TREASURY DEPARTMENT
UNITED STATES PUBLIC HEALTH SERVICE

PUBLIC HEALTH BULLETIN No. 100
NOVEMBER, 1919

STUDIES ON THE TREATMENT AND DISPOSAL OF INDUSTRIAL WASTES

MADE UNDER THE SUPERVISION OF

EARLE B. PHELPS

(Nos. 1 and 2 Published as Public Health Bulletin 97
October, 1918)

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HARRY B. HOMMON

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GOVERNMENT PRINTING OFFICE
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THE PURIFICATION OF TANNERY WASTES.

HARRY B. HOMMON.

INTRODUCTION.

The rapid growth of large cities and industrial establishments upon the watersheds of the interstate rivers during recent years has increased the volume of sewage and industrial waste that these rivers receive to such an extent that Congress, in August, 1912, directed the United States Public Health Service to study "the pollution, direct or indirect, of the navigable rivers of the United States."

The Ohio and Potomac watersheds were selected for extensive study, the Ohio on account of the number and size of the industrial cities located on its watershed, and the Potomac on account of the large oyster industry located at its mouth. The cities and towns located in the Ohio Valley contribute large volumes of domestic sewage and industrial wastes to the river, and, in order to preserve it as a source of water supply for the riparian cities, it is quite evident the time will come, if it is not already here, when protective measures will have to be considered by the cities and industries to maintain the water in a reasonable degree of purity. While there are not so many large cities located in the basin of the Potomac River, nevertheless the possibility of the contamination of oysters by the sewage of Washington has given the oyster growers in the lower part of the river much concern. Thus it will be noted that the authorities interested in the purity of the water in the two rivers viewed the situation from different angles, those along the Ohio from the standpoint of drinking water, and those interested in the Potomac from the standpoint of the shellfish industry.

A brief summary of the history of stream pollution and the laws controlling it in England is of interest as showing the difficulties of enacting legislation after the rivers have become extensively polluted. This was very well stated by John D. Watson, M. Inst. C. E., chief engineer to the Tame and Rea District Drainage Board, Birmingham, England, in a paper presented at the engineering conference in connection with the Congress of the Royal Sanitary Institute on September 6, 1910. The following notes, taken from Mr. Watson's paper, describe the condition of the rivers when the first survey was made and offer suggestions for legislation to restore and maintain the rivers in a reasonable degree of purity.

The first attempt, as stated by Mr. Watson, to inquire into the pollution of the rivers, was the appointment of the royal commission in 1867, and it came as the result of frequent and loud complaints from the general public. This inquiry, which seems to have been of the most thorough and unbiased character, referred to the rivers of the great industrial counties as "rivers running with liquid which had more the appearance of ink than water, owing to trades waste being discharged into them." Reviewing the situation 40 years later, it is stated that "as a nation we can congratulate ourselves on the progress made." Some of our great towns have still much to do in perfecting their sewage disposal works, while some are only beginning to tackle the subject in earnest, but "a lion is in the way." The chief obstacle to the country reaping a full reward for the money which has been spent on sewage purification works is the discharge of unpurified trade waste into the streams.

Referring to the town of Bradford, where Mr. Watson was called in as arbiter regarding the discharge of trade waste into city sewers, he states, "I incline to the view that the maintenance of the purity of the rivers is quite as much national as local in its significance, and we should do all we can to strengthen the hands of the royal commission in pressing upon the Government the importance of this question." Finally, in discussing the excellent results obtained by the corporation of Edinburgh in 1889 in restoring the water of the Leith "to a condition not less pure than many a meadow stream," Mr. Watson sums up the situation as obtained in England in 1910, as follows: "Local authorities are fully alive to the need for purifying domestic sewage and much has been done in this direction. They are desirous also that trades waste should be tackled, but they are bewildered by the nebulous state of the law, and it now remains for them, assisted by all sanitarians, to induce the Government to alter and simplify the law so as to bring about harmonious and consistent action on lines approved by an independent board like the proposed central authority, and I think this can best be done by giving the recommendations of the royal commission on sewage disposal our united and hearty support."

It is obvious, from reading the extracts from Dr. Watson's paper, that the sanitary condition of the rivers of England was not inquired into until the rivers were very seriously polluted and corrective measures were difficult to apply, and it is also evident that the tendency is to urge national control over the whole question of maintaining the rivers in a reasonable degree of purity. In our country the Government may well profit by the experience abroad, and may, at least, assist in protecting the interstate rivers against extensive pollution, by determining the extent of purification of sewage and wastes required, and the type of plant best suited for meeting the requirement specified.

During the surveys made, following the passage of the law of 1912, it was found that the discharge of industrial waste was creating a condition in many of the smaller rivers, and to some extent in the interstate rivers themselves, similar to that referred to by Mr. Watson in his description of the sanitary condition of some of the rivers of England at the time of the first survey. Local sentiment, the fish and game clubs, and the State boards of health were exerting pressure on the State legislatures to pass laws prohibiting the discharge of all industrial wastes into the rivers and streams. The manufacturers, on the other hand, recognized the seriousness of the situation but claimed that the cost of purifying their wastes would force them to abandon their business, and some of the schemes proposed for treating the wastes would have required the expenditure of large sums of money.

A situation had developed along many of the tributaries where neither side to the controversy understood the full significance of the problem of purifying the industrial wastes. As the solution of this problem had a direct bearing on the quality of the water discharged into the interstate rivers and all interested parties desired an impartial investigation, it seemed advisable, therefore, to include the study of methods for purifying industrial wastes as a part of the purpose and intention of the law directing the United States Public Health Service to study "the pollution, direct or indirect, of the navigable rivers of the United States."

The plan adopted was to build and operate testing stations at representative mills of those industries producing liquid wastes for which there was no known method of purification or where the methods proposed were too expensive for general application. The units of the testing stations were of sufficient size and were operated for a long enough period of time to develop the basic data for designing plants to purify all the waste from industries producing wastes similar to those treated in the tests.

The first testing station was constructed at the Deford Tannery, Luray, Va., in the summer of 1914, and closed on August 9, 1916. Another was constructed at the American Strawboard Plant, Noblesville, Ind., in the fall of 1914, and closed July 1, 1916. A testing station was built at the Haffner Bros. Tannery, Cincinnati, Ohio, in the spring of 1916, and closed December 1, 1917. At Grove City, Pa., a station was operated to purify creamery waste, and another at Amelia, Ohio, to treat tomato canning waste. The data obtained from operating the testing stations at the two tanneries are included in this report.

Assistant Sanitary Engineer C. P. Rhynus assisted in the design of the testing station operated at Luray, Va., and had charge of the construction. Sanitary Chemist H. C. Colson, jr., was in charge of the laboratory and the operation of the station from September, 1914, to March, 1916. Following the resignation of Mr. Colson, Attendant Charles C. Bolen was in charge and samples were sent to the laboratory in Cincinnati for analysis.

Sanitary Engineer Harry R. Crohurst assisted in the design of the testing station operated at the Haffner Bros.' tannery in Cincinnati. Sanitary Bacteriologist Walter V. D. Tiedeman constructed the station and had charge of the operation throughout the tests.

Sanitary Bacteriologists Emery J. Theriault and Hugh M. Campbell were responsible for the chemical analyses of the samples received from the testing stations at Luray, Va., and Cincinnati, and Sanitary Bacteriologists E. E. Smith, 2d, and E. M. Meyer made the bacteriological examinations.

Sanitary Engineer H. H. Wagenhals assisted in the preparation of the data contained in the report.

The officials of the Deford Leather Co. and the Haffner Bros.' tannery took an active interest in the tests conducted at their respective tanneries, and through their hearty cooperation contributed much toward the successful operation of the testing stations. Mr. Thomas Deford, vice president of the Deford Leather Co., was especially interested in the tests, and his personal influence greatly assisted the work.

Part I.

EXPERIMENTS AT THE DEFORD TANNERY, LURAY, VA.

RÉSUMÉ OF RESULTS.

The testing station at Luray, Va., was put in operation in September, 1914, and discontinued August 9, 1916. During this time a method of purifying tannery wastes, such as are produced by the organic tanning process, was developed that gave satisfactory results and the cost of construction and operation of a plant to treat all the wastes was considered reasonable by tanners interested in the purification of their wastes.

The Deford Co. make belting leather from the sides of cowhides and sole leather from the heads and bellies. Tan liquor leached from oak bark at the plant is used in tanning the sides, and chestnut extract for tanning the head and bellies. There is no bating and the liming process is the ordinary procedure of practically all tanneries. The removal of the hair is done entirely by machinery and the fleshing is practically all done by machines.

In preparing the hides for tanning there are two different kinds of wastes produced, one from the liming of the hides and the removal of the fleshings, and the other from washing the hair after removal from the hides. In the tanning process proper there are wastes produced in the various stages but the characteristics of all are the same, each one having as its principal constituent tan liquors that have been exhausted, or washed from the leather after leaving the tanning vats.

The volume of wastes from the three different sources varied according to the number of hides tanned, but the average daily discharge of total waste during the tests was approximately 106,000 gallons. This was divided as follows: Beam house wastes (liming and fleshing), 65,500 gallons; hair washing, 23,500 gallons; spent tan liquors and wash water from the sides after tanning, 14,000 gallons; and wash water from rinsing the heads and bellies, 2,900 gallons. The average number of hides tanned per day during the tests was 275. The total amount of wastes discharged, per hide tanned, was 385 gallons, composed of spent tan liquors and water from rinsing the leather after tanning, 61 gallons; wastes discharged from the beam house and liming vats, 238 gallons; and wastes from washing the hair, 86 gallons.

As the tests progressed it developed that it was not feasible to treat each waste separately, on account of the acidity and excessive oxygen demand of the spent tan liquors, and it further became evident that the ordinary methods of purifying sewage would not be applicable in treating tannery wastes. During the last six months of the tests, referred to later on in the text as Period Five, which extended from February, 1916, to August, 1916, a method of treatment was carried out that gave satisfactory results. It consisted of treating the spent tan liquors and the wash water containing tan liquor, with lime sludge from the unhairing vats, and mixing the supernatant from this treatment with the wastes from the beam house, liming vats and hair washing machines. This gave a proportion of 1 part of the treated tan liquors to 3.4 parts of hair washing wastes and 4.8 parts of beam house wastes or 1 part of the treated spent liquors to 8.2 parts of the other wastes. This mixture was treated with ferrous sulphate at the rate of 10 grains per gallon and allowed to settle in a tank a minimum period of 4 hours and then applied to beds of cinders and coke varying in depth from 5 to 7 feet. The wastes were applied to the beds by means of a system of troughs. The rates on these filters varied during the latter part of the tests from 190,000 to 300,000 gallons per acre per day. The effluent from the cinder filters was treated on sand filters, varying in depth from 2 to 5 feet, at rates during the latter part of the tests ranging from 289,000 to 426,000 gallons per acre per day.

The effluents from all the sand filters, regardless of the depths and rates, contained nitrites and nitrates throughout the final period of operation. The oxygen consumed figures were comparatively low, the total suspended matter was on the average not more than 32 p. p. m.,[1] the total organic nitrogen during the last three months of the test was not higher than 7.2 p. p. m. in the monthly averages and the stability such that samples diluted with two parts of creek water had a relative stability number of 96+. Fish (sunfish and minnows) lived in the undiluted effluent of the sand filters more than a month without any apparent discomfort.

In considering the results given above and those in the tables in the body of this report it must be borne in mind that the spent tan liquors contain organic compounds that are very difficult to break down in the filters and that the discharge of the effluents of the filters into streams of water will not be attended by the same rapid decomposition that results when sewage with a like amount of organic matter is similarly discharged. This is demonstrated very clearly in Table 28 where the average total organic nitrogen for the month of April in sand filter 5–S was 57 p. p. m. and the number

[1] The abbreviation p. p. m is employed throughout the text for "parts per million" or more accurately, "milligrams per liter."

of hours required to reduce the methylene blue samples was 240. The organic nitrogen ordinarily ran from 2.5 to 8 p. p. m., but the example given above shows that the interpretation of chemical results obtained from purifying some industrial wastes must be considered from the standpoint of the effect the purified waste will have on the receiving body of water rather than the amount of organic matter present in the effluent.

The color of the sand filter effluents was that of very weak tea, and there was no change in color when a solution of an iron salt was added to them.

All of the wastes containing tanning solutions from the Deford Tannery could not be taken care of in a large plant at the ratio of 1 part of these wastes to the 8.2 parts of all the other wastes. Approximately 10,000 gallons could be treated at the above ratio, and tanneries producing spent liquors in excess of the ratio of 1 to 8.2 will find it necessary either to cut down the waste liquors by using a part back in the "leaches" or else pump enough water to bring the dilution up to 1 to 8.2. In using river water to dilute the spent liquors the dilution required would undoubtedly be less than 1 to 8 but this could only be determined by actual test. Some tanners are returning the wash water from rinsing off the strong liquors adhering to the hides when removed from the lay away yards, back to the "leaches," and if this were done at Luray the total amount of spent tan liquors discharged per day would be less than 10,000 gallons.

The results obtained from the operation of the testing station during the final period of operation were satisfactory and there seemed no doubt that a plant could be designed to treat all the wastes from a tannery at a reasonable cost. There were, however, certain features that could not be definitely decided by the small test units. These applied particularly to the proper depth of the sand and to a certain extent the cinders. (Coke on account of its cost, and the absence of any striking superiority in the results obtained by its use, is not considered a suitable filter medium for the preliminary filters.)

It was, therefore, recommended that the tanners of Virginia interested in the purification of their wastes construct and operate a permanent unit to determine the least depth of sand that would give a saisfactory effluent over a long period of time; to decide the maximum rate at which wastes could be applied to the filters on a large area; and to learn the amount of technical supervision required to obtain the most efficient results.

The tanners readily saw the advantage that would result from the operation of a larger unit than was used in the tests, and the Deford Co., at Luray, the Leas and McVitty Co., of Salem, and

G. R. Cover & Sons, of Elkton, Va., requested the Government to prepare plans for a permanent unit of such size as would demonstrate the practicability of the process developed in the tests. Each company contributed one-third the estimated cost of the plant, and it was located at the Deford Co.'s plant, Luray, Va., on the site formerly used for the testing units. A complete description is given of this plant under the cost data in the conclusions of this report. The data obtained from the operation of the larger unit will be published at a later date.

The permanent unit was completed the latter part of June, 1917, and the results obtained during the summer following have shown the wisdom of building the larger unit. The plant on the whole has given results that check very closely those obtained in the tests, and it now seems assured that a sand filter 3 feet deep will yield as satisfactory an effluent as a bed 5 feet deep. The results have also indicated that a roughing filter 4 feet deep will yield an effluent that can be purified on sand filters 3 feet in depth. The roughing filter and sand filter were each operated 24 hours a day at net rates of 200,000 gallons per acre per day, enough wastes being stored during the day time to supply the filters during the time the tannery was closed down at night.

The cost data given at the end of this report for the filters are based on net rates of 200,000 gallons per acre per day. It did not seem advisable to begin the operation of the shallow filters at a higher rate than 200,000 gallons, and pending further studies on the question of rates the figure given above will be considered as the basis for designing a complete treatment plant.

No further studies were made relating to the drying and disposal of sludge as it is considered that existing data on sewage sludge is sufficiently applicable to this case.

THE PROCESS OF TANNING HIDES, AND WASTES PRODUCED AT THE DEFORD LEATHER CO., LURAY, VA.

The processes of tanning hides are complex and vary in different tanneries, and the wastes produced are largely influenced by the particular method used. A description of the process of tanning employed at the Deford Leather Co. and of the nature of the wastes produced is, therefore, important in order that those interested in the purification of tannery wastes at other plants will be in a position to use the results contained in this report to the greatest advantage.

TANNING THE HIDES.

This company tans cowhides only, producing belting butts, with some sole leather from the heads and bellies. The normal rated capacity is 304 hides per day, but the output during the tests fell short of this figure, averaging 275.

The rawhides are received, heavily salted to prevent decomposition, and are first thoroughly soaked and washed with fresh water to remove the salt and dirt. After soaking they are roughly fleshed to remove the larger pieces of fat and flesh adhering to them and passed on to the liming tanks. These are a series of tanks containing limewater in solution of gradually increasing strengths, through which the hides pass from the weakest to the strongest, the object being to loosen the hair sheaths. In this condition the hair is very readily and quickly removed by an unhairing machine. Small streams of water play on the roller of this machine, serving the double purpose of carrying away the hair and of washing off the lime.

The hides are then refleshed by hand or by a fleshing machine to remove any pieces that may have remained from the first fleshing before liming. The dehaired hides are then thoroughly washed in running water to remove lime, and taken from the beam house to the tanyards. Here they are first placed on the rockers. These consist of a series of racks arranged on a central shaft over a vat containing a tanning solution. As the shaft rotates back and forth through a small arc the arms of the racks are raised and lowered so that the hides suspended from them are raised and lowered in the tan liquor. The liquor in which the hides are first treated is the weakest solution of tan extract used in the tannery. As the tanning progresses this solution is withdrawn and the liquor from the next stronger vat drawn in. In this way the hides are treated with solutions of gradually increasing strength till they are ready for the next step in the tanning process, which is carried on in the handlers.

In the handler pits the hides are hung in the liquor and are continuously submerged. The first handler pit contains a solution stronger than that in the last rocker pit. In fact, the weakest handler solution is run daily into the strongest rocker pit. As in the rockers the hides in the handlers are treated with solutions of gradually increasing strength, so that by the time the strongest solution has completed its action the hides are completely struck through or tanned, and are passed on to the layers.

Here they are spread out in pits and dusted with ground bark, the layers of hides and bark alternating. When the pit is full, concentrated liquor is run in till the hides are completely covered. In this condition they are left undisturbed for about 130 days or until they have taken up as much as possible of the tannic acid and other material. On removal from the last tanks or layers the hides are transferred to vats containing clean water, where they are left to soak overnight. The next morning they are rinsed and drained.

The heads and bellies are tanned in vats containing the chestnut extract liquors, and are then bleached of their surface tannage to obtain a lighter coloring. This is accomplished by the use of tanner's alkali (sodium bicarbonate) which is later neutralized by dilute sulphuric acid. The heads and bellies are then rinsed in water to remove the excess acid, and dewatered in a centrifugal machine.

At the present time tan liquor leached from oak bark is used exclusively at the Deford Leather Co., except for a small amount of chestnut extract for the heads and bellies. However, the supply of oak bark is becoming more distant, increasing the cost of transportation, and the impression at the tannery now is that in the near future the extract will be substituted more and more for the weaker bark solutions extracted at the tannery. This change will tend to reduce the amount of this waste, as the liquors made from the extract do not sour as quickly as those made from the bark at the mill, and there will be less leakage due to the less handling of the liquors.

From the tanyard the hides are taken to the drying loft, where they are thoroughly dried, rubbed, filled with oil, and otherwise prepared for market. As there is no waste produced beyond this stage, the description of the further processes will be omitted.

WASTES PRODUCED.

From the process outlined above different and distinct wastes are produced which present varied problems for treatment studies. The construction or arrangement of the factory itself, whereby different wastes are mixed, is also an important factor. At the tannery of the Deford Leather Co., in particular, the wastes may be summarized as follows:

Wash water from the green hides.

Wastes from the liming vats and unhairing machine.

Wash water from the fleshing and graining floors.

Exhausted or spent tan liquors and rinse water from vats in the lay-away yard.

Excess tan liquors carried by the heads and bellies when removed from the tanning vats.

Leakage from the leaching vats and a small amount of wash water.

Spent alkali and acids from bleaching vats.

Wash water from green hides.—The hides are received, bundled separately, and heavily salted. At the tannery they are unfolded and thoroughly washed with clean water to remove the salt and dirt. These wash waters, therefore, are heavily charged with sodium chloride, but contain relatively small amounts of suspended solids and dissolved organic matter. They do not present any difficulties in treatment, and serve to dilute the stronger wastes from other sections of the beam house with which they are mixed.

Waste from liming vats and unhairing machine.—The unhairing waste may be divided into three distinct classes. Two result from the liming process, the liquor which is emptied from the vats when the liquors become exhausted, and the solid residue which settles to the bottom. The latter is shoveled out of the tanks and piled behind the tannery to be hauled away for fertilizer. It does not, therefore, of itself enter into the treatment problem. The liquid portion, however, must be treated. It contains in suspension small particles of insoluble lime with some hair, and in solution, the soluble portion of the lime not absorbed by the hides, together with some organic matter dissolved from the hides. The solids in this waste, which constitutes the bulk of the waste from the beam house, settle quickly, leaving a clear supernatant that is not difficult to treat.

The third waste from the unhairing process is that from the unhairing machine. As the hides pass under the rough roller of this machine, which is wide enough to cover the whole hide, small streams of water play over it and carry the hair away to the screen and wash out the lime.

The screen, built of ¼-inch mesh galvanized-iron wire covered with a fine-mesh screen, is attached to a shaft which rotates back and forth through a half circle. In this way the screen is dropped into the water in which the hair is floating, and allowed to rest momentarily in this submerged condition until the hair mat is formed over the surface again. It is then lifted out, picking up the hair, carrying it over, and dumping it to the rear of the screen. The operation is, therefore, automatic and the screen self-cleaning, requiring little attention beyond the removal of the accumulation of hair. The waste from the tank passes under a submerged baffle, and then up to the overflow.

This effluent should contain the finely divided lime and dirt washed from the hair with a very small amount of hair itself, but the deposits of hair along the sides of the ditch to the pond, in the settling pond itself, and on the banks of Hawksbill Creek are strong evidence that the apparatus is not very efficient.

The quantity and character of this waste vary but little throughout the day. The bulk of the suspended solids will settle out in a couple of hours, leaving a supernatant capable of satisfactory treatment by filtration.

Although a part of the beam house operation, the waste from the unhairing machine at this tannery is not discharged with the beam house waste, but has a separate outlet.

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Wash water from the fleshing and graining floors.—The waste from the graining and fleshing floor consists of the wash water used for cleaning at the close of the working day. Although the total volume is small, it is of a highly polluting character owing to the heavy suspended matters, which are composed largely of small pieces of fleshings trimmed from the hides. The presence of a large number of buzzards, at times 18 or 20 or more, around sludge shoals of the settling pond into which this waste enters is sufficient evidence of this fact, although there is no odor noticeable. These solids settle readily in about an hour, and as this waste can not be separated from that from the lime soaks, which require about two hours' settling, it is evident that but little flesh can escape a sedimentation tank.

Exhausted or spent tan liquors and rinsing water from vats in lay-away yard.—Waste containing tan liquors at the Deford Plant comes from two different sources. The most important of these is the exhausted liquors from the rocker pits. As a series of packs of hides pass through these tanks the contents of the first tank of each pack is wasted to make room for the solution from the next stronger tank, and this solution becomes the first tank for the next succeeding pack. Several of these tanks are emptied each night. The second source of waste tan liquors is the soak tanks in lay-away or main yards. The total quantity of water used in these tanks is about the same as that in the vats in the handler yards, but the amount of tan extract is much less, as it is only that carried over from the lay-away yard by the hides. The tanks in the main yard are also emptied at night and into the same ditch receiving the liquors from the handler yards. Night emptying is not the customary procedure in the ordinary tannery where extra tanks are available and a more elastic system of piping is installed, but at this plant it is necessary in order that the tanks can be filled and ready for use the following morning.

To the two spent tan liquor wastes referred to above there should be added the leakage from the tanks, called black liquor, from the fact that the leakage has come in contact with iron. There is only a small amount of this liquor which is pumped out once a week.

Excess tan liquors carried by the heads and bellies when removed from the tanning vats.—From the operation of the centrifugal drier the excess water and some tan liquors carried over from the rinse water from the bleaching vats is removed from the heads and bellies. This results in a wastage of a small amount of fairly strong waste. No wash water is used in this process and as a result the drainage liquor is a small amount of strong tanning solution. A somewhat similar waste is discharged from the revolving wash drum in which the excess spent tan and dirt is removed from the heads. This, because of the wash water used, is much greater in quantity, but, while colored brown, is much less concentrated than the liquor from the centrifugal machine. All the wastes from the washing and drying of the heads and bellies are discharged into a separate ditch from the one receiving the spent tan from the rockers and the rinse water from the lay-away yard.

Leakage from the leaching vats and a small amount of wash water.—The waste from the leach house is small in volume and consists principally of the leakage from the vats in which the tan liquors are leached from the ground bark. To this there is added a small amount of wash water which may contain strong tan solutions. Although this waste at present is emptied into a separate ditch, there is no reason why it can not be diverted to the ditch carrying the spent tan liquors from the rockers and main yards, so that it need not be considered a separate waste for treatment, but can be considered as included with other tan liquors.

Spent alkali and acid from bleaching vats.—From the bleaching process there is discharged a waste containing spent alkali and spent acids, together with the liquors resulting from bleaching the heads and bellies. The final reaction of the mixture is strongly acid, but, as it is discharged into the ditch carrying the beam-house waste, which is strongly alkaline, it is neutralized and its treatment must be considered with the latter waste.

CHARACTER OF WASTES AS DISCHARGED FROM THE TANNERY.

The waste or mixtures of wastes upon which treatment studies were made were discharged through five separate outlets.

Beam-house waste.—The discharge from the first one, to be known as beam-house waste, consists of the wash water from the green hides, the water discharged from the liming vats, the floor washings from the graining and fleshing floors, the acid waste from the bleaching tanks, and a small amount of black liquor leakage from the rocker pits, which drains continuously into the beam-house outlet. The black liquor must not be confused with a similar kind of waste that collects for one week under the lay-away yard and is discharged into the spent tan outlet.

This waste is brown colored and contains insoluble particles of lime and some dirt; its polluting character is due to the fleshings and the tan extract both of which possess great avidity for oxygen.

Hair washing waste.—The second outlet discharges hair washing waste exclusively. This waste is grayish in color due to the lime washed from the hair. The lime also is responsible for most of the suspended matter, though there is present a relatively large amount of hair which could be recovered by more efficient screening.

Waste containing tan liquor.—Spent tan, rinse water and black liquor from the main and lay-away yards comprise the entire waste of the third outlet. This, together with the discharge from the fourth and fifth outlets, consisting, respectively, of tan leakage and wash water from the bleach house and excess tan removed in the centrifugal dryer and wash drum, constitute the most objectionable waste from the tannery. The settleable suspended matter can be removed in about two hours settling, but the color is very difficult to remove, single filtration serving only to clarify the waste. The presence of iron in the filtering medium produces an inky-black color. The tan extract in solution, to which the color is due, uses any available oxygen in a receiving stream and in the absence of oxygen, the liquor sours and putrefies rapidly so that the dilution factor must be extremely high to prevent nuisance and support fish life.

VOLUME OF WASTES DISCHARGED FROM DIFFERENT OPERATIONS IN THE TANNERY.

The important wastes at the Deford Co.'s tannery may be included under four headings, each having a separate outlet; beam house, hair wash, spent tan, and leather wash. The last of these is similar to the spent tan, in that it is diluted tan liquor washed from the hides after the tanning process is completed. There are other wastes, as already described, but they are either so similar to one of the four, or so small in volume that their addition to other wastes would not affect the treatment problem.

In Table 1 are given the average daily volume of the four wastes by months.

TABLE 1.—*Average daily volume of wastes by months.*

Date.	Beam house.	Hair wash.	Spent tan.	Leather wash.
1914.	*Gallons.*	*Gallons.*	*Gals.*	*Gallons.*
September				2,640
November				6,080
December	69,000	23,400		4,790
1915.				
January	66,500	27,600		3,310
February	57,700	26,200		3,410
March	65,100	26,400		2,810
April	73,400	29,100		1,360
May	67,000	27,600		2,710
June	66,200	27,500		2,060
July	72,700	19,700		1,660
August	65,000	23,200		2,450
September	74,200	25,000		1,790
October	76,300	20,300		2,750

Date.	Beam house.	Hair wash.	Spent tan.	Leather wash.
1915.	*Gallons.*	*Gallons.*	*Gals.*	*Gallons.*
November	68,800	20,300		
December	56,700	19,000		
1916.				
January	61,400	16,400		
February	60,800	18,400		
March	68,300	24,800		
April	64,000	24,700		
May	64,400	23,600		
June	60,900	27,000		
July	54,100	19,800		
August	60,800	23,500		
Average	65,400	23,500	14,000	2,910

It will be noted that only an average figure is given for the spent tan waste. This is due to the fact that it was discharged during the night, when it was impossible to take continuous readings throughout the tests. Special series of measurements were, therefore, made at different times, which included the number of tanks emptied each night of each series. The average figure obtained for all these series is included in the table as the average for the tests as a whole. This may vary during different seasons of the year, being particularly high in the summer. At this time the tan liquors are at the optimum temperature for the growth of souring bacteria and must be renewed more frequently.

The average total volume of waste from the whole tannery was 106,000 gallons daily. Toward this the beam house contributed 62 per cent, hair washing 22 per cent, spent tan 13 per cent, and leather washing 3 per cent. Adding the leather wash to the spent tan, making 16 per cent, the ratio of the three classes—spent tan, hair wash, and beam house—was 1:1.4:3.9.

During the period covered by the table there were handled, on an average, 275 hides per day. Computed on a basis of product, therefore, the total waste per hide was 385 gallons, and the number of gallons of waste per hide computed for the individual wastes were 238, 86, and 61 gallons for the beam house, hair washing, and spent tan liquors, respectively.

DESCRIPTION OF THE TESTING STATION.

The testing station was located in the rear of the tannery, between it and Hawksbill Creek, into which the wastes are discharged. By building the deep settling tanks partially in excavation it was possible to use the natural fall of the ground to obtain a gravity flow throughout all the units.

To distribute the wastes to the various tanks and filters, wooden flumes were employed. These intercepted the wastes in the ditches and conveyed such portions as were needed to the various devices.

The wide range in volumes to be measured, varying from the total waste from the tannery to the dosage of a sand filter 12 inches in diameter, necessitated the use of different methods of control and measurements. For the large volumes, rectangular weirs of various lengths were used. The triangular notch weirs were best adapted for measurements of tank-treated wastes and for the influents or effluents of the larger filters. The readings on the smaller filters were made with graduated cylinders in which the waste was caught for a definite period.

For a laboratory the Deford Leather Co. permitted the use of one of their offices, which was arranged and equipped with sufficient laboratory apparatus to make the more important tests, such as suspended solids, alkalinity, dissolved oxygen, putrescibility, and specific gravity and moisture of sludges. Toward the end of the tests samples were sent to the central laboratory at Cincinnati, where more complete analyses were made. The analytical methods were, unless otherwise noted, those recommended by the committee on standard methods of analysis of the American Public Health Association.

Whenever possible the samples analyzed represented the composite of one or two working days. In this way the laboratory work was kept within reasonable limits without making the analytical data too fragmentary to be of value.

The following tanks and filters were constructed as experimental units with which to conduct tests. (See Plate I.) As is always the case with such work, results of operation suggested changes. These are included in the description of the various devices.

PLAIN SEDIMENTATION AND CHEMICAL PRECIPITATION TANKS.

Tank A.—This tank was 5 feet in diameter and 10 feet deep, having a total capacity of 1,371 gallons below the flow line, 8 inches from the top. It was constructed of 2-inch pine staves. As originally installed it was arranged to operate as a Dortmund tank. The influent entered through a 4-inch galvanized iron tube, the top and bottom of which flared to 1 foot. Its total length was 5 feet 2 inches, but as it projected above the flow line 8 inches, only 4½ feet were submerged. Allowing the volume of the tank up to within 12 inches of the bottom of this tube as a sludge chamber, the sludge capacity was 75 cubic feet, and the displacement for the waste 810 gallons. The outlet was made of 2-inch iron pipe arranged as an inscribed hexagon. Two tees were inserted in each side, dividing it into three equal parts. The openings were turned up to form a skimming cup to take the waste from the surface. This tank was located to receive the waste from the centrifugal dryer and wash drum in which, as already described, the excess tan liquor is removed from the heads and bellies. A false bottom, made of galvanized iron, in the shape of a shallow cone was installed to assist in the removal of sludge. The sludge pipe led horizontally from the point of the cone through the side of the tank.

As originally constructed no baffles were placed, but difficulty was soon encountered with the scum which was carried away in the effluent, necessitating some form of baffle to protect the outlet. This baffle was made of ⅞-inch lumber and constructed in the form of a square inscribed in the tank. Two of its corners were placed at opposite angles to the pipe forming the outlet hexagon so that no outlet cup or T was contained within it. Holes were cut at the four in-

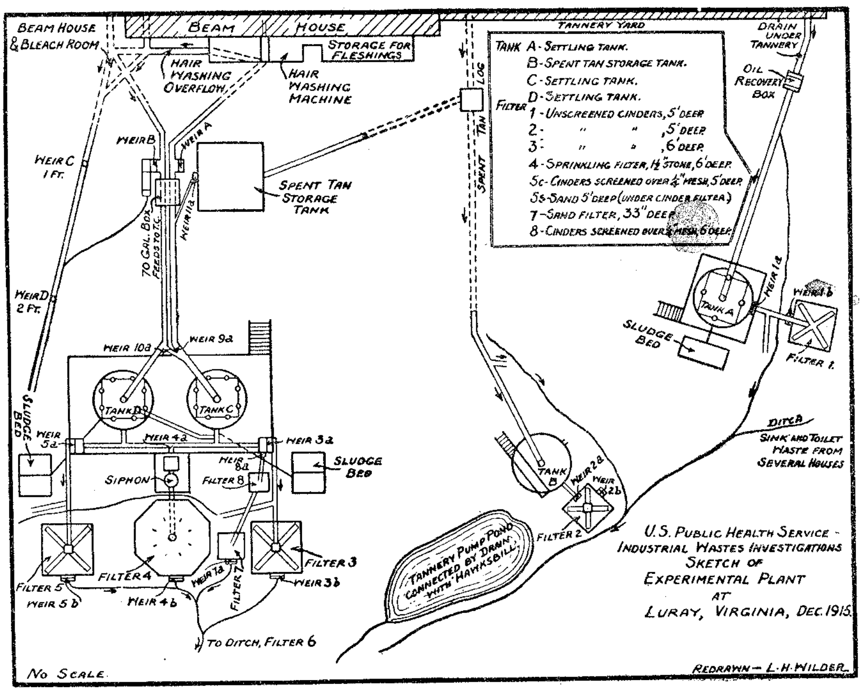

FIG. 1.—Plan of testing station.

tersection points to avoid changing the arrangement of the outlet pipe. The baffle walls extended down 2 feet below the flow line and terminated in a trap similar to that used in an Imhoff tank. This was to divert from the outlet chamber any large mass of sludge rising from the bottom, but did not, of course, accomplish the complete separation of an Imhoff trap as the flow of the waste was in an upward direction through the trap. This change was made November 18, 1914, about two and one-half months after the beginning of the tests.

Tank B.—This was of similar construction to tank A, but slightly larger, being 7 feet in diameter and 10 feet deep. The total capacity was 2,687 gallons from the flow line, 8 inches below the top, to the bottom. It was operated as a Dortmund tank, the inlet dosing tube being identical with that of tank A. This gave a sludge chamber of 147 cubic feet and a flow chamber of 1,583 gallons. The arrangement for removing sludge, including the false bottom, was similar to that in tank A. The outlet was a duplicate of that already described under tank A. No baffles were placed in this tank during its entire period of operation. The waste treated by this tank was the spent tan liquors from the rocker pits and the soak waters in the lay-away yard.

Tank C.—This was a circular wood stave tank 7 feet in diameter and 14 feet deep and with the flow line 8 inches from the top. The total capacity was 3,848 gallons. The Dortmund inlet tube and arrangement for sludge removal were the same as described for tank A. This gave a sludge chamber capacity of 301 cubic feet and a flow chamber of 1,583 gallons. The tank was operated as a Dortmund tank with baffles arranged the same as in tank A; that is, a wooden partition 1 foot from the side of the tank, extending down 2 feet below the water line and slanting to the side of the tank, with a narrow slot protected by a triangular strip nailed to the side of the tank to prevent sludge from rising and escaping in the outlet pipe.

It was intended to use this tank for the treatment of hair-washing waste, but as the test progressed and studies were made of the effect of combining different wastes for treatment this tank received various mixtures of hair-wash, beam-house, and spent-tan wastes. This is treated in more detail in another section.

Tank D.—This was identical in construction and dimensions with tank C. It had, therefore, a total capacity of 3,848 gallons, of which 1,583 gallons was considered as the flow chamber and 301 cubic feet as the sludge chamber. Baffles were installed at the same time as they were in tank A. The design and construction details were the same and are described under tank A.

During the first year the influent to this tank was from the beam house, consisting mostly of the waste from the soak tanks, the lime pools, and bleaching vats, but, as in the case of tank C, during the second year it treated various mixtures of wastes from several departments. In fact, these two tanks were operated in series, the effluent from tank C being the influent to tank D.

Tank E.—In connection with the study of the spent-tan liquor, which included chemical treatment and mixture of it with other wastes, there was constructed a spent tan storage tank. This tank was 7 feet 4 inches by 7 feet 7 inches in plan and 2 feet 2 inches deep. This gave a capacity of 117 cubic feet, or 871 gallons. It was necessary to fill this tank at night when the tan vats in the rocker and lay-away yards were discharged, so that the liquor could be held over to be used the following day or two or as long as it lasted.

PRIMARY AND SECONDARY FILTERS

Filter 1.—This filter was 5 feet square and had an area of 0.000574 acre. At the beginning of the tests this filter contained 3 feet of spent-tan bark. The results, however, were so unsatisfactory that it was at once thrown out of operation and the tan bark replaced by 7 feet of cinders screened over a ¼-inch screen.

The influent was regulated and controlled by a triangular weir, and was distributed by a set of radiating troughs or cross arms set at 90 degrees to each other. The waste was applied at the center, filled the troughs and flowed out through notches cut in the sides. As the troughs could be rotated to cover different sections of the filter, a very fair distribution was obtained. This filter received the effluent from tank A, consisting of the waste from the leather washing drum and centrifugal drier.

Filter 2.—In respect to dimensions, filtering media, control, and distribution, the filter was an exact duplicate of filter 1, as described above. The influent was the effluent from tank B, consisting of the spent tan liquors from the rocker pits and the lay-away yards.

Filter 3.—This filter was also 5 feet square and had an area of 0.000574 acre. The filtering medium through the entire period of the tests consisted of 7 feet of cinders screened over a ¼-inch screen. The methods of control and distribution were the same as already described for filter 1. The influent was the effluent from tank C till this tank was put in series with and preliminary to tank D, after which the influent was received from the latter. The composition of the influent, therefore, varied within wide limits.

Filter 4.—This was a sprinkling filter 7 feet square and had an area of 0.001125 acre. The filtering material was 1 to 2 inch broken limestone laid to a depth of 6 feet. The waste was measured by a triangular weir as it entered a siphon box in which was located a 3-inch Miller siphon that discharged the waste over the filter through a Taylor clover-leaf nozzle. The influent could be taken either from tank C or tank D, and was, in fact, changed several times as the studies progressed.

Filter 5–C.—This filter was 5 feet square and had an area of 0.000574 acre. The filtering material was altered several times during the tests, both in character and depth. At the start it was 7 feet of cinders, screened over a one-fourth inch screen. This was changed to 7 feet of coke retained by the same size screen, and later the coke was replaced by 5 feet of cinders.

The influent was measured by a triangular weir till late in the tests when it was caught directly into a graduated cylinder and the exact flow for one minute measured in cubic centimeters. Distribution was effected by means of troughs already described. The influent was, throughout the test, the effluent from tank D, and it varied with the character of the wastes treated in that tank.

Filter 5–S.—To study the effect of double filtration, sand following coke or cinders, filter 5–S was constructed directly beneath filter 5–C. It was of the same size, 0.000574 acre in area, and the top of the filtering material was 13 inches below the bottom of filter 5–C. Two sides of this opening were boarded up. The filtering material consisted of 5 feet of sand taken from a sand pit on a farm belonging to the tannery. This sand was washed, and had an effective size of 0.34 millimeter and a uniformity coefficient of 1.5.

Distribution was effected by means of the cracks between the boards forming the bottom of 5–C which was located over 5–S. Separate measurements of the volume treated were not necessary as it was the same as for filter 5–C.

Filter 7.—This was constructed for the same purpose as filter 5–C, namely, to study the results obtained by double filtration, in this case of sand following coke. (See filter 8 below.) This filter was located to receive the effluent from filter 8. It was 3 feet square and had an area of 0.000207 acre. The filtering medium was 3½ feet of sand, obtained from the same source as that used in filter 5–C. For distribution a board drilled with holes was used, and the influent was measured at first by a triangular weir, but later by a graduated cylinder.

Filter 8.—This unit was originally constructed to study sand filtration of settled waste without preliminary filtration. It was 2 feet 9½ inches square, giving an area of 0.000024 acre. Sand was placed in it to a depth of 5 feet. The sand used was river sand having an effective size of 0.40 millimeter and a uniformity coefficient of 1.65. The results obtained, however, were not satisfactory and the sand was replaced with 5 feet of coke screened over a one-fourth inch screen. It was during this period that the effluent served as the influent to filter 7.

The method of distribution for both the sand and coke was to apply the influent to the center of the bed on a board 2 feet square and allow the liquor to trickle over the sides. The influent was measured by a triangular weir in the beginning of the tests but this was replaced by direct reading in a graduated cylinder.

Filters 15 and 16.—During the early part of the test the results obtained from sand filter 7, treating the effluent from a coke filter, were so much better than those from sand filter 5–S, treating the effluent from a cinder filter, that it seemed desirable to verify them by two sand filters similar in construction and operation. Filters 15 and 16 were, therefore, installed. Both consisted of 12-inch sewer pipe having an area of 0.00001803 acre and filled to a depth of 2 feet with washed sand from the tannery farm. This sand, as stated under filter 5–S, had an effective size of 0.34 millimeter and a uniformity coefficient of 1.5. The effluents from filters 5–C and 8 were caught in buckets and applied to 16 and 15, respectively. The volume was so small that it was easily measured in a graduated cylinder, and the area to which it was applied was not large enough to require any distributing device.

SLUDGE BEDS.

Four sludge beds, each 10 feet square and 1 foot deep, were constructed convenient to the outlet pipes from the bottom of the settling tanks. Each bed was made by excavating in the ground to the proper depth and throwing the earth up to form a bank to hold the sludge over the filtering medium. This was composed of 10 inches of cinders that passed over a ¼-inch screen with 2 inches of the cinders that passed through the ¼-inch screen on top.

TREATMENT OF THE WASTES.

The studies at Luray, Va., may be roughly divided into two parts; first, the treatment of the four wastes individually with separate devices for each type; and second, the treatment by combination of two or more wastes, whereby it was possible to take advantage of chemical reactions between them.

TREATMENT OF THE INDIVIDUAL WASTES.

Beam house.—This waste was treated separately from the beginning of the tests, September 1, 1914, to June 18, 1915. A portion of the flow from this department was diverted to tank D, in which it was settled for a period of two hours, till March 18, 1915. During this period the average volume treated was 5,560 gallons per 10-hour day, or 8.5 per cent of the average total beam-house waste for the same period. Construction changes prevented the operation of the test units from March 18 to April 6, 1915. From the latter date till June 18, 1915, the detention period was 4 hours, and the average daily volume treated was 3,130 gallons, or 4.5 per cent of the total.

The effluent from the tank was applied to the filters. Filter 4, trickling filter, received this waste from January 15 to March 18, and from April 6 to June 18, 1915. Filter 5 which, as already noted, was a 7-foot cinder filter, received the effluent from this tank from September 1, 1914, to June 18, 1915, and on May 12 it was changed to 7 feet of coke.

The results of this treatment, as indicated by the suspended solids content, are given in Table 2. Under the filters are also shown figures for putrescibility and the 24-hour oxygen demand. The putrescibility results can hardly be called a monthly average, as it is difficult to combine results obtained with different dilutions. The values given are more in the nature of typical results.

TABLE 2.—*Results of analyses of beam-house waste before and after treatments.*

Date.	Raw waste.		Settled waste.			Filter 4.					Filter 5.				
	Average daily volume (gallons).	Suspended solids (p. p. m.).	Average daily volume (gallons).	Suspended solids (p. p. m.).	Sedimentation period (hours).	Rate, million gallons per acre daily.	Suspended solids (p. p. m.).	Oxygen demand, 24 hours (p. p. m.).	Stability by methylene blue.		Rate, million gallons per acre daily.	Suspended solids (p. p. m.).	Oxygen demand, 24 hours (p. p. m.).	Stability by methylene blue.	
									Dilution.	Hours to decolorize.				Dilution.	Hours to decolorize.
1914.															
September	....	1,244	3,100	554	2	......	....	....	....	....	1.28	108	....	....	....
October	....	1,136	5,660	428	2	......	....	....	....	....	.88	144	....	0	23
November	....	668	5,960	168	2	......	....	....	....	....	1.53	168	....	0	21
December	69,000	1,024	6,740	720	2	......	....	....	....	....	2.07	102	....	1:3	84
1915.															
January	66,500	524	5,120	548	2	......	....	....	....	....	.67	162	....	....	....
February	57,700	634	5,990	426	2	1.90	135	....	1:2	240	.68	184	....	1:2	140
March	65,100	948	6,430	736	2	2.05	396	....	1:5	240	.40	120	....	1:5	240
April	73,400	686	3,170	408	4	1.63	350	....	....	....	....	....	....	....	....
May	67,000	711	3,520	402	4	2.00	92	112	1:19	178	.42	112	170	1:19	156
June	66,200	1,049	3,590	524	4	1.85	244	135	1:49	178	.42	270	107	1:49	178
Average	....	862	......	491	....	1.89	243	124	....	....	.93	152	139	....	....

The average suspended matter removal by the settling tank during the entire period covered by the above table was 43 per cent. During the 2-hour sedimentation period it was 42 per cent as compared with 45 per cent during the 4-hour period, indicating that the settleable suspended matter was removed as completely with the 2-hour detention period as with the 4-hour. The trickling filter (No. 4) operating at approximately 1.9 million gallons per acre per day accomplished an average removal of suspended matter during the 5 months of 51 per cent over the tank effluent or 70 per cent over the raw beam-house waste. In filter 5 (cinders) reductions in suspended matter of 70 and 83 per cent over the settled and raw waste respectively were obtained. It should be noted that the greatest removal was in December, during which the rate was the highest, 2.07 million gallons per acre per day. There is nothing in the results to indicate a superiority for either the cinders or stone as a filtering medium. While the reduction effected by filtration is fair, the remaining content of solid matter is still too high to call this treatment successful, even when considered in connection with this one determination. It is readily seen that the percentage reduction is attributable to the large solid content of the raw and settled waste rather than to the low content of the filter effluents.

From the more important standpoint, that of oxidation, the results of filtration are even less satisfactory. Only very occasionally was there any oxygen present in the effluents, and the results of May and June show a 24-hour demand of 124 and 139 p. p. m. for filters 4 and 5, respectively. Stability with methylene blue was obtained only with dilutions, and the dilution factor was being rapidly increased with the approach of warmer weather at the time this series of tests was concluded.

Typical alkalinity results are tabulated in Table 3. An average of the total alkalinity would be of very little value as the degree is relatively less important than the state, whether hydrate, carbonate, or bicarbonate. The table was, therefore, prepared showing analyses of isolated samples. In the selection of the results tabulated the one for the tank effluent is that obtained from a sample taken 2 or 4 hours after the sample of raw waste, depending on the settling period of the tank and those for filters 4 and 5 from samples taken 10 minutes after the tank samples, which represent the approximate treatment periods in the filters. The time given in the table is that at which the raw sample was taken.

TABLE 3.—*Alkalinity of beam-house waste in various stages of treatment.*

Date and time.	Parts per million as $CaCO_3$.											
	Raw waste.			Effluent tank D.			Effluent filter 4.			Effluent filter 5.		
	Hydrate.	Carbonate.	Bicarbonate.	Hydrate.	Carbonate.	Bicarbonate.	Hydrate.	Carbonate.	Bicarbonate.	Hydrate.	Carbonate.	Bicarbonate.
1915.												
Feb. 1:												
9 a. m.	......	352	76	66	616	......	......	486	23	......	374	39
11 a. m.	214	516	......	230	580	......	......	456	22	......	286	89
1 p. m.	......	304	204	88	536	......	......	360	59	200	600	......
Feb. 5:												
7.45 a. m.	......	......	370	728	700	......	213	622	......	422	540	......
8.15 a. m.	4,554	1,472	......	558	684	......	114	486	......	......	752	40
8.45 a. m.	......	560	670	628	644	......	350	484	......	......	536	32
9.15 a. m.	154	428	......	624	680	......	48	764	......	44	484	......
May 28:												
8 a. m.	......	1,244	32	234	852	......	......	364	306	......	392	[illegible]
9 a. m.	716	1,060	......	152	916	......	......	392	296	......	280	358
10 a. m.	76	888	......	......	996	100	......	432	228	......	340	262
11 a. m.	......	400	142	214	796	......	......	320	292	......	372	168
June 5 and 6, composite	......	196	348	......	112	350	......	......	452	......	......	432
June 18:												
8 a. m.	220	844	......	......	156	408	......	......	500	......	......	434
9 a. m.	......	408	172	......	188	280	......	......	480	......	......	514
10 a. m.	......	......	386	......	176	268	......	......	482	......	......	471
11 a. m.	......	292	288	......	120	330	......	......	466	......	......	470

The data from which this table was prepared consisted of sets of analyses made at half-hour intervals throughout the day. The wide variation of the alkalinity figures for the raw waste is well illustrated.

The effluent from the tank fails to show the same rapid changes in the state of its alkalinity. This is probably due to the opportunity for reaction by diffusion with the large volume of liquid in the tank so that if it contains a bicarbonate content a small volume of influent with a high hydrate content would be absorbed by the reaction converting the bicarbonate to the carbonate. This mixture in proper proportions could be responsible for a reduction in the total alkalinity. The reverse of this reaction would also be true. If the tank contained a solution high in hydrates, bicarbonates in the influent might take a long time to remove all the hydrates. On the other hand instances occurred where hydrates in the influent were noted in the effluent in a much shorter time than the stated period of detention. This was due both to the fact that the detention period was computed on a total displacement basis and consequently was in excess of the actual, and to the diffusion in the tank whereby the chemical reaction ran ahead of the current.

The two-day composite sample showed, as in the case of the raw waste, the presence of carbonates and bicarbonates. This is probably typical of samples covering long periods.

In the filters the hydrates show marked decrease, though present at times. The composite sample of June 5 and 6 furnishes the best results for comparison, as the period covered is of sufficient length to minimize any error in estimating the time required for the different steps in the treatment. In this set both the raw and settled wastes contain carbonates and bicarbonates, but the filters only bicarbonates. The bicarbonates in filters 4 and 5 were 452 and 432 p. p. m. respectively, which are practically the same as the total of 462 in the tank effluent in which 112 parts were carbonates. This conversion could occur only in the presence of CO_2, which could be obtained from the decomposition of organic matter within the filters.

Taken as a whole, the final effluent from this treatment of the beam-house waste was not satisfactory, nor in a condition to be discharged into a small body of water without creating a nuisance. On March 18, 1915, studies were undertaken to determine the results of treating different wastes together, and the separate method of treatment abandoned.

Hair-washing-waste.—The unhairing machine was provided with water sprays which played on the knife cylinder, carrying the hair away to an open channel in the floor in which it was caught up by a stream of water and taken to the screen. The effluent from this screen constituted the hair-washing waste. While the suspended matter was high it consisted largely of lime washed from the hair, together with some hair passing the screen.

From September 1, 1914, to April 28 following, this waste was treated alone in tank C. The detention period, computed from total displacement, was 2 hours till March 18, 1915, and 4 hours from April 6 to April 28, the interval between March 18 and April 6 being devoted to reconstruction work and the station not operated.

The effluent from the tanks was applied to filters 3 and 4. Filter 3, consisting of 7 feet of cinders, received this waste during the entire period of this series of tests; and No. 4, trickling filter, from September 1, 1914, to January 15, 1915.

In Table 4 are given the results of these treatments as shown by the suspended solids in the various steps. The total volume of waste, the amount treated in the tank, and the rates on the filters are also included, together with some data on the oxygen content of the filter effluents.

TABLE 4.—*Results of analyses of hair-washing waste before and after treatment.*

Date.	Raw waste.		Settled waste.			Filter 3 (cinders).					Filter 4 (sprinkling).			
	Average daily volume (gallons).	Suspended solids (p. p. m.).	Average daily volume (gallons).	Suspended solids (p. p. m.).	Sedimentation period.	Rate (million gallons per acre daily).	Suspended solids (p. p. m.).	Oxygen demand (p. p. m.).	Stability by methylene blue. Dilution.	Stability by methylene blue. Hours to decolorize.	Rate (million gallons per acre daily).	Suspended solids (p. p. m.).	Stability by methylene blue. Dilution.	Stability by methylene blue. Hours to decolorize.
1914.														
September	....	1,544	6,970	782	2	1.84	316	.....	....	.....	1.24	562	.....	....
October	....	1,608	9,400	900	2	1.70	388	.....	0	100	1.71	446	0	106
November	....	1,116	12,480	648	2	3.28	316	.....	0	111	1.61	232	1:9	142
December	23,400	532	9,740	432	2	4.28	144	.....	....	.....	1.04	200	.....	....
1915.														
January	27,600	548	10,050	572	2	3.08	324	[1] 8	....	.....	1.71	308	.....	....
February	26,200	767	5,850	544	2	.83	221	[2] 26	....	.....	.....	.....	.....	....
March	26,400	720	6,070	578	2	.61	196	[2] 66	....	.....	.....	.....	.....	....
April	29,100	643	2,100	285	4	.43	158	[1] 39	....	.....	.....	.....	.....	....
Average	....	892	....	527	....	......	229	.....	....	.....	.....	.....	.....	....

[1] 24 hours. [2] 48 hours.

The tank removed 41 per cent of the suspended matter during the nine months tabulated. A 2-hour period of sedimentation is sufficient to remove all the economically settleable matter.

Filters 3 and 4 removed 56 and 48 per cent respectively of the suspended solids in the tank effluent and the combined removals by the tank and filters were 74 and 67 per cent, respectively, of that in the raw waste. The residual suspended matter in the effluents was still quite high, being in fact somewhat greater than in an average domestic sewage.

The maximum average oxygen demand shown in the tables is 66 p. p. m. for 48 hours, for the month of March, 1915. Several isolated determinations of the 96-hour or 4-day demand gave values in the neighborhood of 150 p. p. m.

As the waste from this department is derived entirely from one operation, the alkalinity is more fairly uniform than was the case with the more complex waste from the beam house. Table 5 gives typical results of alkalinity determinations.

TABLE 5.—*Alkalinity of hair washing waste in various stages of treatment.*

Date and time.	Parts per million as $CaCO_3$.							
	Raw waste.			Effluent tank C.		Effluent filter 3.		
	Hydrate.	Carbonate.	Bicarbonate.	Hydrate.	Carbonate.	Hydrate.	Carbonate.	Bicarbonate.
1915								
Feb. 10:								
7.30 a. m.	58	220	....	209	180	....	144	39
8 a. m.	402	260	....	226	168	6	182	....
8.30 a. m.	436	252	....	262	192	39	164	....
9 a. m.	160	156	....	293	182	62	164	....
9.30 a. m.	277	186	....	300	212	86	158	....
10 a. m.	364	260	....	328	152	118	138	....
10.30 a. m.	256	156	....	314	164	82	200	....
11 a. m.	589	302	....	290	236	104	166	....
11.30 a. m.	270	236	....	336	228	127	150	....
12 noon	361	310	....	157	114	142	152	....
12.30 p. m.	....	25	7	112	116	136	144	....
1 p. m.	1,050	396	....	218	158	116	138	....
Apr. 22:								
12 noon	252	312	....	673	210	....	....	258
12.30 p. m.	....	14	33	256	182	....	....	236
1 p. m.	....	....	34	277	124	....	....	219
1.30 p. m.	352	244	....	232	174	....	....	221
2 p. m.	326	276	....	244	166	....	....	225
2.30 p. m.	322	176	....	244	144	....	....	212
3 p. m.	730	252	....	237	170	....	....	232
3.30 p. m.	74	208	....	243	178	....	....	235
4 p. m.	96	248	....	253	202	....	....	231
4.30 p. m.	140	200	....	306	160	....	....	224
5 p. m.	8	224	....	322	140	....	....	216
Apr. 20 and 21, composite	76	288	....	130	190	....	....	291

Two typical days were selected—one, February 10, illustrative of the cold winter weather and with a 2-hour sedimentation period, and the other, April 22, illustrative of the warm weather and with a 4-hour sedimentation period. The data from analyses of samples taken at half-hour intervals during half of each day are tabulated.

During the time when the unhairing machine was in operation the results were fairly uniform, the alkalinity being due to hydrate and carbonate, owing to the presence of the lime washed from the hair. Bicarbonates were found during each noon hour when the waste consisted solely of the fresh water in the conveyor trough. This water

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was unusually soft. The minor variations at other times were due to the operation of the unhairing machine.

After mixing in the tank, such variations as were observed in the raw waste disappeared. The alkalinity was uniformly due to hydrates and carbonates, and the amounts of these showed comparatively slight changes, the hydrates varying with few exceptions between 200 and 300 p. p. m. and the carbonates between 150 and 200. Slight reductions in the total alkalinity over that of the raw waste can be accounted for by the settling out of suspended lime particles.

Between the 10th of February and the 22d of April a marked change occurred in the alkalinity of the filter effluents. At the first date bicarbonates were present only in the first sample each day, probably due to the practice of thawing out the filter with hot water. At all other times hydrates and carbonates were present. After April, however, hydrates and carbonates were never present, the total alkalinity being due to bicarbonates alone. As was suggested in connection with similar results obtained in the treatment of the beamhouse waste, this conversion was no doubt due to the absorption of CO_2 from the air and to destructive fermentation of organic matter within the filter during the warm months, with the production of CO_2.

Spent tan liquor from rocker pits and rinse water from lay-away yard.—These form by far the greatest part of all the wastes of this character. The leather-washing liquors from the centrifugal dryer and wash drum were also studied separately, but it is evident that in a permanent plant they can be included with the tan-pit wastes without materially affecting the composition. The same is true of other tan-liquor wastes, such as leakage from the bleach house and from the tan vats, the latter commonly known as black liquor. These, while much stronger than the liquor studied, are comparatively of such small volume that it is not anticipated they can effect a treatment which is efficient for the liquors from the tanning vats.

These wastes were studied as a separate problem during September, 1914, and from November 27 of the same year to March 18, 1915. The tan tanks were emptied during the night and flowed to tank B. When this tank was filled it overflowed to the ditch. The settled waste was taken from the tank through a valve located about halfway from the top and applied to filter 2. In this way a sufficient amount of the liquor was stored in the tank to operate the filter during the succeeding day. The settling period in the tank, therefore, varied greatly, but was never shorter than 8 to 9 hours, which was more than sufficient to remove any settleable suspended matter.

During September filter 2 was filled with spent tanbark to a depth of 3 feet, but it soon became evident that this treatment was not sufficient and the tanbark was removed on November 27 and the bed filled to a depth of 7 feet with screened cinders.

Table 6 contains the data from the analyses of the suspended matter in the effluent from tank B and filter 2, together with other data relative to operation.

TABLE 6.—*Results obtained in the treatment of spent tan liquor.*

Date.	Raw waste, total volume[1] (gallons per day).	Settled waste, total suspended matter (p. p. m.).	Effluent filter 2.	
			Rate (gallons per acre daily).	Total suspended matter (p. p. m.).
1914.				
December	14,000	485	951,000	450
1915.				
January	14,000	592	878,000	512
February	14,000	434	418,000	746
March	14,000	350	420,000	572
Average	....	465	....	570

[1] Average of a series of readings made during two years, September, 1914, to August, 1916.

No analyses were made during September when the filter consisted of 3 feet of tanbark. During the last 4 months, December, 1914, to March, 1915, when the filter contained 7 feet of cinders, the analyses show an average increase in suspended solids of 100 p. p. m. in the filter effluent over the influent. This was due to the souring of the liquors in the filters. The reaction of this waste was consistently acid and remained so throughout all states of treatment, though there was some slight reduction accomplished by the filter. Occasional putrescibility determinations gave results showing that very little oxidation took place within the filter. These determinations were confirmed by oxygen-consumed tests which showed, when the 30 minutes in boiling water method was used, values ranging from 15,000 to 49,000 parts per million.

Leather washing wastes.—The leather washing waste consisted of the effluent from the revolving drum in which the heads were placed to wash off the tan liquor carried over from the tan vats, and other foreign matter. To this was added the effluent from the laundry centrifugal dryer in which the heads and bellies were freed from water mixed with a small amount of tan liquors carried over from the bleaching tanks. The latter was, of course, much stronger than the rinse water from the revolving drum, as there was no diluting water, but it was correspondingly small in volume.

This waste was treated in tank A from September 1, 1914, to October 28, 1915. During about one month of this period, May 24 to June 30, 1915, lime was added at rates varying from 40 to 120 grains of CaO per gallon, but during the remainder of the time no chemical treatment was employed. On November 25, 1914, filter 1, a 7-foot cinder filter, was put in operation as secondary treatment to tank A, and continued in use during the remainder of the studies on this particular waste. The results of these studies are tabulated in Table 7.

TABLE 7.—*Results obtained by treating leather washing waste.*

Date.	Raw waste.		Settled waste.		Effluent filter 1.				
	Total volume (gallons per day).	Suspended solids (p. p. m.)	Total volume (gallons per day).	Suspended solids (p. p. m.)	Rate (gallons per acre daily).	Suspended solids (p. p. m.)	Stability by methylene blue. Dilution.	Stability by methylene blue. Hours to decolorize.	Oxygen demand, 24 hours.
1914.									
September	2,640	....	2,640	....	....	....	....	....	....
November	6,080	620	6,080	650	5,950,000	235	....	....	....
December	4,790	253	4,790	297	2,130,000	251	1:9	171	....
1915.									
January	3,310	170	3,310	296	1,210,000	216	....	....	....
February	3,410	362	3,410	379	1,010,000	274	1:3	105	....
March	2,810	312	2,810	404	836,000	256	1:19	240	....
April	1,360	1,066	1,360	840	711,000	478	1:19	217	....
May	2,710	310	2,710	383	930,000	208	....	....	200+
June	2,060	453	2,068	447	711,000	306	....	....	285
July	1,660	....	1,660	....	795,000	....	....	....	....
August	2,450	795	2,450	702	972,000	442	1:19	98	790
September	1,790	471	1,790	402	763,000	346	1:19	64	486
October	2,750	....	2,750	....	1,275,000	....	1:4	51	330
Average	....	481	....	480	....	301	....	....	418+

The tank effluent contained, on the average as much suspended matter as the raw waste, the average value for the entire 10 months during which analyses were made being 480 p. p. m. This was partly due to the presence of oil and grease which were very difficult to filter in a Gooch crucible in the suspended matter determination, and partly to the progressive souring of the liquors which precipitated compounds in solution. The filter removed but 37 per cent of these solids, the effluent containing 300 p. p. m., about one and two-thirds as much as average domestic sewage. The 24-hour oxygen demand of 418 parts per million was far from satisfactory. While regular analyses were not made to determine the acidity or the alkalinity of this waste, a sufficient number of determinations were made to show that the reaction was acid throughout the entire treatment, though there was some slight reduction in both the tank and filter. During June when lime was added to the raw waste the effluents from the tank and filter were alkaline. From these results it is obvious that the treatment affected the character of this waste very slightly, and that the filter effluent was in no condition for final disposal in any small body of water or stream.

While it seemed evident from the beginning of the test that this waste could not be purified sufficiently by sedimentation and filtration through cinders, still it was considered advisable to continue the operation, making occasional analyses to determine whether it would be possible to develop oxidizing bacteria in the beds after prolonged operation. Here, as was the case in the tests with the liquors treated in tank B and filter 2, it developed that the concentration of the tan liquor was too great to permit the ordinary oxidation processes to start in the filter.

TREATMENT BY COMBINATION OF WASTES.

The general unsatisfactory results obtained from the treatment of the various wastes separately, and the knowledge gained of their characteristics and relations, led to some laboratory tests of the advisability of combining two or more wastes, utilizing the alkalinity of one to neutralize the acidity of another. The results of these tests were promising and the experiment was continued on a larger scale May 1, 1915, by treating in tank C a combination of acid spent tan waste and alkaline hair-washing waste. Many changes were subsequently made; the beam-house waste was added to the two mentioned above; the ratio of the three was varied from time to time; new filters were constructed to allow treatment by double filtration; chemical precipitants were added; and the operation was frequently altered to verify or disprove theories that suggested themselves as the studies proceeded.

Roughly these changes can be grouped into five periods of operation distinguished in their main features as follows:

Period 1, May 1 to June 18, 1915: Treatment of the combination of spent tan liquors and hair-washing waste in tank C with 4 hours detention period; no chemical treatment.

Period 2, June 19 to September 14, 1915: Treatment of the combination of spent tan, hair washing and beam house wastes, in tanks C and D arranged in series, with a 2-hour detention period in each; no chemical treatment.

Period 3, September 15 to December 1, 1915: Same as period 2 except that iron in the form of ferrous sulphate (copperas), was added to the mixture of the beam house and hair wash wastes before the spent tan was added.

Period 4, December 2, 1915, to February 2, 1916: Treatment of the combination of beam house and hair washing wastes without spent tan in tanks C and D, the mixture being treated with iron as ferrous or ferric sulphate.

Period 5, February 3, 1916, to the end of the tests, August 9, 1916: Treatment of a combination of spent tan neutralized with lime, hair washing and beam house wastes; the mixture treated with ferrous sulphate.

In all the above periods filtration through various types and combinations of filters followed the tank treatment.

Period 1—Treatment of hair washing waste and spent tan liquor together.—In order to store the spent tan liquors discharged at night for treatment with the hair washing waste during the daytime, tank E, 7 feet 4 inches by 7 feet 7 inches in plan and 2 feet 2 inches deep was constructed adjacent to the flume carrying the hair wash to supply necessary storage. This tank was filled at night when the tan vats were emptied and used the next day. The supernatant liquor was siphoned over into the flume carrying the hair wash and the mixture passed into tank C. The effluent from the tank was applied to filter 3 (cinders, 7 feet deep) during the entire period. On May 29 a new 5-foot sand filter, (No. 8), was constructed, which also treated this effluent during June.

Table 8 shows the volume of each waste that was used and the suspended matter in the components and in the mixture.

TABLE 8.—*Results obtained by mixing spent tan and hair washing waste together.*

Date.	Components.				Combination.				
	Spent tan.		Hair wash.		Volume (gallons per day).			Ratio spent tan to hair wash.	Suspended solids (p. p. m.).
	Total volume (gallons per day).[1]	Suspended solids (p. p. m.).	Total volume (gallons per day).	Suspended solids (p. p. m.).	Spent tan.	Hair wash.	Total.		
1915.									
May	14,000	350	27,600	....	640	2,160	2,800	1:3.4	590
June	14,000	540	27,500	877	680	2,270	2,950	1:3.3	856

[1] Average of a series of measurements made during two years, September, 1914, to August, 1916.

The results obtained in treating this mixture in the tank and filters are contained in Table 9.

TABLE 9.—*Results obtained by settling and filtering a mixture of spent tan and hair washing wastes.*

Date.	Tank C.			Filter 3.			Filter 8.		
	Gallons treated per day.	Suspended solids (p.p.m.).		Rate (gallons per acre daily).	Parts per million.		Rate (gallons per acre daily).	Suspended solids (p.p.m.)	Oxygen demand 24 hours. (p.p.m.)
		Influent.[1]	Effluent.		Suspended solids.	Oxygen demand 24 hours.			
1915.									
May	2,800	590	112	418,000	100	384	....	....	....
June	2,950	856	225	408,000	233	800+	375,000	335	800+

[1] Mixture of spent tan and hair washing wastes.

The average removal accomplished by the tank during the two months was 77 per cent. This compares very favorably with a removal of but 41 per cent accomplished by the same tank when settling hair washing waste alone. (See Table 4.) This removal is not due to differences in the suspended matter in the tank influent, as in both cases they were practically the same, 892 and 856. The suspended matter in the tank effluent, when treating hair washing wastes alone, was 527 as compared with 168 when treating the combination.

As no analyses were made of the raw spent tan during the period when it was treated alone, it is not possible to make a complete comparison. Some index is, however, to be found in the suspended matter of the tank effluents which (see Table 5) was 465 with separate treatment against 168 with combined treatment.

Referring to Table 8 it will be found that the suspended matter as determined in the mixture of hair washing waste and spent tan was practically the same as computed from the ratio of the suspended matter in each waste. The per cent removal for the suspended solids in the settled mixture of the wastes was considerably higher than it was when each waste was settled separately so that it is apparent some change took place in the character of the solids. The most reasonable explanation seems to be that the finely divided calcium carbonate in suspension in the hair washing waste was dissolved by the acid in the spent tan liquors and that the precipitated calcium tannate, being more settleable than either the calcium carbonate or the organic suspended matter in the spent tan liquors, carried with it in settling much of the finer matter that remained in suspension in the separate wastes.

Filter 3, filled with cinders to a depth of 7 feet, accomplished no further reduction of the suspended matter contained in the tank effluent. Those solids which, in the separate treatment of the hair wash (see Table 4) were removed by this filter, had already been taken out in the tank.

Filter 8, made of sand, showed an increase of suspended matter during the first month and later on the suspended matter clogged the surface of this filter so badly that it did not seem advisable to continue it in operation. It was, therefore, dismantled and when the sand was removed it was found to be black and muddy to a depth of $2\frac{1}{2}$ feet. Below this depth clogging was not so evident and the sand was more normal in appearance, though there were blackened streaks running through it. The sand removed had a strong odor resembling sour tan liquor.

While no oxygen demand determinations were made of the influent to the filters the results obtained from the effluents indicate that very little oxidation was accomplished. A comparison with the relatively low oxygen demand of the hair washing waste, as shown in Table 4, shows the effect of adding the spent tan liquor with a very high demand.

The alkalinity of the waste treated during this period for the various stages of treatment is shown in Table 10.

TABLE 10.—*Alkalinity results for period 1.*

Date and time.	Ratio of spent tan to hair wash.	Parts per million as $CaCO_3$.				
		Tank C.			Effluent of filters.	
		Influent.		Effluent.	3	8
		Carbonate.	Bicarbonate.	Bicarbonate.	Bicarbonate.	Bicarbonate.
1915.						
May 4:						
9 a. m. to 11 a. m.	1:4.5	690	1,062	787	710	.....
2 p. m. to 5 p. m.	1:3.6	.....	636	574	646	.....
May 11, 8 a. m. to 5 p. m.	1:3.9	.....	415	322	562	.....
May 20, 2 p. m. to 5 p. m.	1:3.2	.....	443	468	722	.....
May 19 and 20, composite	1:3.3	.....	576	424	915	.....
June 5 and 7, composite	1:4.6	.....	454	264	572	336
June 18:						
8 a. m. to 12 m.	.....	.....	563	341	444	289
2 p. m. to 5 p. m.	.....	.....	357	332	576	444

This table indicates that one of the objects sought in combining these two wastes was successfully accomplished, that of neutralizing the acidity of the spent tan and of reducing the alkalinity of the hair wash. The resulting akalinity was comparatively uniform, not excessively high, and in the bicarbonate form.

It will be noted that as a general rule the alkalinity of the filter effluents was higher than that of the influent which came from tank C.

Period 2—Treatment of beam house waste, hair washing waste, and spent tan liquors together.—On June 19 construction changes were made whereby the beam house waste was added to the mixture of spent tan and hair washing just before entering tank C. On leaving this tank the mixture of the three wastes passed into tank D. Two hours' storage was allowed in each tank. The object of mixing all three wastes was twofold, first to treat the total wastes from the mill in one plant, thus simplifying the operation and reducing the cost of construction, and second, to provide a larger volume of waste with which to dilute the spent tan liquor.

Secondary treatment was provided by filter 3, with 7 feet of cinders; filter 4, a trickling filter with 6 feet of broken stone; filter 5, with 5 feet of cinders; and filter 8, which had failed as a sand filter during period 1 and was reconstructed as a 5-foot coke (egg size) filter.

At a ratio of one part of spent tan to four of the hair washing waste it would be possible to treat but 6,000 gallons of spent tan, as there were roughly 24,000 gallons of hair washing waste discharged daily. (See Table 1.) This was but little more than one-third of the total spent tan, considering the leather wash as spent tan for treatment purposes. By adding the 65,000 gallons of beam house waste it would be possible to dilute the entire amount of spent tan at a ratio of 1 to 5, or to treat a portion at a much higher dilution ratio.

Table 11 shows the total volumes and the volumes treated of each waste, with the ratio of the mixture during this period.

TABLE 11.—*Wastes treated during period 2.*

Date.	Gallons per day.								Ratio spent tan, hair washing, and beam house.
	Beam house.		Hair wash.		Spent tan.[1]		Combined.		
	Total.	Treated.	Total.	Treated.	Total.	Treated.	Total.	Treated.	
1915.									
June	66,200	4,270	27,500	2,270	14,000	680	107,700	7,220	1:3.3:6.3
July	72,700	4,690	19,700	2,260	14,000	730	106,400	7,680	1:3.1:6.4
August	65,000	4,630	23,200	2,220	14,000	790	102,200	7,640	1:2.8:5.9
September	74,200	4,610	25,000	2,240	14,000	760	103,200	7,610	1:2.9:6.1

[1] Not including leather wash.

With the ratios roughly 1:3:6 of spent tan, hair washing and beam-house waste, respectively, or 1 of spent tan to 9 of the other two combined, it would be possible to treat about 11,000 gallons of spent tan. This is 3,000 gallons less than the waste from the handler and lay-away yards and 6,000 less than the total spent tan, including the leather-washing waste.

The effect of mixing the wastes, as affecting the suspended solids, is shown in Table 12:

TABLE 12.—*Suspended solids in various wastes and combinations during period 2.*

Date.	Suspended solids (p. p. m.).			Mixture of spent tan with hair wash.		Mixture of spent tan and hair wash with beam house.	
	Spent tan.	Hair wash.	Beam house.	Ratio of wastes.	Suspended solids (p.p.m.).	Ratio of wastes.	Suspended solids (p.p.m.).
1915.							
June	318	562	686	1:3.3	456	1:1.47	638
July	...	...	...	1:3.1	...	1:1.56	...
August	480	523	966	1:2.8	706	1:1.55	884
September	502	554	670	1:2.9	866	1:1.56	956

Table 13 is arranged to show the results obtained by settling the mixed waste in tanks and treating the effluent on filters.

TABLE 13.—*Results obtained from treating wastes during period 2.*

Date.	Tanks C–D.		Effluent filter 3.					Effluent filter 4.				
	Influent: [1] Suspended solids (p. p. m.).	Effluent: Suspended solids (p. p. m.).	Rate (million gallons per acre daily).	Parts per million. Suspended solids.	Parts per million. Oxygen demand, 24 hours.	Stability by methylene blue. Dilution.	Stability by methylene blue. Hours to decolorize.	Rate (million gallons per acre daily).	Parts per million. Suspended solids.	Parts per million. Oxygen demand, 24 hours.	Stability by methylene blue. Dilution.	Stability by methylene blue. Hours to decolorize.
1915.												
June	636	212	0.408	190	490	1:49	91	1.85	168	280	1:49	178
July			.418					1.69				
August	884	542	.429	233	781	1:49	240+	1.61	226	656	1:49	240
September	956	202	.418	124	209	1:19	148	1.66	100	249	1:19	100
Average	825	319	.418	182	493	......	......	1.70	165	395	......	......

Date.	Tanks C–D.		Effluent filter 5.					Effluent filter 8.				
	Influent: [1] Suspended solids (p. p. m.).	Effluent: Suspended solids (p. p. m.).	Rate (million gallons per acre daily).	Parts per million. Suspended solids.	Parts per million. Oxygen demand, 24 hours.	Stability by methylene blue. Dilution.	Stability by methylene blue. Hours to decolorize.	Rate (million gallons per acre daily).	Parts per million. Suspended solids.	Parts per million. Oxygen demand, 24 hours.	Stability by methylene blue. Dilution.	Stability by methylene blue. Hours to decolorize.
1915.												
June	636	212	0.418	130	290	1:49	181	0.294	152	555	1:49	98
July			.429					.213				
August	884	542	.429	333	541	1:49	240+	.213	175	551	1:49	240+
September	956	202	.429	164	281	1:19	124	.105	112	......	......	......
Average	825	319	.426	176	371	......	......	.206	146	553	......	......

[1] Mixture of spent tan, hair wash, and beam-house wastes. (For proportions see Table 12.)

The suspended matter in the tank influent averaged for the period 825 p.p.m., practically the same as for June in period 1, but the removal was but 61 per cent as compared with 77 per cent in the earlier period. The filters, however, performed much more efficiently.

In period 1 the effluent from filter 3 contained the same amount of suspended solids as the influent and that of filter 8 showed an increase, so that the maximum removal was 77 per cent, all of which was accomplished in the tank. In this period, however, additional removal was accomplished in all the filters, amounting to 43, 48, 45, and 54 per cent respectively for filters 3, 4, 5, and 8 when referred to the tank effluent. This gave a total removal for the combined treatment of 78, 80, 79, and 82 per cent respectively or about the same as for period 1. In spite of the high removals, the final effluents from the filters were far from satisfactory from the standpoint of final disposal by dilution. The amount of suspended matter was about the same as that found in an average domestic sewage, and the oxygen demand for 24 hours varied between about 300 and 700 parts per million.

The marked improvement in the results obtained with the filters during September was due to the fact that all of them were thoroughly washed and cleaned the 1st of September. This was done with a fire hose, and large amounts of black material which had been retained by the filtering material were removed. This subject is discussed in detail in the conclusions.

Period 3—Treatment of all the wastes mixed together with the addition of ferrous sulphate.—The treatment of the combination of the same three wastes, hair washing, spent tan and beam house, as in period 2 was continued through period 3, and in addition ferrous sulphate (copperas) was applied at a rate of about 10 grains per gallon. The settling period was the same as in the preceding period, 2 hours in tank C followed by 2 in tank D, making a total of 4 hours. The effluent from the tanks was applied to cinder filters 3 and 5–C and coke filter 8, after which secondary filtration was afforded by two newly constructed sand filters, 5–S and 7.

Filter 5–S was 5 feet square in plan and contained 5 feet of sand as filtering medium. It was constructed directly beneath, and received the effluent from cinder filter 5–C.

Filter 7 was 3 feet square and received the effluent from coke filter 8. The filtering medium was $3\frac{1}{2}$ feet of sand, obtained from a different source but similar to that used in 5–S.

The total volume of wastes produced and the amount of each treated during this period are shown in Table 15.

TABLE 15.—*Total wastes and volume treated during period 3.*

Date.	Gallons per day.								Ratio of spent tan to hair wash and beam house.	Ferrous sulphate (grains per gallon).
	Spent tan.[1]		Hair wash.		Beam house.		Combined.			
	Total.	Treated.	Total.	Treated.	Total.	Treated.	Total.	Treated.		
1915.										
September....	14,000	760	25,000	2,240	74,200	4,610	113,000	7,610	1:3.0: 6.1	10
October.......	14,000	360	20,300	2,340	76,300	4,890	111,000	7,590	1:6.5:13.6	10
November....	14,000	790	20,300	2,260	68,800	4,860	103,000	7,890	1:2.9: 6.2	10

[1] Not including leather wash.

During September and November the ratio relation between the three wastes was practically the same as during period 2. In October, in order to get nitrification started before cold weather set in, the amount of spent tan was cut in half, resulting in much higher ratios of hair wash and beam house.

The results of suspended-matter and oxygen-demand determinations upon the component and mixed wastes are given in Table 16.

TABLE 16.—*Analyses of raw wastes treated during period 3.*

Date.	Spent tan.		Hair wash.		Beam house.		Spent tan and hair wash.				Spent tan, hair wash, and beam house.		
	Suspended solids (p. p. m.).	Oxygen demand, 24 hours (p. p. m.).	Suspended solids (p. p. m.).	Oxygen demand, 24 hours (p. p. m.).	Suspended solids (p. p. m.).	Oxygen demand, 24 hours (p. p. m.).	Ratio spent tan to hair wash.	Copperas (grains per gallon).	Suspended solids (p. p. m.).	Oxygen demand, 24 hours (p. p. m.).	Ratio spent tan and hair wash to beam house.	Suspended solids (p. p. m.).	Oxygen demand, 24 hours (p. p. m.).
1915.													
September	674	......	627	......	580	......	1:3	10	1,101	......	1:1.5	917	......
October	575	1,320	627	70	476	165	1:6.5	10	1,221	510	1:1.8	761	425
November	792	1,280	992	10	720	225	1:2.9	10	1,228	506	1:1.6	1,172	580

In the mixture of spent tan with the hair-washing waste to which ferrous sulphate was added, the effect of precipitation is marked. The average increase in the suspended matter is 71 per cent.

Table 17 contains the results obtained in treating this mixture in tanks and preliminary filters:

TABLE 17.—*Analyses of effluents from tanks and preliminary filters during period 3.*

1915	Tank C.				Effluent filter 3 (cinders).					Effluent filter 4 (sprinkling filter).				
	Influent[1] (p. p. m.).		Effluent (p. p. m.).		Rate million gallons per acre daily.	P. p. m.		Stability by methylene blue.		Rate million gallons per acre daily.	P. p. m.		Stability by methylene blue.	
	Suspended solids.	Oxygen demand 24 hours.	Suspended solids.	Oxygen demand 24 hours.		Suspended solids.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.		Suspended solids.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.
September	971	......	320	......	0.418	86	189	1:9	30	1.66	289	282	1:9	23
October	761	425	471	530	.429	111	145	1:4	48	1.62	389	317	1:6	48
November	1,172	580	340	440	.418	188	179	1:19	160	1.61	288	297	1:19	75
Average.	968	502	370	485	.422	128	171	......	......	1.63	322	299	......	......

[1] Mixture of spent tan, hair wash, beam house, and copperas. (See Table 16.)

TABLE 17.—*Analyses of effluents from tanks and preliminary filters during period 3*—Continued.

1915	Effluent filter 5-C (cinders).					Effluent filter 8 (coke).				
	Rate million gallons per acre daily.	P. p. m.		Stability by methylene blue.		Rate million gallons per acre daily.	P. p. m.		Stability by methylene blue.	
		Suspended solids.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.		Suspended solids.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.
September	0.429	147	323	1:9	17	0.105	113	249	......	......
October	.418	281	212	1:6	43	.105	141	170	......	......
November	.292	256	269	1:19	78	.105	196	162	1:9	45
Average	.380	228	268	......	......	.105	150	194	......	......

In the results of suspended matter determinations period 3 parallels very closely period 2. The tanks accomplished a removal of 62 per cent compared with 61 per cent, but the suspended matter in the influent was greater in period 3 so that the absolute quantity in the effluent was slightly greater than in period 2. In the latter period the filters ranged as regards the efficiency of their removal of solids from 43 per cent to 54 per cent. This variation was greater in period 3 when filter 4 was low, with but 11 per cent, while filter 3 was high with 66 per cent, filters 5 and 8 showing 38 per cent and 60 per cent, respectively.

The oxygen demand in the effluents shows some improvement, dropping from an average of above 450 p. p. m. to an average of about 230. It must be remembered that during October the dilution of spent tan was much greater than at any time during period 2, and it is the October results that lower the average. However, even excepting the October results, there is a marked decrease in the oxygen demand. In the final analysis of the polluting effects upon a receiving body of water the best of the filter effluents can make but a poor comparison with an average untreated domestic sewage.

The new feature in period 3 was the introduction of double filtration. Filter 7 was operated as a secondary sand filter following coke filter 8 during the entire period, and in November cinder filter 5 was reconstructed and a sand filter placed directly beneath it. This new filter was designated 5–S and the old cinder filter 5 as filter 5–C.

Table 18 gives the results obtained with these sand filters.

TABLE 18.—*Results obtained by secondary filtration through sand during period 3.*

Date.	Filter 7.									
	Influent (effluent filter 8).					Effluent.				
	Rate million gallons per acre daily.	P. p. m.		Stability by methylene blue.		Rate million gallons per acre daily.	P. p. m.		Stability by methylene blue.	
		Suspended solids.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.		Suspended solids.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.
1915.										
September	0.105	113	249	....	....	0.102	18	45	1:9	42
October	.105	141	170	....	....	.102	12	31	0	+240
November	.105	196	162	1:9	45	.102	41	39	1:9	+240
Average	.105	150	194	....	....	.102	24	38	....	....

Date.	Filter 5–S.									
	Influent (effluent filter 5–C).					Effluent.				
	Rate million gallons per acre daily.	P. p. m.		Stability by methylene blue.		Rate million gallons per acre daily.	P. p. m.		Stability by methylene blue.	
		Suspended solids.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.		Suspended solids.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.
1915.										
September	....	....	....	....	....	....	....	....	....	....
October	....	....	....	....	....	....	....	....	....	....
November	0.136	256	269	1:19	78	0.136	26	71	1:9	77
Average	.136	256	269	1:19	78	.136	26	71	....	....

These results show a marked improvement over any thus far obtained. The removals of suspended matter over that in the influent were 84 per cent and 90 per cent for filters 7 and 5–S, respectively, and when referred back to the raw waste, the combined efficiency of the total treatment was 98 per cent for filter 7 and 97 per cent for filter 5–S. The residual suspended solids are sufficiently low to permit discharge into a body of water even when the dilution is small.

The oxygen demand values show a great improvement, being well below that of an average domestic sewage. The putrescibility results in filter 7 were also very promising, indicating a relative stability of more than 95 per cent. Filter 5 did not give as satisfactory results in this respect, as it was not put in operation until November 9 and hence had been running less than a month.

Reducing the concentration of the spent tan liquors in October had the desired effect in permitting nitrification to start, but operation difficulties developed with the approach of freezing weather and it was thought advisable to discontinue the addition of the spent tan liquors, which caused pooling on the surface, and treat only the beam-house and hair-washing wastes. No doubt remained at this time that the spent tan liquor was the controlling factor in treating tannery wastes, and it was likewise evident that the strength of the tan liquor would have to be reduced before the whole amount could be treated along with the other wastes in the proportions discharged from the tannery. The next two months were devoted to research work in the laboratory in an effort to find a precipitant that would cut down the strength of the tan liquors.

Period 4—Treatment of beam-house and hair-washing wastes together, with the addition of ferrous sulphate.—During this period, which covered the months of December, 1915, and January, 1916, the hair-wash and beam-house wastes were treated together, with the addition of an iron salt. No spent tan liquor, however, was included. This change was made, as noted above, because considerable clogging and pooling of the sand filters occurred toward the end of period 3, and, during the cold weather, this gave difficulty by freezing. The clogging of the surface layers of the sand at that time was attributed to the presence of tannins in the wastes, which, reacting with the iron in the sand of the filters, formed an almost impervious layer on the surface.

Ferrous sulphate was added to the hair-washing waste previous to mixing with beam-house waste up until December 11, and ferric sulphate from that date to the end of this period. This mixture was settled in tanks C and D, connected in series, giving a total detention period of about four hours. Primary filtration was accomplished in filters 3, 5–C, and 8, which were followed by the secondary sand filters 5–S and 7. Laboratory tests using ferric sulphate showed considerable promise in the laboratory, but in practical operation the results were not sufficiently better to warrant the difference in cost between the ferric and ferrous sulphate.

The volume of wastes discharged from the beam-house and hair-washing machines, and the amount of each treated during this period are shown in Table 19.

TABLE 19.—*Total wastes discharged and volumes treated during period 4.*

Date.	Gallons per day.						Treatment ratio hair wash to beam house.	Ferric sulphate, grains per gallon.[1]
	Hair wash.		Beam house.		Combined.			
	Total.	Treated.	Total.	Treated.	Total.	Treated.		
December, 1915	19,000	2,150	56,700	4,760	75,700	6,910	1:2.2	10
January, 1916	16,400	1,970	61,400	5,000	76,800	6,970	1:2.5	10

[1] Ferrous sulphate till Dec. 11.

The ratio of hair washing to beam-house wastes in the mixture used is lower than that of the total wastes for either of the two months covered by the table and lower than that for the average total wastes over the entire period of the tests. This latter was 2.8. (See Table 1.) The ratio of the average wastes during 1915, however, was but 2.6, which is closer to those in the tables, and it was this ratio upon which the operation was based.

The results obtained from the analyses of the two wastes and the composite are contained in Table 20.

TABLE 20.—*Average analyses of raw wastes during period 4.*

Date.	Hair wash.					Hair wash and ferric sulphate.[1]					
	P. p. m.			Stability by methylene blue.		P. p. m.			Stability by methylene blue.		Ferric sulphate, grains per gallon.
	Suspended solids.	Oxygen consumed 30 minutes 96° C.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.	Suspended solids.	Oxygen consumed 30 minutes 96° C.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.	
December, 1915	1,028	......	......	0	45	1,404	......	8	0	240	10
January, 1916	1,234	197	......	0	82	1,378	189	8.	0	126	10

Date.	Beam house.					Hair wash, iron solution, and beam-house mixture (influent to tank C).						
	P. p. m.			Stability by methylene blue.		Ratio hair wash to beam-house waste.	P. p. m.				Stability by methylene blue.	
							Suspended solids.					
	Suspended solids.	Oxygen consumed 30 minutes 96° C.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.		Computed.	Determined.	Oxygen consumed 30 minutes 96° C.	Oxygen demand 24 hours.	Dilution.	Hours to decolorize.
December	1,011	......	......	0	34	1 : 2.2	1,134	1,020	......	......	0	65
January	1,088	555	37	0	40	1 : 2.5	1,171	1,175	418	68	0	28

[1] Ferrous sulphate till Dec. 11.

The effect of leaving out the spent tan liquor is very evident from the results given in this table, and the improvement in the operating conditions was even more satisfactory. The spent tan liquors above a certain concentration form a hard incrusting layer on the sand and make it almost impervious. The amount of suspended matter was practically the same during this period as in the previous one, but the oxygen demand was reduced to 68 p. p. m. and the oxygen consumed was likewise considerably reduced. It must be realized in considering these results that they were obtained in the winter season when bacterial activity was at its lowest point.

The most important conclusion to be drawn from this table is that tanneries using similar methods in the beam house to those where the tests were made, but not discharging spent tan liquors, can more readily purify their wastes than those discharging exhausted liquors. As a natural corollary to the above statement it is evident that tanneries discharging waste containing tanning compounds can simplify their problem of purification just so far as they can reduce the volume and strength of such wastes.

The results obtained by chemical precipitation with an iron salt, settling the waste in tank C, and applying the effluent to roughing filters, are given in Table 21.

TABLE 21.—*Average analyses of tank and primary filter effluents during period 4.*

Date.	Tank C.										Effluent filter 5.					
	Influent (see Table 20).					Effluent.										
	P. p. m.			Stability by methylene blue.		P. p. m.			Stability by methylene blue.		Rate, million gallons per acre daily.	P. p. m.			Stability by methylene blue.	
	Suspended solids.	Oxygen consumed, 30 minutes, 96° C.	Oxygen demand, 24 hours.	Dilution.	Hours to decolorize.	Suspended solids.	Oxygen consumed, 30 minutes, 96° C.	Oxygen demand, 24 hours.	Dilution.	Hours to decolorize.		Suspended solids.	Oxygen consumed, 30 minutes, 96° C.	Oxygen demand, 24 hours.	Dilution.	Hours to decolorize.
December, 1915	1,020	......	....	0	65	292	......	96	0	47	0.408	90	......	79	0	93
January, 1916	1,175	418	61	0	28	364	180	59	0	11	.408	83	177	94	0	68

TABLE 21.—*Average analyses of tank and primary filter effluents during period 4*—Continued.

Date.	Effluent filter 5-C.						Effluent filter 8.					
	Rate, million gallons per acre daily.	P. p. m.			Stability by methylene blue.		Rate, million gallons per acre daily.	P. p. m.			Stability by methylene blue.	
		Suspended solids.	Oxygen consumed, 30 minutes, 96° C.	Oxygen demand, 21 hours.	Dilution.	Hours to decolorize.		Suspended solids.	Oxygen consumed, 30 minutes, 96° C.	Oxygen demand, 24 hours.	Dilution.	Hours to decolorize.
December, 1915	0.146	212	......	84	0	132	0.204	92	......	73	0	132
January, 1916	.167	202	194	103	0	111	.207	89	160	102	0	74

The tank accomplished a removal of 69 per cent of the suspended solids in the influent, which was slightly higher (7 to 8 per cent) than was obtained when spent tan liquor was included. This difference is not greater than would be expected in comparing the results from two different periods treating the same wastes.

The oxygen consumed value shows a reduction in the effluent of the tank over the influent of 57 per cent, while the oxygen demand of the same samples was reduced only 3 per cent. This difference may be taken as an index of the suspended organic matter which would be included in the determination of the oxygen consumed by the action of the permanganate in the hot acid solution but would affect to a much smaller degree the 24-hour oxygen demand values, where the action is much slower. Following the tank the oxygen consumed values remain very uniform in all the filter effluents, while the oxygen demand values show an increase as the remaining suspended organic solids become available for normal oxidation without the assistance of chemical reagents. The putrescibility values represent the average of widely different results, so that too much importance can not be given to them; their general trend in the filters, however, as would be expected, is toward a slightly increased stability.

The filters effected considerably better suspended matter removals than they did during the preceding period. Filters 3 and 8 were practically the same with 74 and 73 per cent, respectively, as compared with 66 and 60 per cent for period 3. Filter 5 again showed the poorest removal, with but 37 per cent, which was 1 per cent lower than in period 3. In period 3 the suspended matter in the influent was higher than this period, so that for the same per cent removal in the two periods the actual suspended solids present in the effluent would be less for this period than for period 3. With the exception of the removal of solids the analyses show that but little chemical change was made in the character of the waste in the primary filters.

The average analytical results obtained from the effluents of the secondary sand filters 5–S and 7 are found in Table 22.

TABLE 22.—*Average analyses of sand filter effluents during period 4.*

Date.	Rate, million gallons, per acre daily.	Influent: p. p. m. Suspended solids.	Influent: p. p. m. Oxygen consumed, 30 minutes 96° C.	Influent: p. p. m. Oxygen demand, 24 hours.	Influent: Stability by methylene blue. Dilution.	Influent: Stability by methylene blue. Hours to decolorize.	Effluent: p. p. m. Suspended solids.	Effluent: p. p. m. Oxygen consumed, 30 minutes 96° C.	Effluent: p. p. m. Oxygen demand, 24 hours.	Effluent: Stability by methylene blue. Dilution.	Effluent: Stability by methylene blue. Hours to decolorize.
Filter 5-S. Influent (effluent filter 5-C).											
1915-16.											
December....	0.146	212	....	84	0	49	15	....	19	0	132
January......	.163	202	194	103	0	24	44	72	50	0	111
Filter 7. Influent (effluent filter 8).											
1915-16.											
December....	0.197	92	....	73	0	132	8	....	5	0	240+
January......	.200	89	160	102	0	74	11	43	9	0	240+

Sand filters 5–S and 7 were 5 feet square and 5 feet deep, and 3 feet square and 3½ feet deep, respectively. The sand in each was from a different source, that in 5–S being slightly finer than that in No. 7 but containing no silt, clay, or loam. No. 5–S was installed to verify the results obtained in No. 7 with a larger and deeper filter, and had not been in operation as long as the latter filter. The results on the whole are very satisfactory, the suspended matter averaging 10 parts in the effluent of No. 7, the oxygen demand for 24 hours less than 10 p. p. m., and the putrescibility showing a stability of 240 hours. Filter 5 removed 86 per cent of the applied suspended matter, and there was a material reduction of the oxygen consumed and oxygen demand, although not quite so low as No. 7, which can be explained as being due to the nitrification which started in this filter before cold weather set in.

Attention is again called to the fact that there was no spent tan liquor treated in the waste during this period and that the problem of purifying all the wastes except spent tan liquors from a tannery of this kind is not a serious one. The effluents from either filter 5-S or 7 could be discharged into any stream, no matter how small, without danger of creating a nuisance, and when the dilution factor is large in the winter months the effluent from a preliminary cinder filter could be discharged without danger of creating a nuisance.

Period 5.—Spent tan liquors treated with lime sludge and mixed with beam-house and hair washing waste to which ferrous sulphate was added.—During period 4, when no spent tan was treated, laboratory tests were conducted with a view of preparing this waste for more satisfactory treatment with the other wastes. During period 5 these experiments were adapted to large scale operation in the testing plant. This period extended from February, 1916, to the end of the tests, August 7, 1916, and constitutes by far the most important part of the tests. The results obtained by treating the various wastes separately and in combination during the preceding periods, and the operating experience obtained from previous tests, afforded essential data for the schedule finally adopted and by which satisfactory results were obtained. In fact, the operation during this period was the logical outgrowth of the earlier experiments.

Plate II shows the arrangement of units during this period. On the extreme right of the picture the weir in the main ditch from the tannery can be seen. The two troughs leading to the tanks carried the wastes from the beam house (on the right), and the hair washing machines (on the left), to tank C just beyond the steps. To the right of the troughs is tank D. The tank in the foreground by the side of the attendant was used for storing the spent tan liquor and for treating it with lime sludge. The small square tank on top of tank C contained the ferrous sulphate solution. The overflow weirs for regulating the wastes treated are shown in the foreground and directly in front of the attendant. The wastes, mixed in definite proportions and treated with the iron solution, first passed through tank C and then to D and on to the filters, just behind the tanks.

The spent tan was first treated with the lime sludge thrown out of the lime vats in the beam house. Sufficient of this material was added to neutralize the acidity of the spent tan, resulting in the precipitation of tannins as calcium tannate. The precipitate was

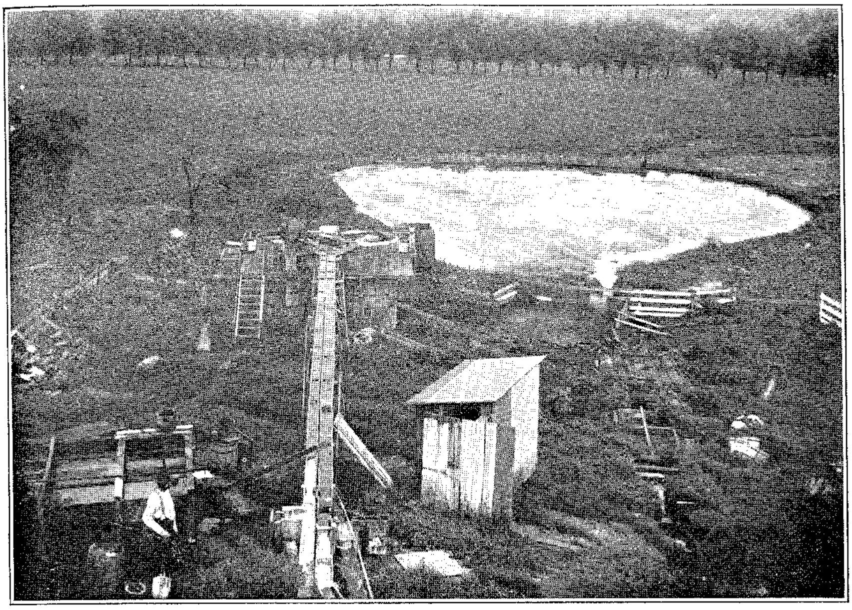

FIG. 2.—GENERAL VIEW OF TESTING STATION AND POND FOR SETTLING THE WASTES FROM TANNERY.

FIG. 3.—VIEW SHOWING DEVELOPMENT OF CORN FERTILIZED WITH TANNERY WASTE SLUDGE: FERTILIZED HILLS IN THE CENTER.

allowed to settle and the supernatant liquor was then siphoned over and added to the hair-washing waste. To this mixture an iron salt was added to act as a coagulant, and this composite was mixed with the beam-house waste just before entering tank C. The settled effluent was given preliminary treatment through filters 3, 5–C, and 8, and the secondary sand filters, 5–S and 7, received the effluents from 5–C and 8, respectively. Inconsistencies in the results obtained from 5–S and 7, in that 7, a sand filter containing but 3.5 feet of filtering medium, gave distinctly better results than 5–S, which was also a sand filter, but contained 5 feet of filtering medium, led to the construction of two new sand filters, 15 and 16. These were identical in every respect, consisting of 12-inch vitrified sewer pipe filled to a depth of 2 feet with the same grade of sand. Filter 15 received the effluent from the same filter as filter 7, and filter 16 from the same as filter 5–S.

The total volume of wastes discharged from the tannery and the amount treated during this period are shown in Table 23.

TABLE 23.—*Total wastes and volumes treated during period 5.*

Date.	Spent tan.[1]			Hair wash.			Beam house.		Combined.		
	Gallons per day.		Lime sludge, grains per gallon, dry basis.[2]	Gallons per day.		$FeSO_4 \cdot 7H_2O$ grains per gallon.[3]	Gallons per day.		Gallons per day.		Treated ratio spent tan to hair wash to beam house.
	Total.	Treated.		Total.	Treated.		Total.	Treated.	Total.	Treated.	
1916.											
February	14,000	240	220	18,400	2,200	10	60,800	4,900	93,200	7,340	1: 9.2:20.4
March	14,000	240	220	24,800	2,650	10	68,300	4,930	107,100	7,820	1:11.1:20.5
April	14,000	240	230	24,700	2,600	10	74,000	4,470	102,700	7,370	1:11 1:18.6
May	14,000	380	220	23,600	2,680	10	64,400	4,440	102,000	7,500	1: 7.0:13.4
June	14,000	420	230	27,000	2,530	10	60,900	4,800	101,900	7,750	1: 6.0:11.4
July	14,000	730	220	19,800	2,450	10	54,100	4,740	87,900	7,920	1: 3.5: 6.5
August	14,000	1,130	220	23,500	3,850	10	60,800	5,400	98,300	10,380	1: 3.4: 4.8

[1] Not including leather wash.
[2] Waste lime from unhairing vats used at rate of 0.063 pound per gallon of spent tan. Average moisture, 50 per cent. CaO 39 per cent.
[3] Ferric sulphate during February.

The procedure adopted during this test relative to the proportions of the various wastes treated was to work up from a safely small amount of the lime-treated spent tan to as large an amount as could be satisfactorily purified by the filters. This is well illustrated by the last column in the above table. Starting with ratios of about 1 part of tan to 10 of hair washing and 20 of beam-house waste, the concentration was worked up to about 1 to 3 to 5. As is shown later, it is believed that the volume of spent-tan liquors could be cut down to 10,000 gallons daily, so that a ratio of 1 to 2.4 to 6.1, or of 1 part of tan to 8.5 parts of hair wash and beam-house waste combined, would have taken care of the full 10,000 gallons of spent tan during the last month, August. The actual ratio of 1:3.4:4.8, or of 1:8.2, came very close to fulfilling this condition, though the amount of hair wash treated was proportionately high and that of the beam-house waste correspondingly low. A much closer agreement was very difficult to obtain, owing to the variations in the flow of the different wastes and to difficulties in operation and control of the test units.

The results obtained from the analyses of the individual raw wastes and the mixtures of these wastes are shown in Table 24:

TABLE 24.—*Analyses of the raw wastes and mixture of the wastes treated during period 5.*

Date.	Spent tan rocker pits (p. p. m.).		Spent tan hide wash (p. p. m.).		Spent tan treated [1] with lime (p. p. m.).		Hair wash and treated tan (p. p. m.).		Beam house (p. p. m.).		Treated tan, hair wash,[2] and beam house (p. p. m.) with ferrous sulphate.[3]			
	Suspended solids.	Oxygen consumed, 30 minutes—96° C.	Suspended solids.	Oxygen consumed, 30 minutes—96° C.	Suspended solids.	Oxygen consumed, 30 minutes—96° C.	Suspended solids.	Oxygen consumed, 30 minutes—96° C.	Suspended solids.	Oxygen consumed, 30 minutes—96° C.	Suspended solids.	Oxygen consumed, 30 minutes—96° C.	Total nitrogen.	Ferrous sulphate, grains per gallon.
1916.														
February	......	......	......	......	......	13,000	......	......	861	455	1,150	710	76	7.6
March	......	......	......	......	......	19,000	......	......	902	465	1,197	988	80	4.5
April	1,780	13,500	1,248	5,900	926	11,900	1,300	1,630	920	433	1,433	866	97	10.2
May	1,320	16,700	893	10,000	832	11,000	968	1,180	762	520	1,124	675	74	15.5
June	1,062	15,800	790	13,700	946	10,100	1,147	1,953	980	585	1,300	790	66	14.2
July	1,055	17,100	755	6,700	576	12,700	750	1,860	777	587	1,146	1,060	62	10.0
August	2,565	19,800	570	7,600	985	17,400	......	......	530	1,140	963	1,385	32	15.0

[1] Mixture of spent tan from rocker pits and hide wash, about half of each.
[2] For ratio of wastes in composite see Table 23. This composite constitutes the influent to settling tanks.
[3] Ferric sulphate during February.

The results given in the preceding table show where the problem lies in purifying tannery wastes where tannic acid is used for tanning leather. The suspended matter in the spent liquors from the rocker pits and hide washing tanks is high but it can be removed in settling tanks, but the oxygen consumed, running as high as 19,800 p. p. m. in the rockers and 13,700 in the rinsing tanks, can not be taken care of so easily. Treating the spent liquors with lime sludge not only reduces the oxygen consuming value of these wastes but changes the reaction from acid to alkaline which is more favorable for bacterial action. Even with the addition of the lime sludge, however, the strength of the spent liquors is high as measured by the oxygen consumed. Some difficulty was experienced in judging the correct amount of the wet lime sludge to add to each tank of spent liquors, and the results given in this table are not as typical of what can be accomplished when the exact water content and strength of the lime sludge is known, as those given in Table 25, where special precautions were taken to obtain the proper reactions.

Tests carried out in the laboratory on a small scale had shown that about 50 per cent of the oxygen consuming value of the spent tan liquors could be removed by treatment of the liquors with lime sludge from the liming vats. To learn how far these results could be duplicated under actual working conditions with the exact strength of the lime sludge and tan liquors known, several runs were made under the most favorable conditions that could be arranged. The results obtained in these special runs are given in Table 25.

TABLE 25.—*Showing the results obtained by mixing lime sludge from unhairing vats with spent tan liquor.*

Days covered by each analysis.	Gallons of spent tan treated.	Pounds of lime sludge added.	Per cent water in sludge	Grains per gallon, dry basis.	Oxygen consumed, 30 minutes.			
					Before lime sludge was added (parts per million).		After lime sludge was added (parts per million).	
					Hot, 96° C.	Cold, 20° C.	Hot, 96° C.	Cold, 20° C.
Jan. 31, Feb. 1	591	24.6	49.2	126	6,004	3,239	3,476	1,501
Feb. 5, 6, and 7	885	55.3	41.6	182	11,771	7,268	5,609	3,160
Feb. 10, 11, and 12	885	75.0	50.6	300	5,925	3,081	5,060	2,765
Feb. 15, 16, and 17	885	55.3	53.0	232	10,902	6,004	4,266	2,528
Feb. 17 and 18	885	55.3	53.0	232	10,902	6,004	3,397	1,817
Feb. 19, 20, and 21	885	55.3	52.8	231	15,287	8,532	4,898	2,686
Feb. 25 and 26	885	55.3	52.8	231	7,350	4,270	4,820	2,530
Feb. 28, 29, and 30	885	55.3	53.7	234	7,347	4,266	4,108	2,449

The results given in the preceding table indicate the maximum results that can be obtained in treating spent tan liquors with lime sludge. In each of the tests which covered two or three days the lime sludge was analyzed and an amount added that gave the most efficient results. In each series the spent tan storage tank was filled to a definite volume and the lime sludge carefully weighed and stirred in with the spent tan. In all the analyses except one in both the hot and cold tests the spent liquors treated with lime have an oxygen-consuming value less than one-half of that in the untreated samples.

Because of the variation in the state of the alkalinity in the different wastes, it was impossible to include the monthly average of this determination in Table 24. A special table, No. 26, has therefore been prepared to show the alkalinity or acidity as determined in individual samples. During February and March this table is not complete. Early in March the laboratory at Luray was closed and analytical work, with the exception of the putrescibility test on the filters, was done at the central laboratory at Cincinnati, Ohio. In making this change the sampling schedule was revised so as to include only samples from those devices which had shown promise of yielding satisfactory results.

TABLE 26.—*Acidity or alkalinity of raw wastes and mixtures of wastes treated during period 5.*

Date.	Parts per million as $CaCO_3$.											
	Spent tan.[1]	Spent tan.[2]	Treated tan.[3]		Treated tan and beam house.[4]			Beam house.			Treated tan, hair wash, and beam house.[5]	
	Acidity by fluorescein.	Acidity by fluorescein.	Acidity by fluorescein.	Bicarbonate.	Hydrate.	Carbonate.	Bicarbonate.	Hydrate.	Carbonate.	Bicarbonate.	Carbonate.	Bicarbonate.
1916.												
Feb. 2												210
21											80	256
Mar. 10											170	265
17											320	380
Apr. 17	1,076	202		1,980			600	600	540		880	70
25	2,790	825	1,140		170	310			340	110		450
29	2,390	1,125	650		85	180			420	60		560
May 5	2,280	650		400	365	230			290	665		650
15	2,850	2,100		338			640		130	250		520
19	2,800	1,540	(6)			100	470			620		600
29	3,225	2,590				680	110		175	245		480
June 10	3,200	1,650	(6)			180	480		440	25		450
16	2,400	2,390				270	720		400	10		480
26	2,350	2,060		410	480	200			320	110		440
30	3,000	2,250		630		420	300		620			
July 11	3,200			800	140	250			130	395		400
20	2,375	2,375		125		790			520	120		720
27	2,500	750	1,475		110	40			180	270		640
Aug. 8	3,000	1,290	288		250	315			75	90		695

[1] Spent tan from rocker pits.
[2] Spent tan from hide wash.
[3] Mixture of spent tan from rocker pits and spent tan from hide wash, treated with lime sludge.
[4] Mixture of treated tan and hair wash.
[5] Mixture of treated tan, hair wash, and beam house with ferrous sulphate. (For ratios see Table 23.)
[6] Neutral.

The acidity of the spent tan from the rocker pits varies considerably but in the average it is about twice as great as that from the hide wash. When it is recalled that the hide wash is clean water in which the hides from the lay-away yards are slid back and forth to remove excess tan and foreign particles, this difference is readily understood. The wide variation in these solutions which, with a mixture of half and half, would range from about 600 to 2,900 parts per million of acidity, made it very difficult to judge the dosage of lime to effect complete neutralization. The above table shows that in four instances, April 25 and 29, July 27 and August 8, insufficient amounts of lime were added. It must also be remembered, however, that the lime used was the wet sludge taken from the unhairing vats in the beam house, and that it was subject to variations in the moisture content. In every case the excessive alkalinity of the lime-saturated hair-washing waste was sufficient to take care of this acidity and to produce an alkaline mixture.

The beam-house waste showed its usual variations, containing hydrates and carbonates on April 17, carbonates alone on June 30, bicarbonates alone on May 19, and both carbonates and bicarbonates in the remainder of the determinations. The final mixture which constituted the influent to the settling tanks contained after March 17, with but one exception, April 17, only bicarbonates.

The results obtained from the analyses of the effluents from the settling tanks and primary filters are shown in Table 27.

TABLE 27.—*Average analyses of effluents from settling tank and primary filters during period 5.*

TREATED TAN, HAIR WASH, BEAM HOUSE (INFLUENT TO SETTLING TANKS).

Date.	Rate (million gallons per acre daily).	Parts per million.								Ferrous sulphate (grains per gallon).	Stability by methylene blue.	
		Suspended solids.	Nitrogen as—					Alkalinity as $CaCO_3$ (bicarbonate).	Oxygen consumed, 30 minutes—96° C.		Dilution.	Hours to decolorize
			Total.	Organic.	Free ammonia.	Nitrites.	Nitrates.					
1916.												
February		1,150	76						710		1:1	13
March		1,197	80						988	9.0	1:2	18
April		1,433	97						866	10.2		
May		1,124	74	41	33			560	675	15.5		
June		1,300	66	32	34			460	790	14.2		
July		1,146	62	18	44			590	1,060	10.0		
August		963	32					695	1,385	15.0		
Average		1,188	70	30	37			576	925	12.3		
EFFLUENT SETTLING TANKS.												
February		460	55						364		1:1	13
March		420	64						495	2.0	1:2	18
April		495	71						532	2.8		
May		460	52	22	30			490	428	9.0		
June		530	58	30	28			460	530	8.0		
July		306	43	12	31			572	640	6.0		
August		440	33					750	720	8.0		
Average		444	55	21	30			588	530	6.0		
EFFLUENT FILTER 3 (CINDERS).												
February	0.398	263							400		1:1	86
March	.345	280	45			0.020	Tr.		350		0	16
April	196	284	44			.003		551	234		0	71
May	.197	612	43	21	12			619	304		0	100
June	.198	310	18	10	8			443	172		0	100
July	.193	273	23	10	13			470	387		1:1	57
August	.193	910	54	51	3	0		575	320	4.8		
Average	.246	419	38	23	9			532	308			
EFFLUENT FILTER 5-C (CINDERS).												
February	0.209	190	46			0		292	199		1:1	159
March	.188	270	48			0.009	Tr.	375	255		0	16
April	.194	121	44			.041		495	209		0	31
May	.253	152	18	12	6	.730	17.0	306	93		0	240
June	.289	144	16	11	5	.520	3.2	370	122		0	100
July	.285	140	23	12	11	.700	3.4	483	349		1:1	47
August	.298	130	16	2	14	0	0	580	210	6.0		
Average	.245	164	30	9	9	.290	5.9	414	205			

TABLE 27.—*Average analyses of effluents from settling tank and primary filters during period 5*—Continued.

EFFLUENT FILTER 8 (COKE).

February	0.192	218	......	......	......	......	......	310	390	....	1:1	75
March	.150	251	......	......	......	......	......	....	420	....	0	16
April	.212	198	48	......	......	0.003	......	429	250	....	0	25
May	.270	480	44	33	11	......	......	442	269	....	0	116
June	.306	243	32	0	32	.080	2.0	443	247	....	0	146
July	.314	537	29	5	22	.070	1.1	515	492	....	1:1	26
August	.314	150	22	6	16	0	0	530	150	7.0	......	......
Average	.251	297	35	11	20	.038	1.0	445	317	....	......	......

By moving the laboratory work from Luray to Cincinnati it was possible to make much more complete analyses of the samples. The stability determinations were still made in the field, but the time lost in transportation prevented satisfactory results from oxygen demand analyses and this determination was not made. For this reason the analytical tables in this period differ from those of preceding periods. Inasmuch, however, as the waste treated during this period differs from that in period 3 only in the lime treatment and concentration of spent tan liquors, a comparison is made whenever possible.

The influent to the tank when the spent tan is treated with lime sludge has a slightly higher suspended solid content than without the lime, the increase on the average being about 22 per cent. As compared with an average domestic sewage, the suspended solids are about 6 times as great, the total nitrogen 4 times, free ammonia 3.1 times, and oxygen consumed 6.1 times.

The effluent from the tank in this period contained 444 p. p. m. of suspended solids. This value is 74 parts higher than the tank effluent in period 3, but because of the higher amount of suspended matter in the tank effluent the reduction in the amount of suspended matter removed is 64 per cent as compared with 62 per cent during period 3. The solids removed were largely mineral as evidenced by the relatively low reduction in oxygen consumed of but 15 per cent. Only 50 per cent of the iron was removed, probably the excess over that required to combine with the tannic acid. It was estimated that enough iron was added to form iron tannate with all the tannic-acid compounds and a slight excess in addition to form a precipitate with the lime to assist in carrying down the suspended matter. The iron tannate exists in the colloidal state and that part which is not carried down with the suspended matter in the wastes escapes with the effluent and is removed by the filters. The free ammonia and organic nitrogen also show reductions comparable with that of the organic solids. As would be expected, the alkalinity remained constant.

The removal of suspended solids in filter 3 was more or less erratic and unsatisfactory. While four out of the seven months show average reductions of from 41.5 to 275 p. p. m., about 34 per cent, two other months show such a decided increase that in a general average of the whole period the amount of solids remain practically the same. Consideration must be given to the fact that this filter had been in continuous operation throughout the entire test, almost two years, and for this reason subject to periods of unloading. That these solids unloaded were in an altered state is indicated by the removal of about 42 per cent in the oxygen consumed. A stability of 100 hours of the undiluted effluent, such as occurred during May and June, is another indication that the solids were at least partly oxidized. The stability dropped in July to 57 hours with a 1:1 dilution owing to the increased dosage of tan liquors. During period 3 the suspended solids were much lower, 128 p. p. m., as against 419, but the stability was only 160 hours with a 1:19 dilution.

Filter 5–C gave a much more satisfactory removal of suspended solids, 63 per cent of that in the influent being removed, and the actual amount present was 164 p. p. m., as compared with 228 p. p. m., in the same filter effluent during period 3. This filter had seen less service than filter 3 and was not unloading during the time covered by the table, but the putrescibility results are more variable and, on the whole, were about equivalent to those obtained from filter 3. The comparison of the results above indicates that filter 3 after two years' operation was still giving an effluent suitable for filtration through sand.

Filter 8, in length of service, falls between Nos. 3 and 5–C, and it will be noted that the suspended solids contents lies about halfway between these two. The total nitrogen was about the same as for filter 3 but higher, about 50 per cent, than for filter 5–C, when corresponding months are averaged. The oxygen consumed is the highest obtained for any of the three primary filters in operation during this period, and the stability stands, for the most part, in the same relation. Compared with itself during period 3 the suspended solids content is about double.

In all these comparisons it is very important to keep in mind the difference in rates. Thus it will be noted that filters 8 and 5–C, are fairly close together during this period, but that from May on they were both treating an appreciably larger volume than filter 3. Moreover, a comparison of rates for the same filters during periods 5 and 3 shows that for filter 3 it was lower during period 5, for filter 5–C lower, and for filter 8 considerably higher, amounting to more than twice as much.

Viewing the results of primary filtration as a whole it may be said that the effluent from these filters was approximately twice as strong as an average untreated domestic sewage.

The effluents from filters 5–C and 8 were treated on four secondary sand filters. Sand filters 5–S and 16 followed 5–C, and filters 7 and 15 followed 8. The analyses of the effluents of these filters are given in Table 28.

TABLE 28.—*Average analyses of effluents from secondary sand filters during period 5.*

EFFLUENT FILTER 5-S (INFLUENT FILTER 5-C).

Date.	Rate (million gallons per acre daily).	Parts per million.								Stability by methylene blue.	
		Suspended solids.	Nitrogen as—					Alkalinity as $CaCO_3$ (bicarbonate).	Oxygen consumed, 30 minutes—96° C.	Dilution.	Hours to decolorize.
			Total.	Organic.	Free ammonia.	Nitrites.	Nitrates.				
1916.											
February	0.209	57	36.0	......	......	0.004	Tr.	380	89	1:1	69
March	.188	40	38.0	......	......	.045	Tr.	445	76	0	240
April	.194	28	57.0	......	......	.240	25.0	565	47	0	240
May	.253	30	15.0	4.0	11.0	.520	34.0	301	30	0	240
June	.289	22	4.0	3.3	.7	.300	18.0	285	32	0	240
July	.285	33	4.5	3.7	.8	.050	33.0	393	41	0	240
August	.289	15	6.8	4.9	1.9	.060	4.1	490	80	0	37
Average	.244	32	23.0	4.0	3.6	.170	22.8	408	56	......	187

EFFLUENT FILTER 7 (INFLUENT FILTER 8).

February	0.186	34	38.0	......	......	0.160	Tr.	388	68	1:1	240
March	.145	47	24.0	......	......	.160	Tr.	382	62	0	240
April	.201	20	29.0	......	......	.620	26.0	414	58	0	240
May	.256	31	8.0	2.5	5.5	.370	36.0	371	60	0	240
June	.291	15	2.4	......	......	.050	12.0	381	68	0	184
July	.299	30	7.3	5.1	2.2	.120	16.0	387	44	0	148
August	.301	15	7.2	6.4	.8	.220	3.5	410	53	0	83
Average	.240	27	16.6	4.7	2.8	.240	18.7	390	59	......	196

EFFLUENT FILTER 16 (INFLUENT FILTER 5-C).[1]

March	0.186	......	......	......	......	......	......	......	......	0	100
April	.185	15	10.0	......	......	0.110	7.6	189	42	0	240
May	.304	15	......	......	......	.062	21.0	165	......	0	240
June	.379	15	2.4	1.4	1.0	.410	13.0	260	......	0	240
July	.386	15	3.0	2.7	.3	.120	4.2	390	35	0	184
August	.426	15	5.2	2.7	2.5	.200	.7	470	158	0	70
Average	.311	15	5.2	2.3	1.3	.180	9.3	295	78	......	179

EFFLUENT FILTER 15 (INFLUENT FILTER 8).

March	0.182	......	......	......	......	......	......	......	......	0	144
April	.185	15	7.2	......	......	0.080	12.0	208	28	0	240
May	.306	15	......	......	......	.070	16.0	205	......	0	240
June	.383	15	3.2	2.4	0.8	.070	12.0	310	......	0	240
July	.383	15	2.7	1.1	1.6	.300	14.0	328	38	0	240
August	.426	15	4.8	3.3	1.5	.220	3.2	450	47	0	107
Average	.311	15	4.5	2.3	1.3	.150	11.4	300	38	......	202

[1] Influent changed to filter 3 June 22.

These results indicate a wholly satisfactory effluent, and they were further confirmed by the physical condition of the filters observed during operation.

The highest average suspended solids content was 32 p. p. m., obtained from filter 5-S, and this figure includes results obtained during February and March, before routine operation was well established. It seems safe to say that in a permanent plant, a uniform effluent could be obtained from secondary sand filters with about 25 p. p. m. suspended solids.

Oxidation had progressed sufficiently to warrant a stable effluent, the nitrates at times averaging as high as 36 p. p. m., as during May for filter 7. With the increased rate and the concentration of spent tan during August, this constituent, as would be expected, dropped to a much lower figure; but in only one filter, No. 16, did the results drop below 1 part per million. In this connection it should be stated that the results given for August were obtained from the analysis of three sets of samples for nitrates covering five days, and two sets covering four days for all other results.

The oxygen consumed which was, with few exceptions, well within safe limits, also showed the effect of the additional spent tan, but in this case also the worst effluent obtained would admit of disposal by dilution even where the dilution factor was comparatively low. The same may be said of the stability values for August. While filter 5-S showed a reduction of mythelene blue in but 37 hours with undiluted samples, it is believed that it would have stood the maximum incubation period of 240 hours, with a dilution as low as 1:1.

A comparison of the August results in the above table with those shown in Table 18 for November, 1915, gives an indication of the value of the preliminary treatment of the spent tan with lime sludge. The concentration of spent tan during both months was approximately the same, 1:2.9:6.2 or 1:9.1 for November, and 1:3.4:4.8 or 1:8.2 for August, but the rates were two to four times as high, so that an average of about three times as much spent tan was applied to the filters during period 5 as period 3. Even so, however, stability results during period 3 were obtained with a dilution of 1:9, while in period 5 no dilution was necessary.

There is a decided drop in the total organic nitrogen results in filter 5-S for the average between May and June and the other filters between April and May. While this drop was not so pronounced in the daily results, nevertheless it is sharp enough to assume that oxidation developed very rapidly when started. During February and March there was only a trace of nitrates in the effluents of filters 5-S and 7, but beginning in April there was an increase to 25 and 26 parts, respectively, and in May, with the nitrates increasing, the organic nitrogen dropped from 57 to 15 p. p. m. in

5–S, and from 29 to 8 in filter 7. The same general relation existed in filters 15 and 16 during this time. The coincidence of the change for the values of total organic nitrogen and nitrates in April and May and the continued high values for nitrates in May show the effects of warm weather on the rate of oxidation. The low figure for the nitrate results for August was due to an increase in the amount of spent tan liquor, but as the amount added at this time represented a fair average for the year, it seems reasonable to assume that the effluent from the sand filters ought not to fall below the results for August.

To confirm the excellent results obtained from sand filter 7 (9 square feet in area and 3½ feet deep), in a large filter, No. 5–S was constructed with an area of 25 square feet, and 5 feet deep. The effluent from the deeper filter was not as satisfactory as was anticipated; in fact the analyses for the first two months showed lower oxidation than the shallower filter. The only difference in the two beds besides the areas and depths was that the sands were obtained from different sources. To learn how far the difference in the sand might affect the results, filters 15 and 16 were installed. They consisted of two 12-inch sewer pipes filled to a depth of 2 feet with the same grade of sand and received the effluents from filters 8 and 5–C, respectively. The rates on these small filters were accurately controlled by catching the influent in a graduated cylinder over a definite period of time every hour.

A comparison of the average monthly results for the periods during which the three different depths of filters were in service is interesting. Filter 7 gave uniformly good results from the beginning. Filter 5 did not develop nitrification to any extent until after several months of operation, while filters 15 and 16 gave excellent results immediately after being put in operation and continued to give a satisfactory effluent throughout the test. The two shallow filters received settled waste during 10 hours, while 7 and 5–S were dosed during the entire 24 hours. The evident conclusion to be drawn from the results obtained from the operation of all the sand filters is that a shallow bed of sand gives better results than a deeper bed. This subject is discussed further in the conclusions.

The early attempts to purify each waste separately proved conclusively that the spent tan liquors were too concentrated for treatment in filters; the lime waste from washing the hair contained so much lime that the sludge could not be removed from the tanks except by shoveling it out, and the beam house wastes contained so much coarse material that it was difficult to remove the sludge through a 4-inch pipe. During the last period, February 3 to August 15, 1916, all the above wastes were mixed together to overcome the difficulties that had been encountered in treating each one separately.

From an operating standpoint the combination worked out admirably. By treating the spent tan liquor with lime sludge and diluting it with the other wastes, to which ferrous sulphate was added, the concentration was reduced so that a stable effluent could be obtained, and at the same time a sludge was produced that readily flowed through a 4-inch pipe under a 4-foot head and dried on drying beds to a spadable condition much quicker than that obtained during any of the previous periods.

THE VOLUME, ANALYSIS AND DISPOSAL OF SLUDGE.

In the treatment and disposal of concentrated industrial wastes, which contain large quantities of suspended solids, the disposal of the sludge is of extreme importance. Throughout the tests at Luray frequent measurements were made of the sludge deposited in the tanks. Samples were taken and chemical analyses made, including the specific gravity and moisture content.

Tests were made to determine the feasibility of drying the sludge, as removed from the tanks, to such a condition as to permit economical handling. The necessary degree of moisture reduction and duration of the drying period were thus established sufficiently close to use in the design of permanent units. Investigations were also made to study the value of the sludge as an ingredient or filler for fertilizers. These studies consisted of field tests, on a small scale, using the sludge as a fertilizer in growing various grains, etc. Samples of the sludge used in the growing tests were analyzed for those constituents which are of value as a fertilizer.

VOLUME AND ANALYSIS OF SLUDGE DEPOSITED.

Sludge deposited in tank A.—During the time when tank A was operated, treating the leather wash or diluted tan liquor from the revolving wash drum, three satisfactory sludge measurements were obtained. These results are tabulated in Table 29.

TABLE 29.—*Sludge deposited in tank A—Treating spent tan and leather wash liquors.*

	Period (1915).		
	Jan. 7 to Feb. 13.	Feb. 13 to Mar. 8.	Apr. 14 to Aug. 9.
Volume of waste treated (thousand gallons)	.1	60.6	205.1
Sludge accumulated (cubic yards)	.89	.37	2.48
Sludge accumulated (cubic yards per million gallons)	9.5	6.10	12.10
Per cent water		74.60	82.40
Specific gravity		1.07	1.07
Dry solids (tons per million gallons)		1.40	1.92

The weighted average of the three values for the volume of sludge deposited is 13.1 cubic yards. Compared with sewage sludge, this sludge is of low moisture content, and consequently of high specific gravity. In physical characteristics, this sludge was smooth to granular, and free from gas. The color resembled that of chocolate, and the odor was the inoffensive odor of tan bark.

Sludge deposited in tank B.—Several attempts were made to measure the volume of sludge deposited in tank B, treating spent tan from the rocker pits, but in no case was any measurable quantity found.

Sludge deposited in tank C.—The operating schedule of tank C admitted of complete and satisfactory sludge measurements. The results obtained during the period when this tank was a separate unit, before being placed in series with tank D, are shown in Table 30.

TABLE 30.—*Sludge deposited in tank C while operated as a separate unit.*

Type of waste treated—	Periods (1914–15).			
	Dec. 16 to Jan. 5.	Feb. 13 to Mar. 8.	Mar. 8 to Mar. 26.	Apr. 10 to June 2.
	Hair washing.			H.W., S.T.[1]
Volume of waste treated (thousand gallons)	112	118	74	115
Average suspended solids, influent (p. p. m.)	887	751	720	566
Average suspended solids, effluent (p. p. m.)	531	555	578	192
Suspended solids removed (p. p. m.)	356	196	142	374
Suspended solids removed (tons per million gallons)	1.48	.82	.59	1.56
Sludge accumulated (cubic yards)	3.22	2.25	.70	8.14
Sludge accumulated (cubic yards per million gallons)	28.7	19.1	9.5	70.8
Per cent water	[2] 88	[2] 88	[2] 88	92.3
Specific gravity	[2] 1.05	[2] 1.05	[2] 1.05	1.03
Dry solids accumulated (tons per million gallons)	3.05	2.03	1.01	4.74
Ratio of dry solids accumulated to suspended solids removed.	2.0	2.5	1.7	3.0

[1] Hair washing, spent tan from rockers.
[2] Computed from analyses of sludge at different depths in tank.

In respect to the sludge deposited, as recorded in cubic yards per million gallons, the results show even wider variations than for tank A. Referred to a dry solids basis and compared with the suspended solids removal, there appears more uniformity. On the average, the sludge accumulated represents 2.3 times as much dry solids as the suspended solids removal figures show. The extremes included in this average are 1.7 and 3. Analytical errors can not account for this difference. The most logical explanation for the difference noted in the table is that the free lime in solution was precipitated as calcium carbonate in the tank and thereby added sludge which was not indicated by the suspended solids in the influent.

During the period when hair wash was treated alone, in which period the first three columns of the above table are included, the sludge was heavy and of comparatively low moisture content. It became compacted in the bottom of the tank and was very difficult to remove. In fact, at one time, April 10, it was necessary to cut a hole in the side of the tank and remove the sludge by shovels. This sludge was grayish in color from the lime; it was for the most part homogeneous and smooth, but contained a large amount of hair, which frequently was matted together in stringy lumps. With these exceptions the mass of sludge was granular. There was very little gas and practically no odor, what little there was being inoffensive.

Shortly after the last run was begun, spent tan was added to the hair wash, which resulted in a sludge entirely different from that previously obtained. This sludge was chocolate-brown in color, from the tan liquor, and streaked with veins of grayish-white lime sediment. It ran freely and was for the most part free from lumps, though there were present small stringy masses, held together by matted hair. The odor was putrid, resembling sour tan, and quite offensive. As is shown in the table, the moisture content was considerably higher, due to the addition of the spent tan. The volume of the deposit, 70.8 cubic yards per million gallons, is too large to be accepted on the basis of one run. The actual amount deposited was probably nearer that computed from the difference between the solids in the influent and that in the effluent.

Sludge deposited in tank D.—During the period covered by Table 30, tank D was operated as a separate unit, treating the beam-house waste. The sludge record for this waste is shown in Table 31.

TABLE 31.—*Sludge deposited in tank D while operated as a separate unit.*

[Type of waste treated, beam-house waste.]

	Period (1914-15).			
	Oct. 16 to Jan. 5.	Jan. 5 to Jan. 15.	Mar. 26 to May 3.	May 3 to June 2.
Volume of waste treated (thousand gallons)	79.3	41.0	70.4	91.2
Average suspended solids, influent (p. p. m.)	1,024	804	686	844
Average suspended solids, effluent (p. p. m.)	720	562	408	492
Suspended solids removed (p. p. m.)	304	242	278	352
Suspended solids removed (tons per million gallons)	1.27	1.01	1.16	1.47
Sludge accumulated (cubic yards)	1.44	.82	.93	1.40
Sludge accumulated (cubic yards per million gallons)	18.2	19.9	13.2	15.4
Per cent water	86.9	86.9	86.7	87.0
Specific gravity	1.044	1.044	1.053	1.05
Dry solids accumulated (tons per million gallons)	2.10	2.30	1.56	1.77
Ratio of dry solids accumulated to suspended solids removed	1.65	2.28	1.34	1.21

The beam-house waste contained considerable quantities of lime sludge from the unhairing vats. There were also present other heavy suspended solids, such as pieces of fleshings, etc. These are responsible for the high specific gravity and low moisture content shown in the above table. Throughout the four runs the sludge accumulated remained fairly constant, ranging from 13.2 to 19.9 cubic yards per million gallons and from 1.56 to 2.30 tons of dry solids. The ratio of the sludge accumulated to the suspended solids removed is again in favor of the sludge accumulated. The same explanation of the difference applies, the free lime in solution having been precipitated as calcium carbonate. Physically, this sludge was smooth and free from gas. It had a uniform dark-brown color, and a slight odor, pungent but not offensive.

Sludge deposited in tanks C and D.—After June 19, 1915, when tanks C and D were connected in series and all three of the principal wastes were treated in combination, the greater part of the sludge, about 90 per cent, was deposited in tank C. From August 18, 1915, to August 1, 1916, approximately one year, 11 sludge measurements and examinations were made. During this period the ratio of spent tan liquor to hair-washing and beam-house wastes was varied, as will be seen by reference to Tables 11, 15, 19 and 23. The average results of these measurements, together with certain analytical data on the influent and effluent wastes, are recorded in Table 32. These results are by far the most important obtained, as they represent the treatment best suited for purifying wastes from tanneries similar to the one where the tests were made.

TABLE 32.—*Sludge deposited in tanks C and D in series.*

Total volume of wastes treated (thousand gallons)	1,656
Suspended solids in influent, tank C (p. p. m.)	1,180
Suspended solids in effluent, tank D (p. p. m.)	370
Suspended solids removed (p. p. m.)	810
Suspended solids removed (tons per million gallons)	3.38
Sludge accumulated (cubic yards)	[1] 82.4
Sludge accumulated (cubic yards per million gallons)	[1] 49.7
Per cent water	91.0
Specific gravity	1.039
Dry solids accumulated (tons per million gallons)	[1] 3.95
Ratio of dry solids accumulated to suspended solids removed	1.17

The average values show about 1.17 times as much sludge accumulated as is estimated from the suspended matter determinations, the minimum ratio for one month having been 0.83 and the maximum, 1.62. Taking the average of the dry solids content in the sludge accumulated in tanks C and D to be 3.95 tons per million gallons of waste treated, with 91 per cent of water and a specific gravity of 1.04, there would be deposited 50 cubic yards per million gallons, or about 5.3 cubic yards per day, from the total daily flow of this tannery of about 106,000 gallons. On the basis of the average number of hides tanned per day, 275, the amount of sludge deposited per 100 hides would be approximately 2 cubic yards. Several analyses more com-

[1] 89.6 per cent in tank C, 10.4 per cent in tank D.

plete than those contained in the above table were made of the sludge from tank C. These analyses were made to determine the fertilizer ingredients, and are included with the discussion of tests made to determine the fertilizing value of the sludge. (See Table 35.)

Sludge deposited in the tan-liquor treatment tank.—In the treatment of the spent tan with lime sludge preliminary to its mixture with the hair wash there was produced a large volume of sludge. This tank in which the sludge settled out was comparatively small, having a capacity of but 885 gallons. This was filled with spent tan, lime sludge added to it and thoroughly stirred, and the precipitate allowed to settle overnight. On certain typical days the residual sludge was measured and analyzed for moisture.

The record of these measurements and analyses is given in Table No. 33.

TABLE 33.—*Sludge deposited in the tan-liquor treatment tank.*

	Date (1916).					
	Feb. 1.	Feb. 5.	Feb. 10.	Feb. 15.	Feb. 19.	Weighted average.
Pounds of lime sludge added	24.6	55.3	75.0	55.3	55.3	....
Per cent of water in lime sludge	49.2	41.6	50.6	53.0	52.8	....
Volume spent tan treated (gallons)	591	885	885	885	885	....
Lime sludge used, dry basis (grains per gallon)	126	182	300	232	231	....
Sludge accumulated (cubic feet)	23.17	18.54	41.71	27.80	20.85	....
Sludge accumulated (cubic yards per million gallons)	1,450	780	1,750	1,160	880	1,190
Per cent water	....	97.0	96.9	95.7	....	96.5
Specific gravity	....	1.024	1.024	1.001	....	1.016
Dry solids (tons per million gallons):						
Deposited as sludge	....	....	....	....	....	35.6
Added as lime sludge	....	....	....	....	....	15.4
Removed from liquor (difference)	....	....	....	....	....	20.2

As would be expected, the variations in the composition of the spent tan caused large differences in the volume of sludge deposited. The weighted average of the five results gives about 1,200 cubic yards of sludge, containing 35.6 tons of dry solids per million gallons. A permanent plant to treat all the wastes of the tannery would have to care for 14,000 gallons daily of spent tan liquor under present operating conditions, so that the sludge accumulation would amount to 16.7 cubic yards a day. With larger tanks for the spent-lime sludge treatment in which the resulting sludge could be held till it had become more dense, or if this sludge were mixed with that drawn from the main settling tank, it could be brought to a water content of about 90 per cent and a specific gravity of about 1.04. This would reduce the volume of sludge from 16.7 cubic yards to about 5.7 cubic yards per day, or approximately 2.1 cubic yards containing 364 pounds dry solids per 100 hides tanned.

This sludge when drawn from the tanks was thin, had a light chocolate-brown color, was homogeneous and flocculent, and flowed readily through a 2-inch pipe. There was a faint tan-bark odor to the sludge when first drawn, but at no time during the drying period did offensive odors develop.

SLUDGE DRYING ON OPEN BEDS.

To determine the length of time required to dry the sludge from the various settling tanks it was drawn to beds prepared, as already described, and the time required for the sludge to dry to a spadable condition was recorded.

Table 34 gives the results of these tests upon sludge from the tanks during different periods of operation and under various kinds of weather conditions.

TABLE 34.—*Results obtained by drying sludges on open beds.*

Test No.	Source tank.	Date applied.	Volume applied (cubic feet).	Number of days drying.	Percent water.
1	D	1915. Mar. 27	228	0	86.0
				2	82.0
				4	80.6
				5	79.9
				7	77.8
				9	76.1
2	C	Apr. 9	128	0	85.8
				5	[1] 85.4
				8	82.0
				11	79.5
3	C	Apr. 10	128	0	[2] 75.5
				7	71.6
4	A	Apr. 15	93	0	82.4
				2	79.7
				7	75.0
5	D	May 3	122	0	....
				2	86.0
				4	83.2
				7	80.1
6	C	June 2	96	0	92.3
				7	67.0
7	D	1915. June 2	117	0	90.6
				7	75.0
8	D	Aug. 16	132	0	93.6
				4	87.0
				7	82.8
9	C	Aug. 17	305	0	92.2
				3	89.5
				6	86.0
10	C	Sept. 25	260	0	92.3
				3	90.6
				17	81.3
11	C	Oct. 16	183	0	90.8
				6	[1] 90.8
				11	85.0
12	C	1916. Jan. 20	210	0	92.4
				5	85.2
13	C	Feb. 28	151	0	94.5
				4	[3] 89.2
14	C	Apr. 28	141	0	91.9
				10	69.2

[1] Wet weather—rain or snow.
[2] Heavy lime sludge; had to be shoveled out through hole cut in tank.
[3] Cold and snow.

The first seven runs recorded in the above table were made during the time when each waste was treated by separate devices. For most of them the water content of the applied sludge was appreciably lower than when the wastes were treated in combination and contained much of the flocculent precipitate formed by the reaction between them. The water content of the sludge of the combination treatment averages about 92.5 per cent. It is probable, however, that in larger tanks this could be reduced to about 90 per cent.

With 5.3 cubic yards of sludge daily from the tanks in which the combined wastes are treated, and 5.7 cubic yards from the tank in which the spent tan is given preliminary treatment with lime sludge, it would be necessary to handle 11 cubic yards of sludge daily in the operation of a plant caring for the entire waste from the tannery.

Considering the results obtained during the winter months of January and February, it would seem safe to assume that sludge beds at Luray, Va., could be used the year round, and that even during the winter months 20 days would suffice to reduce the wet sludge to such a state of dryness that it would be practical to remove it with shovels and haul it away in the same type of wagon that is used for hauling manure. With a daily deposit of 11 cubic yards, and allowing a period of 20 days between doses, the total sludge to be taken care of at each dose would be about 220 cubic yards. Applied to a depth of 12 inches, there would be required 5,400 square feet of sludge bed area or a bed 74 feet square. This drying treatment would bring the sludge to a condition in which it could be spaded and shoveled into wagons for final disposal.

There is also the possibility at this tannery of handling the sludge in tank wagons without preliminary drying. A plant could be designed whereby the sludge would flow directly from the tanks into a wagon, and in the tests that are to be continued at the tannery it is planned to compare the cost of hauling the sludge direct from the tanks as drawn with that of drying it on beds, removing it, and hauling the dried sludge to the farm.

DISPOSAL OF SLUDGE AS A FERTILIZER.

The Deford Co. have had in use for several years two settling ponds, one 100 feet and the other 65 feet in diameter, for removing the solids from their wastes. They are used alternately, one being in operation while the other is drying and being emptied. The company owns a large farm on which all the sludge from the ponds is utilized, and the results have been so satisfactory that their farm is producing more and better grain than any of the land adjoining. They have found it valuable not only for growing grain and hay but in mulching apple and peach trees, of which they have several thousand, all in excellent condition.

To determine the comparative value of the sludge taken from the settling tank in growing grain with and without the sludge, a strip of clay ground was prepared containing several areas of 20 square feet each. The plots were planted in wheat, corn, and oats. Six plots were devoted to the wheat and oats, four of which had fertilizer added, the remaining two being controls. The fertilizer was added to the hills of corn, one plot being used. The plants in each of the beds came up at about the same time, but at the end of two weeks the fertilized hills showed stronger growths and from that time on maintained a better growth, but unfortunately an extremely dry season set in and even with watering the wheat and corn did not develop to maturity. The oats were not affected to the same extent as the wheat and corn and the results showed an increase of 30 per cent in the fertilized plots. A picture taken early in the summer, reproduced in Plate III, shows the difference in growth of the corn, the unfertilized rows being on the end and the fertilized hills in the middle. The amount of dry fertilizer used on an acre basis was 3½ and 4½ tons, but the discussion above refers only to the larger quantity as it was on the plots using this amount that the best results were obtained.

There is no doubt as to the value of the solids removed from tannery wastes as a fertilizer, especially for clay ground. Compared with ordinary manure fertilizers they rank higher than stable manure, pound for pound of dry material, in all the essential constituents except potassium, and the presence of the calcium carbonate in the tannery sludge is a distinct advantage. The following analyses of sludge show the complete results of several determinations and in addition an analysis of horse manure taken from Ohio Agricultural Experiment Station Bulletin No. 246, page 726:

TABLE 35.—*Analyses of sludge removed from tank C and one analysis of horse manure.*

Date of analysis.	Source.	Per cent dry basis (100° C.).					
		$CaCO_3$.	N.	P_2O_5.	K_2O.	Iron as Fe.	Ether soluble matter.
Nov. 16, 1915	Tank C	36	3.5	0.82	0.56	1.3	
Do	do	34	4.0	.57	.49	1.4	
Mar. 2, 1916	do	23	2.4	.47	.22		2.6
Apr. 28, 1916	do	22	2.8	.48	.38	1.3	2.6
May 27, 1916	do	22	2.6	.43	.38		2.6
June 30, 1916	do	29	2.5	.72	.10		
Do	Spent tan, lime-treated sludge	33	.95	.52	.27		
Nov. 6, 1915	Horse manure, including litter [1]		1.7	.26	1.50		

[1] Ohio Experiment Station Bulletin 246, Table I, p. 726.

The figures given in the analyses above for tank C cover a period of operation extending from November 16, 1915, to June 30, 1916, and give a very fair average for the composition of the solids in the waste over an extended period. In comparison with horse manure such as is obtained from the ordinary horse stable the average of tannery sludge results shows almost twice as much nitrogen, and more than twice as much phosphate, but only about one-fourth as much potassium. In addition there is a high percentage of lime which most land requires unless it lies directly over beds of limestone.

There is always a small amount of hair present in the sludge, which it is impossible to remove, so it is not likely this material will find a ready market as a filler for commercial fertilizers, but there is a possibility of a market being developed in the neighborhood where the tannery is located. In some comparative tests to determine the value of different kinds of fertilizers the Ohio Agricultural Experiment Station, in Circular No. 96, recommended the use of 6 tons of yard manure per acre every four years and the tests showed that with the addition of lime to the manure there was a good return over the cost of applying the lime and manure. Using these tests as a basis and considering the lime already present in the waste, the solids from a tannery settling pond or disposal plant will be at least equal to the value of manure.

The results given in the table showing the chemical composition of the spent tan, lime-treated sludge indicate that this material does not contain as much of the common fertilizing ingredients as the sludge from the mixture of all the wastes. The lime, reported as calcium carbonate, was the excess added to the spent-tan liquors, and the large amount found shows quite plainly that it will be necessary in large plant installations to mix water with the sludge from the liming vats to form a water suspension before adding it to the spent tan liquors. In the tests the lime sludge was taken from a large pile and stirred in with the spent liquors by hand without forming a suspension in water, and it is evident that more lime was added than was necessary.

WASHING FILTERS.

Up to the beginning of period 3 the filters which had continued in operation to this time had been in service more than a year, a part of the time at high rates, and as a result they were badly clogged. To learn how much of the solids collected in the filters could be removed by flushing the beds with water, arrangements were made with the tannery on September 1, 1915, to use water from their fire protection pumps for washing the filters.

Filter 3, filled with cinders screened to remove the dust and fine particles, was flooded with water for 1½ hours. The first washings were dark-colored, contained a large amount of black particles, and had a slight odor which existed only when the first water came through. At the end of the washing period there was no sediment in the water and no color. The voids in the top layer of cinders 1 foot down were practically free and, as the bed was flushed from the bottom for a few minutes at the end of the washing period and showed no suspended matter, it seems safe to assume that the bed was restored to its original condition by washing. This bed was operated for almost a year after this period without showing the same amount of clogging that took place up to this time and the inference is that the suspended matter in the influent following period 3 was in better condition for storing and unloading. The material in the cinder beds should be washed once a year, and the wash water either settled in separate tanks or pumped back into the main settling tank.

Filter 4 (sprinkling filter) had received the settled effluent from the hair-washing machine for a long time previous to period 3 and had become so clogged with hair and incrustations on the hair and stone that washing out the clogging material became a very difficult matter. To open up holes through the upper 6 inches required a full stream through a 1¼-inch hose under 60 pounds pressure. While flooding was sufficient to clean out filter 3, it required the full force of the nozzle pressure to clean this filter. After 1¾ hours washing this bed was practically free of clogging material. The evidence obtained during the washing of this filter shows conclusively that waste containing large amounts of hair and caustic lime can not be treated on sprinkling filters on account of the incrustations. Filter 3, treating the hair-washing waste over a longer period than 4, did not show the same amount of clogging.

Filter 5 (coke, ¼ inch) was flooded for 1¼ hours with water, and all the material in the voids of the filter were washed out in this time. The even size of the coke permitted a downward flush that carried most of the solids away in the first few minutes, but in order to start the filter in period 3 as free as possible from the accumulation of former periods the washing was continued for 1¼ hours.

Filter 8 (coke, ¼ inch) was washed in the same manner as 5, and the results were the same. The washing was continued for one hour, but 90 per cent of the solids were removed from the bed in the first 15 minutes.

From observations made at the time the filters were washed it was evident that it will be practical and perhaps necessary to flush out cinder filters with water once a year. The time the filters were treated with water was much longer than will be required in practice, as at that time it was desired to get the filters in as near their original condition as possible for a new period. Early in the spring will be the best time to wash the filters, as the oxidation within the beds is lowest in the cold months and therefore the accumulation of solids is greatest, and when life first begins to stir in the deposit it can be more easily detached from the filter medium.

At the close of the tests all the filters in service were examined to determine the extent of clogging. Filter No. 3 had an appreciable amount of finely divided, dark-brown deposit below the surface for about 6 inches, and below that a constantly decreasing amount to the bottom. There was no surface clogging. In the middle of the bed there was some odor, enough when considered with the deposit to assume that this bed was working up to capacity, but with washing once a year not beyond its capacity. Filters 5–C and 8, in operation a little less than one year, did not show the same amount of clogging as No. 3, but in a general way the condition of these filters can be said to be the same as No. 3. When dismantled all the filters had earthworms and other forms of small worms and bugs scattered throughout the upper half of the beds. In the spring and early summer worms and bugs were much more in evidence than during the period when the filters were examined at the close of the tests.

The summarized conclusions from this portion of the investigation will be brought together in another portion of this report, in order that the detailed results of the other branches of the investigation may first be presented and the conclusions considered as a whole.

CONTINUATION OF TESTS IN A LARGER UNIT.

There are certain features of the problem of purifying tannery wastes that can not be definitely determined with small test units. The general principles upon which the design of a treatment plant could be made having been established, it seemed advisable to verify the results in a full-scale plant before deciding definitely upon the best type of settling tank, the necessary depth of the filters, and the most advantageous rate of filtration.

DESCRIPTION OF PLANT.

A preliminary unit for the treatment of 10,000 gallons per day of combined waste was therefore constructed at the Deford Co.'s plant at Luray, Va., by the Deford Leather Co., the Leas & McVitty Co. of Salem and G. R. Cover & Sons of Elkton, Va. Its design was based upon the results obtained in the experimental tests. It consisted of the following devices:

(1) Storage tanks for the spent tan liquors. These wastes were discharged at night and duplicate tanks were required to hold the spent liquors over for treatment during the entire 24 hours. Each tank was 10 by 6 by 3½ feet deep, and there was a dosing apparatus, consisting of float valve and controlling valves, attached to the outlet piping from the tank. These tanks were also used for treating the spent liquors with the lime sludge from the unhairing vats. The bottom of each tank sloped to a sludge outlet pipe.

(2) Two tanks, each $1\frac{1}{2}$ by $2\frac{1}{2}$ by 2 feet deep, were constructed for storing and applying the ferrous sulphate solution to the waste. There was installed the necessary float and valves for controlling the amount of iron solution added to the waste.

(3) A settling tank, 20 by 8 feet by 11 feet deep, was provided for removing the settleable suspended solids. There were provided three 6-inch sludge outlet pipes, and the bottom of the tank was sloped to concentrate the sludge near these pipes. There was one scum baffle across the tank midway between the inlet and outlet pipes. The inlet to the tank was a trough across the tank at the top and the outlet was a 2-inch pipe extending through the end wall, 6 feet 3 inches below the top of the tank. A float valve attached to the end of this outlet pipe controlled the rate on the filters. A baffle wall with a row of 1-inch holes bored through it level with the outlet pipe was set in grooves in the bottom and sides of the tank, 4 feet 4 inches from the end wall, to hold the scum back and to keep the sludge from piling up around the outlet pipe. The level of the waste in the tank is drawn down to within 1 foot of the outlet pipe during the time the tannery is closed down at night.

(4) Siphon box and siphon attached to the outlet from the settling tank to control the rate on the roughing filter.

(5) Roughing filter. This filter is 42 by 30 feet by 4 feet deep. The material comprising this bed is blast furnace slag, varying in size from $\frac{1}{2}$ to 2 inches, the coarser material predominating. The total depth of filtering material is 4 feet, and the total depth of the bed, including the tile and coarse stone underdrainage, varies from 5 feet at the outlet to $4\frac{1}{2}$ feet at the opposite side of the bed. The waste is applied to the bed by means of troughs on the surface. Cinders would have been preferable for this filter, but they could not be obtained within reasonable distance of Luray, and the slag, which was available within 30 miles of the tannery, was substituted. The slag was porous and there was sufficient small material in it to retain the solids in the waste.

(6) A siphon chamber and box were installed to receive the waste from the preliminary filter and apply it to the sand filters.

(7) Sand filters. Three filters were constructed, each 14 by 30 feet in area and 2, 3, and 4 feet deep, respectively. The beds were separated at the surface by 2-inch planks nailed to posts set on the dividing line. The waste is applied by troughs set on the surface of the beds and supported on posts, and the amount each bed receives is measured by weirs in the box receiving the discharge from the siphon. The sand used has an effective size of 0.4 and a uniformity coefficient of 1.05. The underdrainage, consisting of farm tile covered with approximately 8 inches of coarse and fine stone, is not included in the depths of the beds given above.

(8) Sludge beds were not included in the original design, but will be installed later.

RESULTS.

This plant was put in operation July 15, 1917. Unfortunately it was necessary to discontinue the scientific supervision of this investigation in favor of more important war activities. The plant was therefore placed in charge of an attendant, and has been operated continuously to date, January, 1919.

Five sets of composite samples were analyzed during July and August, 1917, and during the last four months of 1918, a series of 10 composite samples were sent to Washington and submitted to partial examination. The results are shown in Table 36. It is apparent that the plant is capable of continuous satisfactory operation under such management as is readily possible at any tannery.

TABLE 36.—*Analytical results of treatment on large unit.*

[Parts per million.]

	Sedimentation basin.		Cinder filter.	Sand filters.		
	Influent.	Effluent.		2-ft.	3-ft.	4-ft.
Average of five sets of composite samples, July, August, 1917:						
Suspended solids	1,800	400	220	76	72	71
Nitrogen, organic and ammoniacal	100	100	56	17	15	16
Nitrate and nitrite	....	....	....	5.6	7.5	9.1
Alkalinity (bicarbonate)	1,000	970	830	820	800	840
Oxygen consumed (30 minutes at 100° C.)	1,600	820	310	66	66	62
Biological oxygen demand (24 hours)	....	....	230	3.5	3.5	10.0
Stability by methylene blue—						
Dilution	....	1:30	1:20	0	0	0
Hours to decolorize	....	90	180	121	121	141
Color	....	....	190	83	70	73
Average of 10 sets of composite samples, September-December, 1918:						
Suspended solids	1,240	412	308	30	20	43
Oxygen consumed (30 minutes at 100° C.)	1,755	1,095	605	155	140	150
Biological oxygen demand (24 hours)	....	....	235	21	17	15

PART II.

EXPERIMENTS AT HAFFNER BROS. TANNERY, CINCINNATI, OHIO.

The results given in the preceding section of this report were obtained from studies made at a tannery producing as its principal product belting leather. There are, however, many other grades of leather made where the same kinds of raw material are used and the processes of manufacture are similar, but differing in certain details, depending on the quality desired in the finished product. Sole-leather tanneries, for example, must produce a leather than will stand the heavy friction of walking, while belting leather must be pliable and firm. Harness leather has other distinctive characteristics. These various grades of leather are often made in the same tannery, and as the processes of manufacture are practically the same, it would be expected that the wastes produced would also be similar. There was, however, so much skepticism among tanners on this point that it seemed advisable to repeat the tests conducted at the Deford Leather Co., Luray, Va., at another tannery where similar raw materials were used but a different grade of leather made. The Haffner Bros. Tannery, located convenient to the laboratories of the United States Public Health Service in Cincinnati, make harness leather, and although the wastes from this tannery are discharged into the city sewers and will not require treatment, the owners were sufficiently interested in the subject of tannery wastes' purification to cooperate in further studies at their tannery. A testing station was, therefore, designed on the basis of the data obtained at the Deford Leather Co., and constructed at the Haffner Bros. Tannery a few months before the Luray tests were completed.

RÉSUMÉ OF RESULTS OBTAINED AT THE TESTING STATION OPERATED AT THE HAFFNER BROS. TANNERY, CINCINNATI, OHIO.

The location of the tannery in Cincinnati was not as favorable for conducting tests as that of the Deford Co. at Luray, Va. At the latter place the wastes were discharged from the tannery in different outlets, and there was sufficient fall between the outlets and the ditches and pond receiving the wastes to operate the various tanks and filters by gravity flow. At the Haffner Bros. Tannery all the wastes are collected in a manhole under the hide house in the rear of the tannery, and from there discharged through a 12-inch sewer into a manhole in the city sewer in the street, about 50 feet away. It was, therefore, necessary to remove a portion of the tannery sewer, install a pumping box, weir, and connections, and pump the wastes required for the tests.

The total volume of wastes discharged was measured by a weir set in a box in the sewer line, and the volume of the individual wastes was determined from the capacity of the tanks emptied or by measuring the discharge from those processes where there was a continuous flow. The total average daily volume of waste discharged from August, 1916, to August, 1917, was 58,400 gallons. The average number of hides tanned daily for the period given above was 165, and the number of gallons of waste per hide was 350. In the tests made at the Deford Leather Co.'s Tannery the average number of gallons discharged per hide tanned daily was 385. The proportion of the wastes discharged from different processes at the two tanneries, however, showed more variation. From the beam house at the Haffner Bros. Tannery there were discharged 235 gallons per hide tanned; from the unhairing machine 55 gallons; from the rocker pits 20 gallons of spent tan liquor; and from the revolving drum used for rinsing the tan liquor off from the hides when removed from the lay-away yard, 40 gallons. The corresponding volumes discharged from the Deford Co. were: Beam house, 238 gallons; hair washing or waste from unhairing machine, 86 gallons; spent tan liquors from rocker pits, 40 gallons; rinse water from hides removed from lay-away yard, 21 gallons. The only significant variation is the difference in strength and volume of the spent tan liquors from the rocker pits. This subject is discussed in detail later on in this report.

All the wastes were treated in the proportion in which they were discharged from the tannery throughout the tests, except for two periods; one in August, when the plant was started in operation and the ratio of the spent tan liquor treated to the other wastes was less than the discharge ratio from the tannery; and the other from March 24 to April 19, 1917, when no tan liquors from the rocker pits were treated. Ferrous sulphate was also added to the wastes at the rate of 10 grains per gallon throughout the period of the tests, except for the interval between February 1 and 16, 1917, when no iron solution was added.

The storage period in the settling tank, computed on a displacement basis, was 4 hours, but the actual detention was about two hours, as determined by the length of time required for dye solutions to pass through the tanks. The determinations made with the Imhoff settling glasses indicated that all the solids that would settle out of the influent were removed at the end of two hours, and in the analyses of the effluent from the tanks it was found that the settleable solids were reduced 95 per cent. In large installations the tanks can be designed with a lower velocity of flow than was possible to accomplish in the test tank, and a higher per cent removal than 95 for the settleable solids may be obtained. More waste was settled in the tanks than was used on the filters, as it was desired to treat sufficient waste in the tanks to obtain a large volume of sludge for measurement, and treatment on drying beds. The outlet from the settling tanks to the filters was at such an elevation that enough wastes were stored in the tanks during the daytime to operate the filters during the 14 hours the tannery was closed down each day.

No difficulty was experienced in removing the sludge from the settling tanks through the 4-inch sludge line. The sludge dried on sand beds to a spadable condition, under average weather conditions, in 20 to 25 days.

Two roughing filters were operated, one filled with cinders screened over a one-half-inch screen, and the other filled with coke averaging in size about one-half inch. The first one is referred to in the text as filter 3, and the second as filter 4. Each filter was 5 feet deep exclusive of the underdrains. No changes of any kind were made in these filters throughout the tests. They were, however, covered with straw during the winter of 1916–17, and they were washed with water twice during the time they were in operation. The rates were the same for both filters, the influents were from the same settling tank, and as far as possible they were operated in the same manner in every way. The cinder filter, however, gave more satisfactory results, and the sand filter receiving the effluent from the cinder filter gave better results than the one receiving the effluent from the coke filter. The weighted average results of the operation of these two filters are given in Table 37, which is a summary of Tables 45 and 46.

TABLE 37.—*Comparative results, coke and cinder filtration of settled tannery waste.*

[Weighted averages; analytical values in parts per million.]

	Cinder filter.	Coke filter.
Nitrate	11.1	3.1
Oxygen consumed	257	329
Biochemical oxygen demand:		
24 hours	42	61
5 days	149	204
10 days	229	313
Stability by methylene blue in dilution of 1:4 (hours to reduce)	99	82
Color	192	261

In explanation of the high nitrification in these filters it should be stated that the results cover only the months of April to December, 1917, when oxidation was at the maximum in the beds. During the preceding winter months there was no nitrate in the effluent.

All the other results cover the period from November, 1916, to December, 1917. (See Tables 45 and 46.)

The difference was apparently not due to the size of the filtering material in the two beds, but rather to the composition. There was a noticeable odor of hydrogen sulphide at the outlet from the coke filter, and the outlet pipe was lined with a growth having the usual whitish opalescent color characteristic of the growths in filters in which hydrogen sulphide is formed. Flushing this filter with water from the top and through the underdrains improved the quality of the effluent for only a short time. There was no odor of any kind at the outlet from the cinder filter, and the growth on the outlet pipe and bottom of the filter was grayish in color without any traces of the white opalescent coloring that covered the underdrainage and outlet pipe from the coke filter. The underdrainage from the two filters was the same, and the examinations made at the close of the tests indicated there was no pooling over the bottom of either of the filters.

The roughing filters were examined at the close of the tests to learn to what extent that material removed by these filters had been retained in the beds and what the condition of this material was. In the upper 2 feet of the cinder filter there was a considerable deposit of wet but not watery solids with an odor somewhat resembling tan liquors. Below this the accumulation was dryer and had the odor of humus although not so pronounced as in sprinkling filters. There were no offensive odors in this filter. In the coke filter, owing to the more open body, a larger proportion of the retained material had worked into the filter and there was a slight odor of hydrogen sulphide near the middle depth. The lower half contained more material than the cinder filter, and it had less the appearance and odor of humus. The physical appearance of the interior of the two beds indicated that the cinder filter was in the more satisfactory condition, but there was not enough difference to attribute the formation of hydrogen sulphide to the difference in the distribution of the suspended matter. It seems more probable that the coke contributed the sulphur.

There was an abundance of small bugs, insects, spiders, and worms in both filters, particularly in the springtime. Small brown spiders appeared at intervals in large numbers, and the little gray fly common to sprinkling filters was present but not in such numbers as are seen about the latter. Earthworms were found only in small numbers, but there were many minute forms of worms. The small white water springtail of the genus Podura was abundant at all times, and they were distributed throughout the beds although most plentiful near the surface. While the same species of organisms were present in both filters, they were far more numerous in the cinder filter.

In all the tests made in the development of methods for purifying industrial wastes there have appeared in the roughing filters large numbers of small organisms, especially in early spring, and coincident with their appearance increased nitrification within the beds developed, as indicated by the analyses of samples of the effluent. It would appear, then, that the characteristic odor of the stored suspended solids in the beds, commonly referred to as resembling humus, is due in large measure to the "working over" of the solids by the myriads of organisms observable with the microscope and with the naked eye on the filtering material.

The roughing filters were covered with a layer of straw, 6 inches thick and supported about 6 inches above the surface of the beds, to prevent freezing of the upper layers. This method proved efficient and inexpensive, and in northern climates it may be required to operate filter plants during the wintertime.

The observations made so far on the operation of filters made of coarse material such as cinders and half-inch coke are that, when operating efficiently, the upper half section of the filter acts as a strainer to remove the suspended matter, and the lower half as an oxidizing medium. This conclusion was formed from the condition of the roughing filters in the two testing stations operated for purifying tannery waste and the cinder filter for treating strawboard waste. In all these filters there was a pronounced difference in the stored organic matter in the upper and lower sections of the beds. Near the surface, after service of six months or more, the suspended matter had the characteristic odor and physical appearance of that in the effluent from the settling tank, while near the bottom the accumulated material was flocculent when suspended in water and smelled more like freshly turned earth high in organic matter.

It was further learned in the operation of these filters that whenever the collection of suspended matter in the upper layers of the filters became so thick that it was forced down below the upper half of the beds, then the effluent deteriorated and offensive odors developed. This condition was avoided by observing the effluent and flushing the filter with water at the surface and through the underdrains whenever the analyses or physical condition of the filtered waste indicated the filter was becoming choked. In large treatment plants it may be necessary to flush the beds in this way twice a year, once in the early spring and again late in the fall.

Two sand filters were operated. One, No. 5, received the effluent from the cinder filter, and the other, No. 6, the effluent from the coke filter. Each of the sand filters contained 5 feet of washed river sand.

The analyses of the effluents from the sand filters show about the same variation from each other as was noted in the results from the two roughing filters. The effluent from filter 5, which received the effluent from the cinder filter, was more satisfactory than that from filter 6, receiving the effluent from the coke filter. The results obtained from the two filters are presented in Table 38, summarized from Tables 47 and 48.

TABLE 38.—*Results on secondary sand filtration, after filtration through cinders and through coke.*

[Weighted averages; analytical values in parts per million.]

	Sand filter.	
	No. 5 (cinder).	No. 6 (coke).
Suspended solids	18	18
Nitrate	15.4	9.9
Oxygen consumed	118	136
Dissolved oxygen (per cent saturation)	23	17.6
Biological oxygen demand:		
24 hours	9	15
5 days	28	44
10 days	53	78
Color	176	218

The rates at which all the filters were operated varied from 200,000 gallons per acre per day for the first three months to 100,000 for the last four. During the intervening nine months the rate averaged about 150,000 gallons per acre daily. It was demonstrated during the first three months of operation that all the wastes could be purified in the proportions in which they were discharged from the tannery at rates on the filters of 200,000 gallons per acre per day. The color of the effluent, however, was very high, and the rates were reduced in an effort to obtain an effluent relatively low in color. Reducing the rate, in November, to 150,000 gallons per acre daily, reduced the color in the case of filter 5 from 400 to 220, and of filter 6 from 410 p. p. m. to 170. Again in August, the color in the effluent of filter 5 was reduced from an average of 113 in July to 92 p. p. m. by lowering the rate to 100,000 gallons per acre daily. In filter 6 there was an increase in the average color for August, but the following months showed considerable reduction.

The results of the chemical analyses of the effluents were entirely satisfactory. During February, March, and April of 1917 the underdrainage of both filters became badly clogged owing to insufficient slope to the bottoms of these filters, and as a consequence the results for the three months are not as satisfactory as the others. During the last five months of operation the biochemical oxygen demand and the color were very low, particularly in the effluent from filter 5. During this period samples taken from both filters and incubated with methylene blue, without dilution, for five days, were not decolorized. The monthly average analyses for filters 5 and 6 are given in Tables 47 and 48.

Practically no clogging took place on the surface of the sand filters, although there was a hardening of the surface layer that required raking with a garden rake to break it up about once every two weeks. A layer of straw 6 inches thick was supported about 1 foot above the sand in each bed to prevent the surface from freezing. This covering was kept over the beds from December 14, 1916, to February 24, 1917. When the straw was removed, the wastes were standing in the furrows made when the covering was placed, to a depth of about 3 inches. Some protection will be required in climates where the winters are severe, to keep the sand filter beds from freezing, especially on Sundays and holidays when the tanneries are closed down. This subject is discussed in detail in the conclusions.

In view of the highly satisfactory results obtained from the sand filters operated at the Haffner Bros. Tannery when treating the wastes in proportion to the flow from the tannery, there would appear to be no further doubt as to the practicability of the method used. At tanneries where the volume and strength of the spent tan liquors discharged are greater in proportion to the other wastes than those at the Haffner Bros. Tannery, there are two courses open to prepare the wastes for the treatment recommended above: The first is to reduce the amount of spent tan liquors discharged, either by evaporating and recovering the strongest of those discharged, or by using them until the strength is reduced; the second is to pump sufficient water to dilute the spent tan liquors so they will be amenable to the system of treatment that has been developed and demonstrated in these studies.

THE PROCESS OF TANNING HIDES AND WASTES PRODUCED.

In order to make the results obtained from the operation of testing stations for treating industrial wastes available for other industries similar to those where studies are made, it is essential to record the processes of manufacture in each case and the volume of wastes produced. Without this information it will be difficult and unsafe to apply generally the results obtained from one manufacturing plant.

THE PROCESS OF TANNING.

The Haffner Bros. Tannery make harness leather from cowhides, and unlike the Deford Leather Co. who make sole leather from the heads and bellies, they make all of the hides into one product. The hides are first placed in tanks of clean water to soak for 24 to 36 hours, depending on their condition, and are then removed and washed for about 15 minutes in running water. They are next placed in liming vats where they remain for five days. At the end of this time the hair sheath has been loosened and the hides are transferred to pools of warm water where they are soaked for 12 hours. The next operation is to run the hides through the unhairing machine, where the hair is removed and washed by jets of water that play over the roller of the machine. They are once more soaked in a pool of fresh water for 12 hours, and when removed they are fleshed and placed in a bate of pigeon manure for 10 minutes and again rinsed in fresh water. The hides are now ready for the tanning process proper.

Tan liquor leached from oak bark at the tannery is used for tanning the leather. After the hides have been fleshed, put through the bate, and rinsed, they are transferred to the rocker pits, where they are first treated with dilute liquor and later with solutions of increasing strength until they have come in contact with the strongest liquors used in the rockers. From the rockers the partially tanned hides are taken to the handlers, where they again pass from the weakest solution to the strongest, and finally they are transferred to the lay-away yard where they remain in strong liquor until the tanning process is completed. About 90 days elapse from the time the hides are placed in the rockers until they are removed from the vats in the lay-away yard.

It will be observed, therefore, that the preparation of the hides for tanning and the tanning process itself are practically the same in principle in this tannery as those used in the Deford Leather Co., Luray, Va., and the description of the apparatus at the latter plant, given in Part I, so nearly applies to the Haffner Bros. plant that no further description will be given.

There are differences, however, in the operation of the two plants that are worthy of mention. At Cincinnati there is no grease rendering at the tannery, the hair is less thoroughly washed, the hides are treated with a bate of pigeon manure, there is no bleaching done, as all the leather is colored before leaving the tannery, and the hides are started in weaker liquors in the rocker pits. This last item is the only significant difference in the operation of the two tanneries as affecting the wastes discharged.

WASTES PRODUCED.

In the operation of the tannery many different kinds of waste were discharged, each with characteristics peculiar to the process producing it. They follow in a general way, however, the classification given in Part I of this report, the differences representing operations not carried on at both tanneries. At Haffner Bros. there are no wastes from bleaching leather, and this company use pigeon manure as bate, which has no counter waste at the Deford Leather Co. The volume of wastes from both these sources is not sufficient, however, to materially affect the problem of treatment. The wastes produced may be briefly described as follows:

Beam-house waste.—The waste from this source is made up of the soak water from the green hides, old limes or exhausted lime solution, and wash water from the floors.

Rinsing water containing no tanning solutions.—There are two sources of wastes included in this division, the first from rinsing the green hides when removed from the soaks, and the second from washing the hides after passing through the unhairing machine.

Waste from unhairing machine.—This waste is made up of the water used to wash the hair off from the unhairing machine.

Spent tan or exhausted tan liquors.—These constitute the weakest liquors in the rocker pits, and include all wastes of this nature discharged from the tannery.

Rinse water from hides removed from lay-away yard. The hides when removed from the lay-away yard are placed in a revolving drum and washed to remove the tan liquor adhering to them. This waste differs from the preceding in that it contains a small amount of strong liquors diluted with a large volume of clean water.

The division of the wastes as given above is more or less arbitrary and is intended only for purpose of comparison with the wastes produced at Luray. In describing the different kinds of wastes produced from the latter plant it was possible to take each waste separately, as it was discharged through a separate outlet, but at Haffner Bros. it was necessary to measure the wastes in the tannery, either in vats or as discharged from the machines.

The beam-house wastes and the rinse water containing no tan liquors are practically the same at both tanneries, but at Luray a continuous running stream of water was used instead of washing in vats with a paddle wheel, as is done at Cincinnati. The waste from the unhairing machine is the same in character from both tanneries, but the Deford Co. wash the hair more thoroughly, and consequently have a larger volume of this waste. Exhausted or spent tan liquors come from the rocker pits in both tanneries, but Haffner Bros. exhaust their liquors to a much greater extent, and the volume discharged is accordingly much less. The rinse water from the hides taken from the lay-away yard is of the same general character from both tanneries, in that each washes off the liquor carried away by the hides on removal from the tan vats. At Luray, however, the excess liquor is rinsed off by sliding the hides backward and forward through clean water in which the hides have soaked overnight, while at Cincinnati the hides are taken from the vats in the lay-away yard, allowed to drain, and rinsed with a continuous flow of water in a revolving drum.

It will be observed, therefore, that the type of wastes produced at these two tanneries is practically the same, but the characteristics or composition vary in those items that are most important in these studies, that is, the wastes containing exhausted or dilute tan liquors.

DESCRIPTION OF TESTING STATION.

LOCATION.

The testing station was located in the rear of the tannery, on property owned by the park department of the city of Cincinnati.

The arrangement of the test units, office, and pump house are shown on Plates 4 and 5. Plate 4 shows a side view of the testing station and the rear of Haffner Bros. Tannery. In the lower left-hand corner of Plate 4 is shown the office, and the building near the fence at the right, with only the roof showing, is the pump house. At the rear of the inclosure is a small building that covered the upper half of the settling tanks, a part of the spent tan storage tank (end projecting on right), weir boxes and controlling devices. This building was heated with an oil stove during severe weather. Immediately in front of the building are the two roughing filters, 3 and 4, and between these filters and the pump house are the two sand filters, 5 and 6. The force main from the pump is shown passing over filter 6 and between filters 3 and 4. In the far corner of the picture, at the left of the building over the settling tanks, are the two sludge beds.

In operation, the waste was pumped into the weir box, measured, and the spent tan liquor and iron solution added as the waste entered the first settling tank. A part of the effluent from the settling tank was treated on filters 3 and 4, and all of the effluent from these filters was applied to sand filters 5 and 6, No. 5 working in series with 3, and No. 6 with 4.

PUMPING EQUIPMENT.

All the wastes from the tannery are discharged into a manhole under the beam house, and the sewer line from the manhole runs under the northwest corner of the tannery to a manhole in the street. This line, running about 12 feet below the level of the ground, was tapped 10 feet from the north wall of the tannery, and four lengths of sewer pipe were removed. A wooden box, 2 feet wide, 4 feet deep, and 8 feet long, was set in the sewer line and connected up with the ends of the sewer pipes where the pieces were removed. The box contained stilling baffles and a weir plate for measuring the discharge from the tannery, and the bottom was 2 feet lower than the invert of the sewer. Above the box a wooden building was constructed 8 feet wide by 10 feet long and 12 feet high. Approximately one-half the building was in excavation. A 2½-inch centrifugal pump direct-connected to a 5½-horsepower gasoline engine was located on a concrete foundation in this building. The pump was provided with a hand primer, and no foot valve was required. The suction lift was 6 feet, and the discharge head 25 feet.

SETTLING TANKS.

Two circular wooden tanks were designed, each 6 feet in diameter and 12 feet deep. At the beginning only tank 2 was used. It was provided with an Imhoff separating baffle of the type giving a horizontal flow through the tank. Allowing a depth of 5 feet for the settling chamber and 6 feet 5½ inches for sludge storage, the capacities of these two sections were 760 gallons and 155.5 cubic feet, respectively. A 4-inch sludge line extended through the side of the tank near the bottom with a 4-inch gate valve attached just outside the tank. This tank was operated as originally designed up to October 6, when it was placed in series with tank 1. Tank 1 was placed in operation October 6, 1916. The inlet consisted of a 4-inch galvanized iron pipe that extended down into the tank 6 feet 2 inches. The outlet was a wooden trough 6 inches wide and 6 inches deep, set level with the inlet pipe to tank 2. These two tanks were operated in parallel, the wastes first passing through tank 1 and then to No. 2. A 4-inch sludge outlet was placed in this tank, similar to that described for tank 2. The settling capacity of the tank was 1,060 gallons, and the volume of the sludge compartment was 182.6 cubic feet. The space occupied by the gas vents in tank 2 accounts for the difference between the settling capacities of these two tanks. The object of operating the two tanks in parallel was to permit more accurate sludge measurements.

In tank 2 measurements could only be made through the gas vents, which were on two sides of the tank, and these did not show the actual volume of sludge. It was considered advisable, moreover, to retain tank 2, containing the Imhoff flow section, in the series, to prevent suspended solids that might rise to the surface due to fermentation in the sludge from escaping with the effluent. These two tanks were operated as described above until April, 1917, when the plant was remodeled and the settling tanks were no longer used.

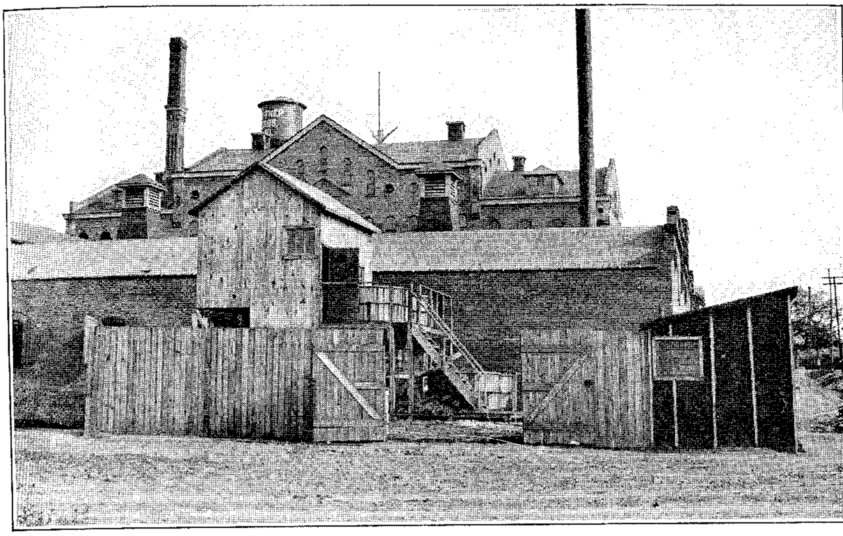

FIG. 4.—GENERAL VIEW OF TESTING STATION, SHOWING ITS POSITION WITH RELATION TO THE TANNERY.

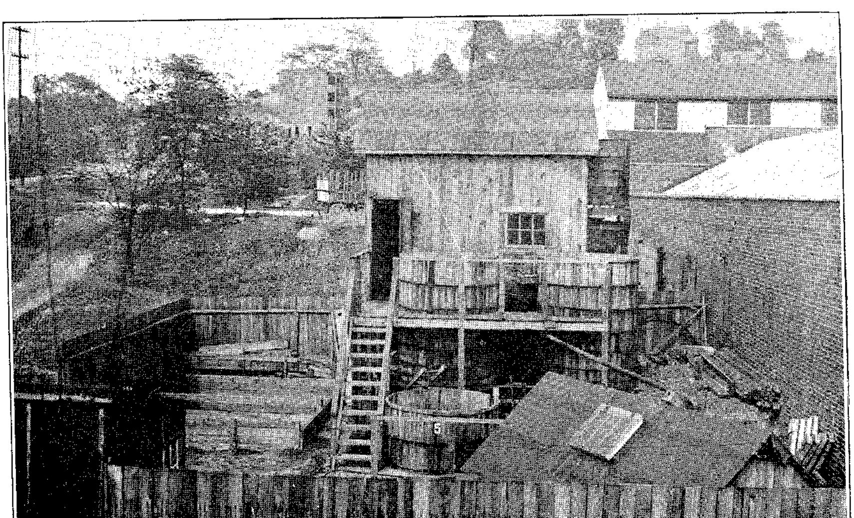

FIG. 5.—GENERAL VIEW OF TESTING STATION, SHOWING ARRANGEMENT OF BUILDINGS AND TEST UNITS.

SPENT TAN STORAGE TANK.

The spent tan liquors were discharged from the rocker pits between 8 and 9 a. m. each day. To store these liquors for mixing with the other wastes during the 24 hours the testing station was operated, a storage tank was constructed. This was a wooden tank 14 feet long by 4 feet deep and 2 feet wide. As this tank was also used for treating the spent liquors with lime sludge, there was a 2-inch sludge line installed in the bottom. This tank was placed immediately over the two settling tanks, and the outlet, consisting of a 1-inch pipe with a float and valve attached to the end, discharged the liquors into the weir box receiving the wastes from the pump. The spent tan liquor was treated with lime after July 1, 1917, till the close of the tests in December.

IRON SOLUTION TANK.

Ferrous sulphate was added to a mixture of all the wastes, and the solution was stored in a box 2 feet square and 2 feet deep. There was provided a regulating device consisting of a float and valve. The tank was set just above the box receiving the discharge from the pump, and the solution was added to the wastes as they entered the first settling tank. This tank was in continuous use up to the time the settling tanks were discontinued, in April, 1917.

WEIR BOX.

The waste discharged from the pump was received in a box 4 feet 6 inches long by 15 inches deep and 15 inches wide. In the original installation, weirs were placed in each end of the box for measuring the amount of wastes treated in each of the settling tanks. Stilling baffles were placed in the box, and an overflow provided to remove the excess pumped and to maintain a constant head over the weirs. Only one weir was used, however, for at no time were the two settling tanks operated separately. The raw wastes entered the box halfway between the two weir plates, and the overflow, consisting of a 4-inch pipe, was placed near the discharge line from the pump, to prevent the box from accumulating sludge.

ROUGHING FILTERS.

There were two of these filters, each contained in a round wooden tank, 6 feet in diameter and having an area of 0.000645 acre. Filter 3 was filled to a depth of 5 feet with cinders that had been screened over ½-inch screen, and filter 4, with 5 feet of coke averaging in size about ½ inch. The bottoms of the tanks containing these filters were covered with concrete varying in thickness from 1 inch at the outlet to 4 inches at the opposite side of the tank. Grooves were made in the concrete to facilitate drainage, and the entire bottom was covered to a depth of about 8 inches, with coarse stone overlaid with fine. Both of these filters were operated throughout the tests as originally installed, without any modifications or changes of any kind.

SAND FILTERS.

These filters were of the same size and construction as the roughing filters. Filter 5 received the effluent from cinder filter 3, and filter 6 received the effluent from coke filter 4; each was filled with 5 feet of washed river sand, having an effective size of 40 millimeters and a uniformity coefficient of 1.35.

Distribution was effected by bringing the inlet pipe to the center of the beds and discharging the wastes into shallow troughs.

These filters were operated throughout the tests as originally installed, except that, owing to the settling of the tanks, it was necessary to throw out the sand and increase the slope of the bottom.

SLUDGE BEDS.

There were two sludge beds, each 8 by 12 feet. They were inclosed by 2-inch planks nailed to posts set in the ground, and the filtering material consisted of 10 inches of sand of the grade used in the filters. The underdrainage consisted of 4-inch farm tile covered with coarse cinders. These beds were located adjacent to the settling tanks, and they were flooded to a depth of about 12 inches by means of wooden troughs.

OFFICE AND LABORATORY.

As this testing station was located near a central laboratory of the Public Health Service at Cincinnati, only a small building was required to serve as an office and for making a few chemical tests. This building was 8 by 12 feet in plan, and 7 feet high on one side and 10 feet on the other. Water service was provided, and the building was heated by oil stoves during the wintertime. The samples collected were stored in an ice box until they were ready to be carried to the laboratory for analysis.

OPERATION OF THE TESTING STATION.

The operation of the testing station at the Haffner Bros. Tannery did not cover the wide range of studies that were made at Luray. In fact, this whole report may be considered as a continuation of period 5 in the Luray tests.

The only important change made in the operation of the station was in April, 1917. The pumping schedule was revised, and only enough waste was pumped to supply the filters. Under this schedule the two large settling tanks were thrown out of service and a partition placed in the spent tan storage tank, dividing it into two equal parts. Each section had sufficient storage capacity to supply the filters 24 hours, and was filled with waste on the day before it was to be used by pumping one-ninth the capacity each hour. To this tank was added the correct proportion of spent tan liquor for the day, and also the iron solution at the rate of 10 grains per gallon of total waste treated.

It was necessary to make certain changes to simplify the operation of the testing station, as most of the personnel of the Industrial Wastes Division had been assigned to extra-cantonment sanitation work, and the operation of the station was left in charge of one attendant. The schedule was therefore arranged so that it could be managed by one man without special supervising attention.

No sludge data are reported for the period following April. Sufficient results had been obtained during the previous eight months, however, to form definite conclusions regarding the volume and composition of the sludge from the Haffner Bros. Tannery. The effluent of the settling tank after April (see Table 10) contained approximately the same amount of suspended matter as during the previous period, and none of the other results show variations greater than were found during the preceding months.

As pointed out earlier in this report, the amount of spent tan liquor treated with the wastes is the controlling factor in obtaining efficient results, and under the revised schedule it was possible to control the treatment ratio more accurately than under the former arrangement of pumping waste for nine hours each day and applying the spent tan liquor continuously through a regulating valve. Sludge data, however, should never be based on the wastes pumped at irregular intervals, and likewise the data relating to the operation of large settling tanks should represent the results from continuous flow throughout each working day. The early period of operation could not, therefore, have been dispensed with, and the later period gave much valuable information regarding the operation of the filters.

VOLUME OF WASTES DISCHARGED FROM VARIOUS OPERATIONS IN THE TANNERY.

No attempt was made to obtain a daily record of the volumes of the individual wastes produced at this tannery. The wastes are discharged into one outlet, and only those were measured that had a direct bearing on the operation of the testing station. Experience at

Luray had shown that for treatment purposes only two wastes need be considered: First, those from tanning the leather, which contain spent or diluted tannin compounds; and second, the composite from all the other operations. The monthly average results showing the volume of wastes discharged from the spent tan vats, and from all other sources, and the ratio of the spent tan liquors to the other wastes, are shown in Table 39.

TABLE 39.—*Wastes discharged from tannery, and ratios or spent tan liquors to beam-house waste.*

Month, 1916-17.	Wastes discharged.			Ratio of spent tan to beam house.	Month, 1916-17.	Wastes discharged.			Ratio of spent tan to beam house.
	Beam house.	Spent tan liquors.	Total.			Beam house.	Spent tan liquors.	Total.	
	Gallons.	*Gallons.*	*Gallons.*			*Gallons.*	*Gallons.*	*Gallons.*	
July	....	....	63,000	....	February	51,000	2,700	53,700	1:19
August	....	....	62,400	....	March	55,100	3,000	58,100	1:18
September	59,700	3,600	63,300	1:17	April	46,900	3,200	50,100	1:15
October	49,300	3,000	51,600	1:16	May	54,500	3,700	58,100	1:15
November	54,900	3,000	57,900	1:18	August	63,800	4,300	68,100	1:15
December	54,300	2,800	57,100	1:19					
January	53,900	3,200	57,100	1:17	Average	54,300	3,250	58,400	1:17

The volume of wastes discharged from the beam house was obtained from readings taken every 30 minutes from a weir set in a box located on the sewer line from the tannery. The spent tan liquor was measured by wier readings taken every five minutes, in a special box set in the tannery. The spent tan liquors were pumped out of the vats in the morning. This required about one hour. The weir measurements were checked by computing the volume of waste liquors in the tanks.

It will be observed in looking over the monthly average results for the beam house, in the table, that the maximum daily discharge of 63,800, and the minimum of 46,900 gallons, are not widely divergent from the average for the nine months. The amount of spent tan liquors discharged does not vary directly with the volume of beam-house wastes in the average monthly results, and this is to be expected, since the operations of the two departments producing these wastes are entirely independent. In fact, an increase in the number of hides worked in the beam house would not affect the wastes discharged from the tanyard until several weeks later. There are other factors also that affect the amount of spent tan liquors discharged, the most important being the time of the year. In warm weather the liquors sour more quickly than in cold, and this is indicated by the amounts discharged during the months of September, May, and August. The number of hides removed daily from the rocker pits during the three months given above was about the same as for the other months given in the table.

The number of hides tanned daily during the period covered by the tests varied from 150 to 188, averaging 165. There was produced, on the average, 350 gallons of waste for each hide tanned. Referred to the beam-house waste and including the hair-washing waste, there were 330 gallons, and to the spent tan liquors, there were 20 gallons discharged for each hide tanned.

Comparing the wastes produced at the two tanneries it is seen that each discharged approximately the same total amount per hide tanned, and from the beam house also practically the same amount of waste was discharged. At Cincinnati the total waste was 350 gallons, and the beam-house waste 235, while at Luray the figures were 385 gallons of total waste, and 238 gallons of beam-house waste. There is a large difference in the amount of spent tan liquors discharged, the figures at Luray being 40 gallons per hide, and at Cincinnati 20 gallons. As will be shown later on, the strength of the spent liquor from the latter place was considerably less. The rinse water from the hides from the lay-away yard was approximately 40 gallons per hide at Cincinnati and 20 at Luray, but the actual amount of liquor in the waste from the former was less, as the hides were piled and drained before rinsing.

Weir measurements.—In planning any investigation where weir measurements are required the question invariably arises as to how often the measurements should be taken. Where the flow is comparatively uniform the chances for large errors are not great, but where liquids are discharged from tanks or vats into a sewer there are opportunities for serious errors. At the beginning of the tests readings over the weir set in a box in the line of the sewer were taken every 30 minutes. Toward the end these readings were checked by a special series taken every 10 minutes over eight days. The results are given in Table 40.

TABLE 40.—*Discharge from the main sewer as computed from readings taken every 10 minutes and every 30 minutes.*

Date.	Discharge (gallons per minute).		10-minute readings are—		Date.	Discharge (gallons per minute).		10-minute readings are—	
	Readings taken every 10 minutes.	Readings taken every 30 minutes.	Higher per cent.	Lower per cent.		Readings taken every 10 minutes.	Readings taken every 30 minutes.	Higher per cent.	Lower per cent.
Aug. 8	96.8	84.8	12.4	....	Aug. 15	114.6	121.7	....	6.2
Aug. 9	117.0	117.0	....	....	Aug. 16	104.8	97.5	7.0	....
Aug. 10	89.4	91.7	....	2.6	Aug. 17	100.3	102.0	....	1.7
Aug. 13	103.5	108.6	....	4.9					
Aug. 14	99.1	95.5	2.7	....	Average	103.2	102.4	1.0	....

The average for the readings taken every 10 minutes in the above table is made up of 432 readings, and the average for the half-hourly reading is made up of 142. The close agreement of the averages is sufficient reason for assuming the average results for the volume of wastes are correct within reasonable limits.

TREATMENT OF THE WASTES.

The design of the testing station at the Haffner Bros.' tannery was much simplified as a result of the studies made at Luray. Tests made at the latter place treating each waste separately had proven that such procedure was not practical. It was further demonstrated that when spent tan liquors up to a specified volume were treated with lime sludge and mixed with all the other wastes and the whole treated with ferrous sulphate, the mixture could be purified by settling the wastes in tanks and filtering the effluent through roughing filters followed by sand filters. The units, therefore, that were operated at Cincinnati were not materially altered during the entire period of the tests, but the filters were operated at lower rates than were used in the earlier studies to learn how far the color could be reduced. This phase of the problem was not considered as important in the Luray tests as the matter of obtaining a stable effluent, but as soon as it became evident that this could be accomplished using the same method of treatment in Cincinnati as was used in Luray, attention was turned to reducing the color in the effluent from the sand filters.

Sampling schedule.—The routine sampling schedule adopted at the beginning of the tests involved collecting separate portions at stated intervals from 7 a. m. to 5 p. m. over two working days and mixing them to form a composite. All samples were stored in an ice box. The samples taken from the sewer are indicated as beam-house waste, as they did not contain an average proportion of the spent tan liquors, and they were taken every 30 minutes. The samples taken, representing the influent to the settling tank, which included a mixture of all the wastes, treated with the iron solution, are marked influent to settling tank, and these samples were collected every 30 minutes. Samples from the effluent of the settling tank were taken at the same intervals. Samples representing the spent tan liquors were taken from the storage tank at the time this was pumped from the sewer. From each of the four filters, samples were taken every hour to form a composite covering two days.

Beam-house waste.—Under this heading are included all the wastes from the tannery except the exhausted or spent tan liquors from the rocker pits. The rinse water from the hides removed from the lay-away yard, which contained dilute tan liquor, is included, as it was impossible to exclude it as was done at the tests made at Luray. The monthly average analyses of the beam-house waste and the weighted average for all the results obtained, are given in Table 41.

TABLE 41.—*Monthly average analyses of samples taken from sewer, together with the weighted average for all determinations made.*

Month, 1916–17.	Parts per million.									Bacteria (thousands per cubic centimeter).		
	Suspended matter.	Nitrogen.		Alkalinity.		Oxygen consumed, 30 minutes 96° C.	Oxygen demand.					
		Organic.	Ammoniacal.	Carbonate.	Bicarbonate.		24 hours.	5 days.	10 days.	Gelatine.	Agar.	B. coli.
December	872	59	19	......	......	768	......	......	......	......	......	......
January	1,290	76	22	497	331	800	450	1,270	1,530	......	......	......
February	1,743	82	18	......	......	1,193	533	1,050	1,456	......	......	......
March	2,417	75	19	......	......	982	302	919	1,185	......	......	......
April	1,653	63	15	576	574	1,024	400	1,120	1,510	......	......	......
May	2,107	66	35	......	......	867	260	1,200	1,600	56	74	0.7
June	1,959	107	30	......	......	1,269	460	1,167	1,407	635	495	2.0
July	2,566	124	36	......	......	1,088	......	......	......	307	278	4.2
August	1,244	68	24	487	590	1,088	......	......	......	2,305	1,631	4.3
September	1,735	72	17	440	910	1,280	......	......	......	802	546	2.8
October	1,200	90	27	384	624	1,156	......	......	......	715	771	2.7
November	1,520	111	31	......	......	1,140	......	......	......	296	646	0.4
December	1,720	46	50	......	800	2,600	......	......	......	24	223	......
Weighted average	1,723	82	24	419	604	1,075	414	1,073	1,382	800	712	2.74

The results given in the preceding table show the composition of all the wastes discharged from the tannery, except the spent tan liquors from the rocker pits. The latter were discharged all at one time in the early morning, and there was no way of mixing this waste in proportion to the other wastes on the days samples were taken. The suspended matter analyses run fairly uniform in the average results for the months, except in December, 1916, when the average was only 872 p. p. m. There was only one analysis for this month, and it is probably too low, as the results for all the other months are considerably higher. The organic and ammoniacal nitrogen and oxygen consumed values indicates the large amount of organic matter present in this waste and illustrate the amount of oxidation required in the filters to produce a stable effluent. The oxygen demand results show the heavy draft this type of waste will make upon the dissolved oxygen of a stream of water. The alkalinity results are only given for the determinations where there were no hydrates present, as averages could not be computed from results made up of the alkalinity in the three different states. Hydrate alkalinity was present in only a comparatively few composite samples. There is no doubt, however, that caustic lime was discharged in the waste from the beam house, but the dilute-tan liquors rinsed off from the hides when removed from the lay-way yard were sufficient to neutralize the free lime in most of the samples. In Table 44 analyses are given for the composite samples in which hydrate and carbonates were present.

There were 66 samples taken, composed of 2,640 small portions, and covering 132 days.

Influent to settling tank.—The spent-tan liquors, discharged in the early morning, were pumped to a storage tank and applied to the general wastes in the proportion this waste bore to the other wastes. No attempt was made to learn the exact ratio on the days the liquors were pumped, but the average for the week preceding was used as the basis for adjusting the mixture. The composite of the mixture of general waste and spent-tan liquor treated with ferrous sulphate at the rate of 10 grains per gallon, constituted the influent to the settling tank, and the results given in Table 42 more properly represent the nature of the composite waste from this tannery.

TABLE 42.—*Monthly average analyses of influent to settling tank, together with the weighted average for all determinations made.*

Month. 1916-17.	Settleable solids.			Parts per million.									Bacteria.		
	Cubic centimeters per thousand.			Suspended matter.	Nitrogen.		Alkalinity.		Oxygen consumed, 30 minutes, 96° C.	Oxygen demand.			Thousands per cubic centimeter.		
	1 hour.	2 hours.	4 hours.		Organic.	Ammoniacal.	Carbonate.	Bicarbonate.		24 hours.	5 days.	10 days.	Gelatine.	Agar.	B. Coli.
August...	....	....	....	1,237	61	30	600	1,225	1,040	....	....	....	....	....	....
September	....	....	....	1,243	63	32	778	576	1,053	....	....	....	....	....	....
October..	....	....	....	1,835	69	36	410	270	1,025	....	....	....	....	....	....
November	....	....	....	1,784	78	30	....	....	1,032	290	1,088	1,430	3,849	2,057	0.9
December	....	....	....	1,715	73	23	....	....	975	285	1,054	1,320	95	91	1.5
January..	45	39	34	1,427	80	23	331	709	1,017	620	1,350	1,720	227	107	1.3
February.	74	69	62	1,725	71	18	1,240	712	1,573	340	1,360	1,753	276	150	2.2
March....	94	84	71	2,241	73	18	....	....	1,297	453	1,135	1,603	369	273	7.1
April.....	75	65	55	2,258	65	15	....	....	1,008	400	1,060	1,370	1,171	1,747	1.8
July......	47	42	38	2,530	117	30	538	1,062	1,618	873	1,670	1,960	....	....	....
August...	61	52	43	1,308	63	26	380	862	1,604	....	....	....	....	....	....
September	67	58	42	1,047	48	24	....	....	1,480	....	....	....	....	....	....
October..	....	....	....	1,288	95	24	....	464	1,600	....	....	....	....	....	....
November	....	....	....	1,933	123	21	....	....	1,973	....	....	....	....	....	....
December	....	....	....	2,680	68	28	1,440	....	1,200	....	....	....	....	....	....
Weighted average..	68	60	52	1,718	76	25	653	741	1,253	448	1,209	1,578	405	420	3.2

The weighted average results given in Table 42 were not computed from the same monthly averages as those given for the analyses of the raw wastes (beam house) taken from the sewer, and no comparison can, therefore, be made of the values given in the two tables. In the former table, 66 samples were represented, covering 132 days and representing 2,640 separate portions taken from the sewer, while in Table 42 there are 82 samples represented, taken on 164 days, and composed of 3,280 half-hourly samples. Comparing the suspended matter results for the same months, the influent to the settling tank shows higher values in practically all the monthly averages, and this is to be expected on account of the precipitate formed by the ferrous sulphate added. The settleable solids were determined by the Imhoff settling glass, and the monthly average results show that practically all of the settleable solids were removed by one hour quiescent settling. The effect of adding the spent tan liquors to the wastes is shown by comparing the monthly average results for the oxygen consumed determination in the raw wastes and the influent to the settling tanks. The influent to the settling tanks shows higher values for all the monthly averages, except for December, and there was only one analysis for this month. The raw-waste result is probably not representative, as it is more than 100 per cent higher than the average for any other month.

Comparing these results with those from Luray, it will be observed that the latter are lower for the oxygen consumed values, except for the months of July and August, 1916. (See Table 24.) The values for these two months, however, are the only ones that bear a direct relation to those for the Haffner Bros. tests, as it was during this period that the maximum amount of spent tan liquor was treated with the other wastes. The suspended matter and total nitrogen are higher at Cincinnati.

Effluent from settling tank.—The monthly average results and the weighted average for all the analyses obtained from the effluent of the settling tank are shown in Table 43.

TABLE 43.—*Showing monthly average analyses of effluent of settling tank, together with the weighted average for all determinations made.*

Month, 1916–17	Settleable solids.			Parts per million.									
	Cu. cm. per thousand.			Suspended matter.	Nitrogen.		Alkalinity.		Iron (Fe).	Oxygen consumed. 30 minutes—96° C.	Oxygen demand.		
	1 hour.	2 hours.	4 hours.		Organic.	Ammoniacal.	Carbonate.	Bicarbonate.			24 hours.	5 days.	10 days.
August	......	......	......	650	42	30	390	957	......	869	......	......	......
September	......	......	......	814	48	31	207	718	......	960	......	......	......
October	......	......	......	385	45	29	160	510	......	705	......	......	......
November	......	......	......	608	48	28	480	448	......	764	163	962	1,258
December	......	......	......	456	48	24	240	590	15	760	268	1,017	1,143
January	3.2	4.0	3.6	534	48	23	390	617	17	803	350	895	1,095
February	.9	2.2	3.0	363	35	21	......	887	9	1,233	213	804	1,192
March	1.4	2.2	3.0	696	47	16	720	733	16	927	284	976	1,293
April	5.4	6.0	6.9	802	32	13	......	682	13	892	294	875	1,120
May	......	......	......	465	26	26	160	900	......	400	130	400	700
June	......	......	......	704	51	24	120	874	......	1,040	396	1,014	1,253
July	......	......	......	674	52	25	440	1,244	11	1,004	480	1,005	1,160
August	......	......	......	526	38	32	720	904	31	1,144	430	1,375	1,980
September	......	......	......	493	77	29	480	470	31	720	125	630	......
October	......	......	......	928	59	26	420	790	26	752	358	865	1,030
November	......	......	......	393	70	26	140	740	36	640	63	830	1,073
December	......	......	......	700	66	30	......	......	28	680	120	520	820
Weighted average	2.4	3.3	3.9	613	48	25	......	......	19	881	284	944	1,224

The monthly average results in Table 43 were obtained from the analyses of 93 samples covering 186 days and made up of 3,348 half-hourly portions.

The suspended matter is 613 p. p. m., and in the influent there were 1,718 parts, so that the settling tanks effected a removal of 64 per cent. At Luray the corresponding result was 63 per cent. (See Table 27.)

The volume of settleable solids in the effluent is not directly comparable with that in the raw wastes, as the solids in the latter were heavy and compacted, the amount showing less after settling for one hour. In the effluent, however, the solids were flocculent and light, and did not compact in the bottom of the settling glass. In fact, they appeared in the settling glass more like a chemical precipitate than suspended matter as this term is usually applied to the solids of sewage and industrial wastes. It should be recalled here that the wastes passed through two settling tanks and that the velocity was greater than would be the case where only one tank is used. In large tanks properly baffled there is no doubt that more suspended matter could be removed than was taken out by the test tanks. The test tanks, however, removed 94.5 per cent of the settleable solids in the influent, and even with the most efficient design and operation of large tanks they could not be expected to remove more than 97 per cent.

The organic nitrogen was reduced from 76 to 48 parts, a removal of 38 per cent. The ammoniacal nitrogen was not affected by passing the waste through the tanks. At Luray the organic nitrogen was reduced from 30 to 21 parts.

The oxygen consumed was reduced from 1,253 to 881 parts, a removal of 30 per cent, compared with a reduction at Luray from 925 p. p. m. to 530 parts, or 43 per cent.

The biochemical oxygen demand results show that the removal of 64 per cent of the suspended matter was accompanied by a reduction of only 37 per cent of the 24-hour, 22 per cent of the 5-day, and 23 per cent of the 10-day value.

All results given for alkalinity in the preceding tables include only those days when there were no hydrate in the composited samples. In order to show how the reaction of the wastes varied, Table 44 has been compiled from the analyses of composite samples taken on various dates throughout the tests.

TABLE 44.—*Alkalinity of the raw waste from sewer and the influent to settling tank, and the acidity of the spent tan liquors.*

Date, 1916–17.	Results in parts per million as $CaCO_3$. Raw wastes (from sewer). Hydrate.	Raw wastes (from sewer). Carbonate.	Raw wastes (from sewer). Bicarbonate.	Influent to settling tank. Hydrate.	Influent to settling tank. Carbonate.	Influent to settling tank. Bicarbonate.	Effluent from settling tank. Carbonate.	Effluent from settling tank. Bicarbonate.	Spent tan liquor. Acidity (fluorescein).	Spent tan liquor. Treated. Acidity (fluorescein).	Spent tan liquor. Treated. Bicarbonate.
Aug. 11	......	......	......	......	......	910	......	740	......	......	......
23	......	......	......	......	1,000	1,700	800	1,140	......	......	......
Sept. 6	......	......	......	......	440	880	40	720	......	......	......
20	......	......	......	......	1,680	240	560	660	......	......	......
Oct. 11	......	......	......	......	880	80	240	440	......	......	......
18	......	......	......	......	320	320	80	680	......	......	......
Nov. 9	......	......	......	440	1,200	......	960	240	......	......	......
28	......	......	......	1,360	1,040	......	480	440	......	......	......
Dec. 19	840	960	......	800	1,120	......	......	760	605	......	......
27	......	240	400	......	......	760	......	640	605	......	......
Jan. 16	......	560	440	......	160	840	160	760	(1)	......	......
23	......	720	240	......	560	480	680	240	(1)	......	......
Feb. 15	......	520	300	......	400	480	......	920	500	......	......
27	1,040	1,520	......	......	800	750	......	......	(2)	......	......
Mar. 13	3,680	4,760	......	2,640	2,960	......	......	1,040	900	......	......
22	280	1,120	......	......	800	480	......	800	450	......	......
Apr. 10	......	640	600	......	700	420	......	380	......	......	......
19	......	......	640	......	150	610	......	750	......	......	......
May 22	......	80	880	......	100	800	......	1,040	(2)	......	......
June 21	1,760	1,040	......	......	300	750	......	960	900	......	......
26	......	......	1,500	......	600	830	......	1,240	1,500	......	......
July 25	2,150	1,700	......	......	150	1,500	......	1,750	2,500	......	700
Aug. 15	......	900	500	......	600	200	......	750	3,650	1,000	......
22	......	560	260	......	150	620	120	750	2,700	100	......
Sept. 19	......	880	1,200	......	880	400	......	1,200	2,500	100	......
Oct. 10	......	720	360	......	450	440	......	640	2,400	......	400
24	......	800	880	......	80	440	80	720	2,900	......	520
Nov. 14	......	510	420	......	400	400	240	640	2,000	......	240
21	1,520	1,680	......	......	640	700	600	720	2,000	......	400

[1] Neutral. [2] Alkaline.

In this table are given representative alkalinity and acidity results covering the entire period of operation of the plant for the raw wastes taken from the sewer, the raw waste settled in the tanks, the effluent from the settling tank, and the spent tan liquor. The samples taken from the sewer were collected half-hourly, but they do not represent a true average of the wastes discharged throughout the day, as the spent tan liquors were all discharged at one time in the morning and there was no way of proportioning the samples. The influent to the settling tank was the raw waste pumped from the sewer, treated with the correct proportion of tan liquors and 10 grains per gallon of ferrous sulphate. Previous to July the spent tan liquors were not treated with lime sludge, and the results given for the influent to the settling tank up to that time are probably a fair average of the alkalinity of all the wastes mixed together. The analyses of the effluent from the settling tank indicate the reaction of the wastes as they were applied to the filters, and for comparison with the analyses of the filter effluents attention is called to the monthly average results of the filters in Tables 47 and 48.

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The acidity of the spent tan liquors shows considerable variation in the untreated waste, the tendency, due to fermentation, being for the acidity to increase with the approach of hot weather. Between December 19, 1916, and March 22, 1917, the acidity of the liquors was not higher than 900 p. p. m., and on two occasions it was either neutral or alkaline, while in August it ran as high as 3,650 p. p. m. Beginning July 25, when the spent tan liquors first showed a high acidity, lime sludge from the unhairing vats was added to reduce the concentration of the liquors, and the results obtained by this treatment are shown in the last two columns.

The indicators used in determining the alkalinity and acidity of the wastes were methyl orange, phenolphthalein, and fluorescein. Titrations where only a small amount of spent tan liquors were present were fairly satisfactory, but in the strong liquors it was difficult to determine the exact end point, and the results given, while agreeing among themselves, probably do not represent the true reaction of the spent tan wastes. The most important consideration, however, was not so much to obtain the exact reaction, but to determine whether the final reaction was alkaline or so low in acidity that the lime in the beam-house waste would render the spent tan liquors alkaline before going to the filters.

Effluent from roughing filters.—A part of the effluent from the settling tank was treated on roughing filters 3 and 4, containing cinders and coke, respectively, as filter mediums. In the Table 45 the analyses of the influent and the effluent of filter 3 are given.

TABLE 45.—*Analyses of influent and effluent of cinder filter No. 3.*

EFFLUENT SETTLING TANK, INFLUENT TO FILTER 3.

Month, 1916-17.	Rate, 100,000 gallons per acre daily.	Parts per million.												Stability by methylene blue.		Color (p. p. m.).
		Suspended matter.	Nitrogen.				Alkalinity.		Iron (Fe).	Oxygen consumed, 30 minutes—96° C.	Oxygen demand.					
			Organic.	Ammoniacal.	Nitrite.	Nitrate.	Carbonate.	Bicarbonate.			24 hours.	5 days.	10 days.	Dilution.	Hours to decolorize.	
August	......	650	42	30	......	.....	390	957	....	869	.....	......	....	.....	.....	....
September	......	814	48	31	......	.....	207	718	....	960	.....	......	....	.....	.....	....
October	......	385	45	29	......	.....	160	510	....	705	.....	......	....	.....	.....	....
November	......	608	48	28	......	.....	480	448	....	764	163	962	1,258	.....	.....	....
December	......	456	48	24	......	.....	240	590	15	760	268	1,017	1,143	.....	.....	....
January	......	534	48	23	......	.....	390	617	17	803	350	895	1,095	.....	.....	....
February	......	363	35	21	......	.....	.....	887	9	1,233	213	804	1,192	.....	.....	....
March	......	696	47	16	......	.....	720	733	16	927	284	976	1,293	.....	.....	....
April	......	802	32	13	......	.....	.....	682	13	892	294	875	1,120	.....	.....	....
May	......	465	26	26	......	.....	160	900	....	400	130	400	700	.....	.....	....
June	......	704	51	24	......	.....	120	874	....	1,040	396	1,014	1,253	.....	.....	....
July	......	674	52	25	......	.....	440	1,244	11	1,004	480	1,005	1,160	.....	.....	....
August	......	526	38	32	......	.....	720	904	31	1,144	430	1,375	1,980	.....	.....	....
September	......	493	77	29	......	.....	480	470	31	720	125	630	....	.....	.....	....
October	......	928	59	26	......	.....	420	790	26	752	358	865	1,030	.....	.....	....
November	......	393	70	26	......	.....	140	740	36	640	63	830	1,073	.....	.....	....
December	......	700	66	30	......	.....	.....	......	28	680	120	520	820	.....	.....	....
Weighted average	......	613	48	25	......	.....	.....	......	19	881	284	944	1,224	.....	.....	....

TABLE 45.—*Analyses of influent and effluent of cinder filter No. 3*—Continued.

EFFLUENT FILTER 3 (CINDER FILTER).

Month, 1916–17.	Rate, 100,000 gallons per acre daily.	Parts per million.													Stability by methylene blue.		Color (p. p. m.).
		Suspended matter.	Nitrogen.				Alkalinity.		Iron (Fe).	Oxygen consumed, 30 minutes—96° C.	Oxygen demand.					
			Organic.	Ammoniacal.	Nitrite.	Nitrate.	Carbonate.	Bicarbonate.			24 hours.	5 days.	10 days.	Dilution.	Hours to decolorize.	
August....	1.98	108	8.2	12.5	0.35	2.1	.....	418	....	165	.....	.....	.....	.....	.....	....
September	1.95	164	13.6	7.9	......	......	.....	416	....	216	.....	.....	.....	.....	.....	....
October...	1.92	120	12.3	16.6	......	......	.....	475	....	292	.....	.....	.....	.....	.....	....
November	1.54	114	19.2	17.2	......	......	.....	544	....	324	49	240	370	.....	.....	....
December.	1.48	120	20.3	17.5	......	......	.....	610	6	373	53	287	390	.....	.....	....
January...	1.50	131	24.0	19.1	......	......	.....	669	6	399	113	398	505	1:4	72	....
February .	1.50	88	11.3	9.5	......	......	.....	710	1	477	79	270	443	1:4	84	....
March....	1.46	101	11.9	6.6	......	......	.....	616	2	382	73	244	372	1:4	86	....
April.....	1.47	93	11.0	8.2	.17	1.8	.....	401	5	138	37	89	98	1:4	96	....
May......	1.49	15	10.5	3.3	2.18	16.3	.....	413	....	87	0	0	0	1:4	120	....
June......	1.52	51	11.3	2.7	3.77	30.7	.....	443	....	167	11	34	76	1:4	120	....
July......	1.50	59	9.8	2.6	2.64	7.0	.....	592	0	150	34	61	107	1:4	110	170
August....	1.00	116	13.9	1.7	1.34	13.4	.....	432	2	228	11	60	147	1:4	120	280
September	.99	71	13.5	5.6	1.28	15.8	.....	395	2	116	14	62	104	1:4	120	120
October...	1.01	102	22.6	8.4	.52	2.9	.....	444	2	149	22	80	96	1:4	113	110
November	1.00	95	26.3	10.0	.13	0	.....	550	8	230	37	136	188	1:4	110	300
December.	1.00	15	22.0	34.0	.10	0	.....	460	0	140	4	32	60	.....	.....	100
Weighted average...	......	103	15.1	9.9	1.51	11.1	.....	518	4	257	42	149	229	.....	99	192

The advantage of treating the settled waste on roughing filters is shown in comparing the analyses of the influent and the effluent. This filter effected a removal of 83 per cent of the suspended matter, 68.5 per cent of the organic nitrogen, and 60.4 per cent of the free ammonia. Nitrification was well established in the filter throughout all the warm months. Qualitative tests made at intervals during the winter months indicated that nitrification did not occur in either of the roughing filters during cold weather, and the absence of nitrates in the analyses for the months of November and December, 1917, bear out this conclusion. The alkalinity appearing in the influent as carbonate and bicarbonate was all in the form of bicarbonate in the effluent.

There was a small amount of iron present in the effluent of the filter in practically all the monthly averages, due to the iron tannate not removed by the filter. The color, averaging 192 p.p.m. for the six months this test was made, was partly due to the iron tannate. The strongest color in the effluent, however, was dark brown, more resembling that of compounds in the tan liquor which did not react with the iron solution added to the untreated waste.

No stability tests were made with the effluent from the settling tank, and those from the filter were all made with dilutions of 1:4, using city water. The weighted average for all the results is not a true average, as all the results in the monthly averages marked 120 hours were for samples removed from the incubator while the color still persisted.

There was a reduction of 71 per cent in the oxygen consumed value, and of 85, 84, and 81 per cent, respectively, for the 24-hour, 5-day, and 10-day biological oxygen demand.

The coke filter received as influent the effluent from the settling tank, and as far as was possible it was operated at the same rates and under the same conditions as the cinder filter. The results obtained by treating settled waste in the coke filter are given in Table 46.

TABLE 46.—*Analyses of influent and effluent of coke filter No. 4.*

EFFLUENT SETTLING TANK, INFLUENT TO FILTER 4.

Month, 1916-17.	Rate, 100,000 gallons per acre daily.	Parts per million.												Stability by methylene blue.		Color (p. p. m.).
		Suspended matter.	Nitrogen.				Alkalinity.		Iron (Fe).	Oxygen consumed, 30 minutes—96° C.	Oxygen demand.					
			Organic.	Ammoniacal.	Nitrite.	Nitrate.	Carbonate.	Bicarbonate.			24 hours.	5 days.	10 days.	Dilution.	Hours to decolorize.	
August	......	650	42	30	....	......	390	957	......	869	....	......	......	....	.....	....
September	......	814	48	31	....	......	207	718	......	960	....	......	......	....	.....	....
October	......	385	45	29	....	......	160	510	......	705	....	......	......	....	.....	....
November	......	608	48	28	....	......	480	448	......	764	163	962	1,258	....	.....	....
December	......	456	48	24	....	......	240	590	15	760	268	1,017	1,143	....	.....	....
January	......	534	48	23	....	......	390	617	17	803	350	895	1,095	....	.....	....
February	......	363	35	21	....	......	.....	887	9	1,233	213	804	1,192	....	.....	....
March	......	696	47	16	....	......	720	733	16	927	284	976	1,293	....	.....	....
April	......	802	32	13	....	......	.....	682	13	892	294	875	1,120	....	.....	....
May	......	465	26	23	....	......	160	900	......	400	130	400	700	....	.....	....
June	......	704	51	24	....	......	120	874	......	1,040	396	1,014	1,253	....	.....	....
July	......	674	52	25	....	......	440	1,244	11	1,004	480	1,005	1,160	....	.....	....
August	......	526	38	32	....	......	720	904	31	1,144	430	1,375	1,980	....	.....	....
September	......	493	77	29	....	......	480	470	31	720	125	630	......	....	.....	....
October	......	928	59	26	....	......	420	790	26	752	358	865	1,030	....	.....	....
November	......	393	70	26	....	......	140	740	36	640	63	830	1,073	....	.....	....
December	......	700	66	30	....	......	.....	......	28	680	120	520	820	....	.....	....
Weighted average	......	613	48	25	....	......	.....	......	19	881	284	944	1,224	....	.....	....

EFFLUENT FILTER 4 (COKE FILTER).

Month, 1916-17.	Rate, 100,000 gallons per acre daily.	Suspended matter.	Organic.	Ammoniacal.	Nitrite.	Nitrate.	Carbonate.	Bicarbonate.	Iron (Fe).	Oxygen consumed, 30 minutes—96° C.	24 hours.	5 days.	10 days.	Dilution.	Hours to decolorize.	Color (p. p. m.).
August	1.96	85	15	19.0	0.55	2.71	.....	520	......	241	.....	......	......	....	.....	....
September	1.99	164	13	17.0	.....	......	160	556	......	353	.....	......	......	....	.....	....
October	1.94	74	12	20.0	.....	......	.....	570	......	310	.....	......	......	....	.....	....
November	1.55	85	20	19.0	.....	......	.....	588	......	364	55	272	451	....	.....	....
December	1.48	138	20	18.0	.....	......	.....	610	5.4	398	67	169	432	....	.....	....
January	1.51	77	22	17.0	.....	......	.....	629	3.4	336	60	255	365	1:4	67	....
February	1.50	99	10	10.0	.....	......	.....	710	2.0	505	58	238	430	1:4	59	....
March	1.50	117	16	9.4	.....	......	.....	667	4.2	462	102	361	531	1:4	68	....
April	1.47	152	15	7.4	0	.30	.....	475	3.5	245	80	238	294	1:4	59	....
May	1.50	15	6	12.0	5.00	1.00	.....	660	......	214	44	136	168	1:4	115	....
June	1.52	59	9	7.3	3.80	13.42	.....	603	......	246	33	86	134	1:4	91	....
July	1.50	67	15	8.2	.37	2.60	.....	760	1.0	332	108	185	252	1:4	120	292
August	1.00	97	17	8.8	.84	.80	.....	552	4.0	310	24	152	238	1:4	102	346
September	.98	71	14	5.6	1.28	15.75	.....	395	2 0	116	14	62	104	1:4	120	120
October	1.00	127	27	11.7	.10	.00	.....	500	4.8	205	50	144	180	1:4	84	164
November	1.00	115	31	9.4	.03	.00	.....	645	9.9	298	33	126	166	1:4	100	325
December	1.00	15	65	7.0	.20	.00	.....	460	.0	250	24	108	184	.....	.....	200
Weighted average	......	105	17	13.1	1.20	3.07	.....	600	4.7	329	61	204	313	.....	82	261

The removal of suspended matter was only slightly less than that effected by the cinder filter. The organic and ammoniacal nitrogen, however, were, respectively, 19 and 32 per cent higher in the effluent from the coke filter than in the effluent from the cinder filter. The oxygen consumed was 28 per cent greater, and the oxygen demand for 24 hours, 5 days, and 10 days was 45, 37, and 41 per cent higher, respectively. The amount of iron in the effluent of the coke filter was 0.7 p. p. m. higher than that in the effluent of the cinder filter, and the color 69 parts higher. In the average stability results there were only two months during which all the determinations for the month were stable for 120 hours, and the weighted average was 82, as against 99 for the cinder-filter effluent, with similar dilutions. Nitrification did not develop in this filter to the same extent as occurred in the bed of cinders, and, as was the case with the latter, there were no nitrates or nitrites developed during cold weather.

The coke-filter effluent failed to measure up to the standard of that from the cinder filter in all the monthly averages. Nitrates appeared in the effluent from the cinder bed in a measurable quantity in April, and were still present to the extent of 2.9 p. p. m. November 1, but the coke bed was giving only 0.3 p. p. m. in April and by November 1, 1917, nitrification had disappeared. All the other analyses show the same measure of difference in comparison with the results from the cinder filter.

There was nothing in the operation of the two roughing filters to account for the difference in the quality of their effluents. Both received the effluent from the settling tank through the same outlet, and the rates were accurately controlled, each receiving the same amount of waste per day. The underdrainage for the two filters was alike, and the material in the beds was carefully selected to see that no foreign matter was included when the filters were constructed. When the filters were washed each was flushed with water at the same time and with practically the same amount, and in every way the same treatment was given to each bed. The difference in the results obtained from the two filters, however, was very pronounced, and it can be explained in either one of two ways: First, the variation in the size of the material in the filters; and second, its composition. There was apparently not enough difference in the size of the material to account for any variation in the quality of the effluent, as each removed practically the same amount of suspended matter and its distribution in the filters was practically the same, although there was a somewhat larger accumulation of the solids near the center of the coke filter. The explanation must therefore lie in the difference in the composition of the filtering media. There was a noticeable odor of hydrogen sulphide at the outlet from the coke filter, and the growths in the outlet pipe and the underdrainage near the outlet had the typical whitish opalescent coloring that appears wherever hydrogen sulphide is formed in sewage. The lower efficiency of the coke filter was most likely due to hydrogen sulphide formed within the bed, the sulphur coming from the coke, as under similar conditions the decomposition of the organic matter in the cinder filter did not produce hydrogen sulphide.[1]

In the tests made at the Deford Tannery, Luray, Va., the coke filters gave no evidence of hydrogen sulphide being formed, and the results from these filters were similar in quality to those from the cinder filters. It is well known, however, that the sulphur content of coke varies, and it is quite possible that the material used in the tests at the Haffner Bros.' Tannery contained an unusually high per cent. Considering the high cost of coke compared with cinders, and the experience with the former in the tests made here in Cincinnati, it is not considered advisable to recommend coke as a filter medium in the roughing filters for treating tannery wastes.

Effluent from sand filters.—The effluents from the roughing filters were applied to sand filters 5 and 6 at the same rate at which the former treated the settled waste. Filter 5 received the effluent from 3, and filter 6 that from 4. The results obtained from filter 5 are given in Table 47.

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[1] A similar experience with coke filters or strainers operated at the sewage testing station, Columbus, Ohio, is reported by Mr. George A. Johnson. In his "Report on Sewage Purification at Columbus, Ohio, 1905," he states (p. 144):

"At all times during their operation there was a pronounced odor of sulphureted hydrogen about the discharge pipes in the coke strainers. The cause of this was presumably due to the fact that the intimate contact under highly anaerobic conditions of the sludge in the coke layer and the applied sewage causing a formation of the gas from the decomposition of the organic matter present, and perhaps from the partial reduction of the sulphur in the coke and the sulphates in the applied sewage. The amount of hydrogen sulphide thus formed was in such relatively large amounts that the iron in the sewage and the sludge was insufficient to hold the gas as iron sulphide, as was probably the case in the septic tanks."

TABLE 47.—*Analyses of influent and effluent of filter No. 5.*

EFFLUENT FILTER 3, INFLUENT FILTER 5.

Month, 1916-17.	Rate, 100,000 gallons per acre daily.	Parts per million.							Dissolved oxygen (per cent saturated).	Parts per million.							Bacteria (thousands per cubic centimeter).		
		Suspended matter.	Nitrogen.				Alkalinity (bicarbonate).	Iron (Fe).		Oxygen consumed, 30 minutes—96° C.	Oxygen demand.			Stability by methylene blue.		Color.	Gelatine, 48 hours at 20° C.	Agar, 24 hours at 37° C.	B. coli.
			Organic.	Ammoniacal.	Nitrite.	Nitrate.					24 hours.	5 days.	10 days.	Dilution.	Hours to decolorize.				
August	1.98	108	8.2	12.5	0.35	2.1	418	......	......	165	......	......	......	......	......	......	......	......	......
September	1.95	164	13.6	7.9	......	......	416	......	......	216	......	......	......	......	......	......	......	......	......
October	1.92	120	12.3	16.6	......	......	475	......	......	292	......	......	......	......	......	......	......	......	......
November	1.54	114	19.2	17.2	......	......	544	......	......	324	49	240	370	......	......	......	......	......	......
December	1.48	120	20.3	17.5	......	......	610	6	......	372	53	287	390	......	......	......	......	......	......
January	1.50	131	24.0	19.1	......	......	669	6	......	399	113	398	505	1:4	72	......	......	......	......
February	1.50	88	11.3	9.5	......	......	710	1	......	477	79	270	443	1:4	84	......	......	......	......
March	1.46	101	11.9	6.6	......	......	616	2	......	382	73	244	372	1:4	86	......	......	......	......
April	1.47	93	11.0	8.2	.17	1.8	401	5	......	138	37	89	98	1:4	96	......	......	......	......
May	1.49	15	10.5	3.3	2.18	16.3	413	......	......	87	0	0	0	1:4	120	......	......	......	......
June	1.52	51	11.3	2.7	3.77	30.7	443	......	......	167	11	34	76	1:4	120	......	......	......	......
July	1.50	59	9.8	2.6	2.64	7.0	592	0	......	150	34	61	107	1:4	110	170	......	......	......
August	1.00	116	13.9	1.7	1.34	13.4	432	2	......	228	11	60	147	1:4	120	280	......	......	......
September	.99	71	13.5	5.6	1.28	15.8	395	2	......	116	14	62	104	1:4	120	120	......	......	......
October	1.01	102	22.6	8.4	.52	2.9	444	2	......	149	22	80	96	1:4	113	110	......	......	......
November	1.00	95	26.3	10.0	.13	.0	550	8	......	230	37	136	188	1:4	110	300	......	......	......
December	1.00	15	22.0	34.0	.10	.0	460	0	......	140	4	32	60	......	......	100	......	......	......
Weighted average	......	103	15.1	9.9	1.51	11.1	518	4	......	257	42	149	229	......	99	192	......	......	......

TABLE 47.—*Analyses of influent and effluent of filter No. 5*—Continued.

EFFLUENT FILTER 5 (SAND FILTER).

Month, 1916-17.	Rate, 100,000 gallons per acre daily.	Parts per million.							Dissolved oxygen (per cent saturated).	Parts per million.							Bacteria (thousands per cubic centimeter).		
		Suspended matter.	Nitrogen.				Alkalinity (bicarbonate).	Iron (Fe).		Oxygen consumed, 30 minutes—96° C.	Oxygen demand.			Stability by methylene blue.		Color.	Gelatine, 48 hours at 20° C.	Agar, 24 hours at 37° C.	B. coli.
			Organic.	Ammoniacal.	Nitrite.	Nitrate.					24 hours.	5 days.	10 days.	Dilution.	Hours to decolorize.				
August	1.98	15	4.1	1.5	0.12	8.0	335	......	......	48	......	......	......	......	......	......	......	......	......
September	1.95	15	2.0	1.7	.12	6.2	365	......	......	57	......	......	......	......	......	350	......	......	......
October	1.92	15	5.0	3.8	.42	9.5	455	......	47	84	0	9	11	0	120	400	118	41.7	0.006
November	1.54	31	8.6	9.1	.87	4.6	544	......	36	129	9	51	79	0	120	220	1,193	187.7	.018
December	1.48	23	7.5	12.3	.36	3.3	607	2	20	215	25	95	140	0	100	250	661	169.0	.074
January	1.50	15	9.7	10.9	.17	1.7	597	1	13	150	8	54	85	1:1	100	174	231	79.6	.024
February	1.50	15	5.0	7.8	.01	.5	783	......	3	348	17	60	123	1:1	100	416	659	202.0	.074
March	1.46	18	7.6	4.4	.01	.3	596	......	0	220	18	47	101	1:1	90	261	1,624	463.7	1.010
April	1.47	15	8.7	5.6	.11	1.4	403	......	......	75	6	11	15	1:1	120	......	59	24.4	.099
May	1.49	15	5.1	1.4	.38	28.0	347	......	68	39	0	0	0	1:1	120	......	3	1.2	.009
June	1.52	11	5.3	.5	.64	35.7	377	......	52	78	2	5	13	1:1	120	115	408	338.4	.138
July	1.50	15	7.7	1.2	.25	10.2	520	0	39	96	17	20	59	0	120	113	771	308.6	.270
August	1.00	32	8.0	1.6	.16	26.0	406	0	46	77	3	6	15	0	120	92	98	44.3	.143
September	.99	15	4.7	1.2	.02	20.0	300	0	77	41	0	0	1	0	120	55	8	4.7	.002
October	1.01	28	7.3	1.2	.06	8.2	380	2	83	60	0	2	3	0	120	63	7	6.8	.012
November	1.00	15	6.6	1.2	.15	3.5	460	0	85	56	0	0	0	0	120	75	349	350.0	.026
December	1.00	15	3.0	13.0	.50	3.5	420	0	......	40	0	0	9	0	120	70	42	70.0	......
Weighted average	....	18	6.4	4.4	.23	9.8	478	1	......	118	9	29	53	......	......	171	534	171.3	.180

The results obtained from the operation of this filter during the first three months were satisfactory in every respect, except the color removal. In the tests made at the Deford Leather Co. all efforts were turned toward getting the highest rates out of the filters that would give an effluent that could be discharged into a river or creek affording only a low dilution, without danger of killing fish or materially lowering the oxygen content of the receiving body of water. The removal of color was considered of secondary importance at that time. In the tests that followed this phase of the problem was given more consideration. As soon as it was learned that the mixed wastes from the Haffner Bros.' Tannery could be satisfactorily treated on the filters at a rate of filtration of 200,000 gallons per acre daily, the rates were reduced to determine the relation between rate of filtration and color removal. Following out this procedure the filters were operated for 3 months at approximately 200,000 gallons, 9 months at 150,000 gallons, and 18 weeks at 100,000 gallons per acre per day.

The effect of reducing the rates was not so evident when changing from 200,000 to 150,000 as it was when the change was made to 100,000 gallons per acre daily. In this connection it should be noted that the first change was made at the beginning of winter when the color removal was low, and that the effect of the poor underdrainage in this filter was first made evident during this period. In September and October of 1916 the color averaged 375, and for the two months following the lowering of the rate, 235. The increase in color in the effluent of February was no doubt due to pooling of the wastes over the bottom of the filter. The value for July, 1917, probably represents what can be expected at a rate of 150,000 gallons, as the drainage of the filter had been improved and the filter was in a normal condition during this month and the three months preceding. Lowering the rate to 100,000 gallons the 1st of August, 1917, caused a drop in the color from 113 to 92, and in September the color in the effluent was 55. For the remainder of the period of operation the monthly averages were considerably lower than any of those at higher rates.

The suspended matter in the effluent of this filter was uniform for all the rates, and the alkalinity results do not show any variation corresponding to the rates. The nitrates increased from 6.2 parts in September, 1916, to 9.5 in October, but decreased again with the coming of cold weather in November. After the relaying of the underdrainage in April, 1917, the nitrates jumped to 28 parts in May, and they again increased from 10 parts in July to 26 in August, when the rate was reduced to 100,000 gallons per acre per day. Dissolved oxygen was present in the effluent in satisfactory quantities throughout the period, except between February 1 and April 30, when all the results were more or less unsatisfactory. Reducing the rate in October, 1916, did not increase the dissolved oxygen in the effluent, but when the rate was reduced from 150,000 to 100,000 gallons there was a slight increase for the first month and a decided increase during the months following.

The biochemical oxygen demand was low for this effluent at all the rates except for the one period of unsatisfactory general operation. It was particularly low for the 100,000-gallon rate, but, except in unusual circumstances where color removal is the essential consideration, the results for the highest rate would be entirely satisfactory.

The inferior results for February were, as already explained, due to the accumulation of the waste over the bottom of the filter, owing to imperfect drainage. Before this was discovered, an attempt was made to increase the efficiency by leaving out the spent tan liquor in the influent to the settling tank. This was done from April 1 to June 1. The treatment of the raw wastes with the iron solution was also discontinued from February 1 to 16. No improvement, however, was observed in the effluent of this filter until the sand was removed in April and the underdrainage relaid with sufficient slope to the bottom to carry the filtered waste away as fast as it came through the sand. Beginning in May, nitrification continued throughout the summer and up to December, and the other results showed similar improvement.

The number of composite samples taken from filter 5 was 90, and each sample covered two days and was made up of 20 hourly portions. The analyses, therefore, represent 1,620 samples of the effluent discharged over 180 days. The composite samples were stored on ice while being collected.

The effluent from the coke filter was treated on sand filter 6 at the same rate at which the former was operated. The results obtained from the analyses of the effluent from filter 6 are given in Table 48.

TABLE 48.—*Analyses of influent and effluent of filter No. 6.*

EFFLUENT FILTER 4, INFLUENT FILTER 6.

Month, 1916-17.	Rate, 100,000 gallons per acre daily.	Parts per million.							Dissolved oxygen (per cent saturated).	Parts per million.							Bacteria (thousands per cubic centimeter).		
		Suspended matter.	Nitrogen.				Alkalinity (bicarbonate).	Iron (Fe).		Oxygen consumed, 30 minutes—96° C.	Oxygen demand.			Stability by methylene blue.		Color.	Gelatine, 48 hours at 20° C.	Agar, 24 hours at 37° C.	B. coli.
			Organic.	Ammoniacal.	Nitrite.	Nitrate.					24 hours.	5 days.	10 days.	Dilution.	Hours to decolorize.				
August	1.96	85	15.0	19.0	0.55	2.71	520	.....	.....	241	.....	.....	.....	.....	.....	.....	.....	.....	.....
September	1.99	164	13.0	17.0	.....	.....	556	.....	.....	353	.....	.....	.....	.....	.....	.....	.....	.....	.....
October	1.94	74	12.0	20.0	.....	.....	570	.....	.....	310	.....	.....	.....	.....	.....	.....	.....	.....	.....
November	1.55	85	20.0	19.0	.....	.....	588	.....	.....	364	55	272	451	.....	.....	.....	.....	.....	.....
December	1.48	138	20.0	18.0	.....	.....	610	5.4	.....	398	67	169	432	.....	.....	.....	.....	.....	.....
January	1.51	77	22.0	17.0	.....	.....	629	3.4	.....	336	60	255	365	1:4	67	.....	.....	.....	.....
February	1.50	99	10.0	10.0	.....	.....	710	2.0	.....	505	58	238	430	1:4	59	.....	.....	.....	.....
March	1.50	117	16.0	9.4	.....	.....	667	4.2	.....	462	102	361	531	1:4	68	.....	.....	.....	.....
April	1.47	152	15.0	7.4	.00	.30	475	3.5	.....	245	80	238	294	1:4	59	.....	.....	.....	.....
May	1.50	15	5.5	12.0	5.00	1.00	660	.....	.....	214	44	136	168	1:4	115	.....	.....	.....	.....
June	1.52	59	9.5	7.3	3.80	13.42	603	.....	.....	246	33	86	134	1:4	91	.....	.....	.....	.....
July	1.50	67	15.0	8.2	.37	2.60	760	1.0	.....	332	108	185	252	1:4	120	292	.....	.....	.....
August	1.00	97	17.0	8.8	.84	.80	552	4.0	.....	310	24	152	238	1:4	102	346	.....	.....	.....
September	.98	71	14.0	5.6	1.28	15.75	395	2.0	.....	116	14	62	104	1:4	120	120	.....	.....	.....
October	1.00	127	27.0	11.7	.10	0	500	4.8	.....	205	50	144	180	1:4	84	164	.....	.....	.....
November	1.00	115	31.0	9.4	.03	0	645	9.9	.....	298	33	126	166	1:4	100	325	.....	.....	.....
December	1.00	15	65.0	7.0	.20	0	460	0	.....	250	24	108	184	.....	.....	200	.....	.....	.....
Weighted average	.....	105	17.0	13.1	1.20	3.07	600	4.7	.....	329	61	204	313	1:4	82	261	.....	.....	.....

TABLE 48.—*Analyses of influent and effluent of filter No. 6*—Continued.

EFFLUENT FILTER 6 (SAND FILTER).

Month, 1916–17.	Rate, 100,000 gallons per acre daily.	Parts per million.							Dissolved oxygen (per cent saturated).	Parts per million.							Bacteria (thousands per cubic centimeter).		
		Suspended matter.	Nitrogen.				Alkalinity (bicarbonate).	Iron (Fe).		Oxygen consumed, 30 minutes—96° C.	Oxygen demand.			Stability by methylene blue.		Color.	Gelatine, 48 hours at 20° C.	Agar, 24 hours at 37° C.	B. coli.
			Organic.	Ammoniacal.	Nitrite.	Nitrate.					24 hours.	5 days.	10 days.	Dilution.	Hours to decolorize.				
August	1.96	15	5.9	4.3	0.16	8.40	432	......	......	71	......	......	......	......	......	......	......	......	......
September	1.99	15	4.0	2.0	.11	7.00	442	......	......	88	......	......	......	......	......	380	......	......	......
October	1.94	15	8.5	5.1	.44	7.10	520	......	38	78	......	5	8	0	120	410	37	20	0.001
November	1.55	45	20.4	12.7	.34	2.60	624	......	18	143	20	64	94	0	120	170	1,050	243	.008
December	1.48	19	5.8	13.0	.11	2.70	613	2	17	228	24	78	124	0	75	268	958	154	.037
January	1.51	15	6.4	13.1	.12	2.50	571	1	13	157	20	84	109	1:1	100	208	407	115	.081
February	1.50	15	8.0	6.3	.17	.20	780	......	6	287	12	69	152	1:1	81	421	377	92	.011
March	1.50	19	9.4	5.1	.00	.25	669	6	0	239	27	87	170	1:1	60	278	1,300	392	1.926
April	1.47	15	8.5	5.0	.10	.40	442	......	......	118	18	51	68	1:1	85	......	1,122	673	2.033
May	1.50	15	8.2	4.6	.93	20.67	460	......	41	56	0	0	0	1:1	120	......	353	220	.007
June	1.52	15	6.4	1.5	.83	27.14	517	......	38	114	4	10	25	1:1	120	......	159	128	.128
July	1.50	15	9.2	1.7	.23	6.60	720	0	15	141	27	33	54	0	120	182	717	498	.392
August	1.00	27	8.0	2.3	.54	6.00	500	0	26	157	22	56	96	0	120	241	136	79	1.627
September	.98	15	7.4	1.6	.09	11.50	430	0	58	52	2	10	14	0	120	92	196	88	.030
October	1.00	15	8.4	1.3	.01	3.50	440	0	65	44	0	0	0	0	120	90	121	114	.112
November	1.00	15	12.0	1.5	.08	1.88	515	0	67	81	0	5	5	0	120	110	565	613	.028
December	1.00	15	12.0	22.0	1.00	1.50	460	0	......	92	0	6	38	0	120	120	14	34	......
Weighted average	......	18	8.3	5.4	.25	6.70	551	1	......	136	15	44	78	......	......	218	566	232	.529

This filter was operated, as far as it was possible, in the same manner as filter 5, and all the influences that affected the results from that filter apply to this one. The same condition of the underdrainage was found when the sand was removed in April, 1917, and the same improvement was noted after better drainage was provided. The straw covering was placed over the bed on December 24, and removed February 24. Leaving out the spent tan liquors in the influent to the settling tank, April 1 to June 1, and the iron solution from February 1 to 16, had the same effect on both filters. The rates on the two filters were practically the same, each one receiving all the effluent from the roughing filter with which it was connected in series, and the rates on cinder and coke filters were maintained as nearly alike as possible.

The suspended matter in the weighted average for the effluent of filter 6 was the same as for No. 5. The reduction was 83 per cent. Computed on the raw waste value there was a total reduction by roughing and sand filters of 98.9 per cent.

The organic and ammoniacal nitrogen were higher in the effluent of this filter than for No. 5, and the nitrates were considerably lower. The oxygen consumed was higher, and the oxygen demand for 24 hours, 5 days, and 10 days was likewise higher in the effluent of filter 6. The dissolved oxygen was slightly lower, as were the stability values.

The most noticeable variation in the quality of the effluents from the two sand filters was the difference in color. The explanation for the difference in these results and all the others for the two sand filters can be found in the tables giving the analyses of the effluents from the two roughing filters that supplied influent to the sand filters. Here it will be observed that the quality of the effluent from filter 3, which was treated on sand filter 5, was invariable of a higher degree than the effluent of filter 4, which was applied to sand filter 6.

In the bacterial analyses the average results for filter 5 show a lower count on gelatine and agar, and fewer B. coli than filter 6. The low total number of bacteria and B. coli in the effluent of both the filters in the average for the last three months, indicates that a receiving body of water would not be seriously affected by the bacteria in the effluent of sand filters treating tannery wastes.

The surface layer of sand filter 6 became hard and black much sooner than that of No. 5, and on the distributing plates of No. 6 there was the same white opalescent color that was noted on the underdrains and outlet pipe of the coke filter. The sulphur compounds formed in the coke filter reduced the efficiency of the sand-filter treatment not only as regards the quality of the effluent but in the mechanical operation as well.

There was no difficulty in keeping minnows and baby bass alive in the effluent of filter 5, but frequently it was necessary to add tap water to the aquarium receiving the effluent from No. 6 in order to keep the fish supplied with oxygen. This was particularly true during hot weather.

The results obtained from treating settled waste on the coke filter and the effluent from this filter on No. 6 were not as satisfactory as those obtained from the combination of cinder and sand-filter treatment of settled waste. The final effluent from filter 6 was nevertheless sufficiently oxidized to permit of disposal in a stream of water affording only a very low dilution, even when the rate on the filter was as high as 200,000 gallons per acre per day. The higher cost of the coke, however, and its lower efficiency as a filtering medium for roughing filters, eliminate it from further consideration in the design of a treatment plant for purifying tannery wastes.

THE VOLUME, ANALYSIS, AND DISPOSAL OF SLUDGE.

In the operation of testing stations for the development of methods for purifying industrial wastes there are two principal problems involved: One the selection of devices for removing the suspended solids and oxidizing the organic matter in solution, and the other the arrangement of the settling tank for concentrating the sludge and disposing of it when removed from the tanks. The first phase of the problem as relating to the purification of tannery wastes has been considered in the preceding section. Data on the accumulation, composition, and disposal of sludge at Luray, were also given in Part I. As far as was practicable the sludge problem was studied at the Haffner Brothers' Tannery, so as to make the results directly comparable with those obtained at Luray. The same method of measurements was used at both stations, similar chemical analyses were made, and the same type of drying bed was installed.

VOLUME, PER CENT MOISTURE, AND SPECIFIC GRAVITY OF SLUDGE DEPOSITED IN SETTLING TANKS, BY PERIODS.

Measuring the sludge.—The sludge deposited in the settling tank was measured whenever the amount accumulated to such extent that it was necessary to remove a portion to maintain the efficiency of the settling tanks. When sludge was removed the volume in the tank before and after the removal was determined by measuring the water above the sludge, and the amount applied to beds was measured in place on the sand. A further check on the amount withdrawn was obtained from the difference in elevation of the waste in the tanks before and after the sludge was removed. There were no serious discrepancies in the amounts found by the three different methods of measurement. The second method, that of measuring the sludge on the drying beds, gave results slightly lower than the other two, and this is to be expected, due to filtration of water through the sand while the sludge is running onto the bed. If the measurements are taken immediately after the sludge is withdrawn from the tanks, and the beds are small enough to permit the full dose to be applied in less than one hour, there ought not to be any material difference in the amount of sludge determined in this manner as compared with the other methods outlined above.

In the tests it was possible to discontinue the operation of the settling tank while sludge was being removed, and the exact amount of sludge taken out could be measured, either by observing the fall of the waste in the tank or by locating the sludge layer under the wastes by a measuring rod with a bottle attached to one end and a cork fastened to the end of a cord for removing the stopper from the bottle at different depths. In the practical operation of large plants, however, it will not be possible to close the plant down except on Sundays and holidays, and the method of measuring the sludge on the beds is recommended where it is not feasible to use either of the two other methods.

Sampling sludge.—Whatever method is used for measuring the volume of sludge there is only one place to take samples for analysis, and that is as the sludge comes from the tank or as near it as possible. It is much simpler to obtain correct measurements of the volume than to obtain a representative sample of the sludge, especially with regard to the water content and specific gravity. The most satisfactory procedure is to take small samples at frequent intervals during the entire time the sludge is flowing and mix them together to form a composite. Samples should not be dipped up out of the sludge flowing in a trough, but should be caught, preferably, at the outlet from the tank, but if this can not be done they should be taken where the first trough discharges the sludge into the second or where it goes onto the beds. After flowing a short distance the heavy sludge will be found at the bottom and the lighter and watery sludge at the surface.

Analysis of sludge.—In making the moisture determinations at least 250 grams of the sludge should be taken from the thoroughly mixed composite of the smaller portions collected. The specific gravity can be best determined by using 250 cubic centimeters Erlenmeyer flasks and comparing the weight of the sludge with the weight of the same volume of water at the same temperature as the sludge. In very cold or hot weather the difference in temperature of ordinary tap water and sludge freshly drawn is considerable, and it will make a noticeable discrepancy in the results if no adjustment or correction is made.

In Table 49 are given data relating to the volume, per cent moisture, and specific gravity of the sludge that accumulated in the settling tanks.

TABLE 49.—*Volume, per cent moisture, and specific gravity of sludge deposited in settling tanks, by periods.*

Source.	Date sludge measured.	Amount sludge found in tank (cubic feet).	Date sludge removed from tank.	Amount sludge removed (cubic feet).	Per cent moisture.	Specific gravity.	Tons dry solids deposited.
Tank 1	Nov. 6, 1916	199.0	Nov. 6, 1916	152.9	91.5	1.035	0.420
	Dec. 1, 1916	169.7	Dec. 1, 1916	74.2	89.6	1.039	.250
	Jan. 2, 1917	177.2	Jan. 2, 1917	146.6	93.25	1.023	.316
	Feb. 16, 1917	229.6	Feb. 16, 1917	127.1	90.5	1.037	.381
	Mar. 3, 1917	183.8					
	Mar. 9, 1917	188.6	Mar. 9, 1917	155.8	92.3	1.023	.383
	Apr. 17, 1917	271.4	Apr. 17, 1917	271.4	95.0	1.025	.600
Tank 2	Sept. 16, 1916	140.5	Sept. 16, 1916	68.0	92.8	1.037	.270
			Oct. 3, 1916	48.0			
	Oct. 9, 1916	109.0					
	Nov. 6, 1916	134.4					
	Dec. 1, 1916	196.8	Dec. 1, 1916	89.5	91.6	1.031	.242
	June 5, 1917	210.0	June 5, 1917	210.0	89.6	1.033	.706
Total				1,343.5			3.568
Average					91.8	1.033	

The two settling tanks were operated in series, the waste first passing through the Dortmund settling tank and then through the Imhoff tank. On account of the unequal amount of sludge deposited in the two tanks and the difficulty of measuring the sludge in the Imhoff tank with the baffles in place, no attempt was made to compute the volume of sludge per million gallons of waste for the different periods as was done in Table 32 in the report of the test made at Luray. The amount of dry solids was computed in the sludge removed at different intervals, and the sum of this column used as the basis for computing the tons of dry solids per million gallons of waste treated in the tests. The total amount of dry solids removed as sludge, when computed from the analyses of samples taken at the different periods when sludge was removed, was 3.568 tons. The total volume of sludge removed during the tests was 1,343 cubic feet, and, computing the dry solids in this sludge from the average moisture and specific gravity values for all the samples analyzed, gives the total weight of 3.549 tons.

Summary of sludge data.—The data given in Table 49 refer only to the amount of sludge removed at different intervals, and the moisture and specific gravity of samples taken when sludge was withdrawn. In Table 50 additional data are given which had a bearing on the sludge deposited, and a summary is made of the results given in Table 49. There is also included, for the sake of comparison, the tons of dry solids deposited per million gallons of waste treated as computed from the suspended solids removed by the settling tanks. The amount of suspended solids removed was based on the analyses of 82 samples covering 164 days and made up of 3,280 half-hourly portions.

TABLE 50.—*Amount and character of sludge deposited in the settling tanks for period covering the full time tanks were operated.*

Period covered by sludge and suspended-matter data, June 15, 1916, to May 17, 1917.	
Ratio of spent tan liquors to other wastes:	
August	1:27
Maximum for other months	1:18
Minimum for other months	1:15
Average for period excepting August	1:16
Ferrous sulphate added (grains per gallon)	10
Volume of wastes treated in tanks (gallons)	956, 300
Total amount of sludge deposited (cubic yards)	49. 7
Suspended solids in influent, average (p. p. m.)	1, 694
Suspended solids in effluent, average (p. p. m.)	605
Suspended solids removed in tanks, average (p. p. m.)	1, 089
Dry solids computed from suspended solids removed (tons per million gallons)	4. 57
Sludge accumulated (cubic yards per million gallons)	52
Per cent water (average from Table 49)	91. 8
Specific gravity (average from Table 49)	1. 033
Dry solids computed from sludge accumulated (tons per million gallons)	3. 73
Ratio of dry solids in sludge measured in tank to suspended solids removed by tank	. 82

The amount of ferrous sulphate added to the wastes was 10 grains per gallon throughout the entire period of the tests. Occasional analyses for iron in the influent to the settling tanks showed the amount varied from 8 to 14 grains per gallon, but the variations from the average were not sufficient to make any appreciable difference in the volume of sludge deposited. For purposes of comparison the amount of sludge as measured in the settling tanks was checked by converting the wet sludge into tons of dry solids per million gallons and comparing this figure with that from the suspended matter removal by the tanks as shown by the difference between the suspended matter in the influent and effluent.

The value of the sludge as a fertilizer.—It has been shown in Table 12 that a large volume of sludge will accumulate in the settling tanks. When dried to contain not more than 10 per cent moisture, the amount to be disposed of will be approximately 5 tons per million gallons of wastes discharged, or on the basis of 100 hides tanned daily there will be about 320 pounds. With higher moisture content the volume will increase according to the amount of water present. The cost of disposing of this large volume of sludge will be a net loss unless it can be disposed of as a filler for fertilizers. In order to learn what the value of the sludge would be as a filler for fertilizer several analyses were made for those constituents on which the value of fertilizers is based. These results are given in Table 51.

TABLE 51.—*Chemical analysis of sludge and scum from settling tanks.*

Date.	Source.	Specific gravity.	Per cent water.	Per cent (dry basis 100° C.).							
				Total nitrogen.	P_2O_5.	K_2O.	Ether-soluble matter.	Ca as $CaCO_3$.	Iron as Fe.	Silica.	Ash.
Oct. 13, 1916	Tank 1	....	65.5	1.80	0.42	0.17	1.0	25	1.5	4.9	48
Nov. 7, 1916	do	1.035	91.5	1.84	.54	.19	1.6	40	1.0	4.4	44
Jan. 2, 1917	do	1.028	95.0	1.60	.96	.61	1.8	39	2.0	3.1	48
Mar. 9, 1917	do	1.023	92.3	1.75	1.15	.48	1.2	29	2.1	3.0	48
Apr. 23, 1917	Tank 1 (scum)	1.009	90.5	2.10	.68	.34	5.5	....	......	......	35

The results given in the preceding table show the analyses of four samples of sludge from the settling tank, and one of the scum taken from the surface. The three values given, with the high per cent moisture, were obtained from samples freshly drawn from the settling tanks, while the sample containing 65 per cent moisture had been on a drying bed for 30 days. The analyses do not indicate that exposure to air and sunlight have any effect on the chemical constituents. The results obtained from the scum show that the material composing it was slightly heavier than water and that the moisture content was lower than that for the other sludge samples. The scum was full of small air bubbles, and these, together with the grease, supported the material that would otherwise have settled to the bottom of the tank. All of the organic constituents are higher in the scum than in the sludge, and the ash is lower. This was due to the fact that only the grease and lighter particles of organic matter was carried to the surface by gas ebullition and this suspended matter contained less ash and consequently more organic matter than the heavier sludge remaining on the bottom of the tank.

The analyses do not show that the dried sludge is a high grade filler for fertilizers, but the presence of the calcium carbonate along with the other constituents is an advantage, and the practical tests carried out at Luray proved that tannery sludge added to soil will increase its fertility. The value of this sludge will, however, depend largely on the nature of the soil. Clay ground can be brought up to a high degree of fertility by a liberal application of the sludge, and in general any soil requiring lime or humus to loosen it up will be greatly benefited by the application of sludge from a tannery waste-treatment plant.

Comparative analyses of the sludge from the two tanneries.—The sludges that accumulated in the settling tanks operated at the two testing stations for the treatment of tannery wastes were produced from similar raw products worked up by like methods of manufacture. The averages of all analyses made at the two tanneries are given in Table 52.

Table 52.—*Average chemical analyses of sludge from Haffner Bros. Tannery and the Deford Leather Co.*

Date.	Source (settling tank).	Specific gravity.	Per cent water.	Per cent (dry basis 100° C.).[1] Total nitrogen.	P_2O_5.	K_2O.	Ca as C_aCO_3.	Iron as Fe.	Ether-soluble matter.
1915–16......	Haffner Bros..........	[2] 1.032	[3] 91.7	1.75	0.77	0.36	33	1.7	1.4
1916–17......	Deford Leather Co....	[2] 1.040	[2] 90.9	3.00	.58	.36	27	1.3	2.6

[1] Average of 4 determinations at each tannery.
[2] Average of 11 determinations.
[3] Average of 14 determinations.

This comparison shows no considerable variation in the specific gravity and moisture, but in the chemical constituents the total nitrogen and ether-soluble matter are about 50 per cent higher in the results from the Deford Leather Co.'s plant. The phosphates are about 25 per cent higher and the calcium is about 20 per cent higher in the Haffner Bros. sludge. The larger amount of ether-soluble matter found in the sludge from the Deford Leather Co.'s plant is readily explained by the fact that they render grease from the fleshings removed from the hides before liming, but the other variations must be attributed either to different methods of operation in the two tanneries or the character of the hides received at each place while the tests were conducted.

SLUDGE DRYING ON OPEN BEDS.

The sludge drawn from the tanks contained, on the average, 91.8 per cent moisture. To learn what length of time would be required to dry this sludge in the open air, it was applied to suitable sand beds and the moisture determined after the lapse of a certain number of days. The results obtained from 14 drying tests are given in Table 53.

Table 53.—*Results obtained by drying sludge on open beds.*

Test No.	Source tank.	Date sludge applied.	Volume sludge applied.	Number days drying.	Per cent water.	Test No.	Source tank.	Date sludge applied.	Volume sludge applied.	Number days drying.	Per cent water.
1	2	1916 Sept. 16	*Cu. ft.* 68	0 26	92.8 65.5	9	1	1917 Feb. 16	69	0 14	92.5 75.5
2	2	Oct. 3	48	0 31	92.8 63.6	10	1	...do.....	59	0 14	89.4 76.0
3	1	Nov. 6	77	0 23	91.5 63.0	11	1	Mar. 9	76	0 8 19	90.2 82.5 70.1
4	2	...do.....	77	0 23	91.5 71.0	12	1	...do.....	80	0 8 19	91.4 80.0 70.0
5	1	Dec. 1	75	0 27	89.6 75.0	13	1	Apr. 17	76	0 6 15 25	91.2 82.0 79.1 70.3
6	2	...do.....	90	0 27	91.6 72.0	14	1	...do.....	91	0 6 15 25	95.0 85.9 79.3 70.0
7	1	1917 Jan. 2	76	0 22	91.5 76.6						
8	1	...do.....	71	0 22	95.0 79.5						

The beds used for drying the sludge removed from the settling tanks were similar to those used in the tests made at Luray. There were two beds, each with the bottom sloping to a central drain and covered with coarse cinders. One foot of sand of the grade used in the filters was placed over the cinders, and the whole was inclosed by 2-inch planks that extended 1 foot above the sand. The beds were located near the tanks, and troughs were used for applying the sludge.

In a general way the sludge dried in about the same time as at Luray. After the third day cracks appeared in the surface, and the sludge along the sides of the beds began to curl up. Most of the drying appeared to be taking place at the surface after the first few days, and when the sludge was removed the top was hard and dry and the bottom layer, next to the sand, sticky. The sludge could be readily removed from the beds at 70 per cent moisture, and this reduction was accomplished, under average weather conditions either in winter or summer, in about 25 days. In large plants designed to treat all the wastes from a tannery it would, however, be advisable to provide sludge bed area sufficient to retain the sludge on the beds for an average period of 30 days. This will assure a reduction to 70 per cent at all times, and during the most favorable drying weather the moisture may be reduced to 60 per cent. In large settling tanks it may also be possible to obtain a sludge for treatment on the beds with a lower moisture content than was obtained in the tests. This will reduce the drying period, as the concentrated sludge dries quickly at the surface, and the cracks that open permit the evaporation of the water retained below the surface.

CONCLUSIONS.

On the basis of the tests made at the Deford Leather Co., Luray, Va., covering a period of about two years, the following conclusions are reached:

The most efficient and economical method of treating tannery wastes requires that all the different wastes be combined and treated as one waste. This reduces the number of devices to be constructed, and results in a compact and simple plant which demands less constant attention than a plant in which each separate waste is treated by itself. It also uses to advantage the chemical reactions between the acid spent tan liquor and the alkaline hair washing and beam-house wastes, and accomplishes a dilution of the spent tan by the other more dilute and easily treated wastes.

The spent tan liquors should be given a preliminary chemical precipitation treatment with the lime sludge from the unhairing vats, before it is added to the other wastes. Special duplicate tanks should be provided for this treatment to allow a day's quiescent sedimentation after treatment and before mixing with the other wastes. This preliminary treatment precipitates a large proportion of the tannins, and does so more efficiently than would the alkalinity of the hair-washing or beam-house wastes, on account of the greater amount of lime in the lime sludge. Another and important advantage is that a long period of quiescent sedimentation can be allowed the relatively small volume of spent tan liquor, which would not be feasible with a much larger volume of the total mixture.

Copperas (ferrous sulphate) should be added ot the combined wastes at a rate of approximately 10 grains per gallon, or 1.5 pounds per 1,000 gallons, to act as a chemical precipitant.

The sedimentation tank for the combined wastes should be of sufficient capacity to store enough waste during the daytime to supply the filters during the time the tannery is closed down at night with a minimum allowance of four hours' time of passage during the daytime. The old style rectangular tank is satisfactory. Scum boards, however, must be provided to hold back from the filters the grease and hair which is carried by the wastes and rises to the surface of the liquid in the tank. A sludge baffle is also required to prevent accumulation of sludge near the outlet.

Preliminary or roughing filters should follow the settling tank. These filters may be constructed of cinders, coke, or slag that have been screened over a one-half inch screen or thoroughly washed to remove dust and dirt. These filters should have a depth of 4 feet and sufficient area to allow a rate of not more than 200,000 gallons per acre per 24 hours.

The preliminary filtration should be followed by secondary filtration through sand. These filters may be constructed of any rough, sharp medium-size sand that is free from clay or dirt. They should have a depth of 3 feet and a sufficient area to allow a rate of not more than 200,000 gallons per acre per 24 hours. The depth of the roughing filter and sand filter and the rates are based on the results obtained from the operation of the permanent unit during the summer of 1917.

The rates as given for both the roughing and sand filters are based on a mixture of which the spent tan does not constitute more than 10 per cent. If the volume of spent tan produced in the tannery is in excess of this and the liquors have the same strength as those treated in the tests it will be necessary to dilute the spent tan with fresh water. It is to be expected that by using fresh water to dilute the spent tan the factor of dilution would not have to be as great as with the hair-wash and beam-house wastes.

The function of the roughing filters is largely mechanical, to strain out the bulk of the suspended solids carried over from the tank. In addition, however, they do to some degree prepare the wastes for oxidation in the sand filters where the main function is that of oxidation. The effluent from the sand filters should contain less than 25 p. p. m. of suspended solids, and be sufficiently oxidized to maintain stability with a dilution of not more than 1:1. In the process of oxidation the color given the waste by the spent-tan liquor will be largely reduced, though it can not be expected that single sand filtration will entirely remove it. However, with a dilution of 1 to 10 it should be negligible.

The sludge capacity in the spent tan lime-sludge treatment tanks should be sufficient to hold a deposition of 1,200 cubic yards per 1,000,000 gallons. This sludge should be withdrawn frequently into the main settling tank. As drawn off from the lime-treatment spent tan tank used in the tests the sludge had a water content of 96 per cent, but in a deeper tank it is believed this will be reduced to 94 per cent.

In the main settling tank there must be capacity to hold the sludge from the lime treatment spent tan tank as well as that deposited in the tank itself. Owing to the depth of sludge that will accumulate in the settling tank, there will be a large reduction of the volume of the spent tan sludge, and the water content should not average above 90 per cent and the specific gravity not more than 1.04. This would reduce the volume of sludge from the lime-treatment tank from 1,200, as found in the tests, to about 410 cubic yards per million gallons of spent tan liquor treated. To this must be added 50 cubic yards per million gallons from the combined wastes treated. Computing all the sludge produced to 90 per cent moisture and 1.04 specific gravity, and on the basis of 14,000 gallons of spent tan and a total of 106,000 gallons from all the operations at the tannery, there should be produced about 1.1 cubic feet of sludge, containing 6.8 pounds of dry solids, per hide tanned. The storage period will depend to a large extent on climatic conditions. In localities where open sludge beds can be used to advantage throughout the entire year, 20 days should be the minimum allowance, and this must be increased in proportion as the availability of sludge beds during the winter months is lessened by more severe weather.

The sludge beds should consist of 1 foot in depth of fine cinders, coke, or sand, underdrained and of such area as to fulfill the requirements set by the sludge-storage capacity of the settling tank.

The feasibility of removing sludge in tank wagons, to be spread on land as fertilizer in its liquid state, is worthy of investigation. Local conditions, cost of labor, length of haul, cost of land, etc., are all determining factors in making any comparison between removing the sludge from the premises in its liquid form and subjecting it to partial dewatering on sludge beds before removal.

The sludge accumulating from a disposal plant treating tannery wastes, such as was used in the tests at Luray, has practically twice as much of the common fertilizing ingredients as barnyard manure and in addition more than 30 per cent of calcium as carbonate. The indicated fertilizer value was verified on small test plots and on a large scale on the farm owned by the Deford Co.

In order to construct the most economical treatment plant and operate it at a minimum annual cost, it is highly desirable that as far as possible all raw materials be used up, and grease and hair recovered, before leaving the tannery. Spent tan liquors will likewise have to be reduced to the lowest concentration and as far as possible used over again in leaching out new liquors. These forced economies will bring some return on the investment, the amount depending on the extent such economies are already in practice.

The results obtained from the operation of the testing station at the Haffner Bros. Tannery have confirmed those reported from the studies made at Luray, Va. This company makes harness leather from cowhides by a process of tanning similar to the one used by the Deford Co. in making belting leather, the only difference being in the extent that the tanning compounds are used up in the process of tanning the two different kinds of leather. In tanning hides to be made into harness leather the tan liquors can be used, especially in cold weather, until the final reaction is neutral or practically so, while in preparing hides for belting leather the liquors discharged at all seasons of the year are strongly acid in reaction, indicating that a considerable amount of tanning compound is left in the waste liquors. The analyses have borne out this comparison. Using the weak liquors until the lime carried by the fresh hides has practically neutralized the acid in them has a practical bearing on the purification of the wastes. It was demonstrated in these tests, as it was in the former, that the amount of spent or weak tan liquors discharged is the controlling factor in the design of a treatment plant for purifying tannery wastes.

The same type of plant was operated at the Haffner Bros. Tannery as was used at the Deford Leather Co.'s Tannery, but at the former all the wastes were treated in the proportion in which they were discharged from the tannery, while at the latter it was possible to treat only a portion of the spent tan liquors along with the other wastes. The importance of economizing in the use of tan liquors, and in every way reducing the amount of weak or spent tan wastes discharged, can hardly be overemphasized when considered in connection with the treatment of the wastes from a tannery. Where tanneries discharge wastes containing tanning solutions in amounts and in strength greater than those treated in the tests at the Haffner Bros. Tannery, it will be necessary to add lime or to dilute them with an amount of water sufficient to bring the concentration down to that given in this report.

In the tests made in Cincinnati, lime sludge was not added to the spent tan liquors until July 1, 1917, when, owing to the more active bacterial action in warm weather, it was necessary to discharge them before they were exhausted. The effect of the lime sludge offset the increased strength of the tannin compounds during the hot weather, as evidenced by the high nitrification and relative stability results for the period following July 1st.

During the wintertime a 6-inch layer of straw well compacted was placed on racks over the roughing filters and sand filters, and these effectively prevented freezing of the surface layers. The sand filters were furrowed before the straw covering was placed. In northern climates where the winters are long and severe, the original design of the beds could be made to include posts extending above the surface of the beds to serve as supports for holding a straw covering. The low rates at which the filters are operated and closing the plant on Sundays and holidays make some such protection necessary during the cold weather in the North.

In the tests made at Luray the filters were operated at the highest rates that would yield a well-nitrified effluent without regard to the reduction of the color. In the studies that followed at Cincinnati an attempt was made to obtain not only a well-nitrified effluent but one in which the color would be so reduced that, in a dilution of 1:1 or 1:2 in the receiving body of water, the color imparted to the stream would not be noticeable. The rates at which the filters were operated in the later tests were therefore lower than those in the original studies, and the results were correspondingly more satisfactory. The color was reduced to 55 p. p. m. in the effluent from one of the sand filters and the suspended matter to about 18 p. p. m. Minnows and baby bass lived continuously in the effluent from filter 5 for three months without any diluting water being added, except on Sundays and holidays when the tannery was closed down.

The depth of the roughing filters and sand filters was 5 feet throughout the entire period of operation. In view of the satisfactory results now being obtained in the larger unit operated at the Deford Tannery, Luray, Va., with a depth of 4 feet in the roughing filter and 3 feet in the sand filter, it is quite probable that similar depths of filtering material in the tests made at Haffner Bros. Tannery would have given as satisfactory results as the depths used. The shallower depths are recommended.

The tests made at the Haffner Bros. Tannery have demonstrated that the conclusions drawn from the Luray studies can be applied to other tanneries using similar raw materials but producing different finished products. The only new conclusions developed from these tests are: First, that for better efficiency a settling basin should be installed between the roughing filter and the sand filters of sufficient size to provide a nominal storage of the wastes for one hour; and second, that provision be made for protecting the surface of the beds from freezing during the wintertime.

It is estimated from the results obtained from the operation of the two testing stations that approximately 100 p. p. m. of suspended solids can be removed from the effluent of the roughing filter by settling basins. This computed to 92 per cent sludge with a specific gravity of 1.02 will give about 165 cubic feet of wet sludge per million gallons of waste. On the basis of 368 gallons of waste per hide, the average from the two tanneries, the volume of sludge daily from 100 hides tannned will be roughly 6 cubic feet. As it will be necessary to retain the sludge in the tank for at least 20 days in order to obtain a low moisture content, and as it will not be practicable to remove all the sludge at any one time, the total sludge capacity should be 120 cubic feet plus 10 per cent for the sludge that will remain in the tank each time, making the total sludge storage capacity required 132 cubic feet.

This will add to the plant recommended on the basis of the Luray experiments another settling tank having a sludge capacity of 132 cubic feet and a liquid capacity of 204 cubic feet, and additional sludge-drying area of 326 square feet per 100 hides tanned. The design of this tank will be the same as that recommended for removing and storing the suspended solids in the raw wastes.

Summing up the results obtained from the operation of the two testing stations, it can be stated that a method has been developed whereby wastes from tanneries using raw products similar to those where the studies were made can be purified in a treatment plant that has been considered reasonable in cost by the owners of tanneries interested in the purification of their wastes. There is no doubt, however, that problems will arise in the operation of large plants treating all the waste from a tannery that could not be anticipated in the operation of the testing stations. It was for the purpose of learning what the difficulties will be in working out on a large scale the conclusions formed from the tests, that the tanneries in Virginia cooperated in building and operating a treatment plant at Luray, Va., of much larger size than the test units. This plant has been in operation one year and will be continued in service until July, 1919, and possibly longer. The results obtained up to this time, March 1, 1919, have not indicated that any extensive changes in the original design will be required, except those mentioned above relating to the protection of the filters during the winter time and the installation of a settling basin between the roughing filter and sand filter. These improvements are important, however, and will be made in the plant at Luray during the year.

PROCESS RECOMMENDED.

The process of treatment recommended is, in general outline, as follows:

Treatment of the spent-tan liquor with lime sludge from the unhairing vats, followed by about 24 hours' quiescent sedimentation.

Mixture of the supernatant from this treatment with the remainder of the wastes and treatment of the combined wastes with copperas (ferrous sulphate), at the rate of about 10 grains per gallon.

Sedimentation of the mixed wastes in a tank having sufficient capacity to permit 24 hours' operation of the filters, and to provide for a minimum time of passage during the daytime of 4 hours.

Preliminary filtration of the settled liquors through cinder roughing filters at about 200,000 gallons per acre per day.

Sedimentation in tanks for about one hour.

Secondary filtration through beds of coarse sand.

Addition of the sludge from the spent-tan liquor treatment to the main sedimentation tank at frequent intervals and withdrawal of the sludge from the latter and from the secondary sedimentation tank to sludge-drying beds as necessary.

Utilization of the dried sludge as a fertilizer.

Direct utilization of the liquid sludge to fertilize near-by land by means of tank wagons may be found more economical than the use of drying beds under certain conditions.

The capacities and rates of operation of these various treatment devices will vary with the requirements of the individual case, especially as regards the quality of the final effluent necessary.

In Appendix I will be found the data for the design of a plant for the treatment of the wastes resulting from the tanning of 100 hides per day, under conditions that require a nonputrescible effluent but permit the discharge of considerable color, the most frequently occurring conditions. To meet other requirements, the designing engineer will find it advisable to study the detailed experimental work given in the body of this report.

APPENDIX I.

CONSTRUCTION DATA FOR A PLANT TO TREAT THE WASTES FROM A TANNERY OF 100 HIDES PER DAY CAPACITY.

No attempt will be made to give a detailed estimate of the cost of building a treatment plant for purifying tannery wastes. The cost of the large unit built by the three tanneries and designed to treat 10,000 gallons per day of combined wastes was $2,100. The cost data, however, are not applicable to plants designed at this time or in the future as the prices prevailing then were above normal for peace times and are lower than those at present. Furthermore, the location of the plant at Luray, where no pumping was required and the lay of the ground was favorable for constructing the various devices, could not usually be duplicated.

This plant having been in successful operation for over a year, it will be of definite value to record in detail the principle dimensions and quantities of materials involved. For the purpose of more ready comparison both the dimensions and quantities have been reduced to the basis of 100 cowhides per day. For the most part, larger tanneries would require proportionately larger treatment works, while with decreasing tannery output the size of the treatment plant will decrease in somewhat less proportion.

BASE DATA.

The following data will be assumed:

	Gallons per day.
Spent-tan liquor	5,100
Rinsing water	1,000
Beam house and liming vats	23,800
Hair-washing machine	8,600
Total wastes	38,500

SPENT-TAN STORAGE TANKS.

Two tanks will be required to store the liquors discharged at night for treatment throughout the 24 hours. The storage capacity required for the liquors from 100 hides daily would be 680 cubic feet per tank. The sludge storage capacity required will depend upon the extent to which the sludge compacts. In a deep tank it is believed that a specific gravity of 1.02 and water content of 94 per cent can be obtained. Using these figures and computing the volume of sludge from that accumulated in the test units at 96 per cent moisture and specific gravity of 1.016, there will be deposited 4.2 cubic yards per day. If this sludge be accumulated for six days before discharge into the main settling tank it will require 25 cubic yards or 675 cubic feet of storage capacity. The total capacity of each tank should therefore be approximately 1,355 cubic feet.

The amount of concrete required to construct these two tanks will be about 32 cubic yards. The bottom of each tank should be built with hoppers to facilitate the removal of the sludge. Each hopper should have a 6-inch cast-iron pipe leading through the side of the tank and provided with a 4-inch gate valve. Each of the spent-tan storage tanks will require a regulating device to control the amount of spent-tan liquor discharged into the other wastes. In the plant now in operation a 2-inch valve and float of the type used in ordinary flush tanks is giving very good service. Only one float and valve is used and the piping to which it is attached extends through the storage tanks just above the sludge line. No trouble has been experienced from clogging of the valve, and the liquors have not had any effect on either the valve or the float.

MIXING TANK FOR LIME SLUDGE.

The lime sludge containing about 50 per cent moisture was added direct to the spent tan in the storage tanks during the tests and the mixture stirred together. In a large plant, however, this will not be practical, so that a mixing tank will be required to get a suspension of the lime sludge in water. A circular wooden tank 6 feet in diameter and 6 feet deep will be a convenient size for this purpose. A stirring device will be required for mixing the lime sludge and water together, but it will be operated only while the spent-tan liquors are discharged, as the lime will be added to the waste as it enters the storage tank. An ordinary 2-inch gate valve attached to the outlet pipe from the mixing tank can be calibrated to control the amount of lime sludge added to the spent-tan liquors.

SOLUTION TANKS FOR COPPERAS.

Two solution tanks for copperas will be required, one to be in use while the solution is being prepared in the other. These should be of wood and each tank should have a capacity of about 20 cubic feet.

SETTLING TANK.

The total volume of waste to be settled in this tank is 38,500 gallons per day. In order to store enough waste during the day time to supply the filters at night, the total settling capacity required is 3,000 cubic feet. In 20 days there would be deposited in this tank 34 cubic yards or 918 cubic feet of sludge with 90 per cent water and a specific gravity of 1.04. This tank should have a 20-day capacity for sludge and also a sufficient capacity to receive the thin sludge from the spent tan storage tanks. This sludge will amount to 675 cubic feet per week, as already shown, and will contain about 94 per cent water and have a specific gravity of 1.02. Emptied once a week into the main settling tank, it will be stored 20 days so that the total storage capacity required for sludge should be about 3,200 cubic feet, and the total volume of the tank about 6,200 cubic feet.

There would be required to construct this tank approximately 100 cubic yards of concrete. The bottom of the tank should contain hoppers for concentrating the sludge near the sludge outlet pipe. An outlet pipe 6 inches in diameter with a 6-inch gate valve located outside the tank should be provided for each hopper. A controlling apparatus will be necessary at the outlet end of this tank to give a constant flow to the filters.

SIPHON CHAMBERS.

Two siphons and two siphon chambers would be required, one for applying the settled waste to the roughing filter, and the other for dosing the sand filter. A 6-inch siphon discharging every 10 minutes would require a chamber holding approximately 900 gallons, or 120 cubic feet. There would be required about 2 cubic yards of concrete for the two tanks.

ROUGHING FILTER.

The roughing filter should be composed of cinders from which the fine material has been removed, or slag running about the same size as washed or screened cinders. The bed should be 4 feet deep exclusive of the underdrainage. This filter should treat the waste at a rate of 200,000 gallons per acre per day. With 38,500 gallons to purify the area required would be 0.2 acre, requiring 1,290 cubic yards of cinders. The underdrainage for this filter should consist of farm tile covered with coarse stone. The main drains should be of 6-inch tile and the laterals of 4-inch tile laid 8 feet apart. It will be necessary to cover the tile to an average depth of 6 inches with coarse stone. There will be required 65 feet of 6-inch, and 1,165 feet of 4-inch tile, and, for covering the tile, approximately 161 cubic yards of stone. To distribute the waste over the surface of the bed, troughs made of 6-inch by 2-inch planks should be used, radiating from a box at the inlet of the bed, and approximately 2,400 feet of lumber will be required for this purpose.

To inclose this filter approximately 4,000 feet of 2-inch plank will be required, and 46 posts, 6 by 6 inches. The posts should be set in concrete.

INTERMEDIATE SETTLING TANK.

This tank, the value of which was demonstrated in the Cincinnati experiments, should be included in the design, although it was not contained in the full scale unit at Luray.

It should be of essentially the same design as the preliminary settling tank just described, but of a sludge capacity of about 132 cubic feet and a total volume of about 204 cubic feet.

The construction of this tank will require, approximately, 20 cubic yards of concrete.

SAND FILTER.

The sand filter should have the same area as the cinder filter, and its depth should be 3 feet, excluding the underdrainage. There will be required 970 cubic yards of sand. The underdrainage will be similar to that of the cinder filter, and the distributing troughs will require about 1,200 feet of lumber. The very low temperatures of the winter of 1917–18 at Luray, Va., where the permanent unit is now in operation, have shown that the filters, in particular the sand filters, will require some kind of protection during protracted zero weather. Posts set in the filters and extending 1 foot above the sand and supporting a loose framework of boards covered with 6 inches of straw well compacted, seems to be the most practical and economical form of covering.

It is very essential that the bottom of each filter should be carefully prepared, and the tile and covering of coarse stone carefully placed, in order to prevent the storage of the filtered waste in pools under the filtering material. The prolonged storage of filtered waste on the bottom of the filters will cause secondary decomposition to take place and the effluent will be unsatisfactory. Fresh water forced back through the tile and coarse stone will relieve a bad situation that has developed from the storage of filtered wastes on the bottom of the bed. To do this efficiently, should the necessity arise, the stone must be carefully placed so as to afford ready access of flushing water to all parts of the bottom of the bed and to a height of at least 6 inches above the bottom. It is particularly important that the sand filter bottom should be properly prepared as any failure here will ruin the effluent.

If this filter is not made in excavation the same amount of lumber and posts will be required to inclose it as given for the roughing filter.

SLUDGE BEDS.

The settling tank is designed to hold all the sludge produced in the plant for 20 days, when it is anticipated the sludge will be reduced to 90 per cent moisture and a specific gravity of 1.04. The total volume of sludge to be applied to sludge beds every 20 days will be approximately 74 cubic yards. As 20 days is the shortest drying period that can be depended upon throughout the year, duplicate beds will be required. In the tests it was demonstrated that 10 to 12 inches was the proper depth of sludge to apply to the beds. An area of 2,000 square feet is therefore required for each bed. The beds can be made either of sand or of cinders. If sand is used, a depth of 6 inches is necessary. If cinders are used, and they will probably be cheaper in most localities, the depth should be 1 foot with 4 inches of material at the top that has passed through a ½-inch screen, and 8 inches below, that has passed over a ½-inch screen. This would require 74 cubic yards for each bed or a total of 148 cubic yards.

The underdrainage should consist of lines of 4-inch farm tile laid 10 feet apart over the bottom of the bed. The tile should be laid in ditches with sides sloping 5 feet each way and the coarse cinders placed over them. If sand is used, coarse cinders should be placed over the tile to prevent the sand from washing away.

At the Deford Co. Tannery it will be possible to locate the sludge beds favorably for construction so that the drainage can be discharged into the siphon box receiving the effluent from the roughing filter, and thus receive final treatment on the sand filter. This procedure is recommended whenever possible. The drainage from the sludge beds should not be discharged into the stream without further treatment. It can in most cases, with advantage be returned to the main sewer and passed again through the treatment plant.

MISCELLANEOUS.

There will be required considerable miscellaneous material not listed above that will be necessary for the construction of a treatment plant. This will vary according to local conditions and will include such items as sewer pipe or flumes for conducting the various wastes to the plant and away from the final filters. There will also be required copperas (ferrous sulphate) and storage for it. The copperas will be used at the rate of 5½ pounds per 100 hides. It may be necessary at some tanneries to provide storage for the lime sludge during the winter time.

APPENDIX II.

THE EFFECT OF THE TANNERY WASTE FROM THE DEFORD TANNERY CO. ON THE WATERS FLOWING IN HAWKSBILL CREEK.

The wastes from the tannery are discharged into a small stream, Hawksbill Creek. This creek rises in the Blue Ridge Mountains in the southeastern part of Page County, Va., about 12 miles south of Luray, and enters the south fork of the Shenandoah River about 4 miles to the north.

Discharge measurements were made during 1905 and 1906 by the United States Geological Survey. The monthly averages of these readings are contained in Table 54.

TABLE 54.—*Monthly average discharge of Hawksbill Creek 1½ miles below the Deford Tannery.*[1]

Month.	Discharge in second-feet.			Month.	Discharge in second-feet.		
	Maximum.	Minimum.	Mean.		Maximum.	Minimum.	Mean.
1905.				1906.			
July	46	30	36.1	January	414	52	100.0
August	63	27	32.6	February	83	37	53.9
September	37	24	27.5	March	173	42	85.2
October	46	27	30.0	April	430	69	123.0
November	34	27	30.0	May	83	37	53.6
December	298	30	81.7	June	232	37	68.8

[1] Water Supply and Irrigation Paper No. 192, p. 115, Department of the Interior, U. S. Geological Survey.

Between the point of discharge of the waste and the station at which the above measurements were made there are several small additions to the flow. The total of these amounted to about 2 second-feet, so that the values given in the table are in excess of the flow at the tannery outlet by that volume.

With waste averaging about 90,000 gallons in 10 hours, there would be a dilution, under the minimum flow recorded above, of about 72 times. The spent tan liquors were discharged during the night, but it would be possible to make this operation cover a period of at least 10 hours. With 14,000 gallons daily, which it seems fair to accept as large enough if rigid economy is practiced even though none of the hide wash is used back in the leaches, the dilution, in a 10-hour discharge period, would be about 460 times.

To study the effect of the waste upon the water in the creek, several sampling points were established and frequent determinations made of the dissolved oxygen content at these points. It should be noted that the waste entering the stream at the times the samples were taken contained no spent tan liquors, as the samples were taken during the day and the spent tan was discharged during the night. There was, however, a small amount of clear water from springs, which served to dilute the wastes to some slight degree.

Table 55 contains the results of these analyses averaged by months.

TABLE 55.—*Dissolved oxygen in Hawksbill Creek.*

Month.	Number of samples in average.	Station A.		Station C.		Station D.		Station E.	
		Parts per million.							
		Dissolved oxygen, initial.	Oxygen demand, 24 hours.	Dissolved oxygen, initial.	Oxygen demand, 24 hours.	Dissolved oxygen, initial.	Oxygen demand, 24 hours.	Dissolved oxygen, initial.	Oxygen demand, 24 hours.
1915.									
March	2	14.2	3.7	12.0	3.3	12.0	3.4	11.6	2.8
April	3	11.5	1.8	10.2	3.4	9.3	3.1	10.1	3.9
May	4	10.0	1.1	8.0	2.6	6.9	2.7	6.2	2.0
June	4	9.5	1.2	12.1	3.6	8.4	2.7	8.6	2.5
August	1	13.1	.8	9.6	7.8	7.3	5.2	5.8	4.7
September	2	9.5	1.9	9.1	5.9	6.8	4.3	7.1	5.0
October	1	10.3	.4	9.1	4.1	8.9	3.5	8.8	3.7
November	1	12.4	2.4	10.9	2.9	9.9	3.0	10.8	3.9
December	1	12.2	1.9	11.3	7.3	10.8	7.2	10.8	6.7
1916.									
January	1	10.6	.0	10.6	1.6	10.2	1.5	....	....
February	2	11.9	1.0	12.0	2.6	12.0	2.7	11.7	2.9

Station A.—Creek, 100 feet above tannery outlet.
Station C.—Creek, 200 feet below tannery outlet.
Station D.—Creek, ¼ mile below tannery outlet.
Station E.—Creek, ½ mile below tannery outlet.

At station A the water was saturated with dissolved oxygen in practically every sample taken. The large amount of oxygen carried by the water was due, no doubt, to the large number of water cress beds located along the banks of Hawksbill Creek above Luray, and the oxygen demand as given under A was influenced to some extent by the escape of oxygen during incubation, although glass tubes were used extending down into the bottle to form a seal at the top.

The oxygen demand at station C, when compared with stations D and E, shows that equilibrium was reached in the amount of oxygen immediately required at this point. It is well to bear in mind in considerng the results in this table that no spent tan liquor except a small amount of leakage was present in the wastes and that the dilution was 1 to 65. Samples taken at the same stations at night, when the spent tan liquors were discharged but no other wastes, showed a higher oxygen demand but not enough to exhaust the oxygen in the creek at stations C, D, or E. Methylene blue tests made at intervals during the period covered by the table always gave a relative stability value of 95 for both the periods when the general waste was discharged in the daytime and when the spent tan liquors were discharged at night.

The water flowing by all the stations below the tannery outlet had a very pronounced color during the daytime, and at night the entire stream was colored red from the tan liquors.

Appendix III.

EFFECT OF UNTREATED AND PURIFIED TANNERY WASTE ON FISH LIFE.

Where tanneries are located on small streams or rivers of low discharge during the summer months, the effect of discharging the wastes into such waters is of importance not only from a sanitary standpoint but because of the effects on fish life. At the point where the waste from the Deford Co.'s plant enters Hawksbill Creek the dilution of the waste discharged during the daytime of the driest season of the year is approximately 72 parts of water to 1 of waste, and at night when the tan liquors are discharged the ratio is 1 to 460. Observations made throughout the summer of each year of the tests disclosed the fact that minnows were present at all times within 300 yards of the outlet. Minnows placed in a box in the creek in five different sets of tests at points 100 to 300 yards below the outlet of the tannery ditch showed a death rate varying from 25 to 50 per cent at the end of seven days, while the control above the outlet varied from 3 to 6 per cent. The total number of minnows used in the five different series was 150, 30 to each box. The conclusions to be drawn from the observations and box tests are that minnows can and do live in the creek within 300 yards of the tannery outlet, but when confined in a box they do not live as long below the tannery outlet as above. In the springtime sunfish, suckers, and pike were caught at 300 yards below the outlet, but it is a question whether these fish remained even within 1,000 yards below the outlet to lay their eggs.

From the nature of the deposit on the bottom of the creek after the spring rains were over, it is not likely that any fish spawned in the creek above 1 mile below the tannery outlet, and in this consideration probably lies the greatest danger to fish life in streams below tannery outlets. The accumulation of particles of lime sludge and other forms of suspended matter over the bed of the stream no doubt would drive fish to the cleaner portions of a stream during the spawning season, but at other times the distance they will remain below the entrance of tannery wastes will depend on the dilution.

The United States Geological Survey in 1907 published a report in Water Supply and Irrigation Paper No. 192, dealing with "The Effect of Some Industrial Wastes on Fishes." These studies were carried out in Washington at the United States Bureau of Fisheries, and the samples of wastes used were shipped from the various industries studied.

Under tannery wastes in this report are given the results of placing various kinds of fish in different dilutions of the several different kinds of spent liquors discharged from a tannery. Selecting the dilution in which the fishes lived the longest the results are as follows for the different kinds of wastes:

First. "Sour bark liquors:" A dark-colored acid waste containing a small amount of tannic acid. In a dilution of this waste of 1 to 50 bass were not killed in 65 hours.

Second. "Rocker sour bark liquors:" A brownish, cloudy acid liquor labeled "valueless in tannic acid," specific gravity 1.007 at 10° C. This liquor ordinarily has an acidity of 1,200 parts per million and an oxygen consuming value of 18,000 p. p. m. A dilution of 1 to 60 failed to kill bass in 9 days, but was fatal to perch in 20 hours; 1 to 120 killed perch in 3 days, and 1 to 140 failed to kill at 4 days.

Third. "Dye house liquors:" A greenish liquid with some dark sediment, about neutral in reaction and a specific gravity of 1.003 at 16° C. A dilution of the waste, 1 to 15, failed to kill perch in 51 days, but bass were killed in 9 days.

Fourth. "Bate:" A straw-colored liquor with an alkalinity of 400 parts per million (caustic and hydrate) and specific gravity of 1.004 at 9° C. A dilution of this waste 1 to 10 failed to kill bass in 4 days.

Fifth. "Soak liquors from hides:" A colorless neutral water containing the sodium chloride soaked out of the hides. Bass placed in an aerated and undiluted sample of this waste for 4 days were not affected.

Sixth. "Sour liquor tail handler:" An acid liquor of pinkish color and foul odor, extracted originally from hemlock bark. A dilution of 1 to 60 killed bass in 20 hours, but failed to kill perch in 54 hours.

Seventh. "Sample from hair washing machine:" A cloudy, grayish liquid, of 1.004 specific gravity at 14° C. and alkalinity of 630 p. p. m. (probably hydrates and carbonates). Dilutions of 1 to 50 failed to kill bass in 13 days.

Eighth. "Lime and sodium sulphide:" A dirty yellowish, strongly alkaline (4,000 p. p. m., probably hydrate and carbonate) liquor, with a specific gravity of 1.015 at 7° C. Dilutions of 1 to 120 killed bass in 70 hours, while 1 to 150 failed to kill in 43 days. Perch were able to live in a dilution of 1 to 180 for four days without being affected.

Attention should be called to the fact, as pointed out in the report, that the fish in the tests were kept in containers varying in size from 5 to 30 liters, and, consequently, were not in as favorable surroundings as would be the case in an open stream, where aeration would be rapid and the toxic compounds from the fish and the decomposition products due to bacterial action disseminated.

In applying the data in the Geological Survey report to practical conditions it is well to bear in mind that the wastes tested were selected from special operations in the tannery and were not the composite wastes that were discharged. This is an important consideration, as the separate wastes when mixed together to form the composite have an entirely different character. The acid tan liquors are made neutral by coming in contact with the lime wastes, and the causticity of the lime wastes at the same time is reduced. If, however, a large quantity of one waste is discharged at one time and at the same time a small quantity of another waste with the opposite reaction, then the effect on fish of the wastes in excess will be somewhat in relation to the tests made in the jars for the wastes discharged that represent one process in the tannery.

Ordinarily the routine of a tannery is well established, and during the two years of the tests there was only one variation in the discharge of wastes that had any effect on the fish in the stream. In this case, through a mistake, an extra lime vat was discharged that increased the causticity of all the wastes flowing at the time sufficiently to kill the fish when these wastes reached the creek.

Toward the end of the tests when an adjustment of the wastes had been made so that all could be treated together and a stable effluent obtained, fish (minnows) were placed in the undiluted effluent from the sand filters and lived from June 8 to July 20. Following this test a rock bass placed in the effluent from sand filter 5 lived till the station was closed down August 15.

From all the evidence cited above, the effect of unpurified tannery wastes on fish will depend entirely on the dilution available and the control exercised in discharging the wastes. With careful control at the Deford Co.'s tannery at Luray, and with the wastes produced from this type of tannery, fish could live comfortably with a dilution of 1 to 65 at 300 yards below the outlet. In the data quoted from the United States Geological Survey bulletin, the time fish lived in the tests with separate wastes varied from dilutions of 1 to 180 for " lime and sodium sulphide " to 1 to 10 for wastes from the bating process. If the latter tests had been carried out in a stream of running water, the fish would probably have lived in the same dilutions that were fatal in the basins.

In the sand filter effluent from the test units operated at the Deford Co. tannery, minnows lived for more than 30 days, but it must be borne in mind that the wastes were all mixed together to form the best possible mixture for treatment, and this mixture happened to be the one least detrimental to fish life. Such a combination could not be obtained except by storage of the different wastes in tanks, and there is no doubt that treatment in tanks alone would lower the dilution necessary to maintain life. The condition of the effluent from settling tanks is not such, however, as to meet the requirements of the more important question of the sanitary standard required.

Appendix IV.

BIBLIOGRAPHY OF TANNERY WASTE TREATMENT.

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