of Cu, Zn, Fe, and Al were found, which indicate contamination of these cottons.

Introduction

Trash samples that accumulated on the Pneumafil V-filter frame during the course of processing of the washed cotton samples [2, 5, 6] in the NC State University model cardroom were collected after each run and used as a source of material to separate small particle-size dusts from cotton. The method used to separate the dusts, in 20 to 38-μm and <20-μm fractions, has been described by Brown and Berni [1]. Approximate chemical analyses of dusts separated in this manner have also been previously reported [3].

The 20 to 38-μm and <20-μm dusts were ashed using the procedure previously described [4]. Elemental analyses were performed on the resulting inorganic residues by neutron activation analysis and atomic absorption.

Results and Discussion

A summary of the quantities of total trash collected on the Pneumafil filter for each bale processed in this washed-cotton study is given in Table I. The washing conditions are described in Part II of this paper [6] with the same sample I.D. The amounts of 20 to 38-μm and <20-μm size dusts are included, the weight (in grams) of 20 to 38-μm and <20-μm dust per bale of cotton and per kg of Pneumafil trash are shown, and the ratio of the <20-μm to 20 to 38-μm fractions is also given.

As described by Hersh *et al.* [2], some of the washed cottons presented processing difficulties and could not be run at the usual carding speed of 18.1 kg/h (40 lb/h). Consequently, part of each treatment was run at 6.1 kg/h (15 lb/h). Treatment 2A and each of the washed treatments were divided into two parts and run on separate occasions. The second part of each of the washed treatments was run using an electrostatic eliminator bar on the doffer of the card. Therefore, the quantity of fine dust separated using the procedures described herein could be affected by the washing conditions, processing speed, and whether or not the electrostatic eliminator was used.

The amount of Pneumafil trash collected from the V-frame varied from a low of 1.5 kg/bale (this is an unusually small amount) to a high of 5.8 kg/bale. The average was 4.0 kg/bale. The treatment 2A yield was 3.5 kg/bale, and the average yield from the washed cottons was 4.5 kg/bale.

Relative to the other treatments in this study, a very small quantity of <20-μm dust was separated from bales 1-I and 1-II (the control) (0.41 g and 0.26 g/bale, respectively). The amount of <20-μm dust per kg of Pneumafil trash is also low for bales 1-I and 1-II. The entire treatment 1-I was processed in the model cardroom at 18.1 kg/h, while 77% of treatment 1-II was run at 18.1 kg/h, and 23% at 6.8 kg/h. The electrostatic eliminator was not used in either case. It appears that there is a reduction in both the 20 to 38-μm and <20-μm fractions as the carding rate is reduced. This is better illustrated with the results from treatment 2A. The entire first

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TABLE I. Summary of dust quantities separated from washed cottons by mechanical and sonic separation.

Treatment I.D.	Wt. processed in model cardroom, kg	Pneumafil filter wt., kg		Processing rate weight fraction at		Electrostatic eliminator	Quantity of dust separated				20 to 38-μm wt. per kg of Pneumafil trash, g/kg	<20-μm wt. per kg of Pneumafil trash, g/kg	Ratio of <20-μm dust 20 to 38-μm dust
		Total	Per bale[a]	18.1 kg/h, %	6.8 kg/h, %		20 to 38-μm weight, g	<20-μm weight, g	20 to 38-μm wt/bale, g	<20-μm wt/bale, g			
1-I	236	2.7	2.5	100	0	No	13.55	0.45	12.48	0.41	4.96	0.18	0.03
1-II	271	4.5	3.6	77	23	No	13.12	0.32	10.55	0.26	2.49	0.07	0.02
2A	164	2.3	3.0	0	100	No	3.95	1.22	5.25	1.62	1.74	1.53	0.31
2A (2nd half)	122	2.2	3.9	65	35	No	8.10	2.77	14.51	4.96	3.77	1.28	0.34
2B	179	3.7	4.6	48	52	No	6.24	1.43	7.60	1.74	1.68	0.37	0.23
3	113	1.6	3.0	0	100	No	7.55	1.88	14.55	3.62	4.76	1.19	0.24
3 (2nd half)	69	1.6	5.0	22	78	Yes	4.52	2.54	14.18	7.97	2.84	1.61	0.56
4	106	2.3	4.7	51	49	No	2.02	1.89	4.14	3.88	0.88	0.84	0.76
4 (2nd half)	73	1.1	3.4	0	100	Yes	8.98	4.51	26.77	13.57	7.28	3.97	0.51
5	116	0.8	1.5	0	100	No	1.35	1.29	2.53	2.42	1.70	1.63	0.96
5 (2nd half)	75	1.8	5.3	0	100	Yes	7.03	5.10	20.33	14.75	3.88	2.82	0.73
6	108	2.3	4.6	11	89	No	4.39	4.52	8.89	9.15	1.94	1.98	1.03
6 (2nd half)	82	2.0	5.4	0	100	Yes	6.32	5.28	16.76	14.00	3.09	2.58	0.84
6A	170	2.0	2.6	79	21	Yes	3.21	3.24	4.12	4.16	1.57	1.59	1.01
7	109	1.3	2.5	92	8	No	2.35	2.71	4.68	5.40	1.87	2.16	1.15
7 (2nd half)	93	1.8	4.3	87	13	Yes	6.75	6.21	15.88	14.61	3.73	3.42	0.92
8	108	2.8	5.8	0	100	Yes	7.14	7.18	14.46	14.54	2.51	2.54	1.01
8 (2nd half)	48	1.3	5.6	0	100	Yes	4.56	4.13	20.65	18.70	3.66	3.31	0.91

[a] 1 Bale = 218 kg (480 lb).

half of this bale was processed at 6.8 kg/h, while 65% of the second half was processed at 18.1 kg/h, and the remainder at 6.8 kg/h. There is approximately a three-fold increase in the quantity of both the 20 to 38-μm and <20-μm fractions collected from the cotton processed at the higher rate. Further, treatments 1-I and 1-II had no precleaning in the washing line, while treatment 2A had been passed through the precleaner once (2A served as a control for the washed cotton treatments), and 2B was passed through the precleaner twice. Approximately 52% of bale 2B was processed at 6.8 kg/h and 48% at 18.1 kg/h. At the faster rate, the quantity of <20-μm dust increases dramatically for treatment 2A (2nd half) compared with 1-I and 1-II and, although 2B contains an appreciably higher amount of <20-μm dust than treatments 1-I and 1-II, it contains a smaller amount than 2A (2nd half). Thus, while the precleaner is effective at removing the large trash from cotton, as also shown by the Shirley total trash reported by Hersh [2], it tends to break the friable trash components into smaller particles, which causes the increase in the quantity of <20-μm dust for 2A, as noted above. This trend was also observed in the Shirley invisible trash, which showed a larger amount of invisible for treatment 2A than 1-I and 1-II. Obviously, as the cotton is successively passed through the precleaner, a point would be reached after which the additional amount of small dust generated by crushing of the larger components would be less than the amount of small dust removed by the precleaner. The second pass through the precleaner shows this behavior.

The use of the electrostatic eliminator during processing shows the most dramatic effect of any variable on the quantities of dusts separated from the washed cotton series. Part (*ca.* ½) of the bale treatments 3–7 was processed using the eliminator and part without. There is a significant increase in the quantity of small dust entrapped in the Pneumafil trash when eliminator is used. This is most readily demonstrated in treatments 5 and 5 (2nd half), which were processed at 6.8 kg/h. The increase in the 20 to 38-μm fraction is about ten-fold and about six-fold for the <20-μm fraction. The trend is observed in all the treatments 3–7 (treatment 8 could not be processed without the eliminator).

The eliminator bar is located near an intake for the Pneumafil system. The eliminator reduces static charges, the dust becomes more easily airborne, and significantly more of the smaller particles are captured in the air stream of the Pneumafil. Most of this dust is then probably trapped in the trash layer, which builds upon the V-frame filter during processing and results in appreciably higher quantities of dust that can be removed from this trash.

It is more difficult to access the effects of washing on the quantities collected, because we could not separate the effects of processing speed and the electrostatic eliminator from washing effects. However, the first half of bales 2A, 3, 5, and 6 were processed without the eliminator and at a carding rate of 6.8 kg/h (except treatment 6, in which 11% was processed at 18.1 kg/h). The <20-μm fraction is lowest for treatment 2A (1.62 g/bale) and highest, by far, for treatment 6

(9.15 g/bale)—a bale that was washed with a hot alkaline scour. Treatments 3 and 6 also showed an increase in the 20 to 38-μm fraction compared with the control, while treatment 5 showed a decrease (this may be a result of the unusually low quantity of trash removed from the Pneumafil filter). Another feature that is observed in all the washed treatments except the first half of 3 is that the ratio of <20-μm dust to the 20 to 38-μm fraction is much higher than the control—especially the samples washed with the hot alkaline scour. This ratio has been low for other samples that we have investigated and is relatively low in treatments 1-I, 1-II, 2A, 2A (2nd half), and 2B.

TABLE II. Ash contents of sonic-sifted samples of unwashed cotton.

No. analyzed	Mean, %	Standard deviation, %	Range, %
	<20-μm samples		
30	37.1	9.3	23.0–65.8
	20 to 38-μm samples		
30	28.9	8.7	16.8–52.0

The ash contents for the 20 to 38-μm and <20-μm dusts separated from the Pneumafil trash from a number of unwashed cotton samples [2] are shown in Table II. The data for the series of washed treatments are shown in Table III. The ash content of the washed treatments appear to vary with the processing conditions. There is a large drop in the ash content of 2A and 2A (2nd half) compared to 1-I and 1-II. If the precleaner stage in the washing line tends to break the friable plant parts into small particles, the ash content of the dust separated by the sonic procedure would logically be reduced (the ash content of leaves and bracts are *ca.* 16 and 18%, respectively [4]). The rate of carding also appears to affect the ash content, but there is insufficient data to make definitive statements. The ash contents are reduced when the electrostatic eliminator is used (except sample 4), and this is probably due to the release of plant materials that are electrostatically bound to the cotton lint. The visual appearance of the 20 to 38-μm samples with very low ash contents was much different from the corresponding samples from 1-I and 1-II. The washed series had a large amount of short lint fibers, which reduced the ash content (these were observed under a microscope at 400× magnification). The <20-μm fraction of these samples also had a significantly larger amount of fibrous particles than the <20-μm samples from 1-I and 1-II, but much less than the 20 to 38-μm fraction. The washing procedure probably tends to remove waxes from the lint, which would decrease the physical attraction of the short lint fragments to the cotton. Thus when the electrostatic eliminator is used, a large amount of the short lint particles is released, becomes trapped in the Pneumafil trash, and is eventually separated as fine dust.

TABLE III. Ash content of dusts separated from Pneumafil filter trash from washed cottons.

Treatment ID No.	% Ash	
	20 to 38-μm fraction	<20-μm fraction
1-I	43.5	50.4
1-II	43.0	52.1
1-II (2nd half)	35.2	49.9
2A	26.4	40.4
2A (2nd half)	16.8	29.6
2B	13.0	29.0
3	30.8	49.8
3 (2nd half)	18.0	31.0
4	20.3	38.3
4 (2nd half)	23.2	38.3
5	17.0	20.5
5 (2nd half)	6.7	15.8
6	12.8	33.9
6 (2nd half)	7.6	16.6
6A	11.9	33.8
7	23.0	35.4
7 (2nd half)	10.3	18.7
8	11.7	30.8
8 (2nd half)	10.0	19.9

The samples isolated by sonic sifting do, however, offer a unique opportunity to obtain an accounting of the various inorganic elements present in cotton dust. As noted previously, elemental analyses were conducted using two techniques: neutron-activation analyses and atomic absorption. The neutron-activation analytical data are in Table IV, and the elements analyzed by atomic absorption are in Table V. Chromium, iron, zinc, copper, cobalt, maganese, magnesium, sodium, potassium, and aluminum contents were analyzed by both techniques. Unfortunately, the agreement between the two methods is not very satisfactory, and there is considerable variation in the NAA data. The results show that copper, iron, zinc, magnesium, sodium, potassium, aluminum, and calcium are the most abundant elements present in these dust samples. While high levels of magnesium, sodium, potassium, and calcium were expected for dusts originating from cotton plant parts, the very high levels of copper, iron, zinc, and aluminum were unexpected and perhaps indicate contamination of these cottons.

TABLE IV. Neutron-activation analyses of washed cotton samples (μg/g of dust).

Treatment ID No.	Particle size, μm	Ash, %	Mn	Mg	Cu	V	Al	Na	K
1-I	20–38	43.5	386	10 933	43 264	80	24 458	3 139	17 942
	<20	50.4	795	<2 500	2 090	37	26 686	7 273	33 335
1-II	20–38	43.0	386	16 005	50 041	71	2 269	2 634	13 584
	<20	52.1	408	16 905	92 248	78	23 080	3 567	14 942
1-II (2nd half)	20–38	35.2	379	20 607	44 264	74	22 653	2 199	9 213
	<20	49.9	335	<5 000	557	<20	<1 500	< 600	<1 000
2A	20–38	26.4	279	3 355	1 111	18	18 860	1 913	10 818
	<20	40.4	367	38 983	2 146	15	13 815	2 533	12 885
4	20–38	20.3	245	2 067	1 572	9	4 513	2 077	8 128
	<20	38.3	<8	<1 900	424	<8	< 575	1 740	4 911
5	20–38	17.0	186	1 588	1 048	<3	4 858	2 205	7 333
	<20	20.5	484	3 433	8 681	<4	< 307	3 473	8 606
6	20–38	12.8	111	< 641	50 644	<3	3 239	1 177	2 655
	<20	33.9	208	1 695	174 789	<7	6 067	2 128	3 020
6A	20–38	11.9	109	868	907	4	2 199	1 799	9 388
	<20	33.8	202	<1 692	3 959	<7	< 508	2 762	3 990
6 (raw sample)	20–38		80	<5 000	28 121	5	310	735	<1 000
	<20		203	<5 000	140 201	1 028	5 884	2 037	1 250
7	20–38	23.0	257	3 350	536	11	9 008	2 639	12 826
	<20	35.4	284	3 841	1 498	22	12 805	3 490	15 636
8	20–38	11.7	116	< 572	24 014	10	3 555	1 248	2 970
	<20	30.8	192	<1 538	3 927	5	6 146	2 087	4 930

Treatment ID No.	Particle size, μm	Ash, %	Sb	Br	Sc	Rb	Fe	Co	Zn	Ti
1-I	20–38	43.5	7	1	3	87	12 508	5	6 665	<435
	<20	50.4	11	1	4	57	14 566	5	8 517	<500
1-II	20–38	43.0	6	3	3	90	13 066	5	7 384	<430
	<20	52.1	3	6	4	64	15 446	5	12 434	<521
1-II (2nd half)	20–38	35.2	6	14	4	80	12 568	3	6 813	2 353
	<20	49.9	8	13	3	68	14 373	3	12 246	<1 000
2A	20–38	26.4	16	9	2	33	9 579	3	5 404	<264
	<20	40.4	19	12	3	35	15 452	4	12 001	<400
4	20–38	20.3	21	9	1	11	10 459	3	8 199	<200
	<20	38.3	29	<1	1	14	18 091	6	22 439	<380
5	20–38	17.0	13	<3	1	8	9 894	2	5 915	<170
	<20	20.5	19	7	1	19	11 303	3	5 564	<200
6	20–38	12.8	8	<.3	0.4	<5	4 039	1	7 179	<128
	<20	33.9	12	3	0.9	<14	9 572	4	25 165	<340
6A	20–38	11.9	3	3	0.4	6	4 954	2	4 970	<119
	<20	33.8	11	6	0.6	<14	12 432	3	18 463	<338
6 (raw sample)	20–38		7	<2	0.3	<40	3 165	1	5 130	<1 000
	<20		19	21	1	<40	9 924	3	19 342	<1 000
7	20–38	23.0	5	7	1	17	9 518	4	2 509	<230
	<20	35.4	23	5	2	41	19 411	5	8 061	<354
8	20–38	11.7	9	7	1	<5	5 075	1	3 368	<114
	<20	30.8	17	8	1	<12	10 504	3	19 375	<308

Treatment ID No.	Particle size, μm	Ash, %	Sm	Ce	U	Th	Cr	Eu	La	As
1-I	20–38	43.5	3	33	2	5	61	0.7	16	37
	<20	50.4	2	207	<0.5	4	41	0.6	19	40
1-II	20–38	43.0	2	31	2	5	56	1	16	16
	<20	52.1	3	59	2	5	73	0.5	24	19
1-II (2nd half)	20–38	35.2	2	37	2	5	53	0.6	16	21
	<20	49.9	3	36	2	5	60	1	18	27

Continued

TABLE IV. (*Continued*)

Treatment ID No.	Particle size, μm	Ash, %	Sm	Ce	U	Th	Cr	Eu	La	As
2A	20–38	26.4	1	169	<0.3	2	34	0.4	10	79
	<20	40.4	1	140	<0.4	3	48	0.3	14	82
4	20–38	20.3	1	70	<0.2	1	93	0.1	4	78
	<20	38.3	1	63	<0.4	2	169	0.1	8	2
5	20–38	17.0	1	90	<0.2	1	61	0.1	6	66
	<20	20.5	1	70	<0.2	1	65	0.2	5	87
6	20–38	12.8	0.2	2	<0.1	<0.1	64	<0.01	2	29
	<20	33.9	0.6	6	<0.3	1	144	<0.03	4	41
6A	20–38	11.9	0.2	3	<0.1	1	96	<0.01	2	27
	<20	33.8	0.3	23	<0.3	1	145	<0.03	3	2
6 (raw sample)	20–38		0.3	52	<1	1	189	<0.1	7	86
	<20		0.8	20	<1	<0.5	46	<0.1	<10	16
7	20–38	23.0	0.5	13	<0.2	1	86	0.2	7	66
	<20	35.4	1	104	<0.4	3	140	0.4	10	75
8	20–38	11.7	0.3	35	<0.1	0.4	61	<0.01	2	25
	<20	30.8	0.5	3	<0.3	1	144	<0.03	3	49

TABLE V. Atomic-absorption analyses of washed cotton samples (μg/g of dust).

Treatment ID No.	Particle size, μm	Cu	Cr	Ni	Fe	Zn	Co	Cd	Mn	Mg	Na	K	Ca	Sr	Al
I-II (2nd half)	20–38	34 451	174	53	26 726	10 035	8	4	650	9 481	184	19 045	35 161	96	13 517
	<20	54 620	183	62	24 122	17 667	3	8	719	9 754	186	21 386	49 953	103	13 243
2	20–38	33 248	116	42	14 889	8 687	6	10	307	5 992	170	12 257	23 770	75	8 451
	<20	64 956	175	65	20 359	16 678	9	9	415	5 532	148	11 503	24 927	110	9 762
4	<20	87 303	310	68	18 207	24 620	5	20	251	5 324	196	2 223	19 663	56	3 900
5	20–38	25 153	115	37	11 149	7 292	3	10	170	3 311	142	3 790	12 274	39	2 387
	<20	21 247	159	41	13 571	5 843	—	9	218	5 077	205	5 239	18 259	66	2 858
6A	<20	94 263	298	55	15 229	24 341	—	19	87	4 183	298	3 855	19 050	78	2 568
7	<20	38 686	292	66	25 887	9 661	4	17	355	6 869	285	9 982	31 964	108	7 358
8	<20	63 764	188	56	11 837	10 460	3	5	147	2 812	141	2 999	13 917	44	2 152

The high levels of copper and zinc are somewhat puzzling. It was first suspected that the brass screens used during the dust separation were disintegrating and contaminating the samples (see Tables VI and V). However, samples run in the cardroom and separated just prior to the washed cottons contained a significantly lower amount of copper, and a sample run after the washed cottons also was significantly lower (Table VI). Therefore, the cottons must have been contaminated at an earlier stage. A likely cause of copper is from brass, but the source is unknown. The copper contents for the washed samples is also significantly higher than the amount we found in other cotton dusts that we investigated (unpublished data).

There were detectable amounts of heavy metals such as chromium, vanadium, nickel, and titanium in the dusts. Some of these metals have been implicated in other types of lung disorders. Arsenic was also present in amounts as high as 90 ppm. Presumably, the source of this element is the desiccant used to defoliate the cotton plants prior to harvesting.

Other elements present (50 to 100 ppm) include cerium rhobidium, and strontium. The level of lanthium in several samples is quite high (10 to 26 ppm) and at about the same level as antimony (7 to 20 ppm). Cobalt and cadmium are at the 13 to 20 ppm level. Elements in small amounts (1 to 5 ppm) include samarium, thorium, scandium, uranium, and europium.

There is no consistent pattern regarding the level of any element in the 20 to 38-μm fraction *vs.* the <20-μm fraction. Although the neutron-activation analysis method should be more a sensitive detection method for most elements than atomic absorption, the NAA results in our studies are much more variable. This pattern has been consistent with earlier work on cotton dusts. In fact, the same samples have been re-irradiated in the neutron activator, and results from these have also shown significant variation in a number of elements. We have been unable to account for this wide variability.

TABLE VI. Amount of Cu per g of ash (given in ppm).

Treatment ID No.	% Ash	<20 μm	% Ash	20 to 38 μm
1-I			43.53	92 768
1-II	49.90	122 798	35.15	104 091
2A	40.41	169 361	26.44	133 585
2A (2nd)	29.57	89 371	16.85	34 890
2B	29.0	139 848	13.0	281 130
3	49.76	66 175	30.85	105 676
4	38.29	241 123		
4 (2nd)	38.43	35 457	23.24	25 869
5	20.48	112 178	17.01	156 972
5 (2nd)	15.85	87 539	6.99	238 080
6A	33.83	313 606		
6 (2nd)	16.50	56 567	7.31	61 176
7	35.42	116 361		
7 (2nd)	18.69	44 922	10.29	35 763
8	30.75	227 424		
8 (2nd)	19.87	37 191	10.03	29 617
Bale 221[a]	41.09	4 722		
Bale 224[a]	32.48	4 525		
Bale 226[a]	35.48	4 667		
CWWT-2N[b]	31.13	14 367	19.51	21 049

[a] Run just prior to the washed cottons.
[b] Run just after the washed cottons.

As shown in Table VII, the fraction of the total mass of dust accounted for by the elements analyzed by neutron-activation analysis is quite low, ranging from about 2 to 12% for the 20 to 38-μm fractions and about 4 to 22% for the <20-μm fractions—values much lower than the total ash values for these samples. This is not unexpected, since the presence of several elements known to be present in cotton plant parts, such as Si, O, S, and N, were not tested for by either analytical technique.

TABLE VII. Fraction of the total mass of dust accounted for by the elements detected by NAA.

Treatment I.D. No.	Fraction by NAA 20 to 38 μm	Fraction by NAA <20 μm	Total ash 20 to 38 μm	Total ash <20 μm
1-I	11.96	9.36	43.5	50.4
1-II	10.72	15.12	43.0	52.1
2A	5.43	6.34	26.4	40.4
3			30.8	49.8
4	3.75	4.79	20.3	38.3
5	3.33	3.40	17.0	20.5
6	6.91	22.10	12.8	20.8
6A	2.96	5.55	18.1	42.2
7	5.31	6.56	23.0	35.4
8	4.14	4.75	11.7	30.8

While it is not possible to make exact recommendations as to which washing procedure of those utilized in this study is the optimum as regards lowering the inorganic content, the data presented here does constitute an important data base of the elements present in cotton dust. These results also show that variables in cardroom processing can significantly affect the amount and type of small dusts trapped on the air-conditioning filters and perhaps the dusts generated in the cardroom.

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