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Cotton Contamination: A Review

by

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1. INTRODUCTION

There can be little doubt that the contamination of cotton, by foreign fibres and other materials, represents a serious problem, it having been said that although cotton lint is a valuable raw material, it is often handled and packed as if it were useless waste. The problem of contamination is becoming increasingly acute as automation in the textile mill (eg automatic bale openers and chute feed to the cards) increases, since manual detection and elimination of contamination (ie manual intervention) are consequently highly unlikely and efficient automatic detection and removal systems are not yet available.

Recognising the importance of the problem of contamination in cotton, the International Textile Manufacturers Federation (ITMF) in Zurich has carried out four surveys[1-3] this decade (the most recent in 1989)[1a] in order to gauge the nature, origin and levels of contaminating materials encountered in cotton lint. The ITMF surveys were designed to shed more light on the spinners' perception of the problem of cotton contamination and the occurrence of foreign matter (see next section). The International Cotton Advisory Committee (ICAC) has also recently given attention to the problem of cotton contamination and foreign matter.

Cotton lint contamination can be sub-divided into two main groups, namely those of *natural origin* and those of *man-made origin*[4]. Examples of the first group are honeydew (stickiness), leaf, trash, grass, bark, seed-coat fragments, sand and dust. Examples of man-made contaminants include rubber, oil, grease, tar and synthetics or plastics. Other forms of contamination could result from agricultural sprays and additives (eg pesticides, herbicides, defoliants, etc).

For the purpose of this report, attention will be confined to contamination or foreign matter which does not originate from the cotton plant, or any other plant, and which can present a problem during subsequent processing and use of the cotton, with particular attention to man-made contamination, (eg plastics or synthetics). In the context of this report, plastics and synthetics are regarded as synonomous, both being man-made polymer materials. Not considered therefore, are things like honeydew, dust, dirt, trash, vegetable matter, etc.

Contamination by plastic (synthetic) materials is particularly problematic since these become fragmented and widely dispersed in the cotton during processing and cannot be effectively detected or removed during any of the textile processes, often remaining undetected until the fabric or final product stage is reached where it is often difficult, if not impossible, to remedy the situation. Such contaminants do not take up dyestuff, which contrasts with jute contamination for example, and become very noticeable after dyeing, giving rise to a defect (flaw or fault). When plastic contamination is only detected in the fabric (or garment) stage, it is often difficult and costly to remove it without damaging the fabric. Some firms reportedly resort to subjecting the fabric to intense heat so as to melt the plastic into a ball which could facilitate removal or at least reduce the seriousness of the fault. Others attempt to remove the contaminant physically, by means of tweezers, for example.

TABLE I

PARTICIPATION IN ITMF SURVEYS[1, 1a]

Country	Number of Respondents (participating companies)		
	1989	1987	1985
Australia	5	—	—
Austria	6	9	9
Belgium	6	4	2
Canada	2	—	—
Denmark	1	—	—
France	18	11	11
Germany F.R.	29	32	34
India	3	3	—
Israel	1	—	—
Italy	18	10	13
Japan	10	11	9
Korea (Rep.)	4	5	—
Malaysia	3	—	—
Netherlands	—	1	—
Singapore	1	—	—
Spain	8	4	3
Switzerland	14	11	15
Taiwan ROC	2	2	4
Tunisia	2	—	—
Turkey	20	7	—
United Kingdom	7	1	2
USA	18	3	8
TOTAL	178	114	110

TABLE II (1989)[1a]

The Most Contaminated Descriptions

No.	Description		Average degree of contamination by each of the 16 pre-indicated contaminants: Non-existent/ insignificant (%)	Moderate (%)	Serious (%)	Number of samples (min.: 5)
1.	India	H-4	47	14	39	10
2.	India	India-Others	53	14	33	6
3.	India	Shankar-4/6	61	13	26	10
4.	India	MCU-5	63	13	24	8
5.	India	DCH	67	9	24	16
6.	Pakistan	AmSeed AFZAL	67	16	17	37
7.	Pakistan	Pakistan-Others	69	12	19	17
8.	China	Henan	69	15	16	13
9.	China	Jiangsu	69	20	11	12
10.	Turkey	Cukurova/ South East	69	21	10	33
11.	China	Hebei	70	19	11	9
12.	China	Hubei	71	14	15	12
13.	Pakistan	AmSeed 1505	72	14	14	26
14.	Turkey	Izmir	75	17	8	43
15.	Tanzania	Mwanza	78	11	11	11
16.	China	Anhui	79	16	5	6
17.	Sudan	Shambat	80	10	10	20
18.	China	Shandong	81	12	7	25
19.	Turkey	Antalya	81	15	4	19
20.	Turkey	Turkey-Others	82	11	7	22
21.	USA	Texas High Plains	82	13	5	38
22.	Mexico	Mexicali	82	14	4	6
23.	Brazil	South Brazil	83	7	10	12
24.	Burkina Faso	Burkina Faso	83	10	7	21
25.	Nicaragua	Nicaragua	83	10	7	14
26.	Egypt	Giza	83	11	6	43
27.	Central African Rep.	Central African Rep.	84	7	9	12
28.	Sudan	Barakat	84	8	8	37
29.	Tanzania	Coastal	84	12	4	7
30.	USA	Arizona	84	13	3	22
31.	Syria	Syria	85	9	6	18
32.	Ivory Coast	Ivory Coast	86	11	3	31
33.	Paraguay	Paraguay	87	8	5	35
34.	USA	Memphis Territory	87	12	1	49

The Least Contaminated Descriptions

No.	Description		Average degree of contamination by each of the 16 pre-indicated contaminants: Non-existent/ insignificant (%)	Moderate (%)	Serious (%)	Number of samples (min.: 5)
1.	Israel	Acala	97	3	0	26
2.	Guatemala	Guatemala	96	4	0	17
3.	Mexico	Mexico-Others	96	4	0	5
4.	Zimbabwe	Zimbabwe	96	3	1	35
5.	Iran	Iran	96	1	3	6
6.	Mexico	Juarez	95	5	0	18
7.	Australia	Australia	95	5	0	49
8.	USA	South Eastern	94	6	0	15
9.	USA	El Paso	94	5	1	26
10.	Colombia	Acala	94	4	2	12
11.	Afghanistan	Afghanistan	94	0	6	5
12.	USA	California	93	6	1	80
13.	USA	Rio Grande Valley	93	6	1	17
14.	Spain	Spain	93	4	3	45
15.	Peru	Pima	92	8	0	12
16.	Cameroon	Cameroon	92	6	2	26
17.	USA	Pima	92	6	2	51
18.	China	China-Others	92	3	5	11
19.	Senegal	Senegal	91	9	0	13
20.	Sudan	Sudan-Others	91	8	1	6
21.	Israel	Pima	91	4	5	24
22.	Mexico	Sinaloa/Senora	90	9	1	5
23.	USA	USA-Others	90	8	2	12
24.	USSR	Long staples	90	8	2	37
25.	USSR	Medium staples	90	8	2	62
26.	Togo	Togo	90	7	3	21
27.	Peru	Tanguis	89	11	0	10
28.	Mali	Mali	89	8	3	32
29.	Uganda	Uganda	88	10	2	6
30.	Greece	Greece	88	10	2	25
31.	Benin	Benin	88	9	3	16
32.	Sudan	Acala	88	8	4	22
33.	Argentina	Aregentina	88	8	4	43
34.	China	Xinjiang	88	8	4	18
35.	Chad	Chad	88	7	5	31

To illustrate the serious losses which can be suffered as a result of contamination, it has been calculated[5] that a 5g piece of polypropylene twine in a cotton bale could lead to a financial loss exceeding R50 000 in the case of quality apparel and R100 000 in the case of high quality downproof covers if the contaminant is fragmented during processing (notably carding) and remains undetected until the final product has been manufactured.

2. EXTENT AND NATURE OF CONTAMINATION

2.1 World Situation

In the most recent ITMF survey[1a] undertaken in 1989, some 178 spinning companies in 21 countries participated (Table I).

According to the surveys of 1985, 1987 and 1989 (Table II), certain growing regions and cottons were considerably more prone to contamination than others, none appearing to be entirely free of contamination.

From Table II it is evident that none of the cottons was found to be totally free of contamination, although certain growing areas were rated much better than others. According to the 1987 survey, most of the contamination manifested itself at the spinning (particularly rotor spinning) and finishing stages.

The most common contaminants are shown in Tables III and IV from

TABLE III[1]

PERCEIVED SOURCE OF MOST COMMON CONTAMINANT

Source of Contamination	Total Replies		
	1987	1985	(Pos)
Jute/Hessian Strings	200	157	(2)
Organic Matter	191	191	(1)
Cotton Fabrics	175	122	(5)
Jute/Hessian Fabrics	155	101	(9)
Metal/Wire	137	121	(6)
Cotton Strings	127	118	(7)
Woven Plastic Strings	117	123	(4)
Woven Plastic Fabrics	115	145	(3)
Grease/Oil	98	97	(10)
Stamp Colour	84	107	(8)
Plastic Film Fabrics	77	61	(13)
Sand/Dust	77	78	(11)
Plastic Film Strings	73	72	(12)
Rust	52	40	(14)
Rubber	28	28	(15)
Tar	18	11	(16)

which it can be seen that, in 1987 and 1989, some or other form of plastic was often identified as the contaminant, making it and Jute and Hessian strings and fabrics the most prevalent sources of contamination. Interestingly enough, even cotton string and fabrics are listed fairly frequently as a source of contamination.

The numbers of bales of cotton affected by the different forms of contamination are given in Table V (1987 survey).

According to the ITMF report[1], there was generally a good correlation between the 1985 and 1987 surveys. There appeared to be a slight increase in contamination experienced by the spinners in 1987 compared to 1985, although that associated with plastic materials appeared to be slightly lower. In 1989, plastic was still a very serious source of contamination[1a].

TABLE IV
CONTAMINATION BY SOURCE (1989)[1a]

Number of samples: 1,574 (all)

Source of contamination		**Degree of contamination** Non-existent/ insignificant (%)	Moderate (%)	Serious (%)
1. **Fabrics** made of	woven plastic	87	8	5
2.	plastic film	89	8	3
3.	jute/hessian	85	8	7
4.	cotton	82	11	7
5. **Strings** made of	woven plastic	85	9	6
6.	plastic film	86	9	5
7.	jute/hessian	78	12	10
8.	cotton	83	10	7
9. **Organic matter**	leaves, feathers, paper, leather	70	18	12
10. **Inorganic matter**	sand/dust	84	11	5
11.	rust	90	7	3
12.	metal/wire	85	9	6
13. **Oily substances/chemicals**	grease/oil	86	11	3
14.	rubber	96	3	1
15.	stamp colour	88	8	4
16.	tar	97	2	1
Average of 1 — 16		86	9	5
			No (%)	Yes (%)
Stickiness			79	21

TABLE V
OVERALL INCIDENCE OF DIFFERENT CONTAMINANTS (1987)[1]

Contaminant		Total Replies	Bales Affected	Unspecified Replies	Replies with Frequency Indicators		
					Low	Medium	High
Fabrics made of	Woven Plastic	115	31964	44	9	16	14
	Plastic Film	77	232753	16	20	14	1
	Jute/Hessian	155	205499	36	16	23	38
	Cotton	175	7214	25	23	43	29
String made of	Woven Plastic	117	45850	34	15	13	14
	Plastic Film	73	177852	13	22	10	4
	Jute/Hessian	200	218061	38	22	27	37
	Cotton	127	6942	20	18	32	18
Organic Matter	Leaves, Feathers, Wood, Paper	191	210920	38	29	27	23
Inorganic Matter	Sand/Dust	77	16255	20	11	14	12
	Rust	52	161061	10	11	12	1
	Metal/Wire	137	113471	27	14	33	13
Oily Substances/ Chemicals	Grease/Oil	98	80921	25	14	18	8
	Rubber	28	2300	7	8	7	3
	Stamp Colour	84	112487	20	12	9	5
	Tar	18	72172	10	1	1	—

2.2 Local situation

Although the above summary reflects the global situation, it can be expected that the South African situation was not very different during the same period. It has been stated[6] that losses running into several million rand have been suffered by textile and clothing manufacturers and retailers due to contaminated cotton and that valuable contracts had been cancelled as a consequence.

A survey of a cross-section of local cotton mills was carried out in October 1988 concerning their experiences with contamination over recent years. Of the mills contacted, only one reported never having experienced problems with contamination, although the situation was reported to have improved considerably during the previous 18 months. Most of the mills stated that the main contaminant by far was polypropylene or some allied plastic material and that it generally occurred in a coloured form (red, blue, and orange often being mentioned), suggesting that the source of the contamination was either the picker bags or twines and cords used at various stages prior to the ginning

TABLE VI

EXAMPLE OF CONTAMINATION IN LOCAL AND IMPORTED COTTON OVER A SIX MONTH PERIOD (1987/88)

Gin 1	Gin 2	Gin 3	Gin 4	Gin 5	Imported Cotton	Imported Cotton	Gin 6	Imported Cotton	Gin 7	Gin 8	Gin 9	Gin 10	Imported Cotton	
8	9	2	2	2	1	0	1	0	0	0	0	0	0	Jute
69	19	55	68	65	37	2	9	10	0	1	10	1	54	Polypropylene
12	6	14	5	5	5	2	1	1	0	0	4	0	0	Fibre
28	25	28	18	13	24	8	8	3	9	0	9	1	1	Other
117	59	99	93	85	67	12	19	14	9	1	23	2	55	TOTAL

of the cotton. The general opinion was that much, if not most, of the contamination in the past had in fact occurred prior to ginning. The bale wrapping (cover) was not regarded as such a serious source of contamination now. One large firm had encountered the following distribution of contaminants during a six-month monitoring period (Table VI).

What clearly emerged from the recent survey of local mills was that the local situation had improved considerably during 1988 compared to that experienced in the preceding years. This is no doubt largely due to steps taken by the South African Cotton Board and other interested parties to combat contamination and to appropriate legislation having been implemented.

Following on various deliberations between the South African Cotton Board, Cotton Mills and Ginner's aimed at combating contamination, it was decided[7-11] that:

(i) Producers may not use any synthetic hand-picking bags other than plastic (low density polyethylene) "fertilizer" bags and no polypropylene twine may be used on these bags. The manufacture of suitable plastic fertilizer type bags (low density polyethylene) was to be sponsored and supplied to producers.

(ii) Ginners were to switch over to jute woolpacks, from the polypropylene and polyethylene ones previously used, and no synthetic packing material may be used by the producer and neither may synthetic threads and twines be used for closing the jute woolpacks. Seed cotton must be delivered to the gins in jute woolpacks sewn with cotton sewing threads.

(iii) Ginners were to refuse to receive cotton from producers if it is packed in anything else than the prescribed containers (bags) or sewn up with anything else than cotton twine and that such producers be blacklisted. No seed cotton was to be accepted by any ginner if delivered in polyethylene or polypropylene woolpacks, and no contaminated cotton was to be accepted by any of the ginners.

(iv) All ginners were to switch over to low density polyethylene film or cotton material for the bale covers, trials by the Cotton Board having shown that low density polyethylene (woven) had advantages.

The Cotton Board and ginneries spent some R4 million in an attempt to ensure that uncontaminated cotton reached the textile mills, approximately R1 million of which was spent providing suitable picking bags to the farmers.

Legislation was introduced in 1988 which made it an offence for a farmer to sell or deliver cotton contaminated with foreign fibres, such as polypropylene, to a gin[6]. Farmers found guilty of delivering contaminated cotton to a gin could be fined or sentenced to imprisonment.

3. PROBLEMS CAUSED BY CONTAMINATION

Contaminants are generally regarded as undesirable because they adversely affect textile processing efficiencies (eg by causing yarn breakages during spinning, knitting and weaving), processing machinery (eg damage card wires), dyeing and finishing and, most important of all, the appearance of the fabric and final product (see also Section 1). The different dyeing behaviour and appearance of plastic contaminating material generally presents the most serious problem[12]. Polypropylene, for example, does not take up dye during the dyeing of cotton, and therefore shows up as a blemish or defect in the fabric. In this respect, jute contamination is generally less of a problem than plastics, such as polypropylene, since it is no longer visible after bleaching and its dyeing behaviour is similar to that of cotton, although it can cause end-breakages in both ring and rotor spinning.

The following table provides a list of contaminants (natural and man-made) which cause most problems during *finishing*[13].

TABLE VII
IMPURITIES IN COTTON ARTICLES, WHICH CAUSE MOST PROBLEMS IN TEXTILE FINISHING[13]

Impurity	Effect on the Coloured Articles
Raw Fibres	
Seed capsules, leaves, branches, twigs, etc. Neps	General impairment depending on the article and dyestuff
Residue from: Insecticide Growth regulators Defoliants	Spots, resist
Trace metals	Rust spots Bleaching damage
Foreign Fibres	Resist
After Spinning, Weaving	
Sizing residue	Unevenness, resist
Oil, graphite residue	Bright/dark spots
Metal particles	Bright spots, holes
Dirt, dust from storage	Unevenness, resist

Contaminating black rubber particles from doffer pads, show up as unacceptable black specks in the fabric and end-product. Oil, grease, tar and marking ink, if not removed completely during wet finishing, can interfere with dyeing and cause an unacceptable fabric appearance. Perkins[14,14a] and Bragg[14] showed that excessive hydrocarbon oil causes excessive loading of fibre on the card cylinder, sticking and lapping of stock on card crush rolls, increased spinning end-breakages and a deterioration in yarn strength and evenness. Volatile solvent extraction of a sample of cotton will provide a good measure of such contamination.

Contamination due to foreign fibrous materials (natural or synthetic), which are often coarser than the host fibre, almost inevitably leads to an end

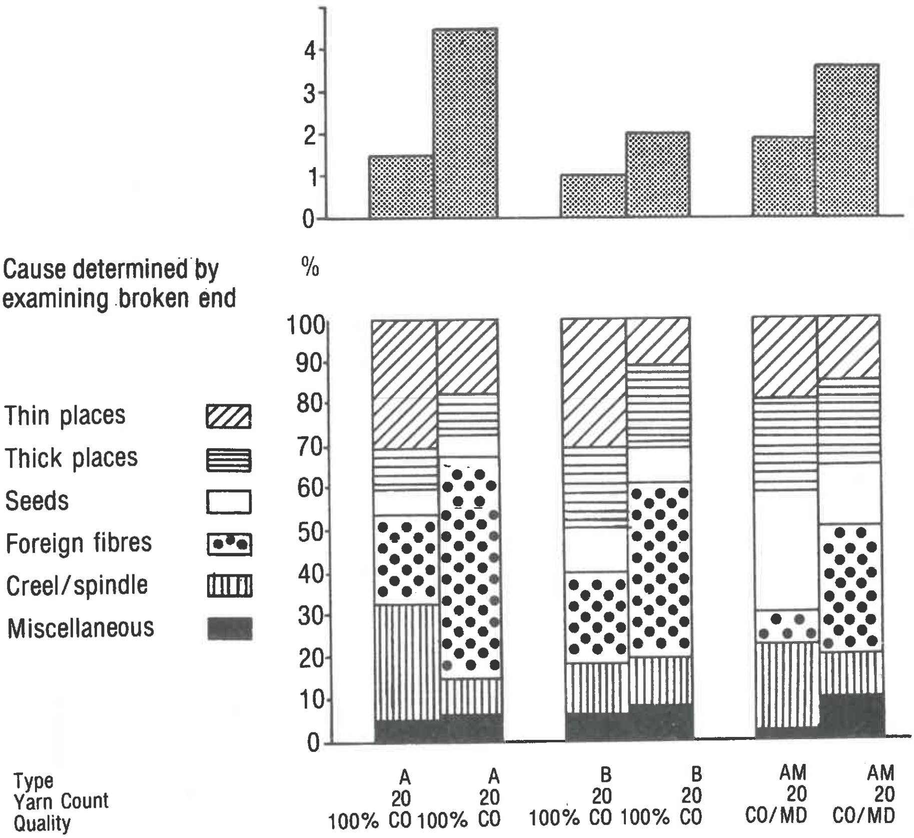

Fig 1.

Cause of End Breakages during Rotor (open-end) Spinning[15].

break in rotor (OE) spinning, and often also in other high-speed open-end spinning systems where the foreign material disturbs the yarn formation process[15-17]. The proportion of such yarn breaks can fluctuate between 10% and 80% of the total number of yarn breaks, as illustrated in Fig 1[15].

Generally, foreign fibres lead to fewer breaks when coarser rotor (OE) yarns are being spun and also when larger diameter rotors are employed as illustrated in Figs 2 and 3[15]. It should also be noted that increased end-breakages during rotor spinning are also invariably associated with a decrease in the performance of the yarn during fabric manufacturing.

One positive aspect of foreign fibres causing an end-break during rotor spinning is that the contaminating material can then be removed and will therefore not present an even more serious problem later on. From this, and the fact that foreign fibres are less likely to cause an end-break in ring spinning, it follows that, when spun from the same raw material, rotor yarns will

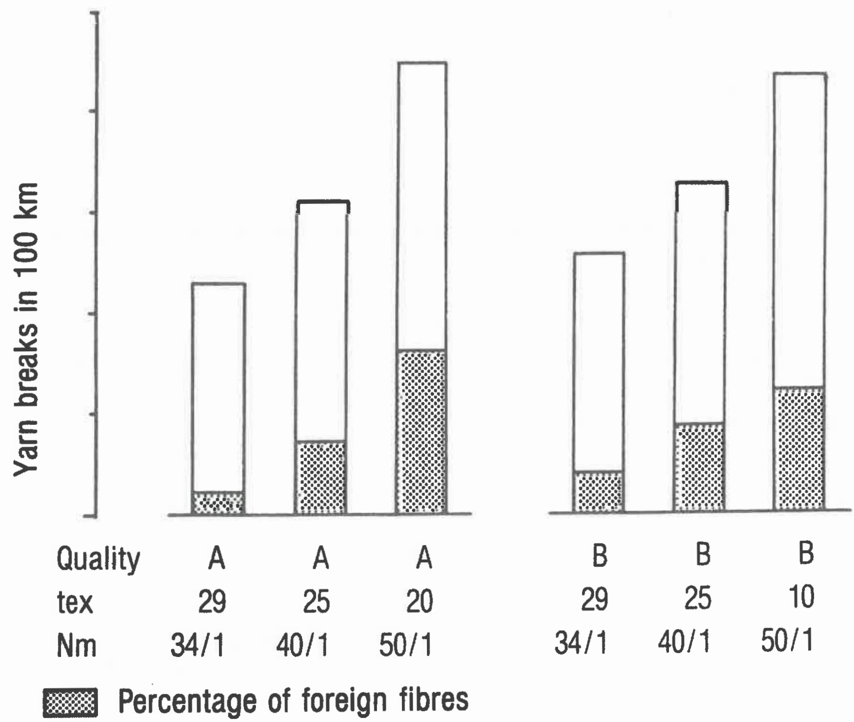

Fig. 2

Effect of Yarn Linear Density (tex) on End Breakages during Rotor Spinning[15].

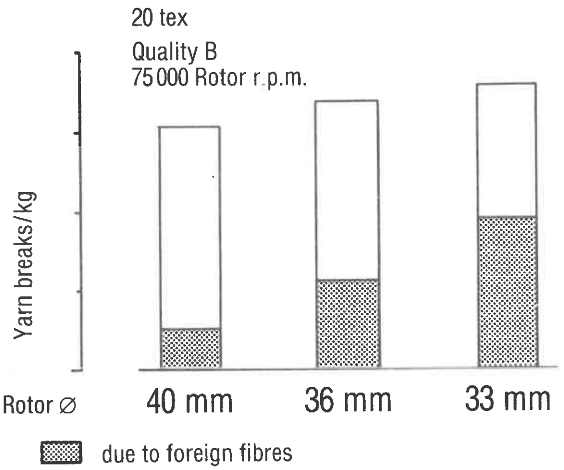

Fig. 3

Effect of Rotor Diameter on End Breakages[15].

generally contain fewer foreign fibres and other related contaminants than ring yarns. Problems caused by foreign fibres in rotor (open-end) and other spinning systems and possible preventative measures have also been discussed by Fabian[16] and Schoeller[18].

4. ORIGINS AND TYPES OF CONTAMINATION AND PREVENTATIVE MEASURES

4.1 General

In order to be in a position to eliminate contamination in cotton, it is important that the sources, actual and potential of contamination be carefully identified. The cotton can become contaminated at any stage from the field to the cotton mill, and even within the textile mill itself. For example, the use of synthetic picking bags and synthetic threads for sewing up the bags can lead to contamination at the producer end of the pipeline, while the use of polypropylene bale wrapping at the gin can lead to contamination there and synthetic fibre contamination can also occur in the spinning mill. Precautions therefore ought to be taken throughout the cotton pipeline, including the storage, handling and transportation of seed cotton and cotton lint to minimise contamination. Careful and gentle handling of bales so as not to damage bale covers for example, proper use of lift trucks and bale handling devices, are necessary to minimise the occurrence of contaminating bagging material being forced into the bale[20]. Recycling of waste in the spinning mill should also be avoided where possible, particularly for critical end-uses.

In practice, an erroneous conclusion is often arrived at concerning the type and source of contamination because only a superficial examination of the contaminant is made. Jordan[19] noted that although many people considered the plastic bale bagging to be the main source of plastic contamination, in his own experience only a small percentage of contamination originated there. Under reasonable care, bagging was not a source of contamination. Frequently the cotton bale wrapping is wrongly blamed for contamination. For example, in one case, plastic contamination, thought to be from the centre marking stripe of the bale cover, was found to actually originate from a black plastic baling twine used on certain modules as a tie-down strip for module covers[19]. A case has even been reported[4] of contamination, consisting of small black specks, being caused by apparel threads from the clothing of field labourers.

Lalor[21] identified some common contaminants and outlined various steps to eliminate them. He identified a common contaminant as the polypropylene used in tie-down rope, tarpaulins, bale bagging, end-caps for bundles of wire-ties and in several other materials used around the farm and gin. Good house-keeping was considered essential to reduce contamination and the use of cotton tarpaulins and twines or sisal string was recommended. Farmers in the USA have also, for example, been warned of the dangers of contaminating cotton lint by running strippers through cover crops or by turning the strippers around on such land[22]. Cotton mills must also ensure that any marking or fugitive tint they use can be, and is, completely removed during subsequent wet finishing.

The Textile Research Centre at Mulhouse (France) undertook a study[12] involving 15 mills, on cotton contamination, identifying the various origins of contamination and the chances of its removal. Although foreign fibres (eg synthetics) can be deposited on the cotton while it is being processed in the mill, this was considered to be a relatively rare problem now-a-days and one which could be remedied by efficient cleaning and fly and dust removal systems, by separating different fibre types and their processing and by proper partitioning of machines which are processing different fibres. It was noted that the bale wrapper can tear during handling and transport with the cotton becoming contaminated by tar, oils, rust, etc. Coring (sampling) the cotton can also introduce bits of bale wrapping material into the cotton lint, this can even happen when a cotton wrapper is used since the coring device may have bits of bale wrapper (eg polypropylene) left in it from a previous coring preparation unless it has been cleaned very thoroughly. These workers[12] stated that almost all the cotton bales examined contained some contaminating fibres, which generally originated not from the bale wrapper, but prior to ginning, often from agricultural thread (coloured polypropylene) used for tying.

Contamination was amongst other things found to be related to the way in which the bales were opened and also to the extent to which card waste was recycled.

Specific attention will now focus on contamination by plastic (synthetic) materials, rubber, grease, oil and marking ink.

4.2 Synthetic and Plastic Materials

As already stated, there can be little doubt that plastic (synthetic) materials, such as polypropylene, are generally one of the most serious sources of contamination, such contamination being possible at any stage from the field to the mill. Sources of plastic contamination include[19,21,23-25]:

(i) Picker Bags.
(ii) Synthetic (often polypropylene) twines, ropes, cords and tie-downs used at various stages from the field to the gin.
(iii) Plastic woolpacks (eg polyethylene).
(iv) Module covers and tarpaulins including protective netting sometimes used on modules.
(v) Bale identification or markings.
(vi) Bale covers and bagging.

Lalor[21,23] stated that sheet plastic contamination has, for example, been observed in surgical cottons and in apparel fabrics, this originating from plastic tarpaulins, plastic twines, irrigation ditch liners and the many other plastic items used around gins and farms. The use of plastic twines to tie down module tarpaulins and covers has led to serious contamination problems[24].

Kueny *et al*[12] discussed some of the processing problems caused by polypropylene contamination and its removal. By sampling the waste produced in 15 textile mills, they concluded[12] that contaminating polypropylene was not removed to any great extent in the blowroom (ie as blowroom waste). Contaminating material was frequently found in card waste[12], carding being fairly effective in removing contaminating fibres, although it was never so effective that it could be regarded as a means of eliminating contamination problems due to foreign fibres. In this particular study, no foreign fibre was found in drawing waste while considerable amounts were found in OE-(rotor) spinning waste, where the foreign fibre often caused an end-break. No polypropylene was found to be removed during waste cleaning (recycling), this in fact causing greater fibrillation, all of it finding its way back into the system, often in a more fibrillated and difficult to remove[12] state. Recycling of waste can therefore clearly increase problems due to contamination and needs to be critically examined in terms of foreign fibres, when attempting to spin relatively fine open-end yarns.

Ginned cotton is wrapped to protect the bale from foreign matter, fire and the weather[26]. Bales were originally packed in the USA with jute bagging weighing over 5 kg per bale and hot rolled steel ties weighing 4 kg per bale.

Woven polypropylene, lightweight jute, burlap and polyethylene material were subsequently introduced because they offered certain advantages[26]. Polypropylene bagging, for example, has the advantage that it provides a durable barrier to oil, dirt and excess moisture[27] and it is also not very flammable, its main disadvantage being that it can seriously contaminate the cotton which it is designed to protect. During bale sampling for example, the bale cover is cut and plastic (eg polypropylene) fragments can enter the cotton in the bale[18]. Plastic packing material can also enter the cotton during bale pressing at the gin. Sampling the cotton prior to wrapping is obviously an effective means of reducing potential contamination by the bale wrapping material.

Uncoated polypropylene bale wrappings were found to be a problem in the USA[28] and coated polypropylene was tried, but found to be unsuitable because of inadequate elasticity and air permeability[29]. *Extrusion coated* or laminated polypropylene base covers were regarded as a better alternative and found application in the USA[29], all woven polypropylene wrapping having to be extrusion coated which minimises fraying when the bag is torn or cut[4,28,30]. Two different extrusion coating systems were considered necessary, the one for bagging under the bands where a solid coating is used on both sides of the bale where samples are taken. The other is for bagging over the bands where strip-coating is used, the strip-coating spiralling around the bale on all sides[29]. Proper extrusion coating coupled with routine inspection in the mill opening rooms appeared to provide an effective measure of bale protection[4]. Most African cottons are now packed in laminated polypropylene[30a], a large scale trial involving jute covering being in progress in the Ivory Coast[30a].

The United States cotton industry has written strict specifications for all bale packaging materials, and materials have to be approved prior to use and performance is reviewed annually. The South African Cotton Board also experimented with different bale wrappings and found low density woven polyethylene to have advantages, all gins having switched to this bale wrapping material, even though it suffers a price disadvantage[7]. This bagging material is less prone to tearing and fibrillation than polypropylene. It is perhaps worth noting that the disposal of polypropylene bale covers also presents a problem, particularly in Europe[31], this sometimes costing as much as R1 per bale, while cotton bagging can be sold as rags for over R2 per bale.

Cotton bagging appears to have found application in the USA, although in many cases still on an experimental basis[31]. Cotton bagging costs almost R4 more than polypropylene bagging when knitted fabric is used[31] and about R6 when woven fabric is used.

Cotton wrapping materials (woven and knitted)[27,31] were developed and evaluated, and appeared to provide the answer[31] although there were certain problem areas, one being cost[27,31]. Size on the cotton could also create a possible problem. Except for cost, the main disadvantage of cotton bagging was that it tears more easily than polypropylene and may require special precautions during handling and transportation[27]. Knitted bagging was claimed to be lighter, more elastic and to protect the bale better than woven bagging[30], with the natural waxes on the cotton fibre rendering the knitted wrapping water repellent[27]. Nevertheless, it appeared that the woven cotton bagging was preferable to the knitted bagging and that the former performed acceptably, provided the stitching used was sufficiently strong, such bagging adding approximately R5 to the cost per bale.

Cotton Incorporated also investigated the use of gin lint cleaner waste as a raw material for producing cotton bale wrappings, the material being rotor-spun and then knitted on a Raschel warp knitting machine. Work was also carried out on a 100% stitch-bonded fabric for bagging[30]. It can be manufactured at a much faster rate than woven fabric and at lower cost, the lint being carded, cross-lapped and stitched[30]. An open weave cotton bale bag with possible applications in the outerwear market[32] was also developed and development has also been directed towards a water-repellent module cover in cotton[27].

In certain countries, such as Peru, the use of cotton material for containers used in the picking, storage and transport of cotton, as well as cotton threads, or cords is enforced by legislation.

The baling and contamination of cotton has also been discussed in another article[33].

A chart[34] published jointly by the National Cotton Council of America, Cotton Incorporated and the USDA provides the following summary for eliminating contamination due to plastic and associated materials.

During Harvesting: Remove all plastic irrigation ditch-liner materials from field prior to harvesting.

Trailer and Modules: Use only cotton covering material on trailers and modules (it also has advantages from the point of view of preventing condensation underneath the cover). Use cotton twine or ropes as tie-down material. Use caution to remove all plastic materials on or near seed cotton.

Gin: Use only approved bale covering materials. Use cotton thread or cord to close the heads of bales.

Warehouse: Use cotton materials to hold bales from dinky to press. Use cotton material to close heads on bales. When repairing broken bales, use care to prevent all foreign materials from getting into bales.

4.3 Oil and Grease

Several reports[14,14a,35,36] deal with the occurrence, origin and prevention of oil and non-oil stains. Oil and grease contamination, has an adverse effect on processing and yarn quality[14a] and mainly originates from over lubrication and improper cleaning of cotton pickers (heads), oil leaks at the gin and dirty and greasy warehouse floors[14a,19,25]. Excessive use of picker oils in spindle moistening (cleaning) systems can also lead to contamination and sticky cotton. Proper picker-drum lubrication is essential. Improper handling of the bale at the gin or warehouse can cause bale coverings to open at the ends resulting in possible contamination from greasy dirty floors, etc[37]. Preventative steps include removal of excess oil and grease from picker bars and bushings[19], periodic cleaning of picker heads[19] and careful handling of bales to prevent contamination from grease and grime on floors, etc., as well as proper covering of the bale, including the heads.

Fully covered bales have obvious advantages in terms of providing mills with a cleaner cotton[20]. It is important that inside the cotton mill, all bale surfaces be inspected and cleaned prior to processing.

A chart published jointly by the National Cotton Council of America, Cotton Incorporated and the USDA Extension Service, gives the following hints for eliminating oil and grease contamination[34]:

Oil

Harvesters: Repair and maintain as prescribed by operator's manual. Lubricate daily and use precautions as prescribed by operator's manual. Exercise caution in the use of mineral oils in lieu of water and wetting agents in moistening system.

Gin: Keep bale press in good repair. Replace hydraulic seals and packing as needed to eliminate leaks onto cotton. Exercise caution in use of mineral oils in the ginning process.

Warehouse: Keep warehouse floors free of oil. Maintain lift truck hydraulic system.

Grease

Harvester: Use recommended procedures for lubricating and repairing picker heads; wipe down fittings after lubrication. Practice proper lubrication and repair of stripper.

Warehouse: Keep floors and work areas clean.

4.4 Bale Marking Ink

Cotton bale marking ink can also stain the cotton and unless easily (completely) removable ink is used it can persist through wet finishing, creating an appearance problem. Conventional spray paint marking can contaminate the cotton and present problems during processing and dyeing[38]. The use of suitable durable marking ink to mark seed cotton and baled cotton can eliminate contamination (discolouration) from this source, provided any residues can be completely removed in subsequent wet processing stages in the textile manufacturing pipeline[4]. Cotton Incorporated has entered into a licencing agreement with a firm to produce a durable but non-contaminating[4,38,38a] and non-toxic[38] bale marking ink for modules or bales of cotton.

4.5 Rubber

The major source of rubber contamination is the doffers of the cotton picker[19,25,39], with the lift truck tyres occasionally also being a source[25]. It was found[19] that improper setting (adjustment) of the doffer-to-spindle clearance could lead to the rubber doffer pad touching the spindle, causing contamination by tiny rubber particles rubbed off during mechanical harvesting, such particles not being removed completely during textile processing[41]. The seriousness of the problem can depend upon both the spindle pad composition and the setting[39-41].

Preventative measures include the use of polyurethane doffers (pads) rather than rubber (neoprene)[27,39] and the proper doffer-to-spindle clearance[19] and moisture pad adjustments.

A chart published jointly by the National Cotton Council of America, Cotton Incorporated and the USDA Extension Services gives the following hints for eliminating rubber contamination[34]:

Picker Doffers: Use care to properly repair, maintain, adjust and align doffers and moistening system. (See operator's manual or consult with dealer).

Strippers: Adjust and repair stripper rolls as needed.

Trailers and Modules: Remove all tie-down straps used to secure covers.

Gin Machinery and Flashing: Maintain proper adjustment of belts during operation and provide yearly maintenance of flashing and belts.

Warehouse-Lift Truck Tyres: Sweep high traffic areas periodically, especially concrete floors. Lift bales completely when transporting, do not slide bales on floor.

5. DETECTING AND ELIMINATING CONTAMINATION

At present there appears to be no ready made and efficient system for detecting and eliminating contamination prior to the final fabric stage. Manual detection and elimination are possible to a limited extent when manual feeding to the blowroom and card (lap feed) is used. With automatic bale-opening and feeding (including chute feeding), however, there is very little chance of detecting any contamination. Thereafter, the contamination is unlikely to be detected until fabric and garment inspection, at which stage it is generally difficult and costly to eliminate, and the fabric can be damaged in the process.

With respect to the automatic detection and elimination of contamination, very little information has been published, although an optical system (Type F.II), for detecting and eliminating *coloured* material from the blowroom line, is apparently available[42]. This system uses (CCD) cameras which screen the fibrous material and transforms the reflected light signals into Red/Blue and Green signals which are then analysed by micro-computer. When a coloured material is detected, it is eliminated by means of an outlet duct.

Checking slivers visually, for example by means of a Toeniessen tester, is a possible quality control means of monitoring contamination, but this is likely to be too ineffective and time-consuming to be of practical importance, particularly considering the occurrence of such contamination in an isolated yet concentrated form.

A large particle removal device incorporated in the blowroom processing line, directly after the bale breaker, is reported to reduce the problem of rotor-end breakages due to foreign fibrous materials[16].

The CSIRO (Siroclear) device, for detecting and removing *coloured* fibres in wool yarns, could quite conceivably also be adapted to remove *coloured* fibres from cotton yarn during normal winding and clearing[43], but this would not solve the problem of undyed contaminants.

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