XIV.—*On the Action of Silicate and Carbonate of Soda on Cotton Fibre.*

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I HAVE lately been engaged in investigating a case of injury to goods, which I hope will prove interesting to chemists and manufacturers, from the novelty of the ascertained chemical facts to which the injury is traceable.

A large quantity of blue-dipped indigo cotton goods, with white reserves, were shipped two or three years ago to South Africa, and when opened some time after their arrival, were found so unsound as to be quite unsaleable, the cotton fibres being so much injured as to give way upon the slightest strain. The goods were, therefore, returned to this country, and placed in my hands to investigate the cause which had produced this damage.

As a large number of bales were returned without having been opened abroad, an excellent opportunity offered itself for selecting a well-defined series of pieces for experiments, and also for judging of the effects of packing on goods generally, when exposed for a long period to the hot and moist atmosphere of tropical climates.

Firstly, on opening the bales, I observed that the boiled-oil cloth which had been employed to protect the goods from external damp, yielded, when subjected to a very slight strain, proving that the texture of the cotton fibre had been injured by the oxidation it had undergone, in consequence of its having been saturated with boiled oil.

Secondly, on examining the goods forming the bales, it was found, in every instance, that the outer folds, including the second, and sometimes the third, were stained and dirty, but this did not extend deeper, the inner folds being perfectly free from stain or mildew. These facts show the importance of returning to this country (where claims are intended to be made upon the manufacturers or packers) entire and unopened bales of goods, instead of a few sample pieces, which cannot show the state of the bales, and enable the examiner to speak with certainty as to the cause of injury.

I also ascertained that the rottenness of the fabrics could not have been caused by their having been packed in a damp condition, for the hygrometric moisture of a piece in the centre of a bale did not exceed 8·5 per cent. Further, the goods were carefully examined to ascertain if any mildew could be discovered, which would have occurred if the goods had been packed in a damp state, and which would certainly have developed itself more fully in the interior of the bales than nearer the outside, if damp packing had been the cause. What completely removed from my mind all doubt as to the cause, was that, on carefully examining the pieces composing the bales, I found among the injured pieces, some which were quite sound, and on submitting these pieces to analysis, comparatively with those which were injured, the following results were obtained :

The sound pieces left only from 0·55 to 0·65 of ash, whilst the injured pieces left 8·29 and 8·59 of ash, the composition of which was as follows :—

	No. 1.	No. 2.
Insoluble Silica	2·94	3·81
Silica combined with soda	2·35	2·53
Soda	1·77	1·60
Other salts.....	} 1·23	0·65
Sulphate of soda,		
Chloride of sodium.....		
Sulphate of lead, &c.		
	8·29	8·59

These analyses show that the pieces had been finished with silicate of soda, which had undergone a partial decomposition ; while the pieces which left only a few thousandths of ash were found, on further examination, to have been finished in the ordinary way, viz., with amylaceous substances. This induced me to examine

more minutely the goods, to ascertain whether it was to the silicate of soda, or to the carbonate of soda, arising out of its decomposition, that the injury sustained was due; and I was further prompted to carry on this investigation from the fact that at the present time the tendency amongst manufacturers is to weight their goods. It is well known that the risk of mildew is considerably increased in proportion to the weight of size; consequently there is a great inducement to use mineral in preference to vegetable substances for that purpose. I, therefore, trust that the results now published will warn manufacturers of the risk they run in using mineral size, without great care and experience, whilst on this point I may be permitted to give here an insight into the nature of the size often used in Lancashire for sizing the warps of grey calicoes, and, therefore, I give a few of the results obtained at my laboratory.

Analyses of Various Cloths.

No. 1.

Mineral matter, principally clay and sulphate of magnesia	5.2
Water in excess	2.8
Fermented flour	10.0
Hygrometric moisture	8.0
Fibre	74.0
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	100.0

No. 2.

Mineral matter, principally sulphates of baryta and magnesia	4.5
Water in excess	2.1
Fermented Flour	11.3
Hygrometric moisture	8.0
Fibre	74.1
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	100.0

No. 3.

Mineral matter, principally sulphate of soda and clay	4.8
Flour	10.0
Water in excess	4.5
Hygrometric moisture	8.0
Fibre	72.7
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	100.0

No. 4.

Mineral matter	..	..	..	..	1·24
Water in excess	..	..	..	..	1·74
Fermented flour	..	..	..	..	13·02
Hygrometric moisture	..	..	..	..	8·00
Fibre.	..	..	..	..	76·00
					<hr/>
					100·00

The above data show that warps are sized with sour flour (viz., flour which has been allowed to ferment for several days or weeks) and various mineral matters, to the amount, irrespective of moisture, of about 15 per cent. There can be no doubt that goods thus sized are extremely liable to mildew, owing on the one hand, to the use of fermented flour or organic matter in a state of decay, and on the other, to the use of clay, which tenaciously retains moisture, which facilitates cryptogamic vegetation when the goods are packed. I may state, *en passant*, that sulphate of magnesia, sulphate of lime, sulphate of baryta, sulphate of soda, and the chlorides of sodium and magnesium are often used, with or without clay, as weighting materials.

On examining the comparative strength of various pieces composing a bale, I observed that the outside folds of the pieces which formed the external parts of the bale (above alluded to as dirty and stained) were comparatively strong when tested against the folds of the same piece which were towards the interior of the bale. I therefore took the same weight of cloth from both classes of folds and submitted them to analysis, with the following results :—

				Interior of bale.	Exterior of bale.
Insoluble silica	..	..	..	4·81	7·08
Silica combined with soda	..		..	2·53	0·20
Soda	..	..	..	1·60	0·47
Other salts	..	..	..	0·65	0·55
				<hr/>	<hr/>
				8·59	8·30

On examining and comparing these figures, it is at once seen that the stained fold shows a large increase in the amount of insoluble silica, and a corresponding decrease in the amount of silica combined with soda; but, notwithstanding this, the total amount of silica is nearly the same in both classes of cloths.

Further, that there is a total disappearance in the stained fold, of 1·13 %, or more than two-thirds, of the total amount of soda. From these results it would appear that the silicate of soda, when first applied to the goods, contained the whole of its silica in combination with the soda, and that under the influence of the carbonic acid of the atmosphere, the silicate of soda has been decomposed into insoluble silica and carbonate of soda, thereby giving rise to great increase in bulk ; whilst in the goods which were protected from an excess of moisture—as towards the interior of the bales,—and also from the action of carbonic acid, there is only a partial decomposition of the silicate of soda. Mr. Walter Crum has kindly suggested, and I believe the view to be correct, that the cotton fibre has, by its organic nature, a cohesive attraction for silica, which enhances the decomposition of the silicate of soda employed to finish and weight the goods.

From these facts we may assume that there were two destructive influences brought to bear upon the cotton-fibre—1st, that of the increase of bulk resulting from the decomposition of the silicate of soda, giving rise to the formation of free silica and carbonate of soda, which exercised a distending and disintegrating action upon the cellular tissue of the cotton fibre, causing it to burst, and necessarily weakening its tensile strength ; 2nd, the direct and destructive action of the free carbonate of soda upon the fibre. The latter appears to be the principal cause of injury, for in the external folds we have a more complete decomposition of the silicate, as shown in the above figures, by the increase in the amount of insoluble silica, and at the same time a decrease of the soda, amounting, as previously stated, to more than two-thirds of the total weight.

We shall now trace more in detail this interesting decomposition of silicate of soda, and endeavour to show what had become of the soda which had disappeared. To attain this object a complete series of specimens were obtained from an entire bale, viz.: 1, a piece which formed the outside and was stained ; 2, some of the paper employed in wrapping the goods, which was in immediate contact with the stained cloth ; and, 3, some of the flax wrapping placed next to the paper and between the latter and the oil-cloth covering above alluded to. The following are the results yielded by analysis :—

	Pieces of Goods.		Paper Wrapping.		Flax Wrapping.	
	No. 1. inside fold.	No. 2. outside fold.	No. 3. in contact.	No. 4. not in contact.	No. 5. in contact.	No. 6. not in contact.
Insoluble silica..	4·05	5·65	0·02	0·03	0·04	0·01
Silica combined						
with soda....	2·21	0·38	0·09	0·02	0·08	0·03
Soda.....	1·76	0·25	0·85	0·01	0·29	0·02
Other substances	1·96	1·91	15·15	15·28	1·19	1·25
Total ash....	9·98	8·19	16·11	15·34	1·58	1·31

In examining these results we have again a most striking and marked difference in the amount of insoluble silica and soluble silicate of soda in the two different parts of the same cloth; and, further, where the carbonate of soda has been removed, the folds of the cloth remain comparatively sound. As to the paper wrapping, it is evident that the paper in contact with the goods has absorbed a great part of the soda which was previously combined with the silica, and that the soda is partly in the state of carbonate, and partly in combination with some of the organic matter of the brown paper; for when some of the paper was treated with water, it yielded a yellowish brown substance, which coloured the liquid, whilst the part of the same paper which had not been in contact with the goods did not discolour water in any marked degree. Further, the aqueous solution was neutral, and not alkaline, as in the previous case. As to the flax wrapping, the same difference as noted in the paper was observed, viz., that the part of the wrapping in contact with the stained paper and the stained fabric contained carbonate of soda, whilst that which was in contact with the clean paper contained only a trace. In looking over the bales, a piece of cloth was found, which had been finished with silicate of soda, and was partly overlapped by another piece, showing one half of its exterior fold stained and comparatively sound, whilst that half of the fold which was prevented from forming the exterior of the bale by being overlapped by the previous one was quite tender and rotten, though it showed no signs of any stains or mildew. I also examined a sound piece which had lain in contact with an injured one, and found that in those folds which had been in contact, there was in the injured piece less soluble silicate, and in the folds of the sound piece a considerable quantity of carbonate of soda, the presence of which could not be found in the folds forming the centre of it.

Having observed that the reserved white patterns of the blue-dipped Indigo cloth were a great deal more tender than the blue portions of the same piece, I carefully cut out a portion of the white parts and submitted them, with the blue parts, to analysis, with the following results :—

				White.	Blue.
Insoluble silica	..	..	..	5·48	3·17
Silica combined with soda	..	..	..	0·18	2·10
Soda	..	..	..	0·78	1·43
Other salts	..	..	..	1·08	0·67
Total				7·52	7·37

These figures illustrate the fact that the decomposition of the silicate of soda has been carried on to a much greater extent in the white parts than in the blue; and I am led to believe that the cause of the increased rottenness in the white is due to the printer having used a resist-paste too acid, and having found that the whites were slightly tendered, he endeavoured to check the further action of the acid on the cotton-fibre (which, as chemists well know, continues until the cotton fibre is completely destroyed) by the employment of a strong solution of silicate of soda, which, being an alkaline salt, was well adapted to neutralise any acid in the cloth and arrest its action. And as previously only weak solutions of silicate of soda had been employed for this purpose, the printer of these goods could not have foreseen that the use of a more concentrated solution would result in such serious consequences. The above figures also prove another interesting fact, viz., that the white parts of the cloth contain a much larger proportion of silicate of soda than the blues, thus proving that the dyed indigo fibres, being partially filled with this resinous dyeing material, were not in a condition to absorb so largely the silicate of soda.

Messrs. H. Caro & Dancer, who were also employed to investigate this matter, entertain a different opinion as to the cause of the white parts being more injured than the blues. These gentlemen are led to believe from their results that the reason why the whites are more injured than the blues is, that a slow chemical action has ensued between the sulphate of lead remaining from the reserve paste and the silicate of soda, and that a silicate of lead has been formed, and as this salt occupies a larger bulk than the sulphate of lead previously existing in the fibre, the production of it inside the cellular tissue of the fibre has been the cause of the increased

tenderness of the whites. But as these gentlemen are engaged in investigating the question more fully, I shall leave to them the pleasure of publishing their results.

Lastly, I deemed it my duty to make some direct experiments on the action of silicate of soda on cotton fibre. I therefore took some white cotton and dyed a portion of it with indigo. This blue-dyed cloth, with a part of the white one, were dipped in a moderately strong solution of silicate of soda, then dried, and a portion of them introduced into a bottle, at the bottom of which a little water had been placed, and to help the action of the carbonic acid of the *atmosphere*, a slow current of carbonic acid was then passed through the bottles containing the cloths. After three months time the warps of these samples were tested, and their comparative breaking weights were found to be as follows:—

	On an average of 10 essays.
The warps of the unsilicated cloth dyed blue	334
The same silicated	299
	284
	289

These results leave no doubt that the warps, even during the short period of three months, had been considerably injured by contact with silicate of soda. In conclusion, I beg to add that I am aware that silicate of soda has been used for finishing coloured goods, but when employed it has been in a very dilute state, and therefore its destructive action has not been sufficiently marked to draw the attention of calico printers.