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PAPER-MAKING MATERIALS AND THEIR CONSERVATION.

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PAPER-MAKING MATERIALS AND THEIR CONSERVATION.

INTRODUCTION.

This circular has been prepared to meet a demand for general information as to the suitability of various products, most of which are not now employed, for paper stock, and also to suggest ways of maintaining sufficient quantities of paper-making materials in the future. No directions for paper making are given. It has been established that numerous materials, while technically suitable for paper making, can not be so employed for economic reasons, but by a rational and conservative use of the materials now employed, the problem of a sufficient supply of paper stock can be much simplified. For this reason, suggestions based largely on the work of the Bureau of Chemistry are here made which, if followed, it is believed would result in greater economy in the use of raw materials as well as in lower cost and better service to the consumer without material reduction in total values. It should be distinctly understood that the figures on the waste materials are only estimates. It has been the aim to make these very conservative, as it is recognized that it is impossible to give even approximately accurate figures as to the quantities of such materials, the amounts that could actually be secured for paper making, or their cost. The aim is to direct attention to the large quantities of suitable material now wasted, leaving to the future the working out of the details of their profitable utilization.

The woods from which the greater part of the paper produced in this country is made are becoming scarcer and are obtained at greater cost each year. This fact has occasioned some concern to the paper industry in the past few years, so that manufacturers and investigators have turned their attention toward other agricultural products, many of which have been shown to be perfectly suited for paper making as far as the quality of the product is concerned. All kinds of wild and cultivated plants which are available in large quantities as well as all kinds of fibrous wastes have been used either experimentally or on a manufacturing scale for paper making. These facts are well known to paper makers, who have themselves experimented on a mill scale with many materials—woods, plants, and fibrous wastes—and have placed their treatment on a practical basis. Nevertheless many inquiries are constantly received from paper manufacturers and others as to the possibilities of making paper from some new material.

Practically all fibrous vegetable materials will make paper, the quality being governed by the percentage of fiber sufficiently resistant to stand the action of the chemicals necessary to reduce to a working condition the most resistant fibers, while the quality of the paper which these materials will make is determined by the length, strength, and felting qualities of the fibers and the chemical nature of the cellulose which they contain; the longer and stronger the fibers and the purer the cellulose (the more closely it corresponds to normal cellulose), the better the paper, the longer it will last, the more wear it will stand, and the less it will discolor with time or use.

CLASSIFICATION OF MATERIALS.

The materials which may be used in paper making can be roughly divided into four groups:

(1) Seed hairs, of which cotton is the only representative.

(2) Bast fibers, such as flax, jute, hemp, ramie, China grass, sun hemp, common nettle, paper mulberry, and the fibers obtained from the fibrovascular bundles of plants such as manila and New Zealand flax.

(3) The whole stems and the leaves of straws and grasses, such as esparto (leaves only), corn, sugar cane, bamboo, other wild and cultivated grasses, cotton stalks, and materials of like nature.

(4) The various kinds of wood, those most used being spruce, hemlock, poplar, and cotton wood.

Most of the materials of the first three classes are used in paper making in the form of wastes from other industries; those of the first two classes as scutching, mill, and rag wastes of the textile industries; while those of the third class are used in the form of wastes from the agricultural industries. Esparto, bamboo, and paper mulberry are not wasted from other industries, but are gathered primarily for paper making. The use of materials in the form of waste is not due to particular difficulties in separation or handling nor to the unsuitability of the original material, but solely to the fact that these materials in their original form command a higher price for other purposes than for paper making. Indeed all of these materials will make paper of greater strength, durability, and value before going through other manufacturing processes, or when used in the form of worn and soiled rags. For example, new cotton fiber, as baled cotton, or that known as "linters," which is removed from the ginned cotton seed as a preliminary step in the cotton-oil industry, is perfectly suited for the manufacture of high-grade paper, but the demand at the price that must be asked does not justify the use of this material for paper making. Similar conditions exist as to the materials of the second class, which command from 3 to 20 cents per pound for the manufacture of cloth, bagging, ropes, and cordage.

The materials of the first two classes, because of the length, strength, and felting qualities of their fiber and the resistance to chemicals and to decay of the cellulose they contain, can be made into papers of the highest quality, and each material gives certain characteristics and individuality to the paper made from it. It is customary to consider the first two classes together.

The materials of the third class belong chiefly to the class of compound celluloses known as pecto- and ligno- celluloses, and are distinguished from the paper-making point of view not only by the presence of celluloses of different chemical composition and lower felting qualities, but also by a larger content of nonfibrous cellulose which, although it has some desirable qualities even when present in large quantities, as in bagasse or cornstalks, produces parchment-like effects in the papers made from them. A further technical objection to these materials is that the chemical treatment required to reduce the fiber properly is too severe for the nonfibrous cellulose, which is overcooked and partly dissolved, resulting in low yields of weak paper. Esparto, of which only the leaves are used, is an exception to these general statements, and yields a larger percentage of a strong, uniform fiber than the other members of this group. This class of materials, except esparto and bamboo, have, as a rule, short fibers and yield a small quantity of low-quality paper in comparison with the other groups, though some of them are not markedly different from woods in the latter respect.

For the past twenty years wood, chiefly spruce and poplar, has furnished the greater part of the paper made in this country. In 1907, 3,962,660 cords were used, yielding on an average 1,200 pounds of pulp per cord of wood, or a total of about 2,547,879 tons of pulp, which would make approximately 80 per cent of the paper and board annually produced in this country. The fibers of the soft coniferous woods are longer than those of the hard deciduous woods, the former being from 1 to 4 millimeters in length, while the latter are from 0.5 to 2.5 millimeters long. Spruce is more commonly used for making ground wood and pulp by the sulphite process, while poplar is almost exclusively reduced by the soda process. However, these woods may be treated by either process, depending on the cost of material, the location of the mill, etc.

Because of the exhaustion of the supplies of spruce and poplar within a reasonable distance of the mills, large quantities of other kinds of wood have been used for many years, not only for making board, bogus manila, and wrapping papers, but also for white papers, such as are used for news, book, and low-grade writing papers. Thus in 1907, 576,154 cords of hemlock, 78,583 cords of various kinds of pine, 43,884 cords of balsam, 66,084 cords of cottonwood, and 125,162

cords of other kinds of wood were used for making paper, the larger part being chemically treated. Among the pines, white, gray, loblolly, and longleaf yellow pines are being used, while among the miscellaneous woods employed are red and white fir, larch, aspen, gum, cypress, beech, birch, maple, basswood, buckeye, and chestnut; other woods which are available in large quantities are being constantly experimented with at various mills. Indeed, practically all woods may be used for paper making, such use being governed chiefly by the character of the wood supply near the mill.

The reasons that have made wood the cheapest and preferred paper-making material are clearly evident. They are low cost of raw material; ease of transportation and handling, particularly by machinery; freedom from dirt; uniform supply, and low digester requirements, as much more wood can be placed in a given digester than any other material. Further than this, mills could be built and operated close to the material. But the spruce and poplar forests contiguous to many of these mills are gone and they can no longer obtain their wood at the old price nor at a price that will enable them to compete with mills more recently built, which are still close to a wood supply. Neither can such mills, built to use wood advantageously, use other materials in competition with mills especially built and equipped for using those materials. The demand developed in the past few years and constantly growing is not primarily so much for new materials as it is a demand for wood at a price that will enable the poorly situated mills to compete with those more economically located with respect to this supply. This demand can only be met either by a large use of other woods or by planting and growing spruce and poplar.

YIELDS OF PULP ON A MANUFACTURING SCALE.

The percentage yield of pulp and paper varies with different materials, and that from a given material varies with the severity of treatment to which it is subjected and the kind of paper made—the better the quality of paper the lower the yield. The yields usually obtained from the more commonly used materials are as follows:

	Per cent of paper obtained.
Rags	70–80
Esparto	40–45
Straw	40–50
Wood, sulphite	40–50
Wood, soda	40–50
Waste fibers, paper, bagging, scutching waste	75–90
Bamboo	40
Jute	50

POSSIBILITIES OF SOME MATERIALS NOT COMMONLY USED.

Besides a proper and conservative utilization of wood, the demand for paper stock may be filled by a more extensive use of other well-known and thoroughly developed materials. The use of these is controlled by the total cost of manufacturing from the cheapest substance an acceptable paper. As has been said, wood is the cheapest paper-making material now obtainable in large quantities. Therefore competing materials must produce paper at as low a cost at the point of consumption as wood does. The local use of other materials is feasible in sections which are distant from mills making paper from wood, as in the Mississippi Valley and in the coast regions of the Southern States, where the total cost of the papers now used is increased by the cost of transportation from distant points. In the never-ceasing search for materials many previously exploited substances are rediscovered from time to time and more or less transient interest taken in them. These materials belong, almost without exception, to the third class mentioned above and rarely possess sufficient merit to compete with those which have been employed regularly for many years, and which experience has demonstrated are the cheapest and best suited to the purpose.

BASIS OF VALUING NEW MATERIAL.

Paper making on an industrial scale is governed by the supply of raw material, the quality of paper it will make, and the total cost of manufacturing it into paper. In valuing a material, therefore, it is as necessary to know how much there is of it and how steadily this supply will be maintained as it is to determine the quality and quantity of fiber it yields, the cost of gathering, transporting, and converting into paper, and whether it can compete economically with other materials used in making the same grade of paper.

In forming an opinion as to whether there is a sufficient supply of the material to justify its use, the fact must be borne in mind, particularly if a mill is to be built, that it is not a question of a temporary supply, but of a continued supply, that there should be enough available to meet all requirements for a number of years. Estimates on these points can only be formed after careful consideration and examination of the source of the material, taking into consideration whether it is naturally grown or cultivated, whether it is an industrial or agricultural waste, and whether it can be obtained in a satisfactory condition as to cleanliness. The value of the material for other purposes must also be considered; if this is greater than the paper-making value, it is useless to consider the subject further.

When it has been determined that the supply of the material is sufficient, samples should be examined in the laboratory. The com-

position of the material and its adaptability to paper making, as well as a fairly accurate idea of the character of paper it will make and the cost of treatment, can all be determined by a laboratory examination, saving a great deal of experimenting in the mill, which is both costly and time consuming. Such an examination can be made in any well-equipped paper laboratory and may be then followed by a mill test on a small scale. The results secured in these ways are rarely duplicated on a commercial scale, so that methods of treatment can only be perfected by experiments in the mill, and in all cases the results should be so confirmed before large sums are invested.

The laboratory examination indicates at once to which of the previously mentioned classes the materials belong and shows the quality and general character of paper which it will make. It also indicates the time and pressure required for the necessary cooking of the material as well as the quantity of chemicals needed in cooking and bleaching. From these data the cost of treating may be approximated. Moreover, the quantity of paper made by a given weight of the material is shown, and from the quality and quantity produced the market value of the paper can be estimated. Materials are valued by comparison with rags, which are the standard for the highest grades of paper, or with wood which makes a good grade of white paper, for the treatment of both of which the mills have been especially designed and located. It is therefore quite evident that materials which are expected to compete with these standard materials must yield a paper fully equal to them in strength, durability, cleanliness, texture, and appearance, and the finished paper must cost no more per pound.

The last factor in valuing a material is the total cost of making paper from it, and this is obtained by adding to the cost of making the expense of gathering and transporting the material to the mill. The yield per given area, cost of harvesting, difficulty of handling, relative bulk of the material, and cost of transportation must all be considered. Whether the waste is one which is always harvested, as are straw and sugar cane, or is usually left ungathered, as are cotton stalks, is a point which also affects the cost.

The relative expense of making paper from different materials can not be discussed in detail. It may be said, however, that the cost of chemicals per ton of paper is greater, as a rule, for wood than for other materials, and the time of cooking is longer. On the other hand, wood is cleaner, more can be placed in the digester, and the pulp requires less beating than longer and stronger fibers. What difference there is in the cost of mill treatment of the various materials, provided they pass through all the chemical processes and are

used in the same grade of papers, is probably in favor of wood. Therefore only those materials which will yield an equal quantity of as good paper and which can be delivered at the mills at no greater cost can compete successfully with it. In other words, it is largely the cost of the raw substance rather than the mill treatment that determines the availability of paper-making materials. The relative cost of various raw materials per ton of paper produced is shown in the following table. It must be understood that the price of the raw material on which the estimation is based is not absolute and will, of course, vary with economic conditions.

Estimated cost of raw material per ton of paper produced.

Material.	Assumed cost of material at mill per ton.	Yield of paper.	Cost of material per ton of paper.
	Dollars.	*Per cent.*	*Dollars.*
Wood	[a] 6	40	10.00
	[a] 8	40	13.25
Cotton stalks, straw, bagasse, cornstalks	2	35	5.75
	5	35	14.33
Flax straw	[b] 3	80	19.00
	[b] 5	80	32.50
Old bagging	16	80	20.00
Scutching waste	20	80	25.00
	40	80	50.00
Linters	20	80	25.00
	60	80	75.00
Waste paper	10	90	11.00
	40	90	44.50
Rags	20	80	25.00
	120	80	150.00
Manila and hemp rope	40	80	50.00
Esparto	20	45	44.50
Hemp fiber	40	80	50.00
Cotton	100	90	111.00

[a] Per cord. [b] Based on 400 pounds of fiber per ton.

Greater cost of production alone, due chiefly to greater cost of raw material, or coupled with lower quality of product, renders impracticable the use of many wild and cultivated plants. Thus an initial cost for straw of $5 per ton at the mill prevents its competing with wood at $8 per cord for making white paper. The same statement holds in a general way for marsh grasses, sugar-cane bagasse, cornstalks, cotton stalks, etc., from all of which acceptable papers can be made, but at a greater cost than from wood under present conditions.

One other factor should be considered, namely, the cost of paper at the point of consumption. There are undoubtedly localities where, because of their distance from the commonly-used raw materials, the unusual materials can be and are used to a limited extent to supply local demand. This is particularly true of the lowest grade of paper, such as box boards and pasteboard, for which straws of all kinds are suitable. The conditions under which utilization, as far as white papers are concerned, is possible must be very carefully considered for each particular case, but are of course chiefly controlled by the

difference between cost of production plus transportation on the one hand and cost of production at the point of consumption on the other.

Finally, from a consideration of the foregoing facts it is evident that the whole subject of new materials is a question of their relative cost rather than a technical one as to their paper-making possibilities. As has been said, broadly speaking, any fibrous vegetable matter will make paper, but its use for this purpose is controlled by the value and cost of the product. It is therefore true that with a rise in the price of the materials generally employed, others will be more largely used and most profitably when obtainable close to the paper mills. For these reasons consideration should be given to some of the proposed materials.

UTILIZATION OF MILL AND FOREST WASTE.

With the present methods of removing bark, rotten wood, and knots, the utilization of mill wastes for making any but low-grade colored papers or boards seems impracticable. If all suitable material is used, as it should be, for making laths and other small articles, the waste from a mill would be too small both in size and quantity to be profitably handled as a paper material. There are, however, large quantities of wood left in the forest which is of sufficient size to be used advantageously by the methods now in vogue. While it is impossible to give an accurate estimate of the material thus available, it is probably safe to say that fully 25 per cent of the tree which has been cut for lumber is still available for paper making and, when properly graded, offers no particular difficulty in treatment at the mill. On this basis fully 12,000,000 cords are available annually as waste from the lumber industry, and furthermore it is obtainable in large quantities over small areas, and, being a waste of the lumber industry, can doubtless be obtained at a lower cost than wood direct from the stump.

UTILIZATION OF STRAWS AND WILD GRASSES.

Straws and other grasses contain compound celluloses which exist both in the form of fiber and of nonfibrous cellular material, and yield from 30 to 50 per cent of white paper. These substances are likely to contain much dirt, collected from the ground, which is difficult to remove; if any remains, it increases the cost of treatment and mars the quality of the paper. Cereal straws were generally employed for the cheaper papers before wood was used, and even now are used extensively for making papers and board. As has been said, the cost of making a good quality of paper from these materials, except possibly under exceptional conditions, is greater

than from wood, but they are suitable for making cheap wrapping papers and boards when the proximity of the mills to the raw material and increased yield compensate for somewhat greater original cost of raw material or greater cost of treatment.

Special mention should perhaps be made of rice straw, with which some experimental work has been done recently in this country. Examination of the fiber and of pulp made from the straw indicates that the paper made from it is similar in all respects to paper made from the more commonly used cereal straws, and any advantage which this material may possess over the latter is due to local conditions under which it is produced. In the tide-water regions of the Southern States, far from the chief points of paper production, paper may possibly be made from the large quantity of rice straw now wasted for less than it can be made in the present paper-making centers and transported to southern markets

With the straws may properly be included the "herds" of hemp, i. e., the broken stems produced in "breaking out" this fiber, as well as bagasse, and cornstalks. These latter materials contain more cellulose in the nonfibrous cellular forms than the straws of oats, wheat, rice, etc., and for this reason are not so well adapted to certain purposes. It may be said, however, that as the high percentage of cellular cellulose gives that property of "wetness" required in certain cases, and only obtained from the better known materials by prolonged beating at great expense, the former may, with better knowledge of the use of materials for definite purposes, be used for mixing with long fibers to give strength or hardness. Indeed it seems quite probable that some of the materials now rarely used may later be utilized by mixing with the standard articles to impart special characteristics or to secure certain effects at less cost than is now possible.

Many years ago Routledge demonstrated that bamboo, which from the paper-making point of view may be classed with straw, is well suited for making papers of medium quality like those produced from wood. Later work has confirmed this conclusion, but the material even in subtropical countries, where it grows luxuriantly and where labor is cheap, is used but little, and it is evident that the cost of standard materials must rise higher before bamboo will play any extensive part in paper making. The large annual growth of bamboo has called attention to it as a suitable plant to grow especially for paper-making purposes, but while bamboos are successfully grown in this country it seems probable that a more extended use of the native-grown crop will precede its cultivation for making paper in this country, particularly as long as a greater profit can be made per acre from other crops.

BAST FIBERS.

WASTE FLAX FIBER.

In the Northern Central States, chiefly in Michigan, Minnesota, and the Dakotas, about 3,000,000 acres of flax are grown annually, practically all for the seed, while the straw is allowed to rot or is burned in the fields. One ton of this straw will yield about 400 pounds of fiber—that is, at the rate of 1 ton of straw per acre, 600,000 tons of fiber suitable for making 480,000 tons of strong, high-quality paper. Small quantities of straw are now being delivered to the tow mills at from $2.50 to $3 per ton, and doubtless practically all of it can be secured at $5 or $6 per ton. As the fiber is one of the best paper-making materials, it is, even at the highest mentioned price, a cheaper raw material for strong wrapping paper than old manila and hemp rope, and if it can be obtained free of the seed, which when present produce grease spots in the paper, the fiber will command even a higher price for fine white paper. Commercially, the presence of seed has been a difficulty in the utilization of the fiber for fine papers.

MALBÓN OR MALVA CASTILLA FIBER.

Another bast fiber which may be mentioned is that of Malbón or malva castilla, a plant which grows wild over large areas from southern California to southwestern Mexico, and is used by the Indians in making cordage, ropes, and coarse fabrics. Examination of the fiber in this laboratory indicates that it will yield about 60 per cent of pulp. The individual fibers are from 0.75 to 6 mm long, averaging 2 mm, and are suitable for making a strong white paper.

MISCELLANEOUS WASTES.

Other materials which have become prominent enough to receive mention are cotton and tobacco stalks, agricultural wastes occurring in large quantities in the Southern States. Low-grade tissue and common wrapping papers have been made from these sources. The fiber from these materials is from 0.4 to 3¼ mm long, averaging 1¼ mm, while the yield of paper is approximately 40 per cent. Owing to the fact that the yields of these materials per acre is small, that they are widely distributed over large areas, and that the former is never brought together in harvesting the cotton crop, the cost of gathering and transporting them to the mills would probably be greater than for many other materials, such as the cereal straws, forest wastes, or flax straw, though at the same price per ton the raw material for a ton of paper costs approximately the same for all of these wastes. It is probable, therefore, that they will not find extended use until more economical materials have been exhausted,

unless, indeed, it can be shown that in limited areas they can be employed for local markets more economically than paper made from other materials and transported to those markets.

Beet pulp from which the sugar has been extracted has been suggested as a paper-making material, but as this substance possesses practically no fiber, much less even than sugar cane or cornstalks, it is not suitable for this purpose.

CONSERVATION OF PAPER-MAKING MATERIALS.

It is evident that more attention must be given in the future to maintaining sufficient supplies of materials to meet the legitimate demands of the paper-making industry. This is an agricultural and economic problem which may be met in several different ways, the essential consideration being that it shall be solved to the greatest advantage of the country at large. It is customary to suggest that other materials than those now generally employed must be used, and particularly that some new material or process must be discovered or that a crop must be especially grown for the purpose. There are, however, a number of ways in which the materials now best known may be made to satisfy still greater demands, some of the more important of which may properly be discussed here.

USE OF LARGER QUANTITIES OF SCUTCHING WASTES.

In preparing textile fibers for use there is much waste in separating the fiber from the body of the plant tissue, and further waste in getting the fiber in proper condition for market. The fiber thus lost may be termed "scutching waste," and while no definite figures can be given as to the quantity of such waste, as most of it occurs in barbarous or semicivilized countries, it has been variously estimated at from 25 to 50 per cent. Assuming the lower figures, the waste from the jute, manila, and sisal imported to this country would equal approximately 150,000 tons annually, and would make 120,000 tons of high-grade paper.

The scutching waste from the hemp industry, though perfectly suitable for paper, is too small in quantity to play any material part in paper making, and the growing of it primarily for this purpose is impractical, owing to the fact that hemp even at the rate of 2 cents per pound makes the paper cost as much as that made from medium-grade rags.

LARGER USE OF WASTE TEXTILES AND WASTE PAPER.

QUANTITY AND VALUE OF AVAILABLE WASTES.

Approximately 2,030,000 tons of cotton, flax, hemp, jute, manila, sisal, and other vegetable textile fibers are made into fabrics annually

in this country, and all of this sooner or later in the form of cuttings, waste from the manufacturing processes, and rags, finally finds its way into other industrial uses or is destroyed. Statistics show that approximately 400,000 tons of this kind of material, 200,000 of which are imported, ultimately reach the paper mill, leaving about 1,800,000 tons of fabrics, practically all of which is destroyed. This is sufficient to make 1,440,000 tons of the very best paper. Of course it is not possible to recover all of this material. There is some loss in the manufacturing processes through which it passes and a great loss due to wear, but it is a conservative estimate to say that 1,000,000 tons of paper stock could be secured annually from this source alone, and at 1 cent per pound (rags sell at from 1 to 6 cents per pound) would be worth $20,000,000.

This 1,000,000 tons of waste textiles would make 800,000 tons of the strongest, most durable, and best paper, or more than enough to supply all the book, cover, plate, writing, high-grade wrapping, and blotting paper and bristol board now made in this country. There is a sufficient quantity of waste textiles to supply all demands for fine paper for years to come, and probably such papers will continue to be made from these materials, as no others which can compete with rags in cost are now known.

More than 3,000,000 tons of paper are now made annually in this country, of which fully 80 per cent, or 2,400,000 tons, becomes waste material in three or four years. Of this, about 25 per cent, or 588,000 tons, is again used in the form of new paper cuttings and trimmings and old paper for making new. Here also we estimate that fully 1,000,000 tons of raw material which would make 900,000 tons of paper could be readily saved from waste at a cost for collecting that would permit its use, as most of it is to be found in the cities and towns in the form of old books, writing paper, news paper, wrapping paper, and pasteboard. Most of this waste is not suitable for high-grade papers, but could readily be used for wrapping, cover, and blotting papers, and boards. The wholesale price of such paper ranges from $2 per hundred pounds for new high-grade cuttings to $1 for new white paper, and from 65 cents for folded newspaper to 20 cents per hundred for common scrap paper of any kind. Valuing the waste paper at 0.5 cent per pound, the 1,000,000 tons of paper now wasted that could be saved is worth $10,000,000 per annum, and would make all of the building, bagging, cover, blotting, and miscellaneous papers, and all the paper board now produced. Though the cost of raw material per ton of paper is slightly greater at the above valuation than when produced from wood, the cost of manufacture from waste paper is much less, so that the product made from waste paper is fully as cheap as that from wood.

A more general appreciation, particularly among the country people, of the market value of rags, old rope, and waste paper of all kinds would increase largely the supply of paper stock and add considerably to the income of the people. The value for paper making of the waste textiles of the country is greater than the value of the rye crop, one-twentieth that of the wheat crop, one-third of the total value of the products of the saddlery and harness industry, half as great as that of the hardware, and as great as that of the fur goods industry. Rags to the value of $9,000,000 annually are now used for paper making and about three times this quantity could probably be secured, which, at the same valuation, would distribute approximately $27,000,000 among the people; $7,000,000 worth of waste paper is used each year in paper making, but it is estimated that three times this amount can be saved, distributing $20,000,000 per year among the people. It is evident, therefore, that the value of the waste textiles and paper annually destroyed is large and that if these can be gathered profitably, their use will serve the double purpose of producing good paper and of conserving other materials.

The various grades of rags with their current prices are shown in the following table:

Market grades for rags, with current prices.

	Cents per pound.
New shirt cuttings, No. 1	5½–6
New shirt cuttings, No. 2	4 –4¼
Fancy shirt cuttings	3⅞–4
New blue cotton	3 –3½
New mixed cottons	1¼–1½
Old linen:	
White	4½–5½
Gray	2¼–4
Colored	1¾–2¾
New black cotton:	
Soft	1½–1¾
Mixed	1¼–1½
No. 1 white, old, clean	2¾–3
Soiled white:	
Street	1¼–1⅓
House	1½–1⅔
No. 2 New Yorks	1⅛–1¼
Street seconds	⅘– ⅚
Thirds and blues	1⅕–1¼
No. 1 satinette	1 –1¼
Mixed satinette	½– ⅔
Tailors' seconds	⅕– ¼
Hard black carpets	½– ⅗

GRADES OF RAGS.

Inspection of the preceding table shows that all rags do not sell for the same price. White rags will bring from 2 to 5 cents per pound more than colored ones, clean rags will sell from ½ to 2 cents per pound more than those that are soiled, and new rags are worth from 1 to 3 cents per pound more than old ones. The paper maker does not cook a mixture of old and new, clean and soiled, white and colored rags together, but wants them properly sorted not only according to color, cleanliness, and amount of wear, but also according to the materials from which the fabrics were made, as cotton, linen, hemp, etc. Unsorted rags, even though they consist largely of the best grades, sell at low prices, and therefore the seller, in order to secure the highest price, should carefully sort them. The higher price of clean rags may even justify washing those that are soiled.

GRADES OF WASTE PAPER.

Different kinds of waste paper also sell at different prices, and as mixed paper sells at a comparatively low price, it is profitable to grade it. The following table shows the market grades for waste paper in this country, with current prices of each:

Market grades for waste paper, with current prices.

	Price per 100 pounds.
No. 1 hard white	$2. 10–$2. 15
No. 2 hard white	1. 80– 1. 90
No. 1 soft white	1. 45– 1. 50
No. 1 colored	. 65– . 70
No. 2 colored	. 45– . 55
Flat stock	. 75– . 80
Crumpled sheet stock	. 70– . 75
Book stock	. 55– . 65
Solid ledger stock	1. 40– 1. 50
Ledger stock	1. 20– 1. 25
No. 1 white news	1. 05– 1. 10
White paper	. 90– 1. 00
Extra new manila cuttings	1. 25– 1. 30
New manila cuttings	1. 05– 1. 15
No. 1 old manila	. 65– . 70
No. 2 old manila	. 40– . 45
New box board chips	. 35– . 40
New straw chips	. 40– . 45
Bogus paper	. 50– . 60
Mill wrappers	. 50– . 60
Strictly new overissue news	. 55– . 65
Strictly folded news	. 40– . 45
Broken news	. 25– . 30
No. 1 mixed news	. 25– . 30
Straight straw and other boxes	. 35– . 40
Mixed straw and other boxes	. 30– . 35
No. 1 mixed papers	. 20– . 35
Common papers	. 15– . 20

As with rags, new, clean, white materials command higher prices than old, soiled, printed, or colored materials. The kind of fiber of which the paper was made also affects the price, as is shown by the quotation of ledger cuttings as compared with No. 1 book stock, the former as a rule being made of rags, while the latter is largely chemical wood. Therefore in order to secure the highest market price, waste paper should be graded as shown by the table.

IMPROVEMENTS IN THE QUALITY OF PAPER.

One of the most striking points brought out in the work of this laboratory in the examination of paper is that the quality of any class is seldom as good as the materials and the technical skill of the maker can produce. The several processes of paper making frequently are not conducted in such a way as to produce the strongest, most durable, and best appearing papers of a given kind. This is particularly true of papers which should have strength or durability, many of which are overloaded with clay, which weakens them, or are not properly beaten and run to give them good formation and the maximum strength of the material. This is found especially in wrapping papers and boards whose value for practical purposes depends on their strength and pliability. Thus 24 by 36 inch paper, weighing 65 pounds per ream of 500 sheets and made from chemical wood fiber, should easily have a strength of 45 pounds (Mullen), and, indeed, by proper manipulation of the processes such a paper can be made with a strength of 50 pounds. As a matter of fact, however, most 100-pound papers have a strength of only 45 pounds or less per square inch, a result due to the use of ground wood or to insufficient preparation of the stock. Again, in the case of ordinary print paper, well made from chemical wood, a 24 by 36 inch paper, weighing 39 pounds per ream, and having a strength varying from 15 to 20 pounds, is more resistant to folding, as opaque, as strong, and as desirable in every way as many 60-pound papers. Often other desirable qualities are sacrificed to secure temporary appearance and "feel," while the strength is obtained by increasing weight, instead of by a better preparation of stock, as should be the case.

REDUCTION OF WEIGHT AND BULK OF PAPERS.

All classes of paper now made are almost invariably needlessly heavy and thick. The purpose for which paper is employed, whether it be for printing, writing, or wrapping, can be as well accomplished in nearly all cases, both from the utilitarian and the æsthetic point of view, by lighter and thinner paper, as suggested in the preceding section, if greater care in manufacturing is taken. The strength and quality are improved at the same time, and the consumption of paper reduced thereby from 15 to 50 per cent, to the advantage and

profit of the consumer. Thus the employment of 60 and 80 pound book papers, or even of 50-pound paper, is a totally unjustified waste in most cases, as every purpose can be accomplished by 30 and 40 pound papers. Much lighter and thinner writing and wrapping papers can be employed in the vast majority of cases with quite as satisfactory results as are obtained from papers that weigh 80, 100, and 120 pounds per ream.

The production of lighter and thinner paper is important not only to the nation, but to the individual as well, since not only are materials thus conserved but better, and frequently cheaper, papers are secured. For example, ordinary printing paper weighs from 45 to 80 pounds per ream (24 by 36 inches), but 35 to 50 pound papers are made from the same materials, which are superior in every particular, a saving of from 22 to 40 per cent in weight. Wrapping papers are of all weights, but many 25 or 50 pound papers are stronger than 50 or 100 pound papers, so that often a saving in weight of as much as 50 per cent can be made. It is true that lighter, thinner, and better papers cost more per pound, but a pound contains more sheets. Paper is sold on the basis of weight, but is used on the basis of area, and a ream of each serves the same purpose. For example, the 35-pound paper mentioned above sells at 4.23 cents per pound, while the 45-pound paper sells at 3.7 cents. Therefore a ream of the former costs $1.65; of the latter $1.77. Again, bogus manila paper made largely of ground wood (low grade) is quoted at 1.75 cents per pound; No. 1 manila (high grade) is quoted at 5.5 cents per pound, and No. 1 sulphite manila (medium) at 4.75 cents per pound. A 100-pound bogus manila has the same strength as a well-made 35-pound No. 1 manila or a 65-pound No. 1 sulphite manila. A ream of each costs, then, $1.75, $1.92, and $2.92, respectively.

The paper of highest quality and price costs but little more per ream than that of the lowest quality and price and much less than the medium grade. Further, the cost of transporting, handling, and storing heavy bulky paper is greater than for the lighter ones. It is therefore believed that not only will raw materials be conserved, but the cost of the total quantity of paper used per year will be less when it is made lighter and of better quality. On the whole it is a conservative statement that the quantity of paper now used in this country can readily be reduced 25 per cent by making from the materials now employed better paper and by using no heavier paper than is required by the service to be performed.

THE NECESSITY FOR GROWING PAPER-MAKING MATERIALS.

It has frequently been suggested that materials be produced for paper making just as any other farm crop is grown, and it is worth while to inquire into the necessity for doing this. Summarizing the

foregoing conservative estimates, there are annually produced in the United States agricultural and industrial wastes furnishing raw materials in much greater quantity than can be consumed in paper making for many years to come.

Estimate of wastes suitable for paper making produced annually.

Material.	Waste.		Yield of paper.
	Quantity.	Value.	
	Tons.	*Dollars.*	*Tons.*
Waste textiles suitable for papers of the highest quality and strength	1,000,000	20,000,000	800,000
Flax fiber suitable for the best and strongest paper	600,000	18,000,000	480,000
Forest waste from lumber industry suitable for medium and low grade paper	[a] 12,000,000	60,000,000	5,000,000
Waste paper suitable for high quality and lowest quality	1,000,000	10,000,000	900,000
Cereal straws suitable for medium quality paper and boards	70,000,000	350,000,000	28,000,000

[a] Cords.

No consideration is given here to the large quantities of marsh and other wild grasses, of bagasse, and corn and cotton stalks, which are also available, but not as desirable technically as those mentioned, nor to the bast fiber of Malbón and other bast fibers which occur in large quantities. While it is true that not all of the above-mentioned materials could be acquired for paper making, owing, for example, to their greater value to those who produce them for other purposes, it is evident that there is no danger of the immediate exhaustion of such raw materials even on the present basis of production of paper.

The industrial conditions that have made wood the chief raw material will undoubtedly continue to encourage its extensive use for many years, so that the price of wood will largely fix the price of any competing material. Manifestly no comparisons in dollars and cents can be made, and it will probably be sufficient to say for the guidance of those interested in growing paper-making plants that the problem primarily resolves itself into a financial one. On the one hand, one must produce a material which can successfully compete in quality and cost with other available paper-making materials. On the other hand, the crop produced must be as profitable as other farm crops. If paper can not be made from the new crop as cheaply as from other materials, the mills will not buy it; and if it will not yield as large profits as other farm crops, the farmer will not raise it. It is believed that no plant so far suggested will fulfil these conditions at the present time, except as previously suggested for local consumption where transportation greatly increases the cost of paper made from the commonly used materials.

A LIST OF MATERIALS THAT HAVE BEEN EXPERIMENTED WITH IN MAKING PAPER.

For more than a hundred years paper makers have sought new materials, and have experimented with all kinds of wild and cultivated plants. The following list embraces those from which acceptable paper of some kind can be made and which at the same time occur or can be produced in large enough quantities to make them suitable for paper making, provided the cost of manufacture is as low as the cost of making paper from the materials now used. In other words, theoretically and scientifically considered, they are paper-making materials, but practically and economically they have not been so utilized, and it remains to be proved that this can be done.

Agave.
Aloes.
Bent grass (*Agrostis spica-venti*).
Black reed (*Claudium radula*).
Blue flag (*Enodium cæruleum*).
Bracken (fern).
Brazilian grass.
Broom.
Bulrush (*Typha angustifolia*).
Cactus.
Canes.
Cat-tails (*Typha latifolia*).
Clover.
Club rush (*Scirpus fluviatilis*).
Coast sword grass (*Lepidosperma elatius*).
Cockle burrs (*Althea frutex*).
Cocoanut husks.
Cord grass (*Spartina cynosuroides*).
Corn stalks and husks.
Cotton-seed waste.
Cotton stalks.
Cotton waste.
Couch grass (*Triticum repens*).
Dog grass (same as couch grass).
Elder.
Ferns.
Flags.
Grapevines.
Hay.
Heather.
Hop vines.
Indian mallow (*Abutilon indicum*).
Jaggery palm (*Caryota urens*).
Maguey (*Agave*).
Mallow fiber.
Malva fiber.
Manure.
Marsh grass (*Glyceria aquatica*).
Okra (*Abelmoschus esculentus*).
Palmetto.
Pampas grass (*Gynerium argenteum*).
Pea stalks.
Peat.
Pineapple (*Biomelia*).
Plantain (*Musa*).
Plume grass (*Arunda conspicua*).
Reeds.
Rice straw.
River rush (*Isolepis nodosa*).
Rush (*Juncus*).
Rye grass (*Hordem murinum*).
Salt hay (*Spartina juncea*).
Seaweed.
Sedge grass (*Carex appressa*).
Sorghum.
Sugar cane.
Sunflower.
Sword grass (*Gahnia psittacorum, Lepidosperma elatius*).
Tobacco stalk.
Tussock grass (*Xerotes longifolia*).
Water oats (*Zizania aquatica*).
Wire grass (*Poa australis, Ehrharta tenacissima*).

Davis, in his "Manufacture of Paper," published in 1886, gives the following yields of fiber from various herbaceous plants:

	Per cent.
Asparagus stalks (*Asparagus officinalis*)	32.56
Banana (*Musa ensete*)	31.81
Barley (*Hordeum vulgare*)	36.21
Bent grass (*Agrostis spica-venti*)	45.82
Blue flag (*Enodium cæruleum*)	40.07
Buckwheat (*Fagopyrum esculentum*)	30.60
Camelina (*Camelina sativa*)	29.16
Canary grass (*Phalaris canariensis*)	44.16
Canna (*Canna*)	20.29
Dog grass (*Triticum repens*)	28.38
Ftomenteau (*Baldengera arundinacia*)	46.17
Giant nettle (*Urtica divaricata*)	21.66
Hop (*Humulus lupulus*)	34.84
Maize (*Zea mays*)	40.24
Marsh grass (*Glyceria aquatica*)	38.80
Marsh rush (*Scripus palustris*)	41.70
Mateva (*Hyphoene thebaica*)	26.08
New Zealand flax (*Phormium tenax*)	32.71
Oats (*Avena sativa*)	35.08
Reed (*Phragmites vulgaris*)	41.57
Rye (*Secale cereale*)	44.12
Sedge (*Carex*)	33.86
Sugar cane (*Saccharum officinarum*)	29.15
Wheat (*Triticum sativum*)	43.14
Wild broom (*Spartium scoparium*)	32.43

Davis also gives the yield of fiber from different species of wood, as shown by the following table:

	Per cent.
Acacia (*Robinia pseud-acacia*)	34.10
Alder (*Alnus glutinosa*)	34.30
Ash (*Fraxinus excelsior*)	32.28
Aspen tree (*Populus tremula*)	35.00
Bamboo (*Bambusa thonarsu*)	34.90
Beech (*Fagus sylvatica*)	30.90
Birch (*Betula alba*)	33.80
Black alder (*Rhamnus frangula*)	37.82
Canadian poplar (*Populus canadensis*)	36.88
Elm (*Ulmus campestris*)	31.81
Filbert tree (*Corylus avellana*)	31.50
Fir (*Pinus sylvestris*)	35.17
Heath (*Erica vulgaris*)	27.14
Horse-chestnut (*Æsculus hippocastanum*)	38.26
Italian poplar (*Populus italica*)	36.12
Lime tree (*Tilia europæa*)	38.16
Oak (*Quercus robur*)	29.16
Osier (*Salix alba*)	29.50
Pitch pine (*Pinus australis*)	31.08
Rattan (*Calamus verus*)	29.19
Red pine (*Pinus sylvestris rubra*)	32.28
Walnut (*Juglans regia*)	26.52

	Per cent.
White pine (*Abies pectinata*)	34.60
White poplar (*Populus alba*)	35.81
Willow (*Salix alba*)	37.82

There is no reason to suppose that all of these woods can not be used in paper making, though the character of the paper and the cost of production will undoubtedly vary with the different species. It is probable that in a well operated mill the yield of fiber will be from 5 to 10 per cent greater than the figures given in the table.

Many other substances have been experimented with, indeed it may be said that but few possible paper-making materials have escaped attention altogether. With the exception of the woods, however, they have remained undeveloped, primarily because paper can be made at a greater profit from other substances. Further developments in the processes of paper making do not promise to affect materially the utility of such materials because the new process would also be applicable to those now more profitably employed.

CONCLUSION.

All fibrous vegetable material from whatever source derived can be used for making paper. The utility of a particular material for this purpose is governed chiefly by the cost and value of the finished paper as compared with the product made from other materials.

Without altering quality, the weights of most papers can be reduced from 10 to 20 per cent, and by decreasing weight and improving quality the amount of paper now consumed can be reduced from 10 to 50 per cent, varying with the kind of paper. It is estimated that the quantity of paper now used in this country can be reduced about 25 per cent by improving its quality and reducing its weight. In other words, 2,250,000 tons of paper will do equally well the service now performed by 3,000,000 tons.

The growing demand for paper-making materials may be supplied by the more conservative use of those which long years of practical paper making have demonstrated are well suited to the purpose. When thus used there are ample quantities to meet normal requirements for many years.

Larger quantities of waste textiles and paper should be employed for paper making. It is estimated that 2,000,000 tons of such wastes, worth approximately $30,000,000, can be secured annually in this country. This material would produce 1,700,000 tons of paper. If this were used, the quantity of wood annually used for paper making could be reduced to about 2,000,000 cords per year.

The cheapest known raw material for medium-grade paper which can be obtained in large quantities is wood. It is highly important to practice conservative methods in its use. Therefore, the great quan-

tity of waste from the lumber industry should be utilized for paper making wherever possible. It is probable that such "new" materials are the cheapest which are available.

There are large quantities of cultivated and wild straws and grasses and of flax fiber available which can be used for paper making. Economic agricultural considerations indicate that the cultivated straws should only be thus employed when the woods and textile and paper wastes can no longer supply the demand or are too costly. Flax fiber, when it can not be put to more important uses, should be employed in paper making.

Finally, when all of these supplies are no longer adequate and when economic conditions are such as to justify such innovations, there are suitable quick-growing materials which may be produced primarily for paper making.

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