EDITORIALS

PREPAREDNESS

In all this ebullition of preparedness for defense, there is at least one prime component which it is the duty of every American chemist to understand. We should not have written this note had we not found by experience that the facts are not generally appreciated. We plan a greater navy and a larger army, but we apparently have no assurance that either could be of use in time of war. We are not only failing to keep our powder dry, but we are not even surely planning to have any powder.

It is not generally realized that no useful explosive for any military use whatever can be made without nitric acid. From black powder and smokeless, through fulminates, nitroglycerine, dynamite, gun-cotton, picric acid, to trinitrotoluol and the latest more complex benzol derivatives, not a pound can be made without nitrates. These are now obtained from Chili exclusively. In the event of any interference with that supply, we should have to revert to the pea shooter, the sling, or the air gun. Can we be sure that Chili will always be willing and able to supply us, and also shall we be able to transport it in face of foreign opposition of conceivable kinds? These are points which chemists in particular should consider.

We have but one other considerable source of fixed nitrogen, the ammonium sulfate from by-product coke-ovens, and this is limited by the coke requirements of the iron industry. Carry the recovery of this salt as far as possible, as should of course be done in the interests of conservation, and the supply would still be quite insufficient.

Without discussing in detail particular sources of power like the Niagara, Tennessee, and Columbia Rivers, the low-grade coals of the culm heaps and of certain mines which do not pay for transportation but can be utilized on the spot, and without referring to

special processes of nitrogen fixation like the arc or cyanamid, it can be stated with certainty that we have all the requisites for a nitrate industry. America has plenty of idle, available power, such as other countries have known enough to use for this and similar purposes, and we have processes capable of economically producing all our needed supply of nitrates, ammonia and nitric acid, while consuming nothing whatever but a little of our limitless air and a small part of the wasting energy of some of our moving waters.

Furthermore, the plant and apparatus for this work can, during times of peace, turn out this same fixed atmospheric nitrogen in the forms which are most demanded by fertilizer requirements. If a manufacturing organization owned the farms and the water rights, it could and would certainly produce nitrogen fertilizer at half the present cost and would produce explosives with but little added equipment in times of war. This would mean that fertilizers would be used where now, though badly needed, they are prohibitively expensive. Can we not, as a nation, accomplish the same end? In spite of all the valuable work of improving the yields of corn in such states as Kansas, by breeding to large grains and big ears, the yield per acre is continually and rapidly falling off. Wheat yields in the northwest have fallen from 40 to 13 bushels per acre as the natural fertilizer has become exhausted. As this decrease continues, a point will be reached where fertilizers at any cost will have to be used. This has been the experience of older countries.

The time for planning work which takes years to bear fruit is at least years before the fruit is expected. We need cheaper fertilizers now and we may need our own explosives at any time. If these words are true, pass them along. If they are not, correct them.

ORIGINAL PAPERS

THE REMOVAL OF THE NATURAL IMPURITIES OF COTTON CLOTH BY THE ACTION OF BACTERIA

By B. S. LEVINE

Received January 6, 1916

The ordinary process of bleaching cotton cloth consists of: (1) a treatment for the removal of certain of the natural impurities which may be present; and (2) a bleaching proper, which decolorizes any impurities left after the preliminary treatment. The natural impurities of the cotton fibers have been studied by several investigators with no apparent relation to the processes of purification of cotton cloth, and by the writer of this paper in connection with a study of the bleaching process. According to the results obtained, the impurities of cotton fibers can be classified for practical purposes as follows:

water-soluble, alcohol-soluble, mineral, ether-soluble impurities and nitrogenous coloring matters.

Not all of the above named impurities, as has been shown by Hebden,¹ are responsible for the yellowing of cloth during the steam test or during storage. According to his opinion, the presence of the alcohol-soluble and of the nitrogenous substances only is responsible for a bleach being imperfect. From a study of the ether-soluble, alcohol-soluble and nitrogenous constituents of the growing cotton fibers,² we were able to corroborate the conclusion of Hebden with regard to the significance of the nitrogenous constituents of the cotton fibers in bleaching, but our unpublished results of a study of cloth in different stages of the bleaching process and of the nature of

¹ Hebden, *This Journal*, **6** (1914), 714.

² Levine, *Sci. N. S.*, **XLI**, 1058 (1915), 543-545.

the alcohol-soluble and ether-soluble impurities of cotton showed that the first, contrary to the opinion of Hebden, have no connection with the yellowing of cloth, whereas the presence of the latter, to which Hebden had ascribed no significance, bears in the yellowing of bleached cloth a share fully equal to that of the nitrogenous substances.

In connection with the determination of a convenient index of purity of cotton cloth, the question has come up whether the present processes of bleaching do not effect any structural differences in the cellulose molecule, thus making it possible to suppose that the quality of a bleach might be due to structural rearrangements. Accordingly, samples of cotton cloth in different stages of bleaching processes obtained from several bleacheries were analyzed for the percentages of carbon, hydrogen, and of oxygen, and tested for their reactivity to certain chemical reagents. From the results obtained, the conclusion was drawn that no structural differences were brought about in the fiber molecule, and that a bleach may be considered to be "good," when all or most of the nitrogenous and ether-soluble substances have been removed from the fibers. Thus, it may be said that the impurities which the bleaching process is supposed to remove or decolorize are the non-cellulose constituents of the cotton fibers, and that they are apparently in no chemical union with the molecules of the fibers. As they are of an organic nature, it seems possible that they might be rendered soluble by the action of certain enzymes of animal or vegetable origin, and that the action of any of these biological agencies upon cotton cloth would result in an efficient and perhaps cheaper method of purification of fabrics.

For some time the writer has been engaged in a study of the principles underlying the action of different enzyme preparations, of moulds, and of bacteria upon the impurities of cotton. The present paper deals with the study of the bacterial treatment of cotton cloth for the purpose of removing its impurities preliminary to bleaching.

PRELIMINARY INVESTIGATION

The analysis of cloth in different stages of the bleaching process and a knowledge of the nature of the non-cellulose constituents of the cotton fiber make it clear, as summarily indicated in the introduction, that if bacteria are to be used for the purification of the cloth preliminary to bleaching, only those which can bring about all or some of the following transformations can be employed:

I—Those which render soluble or otherwise removable the coagulated non-soluble nitrogen-containing constituents of the fibers.

II—Those which render soluble or otherwise removable the alkali-resistant waxes and the fixed fats of the fibers which are represented by the ether extracts.

III—Those which render easily removable the substances which are related to the pectoses.

Most of the soil bacteria and also some of the bacteria which cause certain plant diseases fulfil some

or all of the above conditions. The ammonifying and denitrifying bacteria of the soil, as is well known at present, decompose a large amount of organic matter in the form of fat, waxes, oils, pectins, gums, and celluloses in order that they may get the necessary energy for the metabolism of the living cell. The bacteria which cause the root-rots of certain plants produce strong pectin decomposing enzymes. The cellulose-destroying bacteria, as was pointed out by Herbert¹ in 1892, do not attack the cellulose molecule proper before the pectins, gums, tannins, and other non-cellulose substances have been utilized by them. Thus, the number of bacterial species possessing one or more of the properties required for our purpose is very large, and the question which arose in connection with our problem was not "Can the fibers be purified by bacteria," but, "Which species of bacteria shall we employ for the solution of our problem?"

To answer the above question a number of bacterial species were secured, some of which were soil bacteria, some intestinal bacteria, and some plant pathogens. These were obtained from the collection at the Museum of Natural History in New York, from the Vermont Agricultural Experiment Station, and some were isolated by us. In all cases the identity of the species was established by determining their morphological and physiological characteristics. The selection of those best suited to our purpose was made in the following way: Flasks of standard broth and of synthetic medium (to be described later) were inoculated with the different strains and incubated at 37.5° C. from 10 to 14 days. Cotton yarn, which was thoroughly "wetted out" and sterilized in the autoclave, was introduced into the flasks and they were again incubated for periods not exceeding 10 days. The yarn was then taken out, properly labeled, washed in hot water, and boiled for 5 min. in a 1 per cent solution of caustic soda. It was then subjected to the bleach and sour as in the ordinary bleaching process, washed, dried, and steam-tested. The cultures which gave the best results were selected for further experiment. They were the following:

<i>Bacillus amylolyticus</i>	n. s.
<i>Bacterium fimi</i>	n. s.
<i>Bacillus bibulus</i>	n. s.
<i>Bacillus carotovorus</i>	n. s.
<i>Bacillus subtilis</i> (Ehrenberg).....	Cohn

All these bacterial species produce enzymes by means of which they perform the transformation of such substances as sugars, starches, gums, pectins, celluloses, and various proteins into substances, the molecules of which are much smaller than and possess chemical properties differing from those of the original substances, so that they can be easily distinguished from them. Thus the starches are broken down to dextrins and to dextrose, the pectins are changed to pectic acid, the celluloses to carbon dioxide, methane, various organic acids, and water. The proteins are broken down to carbon dioxide, water, ammonia, nitric and nitrous oxides, free nitrogen, and perhaps some other compounds. These bacterial enzymes

¹ Ann. Agron., 18 (1892), 536-550.

diffuse in the surrounding media to an extent which depends upon the amount and diffusibility of the enzyme produced. Hence, from the amount of substrate transformed, the enzymic strength of the bacteria may be determined by plating the bacteria out on agar containing a known per cent of the substrate and incubating for a few days. The enzyme excreted by the organism usually diffuses equally in all directions, and the circular zones around the colonies may be made visible by treating the plates with suitable reagents. The diameter of the circle can be measured and compared with that of zones produced by other organisms on the same substrate and their relative efficiency may thus be ascertained. The zone formed by a bacterial colony has been called the "enzymic zone" and its diameter expressed in millimeters or fractions thereof.

To further test the suitability of the strains previously selected, the bacteria were grown on cellulose-agar plates, starch-agar plates, pectin-agar plates, and their enzymic zones measured. The starch- and the cellulose-agar were prepared as follows:

CELLULOSE-AGAR	STARCH-AGAR	PECTIN-AGAR	AMOUNTS
Cellulose Solution	Starch Solution	Pectin Solution	500 cc.
Nutrient Solution	Nutrient Solution	Nutrient Solution	500 cc.
Agar	Agar	Agar	10 g.

The cellulose and the starch solutions were made up according to the directions given in *Bulletin 266*, United States Department of Agriculture, Bureau of Plant Industry, page 28. The pectin solution was

	ENZYMIC ZONES		
	STARCH	CELLULOSE	PECTIN
<i>B. bibulus</i>	1.0 to 2.0 mm.	0.1 to 0.3 mm.	1.0 to 1.5 mm.
<i>B. fimi</i>	2.0 to 3.0 mm.	0.5 to 1.0 mm.	0.5 to 1.0 mm.
<i>B. amylophilus</i>	0.5 to 1.0 mm.	0.5 to 1.0 mm.	?
<i>B. carotovorus</i>	1.5 to 2.0 mm.	?	1.5 to 2.5 mm.
<i>B. subtilis</i>	?	0.2 to 0.5 mm.	0.7 to 2.0 mm.

It may be seen from an examination of this table that the transforming strength of the enzymes produced by the bacterial strains selected was great in all cases, and that their suitability to our work, as determined by the previously described flask-incubation method, was confirmed.

ACTION OF BACTERIA UPON THE IMPURITIES OF COTTON CLOTH

The bacterial strains selected as previously described were employed further in the study of the action of their enzymes upon the impurities of cotton cloth. Five hundred cc. of the nutrient solution described above and 50 g. of coarse cotton cloth containing about 5 per cent by weight of starch as a "sizing" material were put in each of 15 flasks and sterilized in the autoclave for 30 min. Sets of 3 flasks were then inoculated with the liquid cultures of the bacteria employed and incubated at 37.5° C. Control flasks with the nutrient solution and cloth were sterilized as described above and incubated without having been inoculated. One sample from each of the cultures was then taken out 1 mo., 2 mo., and 3 mo. after inoculation. The samples were thoroughly washed in boiling water to remove all the solu-

TABLE I—TESTS OF CLOTH SAMPLES AFTER 1 MONTH'S INCUBATION

No.	CULTURE	Starch Test	Transformation to a Dextrin	Softening of Cloth	Condition of "Motes"
A ₁	<i>B. amylophilus</i>	Violet-blue	Probable	Slight	Merely swollen
A ₂	<i>B. bibulus</i>	Violet	Probable	Less than A ₁	Swollen and slightly discolored
A ₃	<i>B. fimi</i>	Greenish	Decided	Considerable	Swollen and slightly discolored
A ₄	<i>B. carotovorus</i>	Greenish	Decided	Considerable	Swollen and slightly discolored
A ₅	<i>B. subtilis</i>	Greenish violet	Less than above	Moderate	Swollen and discolored

TABLE II—TESTS OF CLOTH SAMPLES AFTER 2 MONTHS' INCUBATION

No.	CULTURE	Starch Test	Change beyond 1 Mo. Condition	Softening of Cloth	Condition of "Motes"
B ₁	<i>B. amylophilus</i>	Violet	Not marked	More than A ₁	Same as A ₁
B ₂	<i>B. bibulus</i>	Greenish	Marked	Much more than A ₂	Almost completely gone
B ₃	<i>B. fimi</i>	Light green	Decided	Much	Barely colored and partly gone
B ₄	<i>B. carotovorus</i>	Light green	Decided	Moderate	Swollen and slightly discolored
B ₅	<i>B. subtilis</i>	Greenish violet	Not marked	Slight	Swollen and slightly discolored

TABLE III—TESTS OF CLOTH SAMPLES AFTER 3 MONTHS' INCUBATION

No.	CULTURE	Starch Test	Starch Transformation Indicated	Softening of Cloth	Strength of Cloth	Condition of "Motes"	BLEACHED SAMPLES(a)	MOTES
C ₁	<i>B. amylophilus</i>	Faint violet	Partial removal of amyloextrins	Considerable	Unimpaired	Strongly discolored	White	None
C ₂	<i>B. bibulus</i>	Very faint green	Change or solution of dextrins	Decided(b)	Weakened(c)	Mostly gone	Very white	None
C ₃	<i>B. fimi</i>	Negative	Changed to sugars or achrodextrins	Decided(d)	Impaired(c)	Mostly gone	Whitest of all	None
C ₄	<i>B. carotovorus</i>	Very light green	Removal of dextrins	Considerable	Unimpaired	Mostly gone	Very white	None
C ₅	<i>B. subtilis</i>	Violet (greenish)	Further change in amyloextrins	Some	Unimpaired	Swollen and discolored	White	None

(a) See text for method of bleaching.

(b) Pinkish tint. (c) Signs of disintegration where the cloth was not wholly submerged and came in contact with the air.

(d) Pink tint lighter than C₂.

prepared from the water-soluble substances of cotton in the following way: Unspun non-absorbent cotton was percolated with water for 24 hrs., the cotton pressed out and the solution filtered to clearness; it was then evaporated to dryness on a steam bath, and 10 g. of the dried extract were dissolved in 500 cc. of water. The nutrient solution consisted of 1 g. each of dibasic potassium phosphate and magnesium sulfate, 2 g. each of sodium chloride, ammonium sulfate and calcium hydrate, and 1000 cc. of water.

The bacteria were plated out on each of the media described and incubated at 37.5° C. in a chamber saturated with moisture so as to prevent drying of the plates. After 10 to 14 days' incubation, the enzymic zones were measured. The results were as follows:

ble products of the bacterial metabolism and the adhering chemical reagents of the medium, and the samples taken from the flasks incubated for 1 and 2 mo. were tested for starch; the samples taken from the flasks incubated for 3 mo. were tested for starch, nitrogen, and ether- and alcohol-soluble substances. The strength of the cloth, its softness, and the disappearance of the "motes" were also noted. The results appear in Tables I, II and III.

Samples from all the 3-mo. incubations were bleached for 4½ hrs. in a solution of freshly prepared calcium hypochlorite of 2° Tw. They were then thoroughly washed in cold water and put into a solution of sodium bisulfite (4° Tw.) for another 4½-hr. period. After this, the cloth was thoroughly washed, dried, ironed,

and compared as to whiteness, with the results noted in the last two columns of Table III.

The bleached samples were then subjected to the steam test under a pressure of 10 lbs. per sq. in. for 45 mins. None of the samples were yellowed by such treatment, and we assumed, therefore, that all the substances which cause yellowing of the bleached cloth during steaming or during storage were removed.

In order to determine whether the removed substances were the same as determined by the analysis of cloth in the different stages of the bleaching process, the bleached samples from the bacterial treatments were analyzed for the determination of the percentages of the ether-soluble, alcohol-soluble, and nitrogen-containing substances which were left in or on the fibers after the "chemick" and the "sour." The results are given in Table IV.

The cloth incubated in the control flasks after the 3-mo. incubation showed no starch transformation, very slight reduction in the percentage of the ether-soluble and nitrogen-containing substances, and no change in the percentage of the alcohol-soluble substances.

In all the bacterial treatments, the nitrogen-containing substances were removed from the cloth completely, the ether-soluble substances were removed

The transformation of nitrogenous substances which is usual in the case of decomposition of organic matter in the soil, suggests a way in which the answer might be given. To determine whether the case in our experiment was similar to that of the above mentioned condition in the soil, we tested several samples of media, taken out at various times of incubation, for the presence of ammonia. The quantity of cloth and the small percentage of the nitrogenous substances in it rendered our attempts fruitless. We were about to give up further investigation along that line, when we found in some of the flasks a very slight, white precipitate. On testing, it proved to be calcium carbonate, and it at once occurred to us that in the presence of calcium hydroxide the decomposition of the nitrogen-containing substances may be accompanied by the formation of calcium carbonate, free nitrogen or ammonia, and water.

The nitrogenous coloring substances of cotton in the American and the Egyptian varieties were studied by Dr. Schunk,¹ and according to his analysis the formula for the substances found in the American variety would be $C_{10}H_{12}O_4N$, and that of the substances found in the Egyptian variety $C_{25}H_{30}O_9N_3$. In the presence of calcium hydroxide the reactions brought about during the decomposition of the first

TABLE IV—TESTS SHOWING REMOVAL OF IMPURITIES FROM CLOTH SAMPLES BY INCUBATION FOR 3 MONTHS AND SUBSEQUENT BLEACHING

CULTURE	NITROGEN (OR PROTEIN)						ETHER EXTRACT						ALCOHOL EXTRACT					
	GRAMS		GRAMS AFTER INCUBATION "Sour"	PER CENT REMOVED BY INCUBATION "Sour"		Total	GRAMS		GRAMS AFTER INCUBATION "Sour"	PER CENT REMOVED BY INCUBATION "Sour"		Total	GRAMS		GRAMS AFTER INCUBATION "Sour"	PER CENT REMOVED BY INCUBATION "Sour"		Total
	ORIG-INAL																	
<i>B. amylolyticus</i>	0.156	0.0032	None	75.8	24.2	100.0	0.392	0.059	0.015	78.8	9.3	88.1	0.5107	0.5107	0.4569	0.0	3.2	3.2
<i>B. bibulus</i>	0.156	Trace	None	100.0		100.0	0.392	0.0716	0.0446	78.6	9.3	87.9	0.5107	0.5107	0.472	0.0	3.0	3.0
<i>B. fimi</i>	0.156	0.038	None	97.9	2.1	100.0	0.392	0.117	0.041	85.0	11.2	95.2	0.5107	0.5107	0.4098	0.0	2.5	2.5
<i>B. carotovorus</i>	0.156	0.025	None	84.4	15.6	100.0	0.392	0.075	0.039	80.9	9.1	90.0	0.5107	0.323	0.306	35.9	5.2	41.1
<i>B. subtilis</i>	0.156	0.012	None	92.9	7.1	100.0	0.392	0.125	0.079	68.1	11.2	79.3	0.5107	0.465	0.457	8.9	2.5	11.4

more efficiently than they were after the chemical process of bleaching, the alcohol-soluble substances remained unchanged, except in the case of the cloth subjected to the action of cultures of *B. carotovorus* and of *B. subtilis*.

The weakening of the cloth in the samples subjected to the action of cultures of *B. bibulus* and of *B. fimi* may have been due to the action of the oxygen of the air on those parts of the cloth saturated with the calcium hydroxide of the media which were not completely submerged. It is possible also that during the long period of incubation to which the cloth was subjected, the bacteria may have acted upon it to such an extent that a slight general disintegration was caused.

But as the reactivity of the cloth remained apparently unchanged, we feel safe in concluding that a more thorough investigation of the action of some of the bacteria upon the impurities of cotton cloth would determine the conditions under which the bacteria would remove the nitrogenous and ether-soluble substances of the fibers without impairing the body of the fabric.

THEORETICAL CONSIDERATIONS

The question may be asked in connection with the disappearance of the insoluble nitrogen-containing substances of the cotton fibers: "How have they been removed to such an extent by the action of bacteria?"

by means of oxidation may be represented by the following equations:

and for the oxidation of the latter in the presence of calcium hydroxide the reactions may be represented as follows:

Free ammonia and free nitrogen are thus formed which could not be detected by us on account of their small amounts. As there was no precipitate found in some of the flasks, it may be supposed that mere liquefaction of the protein substances took place which rendered possible their complete removal after the strong oxidation during the "chemick" which had most probably converted the peptones and amino acids formed into nitrates and nitrites.

The reactions just given are of the nature of oxidations and result in liberation of energy. It therefore seems probable that the nitrogenous substances of the cotton fibers form some sources of energy to the

¹ Memoirs, Manchester Literary and Philosophical Society, Vol. IV, 3rd Series.

bacteria. The pectins, gums, and waxes, no doubt, are used up by them first, the nitrogen-containing substances next, and, as the medium used in our experiments was devoid of carbohydrates, the cellulose finally was drawn upon by the bacteria as a source of energy. This probably would not be the case in the practical application of bacteria to the treatment of cotton cloth before bleaching, as the period of incubation would have to be reduced to a minimum. The weakening of the cloth would be eliminated entirely, and a cheaper, safer, and more convenient process for the purification of cotton cloth preliminary to its bleaching would thus be obtained.

Since the conclusion of the above described preliminary experimental investigations, studies have been carried on with a view to applying bacteria to practical purification of various cellulose fibers. By using different combinations of bacterial species, different media, different reactions of the media to start with, and different temperatures during the period of incubation, the latter was reduced to 72, 48, 36, and in some cases even to 24 hrs., all depending upon the nature of the fibers used.

A number of tests on a large scale were also performed for the purification of paper-making stock in connection with one of the eastern paper making factories, and for the purification of cotton yarn and cotton cloth in connection with some of the Rhode Island bleacheries. In all cases the results obtained were very encouraging.

SUMMARY

I—Of all the natural impurities of cotton cloth only the nitrogen-containing and the ether-soluble substances, when insufficiently removed from the cloth previously to the "chemick," cause yellowing of bleached cloth in the steam test or during storage.

II—The nitrogenous substances of the fibers were broken down by bacteria so that they were completely removed from the cloth. This transformation in the presence of the calcium hydroxide has probably resulted in some cases in the formation of either free ammonia or nitrogen, calcium carbonate, and water, and in some in the reduction of the nitrogenous substances to peptones and amino acids which are easily oxidized to nitrates and nitrites.

III—The ether-soluble substances of the cloth were removed in our experiments by bacterial treatment more efficiently than is the case in the ordinary bleaching process.

IV—The alcohol-soluble substances were very little attacked by the bacteria, probably because of the formation of a calcium salt in the presence of the calcium hydroxide of the media.

V—None of the bacteria experimented with have transformed the starch of the cloth any further than to dextrins.

VI—Bacteria may be profitably employed as a substitute for the present method of purifying cloth preliminary to its bleaching.

The present paper records a part of the work done by the author along similar lines for Mr. J. C. Hebden of Providence, R. I., in connection with and under the auspices of the Biological Laboratory of Brown University. The author wishes to express his gratitude to the instructing staff of the Brown University Biological Laboratory and to Mr. Hebden for their general and generous assistance in the work and for permission to publish the results.

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PHYSICAL PROPERTIES OF DENTAL CEMENTS

By PAUL POETSCHKE

Received December 22, 1915

The principal types of dental cement which occupy a useful place in dentistry at the present time are known technically as the silicate, zinc oxyphosphate and copper cements. All of these products reach the dentist in the form of a powder and liquid to be combined, as occasion requires, by a special process of mixing. The constituents and applications of the three types and the various properties upon which their uses in applied dentistry depend, are given in Table I.

In order to determine the "fitness" of a dental

FIG. 1—GENERAL ARRANGEMENT OF APPARATUS

From left to right, apparatus includes: Pail for overflow from mixing slab, clock, stop watch, thermos bottles (arranged for conducting feed water to mixing slab), Gilmore needles (for ascertaining the setting time), container for used spatulas, pipette, electrically controlled incubator, balance, hygrometer and setting device.

cement, due consideration must be given to its various properties, individually and collectively. A silicate cement which does not possess the required color and translucency would be lacking in the essential requirements of this type of cement, and no matter how perfect in other respects, it would fail to fulfil its main purpose—its ability to match the tooth structure in appearance. Likewise, germicidal efficiency is essential in a copper cement. It is obvious that