COMPLIMENTS OF

GEORGE S. WEBSTER,

CHIEF ENGINEER AND SURVEYOR,

BUREAU OF SURVEYS.

(KINDLY ACKNOWLEDGE.)

# PARTIAL REPORT

UPON THE

# COMPREHENSIVE PLAN

FOR THE

# COLLECTION, PURIFICATION AND DISPOSAL OF THE SEWAGE OF THE ENTIRE CITY

## REPORT

OF THE



# BUREAU OF SURVEYS

COMPRISING THE WORK AT THE SEWAGE EXPERIMENT STATION AT SPRING GARDEN
PHILADELPHIA, 1910

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# PROGRESS REPORT

## COMPRISING OPERATIONS AT THE SEWAGE EXPERIMENT STATION AT SPRING GARDEN, PHILADELPHIA

CARRIED ON BY THE

## DEPARTMENT OF PUBLIC WORKS

BUREAU OF SURVEYS

### AUTHORIZATION.

On July 20, 1907, His Honor, the Mayor of the City of Philadelphia, John E. Reyburn, approved an ordinance of Councils entitled "An Ordinance to authorize the Department of Public Works to make investigations and report upon a comprehensive plan for the collection, purification and disposal of the sewage of the City, together with such alterations and extensions of the existing sewerage systems as may be necessary, and to make an appropriation therefor." The ordinance provides, in part, as follows:

**Whereas,** By an Act of Assembly of the State of Pennsylvania, entitled "An Act to preserve the purity of the waters of the State for the protection of the public health," approved April 22, 1905, it is provided, among other things, that "No person, corporation or municipality shall place, or permit to be placed or discharge, or permit to flow into any of the waters of the State, any sewage, except as hereinafter provided, etc." Also, that "Whenever it is their unanimous opinion (Governor, Attorney General and Commissioner of Health), that the general interests of the public health would be subserved thereby, the Commissioner of Health may issue a permit for the discharge of sewage for any such sewer system into any of the waters of the State, and may stipulate in the permit the conditions on which such discharge may be permitted,'' revocable at any time; and

**Whereas,** The Governor of the State, the Attorney General and the Commissioner of Health have by various permits granted the right to the City of Philadelphia to extend various sewer systems, and to discharge the sewage into the waters of the State subject, among others, to the following conditions: ''That the City shall, on or before the year one thousand nine hundred and twelve, prepare and submit to the State Department of Health, for approval, a comprehensive sewerage plan for the collection and disposal of the sewage of the various drainage districts of the City,'' and another condition as follows: ''Extensions shall be immediately approved, provided some progress shall be made each year in the study of a comprehensive system of sewerage for the various drainage districts, and provided that said sewer extensions shall not, as far as practicable, be at cross purposes with said comprehensive system;'' now, therefore,

Section 1. The Select and Common Councils of the City of Philadelphia do ordain, That the Department of Public Works be authorized and directed to make investigations and report upon a comprehensive plan for the collection, purification and disposal of the sewage of the City, together with such alterations and extensions of the existing sewerage systems as may be necessary; also to carry on experiments and report upon the feasibility of the treatment of sewage, together with estimates of the probable cost of altering the present sewage systems as far as may be required, of constructing necessary outfall sewers, of constructing disposal works, and the maintenance of the same.

Section 2. The Director of the Department of Public Works is hereby authorized to employ in consultation such engineers and bacteriologists as may be requisite to reach a satisfactory solution of the problem; and also to employ such engineers and assistants as may be required for making surveys, investigations, experiments and recommendations; all expenses for salaries, inspection, tests, transportation, and incidental expenses, not otherwise provided for, shall be paid out of the appropriation for the work herein authorized.

Section 1 of this ordinance provides for investigation and report, which may be assumed to be divided into the following subjects:

1. A comprehensive plan for the collection, purification and disposal of the sewage of the City.

2. Alterations and extensions of the existing sewer system.

3. Experiments and report on the treatment of sewage.

4. Estimates of the cost of altering the present sewer system.

5. Constructing intercepting sewer systems and disposal works.

6. Maintenance of disposal works.

The accompanying report is intended as a progress report covering Item 3 above.

## SUMMARY OF CONCLUSIONS.

**(See Report following.)**

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### FINE MESH SCREENING.

Page 35. The 35 mesh per inch screen removed one-third of the
suspended matter in the crude sewage as applied; pre-
Page 40. vented the formation of scum in subseqeunt sedimentation
tanks, and prevented the clogging of nozzle orifices on the
Page 36. sprinkling filters.

### SEDIMENTATION.

For the purpose of comparison, the results of sedimentation are given in percentage removal, although it is recognized that effluents which are produced with equal percentage removal are not comparable on the basis of solids content.

**Horizontal Flow.**

Three and one-half hours nominal flow through a
Page 42. baffled sedimentation tank removed two-thirds of the sus-
pended solids in the crude sewage; an increased storage
Page 41. did not produce a proportionate improvement in the
efficiency of the tank. Baffling by equalizing velocity
Page 44. through the cross section prevented dead spots in the tank
Page 170. and restrained sludge and scum at the inlet end.

Between periods of three and a half to six hours flow
the influent was not deoxidized nor rendered offensive
Page 39. when sprayed upon sprinkling filters. To prevent septic
action the tanks required sludging and washing out every
six weeks.

**Vertical Flow.**

The Emscher or Imhoff tank studied illustrated the
principle involved, inasmuch as the substantial separation
of the sewage flow from the digesting sludge keeps the Page 49.
sewage fresh and eliminates offensive odors either in the Page 167.
effluent, the sludge, or in the gas developed. Page 50.

The removal of suspended solids from the crude sew-
age was but little more than one-half due to the shallow- Page 47.
ness of the tank; the efficiency may be increased in tanks
of working size.

## SLATE CONTACT BEDS.

The best results were accomplished when this bed was Page 56.
filled twice a day, or at a rate of two million gallons per
acre per day.

Crude sewage applied, deposited three-fourths of the
suspended solids; the effluent was slightly nitrified and Table No. 8.
rendered partially stable.

The deposit on the slates was inodorous, resembling Page 168.
earth, and could be removed by flushing in the small size
bed experimented with. Page 56.

Where slates are not a waste product the construction of the bed would be costly.

## CONTACT SYSTEM.

The primary and secondary beds treating settled sew- Table No. 11.
age did not mature sufficiently to yield a stable effluent Diag'm No. 21.
although it was very low in suspended matter. The highest Page 58.
rate obtained was 1,350,000 gallons per acre per day.
With sewage containing less trade waste better results
might have been obtained.

## SPRINKLING FILTERS.

**Distribution.**

Best results were obtained with fixed sprinkler nozzles
when the film of sewage was made to constantly travel Page 63.

back and forth over the media, without a resting period; this caused a uniform rate of flow from the underdrains.

Page 65.

## Rate of Operation.

Page 72.

A regular uniform rate of operation produced better results than the same net rate obtained irregularly. With filters exposed to the weather and receiving sewage partially settled, the maximum rate obtained was two and a half million gallons per acre per day, but in the Winter the stability of the effluent deteriorated.

Diag'm No. 18.

With a filter protected from the weather, having fine screened and settled sewage uniformly distributed over its surface, and having a ventilating system, the maximum rate used was three and one-tenth million gallons per acre per day. The effluent was practically always stable. How far this would have been affected by exposure to the weather was not determined.

Diag'm No. 27.

## Kind of Media.

Diag'm No. 26.

Trap and gravel maintained their initial size. Limestone and slag disintegrated to a slight extent.

The smooth surface of the gravel stones was not as well adapted to the formation of a bacterial jelly as rougher media, and the extreme roughness of slag caused it to retain the deposited solids.

Page 71.

Page 99.

The rough, irregular cinders removed all the suspended matter from coarsely screened sewage, so that clogging soon ruined the bed.

Page 108.

## Size of Media.

The completeness of preliminary treatment partially controls the size of media in subsequent filtration.

In filters exposed to the weather and receiving sewage partially settled, operating at two and a half million gallons per acre per day, best results were obtained from

Filter No. 20-4.

trap media one inch to three inches in size. Under the more favorable conditions of fine screened and settled sewage as an influent uniformly distributed, at a rate of three and one-tenth million gallons per acre per day, media three-quarters inch to one and a half inch produced an excellent effluent. Filter No. 23.

**Depth of Bed.**

Filters of less depth than six feet were not satisfactory, but from filters six feet or more in depth effluents could be obtained at rates between two and a half and three million gallons per acre per day of satisfactory quality. The additional depth over six and one-half feet did not seem to be economical.

**Maturing.**

Filters exposed to the weather, receiving sewage partially settled, and put in operation in March, yielded a satisfactory effluent in three weeks and after three months the effluent was perfectly stable. Diag'm No. 21.

A filter protected from the weather, having fine screened and settled sewage uniformly distributed over its surface, and put in operation in July, yielded a perfectly stable effluent after one week of service.

**Unloading.**

In filters operated at rates between two and one-half and three million gallons per acre per day, media composed of stones approximately uniform in size completely unloaded the solids stored up in the interstices, whereas media composed of stones of great diversity in size became badly clogged but did not unload. Diagrams Nos. 16, 18 and 27. Page 97.

**Effect of Freezing Temperature.**

No trouble was experienced from the formation of ice upon the surface of the filters; biological activity was Page 76.

decreased by the low temperature to such an extent, however, that at a rate of two and one-half million gallons per acre per day the fine grain and graded mixture beds pooled and the effluents of all the exposed filters were of lower stability than in summer.

Diagrams Nos. 21 and 22.

## Elimination of Surface Growth.

Page 118. Fungus growths on the surface were completely removed by an application of calcium hypochlorite dissolved in water.

Page 118. The continual disinfection with calcium hypochlorite of the influent to a filter maintained its surface in perfect condition and did not interfere with the biological action of the bed.

## Bacterial Efficiency.

Tables Nos. 30 and 39. The average number of bacteria in the effluent of a mature sprinkling filter operated at rates between two and one-half and three million gallons per acre per day was 400,000 per c.c., which represented a removal of 86 per cent. from the crude sewage.

Table No. 31.

Table No. 31. Bacterial efficiency within a limited range of small size stone was proportional to depth of bed.

## Settlement of the Effluent.

When the effluent was passed through a settling basin in two hours much improvement was obtained by the removal of the suspended matter.

Table No. 42.

# HAMBURG AND INTERMITTENT SAND FILTER.

Page 121. A filter modeled after the so-called Hamburg type, in which distribution is effected by a layer of fine coke; also a shallow, coarse size sand filter both operated at too low a rate to be economical, for the conditions in Philadelphia.

Page 124.

## DISINFECTION.

Fresh sewage from which suspended matter larger than one-twenty-fifth inch had been removed was disinfected to a practical degree with calcium hypochlorite; the amount of disinfectant required depended upon the amount and condition of the organic matter in the sewage.

Table No. 43.
Page 157.

Economy of design and operation can be attained by short storage and mechanical agitation to insure contact of the disinfectant and the sewage.

Page 159.

## DILUTION.

Crude sewage when passed through a fine mesh screen or satisfactorily settled to remove the solids larger than 1-25 inch, and disinfected with calcium hypochlorite to yield six parts per million available chlorine; was added to river water in proportions up to one to ten, and its purification accomplished without offense to sight or smell nor the depletion of the dissolved oxygen of the river water below 50 per cent. saturation.

Page 158.

## SLUDGE.

### Amount.

Horizontal flow in sedimentation tanks produced sludge 88 per cent. moisture at an average rate of five cubic yards per million gallons sewage.

Page 161.

An Emscher tank with 4½ feet vertical flow produced sludge 82.6 per cent. moisture at an average rate of nine-tenths cubic yards per million gallons sewage.

Page 162.

### Condition.

Cleaning plain sedimentation tanks caused considerable offense, but the sludge withdrawn from the Emscher tank had a tarry odor and was not offensive.

Page 167.

Scum formed on sedimentation tanks except when the influent was screened.

Pages 108 and 169.

## Digestion.

Page 175. The placing of sludge from a sedimentation tank in a water-tight, uncovered tank for digestion did not prove successful.

## Lagooning.

Wet sludge from plain sedimentation tanks placed in earth lagoons to a depth of twelve inches in moderate Page 179. weather, dried to a consistency fit to remove within the six weeks elapsing between cleaning tanks, and its volume was four-tenths of that applied.

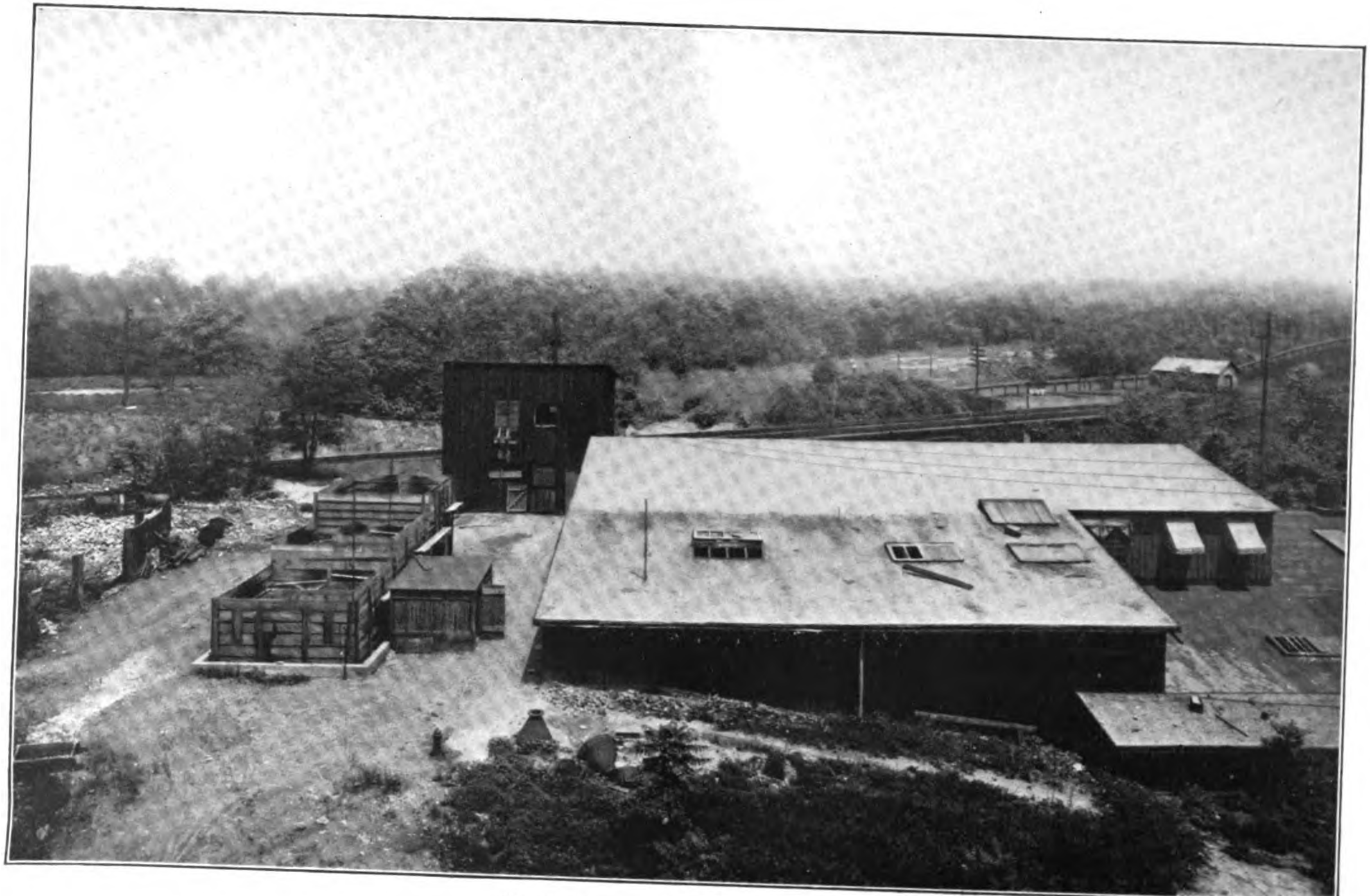
## Sludge Bed.

Fine sand or sawdust over a coarse stone drainage floor was more efficient for reducing moisture in sludge than a plain earth lagoon.

Wet sludge from a sedimentation tank, applied six Table No. 66. inches deep in winter weather, under cover, dried to a consistency fit to remove in six days and under the same conditions but not under cover, in twelve days.

Page 187. Based upon small size tests in winter weather, Emscher sludge 12 inches deep upon a sand bed, dried to a consistency fit to remove in 12 days during freezing weather. In Germany the time is given as from 4 to 5 days, but sludge is not withdrawn in freezing weather which accounts for the difference.

Page 190. When equal weights of rice coal and wet sludge were mixed and placed on sludge beds, the mixture was fit to Page 197. remove in one day, and was successfully burnt.



Spring Garden Testing Station.

# PRELIMINARY INVESTIGATION.

Following the authorization in February, 1908, the Director of the Department of Public Works, Mr. George R. Stearns, and the Chief Engineer of the Bureau of Surveys, Mr. George S. Webster, in order to secure at first hand valuable information concerning the recent advances made in Sanitary Science, and to observe for themselves the effect of treatment in existing plants, visited some of the principal cities of Europe within the countries of England, Belgium, Holland, Germany and France, which had constructed works for the purification and disposal of sewage, a report of which investigation was made to His Honor, the Mayor, under date of February 29, 1908, (for an abstract of which see Proceedings of The Engineers' Club of Philadelphia for January, 1909).

Prior and subsequently these officers, accompanied by assistants directly interested in the design and operation of sanitary works, visited various types in this country, comprising Boston, Lawrence, Worcester and South Framingham, Mass.; Columbus, Marion and Mansfield, Ohio; Baltimore, Md.; Reading and Washington, Pa., and other places of minor interest were visited by the assistants, including, Danville, Pa.; Providence, R. I.; Waterbury, Conn.; Brockton, Mass.; Mt. Vernon, N. Y., and Boonton, N. J.

## ACKNOWLEDGMENT.

Mr. Rudolph Hering, M. Am. Soc. C. E. was engaged to advise in connection with the studies for the Comprehensive Plan of Sewerage, and also in connection with the experiments at the testing station and in the preparation of this report.

Due acknowledgment is made to Mr. F. C. Dunlap, Chief, Bureau of Water, for his hearty co-operation, interest and aid in furnishing both men and materials to further the work. And also through his courtesy to Dr. George E. Thomas, chemist in charge of Belmont Laboratory, for the valuable aid in organizing the bacteriological work and for advice during the operation of the plant.

In the interim between his engagement at Gloversville, New York, and Chicago, Mr. Harry B. Hommon was employed, covering a period from August 17 to September 5, 1909, to furnish expert advice as a chemist and to systematize the work in the chemical laboratory.

## ORGANIZATION AND ROSTER OF EMPLOYEES.

As a further step in this work there was organized a division of the Bureau of Surveys, known as the Sewage Disposal Division, under the supervision of the Principal Assistant Engineer, Mr. George E. Datesman.

Pursuant to the inspections and profiting by the mass of information and data collected, studies comprising many plans and tentative projects were prepared for the collection, purification and disposal of the sewage for the entire City.

The work of this division will comprise the investigation and report upon all the items authorized by the Ordinance above quoted.

In conjunction with the preparation of studies and the collection of data for the comprehensive plan which is to form the basis of the future sanitary development of the City, it was found essential to conduct an exhaustive series of experiments upon sewage treatment.

The roster, together with the dates of appointments of employees engaged in this division, principally in the experimental work at the sewage experiment station, which work forms the subject matter of this report, is as follows:

Assistant Engineer in charge, W. L. Stevenson, September 21, 1908.

Draughtsman, Lynn E. Perry, August 22, 1907.

Chemist, Geo. G. Eysenbach, July 1, 1909, to June 1, 1910.

Assistant Chemist, Lyle L. Jenne, September 20, 1909 to May 31, 1910.

Assistant Bacteriologist, Leroy A. Wilkes, June 11, 1909, to September 15, 1909.

Assistant Bacteriologist, Percy E. Mebus, October 1, 1909, to June 14, 1910.

Apprentice, Walter Young, October 18, 1909, to May 31, 1910.

## SELECTION OF SITE.

There had been built in 1900 by the Bureau of Surveys, a testing station wherein experiments on water purification were conducted prior to the design and construction of the present improved water supply of the City. This station is situated in Fairmount Park adjacent to the Spring Garden Pumping Station of the Bureau of Water, where power for pumping sewage, steam and electricity were available. Under the Park drive at the pumping station there is an intercepting sewer collecting all the sewage from the drainage area bounded by the East bank of the Schuylkill river above Fairmount Dam and its tributary areas.

This area is sewered on the separate system which consists essentially of carrying house sewage and storm water in separate conduits. It comprises an area of more than 4,500 acres of which there is at least 1,500 acres built up and contributing drainage which is of very diverse characteristics. Along the canal and river are located many mills and industrial plants, as shown in table No. 1. Manayunk comprises the flat land adjacent to the river and the steep slopes back to the high ridge separating the Valley of the Wissahickon from the Schuylkill. The settlements along this ridge are called Wissahickon and Roxborough, and the territory is almost entirely residential. The Wissahickon Creek Valley is largely Fairmount Park property but receives the drainage from the westerly side of Germantown, Chestnut Hill and part of Mt. Airy, the territory being entirely residential.

The existing testing station, its proximity to the intercepting sewer, the concentrated sewage and large amount of trade waste present, made it a desirable location to conduct the tests, as mechanical or biological processes found successful with the sewage available should be satisfactory for any portion of the City.

An eight inch vitrified pipe connection was made at right angles to the intercepting sewer and fifteen inches above the invert. The sewer is four feet seven inches in diameter and usually flows 32 inches deep. This pipe was therefore completely submerged. It emptied into a pump well three feet six inches in diameter and thirteen feet deep. The six-inch suction of a 12″ x 8″ x 12″ Barr pump ended one foot above the bottom of the well and so allowed very little sediment to accumulate therein.

The sewage was pumped through a 4-inch cast-iron force main about four hundred and thirteen feet long, and elevated about ninety feet to the testing station, where a connection was made to the 6-inch cast-iron main, which connected with the various tanks and fixtures of the testing station, used in the water experiments.

The experimental work was begun on March 23, 1909, and discontinued May 15, 1910.

## PROCESSES INVESTIGATED.

The processes of sewage disposal studied at the testing station may be divided into groups as shown below. The sampling stations were numbered in accordance with this

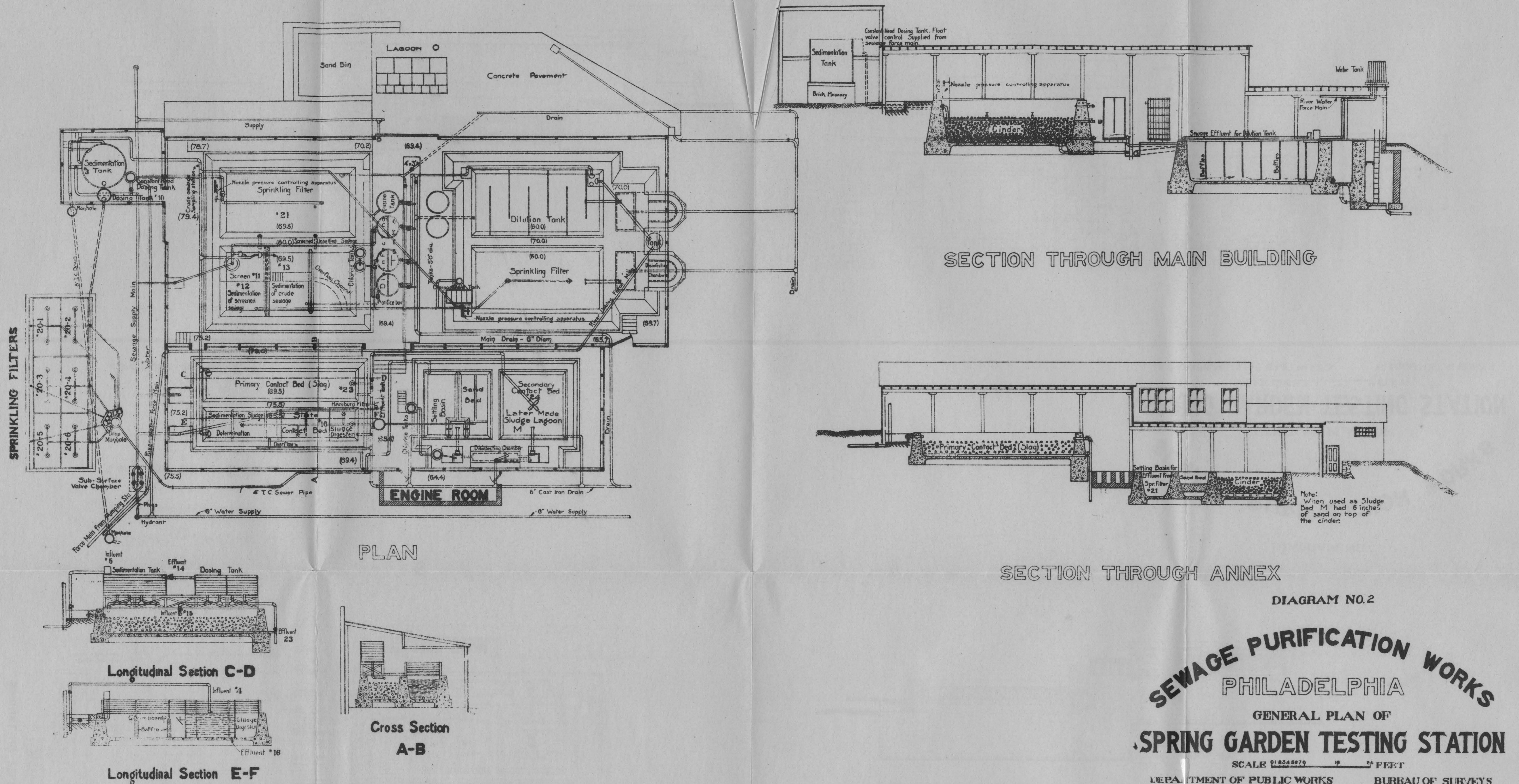



DIAGRAM NO. 2

SEWAGE PURIFICATION WORKS

PHILADELPHIA

GENERAL PLAN OF

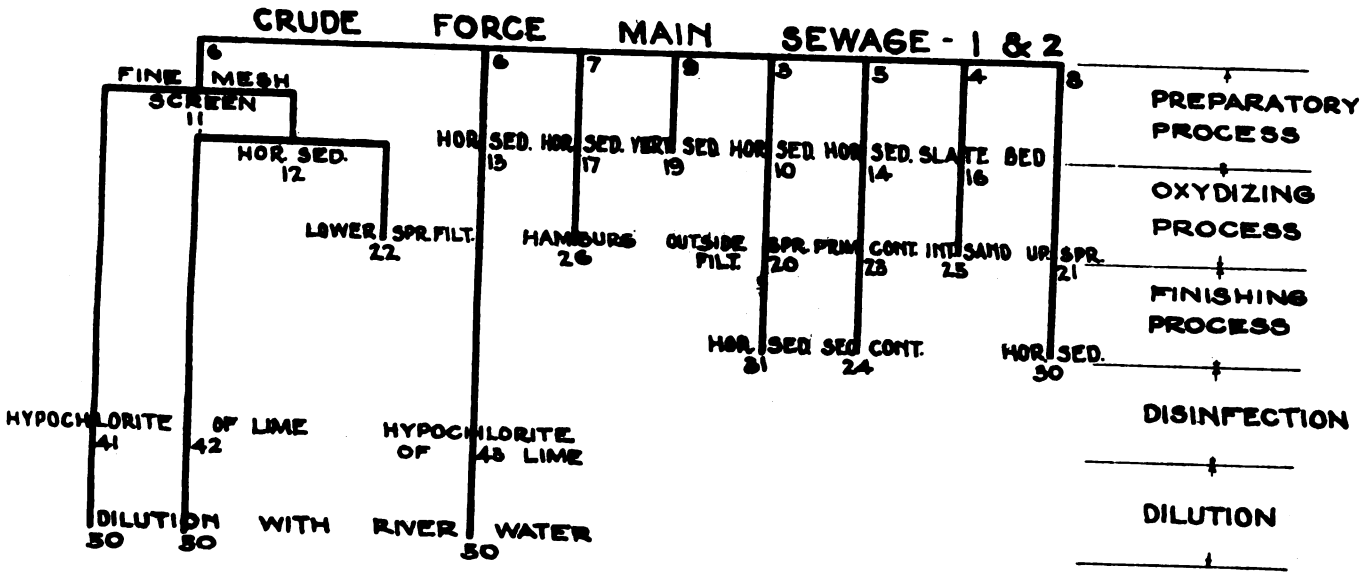
SPRING GARDEN TESTING STATION

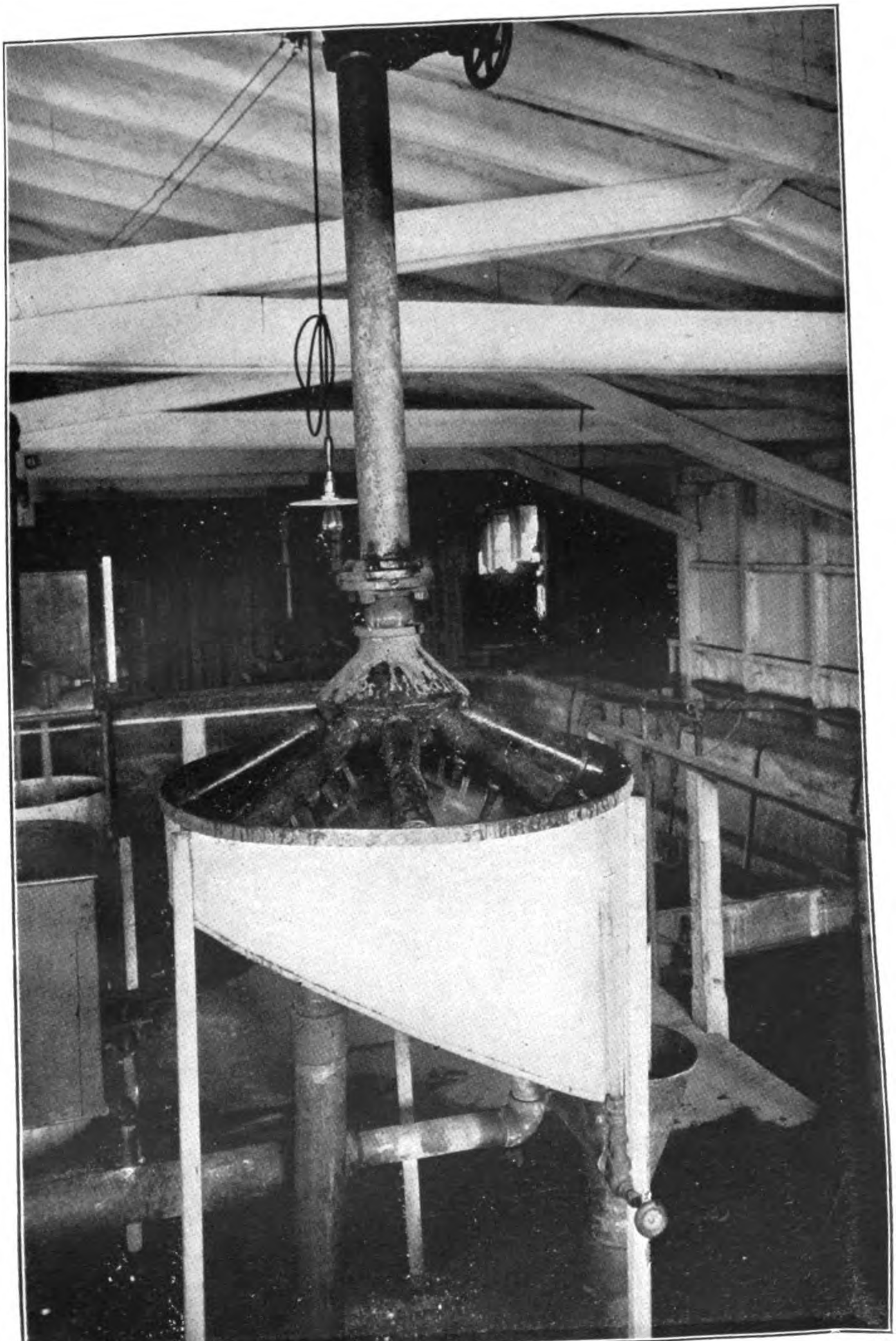
SCALE 0 1 2 3 4 5 6 7 8 9 10 15 20 FEET

DEPARTMENT OF PUBLIC WORKS — BUREAU OF SURVEYS

Apr. 23, 1909

DIAGRAM No. 1
SHOWING RELATION OF
PROCESSES STUDIED
AND
SAMPLING STATION NUMBERS





FINE MESH SCREEN.—Station No. 11.

scheme. Those points at which crude sewage was collected being numbered between 1 and 9, others as follows:

| Process. | Purpose. | Sampling Station Numbers |
|---|---|---|
| Preparatory | Primary removal of suspended solids | 10 to 19 |
| Oxidizing | Removal of putrescibility | 20 to 29 |
| Finishing | Secondary removal of suspended solids | 30 to 39 |
| Disinfection | Removal of pathogenic organisms | 40 to 49 |
| Dilution | Utilization of the natural purifying powers of bodies of water | 50 to 59 |
| Sludge studies | Handling and disposal | A to Z |

The relation and connections between these processes as studied in the station is shown in diagram No. 1.

## DESCRIPTION OF THE TESTING STATION

The testing station having been designed for water experiments, it was equipped with concrete and wooden tanks, elaborately piped together, orifice boxes and meters for measuring flow, etc.

To adapt the existing conditions to the requirements of sewage work required extensive changes in the piping and measuring devices.

The former laboratories and office had been destroyed by fire and were rebuilt and furnished with apparatus.

On plan No. 2 is shown the arrangement of the tanks and filters.

### Fine Mesh Screen.

Crude sewage was played through twenty-four ½-inch nozzles set to discharge at right angles to the conical surface of a fine mesh screen, station No. 11, composed of red metal cloth having thirty-two meshes per inch, leaving clear openings of five-tenths millimeter by five-tenths millimeter. That portion of the applied sewage which did not pass through the screen, splashed over the surface, washing the screenings down into a gutter and thence to the drain. The screened sewage was conveyed to sedimentation basin No. 12 and to disinfection tank No. 41.

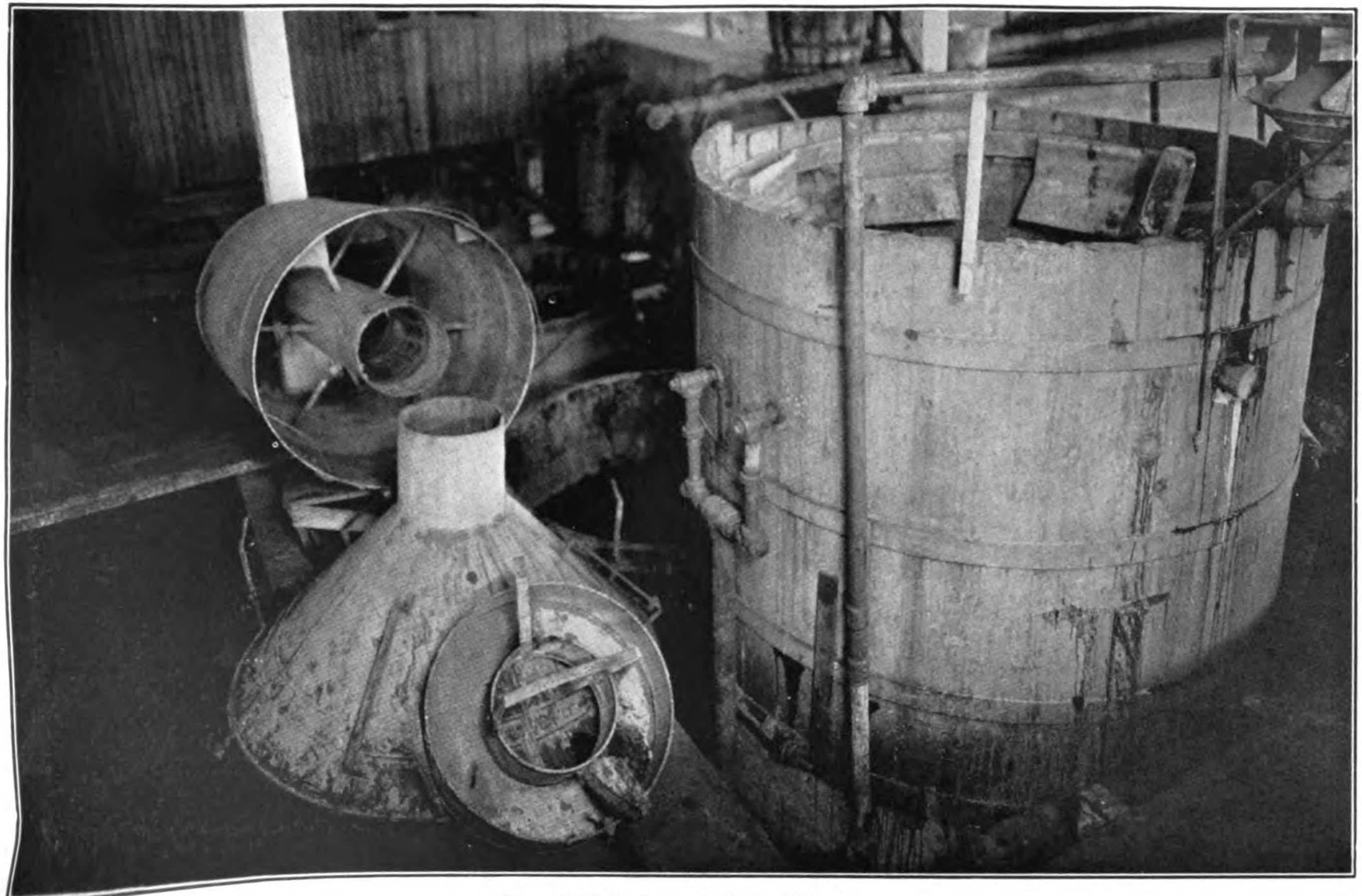
**Horizontal Flow Sedimentation.**

Sedimentation by horizontal flow was studied in three tanks, Nos. 12, 13 and 17. Tanks No. 12 and 13 were formed by building concrete walls across a large tank dividing it into three portions. At first they had level bottoms, no baffles or scum boards and crudely constructed effluent collectors. The ratio of depth to length was one to one and one-half in tank No. 12, and one to two and one half in tank No. 13. The capacity of tank No. 12 was 9,943 gallons and of tank No. 13, 7,767 gallons. In August, 1909, a steeply sloping bottom (16° to the horizontal) toward the inlet end was built in tank No. 12 and in October, 1909, a transverse brick baffle and scum board at midlength and inclined scum boards placed about the effluent collecting pipe. Also in October, 1909, a similar sloping bottom, sludge baffle and scum board were placed in tank No. 13. The collection of the effluent was improved by adding a weir the entire width of the tank, protected by an inclined scum board. These changes reduced the capacity of the tanks to 8,738 gallons for No. 12 and 5,475 gallons for No. 13. (See diagram No. 7.)

Sedimentation tank No. 17 was of better proportion, the ratio of depth to length being one to four. It had an almost level bottom and up to the latter part of September was unbaffled. At that time two transverse baffle walls with scum boards were built and a collecting weir protected by an inclined scum board. (See diagram No. 34.)

**Vertical Flow Sedimentation.**

Sedimentation during vertical flow was studied in an Emscher tank originally five feet in diameter and six feet



EMSCHER TANK.—Station No. 19.

deep, and after January, 1910, five feet diameter and ten feet deep. A concrete bottom forming an inverted cone, whose sides made 30° to the horizontal, was placed in the wooden tank; at four feet above the bottom a galvanized iron baffle was fastened to the sides and upon this rested the inverted funnel with its ventilating stem, concentric with which was a circular baffle extending above the surface of the water, as shown in diagram No. 9 and the photograph.

Crude sewage was added from a circular weir concentric with the funnel, passed down between the ventilating stem and the baffle, turned under it and flowed upward to the collecting weir around the sides of the tank. Scum boards protected this weir.

### Slate Contact Bed.

Between sedimentation and contact processes may be classed the Dibdin slate bed No. 16. This was built in a portion of a tank in the annex, it was .0021 acre and five feet deep. Nineteen horizontal layers of 12″ x 24″ slates were separated by brickbats, leaving a clear space of about three inches between them.

### Contact System.

The contact system consisted of a rectangular, wooden, unbaffled sedimentation tank of 2,060 gallons capacity.

The effluent end of this tank was connected by a 3-inch pipe to a dosing tank of similar capacity and shape. On this pipe was a lever valve the handle of which was extended so as to act as an indicator upon a graduated sector. In this way the valve could be set so as to fill the dosing tank during the time the primary contact bed stood full, was drained and aerated.

The primary contact bed was .0066 acre three feet deep, having brick underdrains and one-half inch to two inch slag media. Its effluent was discharged upon a secondary contact bed .00585 acre three feet deep, having brick underdrains and filled with hard furnace clinker rejected by a half inch screen to remove the dust and fine pieces.

**Sprinkling or Percolating Filters.**

Fourteen sprinkling filters were operated, a battery of six being outside the building, two large ones, a battery of five small ones and a Hamburg filter inside the building.

**Outside Filters.**

The influent to the outside sprinkling filter was sewage which had been roughly settled in a wooden tank ten feet in diameter and nine feet three inches deep, containing 5,600 gallons.

The force main discharged into this tank near the bottom, but the sewage had to flow up through a tight wooden box discharging vertically near the surface. Adjacent to the inlet was an overflow weir connected to the drain and constant head was maintained by varying the speed of the pump to meet the requirements of the station. The head on the overflow weir was not allowed to vary more than a half inch by means of a float and an electric alarm communicating with the pump.

From the inlet box a 3-inch pipe supplied sewage under constant head to those orifice boxes requiring it in a crude state.

Beyond two galvanized iron baffles in the receiving tank was the baffled connection to a dosing tank for the outside sprinkling filters. This consisted of a cylindrical wooden tank the inlet of which was controlled by a float valve and the outlet by a shear valve, both of which were operated by a float and weighted lever in such a way that the tank was alternately filled and automatically emptied. To improve the distribution upon the beds, bricks were placed in the bottom of the tank so as to make it approximately a frustrum of an inverted cone.

OUTSIDE SPRINKLING FILTERS.

The filters were built on a concrete foundation, the floor of each sloping so as to concentrate the effluent at an opening in front of each unit.

Underdrains were built of bricks covered by cobble stones to prevent the media from falling into them. Wooden posts and planking formed the sides and separated the units.

The battery of filters called No. 20 consisted of six beds, Nos. 20-1, 20-2, 20-3, 20-4, 20-5, and 20-6, each .002 acre, so arranged as to form three squares, in the center of which a Columbus nozzle, under falling head from the dosing tank, distributed the sewage.

The media may be described as follows:

| Station Number. | Media. | | | Depth of Underdrains. |
|---|---|---|---|---|
| | Kind. | Size. | Depth. | |
| 20-1 | Limestone | ¾" to 3" | 7' | 1' |
| 20-2 | Limestone | 2¼" to 4" | 8' | 1' |
| 20-3 | Slag | 1" to 3" | 5' | 1' |
| 20-4 | Trap | 1" to 3" | 6' | 1' |
| 20-5† | Gravel | ½" to 2½" | 3'3" | 9" |
| 20-5‡ | Trap | ½" to 3" | 3'3" | 9" |
| 20-6 | Trap | ½" to 2½" | 4'3" | 9" |

†Prior to August 22, 1909. ‡Subsequent to August 22, 1909.

The effluent from each bed having reached the inlet grating sunk in the collecting gutter in front of each unit, flowed underground through a terra cotta pipe to the sampling house, where all six effluents mingled and were conducted to a basin inside the building for settlement.

### Upper Filter.

The upper sprinkling filter, No. 21, was constructed in one of the old concrete water sedimentation basins, upon the floor of which underdrains were formed of slabs of old concrete pavement. Hard clinker rejected by a ½-inch screen to remove dust and fine pieces was filled in, so that the large pieces rolled down the slopes and roughly graded the media.

Its depth above the underdrains was six feet and area .01175 acre. Prior to August, 1909, sewage was distributed through Taylor square nozzles, subsequently through Reading nozzles.

The influent to this bed was sewage which had been screened through $\frac{1}{8}$-inch and $\frac{1}{4}$-inch screens to remove only those particles liable to clog nozzles. Constant head was maintained in the dosing tank by means of a float valve. In order to produce an undulating head upon the nozzles, for good distribution, a butterfly valve was placed in the pipe line, the lever of which was controlled by a cam connected to an overshot water wheel by link belting to reduce its speed.

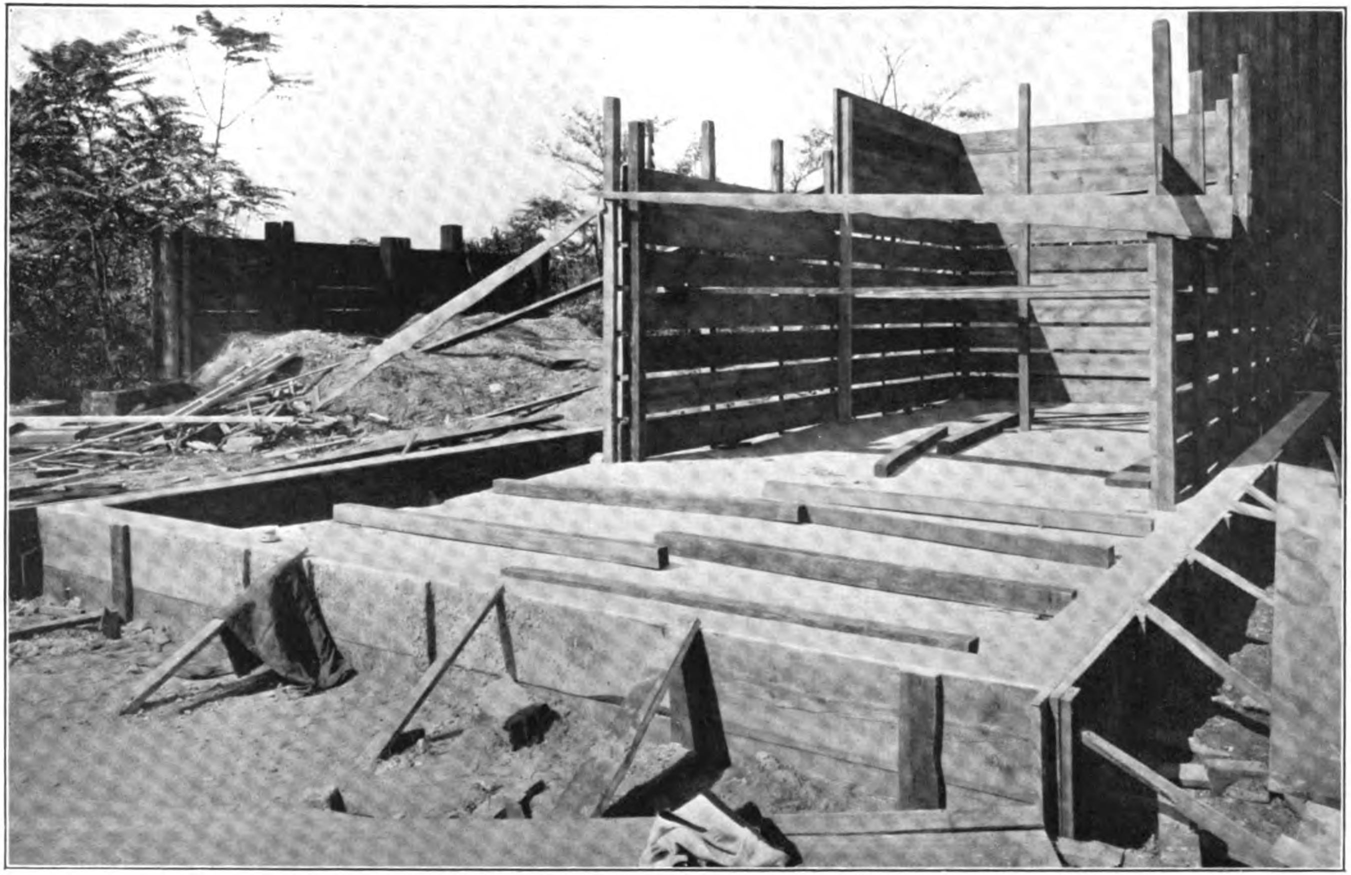
The effluent was piped to a settling basin.

### Lower Filter.

The lower sprinkling filter was constructed in a similar tank to the upper sprinkling filter. Upon its level bottom a concrete floor, having slope of one in sixty, was laid with a 6-inch semicircular main drain along the center line of the length of the tank. Before the concrete had set, the underdrains were laid consisting of 6-inch split vitrified pipe with lugs on the edges. Over the main drain 12″ x 24″ slates were laid longitudinally and on them three 4-inch vitrified pipes perforated by quarter inch holes were placed vertically, and up the sides and corners ventilators of the same type as underdrain tile were stood.

At three feet depth these were connected by horizontal 3-inch perforated pipes (the upper holes being plugged to prevent water entering) to the vertical pipes over the main drain. The vertical ventilators extended to the surface of the media, where circular terra cotta caps were cemented on, giving a complete internal ventilating system.

This ventilating system connected at one corner to a



**Outside Sprinkling Filters During Construction.**

6-inch galvanized iron chimney upon whose top was a cowl, so arranged as to always produce an upward draft, thereby drawing air from above the surface of the media through the ventilating system. To prevent air entering the main drain the effluent pipe was trapped.

The media in this bed was six feet six inches deep, of a hard stone from the quarry of the House of Correction broken by hand and screened at the testing station so that as placed in the bed it ranged in size from three-quarter inch to one and one-half inch.

The influent to this bed was the effluent of tank No. 12, or screened and settled sewage. The sedimentation tank itself served as a constant level tank and the undulating head upon the two Taylor nozzles (square spray) was obtained by a similar device to that used in the upper sprinkling filter, except that the water wheel was geared down by means of a worm instead of a link belt and pinion.

The cam was so designed that the nozzle was playing almost the entire time, rendering the distribution nearly perfect.

The effluent was measured by a hook gauge and "V" notch weir and then passed to the drain.

**Bacterial Surface Filter.**

To study the effect of bacterial surface a battery of small filters called No. 27 was made in an existing wooden tank having five compartments.

A false floor was made of ¼-inch mesh wire upon which was placed eighteen inches of different kinds of media, all of which had passed through a ⅝-inch screen and been rejected by a ½-inch mesh.

| Station No. | Media. | Shape. |
|---|---|---|
| 27-1 | Common marbles | Spheres. |
| 27-2 | Gravel | Spheroids. |
| 27-3 | Broken trap | Irregular. |
| 27-4 | Broken slag | Irregular. |
| 27-5 | Broken coke | Irregular. |

Over the top of the compartments was placed a Stoddart tray of galvanized iron, each compartment being flushed from a tipping tray.

Screened and settled sewage from tank No. 12 was maintained at a constant head in a barrel by a float valve and rubber tubes conducted the water therefrom to glass orifices clamped to a vertical iron rod so that any desired rate could be maintained on the tipping tray.

**Hamburg Filter.**

A Hamburg filter, after Dr. Dunbar, was built in a wooden tank of eight square feet area.

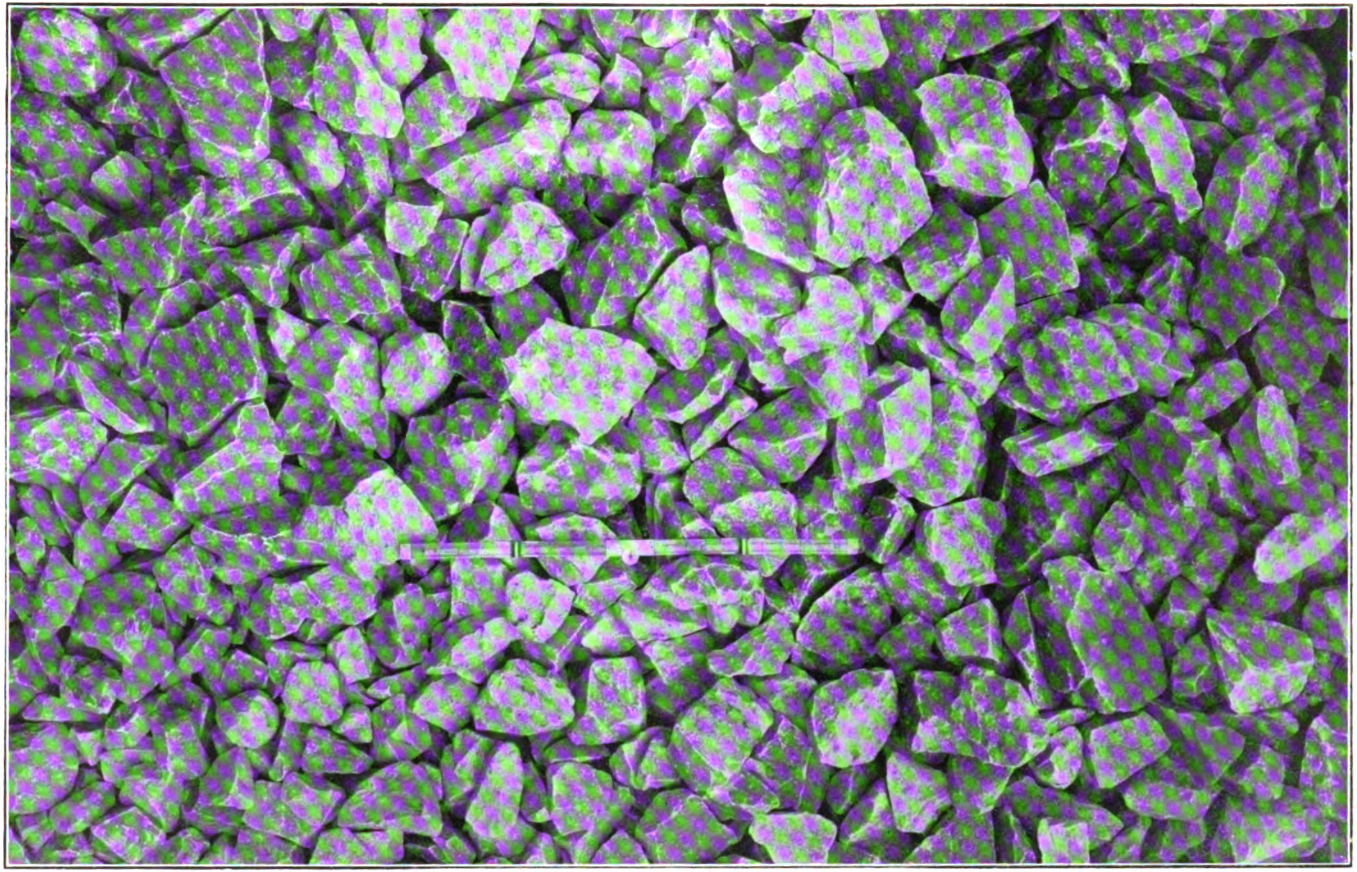
First, a sloping concrete bottom was laid, upon this two feet four inches of clinkers, ranging in size from "fist to child's head;" the spaces between the top layer were filled in with 1⅛-inch (30mm.) clinker. The distributing media was now placed, first a four inch layer of ⅜ to 1⅛ inch (10 to 30 mm.) clinker, then four inches of ⅛ to ⅜ inch (3 to 10 mm.) coke and fourteen inches of one-twenty-fifth to ⅛-inch (1 to 3 mm.) coke.

These distributing layers were banked up against the sides so that the upper surface formed a basin. Ventilation of the media was obtained by boring one inch holes around the tank below the distributing layers and by the opening for the effluent.

The dose was applied by hand from a cylindrical reservoir which could be filled with the effluent of settling tank No. 17 by opening a valve.

**Intermittent Sand Filter.**

The intermittent sand filter, No. 25, was .002 acre and contained eighteen inches of round-grained sand of effective size, 0.6 mm. and uniformity coefficient of 1.45. The underdrain was of 6-inch split tiles, similar to those used in the lower sprinkling filter, surrounded by broken stone and gravel to prevent the sand reaching the drain.



**Outside Sprinkling Filter.—Station No. 20-1.**
**¾-inch to 3-inch limestone media.**

The effluent of the slate bed was applied to this bed by means of a baffled wooden trough distributor.

## Settlement of Sprinkling Filter Effluents.

The settling of sprinkling filter effluents was accomplished in a rectanglar concrete tank called No. 31 when used for the outside filters, and No. 30 when used for the upper sprinkling filter.

This tank was unbaffled until January 12, 1910, on which date a wooden transverse baffle at mid length was built to within six inches of the surface of the water.

## Disinfection.

The disinfection of sprinkling filter effluents has been studied elsewhere, and so it was deemed advisable to determine the practicability of disinfecting sewage from which the large suspended solids had been removed.

For this purpose three circular wooden tanks five feet in diameter were used, the overflow set to give a depth of four feet and baffled to produce comparatively high velocity. The influent was measured by a "V" notch weir and hook gauge.

Bleaching powder or calcium hypochlorite was mixed in a barrel, allowed to settle and the clear liquor drawn down into another barrel from which it flowed to three small constant head reservoirs. These supplied a glass orifice capable of being raised or lowered to discharge any required amount of bleach to the sewage entering the tank.

Studies were made upon screened sewage from No. 11, screened and settled from No. 12 and settled sewage from tank No. 13.

## Dilution.

To determine the oxidizing power of river water a tank containing 35,600 gallons called No. 50 was operated.

A Worthington pump was set up at the adjacent water pumping station whose suction connected with the intake pipes laid in the Schuylkill river, and through a 3½ inch force main delivered to a tank on the roof of the testing station raw river water. This tank supplied an orifice box at the inlet end of the dilution tank beside which another orifice box added a measured quantity of disinfected sewage so that the proportion of sewage to river water could be regulated.

In the concrete tank were hung six galvanized iron baffles to effect a thorough mixture of the influent and increase the velocity to nearly that of a normal river

OUTSIDE SPRINKLING FILTER.—Station No. 20-2.
2½-inch to 4-inch limestone media.

# METHODS OF OPERATION.

## Collection of Samples.

### Chemical.

For the chemical laboratory composite samples were collected over weekly periods. From the force main 75 cc. were taken every half hour and added to a four-liter bottle containing 20 cc. of chloroform. This was examined daily for suspended solids and a quantity proportional to the number of hours the pump ran taken to form the weekly composite sample. Thus, assuming that the pump ran 24 hours each day, the weekly composite sample consisted of 336 separate collections.

From those processes, whose flow was constant, such as sedimentation and filters, the samples were collected in 75 cc. portions every three hours to form weekly chloroformed samples.

From intermittent processes, such as the slate bed, contact beds, sand filter, etc., four samples of the influent were evenly spaced and four of the effluent each time the bed was filled or drained to form the weekly composite sample.

In order to study carefully the Emscher tank, influent and effluent were sampled every half hour, similarly to the method of collecting crude sewage.

The influent and effluent of the dilution tank were collected, generally twice a week, in 500 cc. portions at three hour intervals to form a daily composite sample. The collection ended at 8 A. M. and analysis was begun at once on the iced samples. Two liters of the composite effluent sample were placed in a wide-mouth glass bottle, unstoppered, and hung in the dilution tank for two weeks in order to determine its condition after that length of time.

For these collections and the mechanical operation of the station an operator and three samplers were regularly employed, additional labor being obtained from time to time on construction and sludging out tanks, etc. This allowed the station to be run continuously, not omitting any day.

### Bacteriological.

Bacteriological samples were collected by the Bacteriologist or his assistant in sterilized bottles, and plated at once, every sixth day being omitted, except on the crude sewage, which was plated every day.

### Sludge.

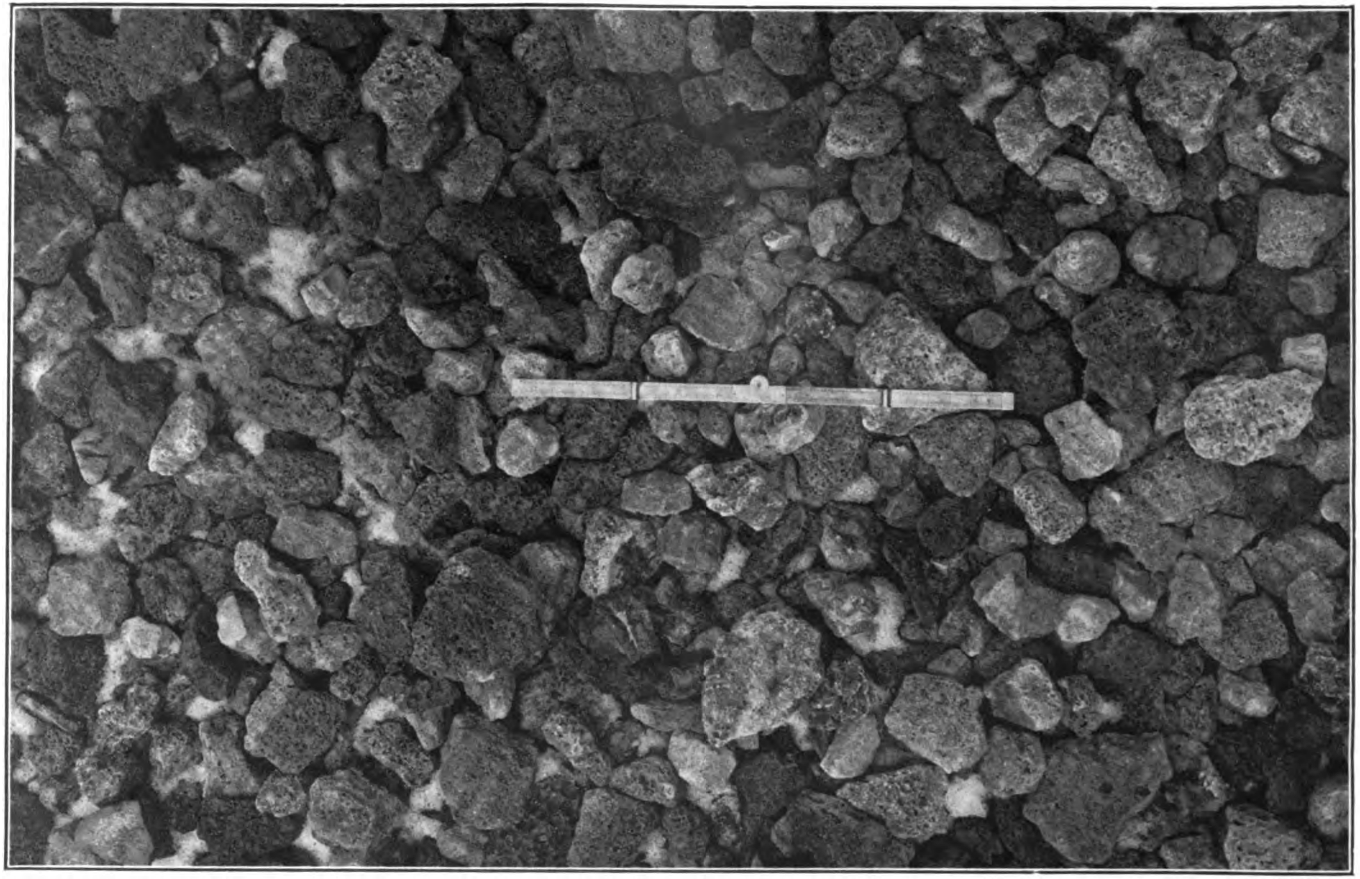
In ending a run on a sedimentation tank the liquor was withdrawn by a loose-jointed overflow, so that all of the supernatant water could be removed from the sludge. If the sludge was not used but run to the drain a composite sample was made by lowering a bucket to the bottom in several places and taking a portion of the contents of each bucket.

But when lagooned a diaphragm pump was used to remove the sludge and a small portion taken every five minutes during pumping to form a large composite sample. From the Emscher tank, sludge was withdrawn into a large can and weighed. The contents were thoroughly mixed by stirring and sample taken for analysis.

## Temperature Observations.

Air temperature was read at the outside sprinkling filters, and at four places inside the building every three hours, so as to observe the hourly variation and obtain daily and weekly averages.

During cold weather the temperature of the applied wa-



Outside Sprinkling Filter.—Station No. 20-3.
1-inch to 3-inch slag media.

ter and combined effluent of the outside filters was similarly taken to find loss of temperature in passage through the filters exposed to the weather.

During the studies at the testing station desirable climatic changes were experienced. The average temperature during the summer of 1909 was moderate, but this was caused by hot days and cool nights, so that the filters were well stimulated. Early in December freezing weather set in and the average weekly temperature remained below freezing until the middle of January (on two occasions reaching very low temperature—14° C.); during the latter part of January the temperature moderated and then fell back to freezing during all of February. On February 7, 1910, the thermometer reached its lowest—16° C. (+4° F.). Beginning about March the temperature gradually rose to the end of the tests.

## Methods of Analysis.

### Chemical.

The general methods of analysis are given to render the tables and diagrams more comprehensive.

Suspended solids were determined by filtration of the sample through an asbestos mat in the Gooch crucible, the volatile portion being driven off by ignition in a nickel crucible over a blast lamp.

Nitrogen was determined as organic by the Kjeldahl method, free ammonia by direct nesslerization, nitrites by the Griess method; nitrates at first were determined by the reduction method and after the publication of McRae's narcotine test, by that method.

For oxygen consumed the potassium permanganate was added to the acidified sample at room temperature and placed in a water bath at 100° C. for 30 minutes. At first the total was separated by filtration through paper into "suspended" and "dissolved," but after July the total value was divided into oxygen consumed by the "settling solids," by "colloids," and by "true solution."

This was accomplished by the analysis of three samples.

First, the sample bottles were shaken and a portion taken for "total." The bottles now stood for two hours, during which time the solids capable of sedimentation in a quiescent state during that time had gone to the bottom, and a portion of the supernatant liquor was pipetted out for the test; this sample contained those oxidizable matters both in a colloidal state and in true solution. Next a similar sample was freed of the colloidal matter by Fowler's clarification test, and upon the filtrate containing only matters in true solution the third test was made:

"Total" was determined direct,

"Settling" by difference of first and second,

"Colloidal" by difference of second and third, and

"Dissolved" by the third determination.

Chlorine was determined by titration with silver nitrate. Lacmoid was used as the indicator in alkalinity. Fats were extracted by ether from an acidified sample.

For dissolved oxygen the Winkler method was used.

The stability of oxydized effluents was examined by the incubation at 20° C. of 150 cc. of the water with 1 cc. of a 0.1 per cent. aqueous solution of methylene blue. They were examined by the samplers every three hours and removed when decolorized; the "reducing time" was converted into "relative stability" by the use of diagram No. 3.

**Bacteriological.**

Total number of bacteria were determined as those growing on gelatine after incubation at 20° C. for two days.

The presence of B. Coli. was determined by the fermentation of lactose in a bile media (Jackson's presumptive test) and numbers of B. Coli. per cc. reported as the reciprocal of the highest dilution giving a positive reaction. This method was proposed by Professor Earl B. Phelps in the American Journal of Public Hygiene, May, 1908.

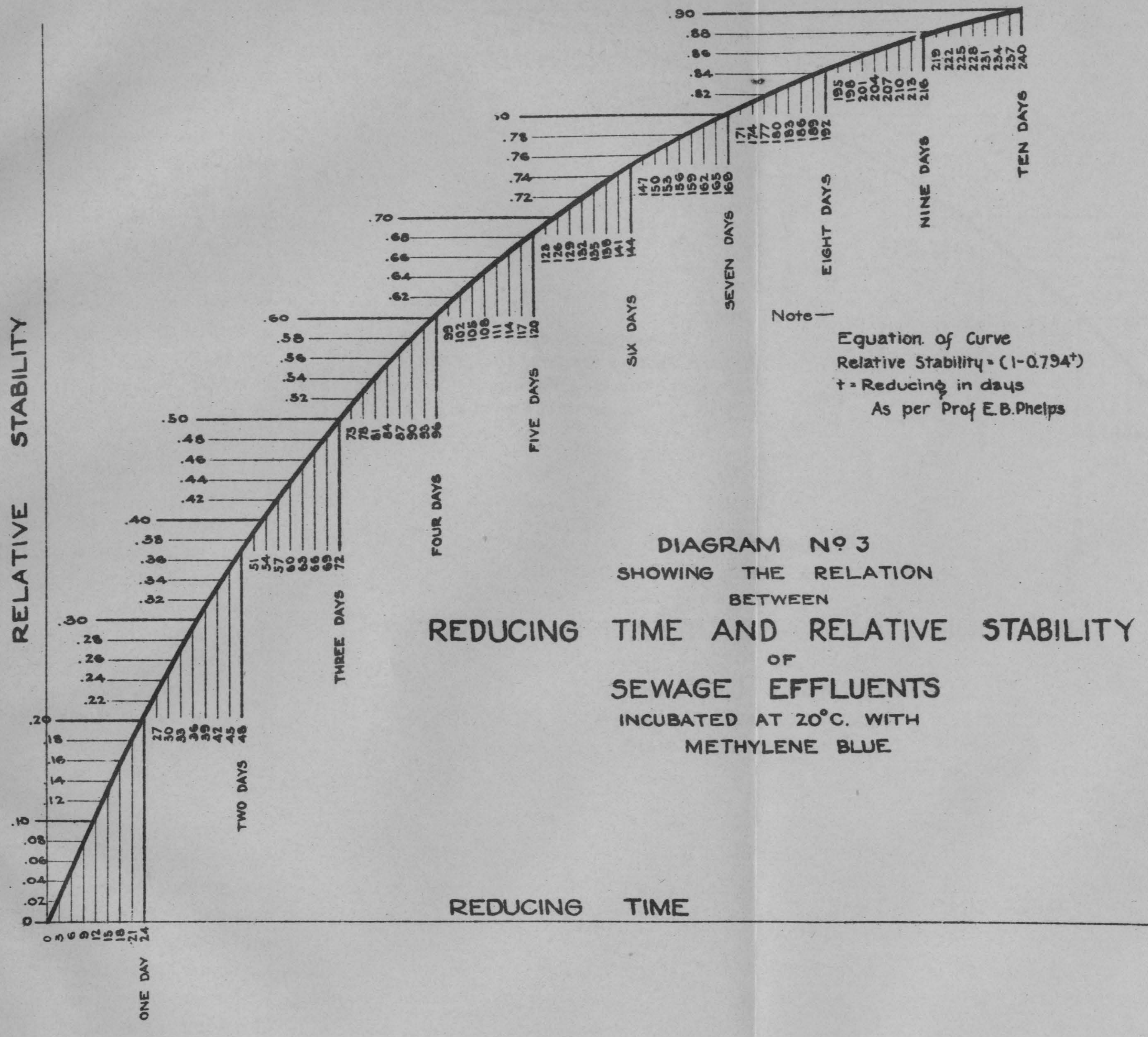
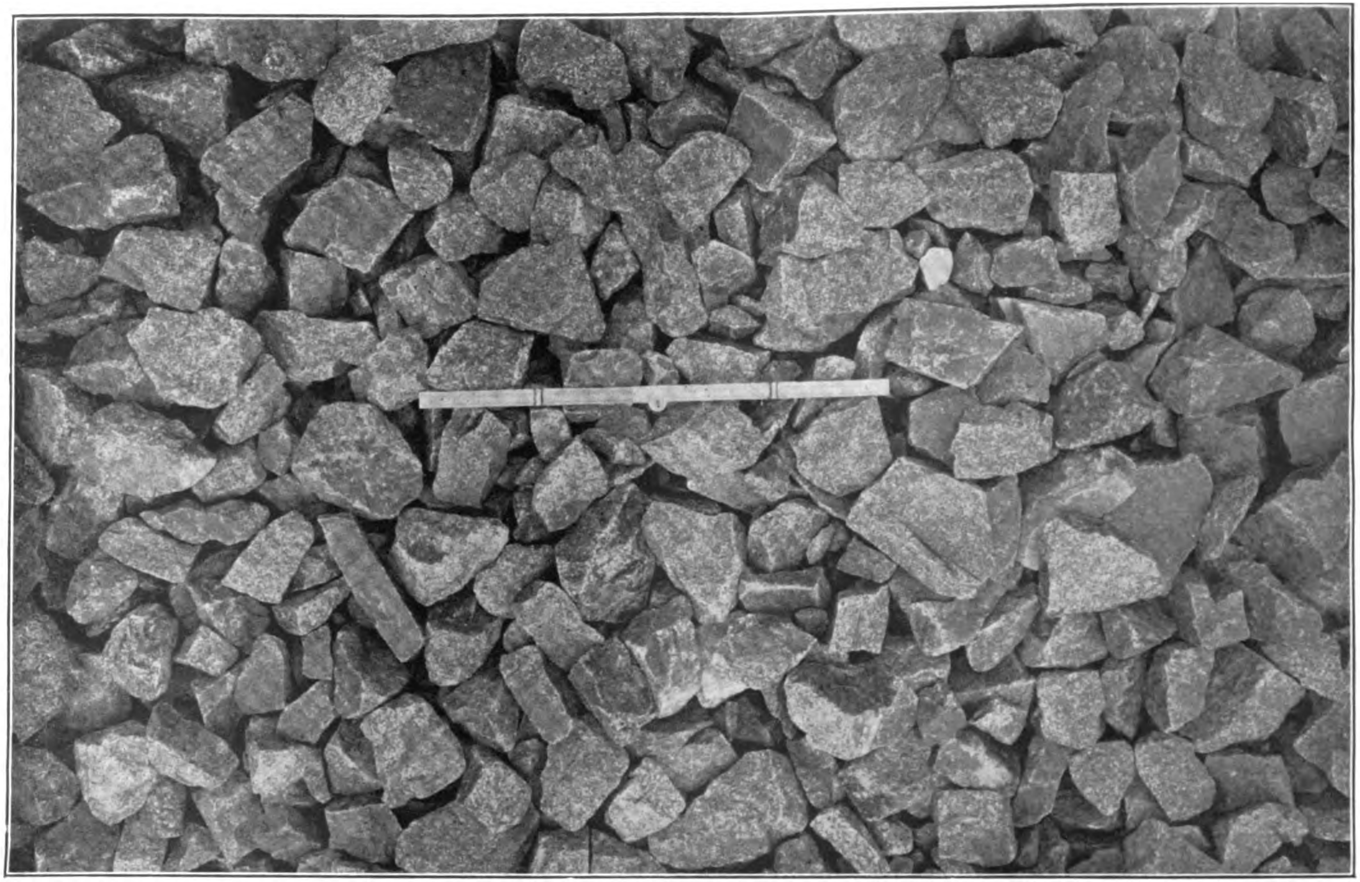



DIAGRAM No. 3
SHOWING THE RELATION
BETWEEN
REDUCING TIME AND RELATIVE STABILITY
OF
SEWAGE EFFLUENTS
INCUBATED AT 20°C. WITH
METHYLENE BLUE



**Outside Sprinkling Filter.**—Station No. 20-4.
1-inch to 3-inch trap media.

### Sludge.

The determination of specific gravity of wet sludge was accomplished by weighing a known volume of the sludge contained in an Erlenmeyer flask having its narrow neck cut off straight.

The percentage moisture was found by evaporating on a steam bath a weighed quantity of the wet mass. A portion of the dry residue was ignited over a blast lamp for "volatile" and upon other portions, nitrogen was determined by the Kjeldahl method, and fats by extraction with ether.

## CHARACTERISTICS OF SEWAGE USED IN EXPERIMENTS.

The crude sewage used at the testing station was expected to be as strong as any in the City, and due to the known presence of trade wastes, as difficult of mechanical or biological treatment as would be delivered to any plant built by the City of Philadelphia.

### Trade Wastes.

Based upon the difference in flow of the intercepting sewer on holidays and workdays during the drought of the Summer of 1909, it would appear that the sewage is not more than 40 per cent. domestic in origin, and also that there is a considerable quantity of ground water present. In describing the area drained by this sewer an idea has been given of the industries contributing trade wastes to the sewage, and their presence could be physically noted in the case of dyes by the coloration of the sewage. Hops and a carbon-dioxide froth indicated the breweries, and the almost constant presence on workdays of wool fibres showed the principal industry of Manayunk. Due to the long journey in the sewer and passing through the valves of the pumps, faecal matter was rarely visible at all, and when so in very finely divided particles.

## TABLE No. 1.

*Showing Number of Industrial Plants Tributary to the Intercepting Sewer.*

| | | | |
|---|---|---|---|
| Spinning or weaving | 27 | In 8 of which dyeing is done.<br>In 2 of which scouring is done.<br>In 2 of which extracting shoddy is done. | |

| | | | | | |
|---|---|---|---|---|---|
| Dyeing and bleaching | 1 or a total of 9 | | | Paper | 2 |
| Extracting shoddy | 1 or a total of 3 | | | Brewery | 2 |
| Gas works | 1 | Machine shop | 1 | Laundry | 2 |
| | | Idle | 1 | Chemical works | 1 |

*Number of Industries Contributing Certain Wastes to the Intercepting Sewer.*

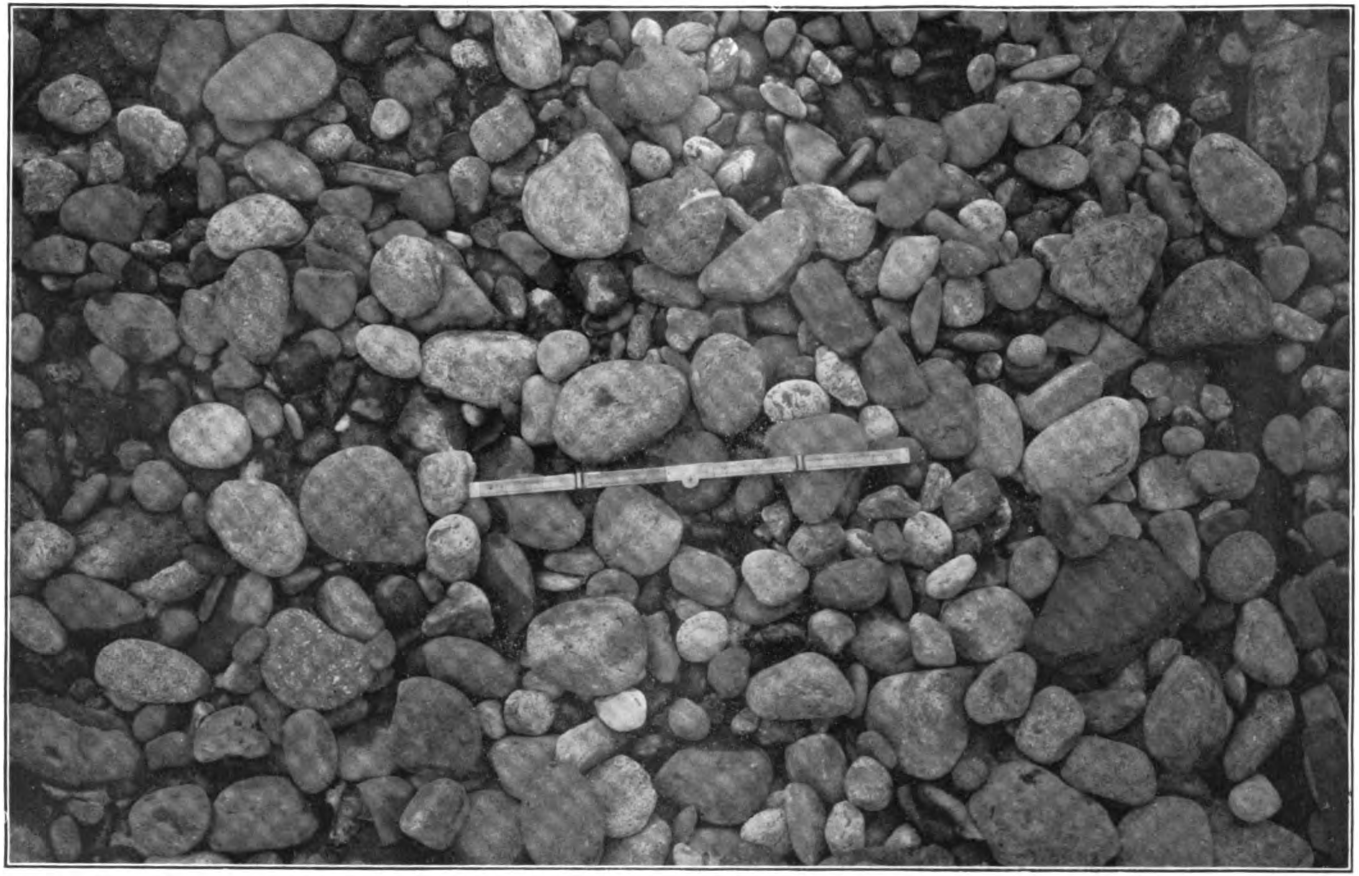
| | | | | | |
|---|---|---|---|---|---|
| Dyes | 8 | Alkali | 8 | Wool washing water | 9 |
| Strong acids | 11 | Weak acids | 5 | Yeast and hops | 2 |
| | | Soap | 2 | | |

### Suspended Solids.

The suspended solids as determined in a laboratory, of course, include only those pieces of floating solids of very moderate size and do not represent the entire amount of floating matter to be handled at a works. But those solids not included are usually removed by the coarse screens and are not a very important part of the operation of works.

There was a very marked variation in the amount of suspended solids in the holiday and workday sewage, the average ratio being about 1 to 2. Additional evidence of the preponderance of trade wastes on workdays is shown by the fact that the percentage of total suspended solids which are fixed or inorganic is 35 per cent. higher on workdays than on holidays.

The average daily amount of suspended solids in crude sewage is given in table No. 2.



**Outside Sprinkling Filter.—Station No. 20-5.**
**½-inch to 2½-inch gravel media.**

## Table No. 2.

*Daily Average Suspended Solids in Crude Sewage.*

| Day of the Week. | 1909. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | September. | | | October. | | | November. | | | December. | | |
| | Total. | Fixed. | Volatile. | Total. | Fixed. | Volatile. | Total. | Fixed. | Volatile. | Total. | Fixed. | Volatile. |
| Sunday | 92 | 8 | 84 | 93 | 14 | 79 | 112 | 21 | 91 | 101 | 21 | 80 |
| Monday | 234 | 75 | 159 | 231 | 54 | 177 | 242 | 64 | 178 | 251 | 108 | 143 |
| Tuesday | 266 | 96 | 170 | 269 | 85 | 184 | 258 | 61 | 197 | 212 | 88 | 124 |
| Wednesday | 258 | 94 | 164 | 267 | 71 | 196 | 243 | 65 | 178 | 220 | 91 | 129 |
| Thursday | 222 | 82 | 140 | 195 | 68 | 127 | 186 | 56 | 130 | 190 | 66 | 124 |
| Friday | 221 | 70 | 157 | 238 | 61 | 177 | 208 | 56 | 152 | 174 | 64 | 110 |
| Saturday | 156 | 29 | 127 | 237 | 63 | 174 | 162 | 85 | 127 | 183 | 74 | 109 |
| Average | 207 | 65 | 142 | 219 | 60 | 159 | 202 | 51 | 151 | 190 | 73 | 117 |

| Day of the Week. | 1910. | | | | | | | | | | | | Average. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | January. | | | February. | | | March. | | | April. | | | | | |
| | Total. | Fixed. | Volatile. | Total. | Fixed. | Volatile. | Total. | Fixed. | Volatile. | Total. | Fixed. | Volatile. | Total. | Fixed. | Volatile. |
| Sunday | 75 | 12 | 63 | 132 | 16 | 116 | 109 | 34 | 75 | *172 | 84 | 88 | 111 | 26 | 85 |
| Monday | 193 | 50 | 143 | 353 | 87 | 266 | 222 | 68 | 154 | 224 | 92 | 132 | 244 | 75 | 169 |
| Tuesday | 194 | 68 | 126 | 269 | 51 | 218 | 205 | 75 | 130 | 223 | 89 | 134 | 237 | 77 | 160 |
| Wednesday | 176 | 31 | 145 | 311 | 94 | 217 | 233 | 68 | 165 | 180 | 56 | 124 | 236 | 71 | 165 |
| Thursday | 222 | 49 | 173 | 278 | 97 | 181 | 205 | 67 | 138 | 164 | 63 | 101 | 208 | 68 | 140 |
| Friday | 226 | 74 | 152 | 262 | 74 | 188 | 193 | 59 | 134 | 177 | 66 | 111 | 213 | 66 | 147 |
| Saturday | 155 | 42 | 113 | 218 | 78 | 140 | 168 | 56 | 112 | 136 | 80 | 106 | 177 | 51 | 126 |
| Average | 174 | 46 | 128 | 260 | 71 | 189 | 191 | 61 | 130 | 189 | 74 | 115 | 204 | 62 | 142 |

*Average of three Sundays, of which April 24 was 272.

TABLE NO. 3.

*Daily Average Number of Bacteria in Crude Sewage.*

| Day of the Week. | Bacteria per CC. on Gelatine at 20 Degrees Cent. | | | |
|---|---|---|---|---|
| | January. | February. | March. | Average. |
| Sunday | 1,800,000 | 1,900,000 | 1,500,000 | 1,600,000 |
| Monday | 1,500,000 | 2,200,000 | 2,500,000 | 2,100,000 |
| Tuesday | 1,500,000† | 1,400,000 | 2,300,000 | 1,700,000 |
| Wednesday | 1,500,000 | 1,900,000 | 2,000,000 | 1,800,000 |
| Thursday | 620,000 | 1,400,000 | 1,800,000 | 1,300,000 |
| Friday | 950,000 | 1,200,000 | 2,000,000 | 1,400,000 |
| Saturday | 880,000 | 1,600,000 | 1,600,000 | 1,400,000 |
| Average | 1,200,000 | 1,700,000 | 2,000,000 | 1,600,000 |

†One sample.

There does not appear to be any seasonal variation in suspended solids except that the three summer months have lower averages than any other time, and there is little monthly variation from the general average, that is, one-third of the suspended solids are fixed and two-thirds volatile.

**Nitrogen.**

Nitrogen as organic and as free ammonia were both much lower than ordinary sewage, the weekly variation being considerable, but the monthly averages show much less variation from the general average.

The low nitrogen content can be attributed to the dilution of the true domestic sewage by the trade wastes and ground water.

During the winter the crude sewage contained considerable amounts of oxidized nitrogen.

**Oxygen Consumed.**

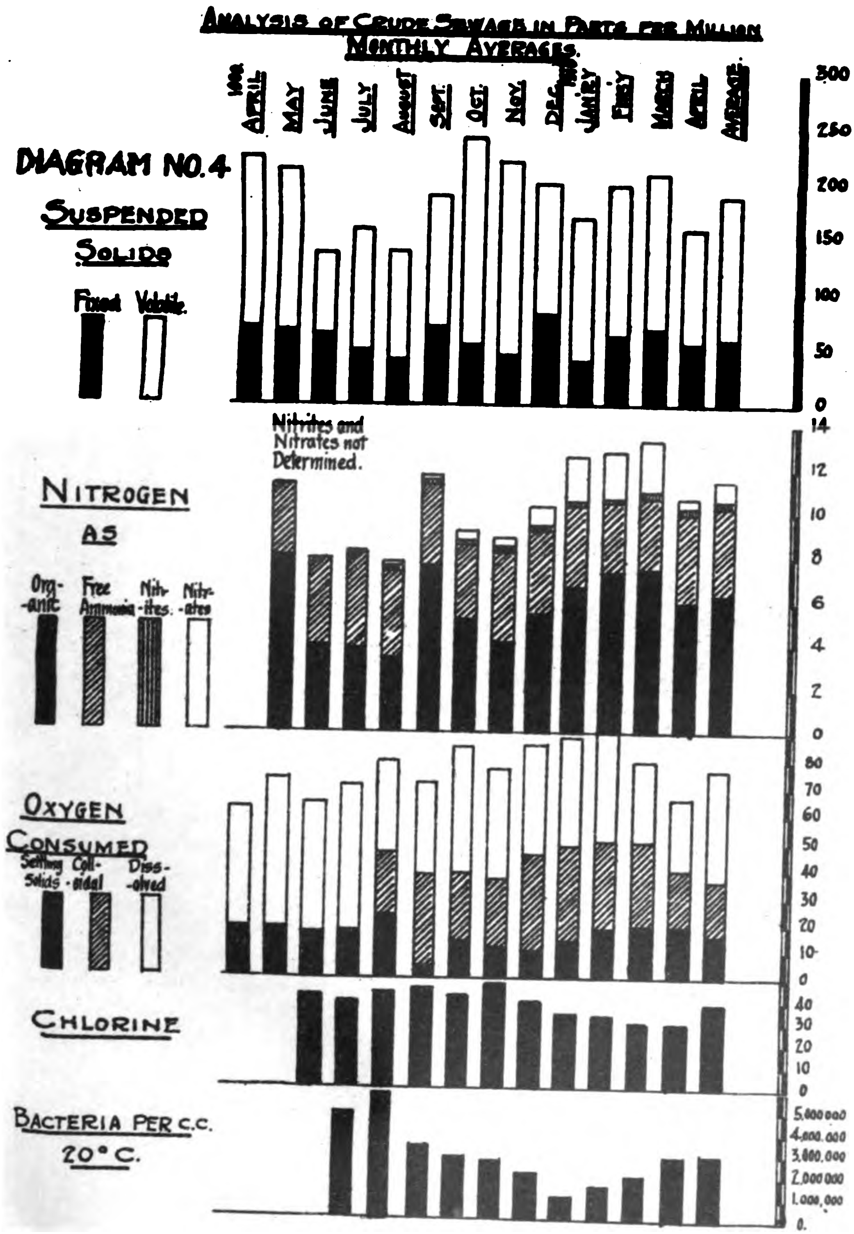
The oxygen consumed value of the crude sewage is probably higher than would be expected from the low

# Table No. 4.

## *Analysis of Crude Force Main Sewage.*

| | PARTS PER MILLION. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1909. | Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | | | | | |
| | Total. | Fixed. | Volatile. | Organic. | Free Amm | Nitrites. | Nitrates. | Total. | Settling. | Colloidal. | Dissolved. | Chlorine. | Alkalinity. | Sulphates. | Fats. |
| March 26 to April 2 | 236. | -------- | -------- | -------- | -------- | -------- | -------- | 75. | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| April 2 to April 8 | 213. | -------- | -------- | -------- | -------- | -------- | -------- | 58.4 | 23.0 | -------- | 35.4 | -------- | -------- | -------- | -------- |
| April 8 to April 15 | 253. | -------- | -------- | -------- | -------- | -------- | -------- | 53.2 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| April 15 to April 22 | 192. | -------- | -------- | -------- | -------- | -------- | -------- | 63.6 | 21.6 | -------- | 42.0 | -------- | -------- | -------- | -------- |
| April 22 to April 29 | 230. | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | 54.4 | -------- | -------- | -------- | -------- |
| April | 225. | -------- | -------- | -------- | -------- | -------- | -------- | 62.5 | 18.6 | -------- | 43.9 | -------- | -------- | -------- | -------- |
| April 29 to May 6 | 226. | -------- | -------- | -------- | 3.5 | -------- | -------- | 74.0 | 16.0 | -------- | 58.0 | -------- | -------- | -------- | -------- |
| May 6 to May 13 | 215. | -------- | -------- | 4.5 | 4.0 | -------- | -------- | 73.2 | 30.8 | -------- | 42.4 | -------- | -------- | -------- | -------- |
| May 13 to May 20 | 217. | -------- | -------- | 10.0 | 2.5 | -------- | -------- | 74.4 | 16.6 | -------- | 57.8 | -------- | -------- | -------- | -------- |
| May 20 to May 27 | -------- | -------- | -------- | 7.4 | 3.4 | -------- | -------- | 72.4 | 16.2 | -------- | 56.2 | -------- | -------- | -------- | -------- |
| May 27 to June 3 | 192. | 11.2 | 80. | 10.0 | 3.2 | -------- | -------- | 71.6 | 12.0 | -------- | 59.6 | -------- | -------- | -------- | -------- |
| May | 212. | -------- | -------- | 8.0 | 3.3 | -------- | -------- | 73.1 | 18.3 | -------- | 54.8 | -------- | -------- | -------- | -------- |
| June 3 to June 6 | -------- | -------- | -------- | 3.5 | 4.5 | -------- | | 70.0 | 10.0 | -------- | 60.0 | -------- | -------- | -------- | -------- |
| June 6 to June 12 | | | | | | | Station shut down. | | | | | | | | |
| June 12 to June 20 | 172. | 93. | 79. | 5.8 | 1.0 | -------- | -------- | 58.8 | 16.8 | -------- | 42. | -------- | -------- | -------- | -------- |
| June 20 to June 27 | 94. | 43. | 51. | 4.8 | 3.2 | -------- | -------- | 66.8 | 23.2 | -------- | 43.6 | 41.7 | -------- | -------- | -------- |
| June 28 to July 5 | 146. | 52. | 94. | 1.92 | 6.08 | -------- | -------- | 60. | 15.6 | -------- | 44.4 | -------- | -------- | -------- | -------- |
| June | 137. | 62. | 75. | 4.0 | 3.9 | -------- | -------- | 63.9 | 16.4 | -------- | 47.5 | 42. | -------- | -------- | -------- |
| July 5 to July 12 | 196. | 56. | 140. | 2.08 | -------- | -------- | -------- | 64.4 | 14.8 | -------- | 49.6 | 44. | -------- | -------- | -------- |
| July 12 to July 19 | 174. | 77. | 97. | 4.08 | 4.32 | -------- | -------- | 72. | 26.8 | -------- | 45.2 | 39.2 | -------- | -------- | -------- |
| July 19 to July 26 | 98. | 22. | 76. | 6.00 | 4. | -------- | -------- | 74.4 | 19.6 | 18. | 36.8 | 36.7 | -------- | -------- | -------- |
| July 26 to August 2 | 164. | 42. | 122. | 2.88 | 5.12 | -------- | -------- | 59.6 | -------- | 52 | 8 | 39.2 | -------- | -------- | -------- |
| July | 158. | 49. | 109. | 3.8 | 4.5 | -------- | -------- | 70.3 | 17.1 | -------- | 53.2 | 40. | -------- | -------- | -------- |
| Aug. 2 to Aug. 9 | 134. | 27. | 107. | 1.20 | 5.60 | -------- | -------- | 69.6 | -------- | 40 | .8 | 46.5 | -------- | -------- | -------- |
| Aug. 9 to Aug. 16 | 140. | 29. | 111. | 1.44 | 2.36 | -------- | -------- | -------- | -------- | -------- | -------- | 44. | -------- | -------- | -------- |
| Aug. 16 to Aug. 23 | 127. | 73. | 54. | 3.5 | 3.7 | -------- | -------- | 66. | 11.40 | 21.40 | 33.20 | 46.5 | 210. | -------- | -------- |
| Aug. 23 to Aug 30 | 134. | 29. | 105. | 6.8 | 4. | .28 | .27 | 73.6 | 16.8 | 25.2 | 31.6 | 40. | -------- | -------- | -------- |
| Aug. 30 to Sept. 2 | 160. | 48. | 112. | 4. | 4. | .14 | .05 | 98.0 | 41.6 | 22.0 | 34.4 | -------- | -------- | -------- | -------- |
| August | 139. | 41. | 98. | 3.4 | 4.0 | 12.1 | .16 | 79.2 | 23.2 | 22.9 | 33.1 | 44. | 210. | -------- | -------- |
| Sept. 2 to Sept. 6 | | | | | | Outside sprinkling filters resting. | | | | | | | | | |
| Sept. 6 to Sept. 13 | 136. | 52. | 84. | 7.6 | 4.4 | -------- | | 76.8 | 8.4 | 37.2 | 31.2 | 52. | -------- | -------- | -------- |
| | | | | Changed from three-hour to one-half hour sampling period. | | | | | | | | | | | |
| Sept. 14 to Sept. 20 | 248. | 92. | 156. | 7.8 | 4.2 | .18 | -------- | 84. | 4.8 | 44.4 | 34.8 | 52. | -------- | -------- | -------- |
| Sept. 20 to Sept. 27 | 216. | 72. | 144. | 8.2 | 3. | .20 | .10 | 59.6 | 2.8 | 24.8 | 32. | 42. | 140. | -------- | -------- |
| Sept. 27 to Oct. 4 | 164. | 64. | 100. | 6.6 | 3. | .18 | .22 | 64. | 3.2 | 27.2 | 33.6 | 37. | 164. | -------- | -------- |
| September | 191. | 70. | 121. | 7.6 | 3.7 | .19 | .16 | 71.1 | 4.8 | 33.4 | 32.9 | 46. | 152. | -------- | -------- |
| Oct. 4 to Oct. 11 | 260. | 84. | 176. | 8.2 | 3. | .2 | .6 | 69.2 | 2.4 | 13.2 | 53.6 | 36. | 148. | -------- | -------- |
| Oct. 11 to Oct. 18 | 246. | 56. | 190. | 7.6 | 3.6 | .16 | .04 | 82.4 | 12.8 | 19.6 | 50. | 49. | 176. | -------- | -------- |
| Oct. 18 to Oct. 25 | 252. | 28. | 224. | 4. | 4. | .16 | .64 | 99.2 | 20. | 41.2 | 38. | -------- | 188. | -------- | -------- |
| Oct. 25 to Nov. 1 | 208. | 52. | 156. | 1. | 3. | .24 | .16 | 87.6 | 20.8 | 25.2 | 41.6 | 43. | 152. | -------- | -------- |
| October | 242. | 55. | 187. | 5.2 | 3.4 | .19 | .36 | 84.6 | 14. | 24.8 | 45.8 | 43. | 166. | -------- | -------- |
| Nov. 1 to Nov. 8 | 188. | 42. | 146. | 12.0 | -------- | .3 | -------- | 84.8 | 11.6 | 30.4 | 42.8 | 51. | 104. | -------- | -------- |
| Nov. 8 to Nov. 15 | 200. | 44. | 156. | .8 | 4. | .25 | .35 | 76.4 | 12.8 | 27.6 | 36. | 45. | 132. | -------- | -------- |
| Nov. 15 to Nov. 22 | 224. | 68. | 156. | 3. | 4.2 | .25 | .2 | 68. | 8.8 | 25.2 | 34. | 49. | 140. | -------- | -------- |
| Nov. 22 to Nov. 29 | 268. | 24. | 244. | .6 | 4.2 | .30 | .5 | 76. | 12.8 | 15.6 | 47.6 | 49. | 128. | -------- | -------- |
| November | 220. | 44.5 | 175.5 | 4.1 | 4.1 | .28 | .35 | 76.3 | 11.5 | 24.7 | 40.1 | 48.5 | 126. | -------- | -------- |
| Nov. 29 to Dec. 6 | 140. | 48. | 92. | 4.4 | 3.6 | .20 | .6 | 80.4 | 2.0 | 38.4 | 40.0 | 52. | 140. | -------- | -------- |
| Dec. 6 to Dec. 13 | 192. | 88. | 104. | 3.6 | 4.4 | .30 | .7 | 72. | 4. | 37.6 | 30.4 | 39. | 148. | -------- | -------- |
| Dec. 13 to Dec. 20 | 260. | 104. | 156. | 5.8 | 3.8 | .15 | 1.3 | 89.6 | 13.2 | 36.4 | 40. | 47. | 100. | -------- | -------- |
| Dec. 20 to Dec. 24 | 208. | 92. | 116. | 9.4 | 3.4 | .10 | .7 | 90. | 20.8 | 29.2 | 40.0 | 35. | 72. | -------- | -------- |
| Dec. 24 to Dec. 27 | | | | | | | | | | | | | | | |
| Dec. 27 to Jan. 3 | 200. | 76. | 124. | 3.6 | 3.6 | .15 | 1.2 | 92. | 9.2 | 34.4 | 48.4 | 31. | 68. | -------- | -------- |
| December | 200. | 82. | 118. | 5.36 | 3.8 | .18 | .9 | 84.8 | 9.8 | 35.2 | 39.8 | 41. | 106. | -------- | -------- |
| Jan. 3 to Jan. 10 | 172. | 64. | 108. | 6.6 | 4.6 | .25 | 2.0 | 92.8 | 14.8 | 30. | 48. | 37. | 76. | -------- | 16. |
| Jan. 10 to Jan. 14 | 116. | 0± | 116.± | 6.4 | 4. | .20 | 1.3 | 91.2 | 6.4 | 40.4 | 44.4 | 31. | 90. | -------- | 35.8 |
| Jan. 17 to Jan. 24 | 192. | 56. | 136. | 10 | .4 | .18 | 2.3 | 88. | 19.6 | 34.4 | 34. | 33. | 100. | -------- | 24. |
| Jan. 24 to Jan. 31 | 192. | 36. | 156. | 6.7 | 2.5 | .20 | 2.8 | 80.8 | 15.6 | 34.0 | 31.2 | 35. | 82. | -------- | 28. |
| January, 1910 | 168. | 39. | 129. | 6.6 | 3.7 | .206 | 2.1 | 88.2 | 14.1 | 34.7 | 39.4 | 34. | 87. | -------- | 25.9 |
| Jan. 31 to Feb. 7 | 164. | 60. | 104. | 7. | 2.6 | .25 | 3.7 | 86. | 18.4 | 27.2 | 40.4 | 33. | 120. | -------- | 18. |
| Feb. 7 to Feb. 14 | 158. | 10. | 148. | 7. | 3.4 | .35 | 1.6 | 92. | 16.8 | 34. | 41.2 | 37. | 116. | -------- | 24.4 |
| Feb. 14 to Feb. 21 | 240. | 94. | 146. | 7.4 | 3.4 | .10 | 2.9 | 92.8 | 16.8 | 32.4 | 43.6 | 35. | 108. | -------- | 55.4 |
| Feb. 21 to Feb. 28 | 238. | 86. | 152. | 7.8 | 3.4 | .10 | .40 | 89.6 | 20.8 | 35.2 | 33.6 | 31. | 92. | -------- | 30.4 |
| February | 200. | 63. | 137. | 7.3 | 3.2 | .20 | 2.15 | 90.1 | 18.2 | 32.2 | 39.7 | 34. | 109. | -------- | 32.0 |
| Feb. 28 to March 7 | 340. | 162. | 178. | 9.8 | 2.6 | .10 | 2.4 | 90. | 24.8 | 30.8 | 34.4 | 33. | 100. | -------- | 25.6 |
| March 7 to March 14 | 200. | 76. | 124. | 6.6 | 3. | .20 | 3.8 | 87.6 | 20.4 | 32.8 | 34.4 | 35. | 92. | 70.4 | 51. |
| March 14 to March 21 | 188. | 44. | 144. | 6.4 | 4.4 | .40 | 2.6 | 81.6 | 14.8 | 33.2 | 33.6 | 31. | -------- | -------- | 25.4 |
| March 21 to March 28 | 138. | 10. | 128. | 7.2 | 2.8 | .45 | .35 | 71.6 | 19.6 | 28.8 | 23.2 | 31. | 144. | -------- | 22.8 |
| March 28 to April 4 | 178. | 46. | 132. | -------- | -------- | -------- | -------- | 64.4 | 18.8 | 24. | 21.6 | 27. | 96. | -------- | 35.2 |
| March | 209. | 68. | 141. | 7.5 | 3.2 | .29 | 2.28 | 79. | 19.7 | 29.9 | 29.4 | 31.4 | 86. | 70.4 | 32. |
| April 4 to April 11 | 188. | 36. | 152. | 6.6 | 4.6 | .35 | .5 | 76.8 | 23.6 | 23.6 | 29.6 | 29. | 100. | -------- | 25.9 |
| April 11 to April 18 | 142. | 40. | 102. | 3.6 | 6. | .008 | -------- | 63.2 | 24.8 | 17.2 | 21.2 | 31. | 92. | -------- | 21. |
| April 18 to April 25 | 172. | 76. | 96. | 7.8 | 1.4 | .45 | .05 | 60. | 17.6 | 18.8 | 23.6 | 29. | 156. | -------- | 22.6 |
| April 25 to April 30 | 136. | 64. | 72. | -------- | -------- | .40 | .6 | 62.4 | 10. | 23.6 | 28.8 | 29. | 92. | -------- | -------- |
| April | 158. | 54. | 104. | 6. | 4. | .302 | .38 | 65.6 | 19. | 20.8 | 25.8 | 29.8 | 110. | -------- | 23.1 |

**OUTSIDE SPRINKLING FILTER.—Station No. 20-6.**
**½-inch to 2½-inch trap media.**


ANALYSIS OF CRUDE SEWAGE IN PARTS PER MILLION
MONTHLY AVERAGES.
DIAGRAM NO. 4
SUSPENDED SOLIDS
Fixed
Volatile.
1908
APRIL
MAY
JUNE
JULY
AUGUST
SEPT.
OCT.
NOV.
DEC.
1909
JAN'RY
FEB'Y
MARCH
APRIL
AVERAGE.
300
250
200
150
100
50
0
Nitrites and Nitrates not Determined.
NITROGEN AS
Org--anic
Free Ammonia
Nitr--ites.
Nitr--ates
14
12
10
8
6
4
2
0
OXYGEN CONSUMED
Settling Solids
Coll--oidal
Diss--olved
80
70
60
50
40
30
20
10
0
CHLORINE
40
30
20
10
0
BACTERIA PER C.C. 20° C.
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0.

# Table No. 5.

*Monthly Averages of Crude Force Main Sewage.*

| Date. | PARTS PER MILLION. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Suspended Solids. | | | Nitrogen, as— | | | | Oxygen Consumed. | | | | | | |
| | Total. | Fixed. | Volatile. | Organic. | Free Amm. | Nitrites. | Nitrates. | Total. | Settling. | Colloidal. | Dissolved. | Chlorine. | Alkalinity. | Fats. |
| 1909. | | | | | | | | | | | | | | |
| April | 225 | ---- | ---- | ---- | ---- | ---- | ---- | 62.5 | 18.6 | ---- | 43.9 | ---- | ---- | ---- |
| May | 212 | ---- | ---- | 8.0 | 3.3 | ---- | ---- | 73.1 | 18.3 | ---- | 54.8 | ---- | ---- | ---- |
| June | 137 | 62 | 75 | 4.0 | 3.9 | ---- | ---- | 63.9 | 16.4 | ---- | 47.5 | 42 | ---- | ---- |
| July | 158 | 49 | 109 | 3.8 | 4.5 | ---- | ---- | 70.3 | 17.1 | ---- | 53.2 | 40 | ---- | ---- |
| August | 139 | 41 | 98 | 3.4 | 4.0 | .21 | .16 | 79.2 | 23.2 | 22.9 | 33.1 | 44 | 210 | ---- |
| September | 191 | 70 | 121 | 7.6 | 3.7 | .19 | .16 | 71.1 | 4.8 | 33.4 | 32.9 | 46 | 152 | ---- |
| October | 242 | 55 | 187 | 5.2 | 3.4 | .19 | .36 | 84.6 | 14.0 | 24.8 | 45.8 | 43 | 166 | ---- |
| November | 220 | 45 | 175 | 4.1 | 4.1 | .28 | .35 | 76.3 | 11.5 | 24.7 | 40.1 | 48 | 126 | ---- |
| December | 200 | 82 | 118 | 5.4 | 3.8 | .18 | .90 | 84.8 | 9.8 | 35.2 | 39.8 | 41 | 106 | ---- |
| 1910. | | | | | | | | | | | | | | |
| January | 168 | 39 | 129 | 6.6 | 3.7 | .21 | 2.1 | 88.2 | 14.1 | 34.7 | 39.4 | 34 | 87 | 26 |
| February | 200 | 63 | 137 | 7.3 | 3.2 | .20 | 2.1 | 90.1 | 18.2 | 32.2 | 39.7 | 34 | 109 | 32 |
| March | 209 | 68 | 141 | 7.5 | 3.2 | .29 | 2.3 | 79.0 | 19.7 | 29.9 | 29.4 | 31 | 86 | 32 |
| April | 158 | 54 | 104 | 6.0 | 4.0 | .30 | .38 | 65.6 | 19.0 | 20.8 | 25.8 | 30 | 110 | 23 |
| Average | 189 | 59 | 130 | 6.3 | 4.0 | .23 | 1.0 | 76. | 15.6 | 20.0 | 40.4 | 39 | 128 | 28 |

nitrogen content, but this may be due to the carbonaceous matter contained in the trade wastes.

**Fats.**

The fat content was regularly determined only during the last four months of operation and is a normal amount. They probably are derived not only from the domestic portion of the sewage but from wool washings. Notwithstanding the presence of acid in manufacturing wastes from Manayunk the sewage was always alkaline.

The bacterial counts are quite normal and follow the usual seasonal fluctuation. See diagram No. 4.

## FINE MESH SCREENING.

The fine mesh screen (Station No. 11) has already been described. On account of its construction it was not possible to obtain the screenings in a semidry state, as the splashing water washed them away. As the screen removed all the large solids which could not be included in analysis by Gooch crucible, a mere comparison of suspended solids in the influent and effluent would give a lower percentage removal than the truth, and it must be borne in mind that the sewage applied to the fine screen had been withdrawn from beneath the surface of the flow in the intercepting sewer, had passed through a coarse screen, and had passed through a plunger type pump. The percentage removal of suspended solids by the screen is therefore not comparable with a disposal works screen.

### Removal Suspended Solids.

The crude sewage applied to the screen during its entire run contained on an average 200 parts per million suspended solids as measured by the Gooch crucible, and the average effluent 133. This would represent a removal of 33.5 per cent. of the suspended solids, or 560 pounds dry solids per million gallons sewage screened.

As a check upon these figures a run was made on tanks Nos. 12 and 13, under identical conditions, except the influent to No. 12 was screened and to 13 crude sewage. The difference in the amount of dried residue deposited in the tanks was used to determine the percentage removed by the screen. Allowing for the inaccuracies in sampling both the sewage and sludge, the test indicates a removal of 37.3 per cent. of the total suspended solids in the crude sewage by the fine mesh screen.

For comparison, with an actual installation of a fine screen of similar mesh to the one described, the operation of the Reading plant as reported by Mr. Emil Kuichling in his notes on Sewage Disposal for Rochester, may be of interest.

There the crude sewage contained 215 parts per million of suspended solids, and the screened sewage 125, showing a removal of 90 parts per million or 750 pounds of dry solids per million gallons sewage. This is a removal of 41.8 per cent of the total suspended solids.

### Effect Upon Subsequent Treatment.

The most important result of the fine mesh screening of a sewage containing trade wastes, such as wool and hops, was the fact that the screened sewage contained no particles larger in size than 1 mm. as frequently determined by microscopic measurements, and as the clear openings in the screen used were 0.5 mm. square, only soft flexible solids larger than that size would be driven through by the force of the jets. This means that the irregularity of the load of suspended solids upon a sewage disposal plant produced by the erratic contribution of trade wastes would be eliminated by fine mesh screening.

The use of fine mesh screen produced a marked effect upon the sludge collected in subsequent sedimentation, as will be described in detail under that subject. Suffice it to say at this time that the use of such a screen lessens the quantity of sludge produced, increases its percentage moisture, and by removing all large particles yields a sludge composed of very finely divided solids, consequently easily pumped.

If sprinkling filters are used, the clogging of nozzles is reduced to a minimum—in fact, the nozzles of the lower sprinkling filter, the influent of which was settled screened sewage, were never clogged during its nine months operation.

## HORIZONTAL FLOW SEDIMENTATION.

### Sedimentation of Screened Sewage in No. 12.

Tank No. 12 has already been described and the work accomplished by the combination of fine mesh screening and sedimentation is shown in diagram No. 5 and table No. 6.

### Comparative Data.

In connection with the above tables the following data is given as typical of sedimentation as practised elsewhere.

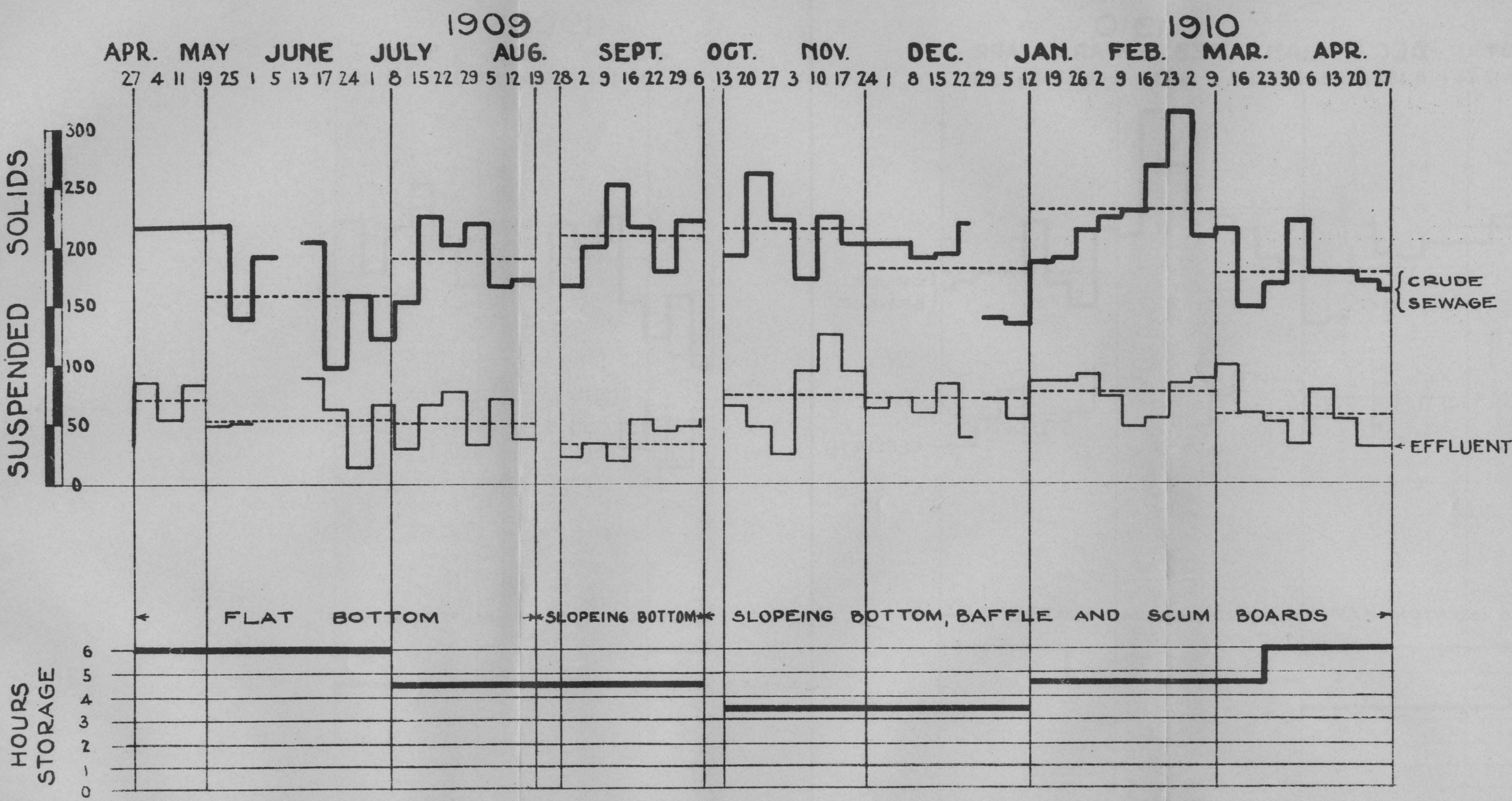



DIAGRAM No. 5
SEDIMENTATION IN TANK No. 12

| Reference. | Location. | Hours Storage | Suspended Solids. Parts per Million. Influent. | Effluent. | Per Cent. Removal. |
|---|---|---|---|---|---|
| Fifth report of the English Royal Commission. | Clifton<br>Oswestry | 5.3<br>4.1 | 490<br>320 | 240<br>158 | 51<br>50 |
| John D. Watson, Proc. Inst. C. E., 1910. | Birmingham | Horizontal<br>Vertical | 408<br>187.6 | 187.6<br>98 | 54<br>47.7 |
| Geo. A. Johnson, Report on Experiments, 1905. | Columbus Testing Station. | 8<br>6 | 147<br>134 | 78<br>73 | 47<br>43 |
| C. B. Hoover, Trans. Am. Soc. C. E., 1910. | Columbus Sew. Dis. Works. | 4.9 | 200 | 82 | 58 |
| Emil Kuichling, Description of Steurnagels Studies, 1910. | Cologne Experiments. | 3.125<br>.625<br>.312 | 288.1<br>314.0<br>398.8 | 76.0<br>93.9<br>154.5 | 73.6<br>70.1<br>60.8 |

### Operation of the Tank.

The first two runs of Tank No. 12 were from April 24, 1909, to July 7, 1909; during this time the tank was rectangular and ran at a nominal storage period of six hours; the average percentage removed of suspended solids under those conditions was 65.3, and the effluent contained on an average 59 parts per million suspended solids.

The next two runs at four and a half hours' storage were July 8 to August 20 and August 28 to October 6. Between them there was made a steeply sloping bottom toward the inlet end in order to allow the deposition of sludge at the inlet end without increasing the velocity of flow above that in a flat-bottom tank. During both runs the average percentage removal was 77.5 and the average effluent contained 45 parts per million suspended solids.

A transverse baffle wall was now built at mid length with a scum board and about the outlet a tight box-like weir protected by inclined scum boards, and the storage time reduced to three and a half hours; under these conditions the tank ran from October 13, 1909, to January 12, 1910, and removed 64.1 per cent. of the suspended solids, yielding an average effluent of 71 parts per million.

The only change in the next run was the length of the storage, which was increased to four and one-half hours, and from January 14, 1910, to March 8, 1910, the percentage removal was 67.1, the tank yielding an effluent containing 76 parts per million suspended solids.

The last run was from March 9, 1910, to April 30, 1910, when the nominal storage period was again increased to six hours; the average sewage was more dilute and while the effluent was lower in suspended solids, containing 60 parts per million, the percentage removal was the same as the former run.

**Conclusion.**

In considering the entire operation of the tank it will be observed that during the 2nd, 3rd and 4th runs the average sewage was steadily increasing in suspended solids, and although the storage period was decreased, the effluent was steadily improving, showing that the long storage period is not essential. Upon still lowering the storage period to 3½ hours, but in a baffled tank, while the effluent contained more suspended solids than before, its content showed lower figures than those given for the English plants quoted above and for the Columbus Sewage Disposal Works during 1909, and was the same as the unbaffled experimental tanks at Columbus operated at six and eight hours.

**Results of Baffles.**

Further evidence of the efficiency of proper baffling is shown in the seventh run, where it will be seen in the diagram that the sewage steadily grew stronger while the effluent was quite uniform in suspended solids.

TABLE NO. 6.

*Results of Horizontal Sedimentation in Tanks Nos. 12, 13 and 17.*

| | Dates. | Condition of Tank. | Hours Storage. | Suspended Solids. | | | | | Cubic Yards of Wet Sludge per Million Gallons. | Sludge Analyses. | | | | | | | Equivalent Number of Cubic Yds. of Sludge if Sp. Gr.=1.02 & 90 per Cent. Moisture. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Parts per Million. | | | Per Cent. Removal. | | | Wet Sludge. | | Percentage of Dry Residue. | | | | | | |
| | | | | Crude. | Screened. | Effluent. | Crude. | Screened. | | Sp. Gr. | Per Cent. Water. | Volatile. | Fixed. | Nitrogen. | Fats. | | | |
| Tank No. 12. | April 27 to May 18<br>May 19 to July 7 | Level bottom. No baffles. | 6 | 215. | 135. | 70. | 68.5 | 48.1 | ---------- | ---------- | 87. | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | |
| | July 8 to August 20 | | | 160. | 84. | 55. | 65.5 | 34.5 | 3.51 | 1.05 | 87.9 | 46.7 | 53.3 | ---------- | ---------- | ---------- | 4.37 | |
| | August 28 to October 6 | Sloping bottom. | 4½ | 190. | 136. | 53. | 72.2 | 61.0 | 4.09 | ---------- | 83.8 | 40.7 | 59.3 | ---------- | ---------- | ---------- | 6.75 | |
| | | | | 208. | 129. | 37. | 82.3 | 71.4 | 3.68 | 1.04 | 90. | 44.7 | 55.3 | 1.8 | 8.7 | ---------- | 3.75 | |
| | October 13 to November 24 | Sloping bottom. Baffle and scum board. | 3½ | 213. | 157. | 75. | 64.8 | 52.2 | 4.54 | 1.05 | 89.6 | 46.7 | 53.3 | 0.9 | 9.2 | Inlet | 5.16 | |
| | November 24 to January 12 | | | | | | | | | 1.037 | 87.3 | 48.5 | 51.3 | 1.5 | 9.0 | Outlet | | |
| | January 14 to March 8 | | | 185. | 141. | 68. | 63.4 | 52.0 | 6.90 | 1.02 | 95.6 | 50. | 50. | 1.1 | 4.9 | ---------- | 3.04 | |
| | March 9 to April 30 | | 4½ | 231. | 150. | 76. | 67.1 | 49.4 | 4.72 | 1.045 | 91.0 | 72.2 | 27.8 | 1.1 | 9. | ---------- | 4.35 | |
| | | | 6 | 182. | 131. | 60. | 67. | 54.2 | 5.09 { 4.6 | 1.010 | 94.2 | 60.3 | 39.7 | 1.4 | 22. | Inlet | 3.10 | |
| | | | | | | | | | 0.49 | 1.031 | 90.7 | 47.1 | 52.9 | 1.5 | 8.6 | Outlet | | |
| | Average | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | 4.9 | 1.036 | 90.0 | 49.0 | 51.0 | 1.3 | 8.1 | ---------- | 5.00 | |
| Tank No. 13. | May 19 to July 7 | Level bottom. No baffles. | 6* | 162. | ---------- | 66. | 59.2 | ---------- | 6.85 | 1.04 | 89.3 | ---------- | ---------- | ---------- | ---------- | ---------- | 7.50 | |
| | July 8 to August 20 | | 4½ | 190. | ---------- | 69. | 63.7 | ---------- | 4.61 | ---------- | 77.7 | ---------- | ---------- | ---------- | ---------- | Inlet | 10.6 | |
| | August 23 to October 6 | | | ---------- | | | | | ---------- | | 86.7 | ---------- | ---------- | ---------- | ---------- | Outlet | | |
| | | Sloping bottom, baffles and scum board. | ---------- | 204. | ---------- | 54. | 73.5 | ---------- | 3.15 | 1.07 | 88.7 | 41.3 | 58.7 | 1.7 | 6.5 | ---------- | 3.74 | |
| | October 13 to December 22 | | 3½ | 207. | ---------- | 81. | 61.0 | ---------- | 3.24 | 1.07 | 81.9 | 55.6 | 44.4 | 2.2 | 14.3 | Scum | 5.18 | |
| | | | | | | | | | | 1.059 | 87.6 | 47.7 | 52.3 | 1.4 | 7.0 | Sludge | | |
| | January 7 to March 9 | | 3⅔ | 220. | ---------- | 77. | 65.0 | ---------- | 2.49 | 1.05 | 81.8 | 65.9 | 34.1 | 1.4 | 18.6 | Scum | 4.85 | |
| | March 11 to April 30 | | 5¾ | 182. | ---------- | 75. | 58.7 | | | 1.045 | 80.5 | 52.6 | 47.4 | 1.2 | 8.5 | Sludge | | |
| | Average | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | 4.07 | ·1.053 | 86.1 | 48. | 52.0 | 1.4 | 7.4 | ---------- | 5.85 | |
| Tank No. 17. | June 13 to July 15 | Unbaffled. | 10 | 131. | ---------- | 65. | 50.4 | ---------- | 7.4 | | | | | | | | | |
| | July 16 to August 20 | | 6 | 212. | ---------- | 69. | 67.5 | ---------- | | | | | | | | | | |
| | August 24 to September 22 | | 4 | 233. | ---------- | 44. | 81.2 | ---------- | 7.2 | 1.02 | 88.5 | 46.3 | 53.7 | 1.8 | 9.8 | ---------- | 8.28 | |
| | September 28 to November 4 | Two baffles, scum boards and collecting weir. | 4 | 224. | ---------- | 54. | 75.8 | ---------- | 6.4 { 3.3 | 1.05 | 84.5 | 50.0 | 50.0 | 1.7 | 10.3 | Inlet | 8.01 | |
| | | | | | | | | | 2.1 | 1.06 | 90.7 | 51.3 | 48.7 | 1.7 | 9.1 | Middle | | |
| | | | | | | | | | 1.0 | 1.05 | 92.9 | 50.0 | 50.0 | 1.5 | 10.5 | Outlet | | |
| | November 6 to January 5 | | 4 | 192. | ---------- | 54. | 71.9 | ---------- | 6.87 { Scum, 1.72 { 1.32 | 1.05 | 85.2 | 56.4 | 43.6 | 1.7 | 8.0 | Inlet | 2.50 | 8.45 |
| | | | | | | | | | .4 | 1.04 | 87.7 | 49. | 51.0 | 1.3 | 9.9 | Outlet | | |
| | | | | | | | | | Sludge, 5.15 { 2.48 | 1.045 | 88.2 | 49.4 | 50.6 | 1.2 | 5.4 | Inlet | 5.95 | |
| | | | | | | | | | 1.69 | 1.038 | 90.0 | 49. | 51.0 | 1.2 | 5.9 | Middle | | |
| | | | | | | | | | .98 | 1.052 | 87.9 | 47. | 53.0 | 1.3 | 6.7 | Outlet | | |
| | January 12 to March 9 | | 4 | 230. | ---------- | 67. | 71.0 | ---------- | 6.07 { Scum, .68 { .51 | 1.04 | 83.7 | 65.4 | 34.6 | 1.9 | 21.7 | Inlet | 1.03 | 4.75 |
| | | | | | | | | | .17 | 1.025 | 89.4 | 55.7 | 44.3 | 1.3 | 11.9 | Outlet | | |
| | | | | | | | | | Sludge, 5.39 { 2.34 | 1.034 | 91.6 | 51.1 | 48.9 | 1.1 | 6.5 | Inlet | 3.72 | |
| | | | | | | | | | 1.85 | 1.023 | 93.7 | 52.4 | 47.6 | 1.3 | 8.7 | Middle | | |
| | | | | | | | | | 1.20 | 1.014 | 95.2 | 58.2 | 41.8 | 1.3 | 12.1 | Outlet | | |
| | March 16 to April 30 | | 9 | 177. | ---------- | 46. | ---------- | ---------- | 6.31 | 1.043 | 87.7 | 50.0 | 50.0 | 1.3 | 7.2 | Sludge | 7.95 | |
| | | | | | | | | | 1.20 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | Scum | 7.49 | |

Another matter not shown in the analysis but noted during the operation of all the tanks was that in unbaffled tanks the presence of visible trade wastes at the influent end was soon followed by the same waste at the outlet, showing a current of high velocity through quiet portions of the tank whereas after proper baffling of the tanks the entire cross section of the tank was placed in service.

The baffles also served to hold the sludge back at the inlet end, where in case septic action should develop the rising masses had much less chance to reach the outlet and pass out upon the filters.

### Length of Runs.

As the sludge deposited in the tank was used and not run to the drain at no labor cost, it became an economic measure to sludge several tanks at once, and therefore, the length of the run was not always fixed by the development of septic action, although tanks were always sludged as soon after ebullition of gas was noted as was practical. From August 28, 1909, to January 12, 1910, nitrogen as free ammonia, nitrites, and nitrates were determined in the crude sewage applied to the screen, and in the effluent of the tank to find if septic action was developing. During that time the average influent and effluent contained nitrogen as follows:

| | PARTS PER MILLION. | | |
|---|---|---|---|
| | Nitrogen as— | | |
| | Free Ammonia. | Nitrites. | Nitrates. |
| Crude sewage | 3.7 | .18 | .41 |
| Effluent No. 12 | 3.2 | .18 | .67 |

This shows no evidence of septic action, but rather an improvement, probably due to the violent splashing at the screen.

It will be noted that excluding the first run, which was not ended because of septic action, the tank was sludged about every seven weeks in cool weather and six in warm weather, averaging every six and one-half weeks.

### Formation of Scum.

On this tank a scum never formed, but prior to the baffles and scum board being placed, froth, caused by the screen, floated along the tank from inlet to outlet and was carried off with the effluent; this was especially noted when the sewage seemed to contain a brewery waste as indicated by the presence of hops and high carbonic acid content.

After the introduction of scum boards this froth was entirely restrained at the inlet end and did not seem to increase in amount toward the end of a run.

## Sedimentation of Crude Sewage in No. 13.

This tank has been previously described. The influent was always crude force main sewage, and the policy adopted was to operate tanks Nos. 12 and 13 under similar conditions in order that comparison could be made between a screened and crude influent.

### Operation.

During the first run, May 19, 1909, to July 7, 1909, the tank was rectangular and entirely unbaffled; the storage period was six hours and during the run the effluent averaged 66 parts per million suspended solids, representing a removal of 59 per cent.

During the next two runs the storage period was lowered to four and one-half hours and the tank produced an effluent of 60 parts per million suspended solids, the result of having removed 69.3 per cent.

At the end of this run an inclined bottom, scum board, and effluent weir protected by an inclined scum board were built and the storage capacity reduced to three and one-half hours.

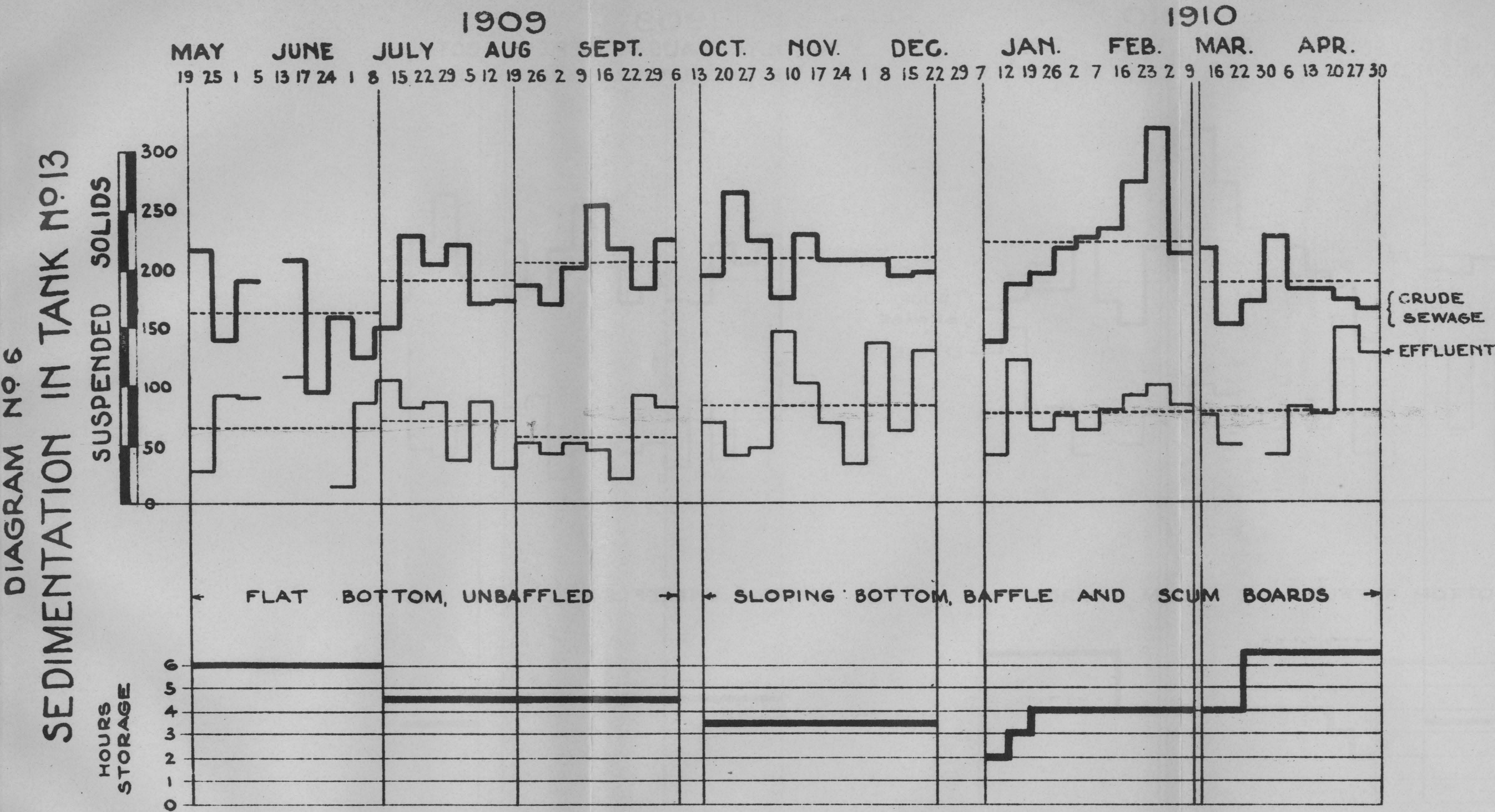


DIAGRAM No 6
SEDIMENTATION IN TANK No 13
1909
1910
MAY
JUNE
JULY
AUG
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
19 25 1 5 13 17 24 1 8 15 22 29 5 12 19 26 2 9 16 22 29 6 13 20 27 3 10 17 24 1 8 15 22 29 7 12 19 26 2 7 16 23 2 9 16 22 30 6 13 20 27 30
SUSPENDED SOLIDS
300
250
200
150
100
50
0
CRUDE SEWAGE
EFFLUENT
FLAT BOTTOM, UNBAFFLED
SLOPING BOTTOM, BAFFLE AND SCUM BOARDS
HOURS STORAGE
6
5
4
3
2
1
0

The effluent contained a larger percentage of solids than under the higher rate of flow, containing 81 parts per million suspended solids, a removal of 61 per cent.

An attempt was now made to run the tank at two hours storage for comparison with the Emscher tank, but the increased rate overtaxed the supply pipe, thus interfering with other processes, and after one week the rate was incrased to three hours and again at the end of the week to four hours, at which rate it was kept until the end of the run.

The average storage determined by weights of periods thus becomes 3.67 hours, and the average effluent during that period contained 77 parts per million suspended solids, or a removal effected of 65 per cent. of the suspended solids in the influent.

In the last run the rate was again decreased, the weighted average being 5.85 hours storage. The effluent was practically the same as before, but owing to a more dilute influent the removal effected was only 58.7 per cent.

### Conclusions.

An examination of the diagram will show that under the conditions studied, the reduction of time of storage from six to four and one-half hours did not decrease the efficiency of the tank, and that in a baffled tank three and one-half hours' storage period accomplished an efficient removal of suspended solids.

### Formation of Scum.

The influent to this tank, being unscreened, contained all of the solids of the sewage and they became apparent in two ways: first, the sludge deposited was composed of much larger particles and contained wool, as is described under sludge. Secondly, scum always formed on this tank; the scum could reach the outlet, which was only crudely protected, but upon the introduction of the baffles the scum was held back in the inlet half, where it became very thick and leathery, a thinner scum formed upon the outlet half but was entirely controlled by the inclined board protecting the outlet weir.

After six weeks the scum would be raised up like a bubble, especially in the outlet portion, showing considerable gas entrained by the tenacious leathery cover.

This scum when punctured or removed was very offensive and contained much volatile and fatty matter, as is described in detail under "sludge."

Its formation in excessive quantity must have seriously decreased the efficiency of the tank, for but small space for the flowing liquid was left at the end of the fourth run on December 22, when scum was found on the inlet end two feet thick, which means that 5.6 cubic yards of wet scum, weighing five tons, floated on the surface. This contained 1,810 pounds of dry solids of which 1,000 pounds were volatile and 260 pounds were fat.

A longitudinal cross section of the tank at this time is shown in diagram No. 7.

### Comparison of Tanks Nos. 12 and 13.

A comparison of the results accomplished by Tanks Nos. 12 and 13 is given in the following table:

| Conditions. | Hours Storage. | | Suspended Solids. | | | |
|---|---|---|---|---|---|---|
| | | | Parts per Million Average Effluent. | | Per Cent. Removal. | |
| | No. 12 | No. 13 | No. 12 | No. 13 | No. 12 | No. 13 |
| Flat unbaffled | 6 | 6 | 55 | 66 | 65.5 | 59.2 |
| Flat unbaffled | 4½ | 4½ | 53 | 60 | 72.2 | 69.3 |
| Sloping bottom baffle and scum | 3½ | 3½ | 71 | 81 | 64.1 | 61. |
| Sloping bottom baffle and scum | 6 | 5.85 | 60 | 75 | 67 | 58.7 |

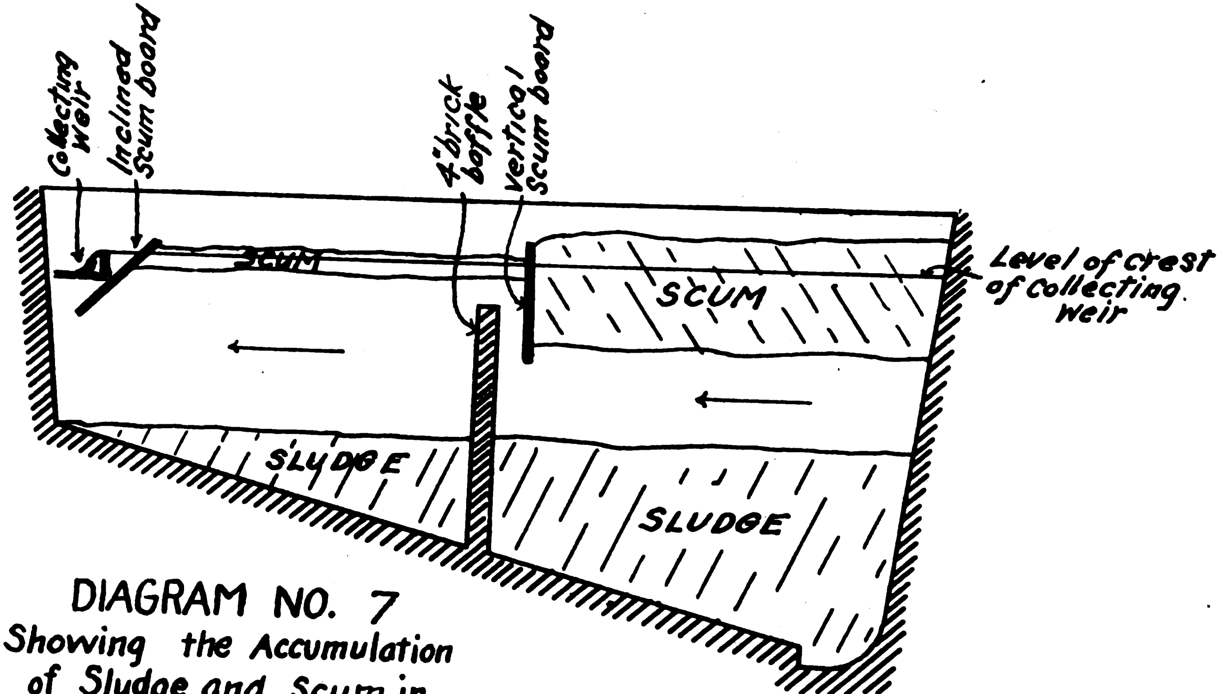



DIAGRAM NO. 7
Showing the Accumulation of Sludge and Scum in Tank No. 13

**Sedimentation of Crude Sewage in No. 17.**

**Operation.**

This tank has already been described. It was of better proportions than either Nos. 12 or 13, its depth being only one-quarter its length. As initially operated it was entirely unbaffled and the effluent collected by a 3-inch pipe; it was run at a long storage period of ten hours from June 13 to July 15, 1909; it yielded an effluent containing on an average 65 parts per million, but as the influent was more dilute than others its percentage removal was ony 50.4.

In the next run the nominal storage period was lowered to six hours, and although the influent was much stronger the tank produced an effluent almost identical with the first run, but due to the higher influent the percentage removal rose to 67.5 per cent.

The storage was now lowered to four hours and at this rate the tank produced a still better effluent, containing only 44 parts per million suspended solids, representing a removal of 81.2 per cent.

This improvement in the quality of the effluent when the storage period was reduced seems abnormal in the light of our present knowledge, but the figures were obtained with equal accuracy to others.

Two brick baffle walls with scum boards and a long collecting weir protected by an inclined scum board were now built, and on September 28, 1909, a new run commenced at the same rate of four hours' storage as before. The tank ran at this rate until March 9, 1910, being sludged twice during that time. Until December 28 the influent was quite regular in its suspended solids content, but at that time it fell down to 140 parts per million and then steadily rose until at the beginning of March it had reached 312. During the entire three runs at four hours storage the tank produced a quite uniform effluent, averaging 59 parts per million suspended solids and not being affected by the steady increase in the influent during February. This represents a percentage removal of 72.5.

During the last run the storage period was put back to ten hours so as to compare long storage in a baffled tank with the first run when unbaffled. The influent was more concentrated than in the first run, but the effluent contained on an average only 46 parts per million suspended solids, representing a percentage removal of 74.

### Conclusions.

The action of this tank corroborates that observed in 12 and 13, that long storage periods are unnecessary for efficient sedimentation and that great improvement in the uniformity of the tank liquor is obtained by efficient baffling, creating uniform velocity over the entire area of the cross section.

### Formation of Scum.

The formation of scum and its action could be well observed in this tank. Prior to baffling, scum formed in islands, floating about, and never becoming very thick or tenacious, but when divided into three compartments, in the inlet portion a scum would begin to form after a few days' running; this rapidly increased in thickness and tenacity, being covered with a leathery surface.

After scum was well developed on the inlet portion it would begin to form on the middle portion and grew much slower, never attaining more than about six inches thickness. By the end of a run small islands of greasy substance formed in the outlet third of the tank, but were successfully restrained by the inclined scum board protecting the outlet weir. During the last run a scum breaker composed of a cross of 1-inch pipes was placed in the middle compartment and was raised and lowered by hand about every half hour; it completely prevented the formation of any scum in this compartment.

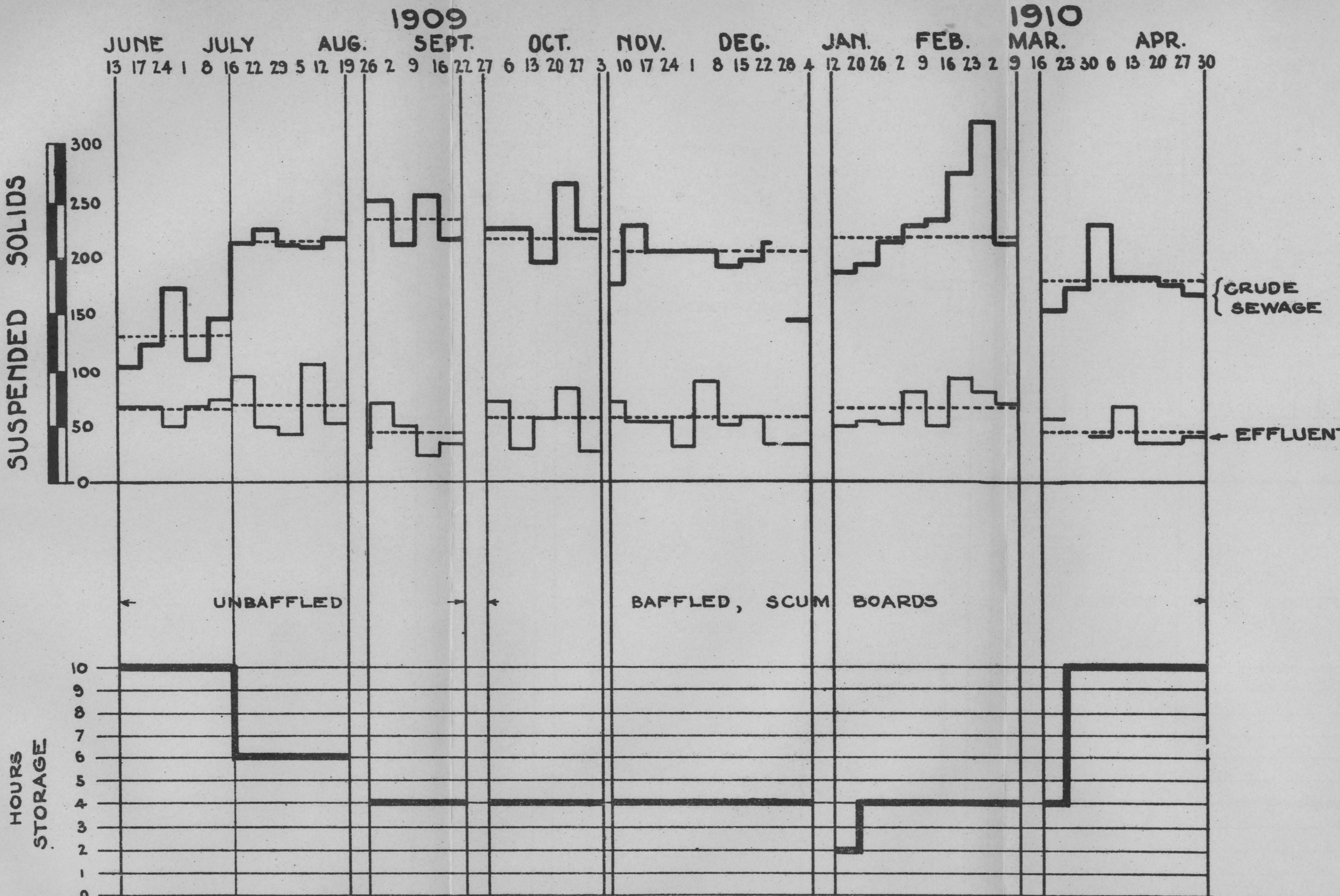



DIAGRAM No. 8
SEDIMENTATION IN TANK No. 17

The scum, especially on the inlet end, was always very offensive, although the tank was never purposely allowed to become septic, being sludged as soon as gas formation was noted.

### Formation of Sludge.

It may be said at this time, although the details are given under "Sludge," that two-thirds of the sludge was deposited at the inlet end, one-quarter in the middle and the remaining one-twelfth in the outlet end, and this restraining of the sludge away from the outlet, undoubtedly increased the uniformity of the effluent, for as sludge and scum developed the velocity of flow must have increased considerably in the inlet portion, but remained as at first in the outlet, where the less easily settled solids still continued to be removed (see diagram No. 34).

## SEDIMENTATION IN AN EMSCHER TANK.

The vertical flow sedimentation of crude sewage in an Imhoff or Emscher form tank was studied under three conditions.

### First Experiment.

On July 31, 1909, the first Emscher tank was put in service. It was a cylindrical wooden tank five feet in diameter and five feet deep and for six weeks ran at one hour storage. In order to hasten the accumulation of sludge one cubic yard of wet sludge from a sedimentation tank was placed in the Emscher tank before it was put in service. The average influent contained 233 parts per million suspended solids, the effluent 87, representing a removal of 63 per cent., but the character of the effluent was very irregular and would not have been at all suitable to apply to bacteria beds due to the uneven load of solids; but it was found that a very excellent quality sludge, lower in moisture, containing less organic matter, and having a tarry, rather than offensive odor, could be withdrawn by the hydrostatic head upon the sludge outlet pipe.

**Second Experiment.**

To correct the erratic character of the effluent, probably due to the very short vertical distance given to sedimentation, the effluent was conducted to a Dortmund form tank and subjected to another hour's vertical sedimentation. During this second stage of the Emscher studies mechanical difficulties interfered with the proper operation of two tanks in series and the results are not as favorable as during the first experiment, the effluent containing, during the period from September 9 to October 16, 1909, 93 parts per million suspended solids, a removal of 57 per cent.

One of the mechanical difficulties was the inability to determine at what level the sludge stood in the digestion chamber, and although sludge was withdrawn in small quantities at frequent intervals it is now believed that at times it was allowed to reach too high a level, so that the ebullition of gas forced it into the settling portion of the tank to the serious detriment of the effluent.

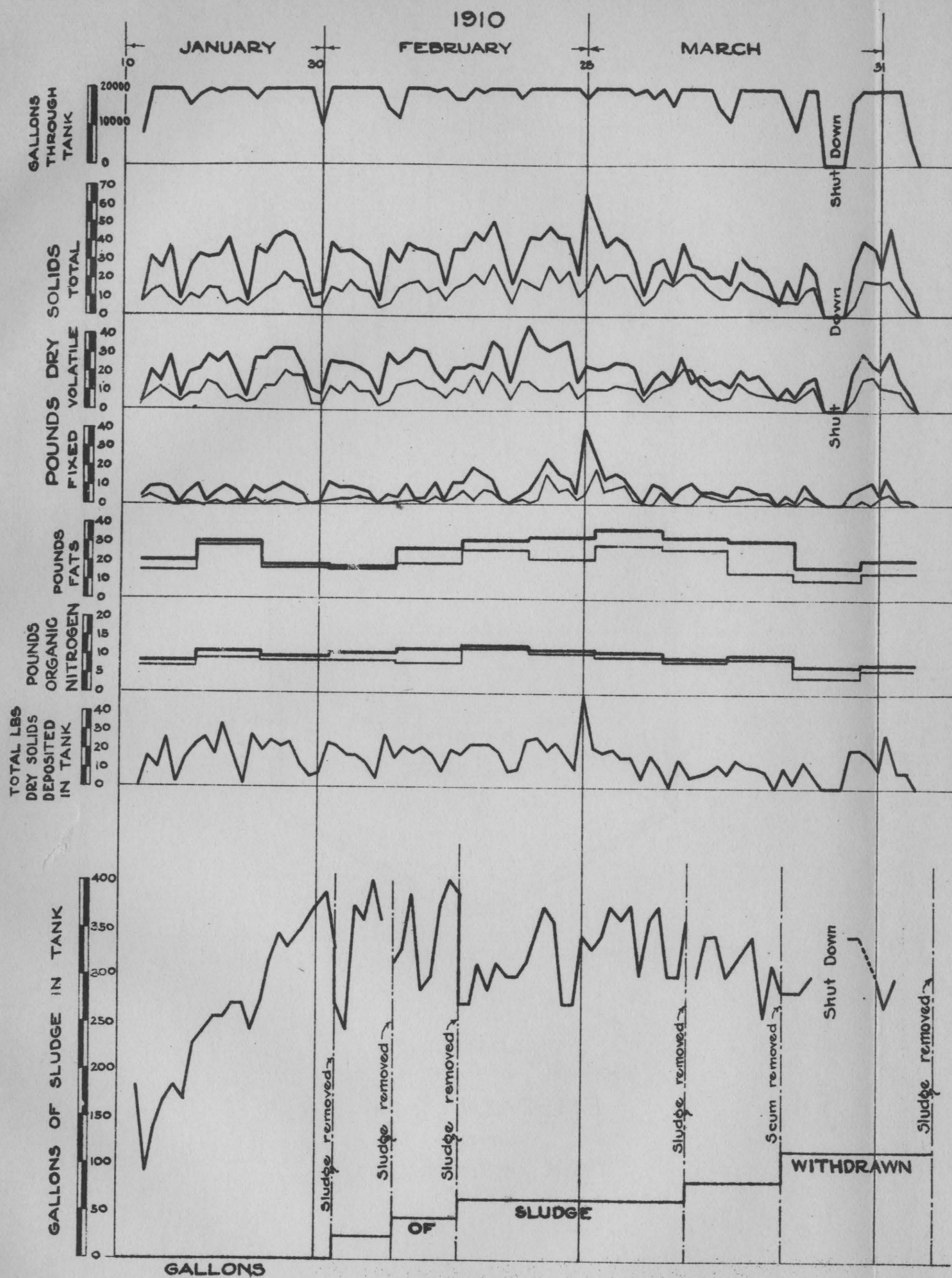
**Third Experiment.**

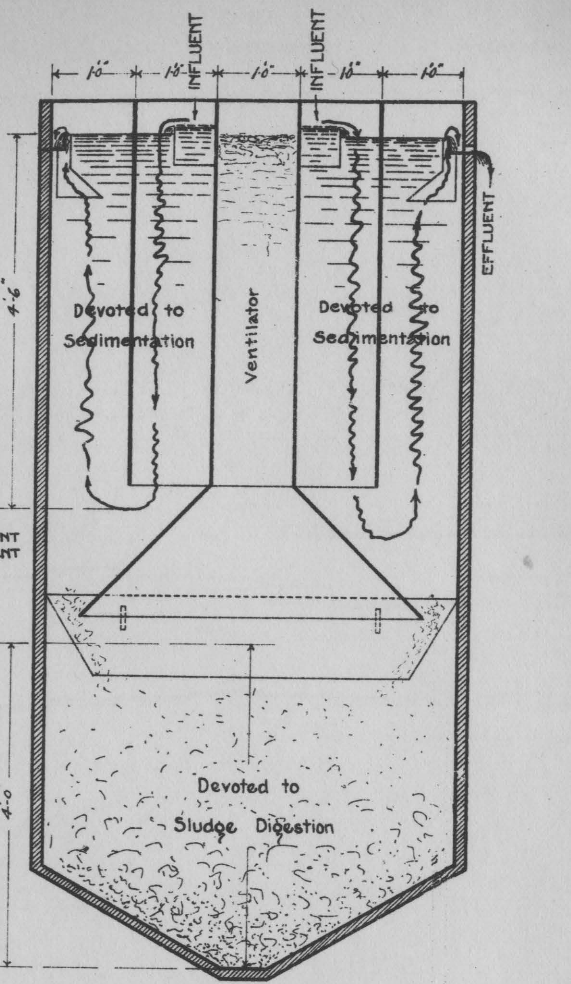
The third experiment on this form of tank was begun on January 10, 1910, in the tank ten feet deep and five feet in diameter, previously described, and shown on diagram No. 9. This tank was seeded with 168 gallons of sludge from the old Emscher tank.

The influent was, as before, crude sewage and the time of passage through the settling portion made two hours.

**Sampling.**

In order to study the action of this tank,both as regards sedimentation and production of sludge the influent and



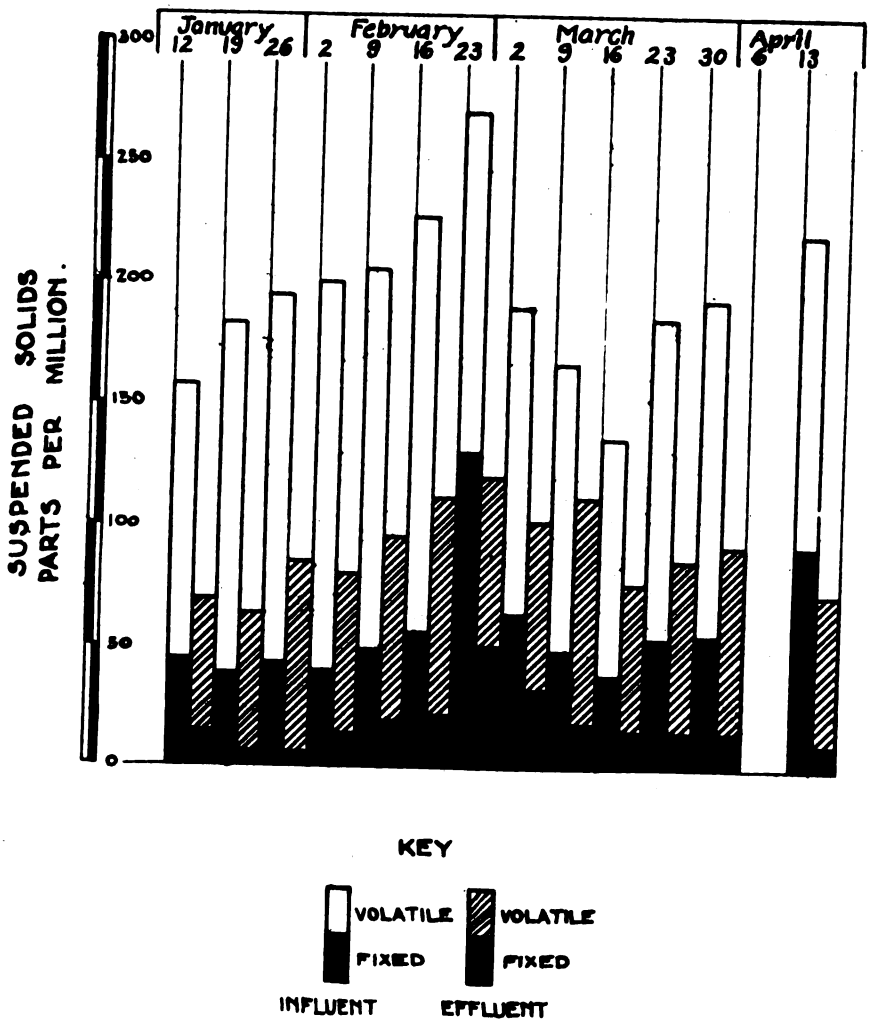




SECTION THROUGH CENTER OF EMSCHER TANK

DIAGRAM Nº 9
SHOWING OPERATION OF
EMSCHER TANK
DURING
THIRD EXPERIMENT

DIAGRAM NO. 10

WEEKLY AVERAGES OF SUSPENDED SOLIDS DATA OF THE EMSHER TANK



effluent were sampled at half-hour intervals for a daily composite sample, which was analyzed for suspended solids and a quantity proportionate to the number of hours the tank ran per day taken to form a weekly composite sample analyzed for nitrogen and fats.

When the sludge was withdrawn it was carefully weighed, mixed to a uniform consistency, and a sample taken for analysis. In this way careful watch was kept over all the matter entering and leaving the tank.

The amount of sludge in the digestion chamber was determined daily by a sounding bottle, so that sludge was only withdrawn when it reached a predetermined level in the tank.

### Conclusions.

In diagram No. 9 is shown the operation of this tank, the amounts given in pounds of each constituent, so that sewage and sludge are comparable.

It will be noticed that the dilute holiday sewage was not very susceptible to rapid sedimentation, but on that day the effluent was of satisfactory character.

Table No. 7 and diagram No. 10 show the weekly averages for this tank.

It will be observed that during January and February the crude sewage steadily increased in strength and that during March it became more dilute, the effluent following a nearly parallel line.

This tank during three months, operated at two hours' sedimentation, effected a removal of 53 per cent. of the suspended solids in the crude sewage, producing an effluent containing 92 parts per million suspended solids. It must be borne in mind that the size of the Emscher tank studied only allowed vertical sedimentation through four and one-half feet, whereas in an actual plant the distance would be much greater.

# Table No. 7.

*Showing Weekly Averages of the Influent and Effluent of the Emscher Tank.*

| Dates—1910. | PARTS PER MILLION. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Influent. | | | | | Effluent. | | | | | Per Cent. Removed Suspended Solids. |
| | Suspended Solids. | | | Fats. | Organic Nitrogen. | Suspended Solids. | | | Fats. | Organic Nitrogen. | |
| | Total. | Fixed. | Volatile. | | | Total. | Fixed. | Volatile. | | | |
| January 12 to January 18 | 157 | 44 | 113 | 19.6 | 8.0 | 69 | 13 | 56 | 15.4 | 7.2 | 55.5 |
| January 19 to January 25 | 183 | 38 | 145 | 26.4 | 9.6 | 63 | 6 | 57 | 25.6 | 8.0 | 65:2 |
| January 26 to February 1 | 195 | 43 | 152 | 16.4 | 9.0 | 86 | 5 | 81 | 15.8 | 8.2 | 55.6 |
| February 2 to February 8 | 200 | 40 | 160 | 15.6 | 9.6 | 80 | 13 | 67 | 16.0 | 8.4 | 59.7 |
| February 9 to February 15 | 206 | 49 | 157 | 23.6 | 10.4 | 95 | 19 | 76 | 16.6 | 7.2 | 55.8 |
| February 16 to February 22 | 227 | 57 | 170 | 27.4 | 10.8 | 111 | 21 | 90 | 22.4 | 10.8 | 51.7 |
| February 23 to March 1 | 270 | 130 | 140 | 28.2 | 9.6 | 120 | 51 | 69 | 18.2 | 9.2 | 55.3 |
| March 2 to March 8 | 193 | 64 | 129 | 33.0 | 9.6 | 101 | 32 | 69 | 25.0 | 8.8 | 47.7 |
| March 9 to March 15 | 167 | 49 | 118 | 31.6 | 9.2 | 111 | 18 | 93 | 25.8 | 8.8 | 33.2 |
| March 16 to March 22 | 136 | 39 | 97 | 30.0 | 10.0 | 77 | 16 | 61 | 14.2 | 8.8 | 43.2 |
| March 23 to March 29 | 185 | 53 | 132 | 26.2 | 11.2 | 86 | 16 | 70 | 16.2 | 7.2 | 53.4 |
| March 30 to April 5 | 193 | 56 | 137 | 28.6 | 10.4 | 92 | 16 | 76 | 20.2 | 8.8 | 52.2 |
| April 6 to April 12 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| April 13 | 220 | 92 | 128 | 18.2 | 9.2 | 72 | 10 | 62 | 9.6 | 7.6 | 67.3 |
| Average | 193 | 56 | 137 | 25.0 | 9.7 | 92 | 19 | 73 | 18.5 | 8.4 | 52.2 |

**Comparison with Existing Tanks.**

As this percentage removal is so much lower than published figures for the tanks as operated by the Emschergenossenschaft it may be advisable to explain the reason.

Dr. Ing. Imhoff divides the solids in sewage into four classes:

1. **Settling solids,** those particles removable by quiescent sedimentation in two hours.

2. **Finely divided solids,** those particles smaller than the above, but removable by filtration through paper or asbestos.

3. **Colloidal matter,** matter finer than the above, but which can be separated from the liquid by a dialyzing membrane.

4. **Matter in true solution.**

The asbestos mat in a Gooch crucible retains all of the settling and finely divided solids and a part of the colloidal matter, the finely divided solids and matter in colloidal state not being susceptible of removal by plain sedimentation are therefore in his opinion unjustly included in "suspended solids" when analyses are made of the influent and effluent of sedimentation processes, and to overcome this difficulty he subjects samples of the influent and effluent of the tanks to two hours' quiescent sedimentation in tall glass cylinders holding 500 cc., the bottom of which is a graduated tube of small diameter in which the depth of deposit is measured.

In this way percentages removal of settling solids from 95 to 100 are obtained and so reported.

**Absence of Septic Action in the Sedimentation Portion.**

All of the gas formed by the decomposing sludge in this form tank is conveyed through the ventilator or stem of the inverted funnel, and so the settling sewage is kept fresh, there being no appreciable loss of dissolved oxygen nor reduction of nitrites or nitrates during the short time of passage through the tank.

Furthermore, the gas which almost continually bubbles up through the ventilator is inodorous and is said to be 75 per cent. methane or marsh gas and 25 per cent. carbon monoxide, although no analysis of it was made at the testing station.

### Formation of Scum.

In the inlet ring of the tank considerable scum formed due to the large amount of wool and hops contained in the crude sewage; this was offensive when disturbed or removed. As a means of disposal an attempt was made to get it into the digestion chamber through the ventilator, but its specific gravity was so low that it would not sink and it was found necessary to remove it from the tank.

Upon the outlet ring a very thin, light, flaky scum formed which was successfully restrained from the outlet weirs by their protecting scum boards and it did not seem to interfere in any way with the normal operation of the tank.

### Theory of the Tank.

The theory of this tank is, that it exercises a dual function—the sedimentation of the sewage and the so-called digestion of the sludge.

The two functions are carried on in separate compartments the lower or digestion compartment being so arranged as to exclude the flow of fresh sewage. In the sludge in this chamber the successful biological action depends upon the generation and growth of bacteria peculiar to its needs. The effect, as noted, of this condition and of the concentration of the mass of sludge in the conical chamber is to produce a sludge very low in moisture, uniform in constituency and lacking hydrogen sulphide either in the gas given off or in the sludge itself, which gas becomes one of the main sources of nuisance in a sewage disposal works.

This in itself is of great value irrespective of its value for sedimentation; another advantage of this form of tank is that the sludge can be removed by the excess head of sewage from the tank without placing it out of service, resulting in great economy.

Further discussion of its action will be found under "sludge."

## DIBDIN SLATE BED.

Dibdin's slate contact bed is another attempt to accomplish both the sedimentation of sewage and the digestion and concentration of the sludge in the same apparatus. In Dr. Imhoff's tank the latter function is accomplished by bacteria in an anaerobic manner, but in Dibdin's slate bed the result is obtained aerobicly and the bacterial work is undoubtedly largely supplemented by worms and other lower forms of animal life.

As the results accomplished by this bed are more than mere sedimentation, including an oxidation of the nitrogen of the applied sewage, it has been considered in two ways: first as a sedimentation tank in which the resulting sludge is digested and concentrated, second, as a contact bed producing a partially stable effluent. If looked upon as a sedimentation process it would consist of nineteen superimposed quiescent basins, each about three inches deep. The bed should be filled at such a rate that the velocity is not high enough to disturb the deposit upon the slates, and then the bed to be allowed to remain quiescent for, say, one hour. During the filling and contact periods the settling solids are deposited upon the upper surface of the slates, where they form a deposit called by Dibden "living earth" on account of the enormous number of animals, especially worms, developed therein. The sludge freshly deposited in sedimentation basins is usually about 90 per cent. water and has a specific gravity of 1.02; using these figures and assuming the crude sewage to contain 200 parts per million of suspended solids and the effluent 50 parts it will be seen that a deposit of wet sludge only

0.118 mm. thick is deposited on the "living earth" each time the bed is filled. Before the bed is filled again the worms and other animals and the bacteria have attacked the organic matter of this deposit and are ready for the next thin layer of food, when the bed is subsequently filled.

If considered as a contact bed, its large void space as compared with a contact bed filled with ordinary media is of great aerating value, also due to the construction in horizontal layers, one slate resting upon another; on the under side of many slates a large, flat bubble of air must be entrained, which would tend to oxygenate the sewage while in the bed.

### Operation.

To determine the optimum mode of operation, the bed was run at several different rates and various length cycles, which are shown in Table No. 8.

During the early operation of this bed, its effluent contained considerable amounts of suspended solids, but was sufficiently oxidized to be fairly stable.

For this reason the rate was rapidly increased from one to two fillings a day and then to three. Under the latter rate the quality of the effluent began to decrease although containing less suspended solids than heretofore.

Assuming that the biological action of the bed had been overtaxed, it was rested for seven days and then started up at the same rate as before. It was not efficient either as a sedimentation nor oxidizing process, only 22 per cent. of the total suspended solids being removed, and the effluent contained more volatile solids than the influent. Nitrogen as free ammonia was higher in the effluent than in the applied crude sewage and the relative stability sank to .13 after the first day.

The contact period was now doubled to allow more opportunity for sedimentation and the aerating period increased to eight hours, which means the bed was filled twice a day.

## TABLE NO. 8.

*Operation of the Slate Contact Bed.*

| Period. See Diagram No. 11. | Dates—1909-1910. | Number of Fillings per Day. | Rate. Million Gallons per Acre per Day. | Rate. Gallons per Cubic Yard per Day. | Cycle in Hours. Fill. | Cycle in Hours. Contact. | Cycle in Hours. Drain. | Cycle in Hours. Aerate. | Number of Fillings in Period. | Total Number of Gallons Sewage Used During a Run. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | March 27 to April 26 | 1 | 1.23 | 173 | 1 | 3 | 1 | 19 | 25 | 64,500 |
| 2 | April 27 to May 10 | 2 | 2.46 | 346 | 1 | 1.5 | 1 | 8.5 | 27 | 131,100 |
| 3 | May 11 to June 5 | 3 | 3.53 | 497 | 1 | 1 | 1 | 5 | 70 | 298,400 |
| | BED RESTED. | | | | | | | | | |
| 4 | June 12 to June 17 | 3 | 3.53 | 497 | 1 | 1 | 1 | 5 | 16 | 335,600 |
| 5 | June 18 to June 23 | 2 | 2.36 | 320 | 1 | 2 | 1 | 8 | 11 | 360,900 |
| 6 | June 24 to July 3 | 1 | 1.05 | 149 | 3 | 2 | 3 | 16 | 10 | 383,600 |
| | BED RESTED AND FLUSHED OUT. | | | | | | | | | |
| 7 | July 16 to October 24 | 1 | 1.21 | 171 | 2 | 1 | 2 | 19 | 84 | 207,100 |
| 8 | October 25 to November 9 | 1.14 | 1.30 | 183 | 2 | 1 | 2 | 16 | 14 | 240,900 |
| 9 | November 9 to November 21 | 1.33 | 1.50 | 212 | 2 | 1 | 2 | 13 | 15 | 277,100 |
| 10 | November 22 to January 18 | 2 | 2.11 | 298 | 2 | 1 | 2 | 7 | 103 | 508,800 |
| 11 | January 19 to March 8 | 3 | 3.04 | 429 | 1.5 | 1 | 1.5 | 4 | 133 | 796,100 |
| | BED RESTED AND FLUSHED OUT. | | | | | | | | | |

During this period the crude sewage was of more than normal strength and the sedimentation effected was satisfactory, 72 per cent. of the applied suspended solids being removed, but the quality of the effluent was even worse than during the preceding period.

The rate was again reduced and cycle changed to three hours to fill and empty instead of one hour, the same contact being given. There was no improvement in the effluent over the crude sewage—in fact, denitrification occurred in the bed and it was finally deemed advisable to end the run.

### Cleaning.

After resting a few days the slates were flushed with water under pressure applied by an iron pipe held at each layer in a small vertical hole left between the slates during the construction of the bed. The accumulated deposit upon the surface of the slates was successfully removed and the water capacity of the bed restored to within 1½ per cent. of its initial capacity, but it should be borne in mind that the area of the bed was only .0021 acres and a method and quantity of water satisfactory on such a small installation might not be practical or economical in a large unit.

The character of the deposit washed out was entirely different from ordinary sludge, for although the wash water was very dirty looking and contained 4.5 per cent. of sludge, yet when incubated at 20° C. with methylene blue it retained the color for a period of four days, indicating a relative stability of .60.

## Second Experiment.

The bed was now in practically the same condition as when new, and it was decided to operate it at a low rate until biological action was well developed and then gradually increase the rate.

During the first experiment the bed had been filled and drained in one hour, but in order to reduce the influent and effluent velocity, and consequently minimize the disturbance of the deposit upon the slates, the bed was filled in two hours and the contact or full period reduced to one hour, and two hours also given to drain.

In this way on July 16, 1909, the bed was started at one filling a day. The applied crude sewage during the seventh period was more dilute than formerly and the effluent was uniformly low in suspended solids, averaging 31 parts per million.

Up to the middle of September the effluent gradually improved in stability, but about that time the crude sewage became not only stronger but rather irregular in its quality and the effluent was generally of lower stability than the average of the entire seventh period. (See diagram No. 21.)

The work of the bed was satisfactory and the bed seemed mature, so its rate was increased by gradually reducing the aerating period. During this transition period, the crude sewage applied was of unusual strength, a weekly sample containing as high as 660 parts per million suspended solids and 23 parts per million organic nitrogen. The sedimentation accomplished during these two periods was perfectly satisfactory. But the biological action was not equal to the severe tax and the stability of the effluent became very low.

At the end of the ninth period the applied crude sewage had resumed a normal concentration and the rate was increased to two fillings a day; during the entire tenth period the sedimentation effected was very satisfactory, the effluent containing 31 parts per million suspended solids and the stability steadily improved, the average of the entire period being .46, a higher value than the effluent of two of the outside sprinkling filters (Nos. 20-5 and 20-6) during the same period.

The rate was increased on January 19 by reducing the time given to filling, draining, and aerating, increasing the number of cycles per day from two to three.

During this eleventh period the air temperature was on an average below freezing three-fourths of the time, but the bed was protected by the building and being filled three times a day must have maintained sufficient heat to continue biological action, for the average effluent contained three parts per million nitrogen as nitrates. Probably due to the increased speed of filling and draining the bed over the last period, sedimentation was not as satisfactory, only 49 per cent. of the applied suspended solids being removed, the effluent containing on an average 88 parts.

The larger amount of suspended matter in the effluent and the cold weather probably account for the lowered stability of the effluent during this period.

The bed was rested and flushed out as before, not on account of an excessive accumulation of deposit, but in order to start a run under new conditions.

**Conclusions.**

The deposit on the surface of the slates will be considered under "Sludge," but certain conclusions can be drawn from the data at hand.

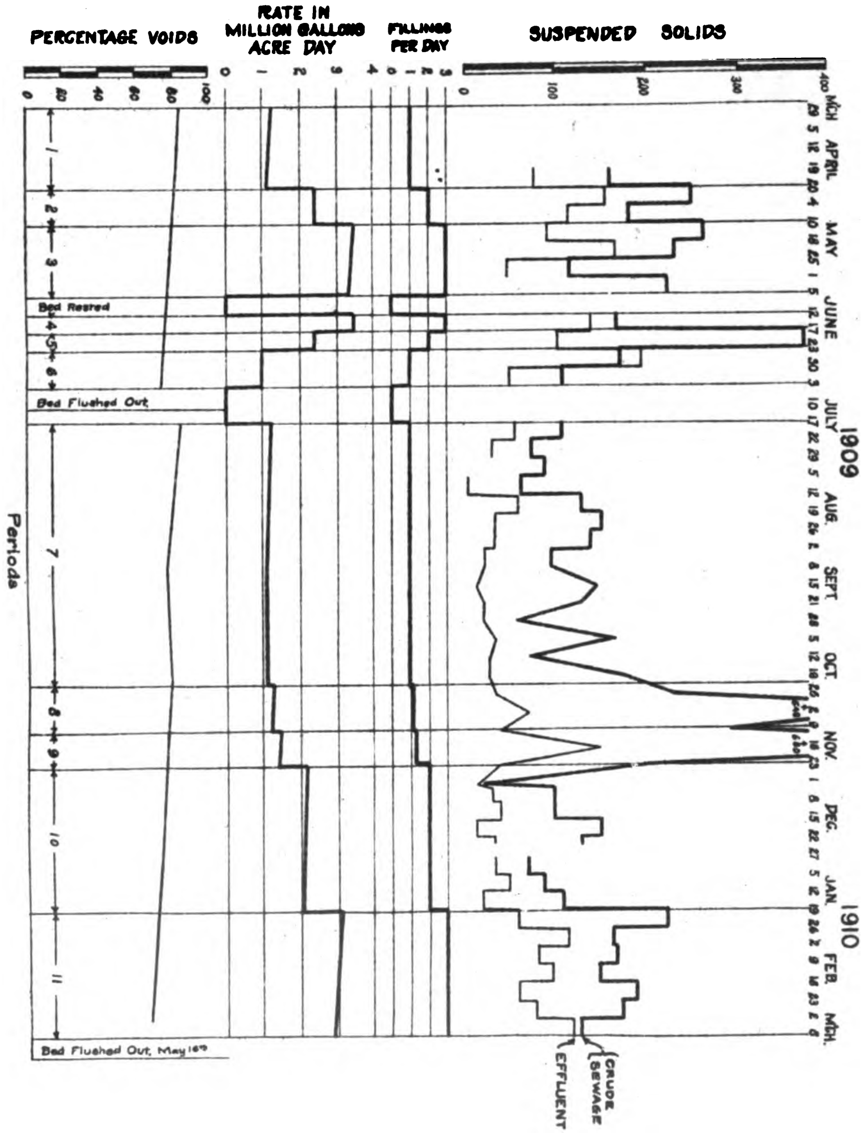
Optimum results were obtained by filling and draining the bed slowly twice a day. Changes in rate of operation should be made gradually, as sudden increases in rate seem to derange the sensitive organization of the bed.

If operated in this way the bed yielded an effluent low in suspended solids and of a fair degree of stability.

The initial water contents of this small bed was nearly restored by flushing with water. But upon dismantling the bed at the end of the tests, those slates farthest away from the flushing holes were covered with the deposits to a depth of one inch.

## DIAGRAM No. 11

# OPERATION OF THE DIBDIN SLATE BED No. 16.



# TABLE NO. 9.

*Average Results of the Treatment of Sewage in a Dibdin Slate Bed.*

| Period Number. | Suspended Solids. | | | | | | Nitrogen as— | | | | | Oxygen Consumed. | | | | | | | | Fats. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total. | | Fixed. | | Volatile. | | Organic. | | Free Ammonia. | | Nitrates. | Total. | | Suspended or Settling Solids. | | Colloidal. | | Solution. | | | |
| | Influent. | Effluent. | Influent. | Effluent. | Influent. | Effluent. | Influent. | Effluent. | Influent. | Effluent. | Effluent. | Influent. | Effluent. | Influent. | Effluent. | Influent. | Effluent. | Influent. | Effluent. | Influent. | Effluent. |
| 1 | 160 | 79 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 76.0 | 57.2 | 22.8 | 7.0 | Separated by filtration through filter paper. | | 53.2 | 50.2 | ------ | ------ |
| 2 | 216 | 188 | ------ | ------ | ------ | ------ | 5.62 | 5.66 | 2.31 | 2.06 | ------ | 70.7 | 62.2 | 29.3 | 16.0 | | | 41.4 | 41.2 | ------ | ------ |
| 3 | 210 | 100 | ------ | ------ | ------ | ------ | 11.7 | 8.77 | 3.13 | 2.96 | ------ | 75.6 | 69.8 | 16.5 | 12.7 | | | 59.1 | 57.2 | ------ | ------ |
| 4 | 167 | 140 | 69 | 22 | 98 | 118 | 4.56 | 1.12 | 7.04 | 10.88 | ------ | 62.0 | 55.2 | 13.6 | 9.6 | | | 48.4 | 45.6 | ------ | ------ |
| 5 | 374 | 103 | 144 | 29 | 230 | 74 | ------ | 6.56 | 6.40 | 5.44 | 1.28 | 82.4 | 67.6 | 21.6 | 14.8 | | | 60.8 | 52.8 | ------ | ------ |
| 6 | 138 | 121 | ------ | ------ | ------ | ------ | 4.56 | 9.60 | 5.84 | 6.40 | 0.40 | 69.0 | 64.6 | 15.6 | 14.2 | | | 53.4 | 50.4 | ------ | ------ |
| 7 | 115 | 31 | 31 | 5 | 84 | 26 | ------ | ------ | ------ | ------ | 1.24 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 8 | 388 | 54 | 128 | 4 | 260 | 50 | 12.2 | 4.4 | 3.0 | 3.2 | .80 | 70.0 | 54.2 | 16.0 | 5.4 | 28.2 | 25.6 | 25.8 | 23.2 | ------ | ------ |
| 9 | 478 | 94 | 182 | 14 | 296 | 80 | ------ | ------ | ------ | ------ | .27 | 128.0 | 100.8 | 26.0 | 16.0 | 45.4 | 39.7 | 56.6 | 44.7 | ------ | ------ |
| 10 | 108 | 31 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 1.26 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 11.9 | 5.5 |
| 11 | 172 | 88 | 34 | 7 | 138 | 81 | ------ | ------ | ------ | ------ | 2.3 | 79.8 | 65.7 | 12.7 | 5.5 | 29.4 | 28.0 | 37.7 | 32.3 | 22.6 | 30.0 |

## CONTACT SYSTEM.

The contact system described heretofore was in operation for about five months, during which time it produced an effluent almost freed from suspended solids, but, considering the low rate at which the beds were operated, of insufficient stability to warrant an extended study of this method of purification.

The system was put in operation on April 6, 1909. The method of maturing the beds was that in use at Manchester, England, where Dr. Fowler gives new beds long periods of contact and long aeration in their initial service, gradually increasing the rate by decreasing the period of contact and later decreasing the aerating time.

### Operation.

The operation of the system is shown in Table No. 10. At all times the effluent of the secondary contact bed was of very good appearance—the preliminary sedimentation and adhesion to the new, rough, porous media of the two beds effected an almost complete removal of suspended solids. This effluent contained, however, considerable matter in a colloidal state, giving it a turbid appearance. The other constituent of the sewage which was efficiently removed was nitrogen as free ammonia, but the effluent was never nitrified to an extent that would indicate that the beds were mature, nor did the daily stability samples (except Sunday sewage, which was very dilute) show satisfactory results. In making this statement it is to be understood that it is given without prejudice to the use of contact beds in combination with a septic tank or other preliminary treatment. The policy of operation of the testing station was to get rid of the sewage in its fresh state and not to allow it to become septic.

On September 16, therefore, the system was abandoned in order to use the secondary bed as a sludge lagoon.

### TABLE No. 10.

*Operation of the Contact System.*

| Dates. 1909. | Cycles per Day. | Operation in Hours. Fill. | Contact. | Drain. | Aerate. | Rate. Million Gallons Acre Day. | Gallons Cubic Yard Day. |
|---|---|---|---|---|---|---|---|
| April 6 to April 15 | | | | Irreg | ular. | | |
| April 15 to April 26 | ½ | 1 | 24 | 1 | 22 | .225 | 37.5 |
| April 26 to May 4 | 1 | 1 | 11 | 1 | 11 | .450 | 75 |
| May 4 to May 11 | 1 | 1 | 6 | 1 | 16 | .450 | 75 |
| May 11 to June 1 | 1 | 1 | 3 | 1 | 19 | .450 | 75 |
| June 1 to June 6 | 2 | 1 | 2 | 1 | 8 | .900 | 150 |
| June 6 to June 13 | | | | —Res | ted— | | |
| June 13 to July 14 | 2 | 1 | 2 | 1 | 8 | .900 | 150 |
| July 14 to August 20 | 3 | 1 | 1 | 1 | 5 | 1.350 | 225 |
| August 20 to August 25 | | | | —Res | ted— | | |
| August 25 to September 16 | 3 | 1 | 1 | 1 | 5 | 1.350 | 225 |

## SPRINKLING FILTERS.

### Methods of Distribution.

#### Outside Filters.

It must be borne in mind that the object sought in the operation of the outside filters was to determine as quickly as possible the best size and depth of stone to economically purify the sewage. With this in view no attempt was made to apply to them a superior tank liquor, nor to develop a perfect distribution.

Although the dosing tank used was tapered, it was not sufficiently so to prevent a ring of overdose. Also due to the different elevations of the surface of the beds, the two lower ones received the water contained in the risers

## Table No. 11.

*Operation and Average Analyses of the Contact System.*

| Period. 1909. | Cycles per Day. | Operation in Hours. Fill. | Contact. | Drain. | Aerate. | Parts per Million. Total Suspended Solids. | Nitrogen as— Organic. | Free Ammonia. | Nitrite+Nitrate. | Oxygen Consumed. Total. | Suspended. | Dissolved. | Relative Stability. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 226 | — | 4.25 | — | 72.2 | 24.1 | 48.1 | — | Crude Sewage. | |
| April 19th | ½ | 1 | 24 | 1 | 22 | 118 | — | 5.0 | — | 68.0 | 16.8 | 51.2 | — | Effluent Sedimentation. | |
| to | | | | | | 132 | — | 4.25 | — | 55.7 | 15.0 | 40.7 | — | Influent Primary Contact Bed. | Tried to mature the beds by Dr. Fowler's method of long contacts. On April 26th shortened contact. Effluent appeared good, but smelt of hydrogen sulphide. |
| May 4th. | 1 | 1 | 11 | 1 | 11 | 55 | — | 1.40 | — | 48.5 | 9.9 | 38.6 | 0.13 | Effluent Primary Contact Bed. | |
| | | | | | | 37 | — | 0.8 | — | 41.2 | 7.7 | 33.5 | 0.29 | Effluent Secondary Contact Bed. | |
| | | | | | | 269 | — | 3.1 | — | 74.7 | 16.8 | 57.9 | — | Crude Sewage. | |
| May 4th | 1 | 1 | 6 | 1 | 16 | 126 | — | 3.1 | — | 66.0 | 9.5 | 56.5 | — | Effluent Sedimentation. | Examination of media showed no formation of a bacterial jelly. |
| to | | | | | | 75 | — | 4.0 | — | 62.9 | 7.9 | 55.0 | — | Influent Primary Contact Bed. | |
| June 1st. | 1 | 1 | 3 | 1 | 19 | 21 | — | 1.3 | — | 52.5 | 7.4 | 45.1 | 0.10 | Effluent Primary Contact Bed. | Effluent still has putrefactive odor. |
| | | | | | | 19 | — | 0.6 | — | 45.2 | 4.5 | 40.7 | 0.17 | Effluent Secondary Contact Bed. | |
| | | | | | | 153 | — | — | — | — | — | — | — | Crude Sewage. | |
| June 1st | 2 | 1 | 2 | 1 | 8 | 89 | — | — | — | — | — | — | — | Effluent Sedimentation. | |
| to | | | | | | 89 | 4.98 | 4.14 | 0.52 | 55.3 | 8.3 | 47.0 | — | Influent Primary Contact Bed. | Same conditions as above. |
| July 14th. | 2 | 1 | 2 | 1 | 8 | 14 | 33.8 | 1.58 | 0.88 | 40.2 | 6.7 | 33.5 | 0.27 | Effluent Primary Contact Bed. | |
| | | | | | | 12 | 38.5 | 0.79 | 0.96 | 34.1 | 4.7 | 29.4 | 0.39 | Effluent Secondary Contact Bed. | |
| July 14th to September 16th. | 2 | 1 | 2 | 1 | 8 | — | — | — | — | — | — | — | 0.18 | Effluent Primary Contact Bed. | Chemical analysis discontinued. Only putresibility done. Effluent remained free from suspended solids, but contained no dissolved oxygen and possessed an offensive odor. |
| | | | | | | — | — | — | — | — | — | — | 0.43 | Effluent Secondary Contact Bed. | |

above the elevation of their nozzle. This water was applied to an area immediately adjacent to the nozzle and probably passed through the bed at such a high rate as to have been but little changed. On May 15, 1909, a funnel 18 inches in diameter was so placed around the nozzle that it caught this water, which was conducted to a nearby manhole on the main drain. An immediate, but slight, improvement was noted in the character of the effluent from the two beds affected.

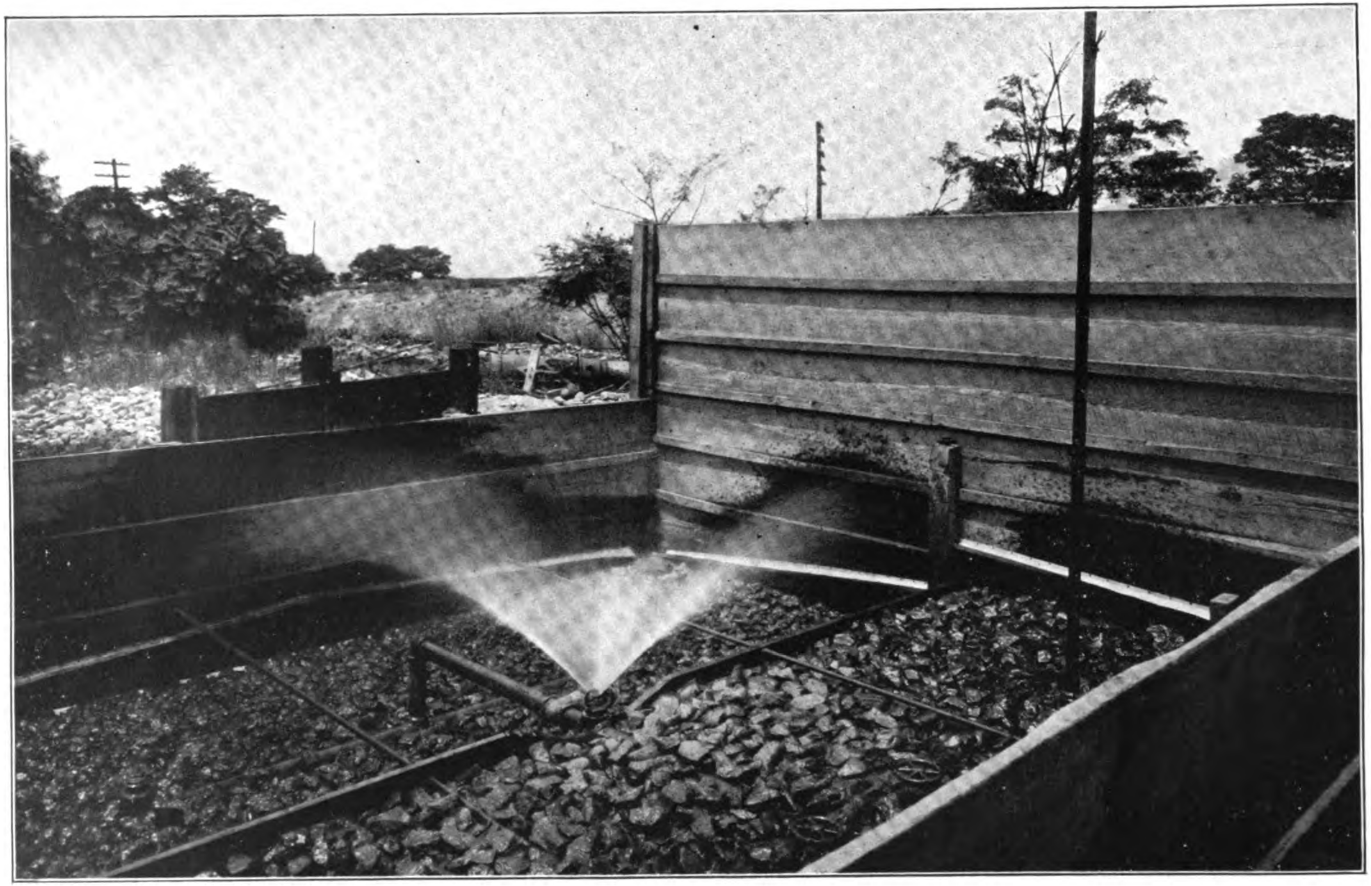
In order to wet as large a part as possible of the square served by a circular nozzle on the beds, it was necessary to allow the spray to strike against the wind shields to make it throw partly into the corners. The water thus striking on the sides was collected by a small gutter and applied to the otherwise undosed corner of the bed, as may be seen in the photograph.

The arms of the Columbus nozzle accumulated considerable material, especially wool fibres, and a tenacious gelatinous growth. They required to be cleaned at irregular intervals, apparently depending upon the character of the influent. No trouble was experienced in the 9/16-inch orifice clogging except when occasionally a match stick or other similar shaped body caught in the nozzle.

### The Upper Sprinkling Filter.

This bed, being 16 feet by 32 feet in plan, was admirably adapted for two square nozzles and initially it was served by two Taylor nozzles, the head on which was controlled by the butterfly valve so that the film wetted slightly the enclosing walls of the filter.

When the lower sprinkling filter was ready to be operated at the end of July, these Taylor nozzles were taken from that bed and replaced by Reading nozzles. A change in the shape of the cam caused the distribution along a radial line to be very satisfactory, but, of course, there being only two circular nozzles in a rectangular bed, those portions of the bed which would have been served by the staggered nozzles were left dry.



OUTSIDE SPRINKLING FILTERS.—Stations Nos. 20-3 and 20-4.
Influent applied through a Columbus nozzle.

### The Lower Sprinkling Filter.

This bed was always dosed through Taylor square nozzles, the head controlled by a similar device to that used on the upper filter, except that the velocity of the water wheel was reduced by worm gearing instead of link belt.

The cam was modified experimentally until distribution over a quadrant-shaped area separated into rectilinear sub-divisions was practically perfect.

The influent to this bed, having been screened prior to sedimentation, contained none of the solids capable of choking the annular orifice, and no trouble of this kind was ever experienced. In the riser pipes, however, a jelly-like substance developed which was easily washed out after drying.

## Dosing Cycle.

### Outside Filters.

The capacity of the tapered dosing tank was 106 gallons, and to obtain the best distribution possible the valves were set so that it required three minutes for the tank to empty; as this was a constant figure the length of time required for the dosing tank to fill controlled the rate on the filters.

For an average rate on the entire battery of one million gallons per acre per day, the time required for the dosing tank to fill and consequently the resting portion of the cycle was 9 minutes and 42 seconds. As the rate was gradually increased this "resting period" was cut down until the "dosing" and "resting" portions of the cycle were equal. Still higher rates were obtained by adjusting the mechanical device controlling the dosing tank so that there was a small flow into the tank during the display of the nozzle.

This increased the time required for display of the nozzle until it was greater than the resting period.

**Upper Filter.**

The dosing cycle of this bed must be considered in two ways—first, the relative "dosing" and "resting" time as determined by the cam, and second, the relative "dosing" and "resting" time as determined by the entire shutting down of the bed for a period of drying.

The cam was so designed that the nozzles displayed for 45 seconds and rested for 2 minutes and 30 seconds and this ratio was practically maintained during the entire run. The second or major dosing cycle was controlled by the state of the media, for when run continuously the suspended solids in the applied water clogged the surface and caused pooling.

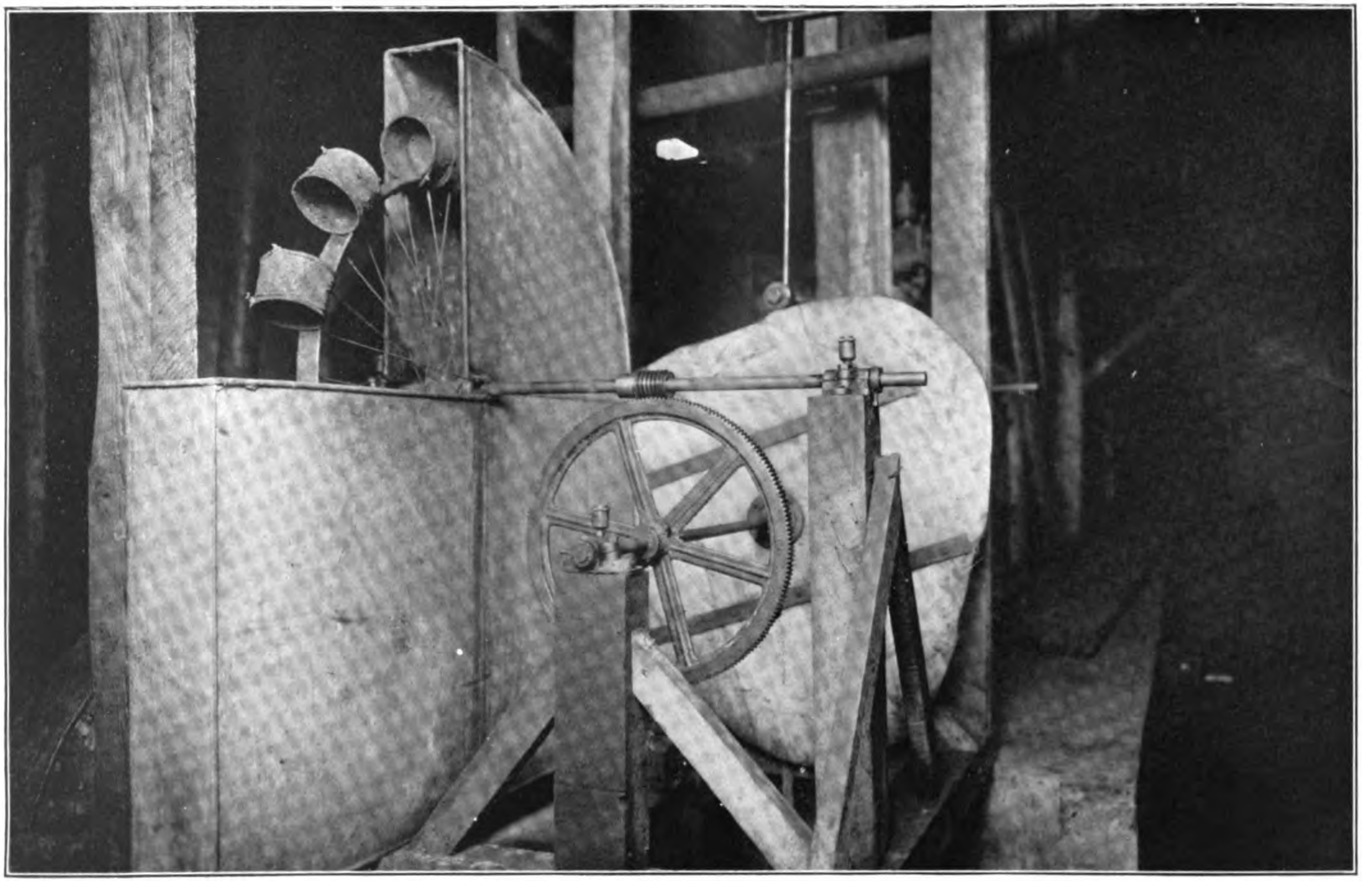
At first it was attempted to run the filter continuously, but after clogging had developed and the bed given a long rest, the cycles were made 24 hours operation and 24 hours rest. This also seemed unsatisfactory and three-hour intervals were chosen with better success.

**Lower Filter.**

The cam controlling the dosing cycle of this filter originally had one lobe, whereby the film of applied sewage slowly worked its way from the nozzle to the edge of the bed, where, after having played for a sufficient length of time, sharp cut off occurred and the entire bed was undosed until the said lobe again opened the valve. Under this condition the nozzle displayed for 22 seconds and the bed rested for two minutes and eight seconds. The resting period was reduced by the addition of lobes until during one revolution of the cam, the nozzle displayed five times.

Under this condition the cam caused the film to travel from the nozzle to the wall in 22 seconds where the sharp cut-off occurred and the nozzle did not display for eight seconds.

This sharp cut-off was unsatisfactory and was eliminated by designing a new cam which caused the film to travel from the nozzle to the edge of the bed and then return,



Device for Regulating Nozzle Pressure.—Lower Sprinkling Filter No. 22.

there being no cut-off at high head; under this condition the nozzle was almost constantly discharging. But each small area of the bed may be considered to have a dosing and resting cycle, for the film traveled over the media, like that from a mechanical distributor.

## Rate of Operation.

### Outside Filters.

As has been described, the dosing tank containing 106 gallons was generally emptied in three minutes upon an area .012 acres. Considering the entire area served the gross rate upon the beds during the display of the nozzle would be 4.24 million gallons per acre per day. But during the display under low head the rate would be materially less than this average, and under the highest head many drops fall on the ring which is overdosed, so that during the display of the nozzle it is very probable that certain areas are being dosed at a rate of over ten million gallons per acre per day, while the net rate of the filters would be considered one million gallons per acre per day.

The policy adopted in regard to all filters was not to operate them in the optimum manner but by continuous running to test them to destruction; therefore, the daily rate was the actual net rate of the filters for long intervals of time.

During winter the rate on the outside filters was slightly increased, not by applying more sewage in a given time, but by the reduction of area in service due to the ice forming in the corners.

### Upper Filter.

Based upon the possible rates at which sprinkling filters were operated during these tests it would seem that, neglecting other factors, the possible rate at which a filter can be economically operated is in inverse proportion to the amount of suspended solids applied.

The influent to the filter had no preparatory treatment save coarse screening and it was necessary to operate it at the lowest rate of any of the sprinkling filters.

**Lower Filter.**

This filter was operated at a higher rate than any other tested, notwithstanding which it produced the best effluent.

The conditions which made this high rate possible were the well prepared influent, the perfect distribution, the aerating system, the efficient false floor, and protection from the inclemency of the winter.

## EFFECT OF THE DOSING CYCLE UPON THE RATE AT WHICH THE EFFLUENT OF A SPRINKLING FILTER LEAVES THE UNDERDRAINS.

When nozzles were operated continually under a fixed head, the rate at which the filter was dosed was prohibitively high, and the difficulty was overcome by dosing the beds at this high rate for a given time and then shutting down the filter, allowing it to rest. With the use of the "falling head" this difficulty was partially overcome and by means of the device controlling nozzle pressure on the lower sprinkling filter, has been eliminated.

The ideal condition in a sprinkling filter would be for each and every portion of the media to perform its share of the work. And all observations have tended to show that biological action is most efficient when regular.

With this in mind, gaugings were made to determine the rate at which the effluent left the underdrains of the outside filter, in the dosing cycle of which there was an appreciable rest; and of the lower filter, where the nozzles discharged practically continuously.

In diagram No. 12 there is shown the variation in rate of flow during complete dosing cycle from beds of differ-

DIAGRAM No. 12

SHOWING THE VARIATION IN

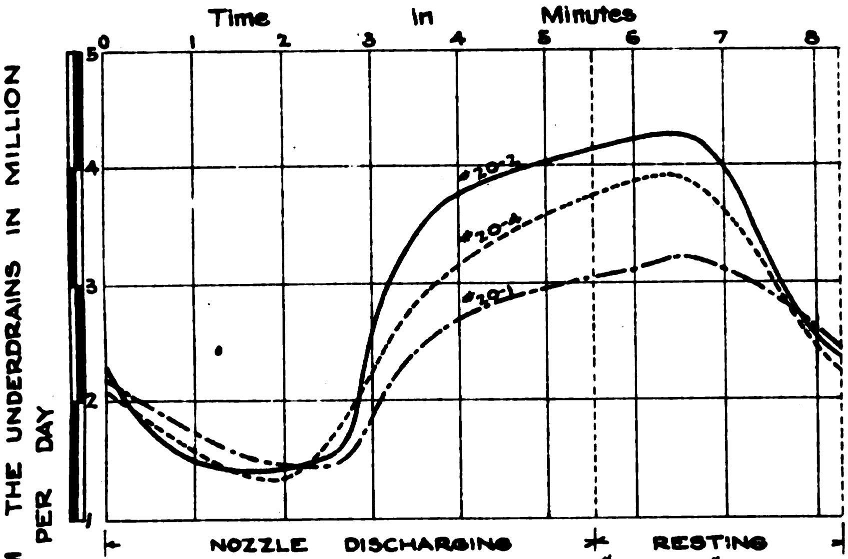
THE RATE OF FLOW

AT WHICH EFFLUENT LEFT

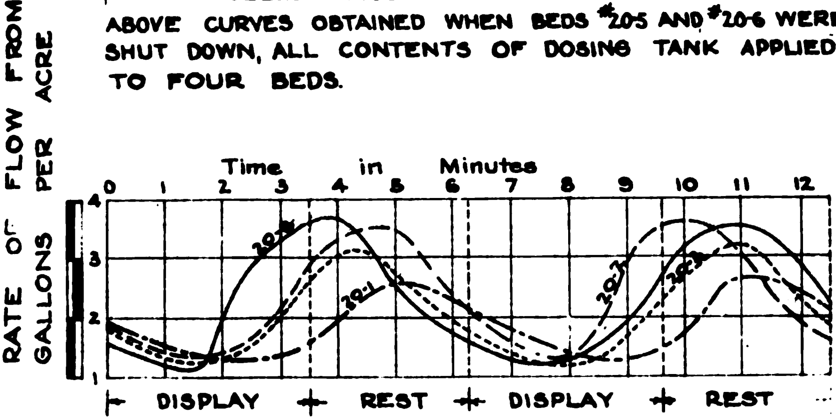
THE UNDERDRAINS

OF THE SPRINKLING FILTERS

NOTE:- 20-1 8ft. of 3/4 in - 3in. LIMESTONE.
20-2 9ft. of 2 1/4 in - 4in LIMESTONE.
20-3 6ft. of 1in - 3in SLAG.
20-4 7ft. of 1in - 3in TRAP.




ABOVE CURVES OBTAINED WHEN BEDS #20-5 AND #20-6 WERE SHUT DOWN, ALL CONTENTS OF DOSING TANK APPLIED TO FOUR BEDS.




ABOVE CURVES OBTAINED WHEN ALL SIX BEDS WERE IN OPERATION, AND SHOWS TWO CYCLES.

ent depths and sizes of media (for which see description of the filters).

The variation in rate is most marked from coarse media and from shallow beds, the finer media and deep beds retaining more water within their interstices, tend to equalize the irregularity of dosing.

The effluent from the lower filter flowed over a V notch weir, back of which a hook gauge indicated the head and consequently the rate of flow.

With the final cam in service, whereby the nozzles discharged almost continuously, the "pimple" formed by the hook gauge varied so little that it was impractical to adjust the vernier to read the fluctuation, which shows that the cyclic variation in the rate of discharge of the nozzle was equalized during the passage of the liquid through the bed.

## GENERAL HISTORY OF THE SPRINKLING FILTERS.

### Outside Filters.

Sewage was first applied to the outside filters on March 23, 1910, the times and rate of dosing being irregular during adjustments of the mechanical apparatus, but by March 26 sampling was commenced, as the operation of the beds was regular.

The initial rates were as follows:

| Station Number.* | Cycle. | | Rate. | |
|---|---|---|---|---|
| | Display. | Rest. | Million Gallons per Acre per Day. | Gallons per Cubic Yards per Day. |
| 20-1 | 8 minutes. | 9 minutes 42 seconds. | .815 | 63.2 |
| 20-2 | | | .815 | 56.5 |
| 20-3 | | | .928 | 96. |
| 20-4 | | | .928 | 82.5 |
| 20-5 | | | 1.260 | 195. |
| 20-6 | | | 1.260 | 156. |

*For depth and size of media, see description of the testing station.

The first action of the filter seemed to be a mechanical retention upon the surface of the stones of the applied suspended solids. It will be noted in the following table that the rough, porous slag retained the largest amount and that the coarse media in 20-2 and the smooth gravel in 20-5 retained the least.

Pounds of suspended solids per cubic yard of media retained in the filters during the first week of operation:

| Station Number. | Cubic Yards of Media in Bed. | Pounds of Suspended Solids per Cubic Yard Media. |
|---|---|---|
| 20-1 | 22.5 | 0.46 |
| 20-2 | 25.8 | 0.30 |
| 20-3 | 16.1 | 0.82 |
| 20-4 | 19.3 | 0.61 |
| 20-5 | 10.4 | 0.32 |
| 20-6 | 13.6 | 0.60 |

Three weeks after the beds were first dosed the determination of the stability of the effluents by methylene blue was commenced, and the average relative stability of the effluents during the first month thereafter indicates the order in which the various beds matured.

| Order in Which the Beds Matured. | Station Number. | Rate in Gallons per Cubic Yard per Day. | Relative Stability. |
|---|---|---|---|
| 8 feet fine limestone | 20-1 | 63.2 | .76 |
| 9 feet coarse limestone | 20-2 | 56.5 | .62 |
| 7 feet coarse trap | 20-4 | 82.5 | .62 |
| 6 feet slag | 20-3 | 96.0 | .55 |
| 4 feet gravel | 20-5 | 195.0 | .55 |
| 5 feet fine trap | 20-6 | 156.0 | .48 |

# TABLE No. 12.

*Bacteria per cc. in Outside Sprinkling Filter System.*

| Period. 1909—1910. | Crude Sewage. | Influent. | Effluent of— Eight Feet of Fine Limestone. 20-1 | Nine Feet of Coarse Limestone. 20-2 | Six Feet of Slag. 20-3 | Seven Feet of Coarse Trap. 20-4 | Four Feet of Gravel. 20-5 | Five Feet of Fine Trap. 20-6 |
|---|---|---|---|---|---|---|---|---|
| July 5 to July 12 | 2,700,000 | 2,100,000 | 31,000 | 107,000 | 57,000 | 108,000 | 154,000 | 121,000 |
| July 12 to July 19 | 1,900,000 | 1,800,000 | 47,000 | 99,000 | 143,000 | 121,000 | 145,000 | 129,000 |
| July 19 to July 26 | 3,800,000 | 2,800,000 | 58,000 | 145,000 | 162,000 | 143,000 | 476,000 | 193,000 |
| July 26 to August 2 | 8,400,000 | 8,000,000 | 217,000 | 326,000 | 274,000 | 232,000 | 1,400,000 | 1,100,000 |
| July average | 4,800,000 | 4,000,000 | 100,000 | 180,000 | 200,000 | 160,000 | 480,000 | 270,000 |
| August 2 to August 9 | 6,700,000 | 7,500,000 | 101,000 | ---------- | 535,000 | ---------- | Old filter dis- | 114,000 |
| August 9 to August 16 | 4,800,000 | 4,000,000 | 141,000 | 123,000 | 133,000 | 224,000 | mantled; new | ---------- |
| August 16 to August 23 | 5,000,000 | 3,600,000 | 100,000 | 248,000 | 209,000 | 312,000 | filter built. | ---------- |
| August 23 to August 30 | 7,800,000 | 6,800,000 | 254,000 | 317,000 | 194,000 | 660,000 | 846,000 | 650,000 |
| August 30 to September 2 | 4,400,000 | 5,300,000 | 80,000 | 225,000 | 218,000 | 340,000 | 1,200,000 | 800,000 |
| August average | 5,800,000 | 5,400,000 | 170,000 | 310,000 | 380,000 | 460,000 | 950,000 | 570,000 |
| September 2 to September 6 | | | | Rest | ing. | | | |
| September 6 to September 13 | 3,600,000 | 2,200,000 | 675,000 | 497,000 | 454,000 | 705,000 | 2,100,000 | 562,000 |
| September 14 to September 20 | 3,500,000 | 3,200,000 | 150,000 | 70,000 | 60,000 | 159,000 | 1,080,000 | 530,000 |
| September 20 to September 27 | 2,400,000 | 4,100,000 | 213,000 | 200,000 | 227,000 | 400,000 | 755,000 | 425,000 |
| September 27 to October 4 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| September average | 3,300,000 | 3,000,000 | 430,000 | 320,000 | 300,000 | 490,000 | 1,340,000 | 550,000 |
| October 4 to October 11 | 2,300,000 | 2,200,000 | 132,000 | 206,000 | 141,000 | 288,000 | 613,000 | 404,000 |
| October 11 to October 18 | 2,200,000 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| October 18 to October 25 | 5,600,000 | 4,100,000 | 319,000 | 440,000 | 517,000 | 308,000 | 430,000 | 430,000 |
| October 25 to October 31 | 3,500,000 | 2,500,000 | 51,000 | 515,000 | 670,000 | 69,000 | 120,000 | 222,000 |
| October average | 2,800,000 | 2,700,000 | 160,000 | 340,000 | 370,000 | 240,000 | 470,000 | 360,000 |
| November 1 to November 8 | 500,000 | ---------- | 275,000 | 76,000 | 360,000 | ---------- | ---------- | 450,000 |
| November 8 to November 15 | 3,200,000 | 2,150,000 | 162,000 | 232,000 | 229,000 | 122,000 | 405,000 | 435,000 |
| November 15 to November 22 | 4,500,000 | 3,300,000 | 277,000 | 338,000 | 204,000 | 260,000 | 453,000 | 900,000 |
| November 22 to November 29 | 1,900,000 | 1,600,000 | 100,000 | 73,000 | 210,000 | 250,000 | 720,000 | 575,000 |
| November average | 2,700,000 | 2,300,000 | 200,000 | 190,000 | 250,000 | 190,000 | 500,000 | 560,000 |
| November 29 to December 6 | 5,400,000 | 2,800,000 | 200,000 | 186,000 | 170,000 | 180,000 | 560,000 | 300,000 |
| December 6 to December 13 | 5,100,000 | 2,400,000 | 300,000 | 570,000 | 500,000 | 450,000 | 840,000 | 600,000 |
| December 13 to December 20 | 2,000,000 | 1,400,000 | 240,000 | 290,000 | 207,000 | 206,000 | 620,000 | 450,000 |
| December 20 to December 24 | 1,200,000 | 940,000 | 210,000 | 220,000 | 221,000 | 210,000 | 490,000 | 370,000 |
| December 24 to December 27 | | | | Rest | ing. | | | |
| December 27 to January 3 | 1,740,000 | 1,400,000 | 530,000 | 510,000 | 440,000 | 610,000 | 890,000 | 800,000 |
| December average | 2,100,000 | 1,400,000 | 310,000 | 360,000 | 300,000 | 330,000 | 640,000 | 480,000 |
| January 3 to January 10 | 1,200,000 | 840,000 | 480,000 | 450,000 | 520,000 | 460,000 | 610,000 | 600,000 |
| January 10 to January 17 | 1,200,000 | 1,000,000 | 740,000 | 710,000 | 740,000 | 780,000 | 830,000 | 760,000 |
| January 17 to January 24 | 1,000,000 | 490,000 | 650,000 | 530,000 | 680,000 | 530,000 | 560,000 | 610,000 |
| January 24 to January 31 | 830,000 | 650,000 | 330,000 | 240,000 | 400,000 | 360,000 | 660,000 | 530,000 |
| January average | 1,100,000 | 910,000 | 540,000 | 490,000 | 570,000 | 550,000 | 660,000 | 610,000 |
| January 31 to February 7 | 1,200,000 | 900,000 | 550,000 | 640,000 | 640,000 | 490,000 | 750,000 | 710,000 |
| February 7 to February 14 | 1,300,000 | 1,400,000 | 1,080,000 | 990,000 | 1,200,000 | 860,000 | 1,100,000 | 1,100,000 |
| February 14 to February 21 | 2,200,000 | 1,800,000 | 1,300,000 | 1,080,000 | 1,700,000 | 1,100,000 | 1,700,000 | 1,500,000 |
| February 21 to February 28 | 1,800,000 | 1,200,000 | 870,000 | 870,000 | 1,500,000 | 790,000 | 1,100,000 | 1,200,000 |
| February average | 1,600,000 | 1,400,000 | 980,000 | 880,000 | 1,250,000 | 840,000 | 1,200,000 | 1,200,000 |
| February 28 to March 7 | 1,700,000† | 224,000 | 660,000 | 650,000 | 620,000 | 630,000 | 460,000 | 380,000 |
| March 7 to March 14 | 1,600,000 | 9,200 | 510,000 | 440,000 | 310,000 | 335,000 | 250,000 | 280,000 |
| March 14 to March 21 | 2,000,000 | 420,000 | 690,000 | 665,000 | 673,000 | 500,000 | 530,000 | 500,000 |
| March 21 to March 28 | 2,600,000 | 224,000 | 660,000 | 650,000 | 620,000 | 630,000 | 460,000 | 377,000 |
| March 28 to April 4 | | | | Rest | ing. | | | |
| March average | 2,000,000 | 210,000 | 600,000 | 620,000 | 600,000 | 530,000 | 500,000 | 440,000 |
| April 4 to April 11 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| April 11 to April 18 | 2,200,000 | 1,400,000 | 300,000 | 275,000 | 332,000 | 300,000 | 480,000 | 205,000 |
| April 18 to April 25 | 3,600,000 | 2,900,000 | 230,000 | 310,000 | 230,000 | 230,000 | 830,000 | 430,000 |
| April 25 to April 30 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| April average | 2,900,000 | 2,000,000 | 270,000 | 290,000 | 280,000 | 260,000 | 660,000 | 350,000 |

†Bleach solution added to influent during March.

During the early operation of these beds, luxurious growths of the grey sewage fungus developed on the floor of the filters, especially in Nos. 20-5 and 20-6 which were yielding the least purified effluents.

As the quality of the effluents improved when the beds became mature, the fungus broke into fragments and washed away, being replaced on the floor of those filters, such as the fine and coarse limestone and the coarse trap, which yielded an oxidized effluent, by chlorophyl plants and diatoms. Upon the surface of the slag bed there soon developed a growth of algae known as the cyanophycea-oscillaria, especially adjacent to the nozzles. This is a similar condition to the slag bed at Reading, Pa., and did not occur on any other sprinkling filter. On May 15 the rate was slightly increased on the filters, as is shown on the diagrams, but the funnels about the nozzles of 20-5 and 20-6 reduced the rate on those beds so that the two highest beds were operated at .89 million gallons per acre per day and the other four beds at 1.01 million gallons per acre per day until June 5th. During this time the effluent continued to improve in all the beds, those yielded from the fine and coarse limestone and the coarse trap being of perfectly satisfactory stability, and from the fine trap, slag, and gravel beds of sufficient stability that they could have been discharged into the river with assurance that they would continue to improve therein.

The suspended solids in the applied water continued to be removed and retained within the filter, so that the effluent was of very good appearance, even unsettled, up to June 1st, when all the beds automatically unloaded the accumulated solids stored up in their interstices.

The two extreme beds—the deep, coarse limestone and the shallow, fine trap—unloaded the most solids, with the seven feet deep coarse trap third in order. The smooth surface of the gravel had not encouraged storage of the solids and, naturally, it unloaded the least.

During this unloading a peculiarity noted was that the effluent from the two deep limestone beds remained stable, whereas that from the other four beds became putrescent.

At this time the effluents were not settled, but based upon our own and others' experience the solids washed from the beds during unloading, even in such large quantities, are successfully settled out in short periods of sedimentation, yielding a final effluent low in suspended solids and fairly stable.

An idea of the character of the effluents at this time may be obtained from the analyses of weekly samples from May 27th to June 3d, including the unload.

| Station Number. | Media. | PARTS PER MILLION. | | | |
|---|---|---|---|---|---|
| | | Suspended Solids. | Oxygen Consumed. | | |
| | | | Total. | Suspended. | Solution. |
| 8 | Force main | 192 | 71.6 | 12. | 59.6 |
| 10 | Influent | 100 | 68.8 | 8.0 | 60.8 |
| 20-1 | Fine lime | 556 | 72.8 | 32.4 | 40.4 |
| 20-2 | Coarse lime | 2,910 | 156.0 | 105.6 | 50.4 |
| 20-3 | Slag | 294 | 64.8 | 30. | 34.8 |
| 20-4 | Coarse trap | 808 | 109.2 | 64.8 | 44.4 |
| 20-5 | Gravel | 286 | 54.4 | 18.4 | 36.0 |
| 20-6 | Fine trap | 2,506 | 113.6 | 59.2 | 54.4 |

In order to make certain changes at the pump it was necessary to shut it down from June 6th to 12th, during which time the average temperature was + 18.4° C.; on four days, however, the temperature rose to summer conditions, so that the filters had an opportunity to dry out considerably.

Upon starting up the filters the first effluent was quite dirty, containing considerable quantities of the desquamated matter. The unloading which commenced on June 1st continued for a short time in the slag bed and the

# Table No. 23.

## *Analyses of the Influent to the Outside Sprinkling Filters.*

### Settled Sewage. Station No. 10.

| Dates. 1909–1910. | PARTS PER MILLION. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | | Fats. |
| | Total. | Fixed. | Volatile. | Organic. | Free Amm. | Nitrites. | Nitrates. | Total. | Settling. | Col-loidal. | Solution. | |
| March 26 to April 2 | 173. | | | | | | | 75.2 | | | | |
| April 2 to April 8 | 96. | | | | | | | 52.8 | 19.6 | | 33.2 | |
| April 8 to April 15 | 196. | | | | | | | 60.4 | | | | |
| April 15 to April 22 | 87. | | | | | | | 61.4 | 22.2 | | 39.2 | |
| April 22 to April 29 | 159. | | | | | | | | | | 61.2 | |
| April average | 142. | | | | | | | | | | | |
| April 29 to May 6 | 141. | | | | | | | 62.00 | 8.0 | | 54.0 | |
| May 6 to May 13 | 115. | | | 1.75 | 4.25 | | | 65.60 | 6.8 | | 58.8 | |
| May 13 to May 20 | (?) | | | 8.00 | 2.00 | | | 65.60 | 3.8 | | 61.8 | |
| May 20 to May 27 | | | | 10.00 | 3.84 | | | 71.60 | 7.4 | | 64.2 | |
| May 27 to June 3 | 100. | | | 6.80 | 4.80 | | | 68.80 | 8.0 | | 60.8 | |
| May average | 118. | | | 6.64 | 3.72 | | | 66.72 | 6.8 | | 59.92 | |
| June 3 to June 6 | | | | 6.72 | 4.48 | | | 71.60 | 8.0 | | 63.6 | |
| June 6 to June 12 | | | | | | Shut | down. | | | | | |
| June 12 to June 20 | 64. | | | | 1.00 | 1.25 | comb | 54.80 | 10.4 | | 44.4 | |
| June 20 to June 27 | 84. | | | 5.28 | 2.72 | 1.12 | comb | 55.60 | 10.4 | | 45.2 | |
| June 27 to July 5 | 90. | | | 1.92 | 6.08 | 1.12 | comb | 60.40 | 13.2 | | 47.2 | |
| June average | 79.3 | | | 4.64 | 3.57 | 1.17 | | 60.6 | 10.5 | | 50.1 | |
| July 5 to July 12 | 50. | | | 1.44 | 4.16 | 1.12 | comb | 56.0 | 6.4 | | 49.6 | |
| July 12 to July 19 | 63. | | | 4.04 | 4.16 | 0.96 | comb | 66.0 | 21.6 | | 44.4 | |
| July 19 to July 26 | 68. | | | 7.20 | 2.80 | 1.12 | comb | 67.6 | 10.8 | 16.8 | 40.0 | |
| July 26 to August 2 | 61. | | | 5.52 | 4.48 | 0.80 | comb | 54.0 | 2.8 | 51 | .2 | |
| July average | 60.5 | | | 4.55 | 3.90 | 1.00 | | 61.1 | 10.4 | | 50.7 | |
| August 2 to August 9 | 93. | 7. | 86. | 1.60 | 4.00 | 0.80 | comb | | | | | |
| August 9 to August 16 | 42. | | | 3.52 | 3.68 | 0.96 | comb | | | | | |
| August 16 to August 23 | 70. | | | 1.90 | 3.70 | 0.96 | comb | 50.6 | 1.80 | 21.12 | 27.68 | |
| August 23 to August 30 | 82. | | | 1.70 | 4.30 | 0.14 | 0.20 | 59.2 | 14.40 | 14.40 | 30.40 | |
| August 30 to September 2 | 74. | | | 7.20 | 4.00 | 0.14 | 0.10 | 76.4 | 22.80 | 17.60 | 36.00 | |
| September 2 to September 6 | | | | | | Shut | down. | | | | | |
| August average | 72. | | | 3.18 | 3.94 | .6 | 6 | 62.07 | 13. | 17.71 | 31.36 | |
| September 6 to September 13 | 44. | 8. | 36. | 6.8 | 4.40 | 0.18 | | 73.6 | 7.6 | 43.2 | 22.8 | |
| September 13 to September 20 | 48. | 10. | 38. | 2.8 | 4.4 | 0.08 | 0.34 | 69.2 | .2 | 34.0 | 32.0 | |
| September 20 to September 27 | 108. | 24. | 84. | 7.2 | 2.4 | 0.10 | 0.20 | 53.6 | 1.6 | 28.0 | 24.0 | |
| September 27 to October 4 | 32. | 4. | 28. | 7.2 | 2.4 | 0.10 | 0.20 | 54.4 | 2.0 | 23.6 | 28.8 | |
| September average | 58. | 11.5 | 46.5 | 6. | 3.4 | 0.115 | 0.247 | 62.7 | 3.6 | 32.2 | 26.9 | |
| October 4 to October 11 | 82. | 14. | 68. | 3.2 | 3.6 | 0.25 | 0.50 | 65.6 | 2.8 | 14.0 | 48.8 | |
| October 11 to October 18 | 54. | 26. | 28. | 4.0 | 4.0 | 0.00 | 0.16 | 76.0 | 11.6 | 28.4 | 36.0 | |
| October 18 to October 25 | 60. | 13. | 47. | 4.4 | 3.6 | 0.20 | 0.60 | 78.4 | 12.0 | 31.6 | 34.8 | |
| October 25 to November 1 | 84. | 0 | 84. | 1.0 | 3.0 | 0.28 | 0.02 | 74.8 | 12.8 | 19.2 | 42.8 | |
| October average | 70. | 13. | 57. | 3.15 | 3.55 | .182 | .32 | 73.7 | 9.8 | 23.3 | 40.6 | |
| November 1 to November 8 | 84. | 0 | 84. | 11.0 | 4.6 | 0.30 | | 80.8 | 9.6 | 32.0 | 39.2 | |
| November 8 to November 15 | 112. | 4. | 108. | 4.0 | 4.0 | 0.25 | 0.25 | 71.2 | 11.2 | 28.4 | 31.6 | |
| November 15 to November 22 | 88. | 16. | 72. | 2.8 | 3.0 | 0.27 | 0.20 | 66.0 | 9.2 | 22.8 | 34.0 | |
| November 22 to November 29 | 72. | 0 | 72. | | 3.6 | 0.20 | 0.80 | 64.8 | 3.2 | 18.4 | 43.2 | |
| November average | 89. | 5. | 84. | 5.9 | 3.8 | 0.255 | 0.417 | 70.7 | 8.3 | 25.4 | 37. | |
| November 29 to December 6 | 72. | 20. | 52. | 3.8 | 0.2 | 0.20 | 0.60 | 84.0 | 16.8 | 24.8 | 42.4 | |
| December 6 to December 13 | 112. | 34. | 78. | 0.4 | 3.6 | 0.15 | 1.30 | 76.4 | 14.8 | 22.4 | 39.2 | |
| December 13 to December 20 | 152. | 40. | 112. | 5.6 | 3.2 | 0.20 | 1.80 | 84.0 | 7.2 | 39.6 | 37.2 | |
| December 20 to December 24 | 204. | 84. | 120. | 8.0 | 3.2 | 0.10 | 0.70 | 80.0 | 10.4 | 28.8 | 40.8 | |
| December 24 to December 27 | | | | | | Shut | down. | | | | | |
| December 27 to January 3 | 72. | 0 | 72. | 2.6 | 3.8 | 0.15 | 1.50 | 67.2 | 7.2 | 24.8 | 35.2 | |
| December average | 153. | 44.5 | 108.5 | 4.08 | 2.8 | 0.16 | 1.18 | 78.3 | 11.3 | 28.1 | 38.9 | |
| January 3 to January 10 | 56. | 0 | 56. | | | | | 70.0 | 9.2 | 23.2 | 37.6 | |
| January 10 to January 17 | 72. | 0 | 72. | | | | | 75.2 | 10.8 | 30.0 | 34.4 | 32.2 |
| January 17 to January 24 | 52. | 12. | 40. | | | | | 64.0 | 11.2 | 24.8 | 28.0 | 18.2 |
| January 24 to January 31 | 88. | 8. | 80. | | | | | 72.0 | 14.0 | 20.4 | 37.6 | 17.2 |
| January average | 67. | 5. | 62. | | | | | 70.3 | 11.3 | 24.6 | 34.4 | 22.5 |
| January 31 to February 7 | 30. | 8. | 22. | | | | | 73.2 | 14.0 | 8.8 | 50.4 | 18.6 |
| February 7 to February 14 | 96. | 12. | 84. | | | | | 71.6 | 8.4 | 30.0 | 33.2 | 13.4 |
| February 14 to February 21 | 104. | 10. | 94. | | | | | 73.2 | 7.2 | 31.6 | 34.4 | 33.4 |
| February 21 to February 28 | 148. | 40. | 108. | | | | | 76.8 | 6.8 | 34.4 | 35.6 | 43.2 |
| February average | 94.5 | 17.5 | 77. | | | | | 73.7 | 9.1 | 26.2 | 38.4 | 27.2 |
| February 28 to March 7 | 132. | 28. | 104. | | | | | 66.4 | 12.8 | 23.6 | 30.0 | 20.2 |
| March 7 to March 14 | 184. | 60. | 124. | | | | | 70.4 | 12.4 | 26.0 | 32.0 | 32.0 |
| March 14 to March 21 | 172. | 54. | 118. | | | | | 75.2 | 18.0 | 26.0 | 31.2 | 28.2 |
| March 21 to March 28 | 138. | 0 | 138. | | | | | 64.4 | 11.2 | 24.4 | 28.8 | |
| March 28 to April 4 | | | | | | Shut | down. | | | | | |
| March average | 156.5 | 35.5 | 121. | | | | | 69.1 | 13.6 | 25. | 30.5 | 26.8 |
| April 4 to April 11 | 60. | 0 | 60. | | | | | 64.4 | 6.8 | 24.8 | 32.8 | 13.2 |
| April 11 to April 18 | 100. | 28. | 72. | | | | | 64.0 | 8.4 | 24.0 | 31.6 | 15.6 |
| April 18 to April 25 | 72. | 38. | 34. | | | | | 60.8 | 8.0 | 20.0 | 32.8 | 10.4 |
| April 25 to April 30 | 100. | 40. | 60. | | | | | 60.4 | 6.8 | 24.8 | 28.8 | |
| April average | 83. | 26.5 | 56.5 | | | | | 62.4 | 7.5 | 23.4 | 31.5 | |

coarse trap; but soon they, in common with other filters, began to store up solids. As would be expected after a rest, nitrification was good and the effluent (except from the gravel bed) of uniformly high stability.

The rate of the filters was again increased on June 27th sc that 20-1 and 20-2 were operating at the rate of 1.6 million gallons per acre per day; 20-3 and 20-4 at 1.825, and 20-5 and 20-6 at 1.987.

This increase had no effect upon the stability of the effluents from the four higher beds (20-1, 2, 3, 4),but the relative stability of 20-6 fell to .70 and of 20-5, to .53.

The beds were operated at the last mentioned rates for three weeks, during which time the fine limestone continuously stored up solids, the effluents from the coarse limestone and the slag yielded a constantly increasing amount of suspended solids, and the two shallow beds, the gravel and fine trap, discharged more suspended solids than they received.

Bacterial examination was being made at sufficiently frequent intervals to obtain averages over this period. All the filters, except the gravel, were removing bacteria to such an extent that the effluents averaged 200,000 per cc. Details shown in Table No. 12.

The effluents from the two latter beds at this rate uniformly contained larger amounts of nitrogen as organic and free ammonia than the other effluents.

The effluent from the gravel bed when compared with the others had been so unsatisfactory that it was advisable to determine whether its failure was due to the character of the media or to its shallowness (3 feet 3 inches of filtering media and 9 inches underdrains). It was therefore discontinued and at once dismantled to examine its condition.

The beds after four months' use were in a satisfactory mature condition, and yielding an effluent similar to the influent in suspended solids. An examination of the media was made, with the following results.

"No. 20-1, 8 ft. of ¾ inch to 3 inch limestone.

The upper side of the top layer of stones is only discolored, the under side covered with bacterial jelly; immediately beneath the surface layer the stones are quite dirty, slightly offensive in odor, no worms found, although they are frequently found in the effluent.

20-2, 9 ft. of 2½ inch to 4 inch limestone.

The top layer of stone similar to 20-1, but beneath, the stones are remarkably clean, humus-like material in patches so loosely attached to the stone that in removing a piece of the media they fell off by their own weight; upon the clean part of the stones are large numbers of the larvae of Pyschoda alternate (which develops into the small moth fly so common about sprinkling filters); the media is entirely inodorous.

20-3, 6 ft. of 1 inch to 3 inch slag.

The surface of the top layer of stones is completely covered with a layer of bacterial jelly, ⅛ of an inch to 3-16 of an inch thick, over a semi-circular area of two feet radius; about the nozzle a luxurious growth of Oscillaria covers the surface, immediately below the surface layer of stones the media is very dirty and offensive; this accumulation must materially reduce the voids and consequently aeration in this filter.

No worms seen in this bed—in fact, it was always noticed that they were only found on clean stones, never in the sludge-like accumulation.

20-4, 7 ft. of 1 inch to 3 inch trap.

The top layer like 20-1 and 20-2, the stones comprising the next 4 to 6 inches are well covered with bacterial jelly in which large numbers of the aforesaid larvae were found, below this the stones grow more dirty.

20-5. 4 ft. of ½ inch to 2½ inch gravel.

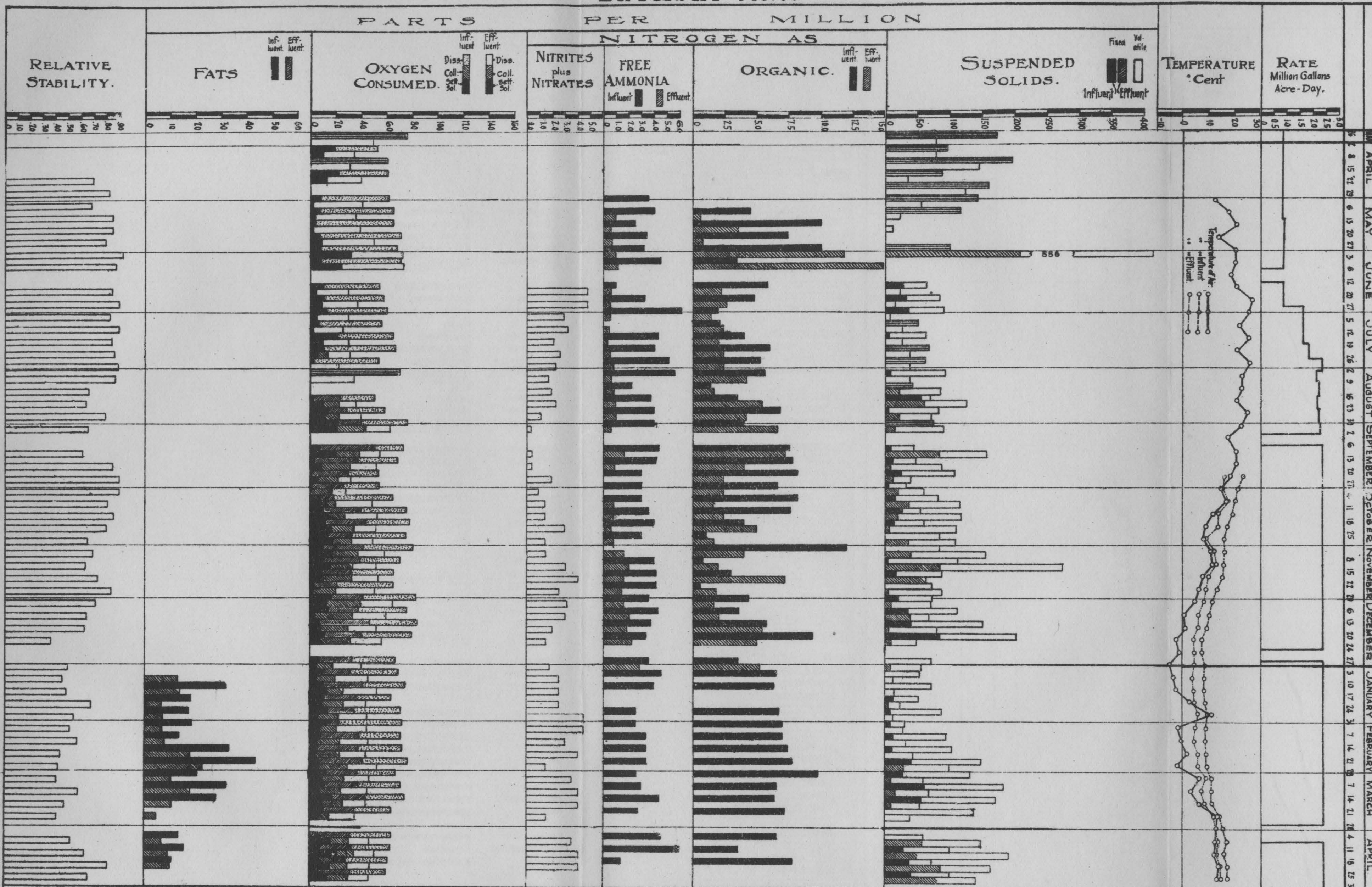
This bed is being dismantled. The top surface of the upper layer of stones is practically clean; on the under-

## Table No. 24.

*Analyses of the Effluent of the Outside Sprinkling Filter. No. 20-1—8ft. of Fine Limestone.*

| Dates. 1909–1910. | PARTS PER MILLION. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | | | | | |
| | Total. | Fixed. | Volatile. | Organic. | Free Amm. | Nitrites. | Nitrates. | Total. | Settling. | Colloidal. | Solution. | Turbidity. | Fats. | Relative Stability. | Air Temperature. |
| March 26 to April 2 | 77. | ---- | ---- | ---- | ---- | ---- | ---- | 49.8 | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| April 2 to April 8 | 77. | ---- | ---- | ---- | ---- | ---- | ---- | 34.4 | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| April 8 to April 15 | 148. | ---- | ---- | ---- | ---- | ---- | ---- | 30.8 | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| April 15 to April 22 | 34. | ---- | ---- | ---- | ---- | ---- | ---- | 39.4 | ---- | ---- | ---- | ---- | ---- | .694 | ---- |
| April 22 to April 29 | 123. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | .815 | ---- |
| April average | 91.8 | ---- | ---- | ---- | ---- | ---- | ---- | 38.6 | ---- | ---- | ---- | ---- | ---- | .754 | ---- |
| April 29 to May 6 | 55. | ---- | ---- | ---- | ---- | ---- | ---- | 40.8 | 1.2 | ---- | 39.6 | ---- | ---- | .68 | 12.4 |
| May 6 to May 13 | 22. | ---- | ---- | .62 | 1.0 | ---- | ---- | 36.4 | 3.6 | ---- | 32.8 | ---- | ---- | .85 | 17.6 |
| May 13 to May 20 | 11. | ---- | ---- | 3.5 | 0.6 | ---- | ---- | 38.6 | 2.2 | ---- | 36.4 | ---- | ---- | .854 | 20.4 |
| May 20 to May 27 | ---- | ---- | ---- | .76 | 0.64 | ---- | ---- | 49.80 | 9.40 | ---- | 40.40 | ---- | ---- | .791 | 13.7 |
| May 27 to June 3 | 556. | ---- | ---- | 11.80 | 1.0 | ---- | ---- | 72.80 | 32.40 | ---- | 40.40 | ---- | ---- | .93 | 20.1 |
| May average | 161. | ---- | ---- | 4.17 | .81 | ---- | ---- | 47.68 | 9.76 | ---- | 37.92 | ---- | ---- | .821 | 16.8 |
| June 3 to June 6 | ---- | ---- | ---- | 14.88 | 1.12 | ---- | ---- | 73.2 | 25.2 | ---- | 48.0 | ---- | ---- | .88 | 20. |
| June 6 to June 12 | | | | | | | Station | shut down. | | ---- | ---- | ---- | ---- | | 17.7 |
| June 12 to June 20 | 22. | ---- | ---- | 2.2 | .60 | 4.80 | | 29.2 | 4.4 | ---- | 24.8 | ---- | ---- | .85 | 20.5 |
| June 20 to June 27 | 14. | ---- | ---- | 2.64 | .56 | 4.80 | | 36.8 | 9.2 | ---- | 27.6 | ---- | ---- | .90 | 26.6 |
| June 28 to July 5 | 6. | ---- | ---- | 1.44 | .56 | 2.88 | | 29.2 | 4.4 | ---- | 24.8 | ---- | ---- | .83 | 25.5 |
| June average | 14. | ---- | ---- | 5.29 | .71 | 4.16 | | 42.1 | 10.8 | ---- | 31.3 | ---- | ---- | .865 | 22.1 |
| July 5 to July 12 | 26. | ---- | ---- | 2.40 | .40 | 3.20 | | 25.2 | 1.6 | ---- | 23.6 | ---- | ---- | .90 | 21.9 |
| July 12 to July 19 | 26. | ---- | ---- | 2.08 | .32 | 2.08 | | 30.4 | 9.2 | ---- | 21.2 | ---- | ---- | .84 | 25.1 |
| July 19 to July 26 | 37. | ---- | ---- | 2.32 | .48 | 2.72 | | 30.8 | 5.6 | 8.4 | 16.8 | ---- | ---- | .863 | 20.7 |
| July 26 to August 2 | 37. | ---- | ---- | 2.40 | .80 | 2.24 | | 22.4 | ---- | 20.0 | | ---- | ---- | .894 | 25.6 |
| July average | 31.5 | ---- | ---- | 2.3 | .50 | 2.56 | | 27.2 | 5.4 | ---- | 21.8 | ---- | ---- | .874 | 23.3 |
| August 2 to August 9 | 37. | 11. | 26. | 4.20 | .60 | 1.76 | | 34.4 | ---- | 22.4 | | ---- | ---- | .87 | 22.8 |
| August 9 to August 16 | 86. | 22. | 64. | 1.60 | .80 | 1.92 | | ---- | ---- | ---- | ---- | ---- | ---- | .663 | 22.8 |
| August 16 to August 23 | 126. | 61. | 65. | 5.4 | .96 | 2.24 | | 36.6 | 10.8 | 12.8 | 13.0 | ---- | ---- | .64 | 20.8 |
| August 23 to August 30 | 71. | 21. | 50. | 4.2 | 1.0 | .25 | .85 | 39.6 | 11.8 | 11.8 | 16.0 | ---- | ---- | .79 | 24.9 |
| August 30 to September 2 | 90. | 16. | 74. | 6.6 | .60 | .18 | .10 | 63.2 | 21.2 | 22.8 | 19.2 | ---- | ---- | .65 | 22.4 |
| August average | 103. | 33. | 56. | 4.4 | .792 | 1.46 | | 46.5 | 14.6 | 15.8 | 16.1 | ---- | ---- | .72 | 22.7 |
| September 2 to September 6 | | | | | | Outside | sprinkling | filter | resting. | | | | | | 17.2 |
| September 6 to September 13 | 158. | 84. | 74. | 7.2 | 1.6 | .30 | .05 | 55.2 | 22.4 | 17.2 | 15.6 | ---- | ---- | .61 | 20.3 |
| September 14 to September 20 | 88. | 8. | 80. | 4.0 | .80 | .16 | .24 | 52.4 | 10. | 22. | 20.4 | ---- | ---- | .85 | 20.5 |
| September 20 to September 27 | 40. | 14. | 28. | 2.4 | ---- | .10 | 1.85 | 32. | 7.4 | 15.2 | 9.4 | ---- | ---- | .90 | 18.4 |
| September 27 to October 4 | 60. | 20. | 40. | 2.4 | ---- | .14 | .76 | 28.4 | ---- | 16.8 | 11.6 | ---- | ---- | .90 | 14.8 |
| September average | 86.5 | 31. | 55.5 | 4.0 | 1.20 | .175 | .725 | 42. | 9.95 | 17.8 | 14.25 | ---- | ---- | .81 | 18.2 |
| October 4 to October 11 | 116. | 36. | 80. | 1.6 | .8 | .16 | 1.3 | 48. | 13.6 | 5.6 | 28.8 | ---- | ---- | .81 | 16.8 |
| October 11 to October 18 | 118. | 20. | 98. | 2.4 | .80 | .16 | 1.3 | 53.2 | 15.2 | 12.8 | 25.2 | ---- | ---- | .85 | 11.5 |
| October 18 to October 25 | 110. | 6. | 10[illegible]. | 5. | .60 | .16 | 2.8 | 52.4 | 18. | 18. | 16.4 | ---- | ---- | .80 | 8.9 |
| October 25 to November 1 | 108. | 36. | 72. | 1.6 | .80 | .16 | 1.3 | 49.2 | 17.2 | 14. | 18.0 | ---- | ---- | .65 | 8.0 |
| October average | 113. | 24.5 | 88.5 | 2.65 | .57 | .16 | 1.7 | 50.7 | 16. | 12.6 | 22.1 | ---- | ---- | .78 | 11.3 |
| November 1 to November 8 | 156. | 40. | 116. | 4. | 1.6 | .20 | 1.3 | 58.4 | 16.8 | 19.6 | 22.0 | ---- | ---- | .69 | 10.8 |
| November 8 to November 15 | 276. | 84. | 192. | 2. | 2. | .30 | 2.7 | 51.6 | 16.0 | 16.8 | 18.8 | ---- | ---- | .63 | 11.1 |
| November 15 to November 22 | 164. | 64. | 100. | 7.2 | 1.6 | .40 | 3.6 | 53.6 | 9.6 | 22.8 | 21.2 | ---- | ---- | .73 | 7.8 |
| November 22 to November 29 | 88. | 4. | 84. | 1.8 | 1.4 | .40 | 2.1 | 50. | 2.8 | 17.2 | 30. | ---- | ---- | .83 | 6.1 |
| November average | 171. | 48. | 123. | 3.75 | 1.65 | .325 | 2.4 | 53.4 | 11.3 | 19.1 | 23. | ---- | ---- | .72 | 8.95 |
| November 29 to December 6 | 72. | 12. | 60. | 1.6 | 1.6 | .40 | 2.8 | 64.4 | 14.4 | 26.0 | 24.0 | ---- | ---- | .71 | 4.5 |
| December 6 to December 13 | 68. | 40. | 28. | 2.0 | 2.0 | .40 | 2.6 | 59.6 | 4.0 | 29.6 | 26.0 | ---- | ---- | .64 | 0.1 |
| December 13 to December 20 | 80. | 4. | 76. | 5.4 | 1.8 | .30 | 1.7 | 52.0 | 8. | 22.0 | 22.0 | 140. | ---- | .62 | 1. |
| December 20 to December 24 | 48. | 8. | 40. | 5. | 2.2 | .30 | 1.2 | 56. | 8.4 | 24.0 | 23.6 | 190. | ---- | .36 | -2.5 |
| December 24 to December 27 | | | | | | | Beds | resting. | | | | | | | |
| December 27 to January 3 | 56. | 8. | 48. | 5.2 | 2.8 | .20 | 1.6 | 40. | 4.8 | 13.2 | 22.0 | 110. | ---- | .49 | -5.1 |
| December average | 65. | 14. | 51. | 3.8 | 2.1 | .32 | 1.98 | 54.4 | 7.9 | 23. | 23.5 | 147. | ---- | .56 | -0.4 |
| January 3 to January 10 | 12. | 0 | 12. | ---- | ---- | ---- | 2.5 | 46. | 4.8 | 15.2 | 26. | 100. | 13. | .45 | -3.4 |
| January 10 to January 17 | 14. | 0 | 14. | ---- | ---- | ---- | 2.5 | 52.8 | 14. | 12.8 | 26. | 80. | 13.8 | .477 | -2.7 |
| January 17 to January 24 | 24. | 4. | 20. | ---- | ---- | ---- | 2.5 | 44. | 9.2 | 16.8 | 18. | 190. | 6.6 | .68 | 2.6 |
| January 24 to January 31 | 12. | 0 | 12. | ---- | ---- | ---- | 4.5 | 44.4 | 6.4 | 16.4 | 21.6 | 65. | 7.2 | .54 | 11.2 |
| January average | 15.5 | 1. | 14.5 | ---- | ---- | ---- | 3. | 46.8 | 8.6 | 15.3 | 22.9 | 109. | 10.15 | .53 | 1.7 |
| January 31 to February 7 | 28. | 0 | 28. | ---- | ---- | ---- | 4.5 | 44.4 | 8.4 | 13.2 | 22.8 | 70. | 6.8 | .51 | -2.0 |
| February 7 to February 14 | 32. | 0 | 32. | ---- | ---- | ---- | 3. | 45.6 | 6.4 | 18. | 21.2 | 70. | 8.2 | .565 | -0.8 |
| February 14 to February 21 | 44. | 0 | 44. | ---- | ---- | ---- | 4. | 44. | 4.8 | 19.2 | 20. | 80. | 18.2 | .436 | 1.8 |
| February 21 to February 28 | 100. | 28. | 72. | ---- | ---- | ---- | 1.5 | 52.8 | 6. | 24.4 | 22.4 | 170. | 22.8 | .424 | -2.2 |
| February average | 51. | 7. | 44. | ---- | ---- | ---- | 3.25 | 46.7 | 6.4 | 18.7 | 21.6 | 97.5 | 14. | .537 | -0.8 |
| February 28 to March 7 | 60. | 8. | 52. | ---- | ---- | ---- | 3.5 | 46.4 | 9.6 | 16.8 | 20.0 | 95. | 11.4 | .41 | 6.2 |
| March 7 to March 14 | 68. | 16. | 52. | ---- | ---- | ---- | 4. | 44.8 | 8.4 | 16. | 20.4 | 100. | 18.2 | .58 | 3.1 |
| March 14 to March 21 | 54. | 10. | 44. | ---- | ---- | ---- | 4. | 44. | 10.4 | 16. | 17.6 | 95. | 11.0 | .47 | 6.5 |
| March 21 to March 28 | 38. | 0 | 28. | ---- | ---- | ---- | 1.5 | 36. | 4.8 | 8.4 | 22.8 | ---- | 4.4 | .41 | 13.4 |
| March 28 to April 4 | | | | ---- | ---- | ---- | Shut | down. | | | | | | | |
| March average | 55. | 8.5 | 46.5 | ---- | ---- | ---- | 3.25 | 42.8 | 8.3 | 14.3 | 20.2 | 97. | 11.2 | .47 | 7 5 |
| April 4 to April 11 | 148. | 56. | 92. | ---- | ---- | .40 | 3.1 | 46.8 | 15.6 | 14. | 17.2 | 190. | 6.6 | .52 | 12.3 |
| April 11 to April 18 | 192. | 48. | 144. | ---- | ---- | ---- | 4. | 50.8 | 22.8 | 12. | 16. | 115. | 9.2 | .63 | 12.2 |
| April 18 to April 25 | 164. | 84. | 80. | ---- | ---- | .20 | 3.8 | 47.2 | 18.4 | 12.8 | 16. | 140. | 10.2 | .81 | 13.9 |
| April 25 to April 30 | 140. | 80. | 60. | ---- | ---- | ---- | ---- | 46. | 14. | 15.6 | 16.4 | 150. | ---- | .65 | 13.2 |
| April average | 161. | 67. | 94. | ---- | ---- | .30 | 3.6 | 47.7 | 17.7 | 13.6 | 16.4 | 149. | 8.7 | .65 | 13.1 |

# DIAGRAM NO. 15




# SPRINKLING FILTER NO. 20-1

side, however, a slight bacterial jelly had formed; the surface of the gravel was apparently too smooth for either suspended solids or the jelly to adhere to, and the stones became progressively cleaner toward the bottom of the bed; on the upper media many worms lived but gradually decreased toward the bottom; the cobbles above the brick underdrains were very clean, upon the sloping concrete floor small pebbles had fallen through the cobbles and formed dams, which had prevented the free flow of the effluent, and caused the deposit of solids in a layer about one inch deep; it was similar in appearance to the deposit in the slate bed. An examination of the number of bacteria (on gelatine at 20° C. in 48 hours) in the bacterial jelly showed 9,240,000 per gram wet material.

20-6, 5 feet of ½ inch to 2½ inch trap.

The top stones are similar to those in 20-1 and 20-2, beneath, the stones are covered with the bacterial jelly in which large numbers of the larvae were found; the humus-like deposit was in much smaller masses than in the other beds, except 20-2."

It will be noticed that those beds most clogged at this time unloaded least on June 1st.

It will be noted that the shallow, fine media beds (20-5 and 20-6) were being operated at a higher rate than the other four beds, that the effluent from the latter was satisfactorily oxidized and therefore the beds were capable of treating larger quantities of sewage.

The usual method of increasing the rate was by reducing the resting portion of the dosing cycle; but if this had been done beds 20-5 and 20-6 would have been overtaxed. To obviate the difficulty caused by the limitation of the dosing apparatus, these two beds were rested during the daytime, the contents of the dosing tank being discharged upon four instead of six beds. During the night all six beds were in service.

The net rate of operation under these variable conditions, over a sampling period as shown on the diagrams, is a weighted average.

This mode of operating the filters was diametrically opposite to that adopted for the lower filter and resulted in greater variation of flow from the underdrains than that shown on diagram No. 12.

As the weather conditions were ideal for the filters during August, the crude sewage practically normal, and the only variable the irregular methods of operation, any change in the effluent ought logically to be attributed to the latter cause.

During this period of irregular operation, which approximately covers August, the filters were yielding an effluent containing generally about the same amount of suspended solids as there was in the influent, except the slag bed, which unloaded all during the month (details shown on diagrams).

The formation of nitrates steadily decreased all month, except in the fine limestone bed, until at the end of the period of irregular operation, the nitrate content of the effluent had become almost negligible.

The relative stability of the effluents indicates the daily change in the ability of the bed to oxidize putrescible matter; and the evil effects of irregular operation may be seen by an examination of the diagram showing daily relative stability where it will be noted that the effluent from the deep fine limestone bed which had been uniform in its high stability became irregular, reaching .50 as a minimum; the coarse limestone was similarly affected, reaching .42 as a minimum.

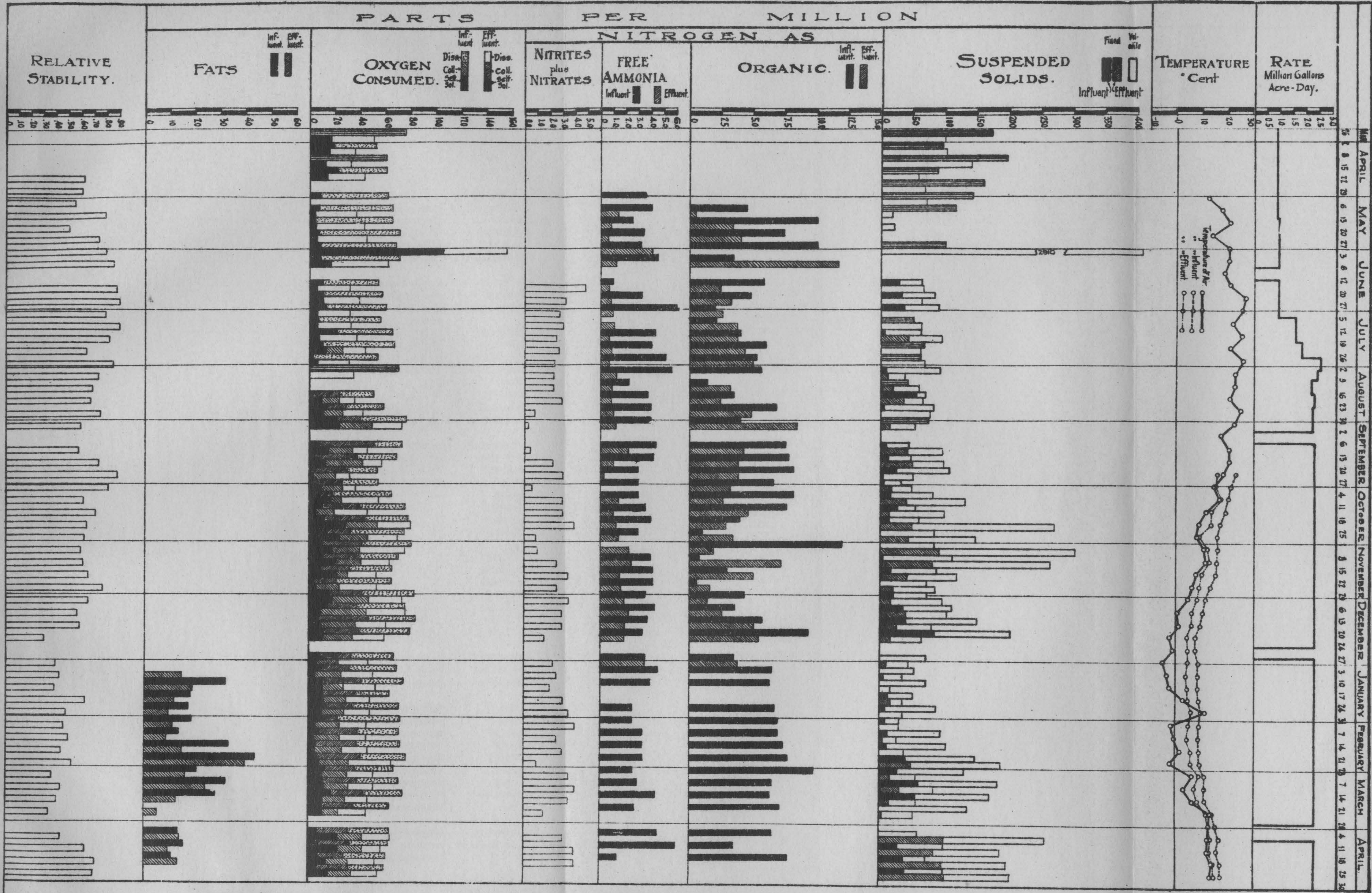
The stability of the effluent of the slag bed had been, prior to the irregular operation of the beds, becoming variable and during August the variableness of the effluent increased; the coarse trap bed was similarly affected; the fine trap bed yielded a stable effluent on Sundays, when the influent was quite dilute, but on week days the effluent was constantly putrescent.

## Table No. 25.

*Analyses of the Effluent of the Outside Sprinkling Filter No. 20-2—9 ft. of Coarse Limestone.*

| Dates. 1909–1910. | PARTS PER MILLION. Suspended Solids. Total. | Suspended Solids. Fixed. | Suspended Solids. Volatile. | Nitrogen as— Organic. | Nitrogen as— Free Amm. | Nitrogen as— Nitrites. | Nitrogen as— Nitrates. | Oxygen Consumed. Total. | Oxygen Consumed. Settling. | Oxygen Consumed. Colloidal. | Oxygen Consumed. Solution. | Turbidity. | Fats. | Relative Stability. | Air Temperature. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| March 26 to April 2 | 100. | | | | | | | 50.4 | 18. | | 32.4 | | | | |
| April 2 to April 8 | 102. | | | | | | | 35.2 | 14.6 | | 20.6 | | | | |
| April 8 to April 15 | 141. | | | | | | | 32.8 | 12.0 | | 20.8 | | | | |
| April 15 to April 22 | 58. | | | | | | | 43. | 13.4 | | 29.6 | | | .623 | |
| April 22 to April 29 | 69. | | | | | | | | | | | | | .604 | |
| April average | 117.5 | | | | | | | 40.3 | 14.5 | | 25.8 | | | .613 | |
| April 29 to May 6 | 71. | | | | | | | | | | | | | .551 | 12.4 |
| May 6 to May 13 | 16. | | | .5 | 1.4 | | | 36.4 | 3.6 | | 32.8 | | | .788 | 17.6 |
| May 13 to May 20 | 20. | | | 3.4 | .8 | | | 43.4 | 4.6 | | 38.8 | | | .502 | 20.4 |
| May 20 to May 27 | | | | 4.0 | .60 | | | 44.80 | 6.40 | | 38.40 | | | .742 | 13.7 |
| May 27 to June 3 | 2910. | 2128. | 782. | | 4.0 | | | 156.0 | 105.60 | | 50.40 | | | .798 | 20.1 |
| May average | 754. | | | 2.6 | 1.70 | | | 70.15 | 30.05 | | 40.1 | | | .676 | 16.85 |
| June 3 to June 6 | | | | 11.60 | 1.20 | | | 62.4 | 16.8 | | 45.6 | | | .857 | 20.0 |
| June 6 to June 12 | | | | | | | Shut | down. | | | | | | | 17.7 |
| June 12 to June 20 | 66. | 0 | 66. | 2.40 | .60 | | 4.80 | 32.0 | 6.4 | | 25.6 | | | .88 | 20.5 |
| June 20 to June 27 | 65. | | | 3.24 | .76 | | 3.20 | 39.2 | 11.2 | | 28. | | | .90 | 26.6 |
| June 28 to July 5 | | | | 2.60 | 1.0 | | 2.72 | 31.6 | 6.0 | | 25.6 | | | .79 | 25.5 |
| June average | | | | 4.96 | .89 | | 3.57 | 41.3 | 10.1 | | 31.2 | | | .857 | 22.1 |
| July 5 to July 12 | 60. | | | 3.76 | 1.04 | | 3.04 | 32.4 | 5.6 | | 26.8 | | | .900 | 21.9 |
| July 12 to July 19 | 96. | 42. | 54. | 3.76 | .64 | | 2.40 | 36.8 | 6.8 | | 30.0 | | | .820 | 25.1 |
| July 19 to July 26 | 62. | | | 4.36 | .84 | | 2.72 | 43.6 | 12.8 | 13.2 | 17.6 | | | .642 | 20.7 |
| July 26 to August 2 | 68. | | | 4.96 | .64 | | 2.40 | 30.8 | 6.8 | 24.0 | | | | .845 | 25.6 |
| July average | 71.5 | | | 4.21 | .79 | | 2.64 | 35.9 | 6.7 | | 29.2 | | | .801 | 23.3 |
| August 2 to August 9 | 37. | 10. | 27 | | 1.20 | | 2.24 | 34.8 | | 25.6 | | | | .730 | 22.8 |
| August 9 to August 16 | 58. | 17. | 41. | 3.12 | .88 | | 2.24 | | | | | | | .676 | 22.8 |
| August 16 to August 23 | 66. | 36. | 30. | 2.4 | .80 | | 2.9 | 35.4 | 10. | 13.2 | 12.2 | | | .673 | 20.8 |
| August 23 to August 30 | 76. | 0 | 76. | 4.8 | 1.0 | .30 | .40 | 41.6 | 10.8 | 14.8 | 16.0 | | | .750 | 24.9 |
| August 30 to September 2 | 54. | 15. | 39. | 8.4 | 1.20 | .15 | .10 | 72.8 | 24. | 25.6 | 23.2 | | | .587 | 22.4 |
| August average | 58. | 16. | 42. | 4.63 | 1.02 | | 1.7 | 49.9 | 14.9 | 17.9 | 17.1 | | | .683 | 22.7 |
| September 2 to September 6 | | | | | | Outside sprinkling filter resting. | | | | | | | | | 17.2 |
| September 6 to September 13 | 96. | 42. | 54. | 4.2 | 2.2 | .32 | .03 | 46.0 | 14.4 | 19.6 | 12.0 | | | .571 | 20.3 |
| September 14 to September 20 | 98. | 48. | 50. | 3.8 | 1.0 | .20 | 2.0 | 57.2 | 12.0 | 29.2 | 16.0 | | | .727 | 20.5 |
| September 20 to September 27 | 50. | 2. | 48. | 3.8 | .20 | .15 | 2.85 | 31.6 | 2.0 | 18.4 | 11.2 | | | .877 | 18.4 |
| September 27 to October 4 | 48. | 16. | 32. | 3.2 | | .12 | .38 | 36.4 | 8.8 | 16.8 | 10.8 | | | .810 | 14.8 |
| September average | 73. | 27. | 46. | 3.75 | 1.13 | .198 | 1.31 | 42.8 | 9.3 | 21.0 | 12.5 | | | .746 | 18.2 |
| October 4 to October 11 | 132. | 40. | 92. | 2.6 | 1.4 | .15 | 2.8 | 54.4 | 16.8 | 8.4 | 29.2 | | | .614 | 16.8 |
| October 11 to October 18 | 100. | 12. | 88. | 4.6 | 1.0 | .19 | 2.8 | 45.6 | 4.0 | 14.0 | 27.6 | | | .707 | 11.5 |
| October 18 to October 25 | 272. | 48. | 224. | 2.8 | 1.2 | .22 | 3.7 | 80.0 | 29.2 | 25.2 | 25.6 | | | .644 | 8.9 |
| October 25 to November 1 | 148. | 44. | 104. | 3.4 | 1.4 | .24 | .56 | 69.2 | 23.6 | 21.6 | 24.0 | | | .624 | 8.0 |
| October average | 163. | 36. | 127. | 3.35 | 1.25 | .20 | 2.49 | 62.3 | 18.4 | 17.3 | 26.6 | | | .647 | 11.3 |
| November 1 to November 8 | 304. | 92. | 212. | 1.8 | 2.2 | .25 | .75 | 75.6 | 18.0 | 22.4 | 35.2 | | | .588 | 10.8 |
| November 8 to November 15 | 264. | 80. | 184. | 7.2 | 2.4 | .30 | 2.2 | 63.2 | 20. | 21.2 | 22. | | | .606 | 11.1 |
| November 15 to November 22 | 120. | 40. | 80. | 5.0 | 1.4 | .55 | 2.9 | 53.2 | 8.8 | 22.0 | 22.4 | | | .649 | 7.8 |
| November 22 to November 29 | 84. | 20. | 64. | 1.6 | 1.6 | .50 | 2.0 | 53.2 | 5.2 | 18. | 30. | | | .760 | 6.1 |
| November average | 193. | 58. | 135. | 3.9 | 1.9 | .40 | 1.96 | 61.3 | 13. | 20.9 | 27.4 | | | .650 | 8.95 |
| November 29 to December 6 | 96. | 16. | 80. | 1.4 | 1.8 | .40 | 3.1 | 73.6 | 18. | 29.2 | 26.4 | | | .647 | 4.5 |
| December 6 to December 13 | 104. | 40. | 64. | 2.6 | 2.2 | .35 | 2.6 | 76. | 9.2 | 35.6 | 31.2 | | | .555 | 0.1 |
| December 13 to December 20 | 80. | 24. | 56. | 5.0 | 1.8 | .25 | 2.7 | 60.8 | 8.8 | 27.6 | 24.4 | 130. | | .584 | 1. |
| December 20 to December 24 | 64. | 16. | 48. | 5.4 | 1.8 | .20 | 1.3 | 59.6 | 10.8 | 23.2 | 25.6 | 160. | | .300 | —2.5 |
| December 24 to December 27 | | | | | | | Beds resting. | | | | | | | | |
| December 27 to January 3 | 44. | 8. | 36. | 3.7 | 3.5 | .20 | 2.1 | 47.2 | 5.6 | 16.8 | 24.8 | 100. | | .393 | —5.1 |
| December average | 77.6 | 20.8 | 56.8 | 3.6 | 2.2 | .28 | 2.36 | 63.5 | 10.5 | 26.5 | 26.5 | 130. | | .496 | —0.4 |
| January 3 to January 10 | 34. | 4. | 30. | | | | 2.5 | 50.8 | 3.6 | 21.2 | 26.0 | 110. | 14.4 | .422 | —3.4 |
| January 10 to January 17 | 16. | 0 | 16. | | | | 2. | 53.6 | 11.2 | 16.0 | 26.4 | 90. | 18.8 | .380 | —2.7 |
| January 17 to January 24 | 36. | 16. | 20. | | | | 3. | 48.8 | 12. | 18.4 | 18.4 | 200. | 11.4 | .627 | 2.6 |
| January 24 to January 31 | 36. | 0 | 36. | | | | 3.5 | 48.8 | 9.6 | 18.4 | 20.8 | 75. | 9.2 | .473 | 11.2 |
| January average | 30.5 | 5. | 25.5 | | | | 2.75 | 50.5 | 9.1 | 18.5 | 22.9 | 119. | 13.5 | .475 | 1.7 |
| January 31 to February 7 | 30. | 0 | 30. | | | | 4. | 46. | 5.2 | 18.8 | 22.0 | 65. | 11.2 | .475 | —2.0 |
| February 7 to February 14 | 28. | 4. | 24. | | | | 2.5 | 46. | 4.4 | 19.6 | 22.0 | 70. | 8.4 | .486 | —0.8 |
| February 14 to February 21 | 38. | 0 | 38. | | | | 3. | 46.4 | 4.8 | 20.8 | 20.8 | 75. | 14.8 | .436 | 1.8 |
| February 21 to February 28 | 188. | 48. | 140. | | | | 1.0 | 65.2 | 8.4 | 23.6 | 33.2 | 250. | 40. | .516 | —2.2 |
| February average | 71. | 13. | 58. | | | | 2.6 | 50.9 | 5.7 | 20.7 | 24.5 | 115. | 18.6 | .478 | —0.8 |
| February 28 to March 7 | 56. | 16. | 40. | | | | 3.5 | 51.6 | 11.2 | 20. | 20.4 | 120. | 16.2 | .361 | 6.2 |
| March 7 to March 14 | 84. | 32. | 52. | | | | 4. | 51.6 | 12. | 18.8 | 20.8 | 120. | 24.2 | .431 | 3.1 |
| March 14 to March 21 | 56. | 14. | 42. | | | | 3.5 | 47.2 | 11.2 | 17.6 | 18.4 | 110. | 12.6 | .403 | 6.5 |
| March 21 to March 28 | 52. | 2. | 50. | | | | 1.5 | 46. | 10.8 | 12. | 23.2 | | 5.2 | .341 | 13.4 |
| March 28 to April 4 | | | | | | | Shut | down. | | | | | | | |
| March average | 62. | 16. | 46. | | | | 3.1 | 49.1 | 11.3 | 17.1 | 20.7 | 117. | 14.6 | .384 | 7.5 |
| April 4 to April 11 | 258. | 102. | 156. | | | .8 | 2.2 | 64.4 | 23.2 | 19.6 | 21.6 | 260. | 14. | .443 | 12.3 |
| April 11 to April 18 | 188. | 84. | 104. | | | | 4. | 57.2 | 22.8 | 19.6 | 14.8 | 160. | 9.4 | .630 | 12.2 |
| April 18 to April 25 | 198. | 98. | 100. | | | .40 | 3.6 | 52.0 | 20.4 | 14.4 | 17.2 | 190. | 13.2 | .707 | 13.9 |
| April 25 to April 30 | 204. | 100. | 104. | | | | | 54.4 | 15.2 | 18.0 | 21.2 | 205. | | .691 | 13.2 |
| April average | 212. | 96. | 116. | | | .24 | 3.3 | 57. | 20.4 | 17.9 | 18.7 | 204. | 12.2 | .618 | 13.1 |

DIAGRAM NO. 16




SPRINKLING FILTER NO. 20 - 2

Although the chemical improvement in the sewage, by passage through the filters during this period, was inadequate, there was a high percentage removal of bacteria, as may be seen in Table No. 12.

During the period described above, a filter was being built in place of the dismantled gravel bed. A mixture of broken stone on hand from the fine and coarse trap beds was used and made four feet deep over the same style underdrains as before. Iron turnings in amount equal to 0.1 per cent. of the weight of the total media in the bed were added to the upper three inches of the broken stone. (See Dunbar's "Principles of Sewage Treatment," page 173.) The trap media was covered with a layer of gravel about two inches in diameter to maintain the clean appearance always made by the old gravel bed.

The experiment on irregular operation, while instructive, produced unsatisfactory results, and before beginning under new conditions the beds were rested four days, operation being resumed on September 6, 1909. The rate was made nearly the same on all six beds by adjustments of the dosing apparatus and the beds operated as regularly as possible.

For the first two weeks in September all of the beds unloaded somewhat, but not in the excessive manner of June 1, 1909, heretofore described. The fine limestone and the coarse trap rid themselves of more stored solids than the other beds; the two shallow beds, 20-5 and 20-6 unloaded the least.

During all of September nitrification was very poor in the fine limestone bed and in the new 20-5 of trap mixture, but in the other filters after the unloading nitrates steadily increased.

When started up after the four days' rest, the slag bed was the only one which produced a stable effluent. An examination of diagram No. 21 will show that as the filters commenced to unload, the relative stability of the unsettled effluents became lower, but after the unloading all the filters (except 20-5, which was not one month old) produced stable effluents, from the two limestone beds and the coarse trap (20-1, 2 and 4) becoming uniformly of high relative stability.

During the first week of operation after the rest, the efficiency of the filters for removing bacteria was lower than during the two preceding months, but compares favorably with the results of the Columbus, Ohio, Sewage Disposal Works at the same time.

After the unloading of solids the percentage removal of bacteria was much higher. In the new trap bed, 20-5 (not yet mature), bacterial efficiency was very low.

In order to determine the amount of humus stored up in the sprinkling filters during their six months of service, on September 27, 1909, 3.04 cubic feet of media were removed from each of the beds and the voids determined. The stone was then thoroughly washed, allowed to drain and the voids redetermined. It must be considered in studying the following table that all the observations have shown that the accumulation of humus in a sprinkling filter is greatest at the surface and decreases with the depth.

In removing stones for this observation it was impracticable to dig deeper than about 2½ feet and therefore the observed conditions are much worse than if representative portions of the entire depth of the media had been obtained.

During the autumn and up to freezing weather no unusual phenomena were observed, the fine lime-stone bed unloaded during the first week of November, the slag bed unloaded heavily about the middle of October, and the other beds generally stored solids.

The effluents from the fine lime-stone bed and the coarse trap bed (Nos. 20-1 and 20-4) were of higher relative stability than the others, but even these two were not uniformly stable as in the summer; the coarse limestone and

DECEMBER
JANUARY
FEBRUARY
TEMPERATURE IN DEGREES CENTIGRADE
KEY
AIR
INFLUENT
EFFLUENT
DIAGRAM Nº 14
SHOWING THE
TEMPERATURE OF AIR
AT THE
OUTSIDE FILTERS
AND OF
INFLUENT AND EFFLUENT

the slag were lower and less uniform than in summer; and the two shallow beds, 20-5 and 20-6, produced effluents of the least relative stability, the average being raised by the dilute Sunday sewage.

TABLE No. 13.

*Examination of the Media of the Outside Sprinkling Filters.*

| No. of Bed. | Percent Voids. Initial, March 23, 1909. | Washed, Sept. 27, 1909. | Dirty, Sept. 27, 1909. | Loss in Voids, per Cent. | Pounds Stored per Cubic Yard Media. | |
|---|---|---|---|---|---|---|
| 20-1 | 46.9 | 47.0 | 44.4 | 2.6 | 71 | ¾-inch to 3-inch limestone—first foot very dirty; cleaner below. |
| 20-2 | 50. | 49.1 | 46. | 3.1 | 75.4 | 2½-inch to 4-inch limestone—first stones quite dirty, becoming very clean in places below. On the clean stones many worms. |
| 20-3 | 52. | 51. | 43.8 | 7.2 | 160. | 1-inch to 3-inch slag—the upper surface of bed covered with oscillaria, especially luxuriant near the nozzle. The upper foot of media very dirty, especially so in the ring of maximum overdose. Beneath, dirty. |
| 20-4 | 47. | 47. | 46.2 | 0.8 | 31. | 1-inch to 3-inch trap, cleanest stones of all the beds—only upper layers dirty. Large number of worms present. |
| 20-6 | 45.7 | 46.2 | 39. | 7.2 | 53.2 | ½-inch to 2½-inch trap—the humus is quite evenly distributed through the media. Second cleanest bed. |

On December 8, 1909, freezing temperature began and continued until December 13th, the lowest temperature recorded was —6° C. No change was made in the operation of the filters on account of this low temperature, but the formation of ice was carefully watched.

The nozzle serving the lime-stone beds discharged under a slightly less head than the other and consequently did not throw quite as far; ice formed in the four corners so that the open area was slightly larger than a circle whose radius was the distance from the nozzle to the side of the bed.

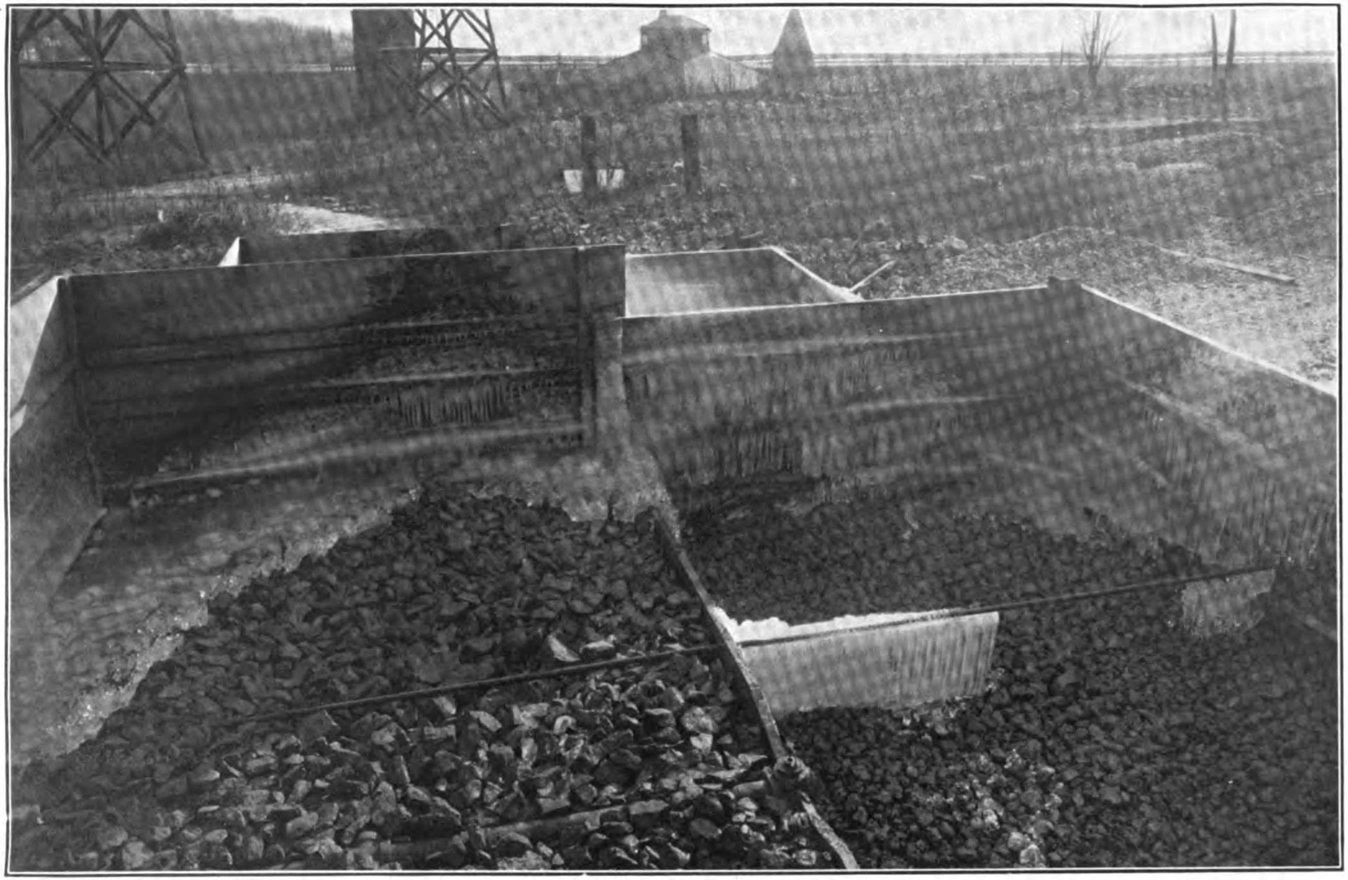
The two trap beds (20-4 and 20-6) had ice in the corners to a slight amount; the slag bed and the mixed trap were entirely free from ice; in the case of the slag bed it appeared as though an internal heat prevented the formation of ice, for during the "rest" of the dosing cycle this bed "steamed" more than any other. The smooth surface of the layer of gravel upon 20-5 was very unfavorable to ice formation.

These four days of freezing temperature caused a deterioration in the stability of the effluents which continued until spring, as may be seen on diagrams Nos. 21 and 22. From December 16th to 31st (except for part of December 23d) the temperature was below freezing, for the last three days averaging —8° C. The formation of ice in the corners was the same as described before; the condition of the slag and coarse trap beds on December 21, 1909, is shown on the photograph.

The average loss in heat, between the sedimentation tank and the combined effluents of the outside filters during December amounted to 3.6° C., but it must be remembered that the sewage passed through exposed 3-inch iron pipes from the dosing tank to the nozzles, and that the filters were small in volume.

Upon two occasions studies were made upon the result of resting the filters in cold weather, the first on December 20th, when the filters were shut down from 8.00 A. M. to 12.00 M. during the cleaning of the pump. For four days previously the temperature had been below zero C. and the average condition of the effluent during that time is shown in Table No. 14.

Examination of the effluent 15 minutes and 4 hours after starting up again is shown in Table No. 15.



Outside Sprinkling Filters.—Stations Nos. 20-3 and 20-4.
December 21, 1909.

## TABLE NO. 14.

*Condition of Outside Filters Prior to Rest on December 20.*

| Number of Bed. | 20-1 | 20-2 | 20-3 | 20-4 | 20-5 | 20-6 |
|---|---|---|---|---|---|---|
| Million bacteria per cc. in effluent | .24 | .37 | .22 | .24 | .71 | .46 |
| Percentage removal bacteria | 84.7 | 76.4 | 86.0 | 84.7 | 54.6 | 70.6 |
| Nitrogen as nitrates | 3 | 2.2 | 2.8 | 2.7 | 1.8 | 1.8 |
| Relative stability of the effluent | .62 | .61 | .61 | .58 | .37 | .40 |

## TABLE NO. 15.

*Condition of Outside Filters Subsequent to Shut Down.*

| | Number of Bed. | 20-1 | 20-2 | 20-3 | 20-4 | 20-5 | 20-6 |
|---|---|---|---|---|---|---|---|
| 15 minutes after first dose. | Million bacteria per cc. in effluent | .27 | .57 | .15 | .23 | .33 | .30 |
| | Percentage removal of bacteria | 85. | 68.5 | 91.5 | 87.4 | 81.8 | 84.5 |
| | Nitrogen as nitrates | 8. | 5. | 8. | 8. | 4. | 4. |
| | Relative stability of effluent | .56 | .62 | .90 | .90 | .56 | .77 |

| | Number of Bed. | 20-1 | 20-2 | 20-3 | 20-4 | 20-5 | 20-6 |
|---|---|---|---|---|---|---|---|
| 4 hours after first dose. | Million bacteria per cc. in effluent | .21 | .64 | .21 | .23 | 1.1 | .82 |
| | Percent. removal of bacteria | 88.8 | 66.4 | 88.8 | 87.7 | 42.1 | 56.8 |
| | Nitrogen as nitrates | 3. | 2. | 3. | 3. | 2. | 2. |
| | Relative stability of effluent | .35 | .29 | .29 | .29 | .23 | .29 |

The second shut down was over Christmas, when the beds were not dosed for three days, from December 24th, 1.30 P. M., to December 27th, 1.00 P. M. During this time the temperature was uniformly between 1° C. and —2° C. On December 25th a very severe snow storm commenced about 8.00 A. M. continuing for 24 hours. The wind-shields caused heavy drifting, so that some portions of the beds were covered with snow three feet deep. Upon starting up, the sewage slowly melted the snow so that at least by the following morning they were entirely free from snow over the wetted area. Samples were collected every half hour after starting and examined with results shown in Table No. 16.

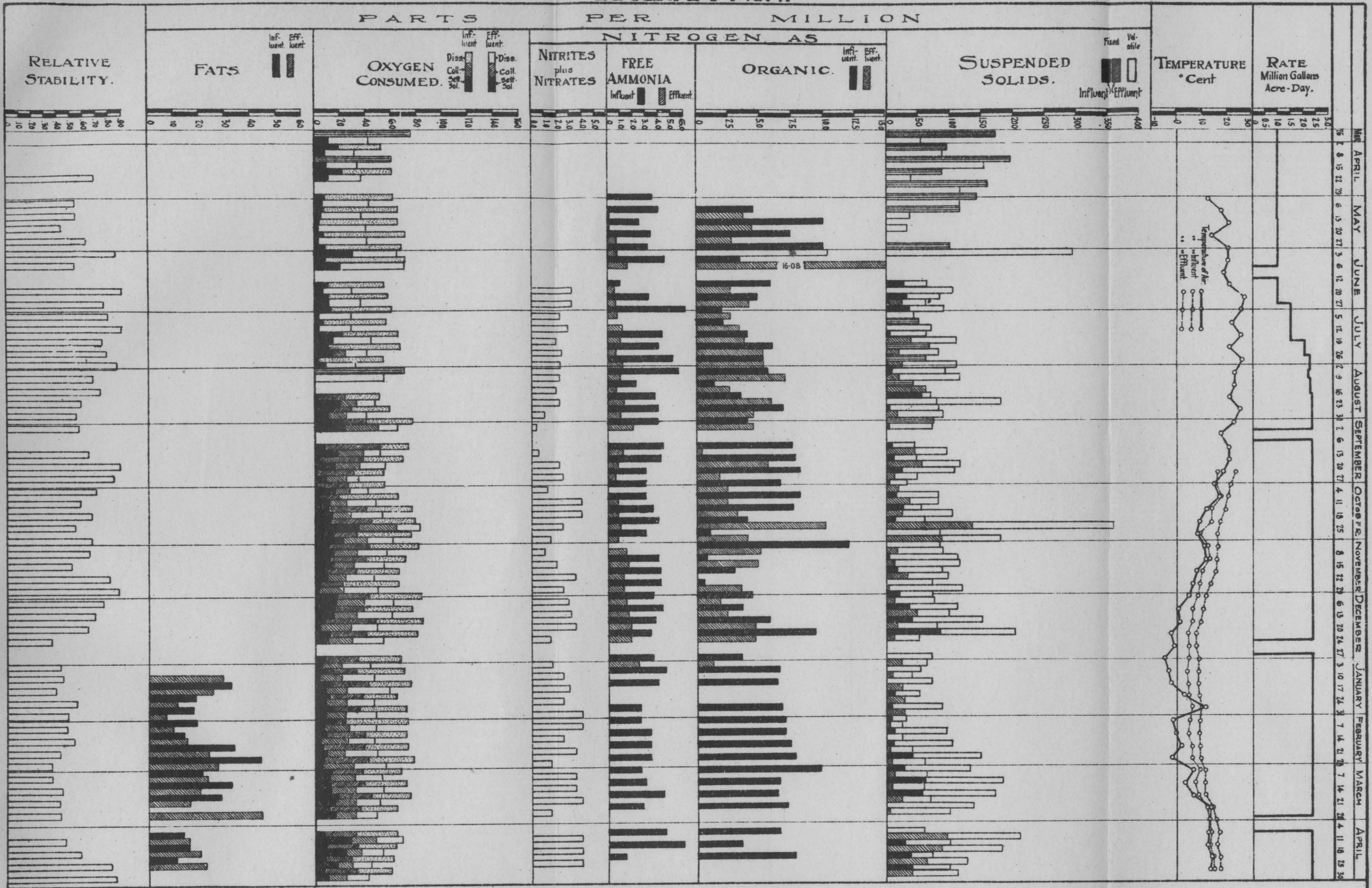
In order to show the quality of the effluent before and after a three days' rest in cold weather there is given in Table No. 17 results on December 24th and average of December 28th and 29th.

TABLE No. 26.

*Analyses of the Effluent of the Outside Sprinkling Filter No. 20-3=6 Feet of Slag.*

| Dates. 1909–1910. | PARTS PER MILLION. Suspended Solids. Total. | Suspended Solids. Fixed. | Suspended Solids. Volatile. | Nitrogen as— Organic. | Nitrogen as— Free Amm | Nitrogen as— Nitrites. | Nitrogen as— Nitrates. | Oxygen Consumed. Total. | Oxygen Consumed. Settling. | Oxygen Consumed. Colloidal. | Oxygen Consumed. Solution. | Turbidity. | Fats. | Relative Stability. | Air Temperature. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| March 26 to April 2 | 53. | | | | | | | 42.4 | 11. | | 31.4 | | | | |
| April 2 to April 8 | 88. | | | | | | | 31.2 | 8.2 | | 23. | | | | |
| April 8 to April 15 | 154. | | | | | | | 34. | 8.8 | | 25.2 | | | | |
| April 15 to April 22 | 38. | | | | | | | 37.2 | 11.2 | | 26.0 | | | | |
| April 22 to April 29 | 117. | | | | | | | | | | | | | .69 | |
| April average | 90. | | | | | | | 36.2 | 9.8 | | 26.4 | | | | |
| April 29 to May 6 | 116. | | | | | | | 43.6 | 6.0 | | 37.6 | | | .54 | 12.4 |
| May 6 to May 13 | 37. | | | .37 | .08 | | | 27.4 | 5.2 | | 32.2 | | | .54 | 17.6 |
| May 13 to May 20 | 32. | | | 4.4 | .08 | | | 40.6 | 3.4 | | 37.2 | | | .43 | 20.4 |
| May 20 to May 27 | | | | 2.76 | .64 | | | 41.4 | 3.4 | | 38.0 | | | .623 | 13.7 |
| May 27 to June 3 | 294. | | | 10.4 | .80 | | | 64.8 | 30. | | 34.8 | | | .85 | 20.1 |
| May average | 120. | | | 4.48 | .40 | | | 56.9 | 12. | | 44.9 | | | .597 | 16.8 |
| June 3 to June 6 | | | | 16.08 | 1.52 | | | 70.4 | 20.4 | | 50.0 | | | .53 | 20. |
| June 6 to June 12 | | | | | | | Station shut down. | | | | | | | | 17.7 |
| June 12 to June 20 | 104. | | | 2.64 | .56 | | 3.20 | 29.6 | 7.2 | | 22.4 | | | .90 | 20.5 |
| June 20 to June 27 | 62. | 24. | 38. | 4.16 | .64 | | 3.20 | 36.4 | 10.8 | | 25.6 | | | .769 | 26.6 |
| June 28 to July 5 | 42. | | | 2.72 | .48 | | 2.24 | 28.8 | 3.2 | | 25.6 | | | .79 | 25.5 |
| June average | 69. | | | 6.4 | .80 | | 2.88 | 41.3 | 10.4 | | 30.9 | | | .747 | 22.1 |
| July 5 to July 12 | 70. | | | 3.40 | .60 | | 2.88 | 28.4 | 3.2 | | 25.2 | | | .900 | 21.9 |
| July 12 to July 19 | 112. | 38. | 74. | 3.76 | .64 | | 1.92 | 44.8 | 13.6 | | 31.2 | | | .753 | 25.1 |
| July 19 to July 26 | 82. | 19. | 63. | 5.24 | .76 | | 2.40 | 41.2 | 13.6 | 10.0 | 17.6 | | | .778 | 20.7 |
| July 26 to August 2 | 111. | 24. | 87. | 5.28 | 1.12 | | 2.24 | 32.4 | 8.4 | | 24.0 | | | .855 | 25.6 |
| July average | 101.6 | 27. | 74.6 | 4.42 | .78 | | 2.36 | 36.7 | 9.7 | | 27.0 | | | .821 | 23.3 |
| August 2 to August 9 | 116. | 20. | 96. | 7.0 | 1.0 | | 2.24 | | | | | | | .674 | 22.8 |
| August 9 to August 16 | | | | 2.56 | .64 | | 1.92 | | | | | | | .729 | 22.8 |
| August 16 to August 23 | 181. | 79. | 102. | 5.9 | 1.3 | | 2.2 | 47.2 | 20.4 | 12.8 | 14.0 | | | .579 | 20.8 |
| August 23 to August 30 | 90. | 16. | 74. | 4.6 | 1.0 | .15 | .85 | 40.2 | 10. | 15.4 | 14.8 | | | .538 | 24.9 |
| August 30 to September 2 | 72. | 2. | 70. | 4.6 | .20 | .10 | .20 | 65.2 | 23.6 | 25.6 | 16.0 | | | .563 | 22.4 |
| August average | 115. | 29. | 86. | 4.93 | .83 | | 1.53 | 50.9 | 18.0 | 17.9 | 15.0 | | | .616 | 22.7 |
| September 2 to September 6 | | | | | | Outside sprinkling filter resting. | | | | | | | | | 17.2 |
| September 6 to September 13 | 96. | 46. | 50. | 0.4 | 1.20 | .24 | .26 | 51.2 | 18.0 | 20.0 | 13.2 | | | .634 | 20.3 |
| September 14 to September 20 | 117. | 57. | 60 | 5.6 | .80 | .10 | 2.1 | 55.2 | 14.8 | 20.0 | 20.4 | | | .876 | 20.5 |
| September 20 to September 27 | 48. | 12. | 36. | 1.8 | .60 | .13 | 2.37 | 34.0 | 8. | 16.0 | 10.0 | | | .833 | 18.4 |
| September 27 to October 4 | 68. | 36. | 32. | 2.4 | | .14 | 1.1 | 41.6 | 14.8 | 12.4 | 14.4 | | | .688 | 14.8 |
| September average | 82. | 38. | 44 | 2.55 | .87 | .15 | 2.04 | 45.5 | 13.9 | 17.1 | 14.5 | | | .757 | 18.2 |
| October 4 to October 11 | | | | 2.4 | .80 | .15 | 3.8 | 47.6 | 10.8 | 13.2 | 23.6 | | | .574 | 16.8 |
| October 11 to October 18 | 104. | 24. | 80. | 3.2 | .80 | .18 | 3.8 | 53.2 | 12.8 | 15.2 | 25.2 | | | .656 | 11.5 |
| October 18 to October 25 | 360. | 136. | 224. | 10.2 | 1.0 | .24 | 2.2 | 82.4 | 34.4 | 28.8 | 19.2 | | | .534 | 8.9 |
| October 25 to November 1 | 180. | 88. | 92. | 4.0 | .80 | .18 | 1.3 | 60.4 | 22.0 | 19.2 | 19.2 | | | .661 | 8.0 |
| October average | 215. | 83. | 132. | 4.95 | .85 | .19 | 2.8 | 60.9 | 20. | 19.1 | 21.8 | | | .606 | 11.3 |
| November 1 to November 8 | 88. | 16. | 72. | 5.0 | 1.4 | .20 | .80 | 55.6 | 14.4 | 18.8 | 22.4 | | | .604 | 10.8 |
| November 8 to November 15 | 116. | 12. | 104. | 4.8 | 1.6 | .30 | 1.7 | 50.4 | 13.2 | 17.2 | 20.0 | | | .501 | 11.1 |
| November 15 to November 22 | 96. | 32. | 64. | | 1.2 | .35 | 3.1 | 45.2 | 9.2 | 14.8 | 21.2 | | | .801 | 7.8 |
| November 22 to November 29 | 120. | 4. | 116. | 3.6 | 1.2 | .40 | 2.1 | 48.8 | 2.0 | 18.8 | 28.0 | | | .866 | 6.1 |
| November average | 105. | 16. | 89. | 4.5 | 1.35 | .31 | 1.98 | 50. | 9.7 | 17.4 | 23.1 | | | .693 | 8.95 |
| November 29 to December 6 | 76. | 12. | 64. | 1.8 | 1.4 | .35 | 2.6 | 61.6 | 15.6 | 22.0 | 24.0 | | | .739 | 4.5 |
| December 6 to December 13 | 100. | 48. | 52. | 2.4 | 1.6 | .35 | 2.8 | 60.0 | 14.4 | 18.0 | 27.6 | | | .677 | 0.1 |
| December 13 to December 20 | 80. | 16. | 64. | 4.6 | 1.8 | .30 | 3.2 | 48. | 3.2 | 24. | 20.8 | 120. | | .629 | 1.0 |
| December 20 to December 24 | 52. | 12. | 40. | 4.6 | 1.8 | .27 | 1.2 | 53.6 | 10.4 | 19.2 | 24. | 110. | | .344 | -2.5 |
| December 24 to December 27 | | | | | | | Beds resting. | | | | | | | | |
| December 27 to January 3 | 64. | 24. | 40. | 1.2 | 2.4 | .20 | 1.4 | 43.6 | 4.8 | 14.8 | 24.0 | 110. | | .414 | -5.1 |
| December average | 74. | 22. | 52. | 2.9 | 1.8 | .29 | 2.24 | 53.4 | 9.7 | 19.6 | 24.1 | 113. | | .360 | -0.4 |
| January 3 to January 10 | 40. | 8. | 32. | | | | 2.5 | 46.0 | 2.8 | 16.8 | 26.4 | 130. | 29. | .432 | -3.4 |
| January 10 to January 17 | 24. | 0 | 24. | | | | 3. | 50.8 | 8.4 | 16.8 | 25.6 | 90. | 25.2 | .368 | -2.7 |
| January 17 to January 24 | 28. | 0 | 28. | | | | 2.5 | 46. | 8. | 16.8 | 21.2 | 190. | 11.2 | .536 | 2.6 |
| January 24 to January 31 | 28. | 0 | 28. | | | | 4. | 48. | 8.4 | 16.4 | 23.2 | 60. | 6.4 | .471 | 11.2 |
| January average | 30. | 2. | 28. | | | | 3. | 47.7 | 6.9 | 16.7 | 24.1 | 118. | 17.9 | .451 | 1.7 |
| January 31 to February 7 | 24. | 4. | 20. | | | | 4. | 47.6 | 6. | 19.6 | 22.0 | 65. | 9.4 | .456 | -2.0 |
| February 7 to February 14 | 24. | 0 | 24. | | | | 2.5 | 47.2 | 4.4 | 20.8 | 22.0 | 90. | 14.8 | .521 | -0.8 |
| February 14 to February 21 | 40. | 4. | 36. | | | | 3.5 | 48.8 | 8.8 | 14. | 26. | 80. | 23.6 | .408 | 1.8 |
| February 21 to February 28 | 60. | 8. | 52. | | | | 1.5 | 55.6 | 5.2 | 25.2 | 25.2 | 180. | 27. | .336 | -2.2 |
| February average | 37. | 4. | 33. | | | | 2.9 | 49.8 | 6.1 | 19.9 | 23.8 | 104. | 18.7 | .430 | -0.8 |
| February 28 to March 7 | 64. | 14. | 50. | | | | 3.5 | 52.4 | 11.2 | 20. | 21.2 | 120. | 23.2 | .346 | 6.2 |
| March 7 to March 14 | 60. | 10. | 50. | | | | 3.5 | 53.6 | 11.6 | 19.2 | 22.8 | 115. | 20.0 | .427 | 3.1 |
| March 14 to March 21 | 70. | 24. | 46. | | | | 4. | 50.4 | 15.2 | 16.8 | 18.4 | 120. | 16.2 | .405 | 6.5 |
| March 21 to March 28 | 100. | 4. | 96. | | | | 1.5 | 48.4 | 15.6 | 16. | 16.8 | | 44.6 | .415 | 13.4 |
| March 28 to April 4 | | | | | | | Station shut down. | | | | | | | | |
| March average | 74. | 13. | 61. | | | | 3.1 | 51.2 | 13.4 | 18. | 19.8 | 118. | 26. | .398 | 7.5 |
| April 4 to April 11 | 212. | 96. | 116. | | | .8 | 3.2 | 68.4 | 28.4 | 20.0 | 20. | 210. | 16. | .448 | 12.3 |
| April 11 to April 18 | 184. | 88. | 96. | | | | 4. | 52.8 | 24.4 | 12.8 | 15.6 | 120. | 10.6 | .570 | 12.2 |
| April 18 to April 25 | 128. | 64. | 64. | | | .25 | 3.7 | 44. | 17.6 | 12.8 | 13.6 | 120. | 12.4 | .813 | 13.9 |
| April 25 to April 30 | 112. | 40. | 72. | | | | | 42. | 10. | 14.4 | 17.6 | 95. | | .846 | 13.2 |
| April average | 159. | 72. | 87. | | | .165 | 3.6 | 51.8 | 20.1 | 15. | 16.7 | 136. | 13. | .669 | 13.1 |

# DIAGRAM NO. 17




# SPRINKLING FILTER NO. 20 - 3

## Table No. 16.

*Condition of Effluents of Outside Filters.*

| No. of Bed. | Time, P. M. | Nitrate. | Putr. in Hours M. B. at 20 Degrees. | Million Bacteria per cc. Gel. Two Days at 20 Degrees. | Per Cent. Removed Bacteria. | |
|---|---|---|---|---|---|---|
| 20-1 8 feet of fine limestone. | 1 | 4.0 | 31 | ------ | ------ | Very dirty, rotifers, amoeba, paramecium, and small worms. |
| | 1-30 | 3.0 | ------ | ------ | ------ | Dirty, large particles, very little animal life. |
| | 2 | 2.5 | ------ | ------ | ------ | Dirty, no animal life. |
| | 2-30 | 1.5 | | | | |
| | 3 | 1.5 | 34 | .84 | 23.6 | Normal appearance. |
| 20-2 9 feet of coarse limestone. | 1 | 4.0 | 31 | ------ | ------ | Very dirty; rotifers, amoeba, paramecium plentiful. |
| | 1-30 | 3.0 | ------ | ------ | ------ | Much cleaner than 1 P. M. sample; few animals. |
| | 2 | 2.5 | ------ | ------ | ------ | No animal life. |
| | 2-30 | 1.0 | | | | |
| | 3 | 1.0 | 34 | .79 | 28.2 | Normal appearance. |
| 20-3 6 feet of slag. | 1 | 4.0 | 31 | ------ | ------ | Dirty; only a few animals, mostly worms. |
| | 1-30 | 3.0 | ------ | ------ | ------ | Cleaner than 1 P. M. sample; no animal life. |
| | 2 | 2.8 | | | | |
| | 2-30 | 1.5 | | | | |
| | 3 | 1.5 | 34 | .92 | 16.4 | Normal appearance. |
| 20-4 7 feet of coarse trap. | 1 | 5.0 | 31 | ------ | ------ | Very dirty, rotifers, amoeba, paramecium, and worms. |
| | 1-30 | 3.5 | ------ | ------ | ------ | Cleaner than 1 P. M. sample; same animals. |
| | 2 | 2.8 | ------ | ------ | ------ | Normal affluent; few animals, mostly worms. |
| | 2-30 | 1.5 | | | | |
| | 3 | 1.5 | 34 | .96 | 12.7 | |
| 20-5 4 feet of gravel. | 1 | 1.5 | 31 | ------ | ------ | Very large flakes, only a few paramecium. |
| | 1-30 | 0.8 | ------ | ------ | ------ | Same appearance as 1 P. M. sample, but no animals. |
| | 2 | 1.0 | | | | |
| | 2-30 | 0.8 | | | | |
| | 3 | 0.8 | 34 | 1.00 | 10. | Normal effluent. |
| 20-6 5 feet of fine trap. | 1 | 2.0 | 36 | ------ | ------ | Slightly dirty; no animal life. |
| | 1-30 | 1.5 | | | | |
| | 2 | 1.5 | | | | |
| | 2-30 | 1.2 | | | | |
| | 3 | 1.0 | 34 | .98 | 10.9 | Normal effluent. |

## Table No. 17.

*Condition of Outside Filters Before and After Shut Down December 25.*

| Filter Number. | | 20-1 | 20-2 | 20-3 | 20-4 | 20-5 | 20-6 |
|---|---|---|---|---|---|---|---|
| Million bacteria per cc in effluent | Before | .30 | .42 | .34 | .31 | .83 | .67 |
| | After | .34 | .44 | .37 | .47 | .82 | .32 |
| Percentage bacteria removed | Before | 84.5 | 76.7 | 81.2 | 83. | 51. | 62.9 |
| | After | 88. | 78. | 81.5 | 76.6 | 59. | 84. |
| Nitrates | Before | 2.5 | 2.5 | 3.0 | 2.8 | 2.0 | 2.5 |
| | After | 3.25 | 3. | 3.0 | 3.25 | 2.0 | 3.5 |
| Relative stability | Before | .44 | .45 | .45 | .37 | .25 | .25 |
| | After | .41 | .29 | .37 | .30 | .26 | .26 |

Considerations prevented the sludging of tank No. 10 during December so that the influent to the outside filters was a much stronger sewage than usual, as may be seen in the diagrams.

During this freezing weather, and unusually strong influent, the beds were storing suspended solids, and apparently were unable to oxidize and digest the organic matters; the natural result followed; on December 12th, the fine trap bed (20-6) was noticel to be pooled in places, next the fine lime-stone and slag (20-1 and 20-3) on December 23d; and on the following day, the coarse trap (20-4) was noticed to be in that condition with the slag and fine trap growing markedly worse.

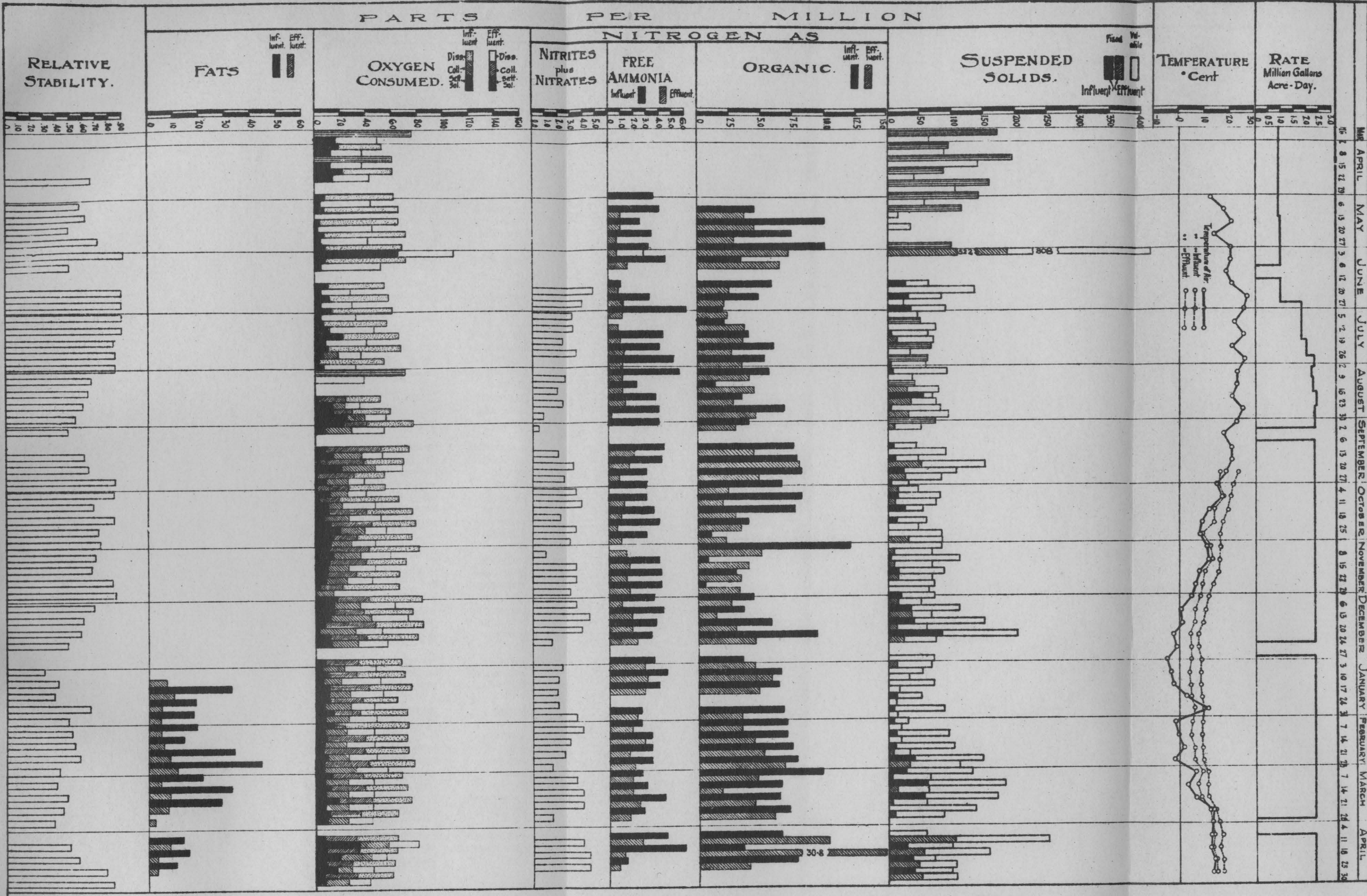
The beds were all shut down from the afternoon of December 24th to the morning of the 27th, during which time a severe snow storm completely covered them; this prevented any possible drying out, and as the snow was melted by the sewage when the beds were started up, it could be seen that 20-3 and 20-6 were pooled as badly as when shut down.

## Table No. 27.

*Analyses of the Effluent of the Outside Sprinkling Filter. No. 20-4—7 Feet of Coarse Trap.*

| Dates. 1909–1910. | PARTS PER MILLION. Suspended Solids. Total. | Suspended Solids. Fixed. | Suspended Solids. Volatile. | Nitrogen as— Organic. | Nitrogen as— Free Amm. | Nitrogen as— Nitrites. | Nitrogen as— Nitrates. | Oxygen Consumed. Total. | Oxygen Consumed. Settling. | Oxygen Consumed. Colloidal. | Oxygen Consumed. Solution. | Turbidity. | Fats. | Relative Stability. | Air Temperature. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| March 26 to April 2 | 64. | | | | | | | 48.8 | 16. | | 32.8 | | | | |
| April 2 to April 8 | 90. | | | | | | | 36.8 | 13.0 | | 23.8 | | | | |
| April 8 to April 15 | 144. | | | | | | | 37.2 | 12.2 | | 2.50 | | | | |
| April 15 to April 22 | 42. | | | | | | | 42.8 | 13.8 | | 29.0 | | | .66 | |
| April 22 to April 29 | 108. | | | | | | | | | | 41.2 | | | | |
| April average | 89.6 | | | | | | | 41.4 | 13.7 | | 27.7 | | | | |
| April 29 to May 6 | 58. | | | | | | | 44.0 | 4.4 | | 39.6 | | | .571 | 12.4 |
| May 6 to May 13 | 17. | | | .37 | 1.0 | | | | | | | | | .625 | 17.6 |
| May 13 to May 20 | 36. | | | 4.5 | 1.0 | | | 44.8 | 2.2 | | 47.6 | | | .485 | 20.4 |
| May 20 to May 27 | | | | 2.88 | 0.72 | | | 42.00 | 4.40 | | 37.60 | | | .723 | 13.7 |
| May 27 to June 3 | 808. | 522. | 286. | 7.20 | 2.80 | | | 109.2 | 64.8 | | 44.4 | | | .920 | 20.1 |
| May average | 230. | | | 4.57 | 1.38 | | | 60. | 18.9 | | 41.1 | | | .661 | 16.8 |
| June 3 to June 5 | | | | 6.48 | 1.52 | | | 52.4 | 5.2 | | 47.2 | | | .500 | 20.0 |
| June 5 to June 12 | | | | | | Shut down. | | | | | | | | | 17.7 |
| June 12 to June 20 | 137. | | | 2.48 | .72 | 4.80 | | 28.0 | 4.8 | | 23.2 | | | .895 | 20.5 |
| June 20 to June 27 | 24. | | | 2.12 | 0.68 | 4.00 | | 28.8 | 4.8 | | 24.0 | | | .900 | 26.6 |
| June 27 to July 5 | 46. | | | 2.40 | 1.20 | 3.20 | | 32.0 | 5.2 | | 26.8 | | | .900 | 25.5 |
| June average | 69. | | | 3.37 | 1.03 | 4.00 | | 35.3 | 5. | | 30.3 | | | .799 | 22.1 |
| July 5 to July 12 | 76. | | | 3.72 | 1.08 | 3.20 | | 47.2 | 12.0 | | 35.2 | | | .90 | 21.9 |
| July 12 to July 19 | 72. | 15. | 57. | 3.60 | 0.80 | 2.40 | | 40.8 | 8.8 | | 32.0 | | | .833 | 25.1 |
| July 19 to July 26 | 34. | | | 2.68 | 1.00 | 3.52 | | 36.0 | 6.8 | 10.8 | 18.4 | | | .845 | 20.7 |
| July 26 to August 2 | 60. | 2. | 58. | 3.52 | 1.28 | | | 32.0 | 7.2 | 24.8 | | | | .853 | 25.6 |
| July average | 60.5 | | | 3.38 | 1.04 | 3.04 | | 39. | 8.7 | | 30.3 | | | .857 | 23.3 |
| August 2 to August 9 | | | | 4.08 | 1.12 | 2.56 | | 39.2 | | 27.2 | | | | .662 | 22.8 |
| August 9 to August 16 | 81. | 30. | 51. | 4.48 | 1.12 | 1.92 | | | | | | | | .635 | 22.8 |
| August 16 to August 23 | 76. | 36. | 40. | 2.80 | 1.10 | 2.40 | | 35.4 | 12.4 | 9.4 | 13.6 | | | .598 | 20.8 |
| August 23 to August 30 | 96. | 32. | 64. | 4.7 | 1.30 | .30 | .45 | 55.4 | 24.2 | 14.4 | 16.8 | | | .537 | 24.9 |
| August 30 to September 2 | 52. | 10. | 42. | 3.0 | .20 | .24 | .25 | 54.0 | 8.4 | 20.4 | 25.2 | | | .48 | 22.4 |
| August average | 76. | 27. | 49. | 3.81 | .97 | 1.62 | | 48.3 | 15. | 14.7 | 18.6 | | | .582 | 22.7 |
| September 2 to September 6 | | | | | | Shut down. | | | | | | | | | 17.2 |
| September 6 to September 13 | 92. | | | 4.4 | 2.0 | .40 | 1.6 | 52.4 | 16.8 | 22.0 | 13.6 | | | .608 | 20.3 |
| September 13 to September 20 | 153. | 53. | 100. | 8.0 | 1.6 | .24 | 3.0 | 68.4 | 21.2 | 26.0 | 21.2 | | | .637 | 20.5 |
| September 20 to September 27 | 84. | 28. | 56. | 4.8 | .80 | .20 | 2.3 | 38.2 | 9.4 | 17.2 | 11.6 | | | .85 | 18.4 |
| September 27 to October 4 | 48. | 16. | 32. | 2.4 | | .18 | 3.3 | 39.6 | 11.2 | 13.6 | 14.8 | | | .836 | 14.8 |
| September average | 95. | 32. | 63. | 4.9 | 1.1 | .255 | 2.55 | 49.7 | 14.7 | 19.7 | 15.3 | | | .733 | 18.2 |
| October 4 to October 11 | 76. | 10. | 66. | 2.0 | 1.2 | .15 | 3.8 | 46.8 | 10.0 | 10.8 | 26.0 | | | .681 | 16.8 |
| October 11 to October 18 | | | | 3.0 | 1.0 | .18 | 2.0 | 51.2 | 6.4 | 19.6 | 25.2 | | | .84 | 11.5 |
| October 18 to October 25 | | | | 3.4 | .60 | .26 | 3.2 | 56.0 | 20.0 | 19.2 | 16.8 | | | .722 | 8.9 |
| October 25 to November 1 | 86. | 32. | 54. | 2.2 | 1.0 | .26 | 2.7 | 47.2 | 12.4 | 15.6 | 19.2 | | | .729 | 8.0 |
| October average | 81. | 21. | 60. | 2.7 | .95 | .21 | 2.9 | 50.3 | 12.2 | 16.3 | 21.8 | | | .743 | 11.3 |
| November 1 to November 8 | 68. | 8. | 60. | 5.0 | 1.4 | .25 | .75 | 58.0 | 14.4 | 21.2 | 22.4 | | | .688 | 10.8 |
| November 8 to November 15 | 68. | 8. | 60. | 4.0 | 1.6 | .35 | 3.15 | 46.4 | 9.6 | 16.8 | 20.0 | | | .664 | 11.1 |
| November 15 to November 22 | 68. | 16. | 52. | 3.4 | 1.4 | .40 | 3.10 | 44.8 | 8.4 | 16.4 | 20.0 | | | .830 | 7.8 |
| November 22 to November 29 | 64. | 0. | 64. | 3.2 | 1.6 | .30 | 2.70 | 46.0 | 0.0 | 13.6 | 32.4 | | | .847 | 6.1 |
| November average | 67. | 8. | 59. | 3.9 | 1.5 | .325 | 2.43 | 48.8 | 8.1 | 17. | 23.7 | | | .757 | 8.95 |
| November 29 to December 6 | 52. | 16. | 36. | 2.6 | 1.0 | .35 | 3.1 | 62.0 | 15.2 | 21.2 | 25.6 | | | .677 | 4.5 |
| December 6 to December 13 | 68. | 36. | 32. | 1.4 | 1.8 | .30 | 4.2 | 72.4 | 12.4 | 31.6 | 28.4 | | | .595 | 0.1 |
| December 13 to December 20 | 60. | 12. | 48. | 3.0 | 1.8 | .22 | 3.7 | 52.0 | 3.2 | 27.6 | 21.2 | 120. | | .581 | 1.0 |
| December 20 to December 24 | 76. | 24. | 52. | 4.6 | 2.2 | .20 | 1.3 | 56.4 | 11.6 | 21.2 | 23.6 | 130. | | .482 | —2.5 |
| December 24 to December 27 | | | | | | | Station shut down. | | | | | | | | |
| December 27 to January 3 | 68. | 12. | 56. | 4.4 | 2.8 | .20 | 2.1 | 47.2 | 5.2 | 17.6 | 24.4 | 130. | | .288 | —5.1 |
| December average | 81. | 25 | 56. | 3.2 | 1.9 | .25 | 2.9 | 58. | 9.5 | 23.9 | 24.6 | 127. | | .524 | —0.4 |
| January 3 to January 10 | 32. | 0. | 32. | 5.8 | 3.0 | .20 | 1.8 | 51.2 | 6.4 | 14.0 | 10.8 | 110. | 14.0 | .405 | —3.4 |
| January 10 to January 17 | 16. | 0. | 16. | 4.8 | 2.8 | .25 | 1.7 | 52.8 | 10.8 | 15.6 | 26.4 | 85. | 19.6 | .371 | —2.7 |
| January 17 to January 24 | 12. | 0. | 12. | 6.0 | | .32 | 1.7 | 46.4 | 7.2 | 21.2 | 18.0 | 140. | 10.4 | .655 | 2.6 |
| January 24 to January 31 | 14. | 0. | 14. | 3.4 | 2.2 | .40 | 3.1 | 48.0 | 7.6 | 18.0 | 22.4 | 65. | 9.0 | .480 | 11.2 |
| January average | 18.5 | 0. | 18.5 | | | .292 | 2.1 | 49.6 | 8. | 17.2 | 24.4 | 100. | 10.8 | .478 | 1.7 |
| January 31 to February 7 | 20. | 0. | 20. | 3.4 | 1.8 | .40 | 3.6 | 46.0 | 6.4 | 18.4 | 21.2 | 65. | 10.2 | .511 | —2.0 |
| February 7 to February 14 | 20. | 0. | 20. | 4.4 | 2.8 | .45 | 2.5 | 46.0 | 6.8 | 16.8 | 22.4 | 80. | 11.6 | .533 | —0.8 |
| February 14 to February 21 | 36. | 6. | 30. | 5.2 | 1.6 | 0.30 | 2.2 | 48.0 | 9.6 | 15.6 | 22.8 | 80. | 17.0 | .573 | 1.8 |
| February 21 to February 28 | 112. | 32. | 80. | 6.8 | 2.0 | .30 | 1.2 | 56.0 | 6.8 | 24.8 | 24.4 | 165. | 22.6 | .414 | —2.2 |
| February average | 47. | 9.5 | 37.5 | 4.95 | 2.05 | .36 | 2.4 | 49. | 7.4 | 18.9 | 22.7 | 97.5 | 15.4 | .508 | —0.8 |
| February 28 to March 7 | 66. | 4. | 62. | 4.6 | 1.8 | .30 | 3.2 | 45.6 | 8.4 | 18.0 | 19.2 | 100. | 9.6 | .389 | 6.2 |
| March 7 to March 14 | 64. | 14. | 50. | 1.8 | 1.8 | .40 | 3.6 | 45.6 | 7.6 | 18.0 | 20.0 | 100. | 16.8 | .474 | 3.1 |
| March 14 to March 21 | 60. | 4. | 56. | 4.4 | 2.4 | .45 | 3.5 | 44.8 | 10.8 | 16.4 | 17.6 | 105. | 15.2 | .441 | 6.5 |
| March 21 to March 28 | 88. | 10. | 78. | 6.0 | 1.6 | .45 | 1.05 | 44.4 | 10.4 | 15.6 | 18.4 | | 5.4 | .370 | 13.4 |
| March 28 to April 4 | | | | | | | Station shut down. | | | | | | | | |
| March average | 69.5 | 8. | 61.5 | 4.2 | 1.9 | .40 | 2.84 | 45.1 | 9.3 | 17. | 18.8 | 102. | 11.8 | .418 | 7.5 |
| April 4 to April 11 | 254. | 106. | 148. | 10.2 | 2.6 | .80 | 3.2 | 80.0 | 35.2 | 21.6 | 23.2 | 340. | 16.8 | .490 | 12.3 |
| April 11 to April 18 | 160. | 56. | 104. | 30.8 | 1.2 | .40 | 4.1 | 55.2 | 19.2 | 24.4 | 11.6 | 130. | 7.0 | .568 | 12.2 |
| April 18 to April 25 | 104. | 48. | 56. | 4.0 | 0.8 | .30 | 4.2 | 45.2 | 17.2 | 10.8 | 17.2 | 95. | 7.2 | .782 | 13.9 |
| April 25 to April 30 | 108. | 52. | 56. | | | | | 42.8 | 7.2 | 18.0 | 17.6 | 130. | | .833 | 13.2 |
| April average | 157. | 66. | 91. | 15. | 1.5 | .50 | 3.8 | 55.6 | 19.7 | 18.5 | 17.4 | 174. | 10.3 | .668 | 13.1 |

# DIAGRAM NO. 18




SPRINKLING FILTER NO. 20-4

6

## Table No. 18.

*Suspended Solid Data For Outside Filters.*

| Period of Observation. 1909—1910. | Suspended Solids in Parts per Million. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Effluents. | | | | | | | | | | | |
| | | | Fine Lime. 20-1. | | Coarse Lime. 20-2. | | Slag. 20-3. | | Coarse Trap. 20-4. | | Gravel. 20-5. | | Fine Trap. 20-6. | |
| | Crude. | Influent. | Effluent. | Stored Up. | Effluent. | Stored Up. | Effluent. | Stored Up. | Effluent. | Stored Up. | Effluent. | Stored Up. | Effluent. | Stored Up |
| November 29 to December 6 | 140 | 72 | 72 | 0 | 96 | —24 | 76 | —4 | 52 | 20 | 64 | 8 | 64 | 8 |
| December 6 to December 13 | 192 | 112 | 68 | 44 | 104 | 8 | 100 | 12 | 68 | 44 | 100 | 12 | 56 | 56 |
| December 13 to December 20 | 260 | 152 | 80 | 72 | 80 | 72 | 80 | 72 | 60 | 92 | 56 | 96 | 36 | 116 |
| December 20 to December 24 | 208 | 204 | 48 | 156 | 64 | 140 | 52 | 152 | 76 | 128 | 48 | 156 | 80 | 124 |
| December 25 and December 26 | Shut | down. | | | | | | | | | | | | |
| December 27 to January 3 | 200 | 72 | 56 | 16 | 44 | 28 | 64 | 8 | 68 | 4 | 32 | 40 | 48 | 24 |
| Total amount stored | ------- | ------- | ------- | 288 | ------- | 224 | ------- | 240 | ------- | 228 | ------- | 312 | ------- | 328 |

The storing up of suspended solids during December is shown in Table No. 18 and it is natural to expect that the extent of pooling would be proportionate to the quantity of matter retained in the filter.

| Order of Beds as Regards Extent of Pooling. | Pounds of Suspended Solids Stored During the Month. |
|---|---|
| 5 feet fine trap, 20-6 | 373 |
| 4 feet fine trap, 20-5 | 354 |
| 6 feet slag, 20-3 | 260 |
| 8 feet fine limestone, 20-1 | 310 |
| 7 feet coarse trap, 20-4 | 246 |
| 9 feet coarse limestone, 20-2 | 242 |

An examination of the condition of the media was now made with the following results:

"20-1. Bed considerably sludged up with a grey deposit; a peculiar condition noted is, that it does not completely bridge the stones and some stones are fairly clean, in a few places knots of the usual larvae.

20-2. This bed is in but little worse condition than in the summer, except that the larvae and flies are much less in number. The large stones completely bridge voids, so that the sludging up cannot prevent large air spaces, which appeared to be connected and afford means of ventilating the media.

20-3. The bed is badly sludged up with a black deposit adhering tightly to the rough, porous slag and in places completely filling the voids. Almost no larvae and but a few flies. In a pit 15 inches deep and 6 inches diameter four broken pieces of slag were found showing the effect of frost.

20-4. Badly sludged up with a black deposit which in some places completely fills the voids, but in other places

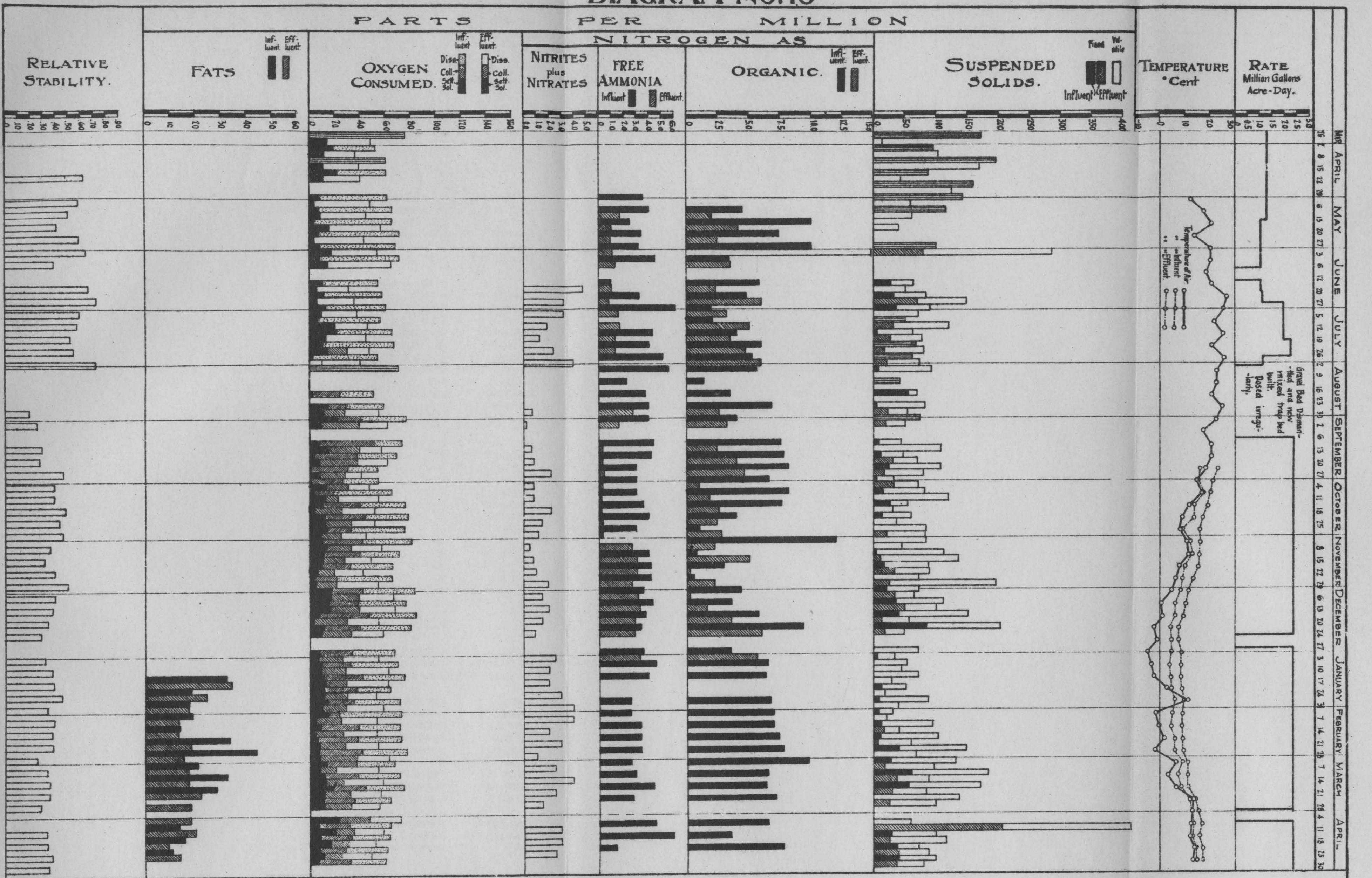
## Table No. 28.

*Analyses of the Effluent of the Outside Sprinkling Filter. No. 20-5=4 Feet of Gravel.*

PARTS PER MILLION.

| Dates. 1909-1910. | Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | | Turbidity. | Fats. | Relative Stability. | Air Temperature. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total. | Fixed. | Volatile. | Organic. | Free Amm. | Nitrites. | Nitrates. | Total. | Settling. | Colloidal. | Solution. | | | | |
| March 26 to April 2 | 142. | | | | | | | 47.8 | 14. | | 33.8 | | | | |
| April 2 to April 8 | 103. | | | | | | | 36. | 11.2 | | 24.8 | | | | |
| April 8 to April 15 | 168. | | | | | | | 38.8 | 11. | | 27.8 | | | | |
| April 15 to April 22 | 43. | | | | | | | 40. | 10.8 | | 29.2 | | | .62 | |
| April 22 to April 29 | 125. | | | | | | | | | | 41.6 | | | | |
| April average | 116. | | | | | | | 40.6 | 11.7 | | 28.9 | | | | |
| April 29 to May 6 | 60. | | | | | | | 47.6 | 4.4 | | 43.2 | | | .575 | 12.4 |
| May 6 to May 13 | 62. | | | 2. | 1.7 | | | 45.2 | 8.8 | | 36.4 | | | .495 | 17.6 |
| May 13 to May 20 | 40. | | | 4.2 | 1. | | | 57.2 | 16.4 | | 40.8 | | | .412 | 20.4 |
| May 20 to May 27 | | | | 2.44 | .96 | | | 43.20 | 3.60 | | 39.60 | | | .588 | 13.7 |
| May 27 to June 3 | 286. | 78. | 208. | 14.88 | 1.12 | | | 54.40 | 18.40 | | 36.00 | | | .64 | 20.1 |
| May average | 112. | | | 5.88 | 1.19 | | | 49.5 | 10.3 | | 39.2 | | | .542 | 16.8 |
| June 3 to June 6 | | | | | | | | 64.80 | 15.2 | | 49.60 | | | .38 | 20. |
| June 6 to June 12 | | | | | | | Shut | down. | | | | | | | 17.7 |
| June 12 to June 20 | 51. | | | 2.20 | 1.00 | | 4.80 | 32.0 | 6.0 | | 26.0 | | | .657 | 20.5 |
| June 20 to June 27 | 150. | 70. | 80. | 6.00 | .80 | | 3.20 | 36.0 | 6.0 | | 30.0 | | | .72 | 26.6 |
| June 28 to July 5 | 72. | | | 3.20 | 1.60 | | 3.20 | 38.4 | 9.2 | | 29.2 | | | .59 | 25.5 |
| June average | 91. | | | 3.8 | 1.13 | | 3.73 | 42.8 | 9.1 | | 33.7 | | | .587 | 22.1 |
| July 5 to July 12 | 120. | 30. | 90. | 5.04 | 1.76 | | 1.92 | 46.0 | 19.6 | | 26.4 | | | .57 | 21.9 |
| July 12 to July 19 | 77. | 25. | 52. | 3.52 | 1.28 | | 1.28 | 45.2 | 11.6 | | 33.6 | | | .52 | 25.1 |
| July 19 to July 26 | 80. | 17. | 63. | 4.72 | 1.28 | | 2.40 | 47.2 | 14.4 | 16.0 | 16.8 | | | .54 | 20.7 |
| July 26 to August 2 | 74. | 19. | 55. | 6.12 | | | 4.00 | 40.0 | 10. | | 30.0 | | | .71 | 25.6 |
| July average | 88. | 21. | 65. | 4.85 | 1.44 | | 2.40 | | | | | | | .585 | 23.3 |
| August 2 to August 9 | | | | | | Gravel | bed dism | antled; ne | w trap be | d built | | | | | 22.8 |
| August 9 to August 16 | | | | | | | | | | | | | | | 22.8 |
| August 16 to August 23 | | | | | | | | | | | | | | | 20.8 |
| August 23 to August 30 | 54. | 22. | 32. | 2.5 | 2.7 | .20 | .50 | 55.0 | 11.4 | 16.8 | 26.8 | | | .19 | 24.9 |
| August 30 to September 2 | 50. | 18. | 32. | 3.2 | 1.6 | .14 | .10 | 62.4 | 8.8 | 30.0 | 23.6 | | | .25 | 22.4 |
| August average | 52. | 20. | 32. | 2.85 | 2.15 | .17 | .30 | 58.7 | 10.1 | 23.4 | 25.2 | | | .22 | 22.7 |
| September 2 to September 6 | | | | | | | Shut | down. | | | | | | | 17.2 |
| September 6 to September 13 | | | | 2.4 | 2.4 | .28 | .32 | 56.8 | 14. | 26. | 16.8 | | | .29 | 20.3 |
| September 14 to September 20 | 70. | 30. | 40. | 4.0 | 3. | .26 | .5 | 61.2 | 7.2 | 30. | 24. | | | .27 | 20.5 |
| September 20 to September 27 | 80. | 16. | 64. | 4.6 | 1.8 | .35 | 1.85 | 41.2 | 8. | 19.6 | 13.6 | | | .46 | 18.4 |
| September 27 to October 4 | 72. | 32. | 40. | 1.00 | 1.4 | .28 | .52 | 47.2 | 13.2 | 18. | 16. | | | .39 | 14.8 |
| September average | 74. | 26. | 48. | 3.0 | 2.15 | .29 | .798 | 51.6 | 10.6 | 23.4 | 17.6 | | | .35 | 18.2 |
| October 4 to October 11 | 118. | | | 1.8 | 2.2 | .20 | .6 | 54.4 | 12. | 9.6 | 32.8 | | | .38 | 16.8 |
| October 11 to October 18 | 30. | | | 2.6 | 1.4 | .20 | 2.0 | 51.2 | 3.2 | 22.0 | 26.0 | | | .47 | 11.5 |
| October 18 to October 25 | 36. | | | 2.4 | 1.6 | .24 | 1.2 | 52. | 11.6 | 20.8 | 19.6 | | | .43 | 8.9 |
| October 25 to November 1 | 84. | 20. | 64. | 2.8 | 2. | .24 | .96 | 44.4 | 8.4 | 16. | 20. | | | .46 | 8.0 |
| October average | 67. | | | 2.4 | 1.8 | .22 | 1.19 | 50.5 | 8.8 | 17.1 | 24.6 | | | .435 | 11.3 |
| November 1 to November 8 | 44. | 0 | 44. | 2.2 | 2.6 | .20 | .30 | 57.6 | 12.8 | 20.4 | 24.4 | | | .35 | 10.8 |
| November 8 to November 15 | 136. | 8. | 128. | 5. | 3. | .25 | .55 | 48.4 | 10.0 | 16.8 | 21.6 | | | .31 | 11.1 |
| November 15 to November 22 | 88. | 32. | 56. | .2 | 3. | .30 | .7 | 42.4 | 5.6 | 18.0 | 18.8 | | | .39 | 7.8 |
| November 22 to November 29 | 196. | 24. | 172. | 2.2 | 2.6 | .30 | 1.7 | 53.6 | 5.2 | 16.8 | 31.6 | | | .59 | 6.1 |
| November average | 116. | 16. | 100. | 2.4 | 2.8 | .26 | .81 | 50.5 | 8.4 | 18. | 24.1 | | | .41 | 8.95 |
| November 29 to December 6 | 64. | 32. | 32. | .2 | 3. | .30 | 1.2 | 66. | 16. | 22. | 28. | | | .39 | 4.5 |
| December 6 to December 13 | 100. | 48. | 52. | 1.6 | 3.2 | .25 | 1.7 | 67.6 | 16. | 21.6 | 30. | | | .37 | 0.1 |
| December 13 to December 20 | 56. | 12. | 44. | 2.6 | 2.8 | .20 | 1.3 | 54. | 2. | 26.4 | 25.6 | 150. | | .34 | 1.0 |
| December 20 to December 24 | 48. | 16. | 32. | 6.0 | 2.8 | .20 | .7 | 58.8 | 8.8 | 22.0 | 28.0 | 160. | | .28 | —2.5 |
| December 24 to December 27 | | | | | | | Beds r | esting. | | | | | | | |
| December 27 to January 3 | 32. | 4. | 28. | 5.6 | 3.2 | .20 | 2.3 | 54.4 | 6.4 | 19.2 | 28.8 | 160. | | .31 | —5.1 |
| December average | 60. | 22. | 38. | 3.4 | 3.0 | .27 | 1.6 | 60.1 | 9.8 | 22.2 | 28.1 | 157. | | .34 | —0.4 |
| January 3 to January 10 | 44. | 0 | 44. | | | | 2. | 62. | 9.2 | 18.8 | 34. | 110. | 34.4 | .37 | —3.4 |
| January 10 to January 17 | 28. | 0 | 28. | | | | 2. | 62. | 12.4 | 17.2 | 32.4 | 110. | 24.4 | .38 | —2.7 |
| January 17 to January 24 | 16. | 0 | 16. | | | | 3. | 52.4 | 10.8 | 17.6 | 24. | 190. | 17.2 | .45 | 2.6 |
| January 24 to January 31 | 40. | 0 | 40. | | | | 4. | 57.6 | 10. | 19.2 | 28.4 | 110. | 13.4 | .33 | 11.2 |
| January average | 32. | 0 | 32. | | | | 2.75 | 58.5 | 10.6 | 18.2 | 29.7 | 130. | 22.4 | .38 | 1.7 |
| January 31 to February 7 | 20. | 0 | 20. | | | | 4. | 52.8 | 5.2 | 19.6 | 28. | 95. | 13.2 | .38 | —2.0 |
| February 7 to February 14 | 40. | 16. | 24. | | | | 2.0 | 52.8 | 4.4 | 22.4 | 26. | 100. | 18.2 | .37 | —0.8 |
| February 14 to February 21 | 60. | 4. | 56. | | | | 3.0 | 54. | 8. | 19.6 | 26.4 | 100. | 14.6 | .38 | 1.8 |
| February 21 to February 28 | 68. | 0 | 68. | | | | 1.0 | 62.4 | 7.6 | 29.2 | 25.6 | 190. | 17.4 | .25 | —2.2 |
| February average | 47. | 5. | 42. | | | | 2.5 | 55.5 | 6.3 | 22.7 | 26.5 | 121. | 15.9 | .345 | —0.8 |
| February 28 to March 7 | 96. | 16. | 80. | | | | 2.5 | 53.6 | 7.6 | 12.4 | 23.6 | 150. | 16.8 | .33 | 6.2 |
| March 7 to March 14 | 88. | 36. | 52. | | | | 4. | 56.8 | 12. | 14. | 30.8 | 160. | 22.2 | .35 | 3.1 |
| March 14 to March 21 | 84. | 28. | 56. | | | | 2.5 | 56. | 11.2 | 21.2 | 23.6 | 150. | 17.6 | .35 | 6.5 |
| March 21 to March 28 | 100. | 24. | 76. | | | | 1.5 | 55.2 | 11.6 | 21.2 | 22.4 | | 18. | .28 | 13.4 |
| March 28 to April 4 | | | | | | | Stati | on shut d own. | | | | | | | |
| March average | 92. | 26. | 66. | | | | 2.6 | 55.4 | 10.6 | 17.2 | 27.6 | 115. | 18.7 | .33 | 7.5 |
| April 4 to April 11 | 412. | 204. | 208. | | | .7 | 2.3 | 72.4 | 22.8 | 24.4 | 25.2 | 240. | 19.6 | .32 | 12.3 |
| April 11 to April 18 | 116. | 24. | 92. | | | | 3.0 | 57.6 | 19.6 | 14.8 | 23.2 | 130. | 9.2 | .33 | 12.2 |
| April 18 to April 25 | 88. | 40. | 48. | | | .45 | 1.6 | 52.4 | 16. | 14.4 | 22.0 | 95. | 14.0 | .37 | 13.9 |
| April 25 to April 30 | 80. | 36. | 44. | | | | | 48. | 11.2 | 14.4 | 22.4 | 120. | | .34 | 13.2 |
| April average | 174. | 76. | 98. | | | .58 | 2.3 | 57.6 | 17.4 | 17. | 23.2 | 146. | 14.3 | .34 | 13.1 |

DIAGRAM NO. 19




SPRINKLING FILTER NO. 20 - 5

stones are sufficiently clean to show original surface with large numbers of worms in knots, as in summer.

20-5. The surface of the gravel is perfectly clean, but between the upper stones and the ones they rest upon is a layer of material which resembles a mat of wool fibres encased in the usual bacterial jelly. This is so tenacious that when wet it can be picked up by one corner and removed from the bed intact in large strips. These mats must have seriously decreased the surface aeration of the bed.

20-6. This bed is in the worst condition of any, the voids being so completely filled with the black deposit that upon digging the observation hole entrained water oozed from the sides and formed a pool in the bottom of the hole, almost no worms or flies found.''

The deposit upon the stones in the upper foot of media was removed and subjected to the same analyses as a sludge sample. Results shown in Table No. 19.

TABLE No. 19.

*Analysis of Deposit in the Sprinkling Filters.*

| Source. Bed Number. | Percentage of Water in the Wet Sludge. | Percentage of the Dry Residue That Is— | | | |
|---|---|---|---|---|---|
| | | Volatile. | Fixed. | Nitrogen. | Fats. |
| 20-1 | 85.9 | 48. | 52. | 2.3 | 6.9 |
| 20-2 | 83.8 | 45.7 | 54.3 | 2.0 | 5.6 |
| 20-3 | 84.7 | 43. | 57. | 1.8 | 4.6 |
| 20-4 | 86.9 | 47. | 53. | 2.3 | 5.0 |
| 20-5 | 78.2 | 30.4 | 69.6 | 0.6 | 2.6 |
| 20-6 | 85.8 | 42.1 | 57.9 | 2.2 | 3.9 |
| Average, omitting 20-5 | 85.3 | 45.2 | 54.8 | 2.1 | 5.2 |

As applied to bed 20-6 this analysis indicates a storage of 338 pounds of dry solids in the upper foot of media.

Typical sludge from sedimentation basins is shown in Table No. 59. This comparison shows the similarity of the deposit to ordinary sludge, but it differed in being inoffensive, the odor being similar to that from slate bed deposit.

The effluents produced by the outside filters during December, under the conditions just described, of high suspended solids applied during freezing weather, were not satisfactory; however, it must be borne in mind that no effort was made to operate the beds in the most desirable manner, but rather to test them to destruction, and then find ways and means to restore them to a normal condition.

On January 1, 1910, the appearance of the filters was perfectly normal, the upper surface of the media was covered with the usual grey bacterial film, 20-2 and 20-5 entirely free from pooling, 20-1, 3 and 4 showed slight evidence of pooling, and 20-6 was considerably pooled.

The following morning bed number 20-6 had a very luxurious growth upon the surface of the media, pink in color, gelatinous in appearance, and adhering tightly to the surface of the stones; to a less degree beds numbered 20-1, 3 and 4 were similarly affected; bed number 20-2 very slightly, and the smooth gravel cover of 20-5 free from it.

Specimens of the growth were submitted to Dr. D. H. Bergey at the University of Pennsylvania, who obtained the growth in pure culture and concluded that it was an intermediate between the "moulds" and "yeast," being closely related to but not identical with "Fusarium aqueductum" described in Saccardo's "Sylloge Fungorum," Vol. X, page 728. A very similar growth developed upon the filters at the Waterbury Experiment Station, and was described in Engineering News, Vol. LVI, page 459. Apparently the only difference between the two organisms, the one observed on the Philadelphia beds and that at Waterbury, was that the gonoidal bodies of the growth at Waterbury were "small oval bodies which were at-

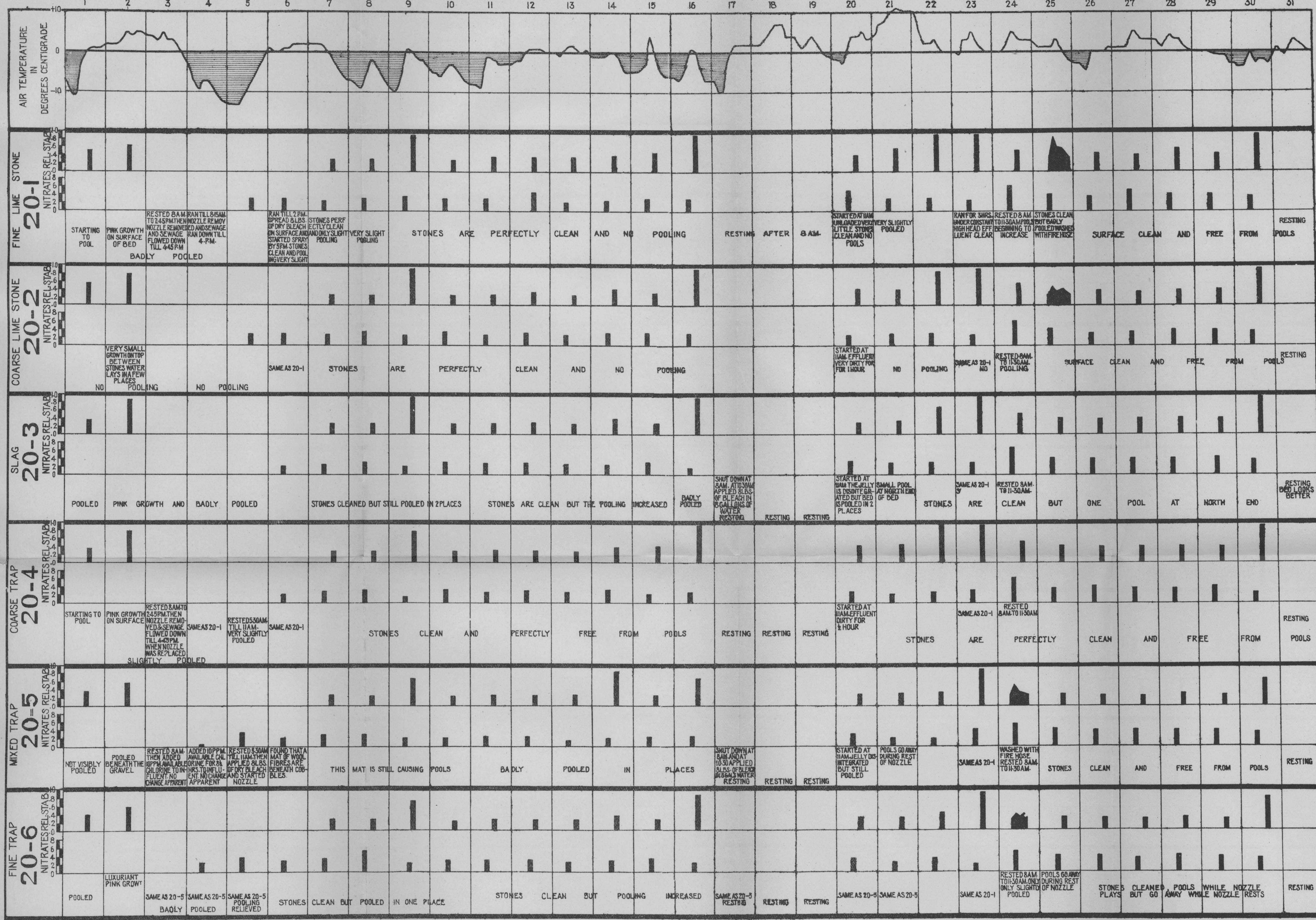



DIAGRAM No 13
SHOWING THE CONDITION AND TREATMENT GIVEN TO THE OUTSIDE SPRINKLING FILTERS DURING JANUARY 1910

tached end to end, a single 'sausage chain,' 30 or 40 of them,'' whereas the growth upon the Philadelphia filters had fruiting bodies which were crescent shaped.

It may be interesting to note that similar growths have appeared at other places.

The Royal Commission on Sewage Disposal of Great Britain in their Fifth Report on page 96, et seq., give some data on ''Growths on Percolating Filters.'' Among the instances cited by it two seem similar to the condition described above. The percolating filters at Dorking are composed of coarse to medium clinker and the precipitation liquor is continuously distributed by sprinklers. ''The filters were started on November 16, 1905, and a pinkish-yellow filamentous growth made its appearance a fortnight later. This flourished until May of the following year, when it dried away. During the last five weeks of this period the effluent from the filter was bad.''

With the same type works at Kingston it is stated ''A short-fibred grey growth appears annually on the surface of the filter, commencing about November and drying off in March.

''In the winter months it forms an almost impervious mat on the surface of the filter, the effluent becoming bad in consequence.'' On page 99 it is stated that ''As the use of percolating filters is likely to spread in the future we are impressed with the need for practical experiments which have for their object either the prevention or the destruction of the growths on the surface of such filters.''

In March, 1907, the Commission experimented with seven chemicals on a filter at Dorking covered with such growths, among which bleaching powder was tried. ''Sufficient of the dry solid was used to cover the surface with a fine layer of powder,'' and to quote further ''* * * the working of the filter was not seriously upset.''

In the Fortieth Annual Report of the State Board of Health of Massachusetts (1908) on page 362 there is reported the effect of adding bleaching powder to the influent of an intermittent sand filter and the conclusion is—

"These experiments show that, if necessary, sewage may be sterilized by chlorine added as bleaching powder without affecting its subsequent purification by intermittent sand or by trickling filters."

Dr. S. Rideal in February, 1909, read a paper on the "Application of Electrolytic Chlorine to Sewage Purification, etc.," reported in Engineering of February 12, 1909, He says that the addition of chlorine to the influent to a filter "* * * did not interfere with the filter efficiency; in fact, it rather added to it by keeping down the grey growth on the top of the filter. That a much larger quantity of oxychloride (up to 8 or even 20 parts per 100,000 of available chlorine) might, indeed, safely be added." Also "* * * and that beds clogged up with growths, internally or on the surface, could be washed and restored by applying occasional doses of oxychlorides, thus preventing or delaying sludging up and the nuisance caused by excessive quantities of solids passing away."

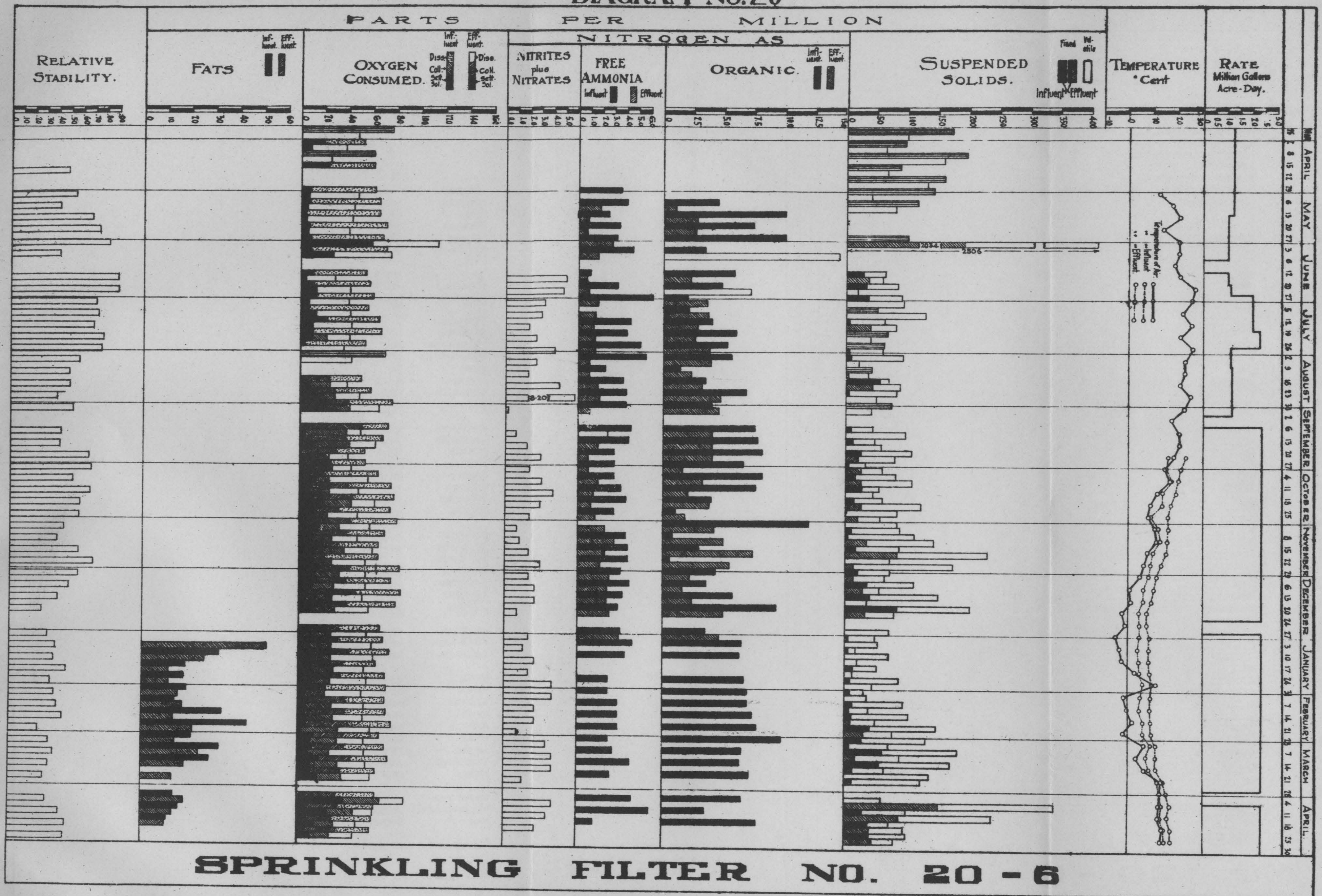
The daily history of the outside filters during January is shown on diagram No. 13. The conditions existing and methods used to remedy them with results accomplished are as follows: A solution of hypochlorite of calcium was added by hand to the dosing tank in amounts of 10 parts per million available chlorine for 17 hours on two days, to kill the pink growth and to relieve the rapidly developing pooled condition. During the time the nozzles were removed from the four higher beds, the influent was allowed to pour down through the media adjacent to the position occupied by the nozzle and no samples were taken of the effluent from those beds; a slight diminution in the growth on 20-6 was noted. On January 5th, 16 pounds of dry bleaching powder was evenly distributed over the surface of beds 20-5 and 6 (equals two tons per acre) and at once the influent was applied as usual; the first effluent smelt strongly of the bleach, and samples collected at half-hour intervals were examined for residual chlorine with the following results:

TABLE No. 29.

*Analyses of the Effluent of the Outside Sprinkling Filter. No. 20-6=5 Feet of Fine Trap.*

| Dates. 1909-1910. | PARTS PER MILLION. Suspended Solids. Total. | Fixed. | Volatile. | Nitrogen as— Organic. | Free Amm. | Nitrites. | Nitrates. | Oxygen Consumed. Total. | Settling. | Colloidal. | Solution. | Turbidity. | Fats. | Relative Stability. | Air Temperature. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| March 26 to April 2 | 98. | | | | | | | 47.4 | | | | | | | |
| April 2 to April 8 | 64. | | | | | | | 37.0 | | | | | | | |
| April 8 to April 15 | 160. | | | | | | | 25.2 | | | | | | | |
| April 15 to April 22 | 67. | | | | | | | | | | | | | .483 | |
| April 22 to April 29 | 132. | | | | | | | | | | | | | | |
| April average | 104. | | | | | | | | | | | | | | |
| April 29 to May 6 | 40. | | | | | | | 47.2 | 7.2 | | 40.0 | | | .541 | 12.4 |
| May 6 to May 13 | 79. | | | 1.0 | 1.8 | | | 43.6 | 5.2 | | 38.4 | | | .414 | 17.6 |
| May 13 to May 20 | 100. | | | 2.8 | 0.8 | | | 42.8 | 4.2 | | 38.6 | | | .677 | 20.4 |
| May 20 to May 27 | 100. | | | 2.68 | 0.72 | | | 40.4 | 6.0 | | 34.4 | | | .735 | 13.7 |
| May 27 to June 3 | 2506. | 2034. | 472. | | 2.8 | | | 113.60 | 59.2 | | 54.4 | | | .823 | 20.1 |
| May average | 600. | | | 2.16 | 1.53 | | | 57.6 | 16.4 | | 41.2 | | | .638 | 16.8 |
| June 3 to June 5 | | | | 14.4 | 1.60 | | | 74.8 | 26.8 | | 48.0 | | | .41 | 20.0 |
| June 5 to June 12 | | | | | | | Station shut down. | | | | | | | | |
| June 12 to June 20 | 58. | 36. | 22. | 2.2 | .60 | 5. | 12 | 28.4 | 3.6 | | 24.8 | | | .90 | 20.5 |
| June 20 to June 27 | 17. | | | 7.2 | .80 | 4. | 80 | 41.2 | 12.8 | | 28.4 | | | .90 | 26.6 |
| June 27 to July 5 | 94. | | | 3.60 | 1.60 | 3. | 20 | 39.6 | 7.2 | | 32.4 | | | .71 | 25.5 |
| June average | 56. | | | 6.85 | 1.15 | 4. | 28 | 61.3 | 16.8 | | 44.5 | | | .73 | 22.1 |
| July 5 to July 12 | 130. | | | 3.36 | 1.44 | 3. | 04 | 41.2 | 12.8 | | 28.4 | | | .73 | 21.9 |
| July 12 to July 19 | 80. | 38. | 42. | 2.8 | 1.20 | 1. | 92 | 42.4 | 10.4 | | 32.0 | | | .69 | 25.1 |
| July 19 to July 26 | 39. | | | 2.72 | 1.28 | 2. | 56 | 41.6 | 10.4 | 12.0 | 19.2 | | | .77 | 20.7 |
| July 26 to August 2 | 60. | 4. | 56. | 3.84 | 1.36 | 4. | 16 | 35.6 | | 28. | 8 | | | .76 | 25.6 |
| July average | 77. | | | 3.18 | 1.32 | 2. | 92 | | | | | | | .74 | 23.3 |
| August 2 to August 9 | 19. | | | 3.92 | .88 | 2. | 56 | 42.4 | | 28. | 8 | | | .57 | 22.8 |
| August 9 to August 16 | 36. | 2. | 34. | 2.32 | .88 | 1. | 92 | | | | | | | .49 | 22.8 |
| August 16 to August 23 | 89. | 43. | 46. | 3.2 | 1.6 | 4. | 50 | 38.8 | 7.6 | 16.6 | 14.6 | | | .49 | 20.8 |
| August 23 to August 30 | 49. | | | 4.7 | 1.7 | .20 | 8.0 | 49.0 | 12.2 | 17.2 | 19.6 | | | .39 | 24.9 |
| August 30 to September 2 | 42. | | | 4.6 | 1.0 | .10 | .10 | 66.4 | 18.0 | 22.8 | 25.6 | | | .52 | 22.4 |
| August average | 47. | | | 3.75 | 1.21 | | | | | | | | | .49 | 22.7 |
| September 2 to September 6 | | | | | | | Station shut down. | | | | | | | | 17.2 |
| September 6 to September 13 | 96. | | | 4.0 | 2.4 | .20 | .65 | 50.0 | 3.6 | 33.6 | 12.8 | | | .42 | 20.3 |
| September 13 to September 20 | 57. | | | 4.0 | 1.6 | .16 | 1.60 | 62.8 | 11.2 | 29.6 | 22.0 | | | .41 | 20.5 |
| September 20 to September 27 | 80. | 20. | 60. | 4.0 | .80 | .20 | 2.80 | 40.0 | 10.8 | 14.8 | 14.4 | | | .65 | 18.4 |
| September 27 to October 4 | 60. | 24. | 36. | 1.6 | .80 | .18 | 1.8 | 41.6 | 10.0 | 17.2 | 14.4 | | | .67 | 14.8 |
| September average | | | | 3.4 | 1.4 | .185 | 1.71 | 48.6 | 8.9 | 23.8 | 15.9 | | | .54 | 18.2 |
| October 4 to October 11 | 108. | 24. | 84. | 3.2 | 1.6 | .15 | 3.0 | 56.4 | 13.2 | 10.8 | 32.4 | | | .52 | 16.8 |
| October 11 to October 18 | | | | 2.0 | 1.2 | .20 | 3.8 | 48.4 | 7.6 | 15.6 | 25.2 | | | .66 | 11.5 |
| October 18 to October 25 | 124. | 24. | 100. | 3.8 | 1.0 | .22 | 2.7 | 61.6 | 20.4 | 22.8 | 18.4 | | | .58 | 8.9 |
| October 25 to November 1 | 56. | 20. | 36. | 1.8 | 1.4 | .16 | 1.8 | 47.6 | 12.4 | 11.2 | 24.0 | | | .57 | 8.0 |
| October average | 96. | 23. | 73. | 2.7 | 1.3 | .18 | 2.8 | 53.5 | 13.4 | 15.1 | 25. | | | .58 | 11.3 |
| November 1 to November 8 | 88. | 8. | 80. | 4.2 | 2.2 | .15 | .85 | 58.0 | 14.0 | 19.2 | 24.8 | | | .45 | 10.8 |
| November 8 to November 15 | 144. | 36. | 108. | 5.0 | 3.0 | .30 | .90 | 47.6 | 9.2 | 18.0 | 20.4 | | | .39 | 11.1 |
| November 15 to November 22 | 232. | 84. | 148. | 7.4 | 2.2 | .30 | 1.70 | 60.0 | 14.4 | 22.8 | 22.8 | | | .57 | 7.8 |
| November 22 to November 29 | 176. | 12. | 164. | 5.4 | 1.8 | .30 | 2.70 | 54.0 | 7.6 | 16.8 | 29.6 | | | .69 | 6.1 |
| November average | 160. | 35. | 125. | 5.5 | 2.3 | .26 | 1.54 | 59.9 | 11.3 | 19.2 | 24.4 | | | .52 | 8.95 |
| November 29 to December 6 | 64. | 12. | 52. | 2.2 | 2.6 | .30 | 1.7 | 55.2 | 10.8 | 21.6 | 22.8 | | | .57 | 4.5 |
| December 6 to December 13 | 56. | 28. | 28. | 1.6 | 2.4 | .25 | 2.2 | 54.8 | 10.8 | 17.6 | 26.4 | | | .49 | 0.1 |
| December 13 to December 20 | 36. | 0. | 36. | 2.4 | 2.4 | .20 | 2.3 | 52.0 | 4.8 | 22.4 | 24.8 | | | .40 | 1.0 |
| December 20 to December 24 | 80. | 32. | 48. | 5.0 | 2.6 | .20 | 0.8 | 58.0 | 6.8 | 22.0 | 29.2 | 190. | | .26 | —2.5 |
| December 24 to December 27 | | | | | | | Station shut down. | | | | | | | | |
| December 27 to January 3 | 48. | 4. | 44. | 4.6 | 3.4 | .20 | 1.8 | 56.4 | 3.6 | 21.6 | 31.2 | 160. | | .31 | —5.1 |
| December average | 57. | 15. | 42. | 3.16 | 2.7 | .23 | 1.76 | 55.3 | 7.4 | 21. | 26.9 | 175. | | .41 | —0.4 |
| January 3 to January 10 | 16. | 4. | 12. | | | | 1.5 | 60.4 | 4.4 | 23.2 | 32.8 | 140. | 51.6 | .38 | —3.4 |
| January 10 to January 17 | 20. | 0. | 20. | | | | 2.5 | 62.0 | 12.8 | 14.4 | 34.8 | 95. | 26.4 | .37 | —2.7 |
| January 17 to January 24 | 12. | 0. | 12. | | | | 2.0 | 53.6 | 8.0 | 20.4 | 25.2 | 120. | 11.0 | .47 | 2.6 |
| January 24 to January 31 | 44. | 0. | 44. | | | | 4.0 | 56.0 | 11.2 | 14.8 | 30.0 | 110. | 11.4 | .34 | 11.2 |
| January average | 23. | 1. | 22. | | | | 2.5 | 58. | 9.1 | 18.2 | 30.7 | 116. | 25.1 | .38 | 1.7 |
| January 31 to February 7 | 36. | 0. | 36. | | | | 4.0 | 52.0 | 5.2 | 16.8 | 30.0 | 90. | 14.8 | .37 | —2.0 |
| February 7 to February 14 | 38. | 6. | 32. | | | | 2.5 | 53.6 | 4.8 | 22.0 | 26.8 | 95. | 16.8 | .40 | —0.8 |
| February 14 to February 21 | 50. | 8. | 42. | | | | 2.5 | 54.0 | 7.2 | 22.0 | 24.8 | 120. | 13.0 | .44 | 1.8 |
| February 21 to February 28 | 78. | 30. | 48. | | | | 1.0 | 60.0 | 3.2 | 29.6 | 27.2 | 180. | 21.0 | .24 | —2.2 |
| February average | 50. | 11. | 39. | | | | 2.5 | 54.9 | 5.1 | 22.6 | 27.2 | 121. | 16.4 | .36 | —0.8 |
| February 28 to March 7 | 72. | 6. | 66. | | | | 3.5 | 54.0 | 9.2 | 22.4 | 22.4 | 140. | 14.0 | .33 | 6.2 |
| March 7 to March 14 | 90. | 18. | 72. | | | | 4.0 | 55.2 | 8.4 | 17.6 | 29.2 | 150. | 23.6 | .37 | 3.1 |
| March 14 to March 21 | 64. | 12. | 52. | | | | 4.0 | 56.0 | 10.4 | 23.2 | 22.4 | 150. | 18.2 | .33 | 6.5 |
| March 21 to March 28 | 124. | 12. | 112. | | | | 1.5 | 60.0 | 16.0 | 19.6 | 24.4 | | 13.2 | .28 | 13.4 |
| March 28 to April 4 | | | | | | | Station shut down. | | | | | | | | |
| March average | 88. | 12. | 76. | | | | 3.25 | 56.3 | 11.0 | 20.7 | 24.6 | 147. | 17.3 | .32 | 7.5 |
| April 4 to April 11 | 340. | 152. | 188. | | | .60 | 3.4 | 88.0 | 38.4 | 29.6 | 20.0 | 250. | 17.6 | .31 | 12.3 |
| April 11 to April 18 | 238. | 88. | 150. | | | | 3.5 | 62.4 | 23.6 | 22.0 | 16.8 | 180. | 12.8 | .42 | 12.2 |
| April 18 to April 25 | 96. | 40. | 56. | | | .35 | 2.2 | 48.0 | 13.6 | 16.0 | 18.4 | 80. | 9.8 | .47 | 13.9 |
| April 25 to April 30 | 80. | 44. | 36. | | | | | 44.1 | 10.0 | 15.6 | 19.2 | 120. | | .46 | 13.2 |
| April average | 189. | 81. | 108. | | | .475 | 3.03 | 60.8 | 21.4 | 20.8 | 18.6 | 158. | 13.4 | .41 | 13.1 |

DIAGRAM NO. 20




SPRINKLING FILTER NO. 20-6

| Time After Bed Was Treated, in Hours. | Residual Chlorine in Parts per Million in the Effluent of— | |
|---|---|---|
| | 20-5 | 20-6 |
| ½ | 2.1 | 1.1 |
| 1 | .1 | .08 |
| 1½ | .08 | .08 |
| 2 | 0 | 0 |

The following morning the fine trap bed (20-6) was freed to some extent of the growth and was less pooled than at any time in the last two weeks.

The treatment, having been beneficial, was applied in a similar manner to the other four beds on the following day; samples of the effluents were analyzed and results shown in Table No. 20.

### Table No. 20.

*Showing the Effects of the Application of Calcium Hypochlorite to the Sprinkling Filters.*

| Time in Hours After Treatment. | EFFLUENT—PARTS PER MILLION. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20-1 | | 20-2 | | 20-3 | | 20-4 | |
| | Residual Chlorine. | Nitrogen as Nitrates. | Residual Chlorine. | Nitrogen as Nitrates. | Residual Chlorine. | Nitrogen as Nitrates. | Residual Chlorine. | Nitrogen as Nitrates. |
| End of first display | 25 | 4 | 206 | 5 | 177 | 4 | 188 | 5 |
| ½ hour | 35 | 3 | 32 | 3 | 21 | 2 | 39 | 2 |
| hour | 21 | 2.5 | 21 | 2.5 | 14 | 2.5 | 21 | 2 |
| 1½ hours | 14 | 2.5 | 14 | 2.5 | 7 | 2.5 | 10 | 3 |
| 2 hours | 7 | 3. | 7 | 2.5 | 7 | 3. | 7 | 2 |

The application of bleach had completely destroyed and eliminated the pink growth, the surface stones were perfectly clean, and pooling almost ended. The coarse limestone and the coarse trap bed remained in this clean and unpooled condition until the middle of February, the fine limestone until January 23d, but the slag bed and the two shallow fine trap beds, while remaining clean, began to pool, so that by the 16th of January they were in bad condition.

It will be noted in Table No. 20 that a large quantity of available chlorine was washed away in the effluent and to save this for use in the beds a change was made in the method of application; instead of spreading dry bleaching powder over the bed, the powder was dissolved in water (one pound dry bleach per gallon of water) and applied to the beds by a watering can. In this way 8 pounds of bleach per bed were put upon the three pooled filters (20-3, 5 and 6) on January 17th and all the filters rested until January 20th. During the rest the bleach changed the appearance and consistency of the clogging matter; its color was a dirty yellow and from a sticky, tenacious mat it had become granular, and was capable of being easily removed from the media by hand. Analysis of the deposit in 20-6 shown below, prior and subsequent to bleach treatment, does not show much change except an increase in fats, which accumulated between the dates of examination.

| Date. 1910. | Wet Sludge. | | Per Cent. of Dry Residue. | | | |
|---|---|---|---|---|---|---|
| | Sp. Gr. | Per Cent Water | Volatile. | Fixed. | Nitrogen. | Fats. |
| January 3 | 1.05 | 85.3 | 42.1 | 57.9 | 2.2 | 3.9 |
| January 21 | 1.17 | 78.1 | 43.9 | 56.1 | 1.7 | 5.9 |

The storage of solids, and especially of fats, between January 3d and 21st is shown by the content in grams of one liter of the deposit as follows:

| Date—1910. | Grams Contained in One Liter of the Wet Deposit. | | |
|---|---|---|---|
| | Dry Solids. | Volatile Solids. | Fats. |
| January 3rd | 154 | 65 | 6 |
| January 21st | 256 | 112 | 15 |

The surface jelly had been disintegrated, but the force of the ordinary spray was not sufficient to wash it through; so on Sunday, January 23, 1910, the dosing mechanism was not used, and the nozzles discharged continuously for three hours, the head being changed from time to time by hand in order to cover the entire area.

The influent did not appear to contain more than 20 parts per million suspended solids and the effluent was but slightly dirtier. The spray, therefore, did not have sufficient force to dislodge the clogging matters.

It seemed that considerable force would be required to dislodge the accumulated solids in the voids of the filters, as all gentle treatments had failed to eliminate pooling on 20-1, 5, and 6. On January 24th, therefore, after three and a half hours' rest, filter No. 20-5 was washed with water under pressure from the fire hydrant, applied through a one-inch fire nozzle, held vertically a few inches above the stones. The rate of discharge was 77 gallons per minute and was applied twice; the first time it required three minutes to go over the area; the second time two minutes and thirty seconds. For the first treatment it would require 115,000 gallons of water and 25 hours to treat one acre of filter.

The force of the jet violently churned the top stones, and cut up and completely dislodged the clogging solids, at least in the upper foot of media. The water leaving the bed appeared like a thin, watery sludge.

After the bed had drained the influent was applied as usual and samples of the effluent from this and the adjoining bed (which had not been washed) were collected for comparison.

| Time in Hours After Bed Was Started Up. | Filter Number. 20-5 Washed. | | 20-6 | |
|---|---|---|---|---|
| | Nitrates. | Rel. Stab. | Nitrates. | Rel. Stab. |
| 0 | 1.5 | .25 | 2.0 | .24 |
| 1 | 2.5 | .50 | 4.0 | .38 |
| 2 | 2.2 | .31 | 4.0 | .30 |
| 3 | 2.5 | .29 | 1.5 | .37 |
| 4 | 2.5 | .24 | 3.0 | .28 |
| 5 | 3.0 | .27 | 4.0 | .27 |
| Average | 2.8 | .32 | 3.7 | .31 |

The following day the fine limestone bed which was pooled (not from surface growth but from a clogging of the voids with the black deposit) was washed in a similar manner to that described above.

The stream was applied for one minute and fifty-four seconds; it required thirty-five seconds for the water to pass through the bed and appear as a thin sludge at the outlet of the underdrains; the flow continued for three and one-half minutes. The second washing was given for one and one-half minutes. The slowness of the water in passing through the bed surely indicates how much the interstices must have been sludged up. Samples collected for comparison yielded the following results:

| Time in Hours After Bed Was Started Up. | Filter Number. | | | |
|---|---|---|---|---|
| | 20-1 Washed. | | 20-2 | |
| | Nitrates. | Rel. Stab. | Nitrates. | Rel. Stab. |
| 0 | 3.5 | .33 | 4.0 | .25 |
| 1 | 2.0 | .89 | 4.0 | .42 |
| 2 | 2.0 | .62 | 3.0 | .37 |
| 3 | 3.0 | .60 | 2.0 | .39 |
| 4 | 2.5 | .44 | 1.5 | .30 |
| 5 | | .39 | | .28 |
| Average | 2.6 | .54 | 2.9 | .33 |

This was a satisfactory method for relieving pooling in a badly clogged bed and did not seem to injure the already feeble biological action in the two beds that were washed.

Both beds remained clean and free from pooling until February 24th.

The above history of the filters during January, 1910, is devoted entirely to their physical condition, and in order to avoid complications no mention was made of their biological condition. In regard to the purification of the applied liquor affected by the beds, the influent contained less suspended solids than usual, and being cold weather the crude sewage contained larger quantities of dissolved oxygen and nitrates than in warm weather, but the clogged condition of the beds and the low air temperatures were very unfavorable to efficient biological action.

The effluent of all the filters during January contained less suspended solids than the influent, except, of course, at those times when bleach had been applied or the media was washed with the fire hose; the formation of nitrates increased during the month in all the filters except the coarse trap bed (20-4).

The fat or ether soluble matter contained in the sewage and effluents was studied beginning in January, and it was found that the effluent of all the filters, except 20-5, contained less fats than were applied. As we have seen that the fat content of the deposit in the filters increased, and as fats are resistant bodies, the supposition is they were being stored up in the filters.

The general tendency of the relative stability curve of the four higher beds (20-1, 2, 3 and 4) was upwards; but if the high stability of the Sunday effluent (due to its dilute character) is omitted the average for the month is low in all the filters; that the curve tends upwards is evidence that the application of bleach and washing with fire hose had a beneficial rather than malignant effect upon the oxidizing power of the beds.

The bacterial content of the crude sewage was lower in January than in any other month, and the sedimentation tank, being but little protected from the cold, further reduced the number of bacteria in the water applied to the outside filters; the effluents generally contained more bacteria than in warmer months and, due to the low numbers in the influent, the percentage removal seems quite low. The coarse trap bed caused the highest reduction in bacteria; the shallow mixed trap bed (20-5) the lowest reduction.

# Table No. 21.

## *Detailed Bacteriological Examination of the Outside Sprinkling Filters During January, 1910.*

**Total Number of Bacteria per CC. on Gelatine at 20 Degrees C. in 48 hours.**

| January. | 1910 | Crude F. M. Sewage. | Settled Inf. to Filters. | Eight Feet Fine Lime. 20-1 | Nine Feet Coarse Lime. 20-2 | Six Feet Slag. 20-3 | Seven Feet Coarse Trap. 20-4 | Four Feet Mixed Trap. 20-5 | Five Feet Fine Trap. 20-6 |
|---|---|---|---|---|---|---|---|---|---|
| Saturday | 1 | | | | | | | | |
| Sunday | 2 | 1,900,000 | 2,100,000 | 450,000 | 400,000 | 240,000 | 550,000 | 1,300,000 | 1,100,000 |
| Monday | 3 | | 1,100,000 | | | | | 330,000 | 320,000 |
| Tuesday | 4 | | 1,400,000 | | | | | 180,000 | 150,000 |
| Wednesday | 5 | 1,900,000 | 820,000 | 400,000 | 340,000 | 220,000 | 270,000 | | |
| Thursday | 6 | 610,000 | 360,000 | 160,000 | 130,000 | 210,000 | 140,000 | 400,000 | 360,000 |
| Friday | 7 | | | | | | | | |
| Saturday | 8 | 780,000 | 980,000 | 370,000 | 350,000 | 410,000 | 360,000 | 590,000 | 610,000 |
| Sunday | 9 | 1,000,000 | 770,000 | | 560,000 | 450,000 | 550,000 | 450,000 | 650,000 |
| Monday | 10 | 1,500,000 | 1,300,000 | 1,000,000 | 900,000 | 1,200,000 | 1,000,000 | 1,000,000 | 800,000 |
| Tuesday | 11 | 1,500,000 | 1,100,000 | 560,000 | 580,000 | 660,000 | 560,000 | 730,000 | 950,000 |
| Wednesday | 12 | 1,200,000 | 1,300,000 | 850,000 | 950,000 | 930,000 | 990,000 | 930,000 | 700,000 |
| Thursday | 13 | | | | | | | | |
| Friday | 14 | 1,200,000 | 1,000,000 | 800,000 | 800,000 | 900,000 | 890,000 | 1,100,000 | 850,000 |
| Saturday | 15 | 900,000 | 800,000 | 650,000 | 500,000 | 670,000 | 600,000 | 560,000 | 550,000 |
| Sunday | 16 | 1,300,000 | | 870,000 | | 570,000 | 880,000 | | |
| Monday | 17 | | | | | | | | |
| Tuesday | 18 | | | | | | | | |
| Wednesday | 19 | | | | | | | | |
| Thursday | 20 | 580,000 | 500,000 | 1,100,000 | 850,000 | 850,000 | 650,000 | 510,000 | 680,000 |
| Friday | 21 | | | | | | | | |
| Saturday | 22 | 960,000 | 340,000 | 360,000 | 430,000 | 550,000 | 880,000 | 490,000 | 420,000 |
| Sunday | 23 | | | | | | | | |
| Monday | 24 | 1,400,000 | 630,000 | 500,000 | 300,000 | 650,000 | 560,000 | 680,000 | 740,000 |
| Tuesday | 25 | | | | | | | | |
| Wednesday | 26 | | | | | | | | |
| Thursday | 27 | 680,000 | 320,000 | 190,000 | 110,000 | 240,000 | 300,000 | 580,000 | 370,000 |
| Friday | 28 | 700,000 | 540,000 | 300,000 | 140,000 | 320,000 | 200,000 | 560,000 | 350,000 |
| Saturday | 29 | | | | | | | | |
| Sunday | 30 | 1,100,000 | 1,100,000 | 600,000 | 470,000 | 640,000 | 580,000 | 850,000 | 860,000 |
| Monday | 31 | | | | | | | | |
| Average | | 1,100,000 | 910,000 | 540,000 | 490,000 | 570,000 | 550,000 | 660,000 | 610,000 |

## Table No. 22.

*Analyses of Crude Sewage, the Influent and Effluent of the Outside Sprinkling Filters During January, 1910.*

| | Period of Sampling. | | Parts per Million. Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | | Fats. | Average Air Temperature. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total. | Fixed. | Volatile. | Organic. | Fr. Amm. | Nitrite. | Nitrate. | Total. | Susp. | Colloid. | Dissolv. | | Deg. C. | Deg. F. |
| Crude Force Main Sewage. 1 | December 27 | January 3 | 200 | 76 | 124 | 3.6 | 3.6 | ---- | ---- | 92.0 | 9.2 | 34.4 | 48.4 | ---- | —5.1 | 23 |
| | January 3 | January 10 | 172 | 64 | 108 | 6.6 | 4.6 | ---- | ---- | 92.8 | 14.8 | 30.0 | 48.0 | 16.0 | —3.4 | 26 |
| | January 10 | January 17 | 116 | 0 | 116 | 6.4 | 4.0 | ---- | ---- | 91.2 | 6.4 | 40.4 | 44.4 | 35.8 | —2.7 | 27 |
| | January 17 | January 24 | 192 | 56 | 136 | 10.4 | | ---- | ---- | 88.0 | 19.6 | 34.4 | 34.0 | 24.0 | +2.6 | 36 |
| | January 24 | January 31 | 192 | 36 | 156 | 6.7 | 2.5 | ---- | ---- | 80.8 | 15.6 | 34.0 | 31.2 | 28.0 | +1.1 | 34 |
| Settled Sewage Influent to Filters. | December 27 | January 3 | 72 | 0 | 72 | 2.6 | 3.8 | ---- | ---- | 67.2 | 7.2 | 24.8 | 35.2 | ---- | ---- | ---- |
| | January 3 | January 10 | 56 | 0 | 56 | ---- | ---- | ---- | ---- | 70.0 | 9.2 | 23.2 | 37.6 | ---- | ---- | ---- |
| | January 10 | January 17 | 72 | 0 | 72 | ---- | ---- | ---- | ---- | 75.2 | 10.8 | 30.0 | 34.4 | 32.2 | ---- | ---- |
| | January 17 | January 24 | 52 | 12 | 40 | ---- | ---- | ---- | ---- | 64.0 | 11.2 | 24.8 | 28.0 | 18.2 | ---- | ---- |
| | January 24 | January 31 | 88 | 88 | 80 | ---- | ---- | ---- | ---- | 72.0 | 14.0 | 20.4 | 37.6 | 17.2 | ---- | ---- |

| Bed No. | Period of Sampling. | | Parts per Million. Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | | Fats. | Turb. | M. B. at 20 Degrees Average Rel. Sta. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total. | Fixed. | Volatile. | Organic. | Fr. Amm. | Nitrite. | Nitrate. | Total. | Susp. | Colloid. | Dissolv. | | | |
| Eight Feet of Fine Limestone. 20-1 | December 27 | January 3 | 56 | 8 | 48 | 5.2 | 2.8 | .20 | 1.6 | 40.0 | 4.8 | 13.2 | 22.0 | ---- | 110 | .487 |
| | January 3 | January 10 | 12 | 0 | 12 | ---- | ---- | ---- | 2.5 | 46.0 | 4.8 | 15.2 | 26.0 | 13.0 | 100 | .450 |
| | January 10 | January 17 | 14 | 0 | 14 | ---- | ---- | ---- | 2.5 | 52.8 | 14.0 | 12.8 | 26.0 | 13.8 | 80 | .444 |
| | January 17 | January 24 | 24 | 4 | 20 | ---- | ---- | ---- | 2.5 | 44.0 | 9.2 | 16.8 | 18.0 | 6.6 | 190 | .682 |
| | January 24 | January 31 | 12 | 0 | 12 | ---- | ---- | ---- | 4.5 | 44.4 | 6.4 | 16.4 | 21.6 | 7.2 | 65 | .539 |
| Nine Feet of Coarse Limestone. 20-2 | December 27 | January 3 | 44 | 8 | 36 | 3.7 | 3.5 | .20 | 2.1 | 47.2 | 5.6 | 16.8 | 24.8 | ---- | 100 | .393 |
| | January 3 | January 10 | 34 | 4 | 30 | ---- | ---- | ---- | 2.5 | 50.8 | 3.6 | 21.2 | 26.0 | 14.4 | 110 | .424 |
| | January 10 | January 17 | 16 | 0 | 16 | ---- | ---- | ---- | 2.0 | 53.6 | 11.2 | 16.0 | 26.4 | 18.8 | 90 | .330 |
| | January 17 | January 24 | 36 | 16 | 20 | ---- | ---- | ---- | 3.0 | 48.8 | 12.0 | 18.4 | 18.4 | 11.4 | 200 | .625 |
| | January 24 | January 31 | 36 | 0 | 36 | ---- | ---- | ---- | 3.5 | 48.8 | 9.6 | 18.4 | 20.8 | 9.2 | 75 | .473 |
| Six Feet of Slag. 20-3 | December 27 | January 3 | 64 | 24 | 40 | 1.2 | 2.4 | .20 | 1.4 | 43.6 | 4.8 | 14.8 | 24.0 | ---- | 110 | .414 |
| | January 3 | January 10 | 40 | 8 | 32 | ---- | ---- | ---- | 2.5 | 46.0 | 2.8 | 16.8 | 26.4 | 29.0 | 130 | .432 |
| | January 10 | January 17 | 24 | 0 | 24 | ---- | ---- | ---- | 3.0 | 50.8 | 8.4 | 16.8 | 25.6 | 25.2 | 90 | .369 |
| | January 17 | January 24 | 28 | 0 | 28 | ---- | ---- | ---- | 2.5 | 46.0 | 8.0 | 16.8 | 21.2 | 11.2 | 190 | .535 |
| | January 24 | January 31 | 28 | 0 | 28 | ---- | ---- | ---- | 4.0 | 48.0 | 8.4 | 16.4 | 23.2 | 6.4 | 60 | .471 |
| Seven Feet of Coarse Trap. 20-4 | December 27 | January 3 | 68 | 12 | 56 | 4.4 | 2.8 | .20 | 2.1 | 47.2 | 5.2 | 17.6 | 24.4 | ---- | 130 | .364 |
| | January 3 | January 10 | 32 | 0 | 32 | 5.8 | 3.0 | .20 | 2.0 | 51.2 | 6.4 | 14.0 | 30.8 | 14.0 | 110 | .405 |
| | January 10 | January 17 | 16 | 0 | 16 | 4.8 | 2.8 | .25 | 1.7 | 52.8 | 10.8 | 15.6 | 26.4 | 19.6 | 85 | .400 |
| | January 17 | January 24 | 12 | 0 | 12 | 6.0 | | .32 | 1.7 | 46.4 | 7.2 | 21.2 | 18.0 | 10.4 | 140 | .655 |
| | January 24 | January 31 | 14 | 0 | 14 | 3.4 | 2.2 | .40 | 3.1 | 48.0 | 7.6 | 18.0 | 22.4 | 9.0 | 65 | .480 |
| Four Feet of Mixed Trap. 20-5 | December 27 | January 3 | 32 | 4 | 28 | 5.6 | 3.2 | .20 | 2.3 | 54.4 | 6.4 | 19.2 | 28.8 | ---- | 160 | .310 |
| | January 3 | January 10 | 44 | 0 | 44 | ---- | ---- | ---- | 2.0 | 62.0 | 9.2 | 18.8 | 34.0 | 34.4 | 110 | .352 |
| | January 10 | January 17 | 28 | 0 | 28 | ---- | ---- | ---- | 2.0 | 62.0 | 12.4 | 17.2 | 32.4 | 24.4 | 110 | .376 |
| | January 17 | January 24 | 16 | 0 | 16 | ---- | ---- | ---- | 3.0 | 52.4 | 10.8 | 17.6 | 24.0 | 17.2 | 190 | .448 |
| | January 24 | January 31 | 40 | 0 | 40 | ---- | ---- | ---- | 4.0 | 57.6 | 10.0 | 19.2 | 28.4 | 13.4 | 110 | .331 |
| Five Feet of Fine Trap. 20-6 | December 27 | January 3 | 48 | 4 | 44 | 4.6 | 3.4 | .20 | 1.8 | 56.4 | 3.6 | 21.6 | 31.2 | ---- | 160 | .310 |
| | January 3 | January 10 | 16 | 4 | 12 | ---- | ---- | ---- | 1.5 | 60.4 | 4.4 | 23.2 | 32.8 | 51.6 | 140 | .382 |
| | January 10 | January 17 | 20 | 0 | 20 | ---- | ---- | ---- | 2.5 | 62.0 | 12.8 | 14.4 | 34.8 | 26.4 | 95 | .331 |
| | January 17 | January 24 | 12 | 0 | 12 | ---- | ---- | ---- | 2.0 | 53.6 | 8.0 | 20.4 | 25.2 | 11. | 120 | .468 |
| | January 24 | January 31 | 44 | 0 | 44 | ---- | ---- | ---- | 4.0 | 56.0 | 11.2 | 14.8 | 30.0 | 11.4 | 110 | .340 |

February started with all the filters clean and all but 20-6 free from pooling. As may be seen in diagram No. 14, the average temperature was about freezing until the 5th, when it suddenly sunk to —16° C., the lowest reached during the tests, and caused the greatest reduction in the working area experienced. As in previous freezing weather, the slag bed had the smallest amount of ice upon its surface. During the night of the 5th a valve bonnet cracked and required 10 hours to repair, so that the beds were not dosed during the extreme low temperature; the moderation in temperature soon melted the ice. By the middle of the month the slag bed and the coarse and fine trap beds were again pooled. The coarse trap bed was washed with a fire hose and the other two allowed to remain in the pooled condition in order to see if they would right themselves.

About this time it was noticed that water stood between the stones of the coarse limestone bed (20-2) which heretofore had never pooled nor even had any indications of it; on the 21st of the month the bed was slightly pooled, but the same day the effluent became quite dirty and the pooling ceased.

By February 26th beds numbered 20-1, 2, 3 and 6 were pooled again, and it was decided to give all the beds another dose of the bleach. Eight pounds of dry powder dissolved in eight gallons of water was sprinkled upon each bed and they were not dosed for two days. When started up they were all clean and all but 20-6 free from pools. The fine trap bed (20-6) had never been washed with water and the well graded media with consequently smaller voids must have been very badly clogged, for by the end of the month its surface was a lake.

All of the filters yielded an effluent very low in suspended solids, although a steadily increasing amount of sewage was applied as the month advanced; the fat content of the applied sewage also increased, reaching the maximum figure at the end of the month, when some of the filters became pooled. The formation of nitrates decreased, but the relative stability changed but little, the deeper beds yielding a more stable effluent than the shallow beds.

Experience with these outside filters, operated under adverse conditions as to poorly prepared influent and unsatisfactory distribution, had shown that when clogging occurred it could be relieved by the bleach treatment, but in general, as the cause of clogging was not removed, the condition returned. It was decided to disinfect the influent to the filters, in order to try out Rideal's theory, as cited above.

Apparatus was therefore assembled similar in design to that used for adding bleach solution to the disinfection tanks, and beginning February 28, 1910, the hypochlorite solution was continuously added to the contents of the dosing tank in quantities equivalent to 290 pounds of dry powder per acre per day, or 124 pounds of dry powder per million gallons of sewage applied to the bed, or five parts per million available chlorine. The dosing tank was emptied about every six minutes, which is not sufficient time to exhaust the oxidizing power of the hypochlorite, and therefore residual chlorine was generally present in the sewage as it fell upon the bed, averaging 2.3 parts per million; during the time that bleach was added the influent to the filters contained on an average 210,000 bacteria per c.c. (and if two high counts are omitted the average in the influent would be 11,400).

In passage through the filter the bacteria developed therein, so that although the influent was disinfected, the effluent was similar in bacterial content to that produced at other times, and the percentage removal from the crude sewage over 70.

The fine limestone and the coarse trap beds (20-1 and 4) remained perfectly clean and free from pools during this treatment; the coarse limestone, slag and mixed trap beds (20-2, 3, and 5) gave very slight evidence of pooling; but on the fine trap (20-6) the pooling soon commenced and steadily grew worse; on March 14th an examination was made of the upper two and one-half feet of media, which showed that 227 pounds of deposit was stored per cubic yard of media, a reduction in voids of 9.7 per cent. The effluent yielded by the filters was of about the same stability as during February. The weather seemed settled and favorable for a few warm days. On March 28th, therefore, the outside beds were shut down in order that the accumulation of solids within the beds might dry and the beds unload. They were rested until April 5th, during which time the average air temperature was 12° C. and clear, dry weather conducive to desquamation of the deposits in the voids.

The filters were then started at the same rate that they had been operating under, 2.32 million gallons per acre per day, and the samples not mixed as usual to form the composite one, but kept on ice for 24 hours in order to observe the manner in which various beds unloaded their voids.

The results were as follows:

"Fine limestone bed (20-1)—Effluent practically normal the composite sample for week following the rest shows an unloading, but it did not occur during the first 24 hours after the rest.

Coarse limestone bed (20-2)—At first the effluent was exceedingly dirty, but gradually cleared up, so that by 24 hours it appeared like a normal effluent.

Slag bed (20-3)—The action in this bed was the reverse of 20-2, for the first effluent was quite clear and gradually grew dirtier, so that after 24 hours it was very dirty.

Coarse trap bed (20-4)—The first effluent was dirty and continued so for the following 24 hours.

Mixed trap bed (20-5)—Same as 20-4.

Fine trap bed (20-6)—The first effluent was very dirty, gradually becoming clearer, but still turbid at end of 24

## Table No. 30.

*Monthly Average Analyses of the Influent and Effluent of the Outside Sprinkling Filters. (For Description of Beds see Text of Report).*

PARTS PER MILLION.

Suspended Solids.

| Month. 1909–1910. | Average Air Temperature | Total: Crude Sewage | Total: Influent | Total: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Fixed: Crude Sewage | Fixed: Influent | Fixed: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Volatile: Crude Sewage | Volatile: Influent | Volatile: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1909 | — | 225. | 142. | 92. | 117. | 90. | 90. | 116. | 104. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| May | 16.8 | 212. | 118. | 161. | 754.* | 120. | 230.* | 112.* | 600. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| June | 22.1 | 137. | 79. | 14. | 65. | 69. | 69. | 91. | 56. | 62. | 31. | — | — | — | — | — | — | 75. | 48. | — | — | — | — | — | — |
| July | 23.3 | 158. | 60. | 52. | 72. | 102. | 60. | 88. | 77. | 49. | — | — | — | 27. | — | 21. | — | 109. | — | — | — | 75. | — | 65. | — |
| August | 22.7 | 139. | 72. | 103. | 58. | 115. | 76. | 52. | 47. | 41. | — | 33. | 16. | 29. | 27. | 20. | — | 98. | — | 70. | 42. | 86. | 49. | 32. | — |
| September | 18.2 | 191. | 58. | 86.5 | 73. | 82. | 95. | 74. | 74. | 70. | 11.5 | 31. | 27. | 38.* | 32. | 26. | — | 121. | 46.5 | 55.5 | 46. | 44. | 63. | 48. | — |
| October | 11.3 | 242. | 70. | 113. | 163. | 215. | 81. | 67. | 96. | 55. | 13.0 | 24.5 | 36. | 83. | 21. | — | 23. | 187. | 57. | 88.5 | 127. | 132. | 60. | — | 73. |
| November | 8.9 | 220. | 89. | 171. | 193. | 105. | 67. | 116. | 160. | 44.5 | 5. | 48. | 58. | 16. | 8. | 16. | 35. | 175.5 | 84. | 123. | 135. | 89. | 59. | 100. | 125. |
| December | −0.4 | 200. | 153. | 65. | 78. | 74. | 81. | 60. | 57. | 82. | 44.5 | 14. | 21. | 22. | 25. | 22. | 15. | 118. | 108.5 | 51. | 57. | 52. | 56. | 38. | 42. |
| January, 1910 | 1.7 | 168. | 67. | 15.5 | 30.5 | 30. | 18.5 | 32. | 23. | 39. | 5. | 1. | 5. | 2. | 0.0 | 0.0 | 1. | 129. | 62. | 14.5 | 25.5 | 28. | 18.5 | 32. | 22. |
| February | −0.8 | 200. | 94.5 | 51. | 71. | 37. | 47. | 47. | 50. | 63. | 17.5 | 7. | 13. | 4. | 9.5 | 5. | 11. | 137. | 77. | 44. | 58. | 33 | 37.5 | 42. | 39. |
| March | 7.5 | 209. | 156.5 | 55. | 62. | 74. | 69.5 | 92. | 88. | 68. | 35.5 | 8.5 | 16. | 13 | 8. | 26. | 12. | 141. | 121.0 | 46.5 | 46. | 61 | 61.5 | 66. | 76. |
| April | 13.1 | 158. | 83. | 161. | 212. | 159. | 157. | 174. | 189. | 54. | 26.5 | 67. | 96. | 72. | 66. | 76. | 81. | 104. | 56.5 | 94. | 116. | 87. | 91. | 98. | 108. |
| | | 189. | 95.5 | 86.2 | 149.9 | 97.8 | 87.8 | 86.2 | 124.7 | 57. | 21.1 | 26. | 32. | 30.6 | 21.8 | 23.7 | 25.4 | 126.8 | 73.4 | 65.2 | 72.5 | 68.7 | 55. | 57.9 | 69.3 |

Nitrogen as—

| Month. 1909–1910. | Average Air Temperature | Organic: Crude Sewage | Organic: Influent | Organic: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Free Ammonia: Crude Sewage | Free Ammonia: Influent | Free Ammonia: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Nitrites: Crude Sewage | Nitrites: Influent | Nitrites: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Nitrates: Crude Sewage | Nitrates: Influent | Nitrates: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1909 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| May | 16.8 | 8.0 | 6.6 | 4.2 | 2.6 | 4.5 | 4.6 | 5.9 | — | 3.3 | 3.7 | 0.8 | 1.7 | 0.4 | 1.4 | 1.2 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| June | 22.1 | 4.0 | 4.6 | 5.3 | 5.0 | 6.4 | 3.4 | 3.8 | — | 3.9 | 3.6 | 0.7 | 0.9 | 0.8 | 1.0 | 1.1 | — | — | — | — | — | — | — | — | — | — | 1.17 | 4.2 | 3.6 | 2.9 | 4.0 | 3.7 | — |
| July | 23.3 | 3.8 | 4.5 | 2.3 | 4.2 | 4.4 | 3.4 | 4.9 | — | 4.5 | 3.9 | 0.5 | 0.8 | 0.8 | 1.0 | 1.4 | — | — | — | — | — | — | — | — | — | — | 1.00 | 2.5 | 2.6 | 2.4 | 3.0 | 2.4 | — |
| August | 22.7 | 3.4 | 3.2 | 4.4 | 4.6 | 4.9 | 3.8 | 2.85 | — | 4.0 | 3.9 | 0.8 | 1.0 | 0.8 | 1.0 | 2.15 | — | .21 | — | — | — | — | — | .17 | — | .16 | 0.66 | 1.5 | 1.7 | 1.5 | 1.6 | .30 | — |
| September | 18.2 | 7.6 | 6.0 | 4.0 | 3.75 | 2.55 | 4.9 | 3.0 | 3.4 | 3.7 | 3.4 | 1.2 | 1.13 | .87 | 1.1 | 2.15 | 1.4 | .19 | 0.115 | .175 | .198 | .15 | .255 | .29 | .185 | .16 | 0.247 | .72 | 1.31 | 2.04 | 2.55 | .80 | 1.71 |
| October | 11.3 | 5.2 | 3.15 | 2.65 | 3.35 | 4.95 | 2.7 | 2.4 | 2.7 | 3.4 | 3.55 | .57 | 1.25 | .85 | 0.95 | 1.8 | 1.3 | .19 | 0.182 | .16 | .20 | .19 | .21 | .22 | .180 | .36 | 0.32 | 1.7 | 2.49 | 2.8 | 2.90 | 1.19 | 2.8 |
| November | 8.9 | 4.1 | 5.9 | 3.75 | 3.9 | 4.5 | 3.9 | 2.4 | 5.5 | 4.1 | 3.8 | 1.65 | 1.9 | 1.35 | 1.5 | 2.8 | 2.3 | .28 | 0.255 | .32 | .40 | .31 | .325 | .26 | .26 | .35 | 0.417 | 2.4 | 1.96 | 1.98 | 2.43 | .81 | 1.54 |
| December | −0.4 | 5.4 | 4.08 | 3.8 | 3.6 | 2.9 | 3.2 | 3.4 | 3.16 | 3.8 | 2.8 | 2.1 | 2.2 | 1.8 | 1.9 | 3.0 | .27 | .18 | 0.16 | .32 | .28 | .29 | .25 | .27 | .23 | .90 | 1.18 | 1.98 | 2.36 | 2.24 | 2.9 | 1.60 | 1.76 |
| January, 1910 | 1.7 | 6.6 | — | — | — | — | — | — | — | 3.7 | — | — | — | — | — | — | — | .21 | — | — | — | — | .292 | — | — | 2.10 | — | 3.0 | 2.75 | 3.0 | 2.1 | 2.75 | 2.5 |
| February | −0.8 | 7.3 | — | — | — | — | 4.95 | — | — | 3.2 | — | — | — | — | 2.05 | — | — | .20 | — | — | — | — | .36 | — | — | 2.15 | — | 3.25 | 2.6 | 2.9 | 2.4 | 2.50 | 2.5 |
| March | 7.5 | 7.5 | — | — | — | — | 4.2 | — | — | 3.2 | — | — | — | — | 1.9 | — | — | .29 | — | — | — | — | .40 | — | — | 2.28 | — | 3.25 | 3.1 | 3.1 | 2.84 | 2.60 | 3.25 |
| April | 13.1 | 6.0 | — | — | — | — | 15.0 | — | — | 4.0 | — | — | — | — | 1.5 | — | — | .30 | — | .30 | .24 | .165 | .50 | .58 | .475 | .38 | — | 3.6 | 3.3 | 3.6 | 3.8 | 2.3 | 3.0 |
| | | 5.7 | 4.75 | 3.8 | 3.87 | 4.39 | 4.91 | 3.58 | 3.69 | 3.73 | 3.58 | 1.04 | 1.36 | .96 | 1.39 | 1.95 | 1.93 | .23 | 0.178 | 0.255 | 0.264 | 0.221 | 0.324 | 0.298 | 0.266 | .98 | 0.713 | 2.55 | 2.52 | 2.59 | 2.77 | 1.90 | 2.38 |

PARTS PER MILLION.

Oxygen Consumed.

| Month. | Average Air Temperature | Total: Crude Sewage | Total: Influent | Total: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Suspension: Crude Sewage | Suspension: Influent | Suspension: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Colloidal: Crude Sewage | Colloidal: Influent | Colloidal: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Solution: Crude Sewage | Solution: Influent | Solution: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1909 | — | 62.5 | 62.5 | 38.6 | 40.3 | 36.2 | 41.4 | — | — | 18.6 | 22.5 | 12.2 | 14.5 | 9.8 | 13.7 | — | — | — | — | — | — | — | — | — | — | 43.9 | 40.0 | 26.4 | 25.8 | 26.4 | 27.7 | — | — |
| May | 16.8 | 73.1 | 66.7 | 47.7 | 70.1 | 56.9 | 60.0 | — | — | 18.3 | 6.8 | 9.8 | 30.0* | 12.0 | 18.9 | — | — | — | — | — | — | — | — | — | — | 54.8 | 59.9 | 37.9 | 40.1 | 44.9 | 41.1 | — | — |
| June | 22.1 | 63.9 | 60.6 | 47.1 | 41.3 | 41.3 | 35.3 | — | — | 16.4 | 10.5 | 10.8 | 10.1 | 10.4 | 5.0 | — | — | — | — | — | — | — | — | — | — | 47.5 | 50.1 | 31.3 | 31.2 | 30.9 | 30.3 | — | — |
| July | 23.3 | 70.3 | 61.1 | 27.2 | 35.9 | 36.7 | 39.0 | — | — | 17.1 | 10.4 | 5.4 | 6.7 | 9.7 | 8.7 | — | — | — | — | — | — | — | — | — | — | 53.2 | 50.7 | 21.8 | 29.2 | 27.0 | 30.3 | — | — |
| August | 22.7 | 79.2 | 62.1 | 46.5 | 49.9 | 50.9 | 48.3 | 58.7 | — | 23.2 | 13.0 | 14.6 | 14.9 | 18.0 | 15.0 | 10.1 | — | — | 17.7 | 15.8 | 17.9 | 17.9 | 14.7 | 23.4 | — | 33.1 | 31.4 | 16.1 | 17.1 | 15.0 | 18.6 | 25.2 | — |
| September | 18.2 | 71.1 | 62.7 | 42.0 | 42.8 | 45.5 | 49.7 | 51.6 | 48.6 | 4.8 | 3.6 | 9.95 | 9.3 | 13.9 | 14.7 | 10.6 | 8.9 | 33.4 | 32.2 | 17.8 | 21.0 | 17.1 | 19.7 | 23.4 | 23.8 | 32.9 | 26.9 | 14.3 | 12.5 | 14.5 | 15.3 | 17.6 | 15.9 |
| October | 11.3 | 84.6 | 73.7 | 50.7 | 62.3 | 60.9 | 50.3 | 50.5 | 53.5 | 14.0 | 9.8 | 16.0 | 18.4 | 20.0 | 12.2 | 8.8 | 13.4 | 24.8 | 23.3 | 12.6 | 17.3 | 19.1 | 16.3 | 17.1 | 15.1 | 45.8 | 40.6 | 22.1 | 26.6 | 21.8 | 21.8 | 24.6 | 25.0 |
| November | 8.9 | 76.3 | 70.7 | 53.4 | 61.3 | 50.0 | 48.8 | 50.5 | 59.9 | 11.5 | 8.3 | 11.3 | 13.0 | 9.7 | 8.1 | 8.4 | 11.3 | 24.7 | 25.4 | 19.1 | 20.9 | 17.4 | 17.0 | 18.0 | 19.2 | 40.1 | 37.0 | 23.0 | 27.4 | 23.1 | 23.7 | 24.1 | 24.4 |
| December | −0.4 | 84.8 | 78.3 | 54.4 | 63.5 | 53.4 | 58.0 | 60.1 | 55.3 | 9.8 | 11.3 | 7.9 | 10.5 | 9.7 | 9.5 | 9.8 | 7.4 | 35.2 | 28.1 | 23.0 | 26.5 | 19.6 | 23.9 | 22.2 | 21.0 | 39.8 | 38.9 | 23.5 | 26.5 | 24.1 | 24.6 | 28.1 | 26.9 |
| January, 1910 | 1.7 | 88.2 | 70.3 | 46.8 | 50.5 | 47.7 | 49.6 | 58.5 | 58.0 | 14.1 | 11.3 | 8.6 | 9.1 | 6.9 | 8.0 | 10.6 | 9.1 | 34.7 | 24.6 | 15.3 | 18.5 | 16.7 | 17.2 | 18.2 | 18.2 | 39.4 | 34.4 | 22.9 | 22.9 | 24.1 | 24.4 | 29.7 | 30.7 |
| February | −0.8 | 90.1 | 73.7 | 46.7 | 50.9 | 49.8 | 49.0 | 55.5 | 54.9 | 18.2 | 9.1 | 6.4 | 5.7 | 6.1 | 7.4 | 6.3 | 5.1 | 32.2 | 26.2 | 18.7 | 20.7 | 19.9 | 18.9 | 22.7 | 22.6 | 39.7 | 38.4 | 21.6 | 24.5 | 23.8 | 22.7 | 26.5 | 27.2 |
| March | 7.5 | 79.0 | 69.1 | 42.8 | 49.1 | 51.2 | 45.1 | 55.4 | 56.3 | 19.7 | 13.6 | 8.3 | 11.3 | 13.4 | 9.3 | 10.6 | 11.0 | 29.9 | 25.0 | 14.3 | 17.1 | 18.0 | 17.0 | 17.2 | 20.7 | 29.4 | 30.5 | 20.2 | 20.7 | 19.8 | 18.8 | 27.6 | 24.6 |
| April | 13.1 | 65.6 | 62.4 | 47.7 | 57.0 | 51.8 | 55.6 | 57.6 | 60.8 | 19.0 | 7.5 | 17.7 | 20.4 | 20.1 | 19.7 | 17.4 | 21.4 | 20.8 | 23.4 | 13.6 | 17.9 | 15.0 | 18.5 | 17.0 | 20.8 | 25.8 | 31.5 | 16.4 | 18.7 | 16.7 | 17.4 | 23.2 | 18.6 |
| | | 76.1 | 67.2 | 45.1 | 51.9 | 48.6 | 48.5 | 55.4 | 55.9 | 15.7 | 10.6 | 10.7 | 13.4 | 12.3 | 11.6 | 10.3 | 11.0 | 29.5 | 25.1 | 16.7 | 19.8 | 17.9 | 18.1 | 19.9 | 20.2 | 40.4 | 39.3 | 22.9 | 24.9 | 24. | 24.4 | 25.2 | 24.2 |

| Month. | Average Air Temperature | Fats: Crude Sewage | Fats: Influent | Fats: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Turbidity: Crude Sewage | Turbidity: Influent | Turbidity: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Relative Stability: Crude Sewage | Relative Stability: Influent | Relative Stability: Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Number of Bacteria at 20 Degrees C.—Millions per C.C.: Crude Sewage | Influent | Effluent of— 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1909 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | .70 | .59 | .63 | .61 | .55 | .46 | — | — | — | — | — | — | — | — |
| May | 16.8 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | .83 | .68 | .59 | .66 | .49 | .63 | — | — | — | — | — | — | — | — |
| June | 22.1 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | .86 | .86 | .77 | .84 | .63 | .78 | — | — | — | — | — | — | — | — |
| July | 23.3 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | .88 | .82 | .83 | .86 | .58 | .75 | 4.8 | 4.0 | 0.10 | 0.18 | 0.20 | 0.16 | 0.48 | 0.27 |
| August | 22.7 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | .73 | .70 | .63 | .61 | .32 | .51 | 5.8 | 5.4 | 0.17 | 0.31 | 0.38 | 0.46 | 0.95 | 0.57 |
| September | 18.2 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | .69 | .74 | .74 | .71 | .34 | .51 | 3.3 | 3.0 | 0.43 | 0.32 | 0.30 | 0.49 | 1.34 | 0.55 |
| October | 11.3 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | .78 | .66 | .61 | .75 | .44 | .59 | 2.8 | 2.7 | 0.16 | 0.34 | 0.37 | 0.24 | 0.47 | 0.36 |
| November | 8.9 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | .72 | .65 | .70 | .75 | .41 | .53 | 2.7 | 2.3 | 0.20 | 0.19 | 0.25 | 0.19 | 0.50 | 0.56 |
| December | −0.4 | — | — | — | — | — | — | — | — | — | — | 147 | 130 | 113 | 127 | 157 | 175 | — | — | .55 | .49 | .55 | .52 | .33 | .41 | 2.1 | 1.4 | 0.31 | 0.36 | 0.30 | 0.33 | 0.64 | 0.48 |
| January, 1910 | 1.7 | 25.9 | 22.5 | 10.2 | 13.5 | 17.9 | 10.8 | 22.4 | 25.1 | — | — | 109 | 119 | 118 | 100 | 130 | 116 | — | — | .55 | .48 | .46 | .48 | .38 | .38 | 1.1 | 0.91 | 0.54 | 0.49 | 0.57 | 0.55 | 0.66 | 0.61 |
| February | −0.8 | 32.1 | 27.2 | 14.0 | 18.6 | 18.7 | 15.4 | 15.9 | 16.4 | — | — | 98 | 115 | 104 | 98 | 121 | 121 | — | — | .53 | .47 | .43 | .51 | .35 | .37 | 1.6 | 1.4 | 0.98 | 0.88 | 1.25 | 0.84 | 1.20 | 1.20 |
| March | 7.5 | 32.0 | 26.8 | 11.2 | 14.6 | 26.0 | 11.8 | 18.7 | 17.3 | — | — | 97 | 117 | 118 | 102 | 115 | 147 | — | — | .47 | .39 | .40 | .43 | .33 | .34 | 2.0 | 0.21 | 0.60 | 0.62 | 0.60 | 0.53 | 0.50 | 0.44 |
| April | 13.1 | 23.1 | 13.1 | 8.7 | 12.2 | 13.0 | 10.3 | 14.3 | 13.4 | — | — | 149 | 204 | 136 | 174 | 146 | 158 | — | — | .66 | .62 | .67 | .67 | .34 | .42 | 2.9 | 2.0 | 0.27 | 0.29 | 0.28 | 0.26 | 0.66 | 0.35 |
| | | 28.3 | 22.4 | 11.0 | 14.7 | 18.9 | 12.1 | 17.8 | 18.1 | — | — | 120 | 137 | 118 | 120 | 134 | 143 | — | — | .69 | .63 | .62 | .65 | .42 | .51 | 2.9 | 2.33 | 0.37 | .398 | 0.45 | .40 | .74 | .539 |

hours. This is the only bed still pooled and only in one small spot."

As an approximate measurement of the settling solids contained in the effluent during the first six hours after the rest, the first six samples were mixed and 500 cc. placed in cylinders and allowed to settle for two hours; the depth of the deposit was as follows:

| Number of Bed. | Depth of Deposit in MM. |
|---|---|
| 20-4 | 8 |
| 20-6 | 5 |
| 20-5 | 5 |
| 20-2 | 4 |
| 20-3 | 2 |
| 20-1 | Bottom not covered. |

Considering also the results of analysis for suspended solids on the composite weekly sample (to be discussed later) it would appear that the two shallow beds discharged the largest amount of stored solids; as they were found to be badly clogged only one month later when dismantled, an idea may be formed of the large amount of material which they must have stored.

The coarse trap bed unloaded the best, the process being a steady, even discharge of solids, which continued for quite a time.

The coarse limestone, due to its large voids, easily yielded the stored solids, while the slag bed, probably due to the porous nature of the media, which allowed the slimy deposit to take a firmer hold upon it, discharged the solids only after several hours' service and in less amount than the similar sized media in 20-4.

The fine limestone, either on account of its depth, or the small size of the voids, or other unknown causes, discharged very little of the stored matters.

At once after the unloading the quality of the effluents all improved; this might not be entirely due to the rest and unload, but partially to the increasing temperature stimulating biological activity.

For the remainder of the tests to April 30th all the filters except 20-6 discharged more suspended matter than they received, which shows that all were trying to recover from the bad conditions of winter. Nitrification became more vigorous and had the tests been carried on longer, it appeared that the four upper beds would have completely recovered their full oxidizing power.

The bacterial examination of the filters at this time was not as complete as formerly, but those made, indicate that effluents from the four deeper beds were of equal purity to that yielded before the winter.

That the physical condition of the beds was not completely remedied is shown by the fact that by the 10th of April, or only five days after the rest, the fine trap bed (20-6) was pooled and steadily grew worse, until at the end of the tests its surface was practically a lake; the mixed trap bed (20-5) by the middle of April similarly pooled but was not as bad as 20-6. The fine limestone (20-1) gradually pooled so that at the end it did not present a satisfactory appearance. On the other hand, the coarse limestone (20-2) very slightly pooled about the middle of April but soon righted itself.

The slag and coarse trap beds (20-3 and 4) presented the best physical appearance of all, being quite free from pooling and normal looking.

As soon as the filters were finally shut down an examination of the media was made, a large representative sample taken for mechanical analysis, and the deposits upon the surface analyzed like sludge; the results were as follows:

"Fine limstone bed (20-1):

The upper surfaces of the top stones were perfectly clean and free from growths of any kind, the white lime-

## TABLE No. 31.

*Monthly Average Percentage Removal from Crude Sewage by the Outside Sprinkling Filters (For description of Beds see Text of Report).*

PERCENTAGE REMOVED FROM CRUDE SEWAGE.

Suspended Solids.

| Month. | Average Air Temperature | Total. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Fixed. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Volatile. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1909 | — | 59 | 48 | 60 | 60 | 48 | 54 | | | | | | | | | | | | |
| May | 16.8 | 24 | —256 | 43 | —8 | 47 | —183 | | | | | | | | | | | | |
| June | 22.1 | 90 | 53 | 50 | 50 | 34 | 59 | | | | | | | | | | | | |
| July | 23.3 | 80 | 54 | 35 | 62 | 44 | 51 | | | 45 | | 57 | | | | 31 | | 40 | |
| August | 22.7 | 26 | 58 | 20 | 45 | 63 | 66 | 20 | 61 | 29 | 34 | 51 | | 29 | 57 | 12 | 50 | 67 | |
| September | 18.2 | 55 | 62 | 57 | 50 | 61 | 61 | 56 | 61 | 46 | 54 | 63 | | 54 | 62 | 64 | 48 | 60 | |
| October | 11.3 | 53 | 33 | 11 | 67 | 72 | 60 | 55 | 35 | —51 | 62 | | 58 | 53 | 32 | 29 | 68 | | 61 |
| November | 8.9 | 22 | 12 | 52 | 70 | 47 | 27 | —8 | —30 | 64 | 82 | 64 | 21 | 30 | 23 | 49 | 66 | 43 | 29 |
| December | —0.4 | 68 | 61 | 63 | 60 | 70 | 72 | 83 | 74 | 73 | 70 | 73 | 82 | 57 | 52 | 56 | 53 | 68 | 64 |
| January, 1910 | 1.7 | 91 | 82 | 82 | 89 | 81 | 86 | 97 | 87 | 95 | 100 | 100 | 97 | 89 | 80 | 78 | 86 | 75 | 83 |
| February | —0.8 | 75 | 65 | 82 | 77 | 77 | 75 | 89 | 79 | 94 | 85 | 92 | 83 | 68 | 58 | 76 | 73 | 69 | 72 |
| March | 7.5 | 74 | 70 | 65 | 67 | 56 | 58 | 88 | 76 | 81 | 88 | 62 | 82 | 67 | 67 | 57 | 56 | 53 | 46 |
| April | 13.1 | —2 | —34 | —1 | 1 | —16 | —20 | —24 | —78 | —33 | —22 | —41 | —50 | 10 | —12 | 17 | 13 | 6 | —4 |
| | | 54 | 21 | 48 | 54 | 54 | 34 | 54 | 44 | 46 | 62 | 58 | 55 | 49 | 43 | 46 | 57 | 54 | 45 |

Nitrogen as—

| Month. | Organic. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Free Ammonia. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Nitrites. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Nitrates. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1909 | | | | | | | | | | | | | | | | | | | | | | | | |
| May | 47 | 67 | 44 | 43 | 26 | | 76 | 48 | 88 | 58 | 64 | | | | | | | | | | | | | |
| June | —33 | —25 | —60 | 15 | 5 | | 82 | 77 | 80 | 74 | 72 | | | | | | | | | | | | | |
| July | 39 | —11 | —16 | 10 | —29 | | 89 | 82 | 82 | 78 | 69 | | | | | | | | | | | | | |
| August | —29 | —35 | —44 | —12 | 16 | | 80 | 75 | 80 | 75 | 46 | | | | | | 19 | | — 840 | — 962 | — 838 | — 900 | — 88 | |
| September | 47 | 51 | 66 | 36 | 61 | 55 | 68 | 69 | 76 | 70 | 42 | 62 | 8 | —4 | 21 | —34 | —53 | 3 | — 350 | — 719 | —1163 | —1494 | — 400 | — 969 |
| October | 49 | 36 | 5 | 48 | 54 | 48 | 83 | 63 | 75 | 72 | 47 | 62 | 16 | —5 | 0 | —11 | —16 | 5 | — 372 | — 592 | — 678 | — 706 | — 230 | — 678 |
| November | 9 | 5 | —10 | 5 | 41 | —34 | 60 | 54 | 67 | 63 | 32 | 44 | —14 | —43 | —11 | —16 | 7 | 7 | — 586 | — 460 | — 466 | — 594 | — 131 | — 340 |
| December | 30 | 33 | 46 | 41 | 37 | 41 | 45 | 42 | 53 | 50 | 21 | 9 | —78 | —55 | —61 | —39 | —50 | —28 | — 114 | — 162 | — 149 | — 222 | — 56 | — 96 |
| January, 1910 | | | | | | | | | | | | | | | | —39 | | | — 43 | — 31 | — 43 | 0 | — 31 | — 19 |
| February | | | | 32 | | | | | | 36 | | | | | | —80 | | | — 51 | — 21 | — 35 | — 12 | — 16 | — 16 |
| March | | | | 44 | | | | | | 41 | | | | | | —38 | | | — 43 | — 36 | — 36 | — 26 | — 14 | — 43 |
| April | | | | —60 | | | | | | 63 | | | 0 | 20 | 45 | —67 | —93 | —58 | — 848 | — 768 | — 848 | — 913 | — 505 | — 769 |
| | 33 | 32 | 23 | 14 | 37 | 35 | 72 | 64 | 74 | 63 | 48 | 48 | —11 | —15 | 4 | —41 | —30 | —16 | — 160 | — 157 | — 164 | — 183 | — 94 | — 143 |

PERCENTAGE REMOVED FROM CRUDE SEWAGE.

Oxygen Consumed.

| Month. | Average Air Temperature. | Total. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Suspension. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Colloidal. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Solution. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1909 | — | 38 | 35 | 42 | 34 | | | 34 | 22 | 47 | 26 | | | | | | | | | 40 | 41 | 40 | 37 | | |
| May | 16.8 | 35 | 4 | 22 | 18 | | | 46 | —64 | 34 | —3 | | | | | | | | | 31 | 27 | 18 | 25 | | |
| June | 22.1 | 34 | 35 | 35 | 45 | | | 34 | 38 | 37 | 70 | | | | | | | | | 34 | 34 | 35 | 36 | | |
| July | 23.3 | 61 | 49 | 48 | 45 | | | 68 | 61 | 43 | 49 | | | | | | | | | 59 | 45 | 49 | 43 | | |
| August | 22.7 | 41 | 37 | 36 | 39 | 26 | | 37 | 36 | 22 | 35 | 56 | | | | | | | | 51 | 48 | 55 | 44 | 24 | |
| September | 18.2 | 41 | 40 | 36 | 30 | 27 | 32 | —107 | —90 | —190 | —203 | —121 | —88 | 47 | 37 | 49 | 41 | 30 | 29 | 57 | 62 | 56 | 54 | 47 | 52 |
| October | 11.3 | 40 | 26 | 28 | 41 | 40 | 37 | — 14 | —31 | — 43 | 13 | 37 | 4 | 49 | 30 | 23 | 34 | 31 | 39 | 52 | 42 | 52 | 52 | 46 | 45 |
| November | 8.9 | 30 | 20 | 35 | 36 | 34 | 22 | 0+ | — 1 | 2 | 3 | 3 | 0+ | 23 | 15 | 30 | 31 | 27 | 22 | 43 | 32 | 42 | 41 | 40 | 39 |
| December | —0.4 | 36 | 25 | 37 | 32 | 29 | 35 | 19 | — 7 | 1 | 3 | 0 | 25 | 35 | 25 | 44 | 32 | 37 | 40 | 41 | 33 | 39 | 38 | 29 | 32 |
| January, 1910 | 1.7 | 47 | 43 | 46 | 44 | 34 | 34 | 39 | 35 | 51 | 43 | 25 | 35 | 56 | 47 | 52 | 50 | 48 | 48 | 42 | 42 | 39 | 38 | 25 | 22 |
| February | —0.8 | 48 | 44 | 45 | 46 | 38 | 39 | 65 | 69 | 66 | 59 | 65 | 72 | 42 | 36 | 38 | 41 | 30 | 30 | 46 | 38 | 40 | 43 | 33 | 31 |
| March | 7.5 | 46 | 38 | 35 | 43 | 30 | 29 | 58 | 43 | 32 | 53 | 46 | 44 | 52 | 43 | 40 | 43 | 42 | 31 | 31 | 30 | 33 | 36 | 6 | 16 |
| April | 13.1 | 27 | 13 | 21 | 15 | 12 | 7 | 7 | — 7 | — 6 | — 4 | 8 | —13 | 35 | 14 | 28 | 11 | 18 | 0 | 36 | 28 | 35 | 33 | 10 | 28 |
| | | 41 | 32 | 36 | 36 | 27 | 27 | 32 | 15 | 22 | 26 | 34 | 30 | 43 | 33 | 39 | 39 | 33 | 32 | 43 | 38 | 40 | 39 | 38 | 40 |

| Month. | Fats. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 | Number of Bacteria at 20 Degrees C.—Millions per C. C. Percentage removed from influent. Effluent of— 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1909 | | | | | | | | | | | | |
| May | | | | | | | | | | | | |
| June | | | | | | | | | | | | |
| July | | | | | | | 97.5 | 95.5 | 95.0 | 96.0 | 88.0 | 93.2 |
| August | | | | | | | 97.0 | 94.2 | 93.0 | 91.5 | 82.5 | 89.4 |
| September | | | | | | | 85.7 | 89.3 | 90.0 | 83.7 | 55.3 | 81.7 |
| October | | | | | | | 94.1 | 87.5 | 86.4 | 91.2 | 82.9 | 86.7 |
| November | | | | | | | 91.4 | 91.8 | 89.2 | 91.8 | 78.4 | 75.6 |
| December | | | | | | | 77.9 | 74.3 | 78.6 | 76.5 | 54.3 | 65.7 |
| January, 1910 | 61 | 48 | 31 | 58 | 14 | 3 | 40.6 | 46.1 | 37.4 | 39.5 | 27.5 | 32.9 |
| February | 56 | 42 | 42 | 52 | 50 | 51 | 30.0 | 37.1 | 10.7 | 40.0 | 14.3 | 14.3 |
| March | 65 | 54 | 19 | 63 | 42 | 46 | —18.6 | —19.5 | —18.6 | —15.2 | —13.8 | —10.9 |
| April | 62 | 47 | 44 | 55 | 38 | 42 | 86.6 | 85.5 | 86.0 | 86.7 | 67.2 | 82.2 |
| | 61 | 48 | 33 | 57 | 37 | 36 | 87. | 86. | 85. | 86. | 75. | 81. |

stone being discolored in places by iron oxide; for six inches beneath the surface the voids were badly sludged up, especially so in those places where it was noted that pooling would first develop; there were many flies on the media but very few larvae; for the next six inches, or at a depth of one foot, the media became cleaner, the deposits occurring in patches upon the white surface of the stones. In the corners of the bed (undosed by the circular spray) the media, to a depth of two and one-half feet at least, was perfectly clean and plainly showed that there had been no lateral subsurface distribution.

Coarse limestone bed (20-2):

The upper surface of the top layer of stone was perfectly clean like 20-1; immediately beneath there was a considerable amount of sludge occurring in lumps, rather than films, upon the stones; this condition only exists for about six inches, below which the stones gradually and uniformly grow cleaner, until at a depth of two feet the large voids of this bed are entirely open and the stones fairly clean.

Slag bed (20-3):

The film upon the surface of the top stones quickly dried, forming flakes, but immediately below the surface the pores of the slag, being filled with the usual jelly, retained moisture for a long time (at least two weeks). There were innumerable flies but few larvae, the black deposit was more sticky than in other beds and of slightly offensive odor; an important matter always noted in examining the slag media was that the bacterial jelly and also the sludge-like deposit adhered more tenaciously to the rough porous slag than the other kinds of stone.

The bed was thus sludged up for a depth of sixteen inches, below which it began to grow cleaner, but was still quite dirty at two and one-half feet depth.

## TABLE No. 32.

*Showing the Amount and Quality of Deposits Found in the Outside Filters when Dismantled at the End of the Test.*

| Kind of Media. | Station Number. | Number of Days After Shut-Down that Deposit Was Collected. | Depth at which Sample Was Taken. | Per Cent. Voids. Mch. 23 1909. Initial. | Per Cent. Voids. May 6th to 10th, 1910. Washed. | Per Cent. Voids. May 6th to 10th, 1910. Dirty. | Per Cent. Voids. Loss. | Pounds of Deposit per Cubic Foot Media. | Analysis of the Deposit. Wet Deposit. Per Cent. Water. | Analysis of the Deposit. Wet Deposit. Specific Gravity. | Per Cent. of the Dry Residue that is Volatile. | Per Cent. of the Dry Residue that is Fixed. | Per Cent. of the Dry Residue that is Nitrogen. | Per Cent. of the Dry Residue that is Fats. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fine limestone | 20-1 | 9 | 1′ | 47.1 | 46.6 | 42.6 | 4.0 | 4.55 | 68.8 | 1.14 | 30.6 | 69.4 | 1.0 | 8.5 |
| Coarse limestone | 20-2 | 9 | 1′ | 49.5 | 49.4 | 48.6 | 0.8 | 1.05 | 65.8 | 1.17 | 29.4 | 70.6 | 1.4 | 9.5 |
| Slag | 20-3 | 9 | 1′ | 52.5 | 49.5 | 47.2 | 2.3 | 1.40 | 77.8 | 1.10 | 35.9 | 64.1 | 1.8 | 3.8 |
| Coarse trap | 20-4 | 6 | 9″ | 46.4 | 46.6 | 47.3 | 0.8 | 0.70 | 71.9 | 1.25 | 26.2 | 73.8 | 1.4 | 2.1 |
| | | 6 | 1′6″ | 46.4 | 47.4 | 46.5 | 0.9 | 0.87 | 55.0 | 1.38 | 9.2 | 90.8 | 0.6 | 0.8 |
| | | 6 | 3′ | 46.4 | 45.5 | 46.4 | 0.9 | 1.57 | 55.0 | 1.38 | 9.2 | 90.8 | 0.6 | 0.8 |
| | | 6 | 5′ | 46.4 | 46.5 | 46.0 | 0.5 | 1.05 | 55.0 | 1.38 | 9.2 | 90.8 | 0.6 | 0.8 |
| | | 7 | 6′ | 46.4 | 45.5 | 44.6 | 0.9 | 1.92 | 55.0 | 1.38 | 9.2 | 90.8 | 0.6 | 0.8 |
| | | 7 | Floor | -------- | -------- | -------- | -------- | -------- | 48.0 | 1.52 | 7.4 | 92.6 | 0.3 | 0.5 |
| Mixed trap | 20-5 | 10 | 3″ | 46.3 | 46.7 | 43.4 | 3.3 | 5.60 | 68.5 | 1.13 | 24.3 | 75.7 | 1.1 | 4.3 |
| | | 10 | 9″ | 46.3 | 48.3 | 43.2 | 5.1 | 4.72 | 68.5 | 1.13 | 24.3 | 75.7 | 1.1 | 4.3 |
| Fine trap | 20-6 | 10 | 3″ | 45.7 | 48.4 | 43.4 | 5.0 | 6.75 | 75.3 | 1.09 | 26.6 | 73.4 | 1.2 | 5.2 |
| | | 10 | 9″ | 45.7 | 46.4 | 45.0 | 1.4 | 3.75 | 75.3 | 1.09 | 26.6 | 73.4 | 1.2 | 5.2 |
| | | 10 | Floor | -------- | -------- | -------- | -------- | -------- | 56.0 | 1.36 | 10.8 | 89.2 | 0.4 | 1.2 |

**Outside Sprinkling Filter.—Station No. 20-4.**
**Condition of 1-inch to 3-inch trap media at end of tests.**

Coarse trap bed (20-4):

The film on the surface of the top layer of stones dried and desquamated very quickly; beneath the surface layer a heavy accumulation had formerly been observed; the stones were only slightly dirty; in the upper six inches were many flies and beginning at that depth the larvae occurred in greater numbers than in any other bed, being especially numerous upon the cleaner stones.

At a depth of one foot the only portion of the media showing any clogging was the overdosed ring about one foot wide and two and one-half feet from the nozzle; at two feet depth sludge had entirely disappeared, every stone except in the undosed corners being literally white with larvae; between this depth and four feet the stones grew dirtier but with a different quality material; in the upper portion of the beds the deposit had a sticky, tenacious, gelatinous composition, whereas at this point the deposit was granular and more like mud than sludge. This condition continued until the cobbles were reached, the surfaces of which were fairly clean, only in pockets and on level surfaces was any dirt found, which resembled sand more than mud; between the brick underdrains small stones had fallen upon the floor and had slightly retarded the free flow through the underdrains indicated by the fact that back of them were found deposits of sandy material up to the depth of one-quarter inch; there were no fungus growths in the underdrains nor upon the floor, so that it is not at all probable that any reducing action occurred therein.

Mixed trap bed (20-5):

The surface of the gravel layer was perfectly clean, but upon removing the top stones a horizontal layer or mat of wool fibres and sludge was found which was nearly impervious to the rapid passage of the influent; the trap stones beneath this mat were imbedded in a black, tenacious mass like sludge, through this reddish-yellow spots showed where the iron turnings (placed in this bed when reconstructed) had been oxidized; this complete clogging of the media extended to a depth of six inches, where the voids began to be slightly open, so that at a depth of eighteen inches the voids were not clogged, but the stones covered with a film of the black deposit. Even in this badly sludged up bed the undosed corners were found perfectly clean and dry.

Fine trap bed (20-6):

The surface was quite clean, but the same mat existed as in 20-5 and described above; the worst clogging was in the upper three inches, beneath which flies were present and some voids open, but the media was very dirty.

Beginning about one foot below the surface, the size of the media was undoubtedly smaller than appeared on the surface of the bed, stones between one-half inch and one inch forming a large percentage of the total; at a depth of one foot the media was cleaner than above, except in the over-dosed ring, and on the cleaner stones the larvae were found; the cobbles and underdrains were found in a similar condition to 20-4."

The results of mechanical analysis, void determination, and sludge analysis of the deposits are shown in diagram No. 26 and Table No. 32. The dotted straight line on the mechanical analysis diagram shows probable composition of the mixtures as screened. The disintegration of limestone and slag is clearly seen by the divergence of the curve from the dotted line.

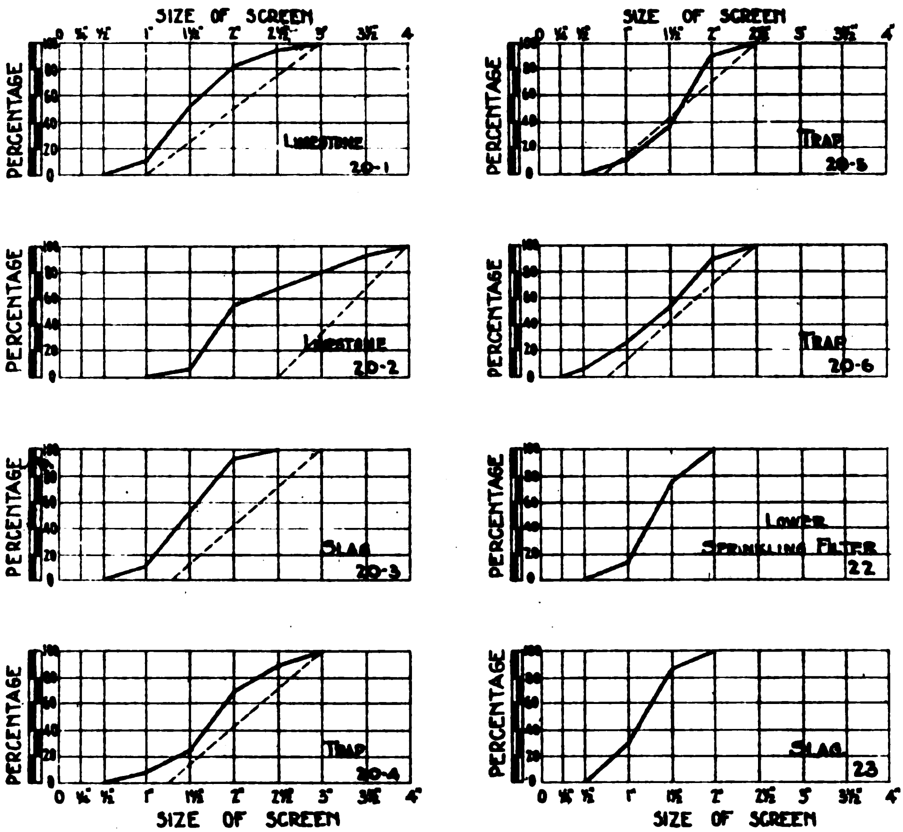
The character and amount of deposit as shown in Table No. 32 agrees with the ocular observation, and attention is drawn to the small amount of organic matter stored in the coarse trap bed—in fact, a representative sample of deposit on this bed was difficult to collect, due to the small amount on each stone.

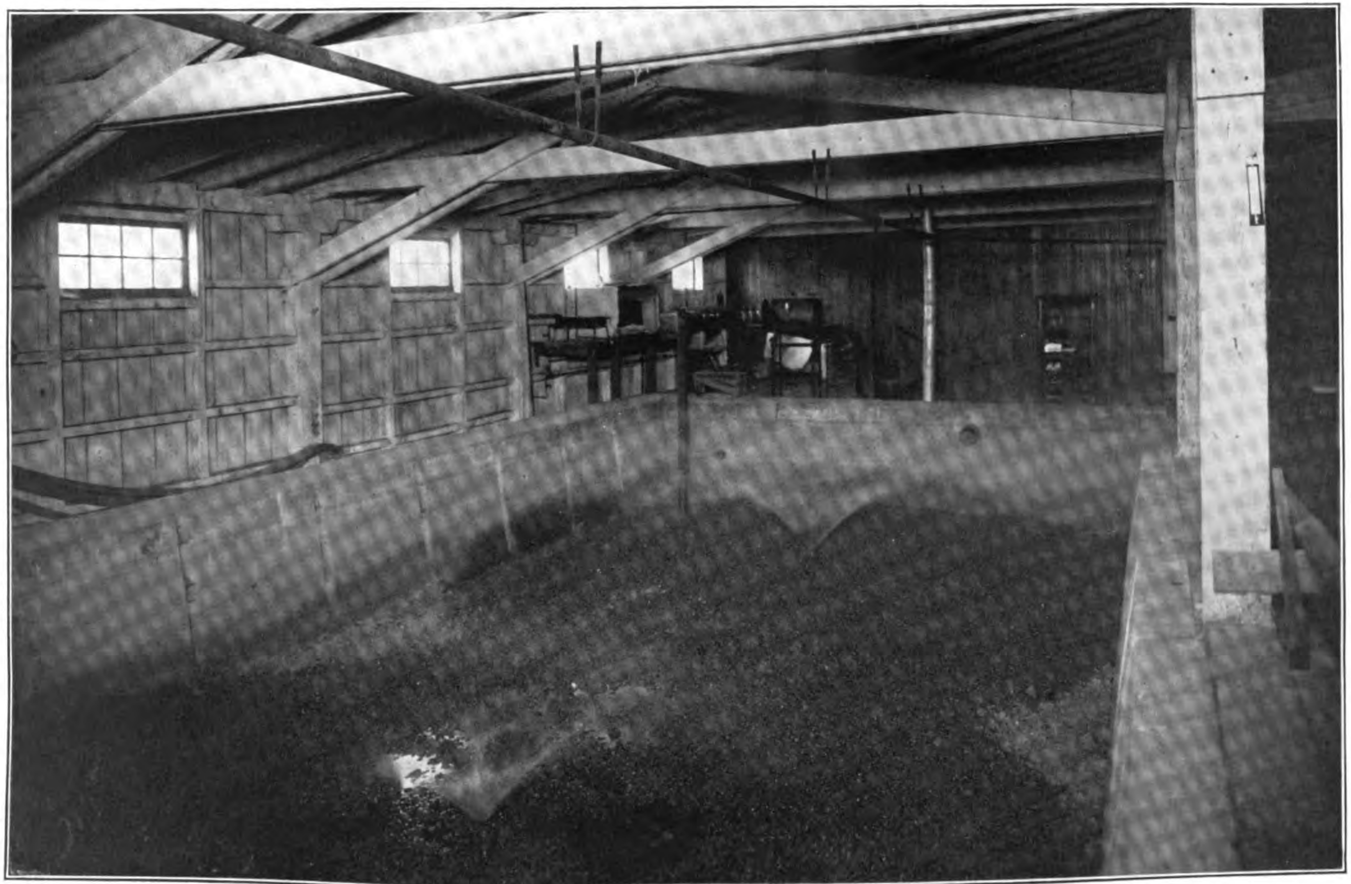
Monthly averages of the chemical and bacteriological examinations of the filters are given in Tables No. 30 and 31.

## DIAGRAM Nº 26

# MECHANICAL ANALYSES

### OF THE MEDIA MADE WHEN THE FILTERS WERE DISMANTLED





**Upper Sprinkling Filter.—Station No. 21.**
**6 feet of coarse clinker. Reading nozzles.**

**Upper Filter (No. 21):**

The object sought for in operating this filter was to find whether it was possible to operate a fine media bed, over which roughly screened sewage was well distributed, by properly arranged resting periods and raking.

The mode of operating this filter has already been described, and it is only necessary to examine the analysis of weekly samples of influent and effluent shown in Table No. 33 and the relative stability on diagram No. 21 to see that the superior quality of effluent produced was caused by complete storage of the suspended and colloidal solids (the early effluents being as clear as filtered water).

When the mat formed on the surface, oxidation ceased and the effluent became putrescent, as is seen by the rapid fall in the relative stability diagram.

It would seem from this experiment that it is not practicable to apply a poorly prepared influent to a sprinkling filter, expecting to maintain it by rest and rakings, on account of the low rate of operation and the high cost of maintenance, together with the inequality of the effluent over extended periods.

**Lower Filter (No. 22):**

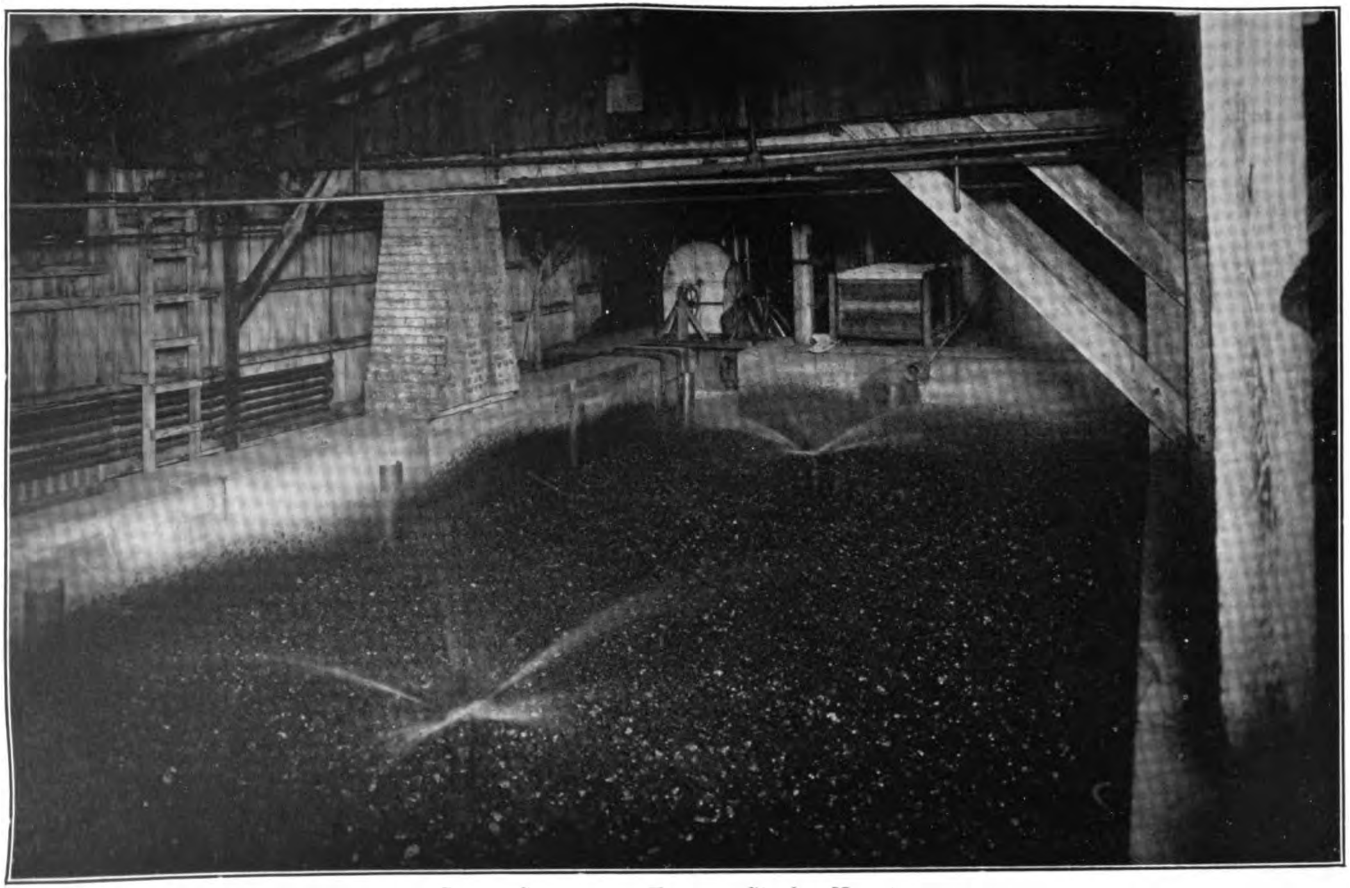
During the experimental design of the cam which controlled nozzle pressure on this bed, the influent was applied in an unsystematic and irregular manner; this condition existed during the daytime from July 15th until the 22d, when regular operation began.

The effluent from the bed during its initial operation was very low in suspended solids, contained nitrates and was perfectly stable. The rate was raised each week by increasing the number of lobes upon the cam. Until September 15th the average influent had contained 45 parts per million suspended solids and the effluent only 23; practically one-half of the applied solids had been retained within the bed, and on that date the bed was noticed to be pooled. Trusting in the uniform size of the media

## Table No. 33.

*Influent and Effluent of the Upper Sprinkling Filter No. 21.*

| Dates. | PARTS PER MILLION. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total Suspended Solids. | | Nitrogen as— | | | | | Oxygen Consumed 30 Min. at 100°. | |
| | | | Organic Nitrogen. | | Free Ammonia. | | Nitrites + Nitrates. | | |
| | Influent. | Effluent. | Influent. | Effluent. | Influent. | Effluent. | Effluent. | Influent. | Effluent. |
| 1909. | | | | | | | | | |
| June 18 to June 21 | 94 | 0 | 7.0 | 1.2 | 1.0 | 0.4 | 3.2 | 68.4 | 26.8 |
| June 21 to June 28 | 107 | 0 | 9.0 | 2.2 | 2.2 | 0.6 | 3.0 | 59.6 | 22.0 |
| June 28 to July 5 | 168 | 0 | ---------- | 0.7 | 5.8 | 0.9 | 4.8 | 58.8 | 20.0 |
| July 5 to July 12 | 96 | 54 | 1.8 | 0.3 | 3.8 | 2.1 | 2.6 | 63.2 | 26.0 |
| July 12 to July 15 | 142 | 22 | 4.8 | 1.0 | 4.0 | 2.2 | 0.8 | 70.4 | 41.2 |
| Bed rested and surface forked: | | | | | | | | | |
| July 30 to August 2 | 73 | 0 | ---------- | 1.2 | 3.2 | 1.6 | 5.1 | 65.2 | 30.0 |
| August 2 to August 9 | 117 | 0 | 6.0 | 1.8 | 4.0 | 0.6 | 3.8 | 71.2 | 24.0 |
| August 9 to August 16 | 169 | 0 | 4.8 | 0.8 | 3.2 | 0.4 | 3.8 | ---------- | ---------- |
| August 16 to August 23 | 218 | 0 | 6.7 | 2.2 | 2.9 | 1.0 | 2.4 | 60.0 | 21.8 |
| August 23 to September 4 | 210 | 22 | 4.4 | 0.2 | 3.6 | 0.6 | 0.2 | 87.2 | 47.6 |



**Lower Sprinkling Filter.—Station No. 22.**
**6½ feet of ¾-inch to 1½-inch stone. Taylor square nozzles.**

giving maximum voids, the aeration effected by the ventilating system, and the nearly perfect distribution, no attention was paid to the pooling, but immediately upon its occurrence the bed yielded a dirtier effluent than formerly, and in two weeks the slight pooling disappeared. During the pooling no deterioration was noted in the uniform stability of the effluent.

The filter was shut down from October 6th to 13th, during construction in sedimentation tank No. 12 and it is to be noted that the bed did not unload thereafter. Subsequent observation on the physical condition of this bed would indicate that the solids accumulated near the surface, and if they dried out sufficiently during this rest to desquamate, when the filter started up they were only carried deeper into the bed, not all the way down so as to pass out in the effluent.

While the bed was shut down the orifices of the nozzles were reamed out in order to allow them to discharge a larger amount of sewage upon the bed and the distribution was injured thereby, but the effluent still remained uniformly stable.

About October 20th slight pooling again developed (apparently not due to any growths but to an accumulation of solids within the upper three inches of media) and this time grew quite bad. It was anticipated that the bed would clear itself, therefore no change in operation was made, and automatically the bed heavily unloaded, as is graphically shown on diagram No. 27. This caused a deterioration in the stability of the effluent, but it steadily recovered its perfect stability. After the bed had unloaded new Taylor nozzles were placed, which restored the distribution to its former excellence. For one week about this time it was necessary, due to construction, to operate the bed irregularly, but it did not produce any adverse effect upon the character of the effluent.

Beginning in November, a thermometer was placed in the underdrains at the ventilator and read daily; it was soon found that the temperature of the bottom of the bed was subject to sudden and considerable variations, apparently having no definite connection with the air temperature within the building at the filter; at this time the physical and biological condition of the bed was excellent, and it was thought advisable to determine the effect of stopping the artificial ventilation of the bed; on December 8th, therefore, the cowl was removed and the venilator plugged; four days later slight pooling was noticed, which gradually increased in area, but no deterioration in the quality of the effluent was apparent, although the filter was built in an enclosed concrete tank, and the artificial ventilation was not in service.

In this condition the bed was shut down over Christmas, as has been described under the history of the outside filters. When put in service again on December 28th the bed did not unload nor was there any change in the extent of the pooling.

On January 1st the bed was pooled, apparently caused by superficial clogging with suspended solids; the following day the bed was covered with the same pink growth already described as occurring on the same date on the outside filters.

It was decided to experiment on the outside filters before attempting any treatment of this bed; therefore, the growth was allowed to develop for seven days, in which time it grew to such an extent that the entire surface of the filter was covered with it, and the pools had joined into one lake.

In the previous use of bleach upon the outside filters, considerable amounts of available chlorine had been wasted by passage through the bed at a faster rate than it could be used by the oxidizable matters contained therein.

A solution of 10 pounds of 38 per cent. bleach in nine gallons of water was added in 250 cc. portions to the effluent of tank No. 12 (influent to lower filter), the rate

## Table No. 34.

*Data From Lower Sprinkling Filter No. 22 During January, 1910.*

| Dates. | Station Number. | Parts per Million. Suspended Solids. Total. | Suspended Solids. Fixed. | Suspended Solids. Volatile. | Nitrate. | Oxygen Consumed. Total. | Oxygen Consumed. Settling. | Oxygen Consumed. Colloidal. | Oxygen Consumed. Dissolved. | Fats. | Turbidity. | Relative Stability. | Average Air Temperature. ° C. | Pounds Dry Bleach Added per Acre per Day. | Pounds Dry Bleach Added per Million Gallons. | Condition of Ventilator. | Remarks: 12—Influent. 22—Effluent. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| December 28 to January 5 | 12 | 72. | 8. | 64. | | 76.4 | 17.2 | 22.4 | 36.8 | 17.8 | | | +10. | | | | The filter had been shut down over Christmas for three days. When started up on December 28th pooling was noticed. January 1st it had increased, and on January 2nd the bed was covered with a pink fungus growth, and pooled very badly, which condition continued during remainder of sampling period. |
| | 22 | 60. | 12. | 48. | 2.3 | 54.4 | 17.2 | 14.0 | 23.2 | 21.4 | 80. | .85 | | | | | |
| Per cent. removed | | 17. | — | 25. | | 29. | 0. | 37. | 37. | — | | | | | | | |
| January 5 to January 12 | 12 | 56. | 12. | 44. | | 68.8 | 6.8 | 28.8 | 33.2 | 20.8 | | | +9. | | | | January 5th, pooling very bad. Ten pounds of 38 per cent. bleach dissolved in nine gallons of water and tin cup portions added every two minutes, so that the effluent always contained a trace of residual chlorine. In five hours one-half of the growth was destroyed, and nitrates had risen from 1.5 to 4. January 10th, after twenty-four hours' rest to dry bed out, forty-seven pounds of bleach dissolved in forty-seven gallons of water applied to bed through the nozzles, and after one hour's retention, influent applied regularly. Next morning the stones were perfectly free from the fungus, but bed still pooled in a few places |
| | 22 | 24. | 4. | 20. | 2.5 | 54.0 | 5.6 | 22.8 | 25.6 | 18.4 | 130. | .57 | | | | | |
| Per cent. removed | | 57. | 66.5 | 54.5 | | 21.5 | 17.5 | 21.0 | 23.0 | 11.5 | | | | | | | |
| January 12 to January 19 | 12 | 84. | 0. | 84. | | 66. | 7.6 | 22. | 36.4 | 21.8 | | | +10.6 | | | | January 12th, after six hours' rest, again applied forty-seven pounds of bleach in forty-seven gallons of water through the nozzles, and kept bed idle for sixty-eight hours. On January 15th started up, operating the valve by hand, so as to allow the nozzles to play on one portion of the bed constantly. The stones are perfectly clean and the effluent quite dirty. The bed is now free from pools and has remained so. |
| | 22 | 36. | 0. | 36. | 1.5 | 52. | 8.0 | 19.2 | 24.8 | 11.2 | 180. | .50 | | | | | |
| Per cent. removed | | 57. | | 57. | | 21. | — | 13. | 32. | 48.5 | | | | | | | |
| January 19 to January 26 | 12 | 84. | 16. | 68. | | 70.8 | 10.0 | 25.2 | 35.6 | 17.8 | | | +12.9 | | | | January 25th, began to disinfect the INFLUENT to the filter by constantly adding bleach at rate of 5 ppm. available chlorine. Stones perfectly clean and no pools. |
| | 22 | 40. | 0. | 40. | 3.0 | 50.4 | 8.4 | 20.8 | 21.2 | 13.0 | 55. | .87 | | | | | |
| Per cent. removed | | 52.5 | 100. | 41. | | 29.0 | 16. | 17.5 | 40.5 | 27. | | | | | | | |
| January 26 to February 2 | 12 | 92. | 8. | 84. | | 67.2 | 10.0 | 23.6 | 33.6 | 14. | | | +11.4 | | | | Bleach added constantly to influent at rate of 350 pounds of dry bleach per acre per day, or 110 pounds per million gallons sewage. Stones clean and free from pools. |
| | 22 | 56. | 12. | 44. | 3.5 | 47.6 | 8.8 | 20.0 | 18.8 | 6.6 | 80. | .65 | | | | | |
| Per cent. removed | | 39. | — | 47.5 | | 29.0 | 12. | 15. | 44.0 | 53. | | | | | | | |
| February 2 to February 9 | 12 | 72. | 0. | 72. | | 70.4 | 7.6 | 27.6 | 35.2 | 15.6 | | | | 293. | 93.5 | Closed | Stones clean and free from pools. |
| | 22 | 40 | 0. | 40. | 3.5 | 49.2 | 8.0 | 17.6 | 23.6 | 10.6 | 75. | .82 | +10.2 | | | | |
| Per cent. removed | | 44.4 | | 44.4 | | 30. | — | 36. | 33. | 32. | | | | | | | |
| February 9 to February 16 | 12 | 48. | 28. | 20. | | 64.4 | 8.4 | 25.6 | 30.4 | 17.8 | | | | 192. | 61. | Closed | Stones clean and free from pools. |
| | 22 | 48. | 20. | 28. | 2.0 | 59.2 | 1.6 | 36.8 | 20.8 | | 85. | .88 | +10.5 | | | | |
| Per cent. removed | | 0. | 29. | — | | 8. | 81. | — | 31.6 | | | | | | | | |
| February 16 to February 23 | 12 | 58. | 0. | 58. | | 70. | 6.8 | 30. | 33.2 | 25.6 | | | | 214. | 68. | Closed | Stones clean and free from pools. |
| | 22 | 64. | 0. | 64. | 1.5 | 52. | 14.8 | 13.2 | 24.0 | 11.2 | 85. | | +12.4 | | | | |
| Per cent. removed | | — | | — | | 26. | — | 56. | 28.0 | 56.4 | | | | | | | |

# Table No. 35.

*Bacteriological Data from Lower Sprinkling Filter During January, 1910.*

| January, 1910. | | Bacteria per C. C. | | |
|---|---|---|---|---|
| | | Influent. | Effluent. | |
| Saturday | 1 | ------------ | ------------ | Pooling noticeable. |
| Sunday | 2 | 2,000,000 | 660,000 | Bed covered with pink fungus growth and badly pooled. |
| Monday | 3 | ------------ | ------------ | Bed covered with pink fungus growth and badly pooled. |
| Tuesday | 4 | 790,000 | 880,000 | Bed covered with pink fungus growth and badly pooled. |
| Wednesday | 5 | 860,000 | 370,000 | Bed covered with pink fungus growth and badly pooled. |
| Thursday | 6 | 460,000 | 220,000 | Bed covered with pink fungus growth and badly pooled. |
| Friday | 7 | ------------ | ------------ | Bed covered with pink fungus growth and badly pooled. Bleach applied to influent. See chemical table. |
| Saturday | 8 | 520,000 | 200,000 | Stones are cleaner, but still pooled. |
| Sunday | 9 | ------------ | ------------ | Resting. |
| Monday | 10 | ------------ | ------------ | Rested until 1 P. M. Then applied bleach solution through nozzles. Bleach applied to influent. See chemical table. |
| Tuesday | 11 | 660,000 | 530,000 | Stones quite clean, but still some pooled. |
| Wednesday | 12 | ------------ | ------------ | Applied forty-seven pounds of bleach through nozzles. Then rested. Bleach applied to influent. See chemical table. |
| Thursday | 13 | ------------ | ------------ | Resting. |
| Friday | 14 | ------------ | ------------ | Resting. |
| Saturday | 15 | 500,000 | 1,400,000† | Ran at constant head. Effluent dirty. Bed clean and no pools. |
| Sunday | 16 | 820,000 | 1,450,000* | Ran at constant head. Effluent dirty. Bed clean and no pools. |
| Monday | 17 | 610,000 | ------------† | Bed is clean and entirely free from pools. |
| Tuesday | 18 | 700,000 | 900,000† | Bed is clean and entirely free from pools. |
| Wednesday | 19 | ------------ | ------------ | Bed is clean and entirely free from pools. |
| Thursday | 20 | 710,000 | 660,000 | Bed is clean and entirely free from pools. |
| Friday | 21 | 510,000 | ------------† | Bed is clean and entirely free from pools. |
| Saturday | 22 | 540,000 | 400,000 | Bed is clean and entirely free from pools. |
| Sunday | 23 | 730,000 | 550,000 | Bed is clean and entirely free from pools. |
| Monday | 24 | 470,000 | 410,000 | Bed is clean and entirely free from pools. |
| Tuesday | 25 | ------------ | ------------ | Bed is clean and entirely free from pools. Began to disinfect influent. |
| Wednesday | 26 | 670,000 | 178,000 | Bed is clean and entirely free from pools. Influent disinfected. See chemical table. |
| Thursday | 27 | 1,300 | 110,000 | Bed is clean and entirely free from pools. Influent disinfected. See chemical table. |
| Friday | 28 | 500 | 105,000 | Bed is clean and entirely free from pools. Influent disinfected. See chemical table. |
| Saturday | 29 | 225 | 130,000 | Bed is clean and entirely free from pools. Influent disinfected. See chemical table. |
| Sunday | 30 | 175 | 140,000 | Bed is clean and entirely free from pools. Influent disinfected. See chemical table. |
| Monday | 31 | ------------ | ------------ | Bed is clean and entirely free from pools. Influent disinfected. See chemical table. |

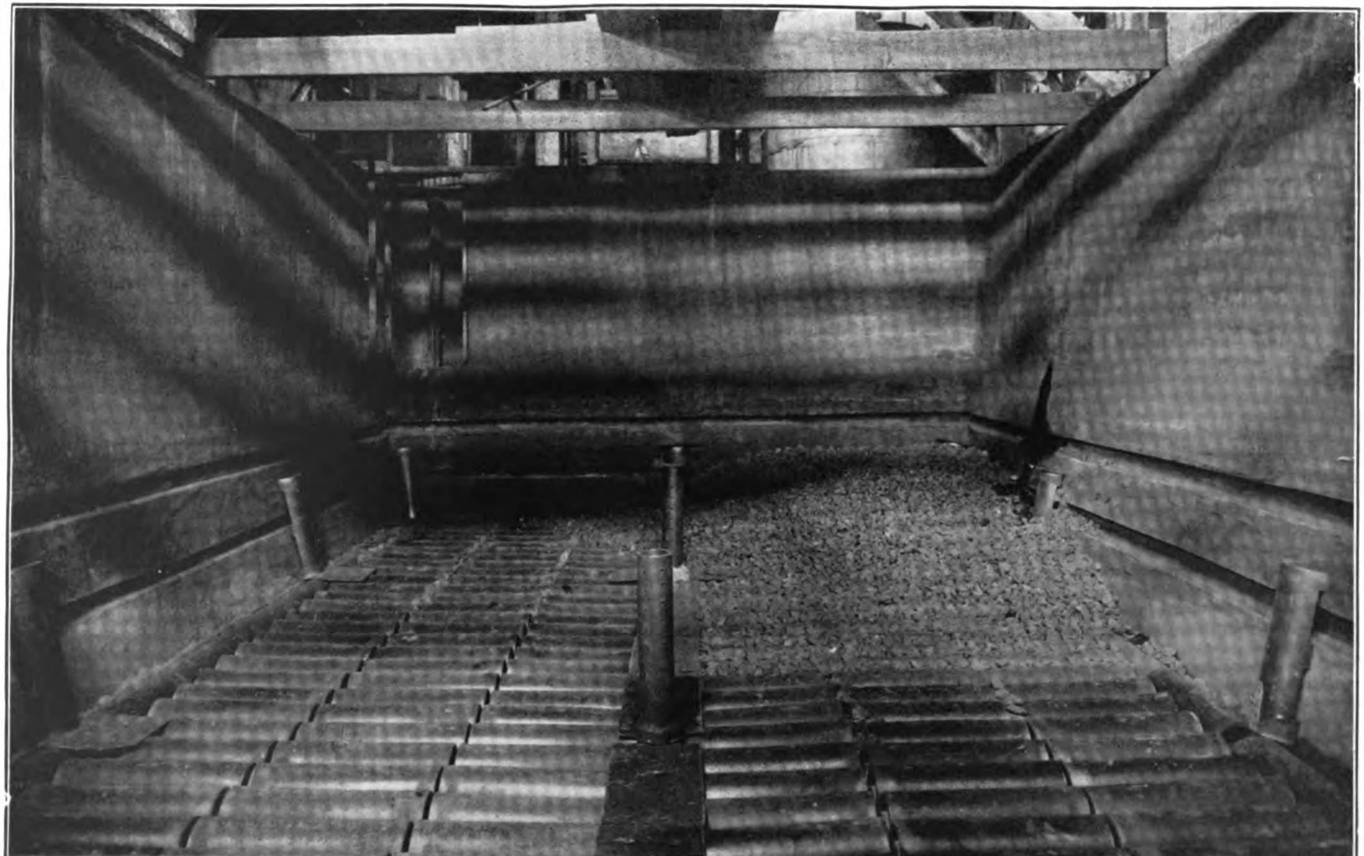
* Liquifiers over 300,000 per C. C.

† Bed unloading. Many liquifiers present.

being regulated so that the effluent of the filter contained only a small amount of available chlorine as determined by samples taken every five minutes and analyzed at once. This method was used successfully to correct the fault of washing the chemical through, as done upon the outside filters.

One-half hour after commencing the treatment the edges of many stones were visible through the pink coating; at the end of three and one-half hours the pooling had markedly decreased, and the stones were becoming visible in places; after the lapse of five hours, treatment was discontinued with at least 40 to 50 per cent. of the surface freed from the growth and pooling ended. Bleach had been applied in this manner at the rate of 850 pounds dry powder per acre; during the treatment the nitrates in the effluent rose from 1.5 to 4 parts per million and a sample of the effluent 4¾ hours after treatment began had a relative stability of .42 (the residual chlorine was neutralized before incubation), the stability of the effluent increased, although the filter still was at least half covered with the growth and pooled.

The filter was shut down at noon on January 9th and allowed to dry out until 1.00 P. M. on January 10th, at which time a solution (one pound bleach per gallon water) containing 47 pounds bleach (two tons per acre) was sprayed over the bed through the influent pipe and nozzles; it was allowed one hour contact with the bed and then the usual influent applied; where the bed was pooled the strong bleach solution remained on the surface, but elsewhere it penetrated the clogging layer and caused the same change in its composition as has been noted before; after the bleach was applied the effluent outlet was watched but no water drained through, so all of the 47 gallons must have remained in the bed.



Underdrain and Ventilating Systems of the Lower Sprinkling Filter.—Station No. 22.

When the bed was started the effluent was examined for residual chlorine with the following results:

| Time After Bed Was Started. | Parts per Million. Available Chlorine in the Effluent. | Appearance. |
|---|---|---|
| 0 | 6,390 | Heavy white precipitate. |
| 10 minutes | 160 | All samples appeared dirty, but each succeeding one less so. |
| 20 minutes | 39 | |
| 30 minutes | 25 | |
| 1 hour | 10.6 | |
| 1½ hours | 7.1 | |
| 2 hours | 7.1 | |

This left the top stones quite free from the pink growth and clean, but below there were still considerable amounts of clogging matters.

On January 12th the bed was rested for 6 hours in order that the water within the bed might drain out, then 47 pounds of bleach in a strong solution was applied through the nozzles and allowed to remain in the bed for 68 hours; the top stones soon turned white and 48 hours after it was applied an examination of the media was made, and it was found that the formerly black deposit had been changed to a yellowish-grey for a depth of at least 6 inches.

When the bed was started up the cam was not used, but the nozzles allowed to play constantly, the head being regulated from time to time by hand so that the entire area of the bed was thus dosed at a high rate. The initial effluent was opaque, full of dead larvae, and contained 5.6 parts per million residual chlorine; 10 minutes later the effluent was less opaque, contained no larvae, and 3.5 residual chlorine; in one-half hour the effluent was free from residual chlorine, and the suspended matter appeared to be composed of desquamated flakes; each succeeding sample became clearer.

The bed was now perfectly clean and free from pooling and was operated in the usual manner until January 25th, when an apparatus was set up to add a solution of bleach to the effluent of tank No. 12 (the influent to this filter) in the same way as described for disinfection studies.

In this way the lower sprinkling filter No. 22 was operated until March 2d, during which time the rate at which bleach was added was as follows:

| Period—1910. | Average Rate of Application Bleach. | |
|---|---|---|
| | Pounds per Acre per Day. | Pounds per Million Gallons. |
| January 26th to February 2d | 350 | 112 |
| February 2d to February 9th | 293 | 93.5 |
| February 9th to February 16th | 192 | 61 |
| February 16th to February 23d | 214 | 68 |
| February 23d to March 2d | 222 | 71 |

During the time that the influent to the lower filter was being disinfected the bed remained entirely free from pooling and had the appearance of a perfectly new bed; the effluent returned to its former condition of high stability, although less regular than in summer.

Soon after the addition of bleach to the influent was stopped the stones began to grow gray and the normal slimy jelly developed; twelve days after, or on March 14th, the bed showed evidence of pooling; a pit was dug three feet from a nozzle at a point that appeared clogged, where an examination showed that there was no accumulation of wool fibres as had been found in the outside filters (the influent of which was not screened), but the voids in the upper part of the media were largely filled with a black, offensive deposit; near the surface many flies were found and also numbers of larvae down to a depth of two and one-half feet, at which point the media was dirty but the voids not entirely filled.

# Table No. 36.

*Bacteriological Examination of the Lower Sprinkling Filter when Influent was Disinfected.*

| 1910. | Bacteria per cc. | | B. Coli. (Jackson's Bile). | | Remarks. |
|---|---|---|---|---|---|
| | 12-Influent. | 22-Effluent. | 12-Influent. | 22-Effluent. | |
| February 1 | | 290,000 | | | Bleach solution added to influent at outlet of tank No. 12 at rate of 293 pounds of 38 per cent. powder per acre per day, or 93.5 pounds per million gallons. Stone clean—no pools. |
| February 2 | 75 | 210,000 | | | |
| February 3 | 65 | 138,000 | | | |
| February 4 | 61,000 | 450,000 | | | |
| February 5 | 1,000 | 375,000 | | | |
| February 6 | | | | | |
| February 7 | 120 | 450,000 | | | |
| February 8 | 67,000 | 750,000 | | | |
| February 9 | 420,000 | 460,000 | | | Bleach solution added to influent at outlet of tank No. 12 at rate of 192 pounds of 38 per cent. powder per acre per day, or 61 pounds per million gallons. Stones clean—no pools. |
| February 10 | 410,000 | 630,000 | | | |
| February 11 | 500,000 | 1,100,000 | | | |
| February 12 | | | | | |
| February 13 | 180,000 | 530,000 | 10,000 | 10,000 | |
| February 14 | 920,000 | 580,000 | | | |
| February 15 | 1,100,000 | 940,000 | 5,000 | 500 | |
| February 16 | 760,000 | 500,000 | 50,000 | 500 | |
| February 17 | 1,000,000 | 630,000 | 1,000 | 5,000 | Bleach solution added to influent at outlet of tank No. 12 at rate of 214 pounds of 38 per cent. bleach powder per acre per day, or 68 pounds per million gallons. Stones clean—no pools. |
| February 18 | | | | | |
| February 19 | 750,000 | 490,000 | 10,000 | 5,000 | |
| February 20 | 20,000 | 810,000 | 500 | 1,000 | |
| February 21 | 1,000,000 | 630,000 | | | |
| February 22 | 1,200,000 | 920,000 | 50,000 | 50,000 | |
| February 23 | 1,700,000 | 780,000 | 100,000 | 150,000 | |
| February 24 | 490,000 | 550,000 | | | |
| February 25 | | | | | |
| February 26 | | | | | |
| February 27 | | | | | |
| February 28 | | | | | |

Two days later, or on March 16th, the ventilator was opened, the cowl restored, and an airmeter placed in the six inch vertical ventilator. The rate at which air passed through the bed is shown at the bottom of diagram No. 27.

The bed from this time to the end of the tests on April 30th, generally yielded an effluent containing more suspended solids than the influent; the formation of nitrates steadily increased and the effluent finally attained high stability, as in the early operation of the bed, indicating complete recovery.

On April 30th, when the tests were ended, the lower sprinkling filter (No. 22) was yielding an ideal effluent, the surface stones were covered with a thin layer of hydrogel, and not the slightest pooling. An examination of the condition of the media was begun on May 3d by digging a pit five feet wide at the top and extending from the riser to the edge of the bed.

The upper two or three inches of stone were very slightly dirty, the deposit not having a sewage odor but rather a damp sea weed smell; large numbers of flies were present and many stones were covered with larvae; a determination of voids upon the dirty and washed stone of the upper three inches showed a loss of 2.1 per cent.

Between a depth of three inches and one foot the media became perfectly clean, and continued in that condition throughout its entire depth—in fact, except for large numbers of stones covered by very active white larvae the media appeared as though it had been wet by water only. The vertical and horizontal ventilating pipes were as clean as when placed in the bed, the inside being dry and unstained.

The only difference in the condition of the media here was that larvae and full-grown flies were more numerous adjacent to the ventilating pipes. The main drain was found clean and entirely free from any growths, the floor of the filter and under side of split tile drains similarly clean; the floor, however, was covered with a layer of

## Table No. 37.

*Influent to the Lower Sprinkling Filter.*

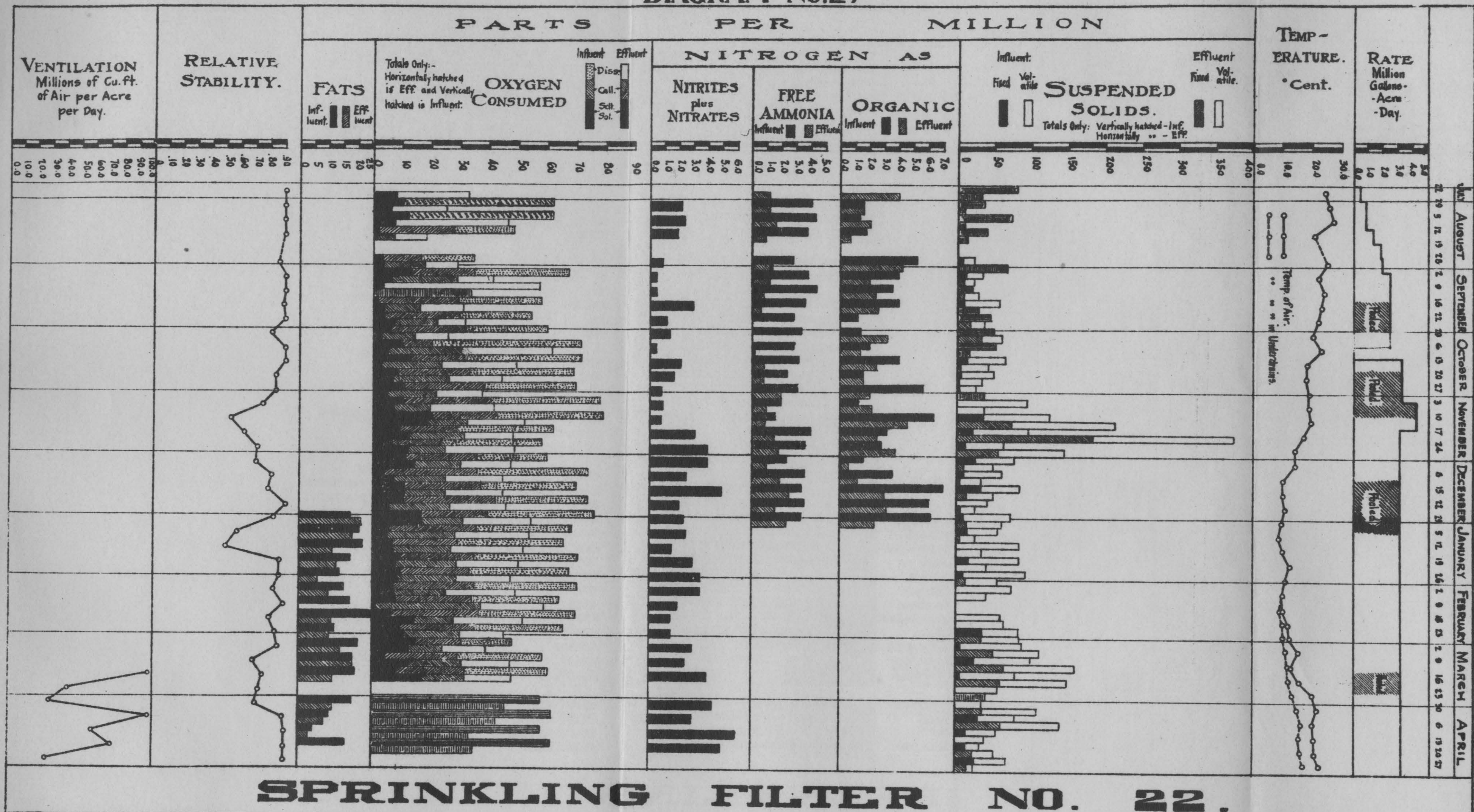
| 1909-1910. Dates. | Parts per Million. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | | Fats. |
| | Total. | Fixed. | Volatile. | Organic | Free Amm. | Nitrites. | Nitrates. | Total. | Settling. | Colloidal. | Solution. | |
| July 29 to August 5 | 35. | | | 1.6 | 4.0 | 0.64 | | 62. | | 51.2 | | |
| August 5 to August 12 | 72. | | | 1.3 | 4.3 | 0.96 | | 62. | | 49.6 | | |
| August 12 to August 19 | 39. | | | 1.1 | 3.7 | 1.44 | | 48.6 | 2.4 | 25.2 | 21.0 | |
| August 28 to September 2 | 22. | 5. | 17. | 5.2 | 2.8 | 0.2 | 0.1 | 34.8 | 3.6 | 13.2 | 18.0 | |
| August average | 42. | | | 2.3 | 3.7 | | | 51.9 | 3.0 | | | |
| September 2 to September 9 | 34. | 8. | 26. | 4.0 | 4.0 | 0.6 | 0.1 | 67.6 | 13.6 | 21.6 | 32.4 | |
| September 9 to September 16 | 20. | | | 3.6 | 4.4 | 0.12 | 0.02 | 57.6 | 3.6 | 54.0 | | |
| September 16 to September 22 | 56. | 6. | 50. | .4 | 3.6 | .04 | | 58. | 2. | 27.6 | 28.4 | |
| September 22 to September 29 | 44. | | | 1.2 | 2.8 | .12 | 0.68 | 54.8 | 4. | 26. | 24.8 | |
| September average | 39. | | | 2.3 | 3.7 | .22 | .27 | 59.5 | 5.8 | 18.8 | 34.9 | |
| September 29 to October 6 | 48. | | | 1.4 | 3.4 | .02 | .28 | 60.4 | 6.8 | 25.6 | 28.0 | |
| October 6 to October 7 | 52. | | | 2.0 | 2.8 | .30 | 1.2 | 71.6 | 10.8 | 9.6 | 51.2 | |
| October 13 to October 20 | 64. | 12. | 52. | 4.0 | 3.2 | .25 | .15 | 72. | 13.6 | 18.0 | 40.4 | |
| October 20 to October 27 | 48. | 4. | 44. | 1.6 | 2.4 | .28 | .52 | 69.2 | 9.2 | 24.4 | 35.6 | |
| October 27 to November 3 | 24. | 2. | 22. | 5.6 | 3.2 | .20 | .40 | 70. | 11.2 | 27.2 | 31.6 | |
| October average | 47. | | | 2.9 | 3.0 | .21 | .51 | 68.6 | 10.3 | 20.9 | 37.4 | |
| November 3 to November 10 | 96. | 0. | 96. | 1.2 | 2.0 | .15 | .65 | 78.0 | 10.8 | 30.0 | 37.2 | |
| November 10 to November 17 | 124. | 32. | 92. | 6.4 | 1.6 | .25 | .20 | 78.8 | 21.2 | 22.0 | 35.6 | |
| November 17 to November 24 | 96. | 20. | 76. | 3.2 | 4.0 | .25 | .49 | 62. | 9.6 | 19.2 | 33.2 | |
| November 24 to December 1 | 62. | 10. | 52. | 2.8 | 3.6 | .16 | 2.0 | 58. | 6.8 | 16.4 | 34.8 | |
| November average | 95. | 16. | 79. | 3.4 | 2.8 | .202 | .81 | 69.2 | 12.1 | 21.9 | 35.2 | |
| December 1 to December 8 | 76. | 24. | 52. | 1.6 | 2.4 | 0. | .2 | 60. | 11.6 | 24.4 | 24. | |
| December 8 to December 15 | 60. | 8. | 52. | 3.6 | 3.6 | .16 | 1.4 | 73.6 | 4.4 | 31.2 | 38.0 | |
| December 15 to December 22 | 84. | 32. | 52. | 7.0 | 3.4 | .16 | 1.8 | 76. | 11.6 | 25.2 | 33.2 | |
| December 22 to December 24 | 40. | 0. | 40. | 6.0 | 3.6 | .14 | 1.4 | 74. | 10.8 | 31.2 | 32.0 | |
| December average | 65. | 16. | 49. | 4.55 | 3.25 | .12 | 1.2 | 69.4 | 9.6 | 28. | 31.8 | |
| December 28 to January 5 | 72. | 8. | 64. | 6.2 | 3.4 | .14 | 1.6 | 76.4 | 17.2 | 22.4 | 36.8 | 17.8 |
| January 5 to January 12 | 56. | 12. | 44. | | | | | 68.8 | 6.8 | 28.8 | 33.2 | 20.8 |
| January 14 to January 19 | 84. | 0. | 84. | | | | | 66.0 | 7.6 | 22. | 36.4 | 21.8 |
| January 19 to January 26 | 84. | 16. | 68. | | | | | 70.8 | 10. | 25.2 | 35.6 | 17.8 |
| January 26 to February 2 | 92. | 8. | 84. | | | | | 67.2 | 10. | 23.6 | 33.6 | 14.0 |
| January average | 78. | 9. | 69. | | | | | 69.8 | 10.3 | 24.4 | 35.1 | 18.4 |
| February 2 to February 9 | 72. | 0. | 72. | | | | | 70.4 | 7.6 | 27.6 | 35.2 | 15.6 |
| February 9 to February 16 | 48. | 28. | 20. | | | | | 64.4 | 8.4 | 25.6 | 30.4 | 17.8 |
| February 16 to February 23 | 58. | 0. | 58. | | | | | 70. | 6.8 | 30. | 33.2 | 25.6 |
| February 23 to March 2 | 84. | 34. | 50. | | | | | 65.6 | 9.6 | 25.2 | 30.8 | 12.6 |
| February average | 66. | 16. | 50. | | | | | 67.6 | 8.1 | 27.1 | 32.4 | 17.9 |
| March 2 to March 8 | 88. | 4. | 84. | | | | | 48.4 | 15.2 | 15.6 | 17.6 | 20.4 |
| March 9 to March 16 | 100. | 24. | 76. | | | | | 58.8 | 4.8 | 24.8 | 29.2 | 18.6 |
| March 16 to March 23 | 60. | 4. | 56. | | | | | 60.8 | 8.8 | 22.8 | 29.2 | 19.2 |
| March 23 to March 30 | 56. | 7. | 49. | | | | | | | | | |
| March average | 76. | 10. | 66. | | | | | 56. | 9.6 | 21.1 | 25.3 | 19.4 |
| March 30 to April 6 | 36. | 0. | 36. | | | | | 58. | | | | 18.6 |
| April 6 to April 13 | 80. | 30. | 50. | | | .40 | 1.1 | 61.2 | | | | 10.4 |
| April 13 to April 20 | 56. | 12. | 44. | | | | 3.5 | 58. | | | | 5.0 |
| April 20 to April 27 | 32. | 12. | 20. | | | .18 | 3.3 | 61.6 | | | | 16.2 |
| April average | 51. | 13. | 38. | | | .29 | 2.6 | 59.7 | | | | 12.6 |

# Table No. 38.

## *Effluent of the Lower Sprinkling Filter No. 22.*

| Dates. 1909–1910. | PARTS PER MILLION. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | | | | | Temperature. | |
| | Total. | Fixed. | Volatile. | Organic. | Free Amm. | Nitrites. | Nitrates. | Total. | Settling. | Colloidal. | Solution. | Turbidity. | Fats. | Relative Stability. | Air. | Underdrain. |
| July 22 to July 29 | 30. | ------ | ------ | 4.0 | 1.2 | 4. | 0 | 32.8 | ------ | 24 | .4 | ------ | ------ | .900 | 24.6 | ------ |
| July 29 to August 5 | 7. | ------ | ------ | 1.6 | 1.2 | 2. | 24 | 25.6 | ------ | 19 | .2 | ------ | ------ | .900 | 26.1 | ------ |
| August 5 to August 12 | 6. | ------ | ------ | 2.0 | 1.6 | 2. | 40 | 46.4 | ------ | 38 | .4 | ------ | ------ | .900 | 27.3 | ------ |
| August 12 to August 19 | 12. | ------ | ------ | .6 | 1.0 | 1. | 92 | 18.2 | 0. | 7.8 | 10.4 | ------ | ------ | .900 | 21.3 | ------ |
| August 28 to September 2 | 64. | ------ | ------ | 4.2 | 1.4 | .04 | .82 | 29.2 | 3.6 | 14.4 | 11.2 | ------ | ------ | .857 | 25.3 | ------ |
| August average | 22. | ------ | ------ | 8.4 | 1.3 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | .889 | 25.0 | ------ |
| September 2 to September 9 | 8. | ------ | ------ | 2.0 | 1.2 | .10 | .45 | 41.6 | 6.4 | 22.4 | 12.8 | ------ | ------ | .900 | 22.5 | ------ |
| September 9 to September 16 | 28. | 8. | 20. | 2.4 | .8 | .15 | .35 | 34.4 | 5.8 | 15.7 | 12.7 | ------ | ------ | .900 | 24.3 | ------ |
| September 16 to September 22 | 28. | 0. | 28. | 2.6 | .6 | .12 | 2.9 | 31.2 | 4.0 | 12.4 | 14.8 | ------ | ------ | .895 | 23.2 | ------ |
| September 22 to September 29 | 38. | 16. | 22. | ------ | ------ | .12 | 1.1 | 32.8 | 7.6 | 14.4 | 10.8 | ------ | ------ | .900 | 22.5 | ------ |
| September average | 26. | ------ | ------ | 2.3 | .87 | .123 | 3.0 | 35. | 5.9 | 16. | 13.1 | ------ | ------ | .899 | 23.1 | ------ |
| September 29 to October 6 | 60. | 32. | 28. | 3.2 | ------ | .02 | 1.4 | 26. | 3.2 | 11.2 | 11.6 | ------ | ------ | .805 | 20.5 | ------ |
| October 6 to October 7 | 17. | 3. | 14. | 1.4 | .20 | .06 | .34 | 62. | 5.6 | 25.2 | 31.2 | ------ | ------ | .900 | 23.5 | ------ |
| October 13 to October 20 | 42. | 4. | 38. | 2.4 | .80 | .14 | 2.0 | 49.2 | 3.2 | 20.4 | 25.6 | ------ | ------ | .900 | 18.9 | ------ |
| October 20 to October 27 | 34. | 2. | 32. | 1.6 | .80 | .06 | 1.7 | 44.8 | 7.2 | 18.8 | 18.8 | ------ | ------ | .840 | 18.4 | ------ |
| October 27 to November 3 | 36. | 0. | 36. | 2.0 | 2.0 | .06 | .9 | 38. | 5.2 | 16.8 | 16.0 | ------ | ------ | .845 | 19.2 | ------ |
| October average | 38. | 8. | 30. | 2.1 | .95 | .07 | 1.27 | 44. | 4.9 | 18.5 | 20.6 | ------ | ------ | .858 | 20.1 | ------ |
| November 3 to November 10 | 36. | 0. | 36. | 2.2 | 1.0 | .06 | .9 | 41.6 | 7.6 | 12.0 | 22.0 | ------ | ------ | .746 | 19.1 | ------ |
| November 10 to November 17 | 212. | 72. | 140. | 4.6 | 1.0 | .10 | .7 | 52.4 | 19.6 | 12.4 | 20.4 | ------ | ------ | .527 | 19.8 | ------ |
| November 17 to November 24 | 372. | 182. | 190. | 2.5 | 1.5 | .16 | 3.0 | 48. | 12.8 | 18.4 | 16.8 | ------ | ------ | .620 | 17.5 | ------ |
| November 26 to December 1 | 146. | 54. | 92. | 3.8 | 1.8 | .22 | 3.7 | 48.8 | 12.8 | 12.4 | 23.6 | ------ | ------ | .710 | 14.5 | ------ |
| November average | 192. | 77. | 115. | 3.3 | 1.3 | .14 | 2.1 | 47.7 | 13.2 | 13.8 | 20.7 | ------ | ------ | .651 | 17.7 | ------ |
| December 1 to December 8 | 48. | 8. | 40. | .6 | 1.0 | .20 | 3.8 | 47.2 | 14.4 | 16. | 16.8 | ------ | ------ | .696 | 14.5 | ------ |
| December 8 to December 15 | 30. | 4. | 26. | 1.2 | 2.0 | .12 | 2.4 | 44.4 | 7.6 | 18.0 | 18.8 | ------ | ------ | .808 | 11.6 | ------ |
| December 15 to December 22 | 48. | 12. | 36. | 3.0 | 2.6 | .18 | 4.8 | 44.8 | 11.6 | 13.2 | 20.0 | ------ | ------ | .780 | 11.6 | ------ |
| December 22 to December 24 | 24. | 4. | 20. | 3.2 | 1.6 | .12 | 1.9 | 46.4 | 5.6 | 21.6 | 19.2 | 120. | ------ | .900 | 11.9 | ------ |
| December average | 38. | 7. | 31. | 2.0 | 1.8 | .16 | 3.2 | 45.7 | 9.8 | 17.2 | 18.7 | ------ | ------ | .796 | 12.4 | ------ |
| December 28 to January 5 | 60. | 12. | 48. | 2.4 | 2.4 | .12 | 2.3 | 54.4 | 17.2 | 14.0 | 23.2 | 80. | 21.4 | .819 | 10. | ------ |
| January 5 to January 12 | 24. | 4. | 20. | ------ | ------ | ------ | 2.5 | 54. | 5.6 | 22.8 | 25.6 | 130. | 18.4 | .571 | 9. | ------ |
| January 15 to January 19 | 36. | 0. | 36. | ------ | ------ | ------ | 1.5 | 52. | 8.0 | 19.2 | 24.8 | 180. | 11.2 | .492 | 10.4 | ------ |
| January 19 to January 26 | 40. | 0. | 40. | ------ | ------ | ------ | 3.0 | 50.4 | 8.4 | 20.8 | 21.2 | 55. | 13.0 | .867 | 12.9 | ------ |
| January 26 to February 2 | 56. | 12. | 44. | ------ | ------ | ------ | 3.5 | 47.6 | 8.8 | 20.0 | 18.8 | 80. | 6.6 | .861 | 11.4 | ------ |
| January average | 43. | 6. | 37. | ------ | ------ | ------ | 2.6 | 51.7 | 9.6 | 19.4 | 22.7 | 105. | 14.1 | .722 | 10.7 | ------ |
| February 2 to February 9 | 40. | 0. | 40. | ------ | ------ | ------ | 3.5 | 49.2 | 8.0 | 17.6 | 23.6 | 75. | 10.6 | .823 | 10.2 | 10.2 |
| February 9 to February 16 | 48. | 20. | 28. | ------ | ------ | ------ | 2.0 | 59.2 | 1.6 | 36.8 | 20.8 | 85. | ------ | .884 | 10.5 | 9.7 |
| February 16 to February 23 | 64. | 0. | 64. | ------ | ------ | ------ | 1.5 | 52. | 14.8 | 13.2 | 24. | 85. | 11.2 | .795 | 12.4 | 10. |
| February 23 to March 2 | 84. | 34. | 50. | ------ | ------ | ------ | 1.5 | 45.2 | 11.2 | 18.8 | 15.2 | 90. | 10.6 | .830 | 12.9 | 10.1 |
| February average | 50. | 14. | 45. | ------ | ------ | ------ | 2.1 | 51.4 | 8.9 | 21.6 | 20.9 | 84. | 10.8 | .833 | 11.5 | 10.0 |
| March 2 to March 8 | 112. | 50. | 62. | ------ | ------ | ------ | 3.0 | 39.2 | 13.2 | 11.2 | 14.8 | 80. | 14.2 | .846 | 15.8 | 11.3 |
| March 9 to March 16 | 160 | 64. | 96. | ------ | ------ | ------ | 2.5 | 48. | 13.6 | 17.2 | 17.2 | 160. | 18.8 | .685 | 13.1 | 12. |
| March 16 to March 23 | 148. | 60. | 88. | ------ | ------ | ------ | 4.0 | 48.4 | 17.6 | 14.0 | 16.8 | 140. | 16.8 | .750 | 15.8 | 12. |
| March 23 to March 30 | 40. | 16 | 24. | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | .723 | 20.7 | 13.1 |
| March average | 115. | 47. | 68. | ------ | ------ | ------ | ------ | 45.2 | 14.8 | 14.1 | 16.3 | ------ | ------ | .751 | 16.4 | 12.1 |
| March 30 to April 6 | 110. | 34. | 76. | ------ | ------ | .55 | 3.9 | 45.2 | ------ | ------ | ------ | 75. | 11.8 | .703 | 22.1 | 15.1 |
| April 6 to April 13 | 140. | 60 | 80. | ------ | ------ | .40 | 2.6 | 42.8 | ------ | ------ | ------ | 80. | 8.8 | .887 | 20.4 | 16.2 |
| April 13 to April 20 | 38. | 0. | 38. | ------ | ------ | .40 | 5.6 | 33.6 | ------ | ------ | ------ | 65. | 3.4 | .900 | 20.8 | 15.7 |
| April 20 to April 27 | 52. | 22. | 30. | ------ | ------ | .18 | 4.8 | 35.2 | ------ | ------ | ------ | 70. | ------ | .900 | 20.7 | 16.2 |
| April average | 85. | 29. | 56. | ------ | ------ | .38 | 4.2 | 39.2 | ------ | ------ | ------ | 73. | 8.0 | .848 | 21. | 15.8 |

DIAGRAM NO.27



## Table No. 39.

### *Showing Bacteriological Examination of the Lower Sprinkling Filter, No. 22.*

| Dates, 1909–'10. | Bacteria per C. C. | | | B. Coli. per C. C., Presumptive. | |
|---|---|---|---|---|---|
| | Crude Sewage. | Screened and Settled Sewage Influent. | Effluent of No. 22. | Screened and Settled Sewage Influent. | Effluent of No. 22. |
| July 29 to Aug. 5 | 9,600,000 | 9,500,000 | 70,600 | | |
| Aug. 5 to Aug. 12 | 6,700,000 | | | | |
| Aug. 12 to Aug. 19 | 5,400,000 | | | | |
| Aug. 19 to Aug. 28 | 6,200,000 | | | | |
| Aug. 28 to Sept. 2 | 4,000,000 | 4,000,000 | 200,000 | 750,000 | 550 |
| August average | 5,800,000 | 6,300,000 | 173,000 | | |
| Sept. 2 to Sept. 9 | 3,700,000 | 3,600.000 | 340,000 | 500,000 | 10,000 |
| Sept. 9 to Sept. 16 | 3,200,000 | 2,400,000 | 260,000 | 180,000 | 12,500 |
| Sept. 16 to Sept. 23 | 3,700,000 | 2,300,000 | 116,000 | | |
| Sept. 23 to Sept. 29 | 1,800,000 | 1,600,000 | 122,000 | | |
| September average | 3,600,000 | 2,600,000 | 186,000 | 400,000 | 8,700 |
| Sept. 29 to Oct. 6 | 2,300,000 | 4,000,000 | 330,000 | | |
| Oct. 6 to Oct. 7 | 1,400,000 | 1,200,000 | 110,000 | | |
| Oct. 17 to Oct. 20 | 2,200,000 | 2,100,000 | 845,000 | | |
| Oct. 20 to Oct. 27 | 5,600,000 | 3,500,000 | 126,000 | | |
| Oct. 27 to Nov. 3 | 3,500,000 | 1,700,000 | 304,000 | | |
| October average | 2,800,000 | 2,200,000 | 320,000 | | |
| Nov. 3 to Nov. 10 | 1,200,000 | 2,200,000 | 475,000 | | |
| Nov. 10 to Nov. 17 | 4,600,000 | 2,950,000 | 830,000 | | |
| Nov. 17 to Nov. 24 | 4,500,000 | 3,200,000 | 680,000 | | |
| Nov. 26 to Dec. 1 | 1,900,000 | 1,750,000 | 430,000 | | |
| November average | 2,700,000 | 2,700,000 | 627,000 | | |
| Dec. 1 to Dec. 8 | 5,400,000 | 2,850,000 | 330,000 | 200,000 | 3,400 |
| Dec. 8 to Dec. 15 | 3,500,000 | 1,700,000 | 370,000 | 80,000 | 11,000 |
| Dec. 15 to Dec. 22 | 1,800,000 | 720,000 | 190,000 | 50,000 | 3,300 |
| Dec. 22 to Dec. 24 | 1,300,000 | 620,000 | 230,000 | 53,000 | 7,500 |
| December average | 2,100,000 | 1,400,000 | 310,000 | 100,000 | 10,000 |
| Dec. 28 to Jan. 5 | 1,700,000 | 1,200,000 | 650,000 | 180,000 | 32,000 |
| Jan. 5 to Jan. 12 | 1,200,000 | 625,000 | 330,000 | | |
| Jan. 15 to Jan. 19 | 1,100,000 | 880,000 | 1,250,000 | | |
| Jan. 19 to Jan. 26 | 980,000 | 592,000 | 500,000 | | |
| Jan. 26 to Feb. 2 | 920,000 | 134.000 | 157,000 | | |
| January average | 1,100,000 | 578,000 | 515,000 | 200,000 | 25,000 |
| Feb. 2 to Feb. 9 | 1,200,000 | 25,600 | 395,000 | | |
| Feb. 9 to Feb. 16 | 1,300,000 | 590,000 | 700,000 | 7,500 | 5,200 |
| Feb. 16 to Feb. 23 | 2,100,000 | 790,000 | 580,000 | 22,300 | 12,300 |
| Feb. 23 to March 2 | 2,000,000 | 1,200,000 | 570,000 | 45,000 | 14,000 |
| February average | 1,600,000 | 695,000 | 560,000 | 29,000 | 12,000 |
| March 2 to March 8 | 1,500,000 | 940,000 | 520,000 | 54,000 | 4,400 |
| March 9 to March 16 | 1,700,000 | 1,500,000 | 440,000 | 80,000 | 16,000 |
| March 16 to March 23 | 2,000,000 | 1,400,000 | 470,000 | 52,000 | 16,000 |
| March 23 to March 30 | 2,600,000 | 2,300,000 | 430,000 | 180,000 | 30,000 |
| March average | 2,000,000 | 1,600,000 | 460,000 | 77,000 | 16,000 |
| March 30 to April 6 | 2,750,000 | | | | |
| April 6 to April 13 | | 4,900,000 | 1,100,000 | | |
| April 13 to April 20 | 2,200,000 | 2,100,000 | 260,000 | 50,000 | 10,000 |
| April 20 to April 27 | 3,600,000 | 2,000,000 | 208,000 | 10,000 | 1,000 |
| April average | 2,900,000 | 2,540,000 | 444,000 | 37,000 | 7,000 |

active larvae which probably came down from the filter media after the bed was shut down, for a slight stream of water washed them into the main collector.

A sample of the deposit upon the stones composing the upper few inches was analyzed similarly to the sludge with the following results:

| Wet Sludge. | | Dry Residue. | | | |
|---|---|---|---|---|---|
| Spr. Gr. | Per Cent. Water. | Volatile. | Fixed. | Nitrogen. | Fats. |
| 1.11 | 82.1 | 40.4 | 59.6 | 1.6 | 20 |

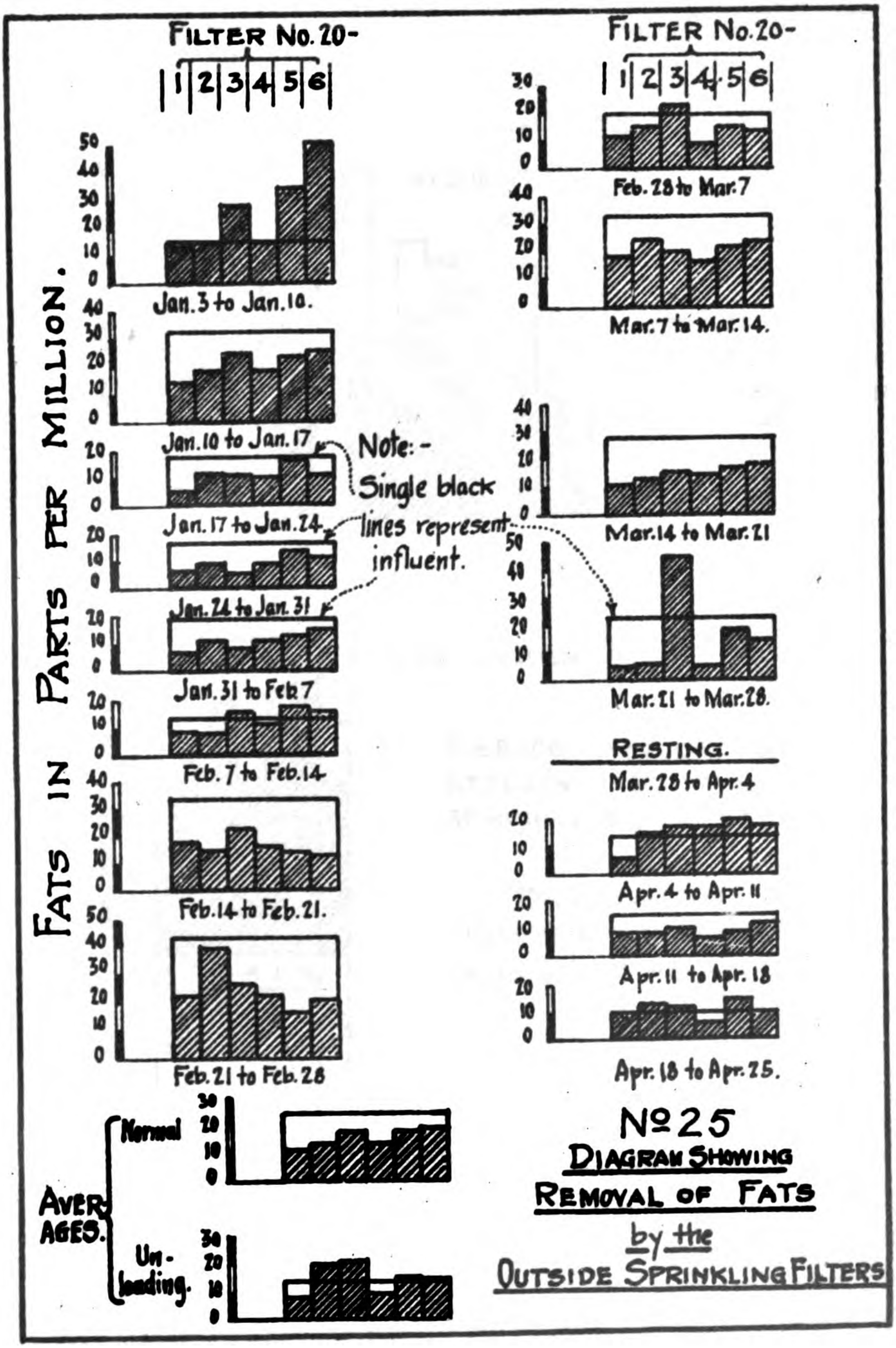
It must be remembered that the sample included the bacterial jelly and large numbers of worms, which would increase the volatile figure.

**Fats in Sprinkling Filters.**

The amount of fat (ether soluble matter from an acidified sample) in the sewage applied to, and in the effluent from sprinkling filters is given in Table No. 40 and shown separately on the diagrams of the outside and lower filter and collectively on diagrams Nos. 25 and 29.

From an inspection of these data it will be observed that at least during the period from January to the end of the tests (covering the time in which fats were determined) the fine limestone bed (20-1), the coarse trap bed (20-4), and the lower filter (22) yielded on an average effluents markedly lower in fat content than the effluents from the other beds, and it is known that in these beds biological action was more vigorous than in the others, and it, therefore, may be surmised that, although fats are very resistant substances, in these three beds at least the fats were oxidized.

That the removal effected by the lower filter (No. 22) was not due to storage of the fats within the pores of the media is shown conclusively by the fact that although




No. 25
Diagram Showing Removal of Fats by the Outside Sprinkling Filters

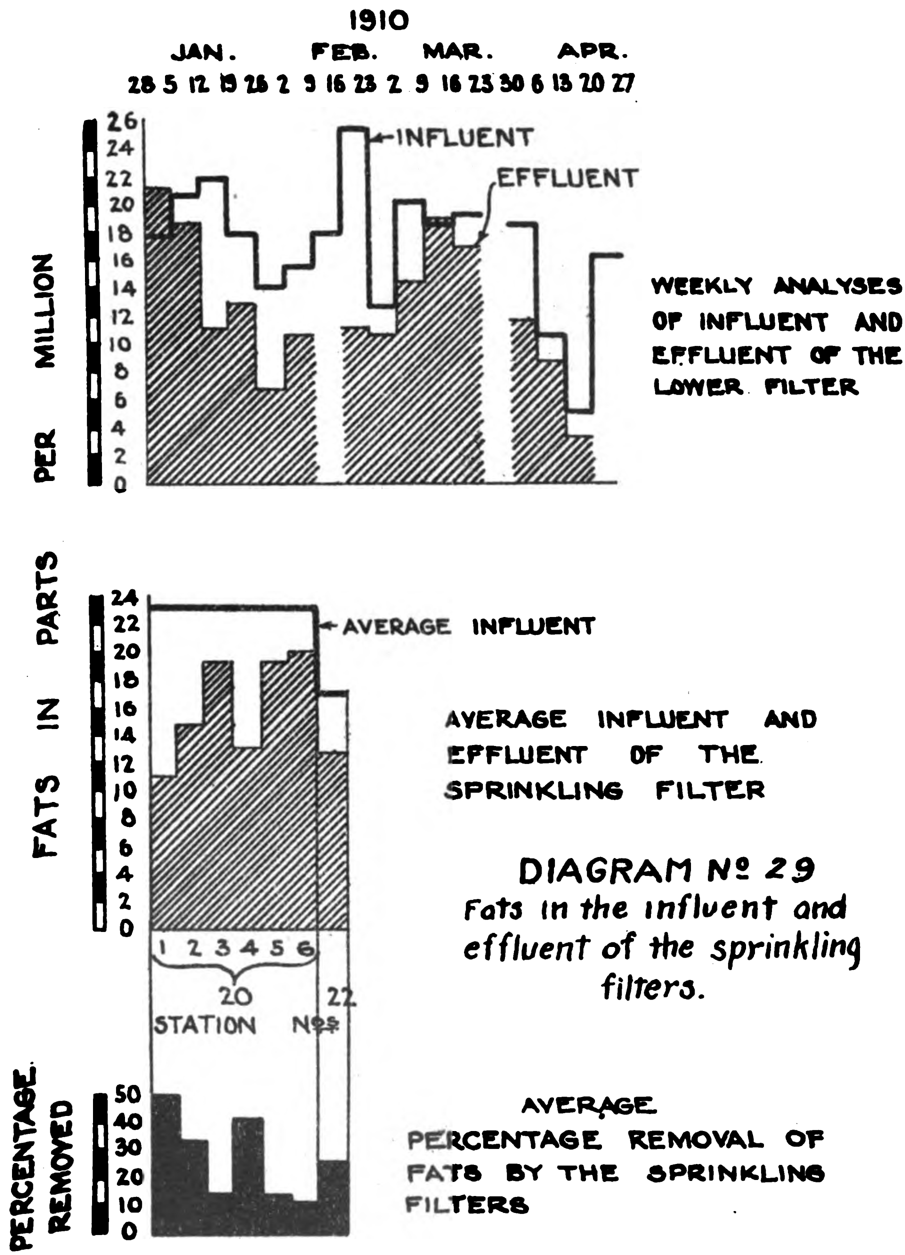



DIAGRAM No 29

*Fats in the influent and effluent of the sprinkling filters.*

# Table No. 40.

## *Fats in the Influent to and the Effluent of the Sprinkling Filters.*

| Date. 1910. | Outside Filters, In-fluent. | | | Effluent. | | | | Lower Filter. Date. 1910. | Influent. | Effluent. |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20-1 | 20-2 | 20-3 | 20-4 | 20-5 | 20-6 | | 12 | 22 |
| January 3 to January 10 | 16.0 | 13.0 | 14.4 | 29.0 | 14.0 | 34.4 | 51.6 | December 28 to January 5 | 17.8 | 21.4 |
| January 10 to January 17 | 32.0 | 13.8 | 18.8 | 25.2 | 19.6 | 24.4 | 26.4 | January 5 to January 12 | 20.8 | 18.4 |
| January 17 to January 24 | 18.2 | 6.6 | 11.4 | 11.2 | 10.4 | 17.2 | 11.0 | January 14 to January 19 | 21.8 | 11.2 |
| January 24 to January 31 | 17.2 | 7.2 | 9.2 | 6.4 | 9.0 | 13.4 | 11.4 | January 19 to January 26 | 17.8 | 13.0 |
| Average for January | 22.5 | 10.1 | 13.4 | 17.9 | 13.2 | 22.3 | 25.1 | ---------- | ---------- | ---------- |
| January 31 to February 7 | 18.6 | 6.8 | 11.2 | 9.4 | 10.2 | 13.2 | 14.8 | January 26 to February 2 | 14.0 | 6.6 |
| February 7 to February 14 | 13.4 | 8.2 | 8.4 | 14.8 | 11.6 | 18.2 | 16.8 | February 2 to February 9 | 15.6 | 10.6 |
| February 14 to February 21 | 33.4 | 18.2 | 14.8 | 23.6 | 17.0 | 14.6 | 13.0 | February 9 to February 16 | 17.8 | ---------- |
| February 21 to February 28 | 43.2 | 22.8 | 40.0 | 27.0 | 22.6 | 17.4 | 21.0 | February 16 to February 23 | 25.6 | 11.2 |
| Average for February | 27.1 | 14.0 | 18.6 | 18.7 | 15.3 | 15.8 | 16.4 | ---------- | ---------- | ---------- |
| February 28 to March 7 | 20.2 | 11.4 | 16.2 | 23.2 | 9.6 | 16.8 | 14.0 | February 23 to March 2 | 12.6 | 10.6 |
| March 7 to March 14 | 32.0 | 18.2 | 24.2 | 20.0 | 16.8 | 22.2 | 23.6 | March 2 to March 8 | 20.4 | 14.2 |
| March 14 to March 21 | 28.2 | 11.0 | 12.6 | 16.2 | 15.2 | 17.6 | 18.2 | March 9 to March 16 | 18.6 | 18.8 |
| March 21 to March 28 | 23.8 | 4.4 | 5.2 | 44.6 | 5.4 | 18.0 | 13.2 | March 16 to March 23 | 19.2 | 16.8 |
| March 28 to April 4 | | | | Shut down. | | | | March 23 to March 30 | ---------- | ---------- |
| Average for March | 26.8 | 11.2 | 14.5 | 26.0 | 11.7 | 18.6 | 17.2 | ---------- | ---------- | ---------- |
| April 4 to April 11 | 13.2 | 6.6 | 14.0 | 16.0 | 16.1 | 19.6 | 17.6 | March 30 to April 6 | 18.6 | 11.8 |
| April 11 to April 18 | 15.6 | 9.2 | 9.4 | 10.6 | 7.0 | 9.2 | 12.8 | March 6 to March 13 | 10.4 | 8.8 |
| April 18 to April 25 | 10.4 | 10.2 | 13.2 | 12.4 | 7.2 | 14.0 | 9.8 | March 13 to March 20 | 5.0 | 3.4 |
| April 25 to April 30 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | March 20 to March 27 | 16.2 | ---------- |
| Average for April | 13.1 | 8.7 | 12.2 | 13.0 | 10.3 | 14.3 | 13.4 | ---------- | ---------- | ---------- |
| Grand average | 22.3 | 11.1 | 14.8 | 19.3 | 13.4 | 19.5 | 20.0 | ---------- | 17.0 | 12.6 |
| Per cent. removal | ---------- | 50. | 33.5 | 13.5 | 40.0 | 12.5 | 10.0 | ---------- | ---------- | 26.0 |

the bed did not discharge as much fat as was applied to it, there was no evidence of stored matters when it was dismantled.

## Bacterial Content of Effluents of Sprinkling Filters.

It is not to be expected of a rapid purification process that it will yield an effluent low in number of bacteria, but when a sprinkling filter is satisfactorily oxidizing the applied sewage it is also effecting a considerable removal of bacteria.

The effluents of the outside filters (No. 20) are not justly comparable with that from the lower filter (No. 22) as their influents were quite different and the physical conditions of the filters very diverse.

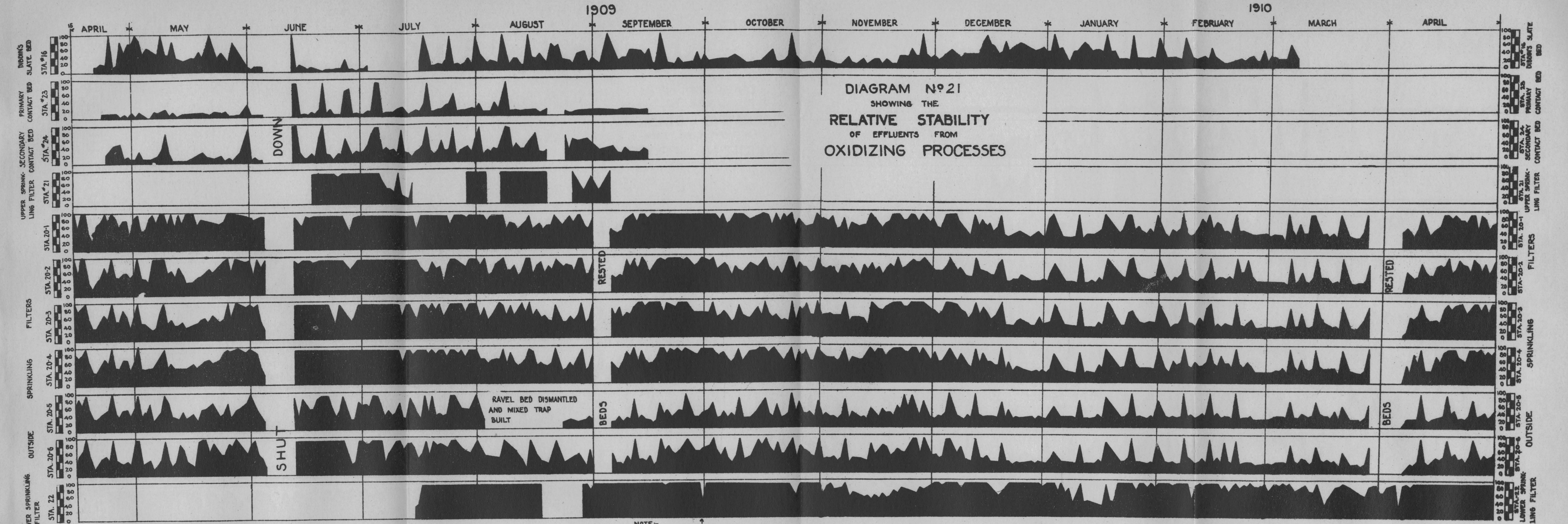
Considering the outside filters, it will be seen in Table No. 31 that on an average the removal of bacteria is directly proportional to the depth of the filter.

The lower sprinkling filter (No. 22) produced an effluent whose average bacterial content is identical with the fine limestone bed (20-1), although the latter was deeper and operated at a lower rate.

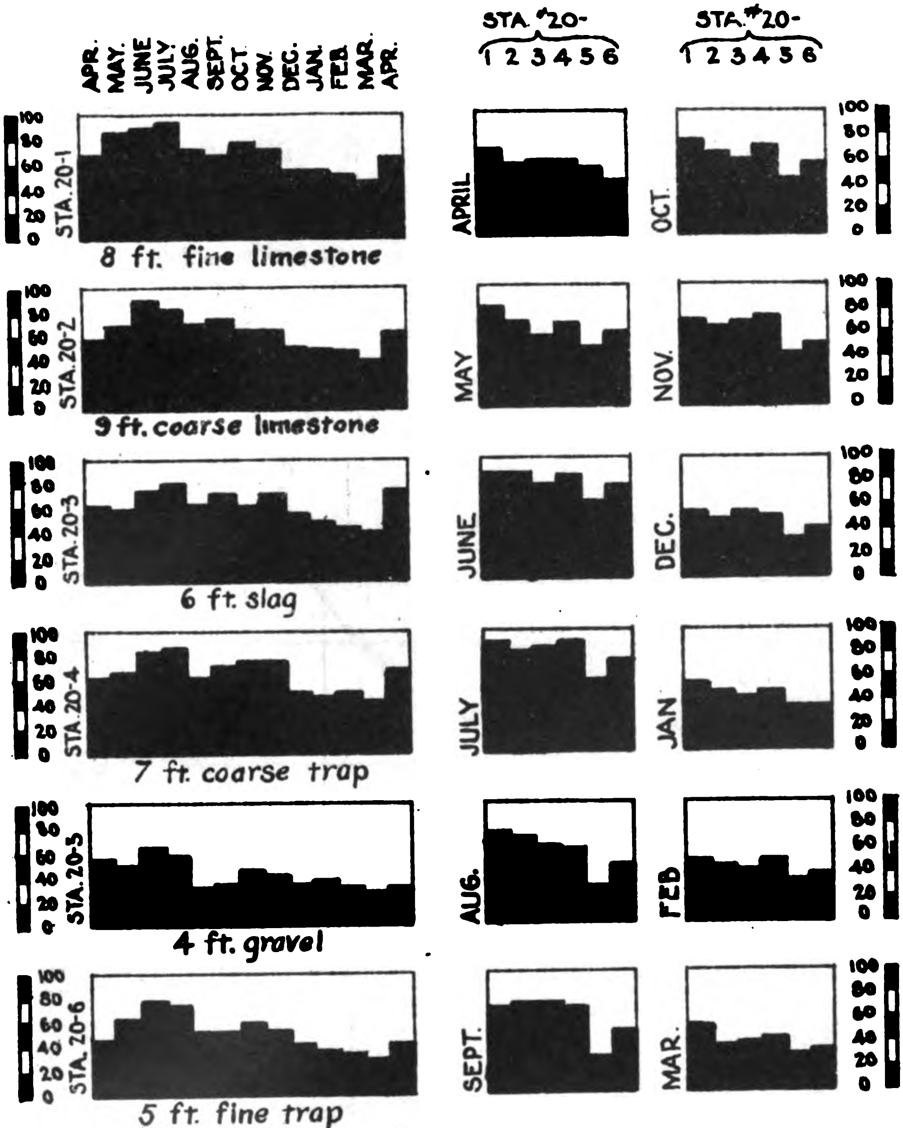
## Stability of the Effluent of Sprinkling Filters.

The object of the sprinkling filter is to render stable the putrescent matters of sewage. Over long periods of time it ought not to remove solids, for in order that such a filter shall not become clogged it must unload the accumulated matter, and thus establish an equality between total suspended solids in the influent and effluent.

Also many substances nitrogenous or carbonaceous in their composition and therefore reported in the analyses under organic nitrogen or oxygen consumed, are stable, and not acted upon in transit through the filter, therefore, to preserve the permanence of the filter they should be thrown off.




NOTE:- On Sept. 30, 1909, during distribution Experiments, a bucket was placed over the nozzle thereby causing the crude sewage to flow down along the riser and thus contaminating the Effluent and causing the low stability value.



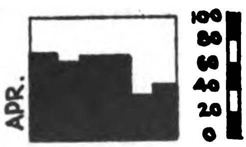


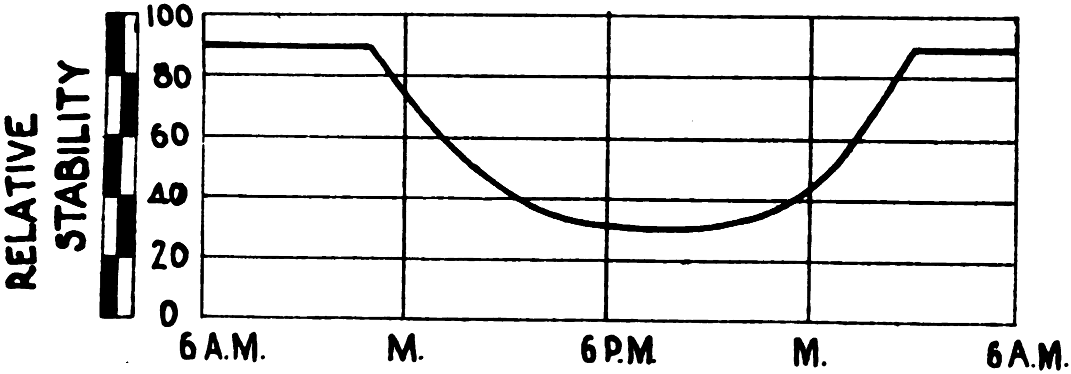

DIAGRAM No. 22
SHOWING MONTHLY
AVERAGE RELATIVE STABILITY
OF THE
OUTSIDE SPRINKLING FILTERS
ARRANGED FOR COMPARISON

DIAGRAM No. 23

SHOWING THE HOURLY VARIATION IN THE

RELATIVE STABILITY OF EFFLUENT FROM

A SPRINKLING FILTER




the slightly clogged condition of the finer media is much in the favor of the shallower and coarser bed.

The practically perfect record of the lower sprinkling filter, as shown at the bottom of diagram No. 21, having retrograded at only two places, in November when the

The measure of the putrescence of sewage is its avidity for oxygen. An effluent which requires but little oxygen from the stream into which it may be discharged will continue to improve as the stream flows on regardless of the stable organic matter contained in said effluent.

For these reasons much weight should be given to the determination of relative stability of sprinkling filter effluents.

The biological condition of the filters during different times of the year has been partially interpreted by the relative stability of the effluent at those times, but in selecting the most economical depth and range of sizes of stone the average and the regularity of the relative stability must be considered.

Examining diagrams Nos. 21 and 22 and the monthly averages relative stability in Table No. 30, it will be seen that the average figure for the 13 months' operation is very similar for the fine and coarse limestone, the coarse trap, and the slag beds (20-1, 2, 3 and 4), therefore they may be properly compared. The two shallow filters seem to be in a class by themselves and should be considered separately.

Diagram No. 21 shows how the fine limestone bed yielded a stable effluent very soon after its start, and that the stability was more regular than any of the outside filters; the coarse trap bed produced a stable effluent in a time slightly in excess of this bed, and the general similarity of diagrams of these two filters shows that the oxidizing power of the seven foot bed of coarse trap was equal to the eight foot depth of fine limestone; and the almost perfect condition of the media at the end of the tests in the coarser and shallower bed as compared with the slightly clogged condition of the finer media is much in the favor of the shallower and coarser bed.

The practically perfect record of the lower sprinkling filter, as shown at the bottom of diagram No. 21, having retrograded at only two places, in November when the filter unloaded, and in January when it was clogged, is evidence of the efficiency of a well prepared tank liquor, evenly distributed over a uniform size media.

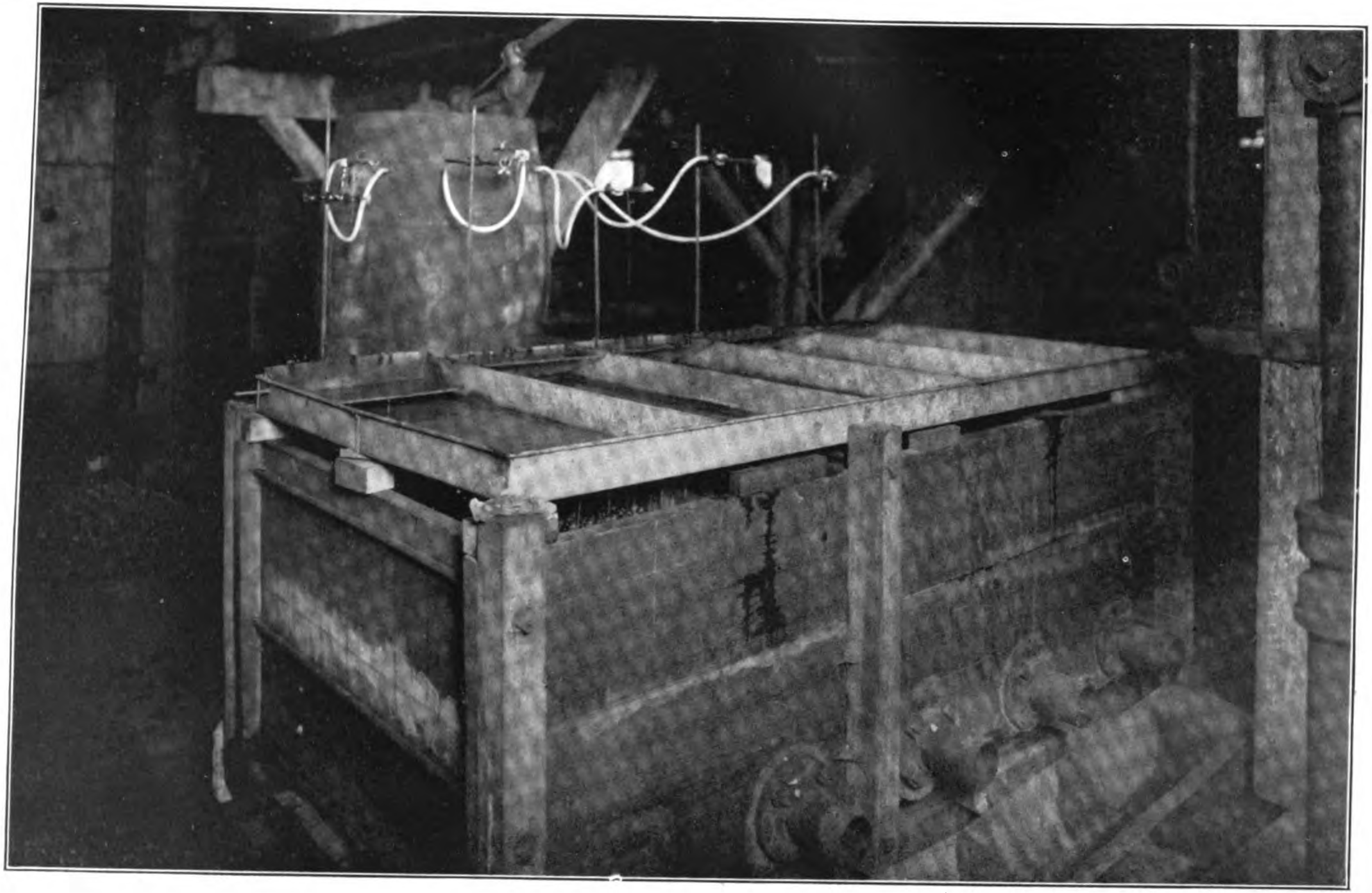
From the fact that the ventilator was open during the warmer weather, which in itself would tend to secure favorable results, and was closed during the extremely cold weather, which would tend to produce unfavorable conditions, thereby introducing another variable, it is manifest from an examination of the diagram No. 27 that there is not sufficient variation in the action of the filter under these two conditions to show conclusively any distinct advantage due entirely to the use of ventilating appliances, although it is believed that ventilation will distinctly benefit and render uniform the action of the various parts of a percolating filter, and that its absence might tend to foster clogging or reduce the effectiveness of a filter in spots.

### The Relative Economy of Various Methods Used to Relieve Clogging of Sprinkling Filters.

The methods used to relieve clogging in the sprinkling filters were: (a) resting the beds in order that the accumulated matter would dry sufficiently to desquamate and be washed out by the ordinary discharge from the nozzle; (b) washing the filter with water from a fire hose; (c) applying dry bleaching powder to the surface; (d) applying a strong solution of bleach through the nozzles; (e) continuous disinfection of the influent.

(a) In the warm, dry weather this method proved successful at no labor cost, but during the winter it did not cause the beds to unload.

(b) In washing with a fire hose the force of the jet was so great that no forking over the media was necessary and it was found that large quantities of solids could be removed without injury to the biological action of the



**Bacterial Surface Filters.—Station No. 27.**

filter by the use of 115,000 gallons of water per acre, and that about 24 hours would be required for the work. It would require two or three men to manage the hose.

(c) The application of dry bleaching powder, while successful, was not economical, for it does not act as efficiently as the strong solution which penetrates the bed, and furthermore, when the influent is applied a large proportion of the available chlorine passes through the bed so rapidly that it is not used by the oxidizable matters.

(d) The application of a strong solution of bleach in quantities of two tons per acre through the nozzles was accomplished in a very economical manner. It is only necessary to empty the contents of the drums into the dosing tank, stirring it until it is at least partially dissolved or in suspension and then apply it through the nozzles as an ordinary influent.

This would require only the labor to empty the bleach into the dosing tank and to mix it.

(e) The continuous disinfection of the influent maintained the lower sprinkling filter in perfect condition and supports the claims of Dr. Rideal as mentioned heretofore.

It would require an inexpensive apparatus for the addition of the solution to the influent and the services of an attendant, the same as in any disinfection process.

## THE BACTERIAL SURFACE FILTERS.

This battery of filters was put in service on April 6, 1910; the screened and settled influent was applied to each unit of the battery at a net rate of 500,000 gallons per acre per day; this was accomplished by setting the movable orifices so that they discharged 100 cc. per minute into the tipping trays beneath.

Although the volume or space occupied by each filter was the same, and as near as possible the size of the media identical, the "bacterial surface" (as described by

Mr. Rudolph Herring in the Engineering News of May 6, 1909) was quite different, and constituted the only variable in this battery of filters.

The physical appearance of the effluents showed the effect of surface attraction—those yielded from the smooth marbles and gravel being very similar to the applied water, showing little or no adhesion; on the other hand the rough porous slag and coke from the first produced a greatly clarified effluent.

The rapidity of maturing of the beds having large bacterial surface is shown in the following table and on diagram No. 28.

*Average Relative Stability and Nitrates in the Composite Weekly Samples of Effluent from the Bacterial Surface Filters.*

| Number of Bed. | 27-1 | | 27-2 | | 27-3 | | 27-4 | | 27-5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Kind of Media. | Marbles. | | Gravel. | | Stone. | | Slag. | | Coke. | |
| April, 1910. | Rel. Stab. | Nitrates. | Rel. Stab. | Nitrates. | Rel. Stab. | Nitrates. | Rel. Stab. | Nitrates. | Rel. Stab. | Nitrates. |
| 6th to 13th | .41 | 0.1 | .49 | 0.1 | .60 | 0.1 | .69 | 0.1 | .69 | 2.0 |
| 13th to 20th | .40 | 0.1 | .53 | 1.0 | .52 | 1.5 | .79 | 1.0 | .69 | 4.0 |
| 20th to 27th | .45 | 0.2 | .57 | 1.0 | .78 | 1.0 | .81 | 1.5 | .83 | 3.5 |
| 27th to 30th | .58 | 0.2 | .76 | 1.0 | .89 | 2.0 | .89 | 3.0 | .90 | 2.5 |

This experiment was too small in size and, owing to the necessity of shutting down the experiment station, covered too short a period of time to justify very extensive conclusions being drawn, but it would appear from the short run with these media that other variables may have a governing bearing upon the general principles laid down in connection with the theory of bacterial surface. These may arise from certain constituents of the applied

APRIL - 1910

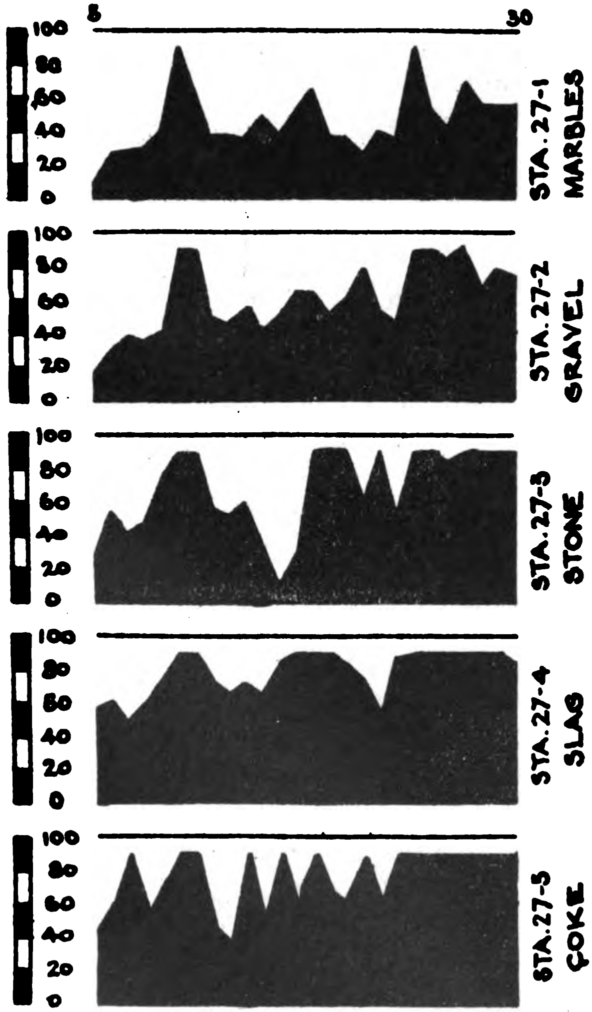



DIAGRAM No. 28
SHOWING THE
RELATIVE STABILITY
OF THE
EFFLUENT
FROM THE
BACTERIAL SURFACE FILTERS

liquor, such as fats or brewery wastes and the ease of clogging from these or other causes of the various media, even where the interstices are of equal size.

The case of the slag bed (20-3) and the gravel bed (20-5) may be cited as instances. The smooth surface of the latter did not allow either the formation of an effective "Smutzdecke" nor the adhesion of suspended solids, while the pores of the slag soon became filled and the rough surface covered by a thick jelly, after the formation of which the bed became more clogged than broken stone beds and when unloading occurred the porosity of the slag prevented the clogging matters from efficiently being washed out.

## THE HAMBURG FILTER.

The construction of this filter has already been explained under "Description of the Testing Station."

It was intended to dose it with 23 gallons of the effluent from sedimentation tank No. 17 every three hours or at a rate of one million gallons per acre per day, resting the filter every eighth day in order that the fine distributing layer might have an opportunity to dry. The history of this filter is very similar to the upper sprinkling filter; it produced a clear, bright effluent, well nitrified and stable.

But it was not possible to maintain a sufficiently high rate to justify extensive study of this method of distributing sewage over a percolating filter. Its history briefly is as follows: On November 4th the filter was started; the influent during the first week of operation contained only 34 parts per million suspended solids (a very good tank liquor). The first effluent carried through considerable amounts of fine coke, but by the end of the first dose this had ceased and the effluent was clear.

After one week of service the upper or distributing layer of media was so clogged with the suspended solids and much of the colloidal matter of the influent, that sewage stood continuously on the surface. A day's rest at this time did not relieve the clogging, after which the bed was again started and after another week's service the bed was rested, and just before starting raked over. This only temporarily benefited the distributing layer, and at the end of the third week it was rested four days and the upper layer of fine coke thoroughly raked. It was noticed that the fine pieces of coke were imbedded in a gelatinous mass undoubtedly composed of suspended solids and "hydrosols" which had been changed to the "gel" condition. During the three weeks of operation the influent, though low in suspended solids, was turbid, due to matter in a colloidal state, and the effluent clear and bright.

This change must have been brought about by the retention of the finely divided matter in the distributing layer of coke.

When the filter was again put in service it was found that the dose would not percolate through the clogged distributing layer of coke in three hours, when it was time to apply another 23 gallons of the influent. The upper three layers of fine material were carefully removed, washed, dried and screened, and replaced in layers one inch thick instead of four inches as in the original construction. It must be understood that this was not considered a practical method of building a filter, but was done to see if the fault was entirely due to the deep layer of fine coke.

The same conditions developed with this construction as the original and after a total test of 15 weeks, during which time the net rate of operation was only 640,000 gallons per acre per day, the experiment was ended.

Table No. 41 shows the results accomplished by this filter up to December 31, 1909.

## Table No. 41.

*Action of the Hamburg Filters.*

| | Parts per Million. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | |
| | Total. | Fixed. | Volatile. | Organic. | Free Amm. | Nitrites. | Nitrates. | Total. | In Susp. | As Colloids | In Solution. |
| Crude sewage | 200 | 82. | 118 | 5.3 | 3.8 | ------- | ------- | 85. | 10. | 35. | 40. |
| Settled—Influent | 54 | 8. | 46 | ------- | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| Effluent | 16 | 2. | 14 | 1.8 | 1.8 | .1 | 2.3 | 31.9 | 1.9 | 10.9 | 19.1 |
| Per cent. removed from influent | 70 | 75. | 69 | ------- | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| Per cent. removed from crude | 92 | 97.5 | 88 | 66. | 53. | ------- | ------- | 62. | 81. | 69. | 52. |

## INTERMITTENT SAND FILTER

The slate bed effluent being low in suspended solids, and already somewhat nitrified, it was thought that it could be finally oxidized by a shallow coarse sand filter at high rates, but it was found that either the applied liquor passed through the bed too quickly for any biological action upon it, or after the mechanical straining of the influent had sufficiently clogged the surface of the sand and the influent slowly percolated through the bed, that aeration was interfered with.

In the latter case the effluent was clear and bright, but the bed was unable to produce this character effluent at a gross rate of 200,000 gallons per acre per day for more than a week at a time, when it would be necessary to rest the bed and fork over its surface, then the cycle described above would be repeated.

The experiments were carried on from December 1, 1909, to March 2, 1910.

## THE SETTLEMENT OF SPRINKLING FILTER EFFLUENTS.

The suspended solids in the effluent from a mature sprinkling filter are different, both in appearance and composition, from those in crude sewage. If samples of each are examined it will be noticed that the solids in crude sewage appear to be sticky and mucilaginous, whereas, after having passed through and been acted upon in the bacteria bed, they are either granular or flaky. Concerning the composition of these solids: the suspended solids in crude sewage during August, 1909, were on an average 29.5 per cent. fixed or mineral matter, and in the effluent from bed No. 20-4, 35.5 per cent. were fixed matter.

In order that the final effluent as discharged into a river shall be uniform in amounts of these solids regard-

## TABLE No. 42.

| Dates. 1909-1910. | Suspended Solids (Parts per Million). Combined Effluents of the Outside Filters. | Effluent of the Settling Basin. | Remarks. |
|---|---|---|---|
| November 22 to November 29 | 121 | 60 | Flat bottom. No baffles. |
| November 29 to December 6 | 71 | 28 | |
| December 6 to December 13 | 82 | 32 | |
| December 13 to December 20 | 65 | 32 | |
| December 20 to December 24 | 61 | 44 | |
| December 27 to January 3 | 52 | 24 | |
| January 3 to January 4 | ---------- | 28 | |
| Average | 75 | 35 | |
| January 10 to January 17 | 20 | 8 | Baffle at mid-length. Up to the middle of February the filters stored solids. |
| January 17 to January 24 | 21 | 16 | |
| January 24 to January 31 | 29 | 22 | |
| January 31 to February 7 | 26 | 32 | |
| February 7 to February 14 | 30 | 38 | |
| February 14 to February 21 | 45 | 28 | |
| February 21 to February 28 | 101 | 42 | |
| February 28 to March 7 | 69 | 36 | |
| March 7 to March 14 | 75 | 50 | |
| March 14 to March 21 | 65 | 30 | |
| March 21 to March 28 | 83 | -------- | |
| Average | 51 | 30 | |
| April 5 to April 11 | 271 | 12 | Filters unloading. |
| April 11 to April 18 | 180 | 40 | |
| April 18 to April 25 | 130 | 32 | |
| April 25 to April 30 | 121 | -------- | |
| Average | 175 | 28 | |

less of the unloading of the sprinkling filters, it is usual to subject the filter effluent to rapid settlement.

The settling of the combined effluents of the outside sprinkling filters for a nominal storage of two hours in a horizontal tank proved sufficient to remove a large part of the suspended solids and yield a uniform effluent.

The results accomplished are given in Table No. 42.

It will be noticed that the amount of suspended solids in the settled effluent during the time that the filters unloaded was on an average the same as when the filters were storing solids. The amount and quality of sludge produced is discussed under "sludge."

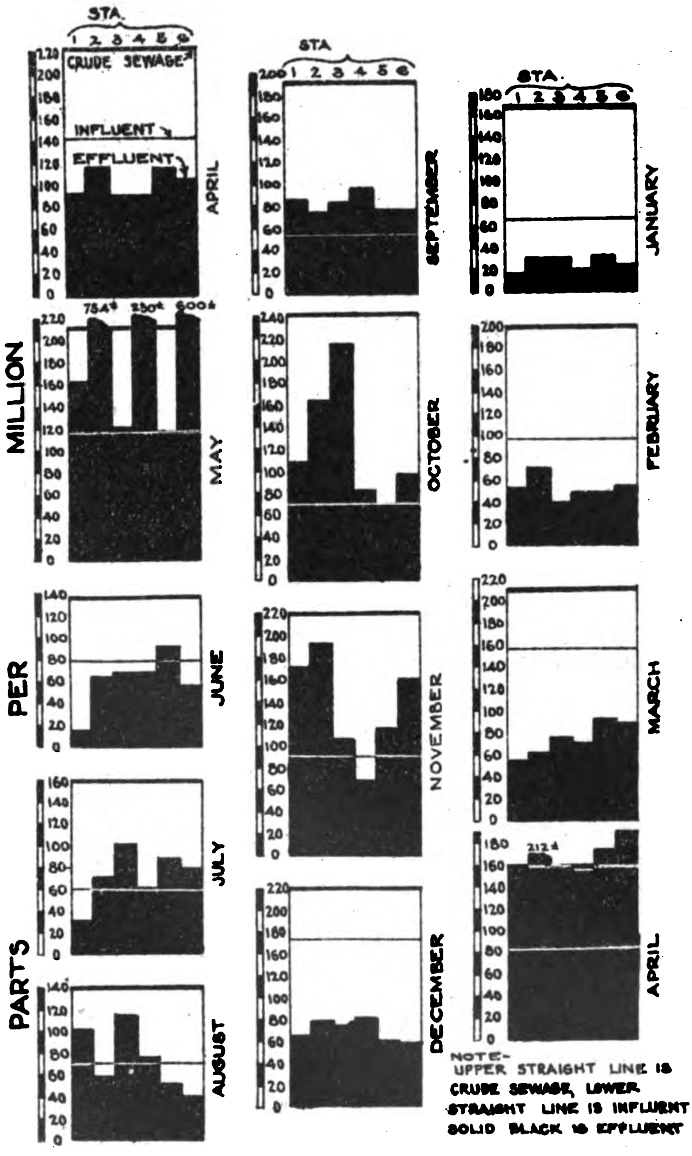



DIAGRAM No. 24
SHOWING BY MONTHLY AVERAGES THE
STORING AND UNLOADING
OF
TOTAL SUSPENDED SOLIDS
BY THE
OUTSIDE SPRINKLING FILTERS

## THE DISINFECTION OF SEWAGE.

These studies were carried on to determine the practicability of disinfecting sewage which had only been freed from its larger suspended solids, and if so, to find the economical amount of disinfectant required.

Others have shown that it is not practicable to disinfect sewage containing particles larger than 1 mm., and consequently no experiments were made upon crude force main sewage.

Experiments were conducted upon sewage which had been subjected to three different degrees of preliminary treatment, i. e., fine mesh screening, sedimentation, and sedimentation subsequent to fine mesh screening. These are arranged in the order of their efficiency in removing suspended solids and consequently of oxidizable matter.

The amount of calcium hypochlorite (the material used in all experiments) necessary to disinfect sewage is directly proportional to the amount of oxidizable matter contained therein. It was expected and the experiments showed that the screened sewage required the largest quantity of disinfectant and screened and settled sewage the least.

As the strength of sewage has a daily and hourly fluctuation, an amount of calcium hypochlorite adequate for disinfection at one time would be insufficient at times of greater strength, and uneconomical at times of lesser strength; and as disinfection to be depended upon must be uniform in its results, the amount added must be that needed to meet the maximum requirements.

### Period of Contact.

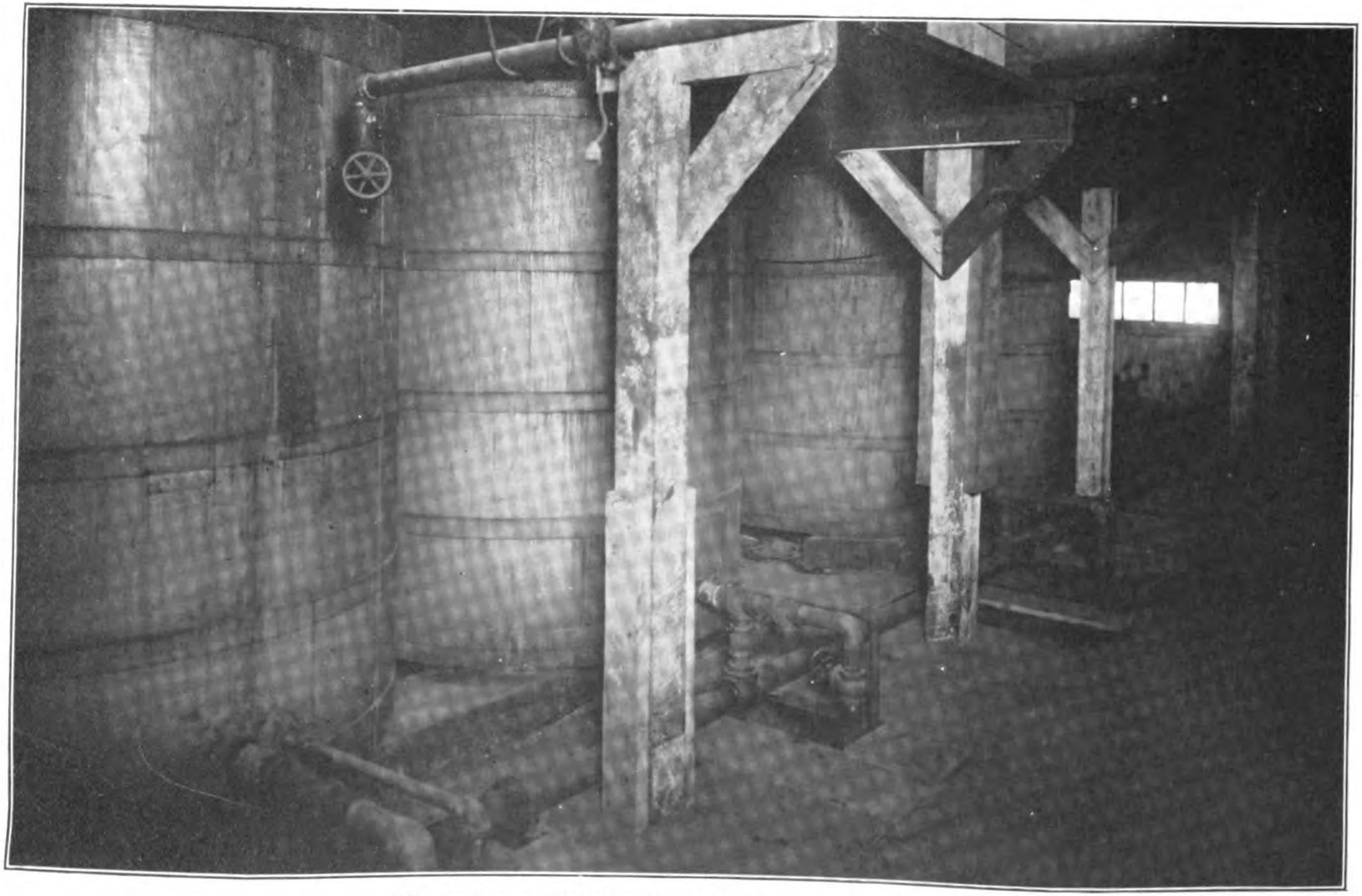
In the large scale experiments only one period of contact was studied, namely, two hours nominal flow through the tank. The actual flow through the tank was in less than two hours as determined by the passage of dyes.

**Results.**

The results of disinfection are shown in Table No. 43, in which two conditions are shown: first, such an amount of disinfectant added that during an epidemic considerable assurance would be felt that other municipalities lower down the river were adequately protected; secondly, such an amount added that would destroy over 95 per cent. of the B. Coli. at a moderate cost. With the after effect of dilution and oxidation this would clearly indicate efficient disinfection from a practical standpoint.

It will be seen that in the first case 12 parts per million available chlorine (approximately 300 pounds of dry bleaching powder per million gallons of sewage) effected almost complete disinfection, there being residual chlorine present in considerable quantity after two hours. Under the second or ordinary condition, adequate disinfection was accomplished with less than one-half the amount.

Sewage which had been passed through the fine mesh screen only and treated with about 150 pounds of dry bleach per million gallons, or when screened and settled and treated with 105 pounds of bleach, was economically disinfected.



Disinfection Tanks. Stations Nos. 41, 42 and 43.

TABLE NO. 43.

*Average Results of the Disinfection of Sewage from which Suspended Solids, at least larger than 1 mm. have been Removed by Preparatory Treatment. (Based upon 112 Samples.)*

| Sewage Used in the Experiments. | Available Chlorine Added. | Residual Chlorine in Effluent. | Total Number of Bacteria per C. C. on Gelatine at 20 Degrees C. in 48 Hours. | | | B. Coli. per C. C. as per Jackson's Presumptive Test. | | |
|---|---|---|---|---|---|---|---|---|
| | | | Initial. | Final. | Per Cent. Removed. | Initial. | Final. | Per Cent. Removed |
| Fine mesh screen | 12.4 | 4.7 | 2,470,000 | 337 | 99.99 | 121,000 | 20 | 99.98 |
| | 6.0 | 0.5 | 2,060,000 | 181,000 | 91.21 | 149,000 | 7,470 | 95.42 |
| Effluent of horizontal flow, Sedimentation Tank No. 18 (influent crude sewage) | 11.9 | 3.4 | 2,450,000 | 350 | 99.99 | 143,000 | 10 | 99.99 |
| | 5.4 | 0.7 | 760,000 | 31,000 | 95.92 | 67,000 | 745 | 98.89 |
| Effluent of horizontal flow, Sedimentation Tank No. 12 (influent screened sewage) | 12.0 | 3.1 | 2,130,000 | 310 | 99.99 | 86,000 | 20 | 99.98 |
| | 4.3 | 1.1 | 660,000 | 22,500 | 96.59 | 317,000 | 1,350 | 99.57 |

# Table No. 44.

*Disinfection of Fine Screened Sewage. Influent Station No. 11. Effluent Station No. 41.*

| Dates. 1909-1910. | Hours Storage. | Average Temperature, Degrees Cent. | Parts per Million. Total Suspended Solids in the Influent. | Parts per Million. Oxygen Consumed, Influent. | Parts per Million. Available Chlorine Added. | Parts per Million. Residual Chlorine. | Bacteria per C. C., 20 Degrees C. Influent. | Bacteria per C. C., 20 Degrees C. Effluent. | B. Coli. per C. C., Presumptive. Influent. | B. Coli. per C. C., Presumptive. Effluent. |
|---|---|---|---|---|---|---|---|---|---|---|
| October 13 to October 20 | 2 | 16 | 190 | ---- | 14.4 | 8.0 | 1,700,000 | 500 | 50,000 | 50 |
| October 20 to October 27 | 2 | 16 | 148 | ---- | 12.8 | 3.5 | 2,850,000 | 350 | 50,000 | 50 |
| October 27 to November 3 | 2 | 15 | 168 | ---- | 10.9 | 3.0 | 1,600,000 | 690 | 200,000 | 15 |
| November 3 to November 10 | 2 | 20 | 142 | 88.8 | 11.2 | 4.5 | 3,500,000 | 470 | 250,000 | 50 |
| November 10 to November 17 | 2 | 20 | 124 | 74.0 | 12.5 | 6.3 | 2,000,000 | 100 | 150,000 | 25 |
| November 17 to November 24 | 2 | 17 | 172 | 73.6 | 13.8 | 4.9 | 3,900,000 | 100 | 100,000 | 10 |
| November 24 to December 1 | 2 | 16 | 142 | 68.8 | 11.2 | 7.1 | 4,000,000 | 150 | 50,000 | 5 |
| January 5 to January 12 | 2 | 6 | 108 | 72.8 | 6.0 | 0.2 | 1,400,000 | 7,000 | ---- | ---- |
| January 12 to January 19 | 2 | 8 | 224 | 70.8 | 6.7 | 1.4 | 1,200,000 | 2,100 | 175,000 | 2,500 |
| January 19 to January 26 | 2 | 11 | 136 | 73.6 | ---- | ---- | ---- | ---- | ---- | ---- |
| January 26 to February 2 | 2 | 9 | 116 | 76.4 | ---- | ---- | ---- | ---- | ---- | ---- |
| February 2 to February 9 | 2 | 7 | 152 | 78.4 | 5.4 | 0.3 | 1,300,000 | 320,000 | 140,000 | 14,000 |
| February 9 to February 16 | 2 | 7 | 156 | 82.4 | 5.7 | 0.7 | 1,700,000 | 11,000 | 40,000 | 160 |
| February 16 to February 23 | 2 | 10 | 156 | 75.6 | 6.4 | 0.2 | 1,900,000 | 188,000 | 100,000 | 5,000 |
| February 23 to March 2 | 2 | 10 | 180 | 74.0 | 5.6 | 0.2 | 2,250,000 | 440,000 | 250,000 | 29,000 |
| March 2 to March 8 | 2 | 13 | 82 | 68.8 | 6.9 | 1.0 | 1,550,000 | 2,200 | 200,000 | 50 |
| March 9 to March 16 | 2 | 10 | 148 | 74.4 | 5.05 | 0.9 | 1,900,000 | 253,000 | 64,000 | 10,000 |
| March 16 to March 23 | 2 | 12 | 92 | 67.6 | 5.7 | 0.0 | 2,400,000 | 150,000 | 187,000 | 7,000 |
| March 23 to March 30 | 2 | 18 | ---- | ---- | 5.6 | 0.75 | 2,400,000 | 50,000 | 230,000 | 7,000 |
| March 30 to April 6 | 2 | 20 | 136 | ---- | 6.8 | 0.0 | ---- | ---- | ---- | ---- |
| April 6 to April 13 | 2 | 16 | 144 | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| April 13 to April 20 | 2 | 17 | 120 | ---- | 6.2 | 0.0 | 2,500,000 | 750,000 | ---- | ---- |
| April 20 to April 27 | 2 | 18 | 152 | ---- | 6.3 | 0.7 | 4,300,000 | 4,200 | 100,000 | 10 |

# Table No. 45.

*Disinfection of Settled Sewage. Influent Station No. 13—Effluent Station No. 43.*

| Dates. | Hours Storage. | Average Temperature, Degrees Cent. | Parts per Million. | | | | Bacteria per C. C., 20 Degrees C. | | B. Coli. per C. C., Presumptive. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total Suspended Solids in the Influent. | Oxygen Consumed, Influent. | Available Chlorine Added. | Residual Chlorine. | Influent. | Effluent. | Influent. | Effluent. |
| 1909. | | | | | | | | | | |
| October 13 to October 20 | 2 | 16 | 64 | ---------- | 14.5 | 4.0 | 1,000,000 | 250 | 200,000 | 50 |
| October 20 to October 27 | 2 | 16 | 40 | ---------- | 13.2 | 5.8 | 1,550,000 | 180 | 30,000 | 5 |
| October 27 to November 3 | 2 | 15 | 44 | ---------- | 11.5 | 2.3 | 2,400,000 | 350 | 250,000 | 5 |
| November 3 to November 10 | 2 | 20 | 144 | 89.6 | 11.2 | 1.5 | 2,500,000 | 500 | 250,000 | 5 |
| November 16 to November 17 | 2 | 20 | 100 | 75.2 | 12.2 | 3.7 | 2,300,000 | 250 | 100,000 | 7 |
| November 17 to November 24 | 2 | 17 | 64 | 73.2 | 10.2 | 1.4 | 3,200,000 | 500 | 100,000 | 50 |
| November 24 to December 1 | 2 | 16 | 82 | 64.8 | 10.4 | 6.6 | 4,200,000 | 430 | 75,000 | 5 |
| 1910. | | | | | | | | | | |
| January 5 to January 12 | 2 | 6 | 40 | 62.0 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| January 12 to January 19 | 2 | 8 | 120 | 74.8 | 5.6 | 0.0 | 850,000 | 45,000 | 100,000 | 2,600 |
| January 19 to January 26 | 2 | 11 | 60 | 72.0 | 6.3 | 0.5 | 730,000 | 24,000 | 50,000 | 50 |
| January 26 to February 2 | 2 | 9 | 72 | 69.6 | 5.4 | 0.0 | 440,000 | 56,000 | 50,000 | 500 |
| February 2 to February 9 | 2½ | 7 | 60 | 70.0 | 5.1 | 1.1 | 1,000,000 | 20,000 | 80,000 | 300 |
| February 9 to February 16 | 2½ | 7 | 78 | 66.8 | 4.5 | 2.0 | 770,000 | 12,000 | 55,000 | 275 |

## TABLE No. 46.

*Disinfection of Fine Screened and Settled Sewage. Influent Station No. 12—Effluent Station No. 42.*

| Dates. 1909-1910. | Hours Storage. | Average Temperature, C. Degrees. | Parts per Million. | | | | Bacteria per C. C., 20 Degrees C. | | B. Coli. per C. C., Presumptive. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total Suspended Solids in the Influent. | Oxygen Consumed, Influent. | Available Chlorine Added. | Residual Chlorine. | Influent. | Effluent. | Influent. | Effluent. |
| October 6 to October 7 | 2 | ------ | 52 | 71.6 | *23.6 | ------ | 1,200,000 | 500 | 100,000 | ------ |
| October 7 to October 13 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| October 13 to October 20 | 2 | 16 | 64 | 72.0 | 12.1 | 3.0 | 1,720,000 | 250 | 66,000 | 50 |
| October 20 to October 27 | 2 | 16 | 48 | 69.2 | 10.6 | 2.7 | 2,050,000 | 200 | 50,000 | ------ |
| October 27 to November 3 | 2 | 15 | 24 | 70.0 | 9.4 | 2.5 | 1,370,000 | 290 | 220,000 | 15 |
| November 3 to November 10 | 2 | 20 | 96 | 78.0 | 9.4 | 2.8 | 2,300,000 | 430 | 30,000 | 5 |
| November 10 to November 17 | 2 | 20 | 124 | 78.8 | 12.5 | 4.5 | 2,100,000 | 150 | 36,000 | 4 |
| November 17 to November 24 | 2 | 17 | 96 | 62.0 | 9.2 | 0.4 | 3,300,000 | 600 | 100,000 | 50 |
| November 24 to December 1 | 2 | 16 | 62 | 58.0 | 9.0 | 5.6 | 3,000,000 | 260 | 100,000 | 5 |
| December 28 to January 5 | 2 | ------ | 72 | 76.4 | 4.13 | 0.0 | 820,000 | 35,400 | 150,000 | ------ |
| January 5 to January 12 | 2 | 6 | 56 | 68.8 | 4.8 | 4.5 | 660,000 | 500 | ------ | ------ |
| January 12 to January 19 | 2 | 8 | 84 | 66.0 | 4.4 | 0.0 | 650,000 | 84,400 | 75,000 | 1,700 |
| January 19 to January 26 | 2 | 11 | 84 | 70.8 | 4.1 | 0.0 | 510,000 | 20,000 | 50,000 | 1,000 |

The above data are based upon experiments conducted in the tanks heretofore described and through which over 20,000 gallons of sewage flowed per day. To study some of the details of disinfection, laboratory experiments were carried on, using three liters of fine screened sewage in four-liter glass-stoppered bottles.

## LABORATORY EXPERIMENTS.

### Rate of Exhaustion.

Fresh sewage was obtained from the intercepting sewer and passed through the fine mesh screen, 18 liters of which were equally divided among six bottles, and to each a different quantity of strong calcium hypochlorite solution added in amount required to yield the parts per million shown in Table No. 47 At the end of the times indicated in the table the bottle was agitated and a measured portion withdrawn for the determination of residual chlorine, also when the residual chlorine was exhausted, or if not, at the end of the test, 250 cc. were taken and as soon as the residual chlorine had been determined, an amount of sterile sodium thiosulphite, just sufficient to neutralize the residual chlorine added and a "methylene blue" sample placed in the incubator.

The exhaustion of the available chlorine and the relative stability of the disinfected sewage are shown in diagram No. 30, wherein it will be seen that those oxidizable matters in the sewage capable of absorbing the disinfectant do so within the first hour, after that time the residual chlorine is very slowly reduced; also when the effluent is incubated by itself the disinfection is shown to have prevented the subsequent putrefaction of the screened sewage when over 10 parts per million available chlorine were added. From this experiment it would seem the work accomplished by the disinfectant was done quickly, at least within the first hour.

### Table No. 47.

*Chlorine Absorption When Constant Volumes of Sewage are Treated With Different Quantities of Hypochlorite of Lime Solution for Different Lengths of Time. Volume Treated, 3,000 cc. Screened Sewage. March 24, 1910.*

| Available Chlorine Added. | PARTS PER MILLION. Residual Chlorine. Elapsed Time in Hours. | | | | | | | | | Rel. Stab. with Methy'ne Blue at 20 Degrees C. |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | 1.0 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.47 |
| 7.5 | 2.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.59 |
| 10.0 | 4.0 | 2.0 | 1.5 | 1.0 | 0 | 0 | 0 | 0 | 0 | 0.79 |
| 15.0 | ....... | 6.0 | 6.0 | 6.0 | 5.0 | 5.0 | 4.0 | 4.5 | 4.5 | 1.00 |
| 20.0 | ....... | 7.0 | ....... | 6.5 | 4.0 | 3.0 | 3.0 | 2.5 | 2.0 | 0.96 |
| 25.0 | ....... | 8.0 | ....... | 6.5 | 5.0 | 4.0 | 4.0 | 3.5 | 3.0 | 1.00 |

## Diffusion of Calcium Hypochlorite Solution.

The efficiency of disinfection depends somewhat upon every portion of the sewage coming in contact with the disinfectant, and this in turn involves the diffusion of the solution with the sewage. To determine this many indicators were experimented with, among which may be mentioned cochineal, erythosin, indigo, lacmoid, methyl-orange, eosine, litmus, methyline blue, phenolphthaleïn, and rosolic acid.

Of these, indigo was chosen as the most sensitive indicator of the presence of calcium hypochlorite, being quickly decolorized by faint traces of the hypochlorite solution.

## Table No. 48.

*Relation Between Time of Contact and Efficiency of Disinfection With Calcium Hypochlorite. Volume Treated = 3,000 cc. April 30, 1910. Bottles Agitated Before Sampling.*

| Parts per Million. Chemical Analysis of Sewage. Kind. | Total Suspended Solids. | Oxygen Consumed. | Available Chlorine Added. | 10 Residual Chlorine. | 10 Bacteria per C. C. 20 Degrees. | 10 B. Coli. per C. C. Presumptive. | 10 Per Cent. Reduction, 20 Degrees. | 10 Per Cent. Reduction, B. Coli. | 10 Relative Stability. | 20 Residual Chlorine. | 20 Bacteria per C. C. 20 Degrees. | 20 B. Coli. per C. C. Presumptive. | 20 Per Cent. Reduction, 20 Degrees. | 20 Per Cent. Reduction, B. Coli. | 20 Relative Stability. | 30 Residual Chlorine. | 30 Bacteria per C. C. 20 Degrees. | 30 B. Coli. per C. C. Presumptive. | 30 Per Cent. Reduction, 20 Degrees. | 30 Per Cent. Reduction, B. Coli. | 30 Relative Stability. | 60 Residual Chlorine. | 60 Bacteria per C. C. 20 Degrees. | 60 B. Coli. per C. C. Presumptive. | 60 Per Cent. Reduction, 20 Degrees. | 60 Per Cent. Reduction, B. Coli. | 60 Relative Stability. | 120 Residual Chlorine. | 120 Bacteria per C. C. 20 Degrees. | 120 B. Coli. per C. C. Presumptive. | 120 Per Cent. Reduction, 20 Degrees. | 120 Per Cent. Reduction, B. Coli. | 120 Relative Stability. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Screened. | 120 | 58.4 | 5.0 | 0.7 | 1,250 | 1,000 | 99.88 | 99.90 | .45 | 1.4 | 1,875 | 1,000 | 99.81 | 99.90 | .50 | 0.7 | 720 | 1,000 | 99.97 | 99.90 | .50 | 1.4 | 440 | 1,000 | 99.95 | 99.90 | .56 | 0.7 | 560 | 100 | 99.94 | 99.99 | .58 |
| | | | 7.5 | 3.6 | 910 | 20 | 99.90 | 99.99 | .53 | 2.8 | 570 | 20 | 99.94 | 99.99 | .53 | 2.8 | 730 | 2,000 | 99.92 | 99.80 | .71 | 2.8 | 470 | 200 | 99.95 | 99.98 | .57 | 2.8 | 570 | 20 | 99.94 | 99.99 | .55 |
| | | | 10.0 | 7.7 | 1,280 | 20 | 99.87 | 99.99 | .47 | 4.3 | 1,090 | 200 | 99.89 | 99.98 | .62 | 3.5 | 500 | 200 | 99.95 | 99.98 | .90 | 4.3 | 1,230 | 20 | 99.88 | 99.99 | .57 | 2.8 | 750 | 20 | 99.92 | 99.99 | .58 |

NOTE—For comparison, counts reduced to initial content of 1,000,000 per C. C. Oxygen consumed equals 30 minutes on water bath at 100 degrees C.

Four-liter bottles containing 3000 cc. of distilled water faintly colored with indigo solution were first used. A 1 per cent. bleach solution was carefully added at the surface from a pipette having a large orifice in order to avoid the formation of a current. The diffusion of the calcium hypochlorite could be plainly noted by the decoloration of the indicator.

It showed that the solution very rapidly passed through the upper portion of the water and sunk to the bottom, diffusion being entirely from that part upward and was accomplished very slowly, the surface of the water in some cases remaining blue for an hour.

As these phenomena might have been caused by the difference in specific gravity of the liquids used, they were repeated, using clear, settled sewage instead of distilled water. The same results were obtained.

As a check upon these observations 3,000 cc. of screened sewage were taken and a sufficient quantity of the 1 per cent. calcium hypochlorite solution added to produce six parts per million available chlorine; after ten minutes 100 cc. were pipetted one-half inch below the surface, and another 100 cc. one-half inch above the bottom; exactly one-half of each was examined for residual chlorine, and then the other half neutralized with sterile sodium thiosulphite and plated. The results are shown in Table No. 49, where it will be seen that the residual chlorine and tne reduction of bacteria were found to be the greater at the bottom of the bottle.

As a result of these two tests it is indicated that a 1 per cent. solution of hypochlorite of calcium would pass rapidly through the upper part of a stream of sewage, inadequately disinfecting it, and that diffusion from the bottom would not be rapid; consequently the mechanical mixture of the solution with the sewage should increase the efficiency of disinfection.

TABLE NO. 49.

*Relation Between Disinfection at the Top and Bottom of the Sewage When Allowed to Remain Quiescent in the Bottle. Volume 3,000 C. C.*

| Notes. | Parts per Million. | | | | Elapsed Time in Minutes. | | |
|---|---|---|---|---|---|---|---|
| | Chemical Analysis of Sewage. | | | | 10 | | |
| | Kind. | Total Suspended Solids. | Oxygen Consumed. | Available Chlorine Added. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Reduction, 20 Degrees. |
| Sample taken from top of bottle just beneath the surface.. | Screened. | 116 | 56.0 | 6.0 | 0 | 16,100 | 98.39 |
| Sample taken about one-half inch from bottom of bottle.. | | | | 6.0 | 4.0 | 200 | 99.98 |

NOTE.—Oxygen consumed—30 minutes on water bath at 100 degrees C.
All numbers of bacteria converted to a uniform basis of 1,000,000 initial bacteria per c. c.

## Quiescent and Agitated Samples.

Before describing these experiments, two matters must be stated—the sample of sewage used for the quiescent test proved to be unusually strong, as may be seen by comparing its high values for suspended solids and oxygen consumed with the other samples; also this test was conducted prior to the experiments to show diffusion and in taking samples for plating they were removed near the surface. Both of these facts would decrease the value of the comparison.

There is shown in Tables No. 48 and 50, and on diagram No. 30 the detailed results of the disinfection of screened, fresh sewage, with varying amounts of available chlorine. The markedly higher removal of bacteria when the bottle was agitated before sampling over the quiescent condition

### Table No. 50.

*Relation between time of Contact and Efficiency of Disinfection with Calcium Hypochlorite. Volume Treated=3000 C. C., April 30, 1910. Bottles allowed to remain quiescent throughout the test, and sampled at the top.*

| Parts per Million. | | | | ELAPSED TIME IN MINUTES. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chemical Analysis of Sewage. | | | | 10 | | | | | | 20 | | | | | | 30 | | | | | | 60 | | | | | | 120 | | | | | |
| Kind. | Total Suspended Solids. | Oxygen Consumed. | Available Chlorine Added. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | B. Coli. per C. C. Presumptive. | Per Cent. Reduction, 20 Degrees. | Per Cent. Reduction, B. Coli. | Relative Stability. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | B. Coli. per C. C. Presumptive. | Per Cent. Reduction, 20 Degrees. | Per Cent. Reduction, B. Coli. | Relative Stability. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | B. Coli. per C. C. Presumptive. | Per Cent. Reduction, 20 Degrees. | Per Cent. Reduction, B. Coli. | Relative Stability. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | B. Coli. per C. C. Presumptive. | Per Cent. Reduction, 20 Degrees. | Per Cent. Reduction, B. Coli. | Relative Stability. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | B. Coli. per C. C. Presumptive. | Per Cent. Reduction, 20 Degrees. | Per Cent. Reduction, B. Coli. | Relative Stability. |
| Sewage. | 324 | 88 | 5.0 | 0 | 150,000 | 100,000 | 85.0 | 90.0 | .35 | 0 | 131,000 | 100,000 | 86.9 | 90.0 | .40 | 0 | 123,000 | 100,000 | 87.2 | 90.0 | .40 | 0 | 92,900 | 100,000 | 90.71 | 90.0 | .39 | 0 | 95,700 | 100,000 | 90.43 | 90.0 | .39 |
| | | | 7.5 | 0 | 443,000 | 1,000,000 | 55.7 | 0.0 | .26 | 0 | 148,000 | 100,000 | 85.2 | 90.0 | .35 | 0 | 71,400 | 100,000 | 92.86 | 90.0 | .40 | 0 | 142,000 | 100,000 | 85.70 | 90.0 | .27 | 0 | 131,000 | 100,000 | 86.90 | 90.0 | .27 |

NOTE—For comparison, counts reduced to initial content of 1,000,000 per C. C. Oxygen consumed equals 30 minutes on water bath at 100 degrees C.

led to further study of the matter. In Table No. 51 is shown the result of adding equal quantities of calcium hypochlorite solution to two bottles containing the same quantity of screened fresh sewage and allowing one to remain quiescent, while the other was agitated before sampling. As a compromise position the quiescent sample was withdrawn at mid depth. The absence of residual chlorine in the quiescent sample is due to lack of diffusion. The agitation produced much better results, so that it would seem that a smaller amount of disinfectant thoroughly mixed with the sewage would accomplish the same results as a larger quantity not properly mixed.

To determine this only one-fourth as much available chlorine was added to the agitated sample and in Table No. 52 it will be seen that this was too great a reduction in the amount of disinfectant.

The test was repeated, using one-third as much solution for the agitated as the quiescent and from results shown in table No. 53 it will be seen that the agitated sample was adequately disinfected with a very small quantity of disinfectant, although not as efficiently as in the case of the three times larger quantity.

## Conclusions.

As a result of all the tests upon disinfection, it may be said that fresh sewage from which particles larger than 1 mm. have been removed, either by fine mesh screening or by sedimentation, can be disinfected by means of calcium hypochlorite with the quantities given, and that if the complete mixture of the disinfectant with the sewage be accomplished by mechanical means rather than relying on diffusion, a much smaller amount need be used. The above described experiments and the observations of others indicate that the action of calcium hypochlorite is very rapid. It is therefore probable, although no confirming tests were made, that long contact with the disin-

## Table No. 51.

*Showing the Efficiencies of Disinfection in Quiescent and Agitated Samples with Calcium Hypochlorite. Volume= 3,000 CC. Sampled at middle depth.*

| Notes. | Parts per Million. | | | | Elapsed Time in Minutes. | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chemical Analysis of Sewage. | | | | 10 | | | | 20 | | | | 30 | | | | 60 | | | | 120 | | | |
| | Kind. | Total Suspended Solids. | Oxygen Consumed. | Available Chlorine Added. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Reduction, 20 Degrees. | Relative Stability. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Reduction, 20 Degrees. | Relative Stability. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Reduction, 20 Degrees. | Relative Stability. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Reduction, 20 Degrees. | Relative Stability. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Reduction, 20 Degrees. | Relative Stability. |
| Quiescent | Screened | 168 | 52 | 6.0 | .0 | 286,000 | 71.4 | .64 | .0 | 7,100 | 99.29 | .79 | .0 | 2,600 | 99.74 | .62 | ---- | ---- | ---- | .79 | ---- | ---- | ---- | ---- |
| Agitated | | | | 6.0 | 2.0 | 7,500 | 99.25 | .48 | 1.5 | 1,200 | 99.80 | .51 | 1.0 | 100 | 99.99 | .51 | .0 | 100 | 99.99 | .57 | .0 | 95 | 99.99 | .56 |

NOTE—All numbers of bacteria converted to a uniform basis of 1,000,000 initial bacteria per C. C. Oxygen consumed equals 30 minutes on water bath at 100 degrees C.

# TABLE No. 52.

*Showing the Efficiency of Disinfection in Quiescent and Agitated Samples with Calcium Hypochlorite. One-fourth as much added to Agitated Sample as to Quiescent. Volume=3,000 CC.*

| Notes. | PARTS PER MILLION. Chemical Analysis of Sewage. Kind. | Total Suspended Solids. | Oxygen Consumed. | Available Chlorine Added. | 10 Residual Chlorine. | 10 Bacteria per C. C. 20 Degrees. | 10 Per Cent. Reduction, 20 Degrees. | 20 Residual Chlorine. | 20 Bacteria per C. C. 20 Degrees. | 20 Per Cent. Reduction, 20 Degrees. | 30 Residual Chlorine. | 30 Bacteria per C. C. 20 Degrees. | 30 Per Cent. Reduction, 20 Degrees. | 60 Residual Chlorine. | 60 Bacteria per C. C. 20 Degrees. | 60 Per Cent. Reduction, 20 Degrees. | 120 Residual Chlorine. | 120 Bacteria per C. C. 20 Degrees. | 120 Per Cent. Reduction, 20 Degrees. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quiescent | Screened.. | 168 | 76.4 | 6.0 | 0 | 77,000 | 92.30 | 1.0 | 760 | 99.91 | 1.0 | 350 | 99.96 | 1.0 | 300 | 99.97 | 1.0 | 50 | 99.99 |
| Agitated | | | | 1.5 | 0 | 170,000 | 83.00 | 0.0 | 35,000 | 96.5 | 0.0 | 17,000 | 98.30 | 0.0 | 9,000 | 99.10 | 0.0 | 14,100 | 98.59 |

(ELAPSED TIME IN MINUTES: 10, 20, 30, 60, 120.)

NOTE—All numbers of bacteria converted to a uniform basis of 1,000,000 initial bacteria per C. C. Oxygen consumed equals 30 minutes on water bath at 100 degrees C.

## Table No. 53.

*Showing the Efficiency of Disinfection in Quiescent and Agitated Samples with Calcium Hypochlorite. One-third as much Bleach added to Agitated as to Quiescent. Volume=3,000 C. C.*

| Notes. | PARTS PER MILLION. | | | | ELAPSED TIME IN MINUTES. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chemical Analysis of Sewage. | | | | 10 | | | 20 | | | 30 | | | 60 | | | 120 | | |
| | Kind. | Total Suspended Solids. | Oxygen Consumed. | Available Chlorine Added. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Removal, 20 Degrees. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Removal, 20 Degrees. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Removal, 20 Degrees. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Removal, 20 Degrees. | Residual Chlorine. | Bacteria per C. C. 20 Degrees. | Per Cent. Removal, 20 Degrees. |
| Quiescent | Screened | 132 | 71.2 | 6.0 | 5.0 | 550 | 99.94 | 4.0 | 520 | 99.95 | 4.0 | 810 | 99.91 | 3.0 | 3,000 | 99.70 | 0.0 | 220 | 99.98 |
| Agitated | | | | 2.0 | 0.0 | 69,500 | 93.05 | 0.0 | 44,400 | 95.56 | 0.0 | 43,000 | 95.57 | 0.0 | 5,500 | 99.45 | 0.0 | 4,200 | 99.58 |

NOTE—All numbers of bacteria converted to a uniform basis of 1,000,000 initial bacteria per C. C. Oxygen consumed equals 30 minutes on water bath at 100 degrees C.

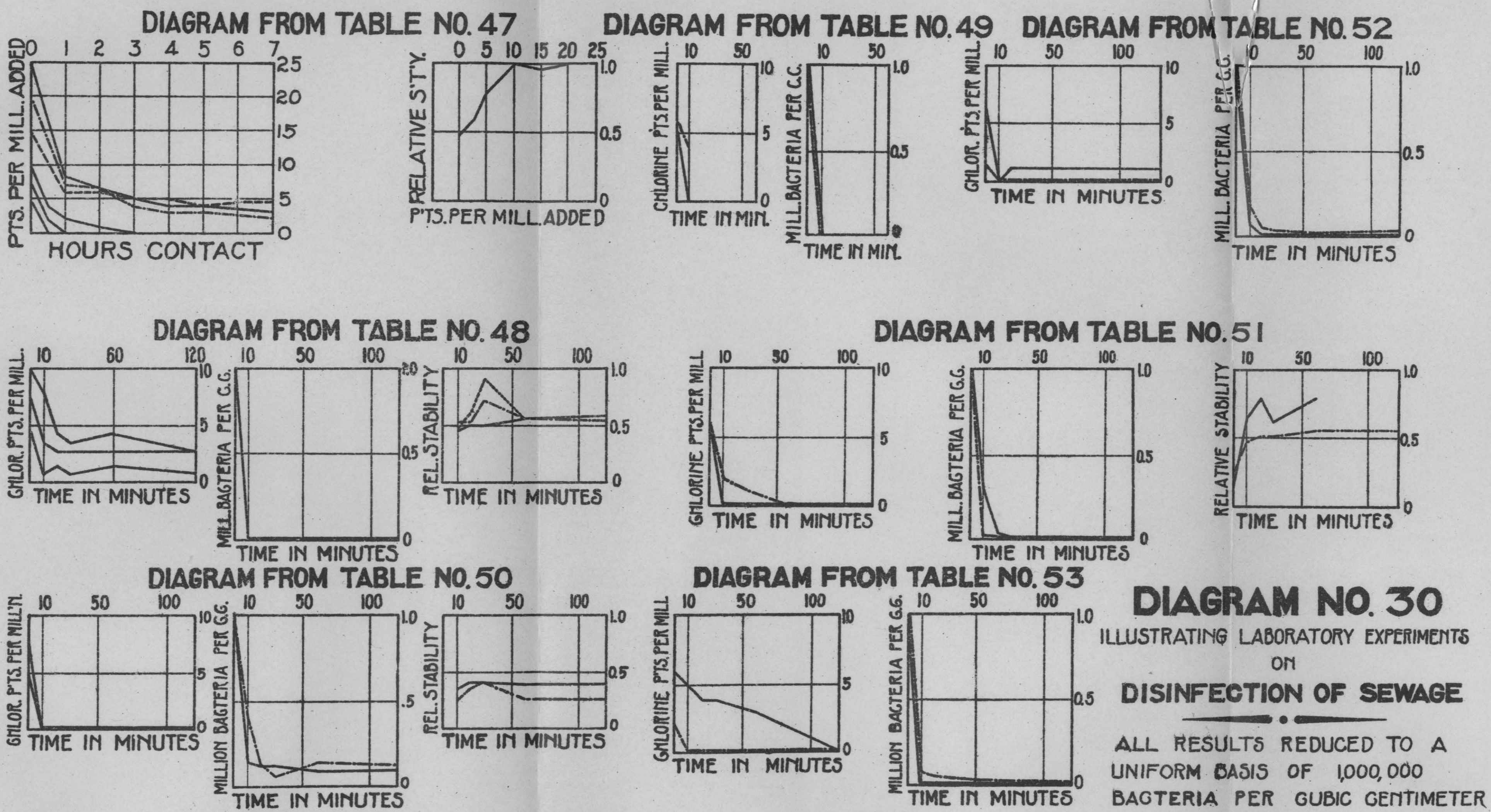



**DIAGRAM NO. 30**

ILLUSTRATING LABORATORY EXPERIMENTS
ON
**DISINFECTION OF SEWAGE**

ALL RESULTS REDUCED TO A UNIFORM BASIS OF 1,000,000 BACTERIA PER CUBIC CENTIMETER fectant in a tank is unnecessary providing mechanical agitation of the sewage is used to cause complete mixture. This would greatly reduce the cost of land and tank construction for a large disposal works, where disinfection is found necessary.

## DISINFECTED SEWAGE COMPARED WITH THE EFFLUENT FROM OXYDIZING PROCESSES.

On March 23, 1910, screened sewage was being disinfected with 6.9 parts per million available chlorine; analysis showed that there was no residual chlorine present in the effluent, and the disinfectant had destroyed 97.1% of the bacteria. A sample of the effluent was added to tap water to make nine dilutions, ranging from one part effluent to two parts tap water up to one to ten. These were incubated at 20° C. with methylene blue, and were still stable at the end of ten days (except the one to two dilution).

During April the relative stability of the screened and disinfected sewage was determined the same as the effluents from sprinkling filters, and the comparative data is shown in the following table:

*Average Relative Stability During April, 1910.*

(Sunday samples excluded.)

| | Relative Stability. |
|---|---|
| Screened and disinfected sewage: | |
| Undiluted | .31 |
| Diluted with equal column of tap water | .34 |
| Effluents of sprinkling filters operated at 2½ million gallons per acre per day: | |
| No. 20-4, 7 ft. of 1-in. to 3-in. trap | .64 |
| No. 20-5, 4 ft. of ½-in. to 3-in. trap | .28 |

From this comparison it is seen that screened and disinfected sewage was more stable than a poor sprinkling filter effluent, although not equal to that from an efficient one.

It was discussed, but not determined, whether this result was accomplished by the chemical oxidation by the calcium hypochlorite of the putrescent matter; or by the retarding of putrefaction by the disinfecting action of the bleach until the oxidation of the putresible matter was brought about biologically.

Funds were insufficient to carry on these experiments further, and on account of their small scale and short duration they must be considered unfinished.

But the fact remains that there were changes outside of the disinfection which invited further investigation.

# THE PURIFICATION OF SEWAGE BY DILUTION.

## Applicability of the Process.

### The Oxidation of Sewage.

If fresh sewage is allowed to stand, the unstable organic matters contained therein rapidly exhaust the dissolved oxygen present in the water, anaerobic conditions develop, and the subsequent putrefaction produces bad odors and usually black deposits. This foul condition is prevented by the continual presence of oxygen or aerobic treatment. The oxidation to a stable condition of the putrescible matters in sewage can be accomplished by means of artificially constructed bacteria beds, but this is at a large expense for purchase of land, construction costs, and the constant maintenance charges.

Natural bodies of water contain bacteria (such as B. racemosus, nitrosomonas and nitrobacter) required to convert organic nitrogen into nitrates through the steps of free ammonia and nitrites; and also the necessary oxygen to maintain these chemical changes to a certain extent. Water has the property of absorbing oxygen from the air, the rate and amount of which is dependent upon the temperature and barometric pressure. The rate of absorption, according to Dibdin, is shown in diagram No. 31 and the valuable work of Dr. Adeney, published in the VI Appendix of the Fifth Report of the Royal Commission on Sewage Disposal of England, shows that the absorption and rapid diffusion of the atmospheric oxygen by water replenishes the dissolved oxygen, as it is used in the oxidation of putrescent organic matter by the bacteria.

The similarity of biological methods and results accomplished in bacteria beds and in a river are therefore evident, and the economy of the latter proposition makes its serious study important.

The purification of water to a potable condition has been developed to such an extent that it is now possible to render water so polluted that it could almost be classed as a very dilute sewage into a water which, although analysis shows the presence of more ammonia and chlorine than standards of potable water require, their presence are not, per se, detrimental to health, and the bacteria in the final effluent in such cases ranges from 1 to 55 per cc.

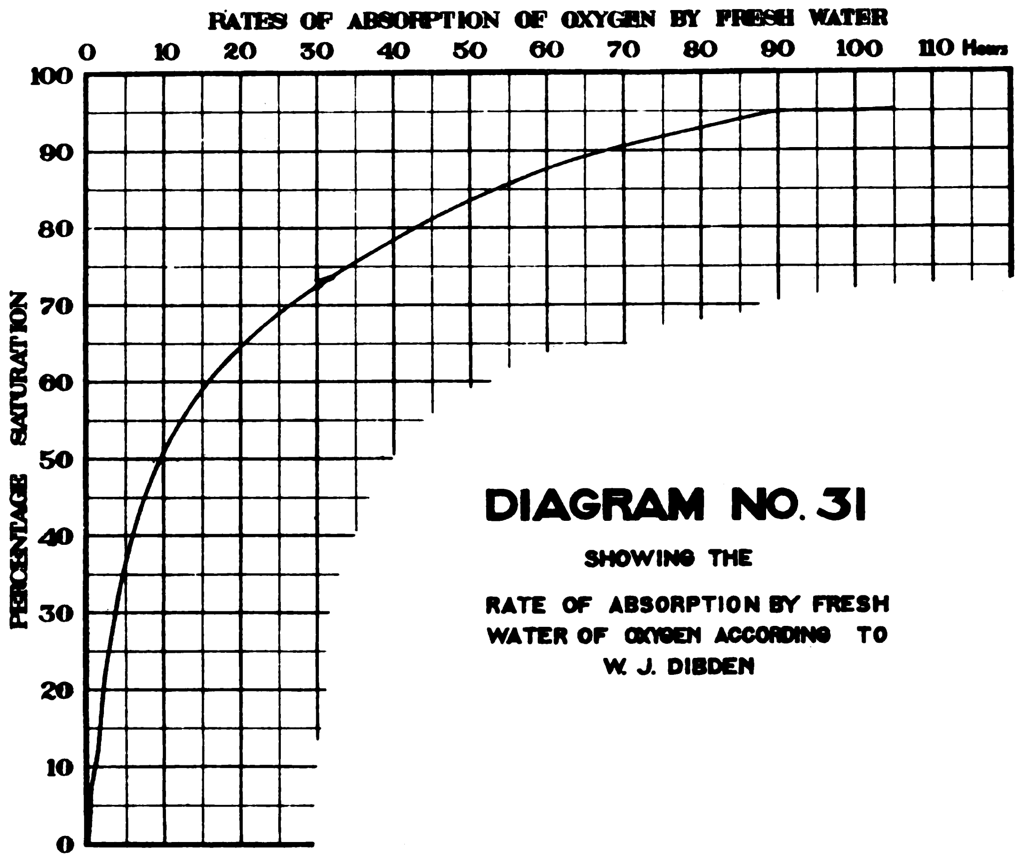
While this condition may be dismissed from consideration, it may, however, be well to consider the establishment of an economical balance between the amount of purification of the sewage discharged into a large river, and the load placed upon the water purification plants of cities using that river for their water supply.

This natural method of sewage purification should not be condemned and set aside as unsanitary without the most careful inquiry and experiments, for the great cost of purifying the sewage of a large city is such that it is necessary to utilize every natural method of sewage purification as far as possible without endangering the public health.

**Limits of Effective Dilution.**

The difference between offensive and inoffensive pollution of a water course is to a large extent caused by the absence or presence of dissolved oxygen therein; for as long as aerobic conditions are maintained the breaking down of complex organic bodies by bacteria will be accomplished inoffensively.

On the other hand, when oxidizable matters are added in such quantities that the oxygen of the water is ex-


RATES OF ABSORPTION OF OXYGEN BY FRESH WATER
0 10 20 30 40 50 60 70 80 90 100 110 Hours
100 90 80 70 60 50 40 30 20 10 0
PERCENTAGE SATURATION
DIAGRAM NO. 31
SHOWING THE
RATE OF ABSORPTION BY FRESH
WATER OF OXYGEN ACCORDING TO
W. J. DIBDEN

hausted, the anaerobic bacteria become active, and the unstable organic matter putrefies, producing the foul odors and unsightly appearance to be seen when a small stream is the carrier of a town's unpurified sewage.

The amount of sewage water produced per capita varies between wide limits in different cities, but the actual amount of polluting material produced per capita is quite uniform. The relation between stream flow and population contributing polluting matter is therefore a more satisfactory method of considering the subject of dilution than the ratio between stream flow and sewage. Sanitary engineers have definitely agreed upon the critical point separating offensive from inoffensive dilution. The limits are shown in the following table:

| | | Cubic feet per second per 1,000 people contributing. | |
|---|---|---|---|
| Authority | | Offensive | Inoffensive. |
| R. Hering, | 1887 | Less than 2¼ | more than 7 |
| F. P. Stearns, | 1890 | Less than 2 | more than 8+ |
| X. H. Goodnough, | 1903 | Less than 3½ | more than 6 |

The most notable example of the purification of crude sewage of a large inland city by the natural process of dilution is the Chicago Drainage Canal, where the amount of dilution required by law is three and one-third cubic feet per second of lake water added to the sewage of each 1,000 persons; and the success of the method is shown in the many thorough examinations by engineers, chemists and bacteriologists of the water of the canal.

**Practicability of Purification by Dilution.**

The practicability of purifying crude sewage by dilution having been established, it became desirable to increase the rate of purification by some preliminary treatment.

The solids contained in crude sewage are of variable size and characteristics. A portion consists of large, buoyant bodies, which would remain upon the surface of a river until washed ashore; others are more nearly of the specific gravity of water and when the velocity is reduced will settle to the bottom; still finer particles exist and are not capable of sedimentation, finally there are the solids in true solution. It must also be remembered that all of this solid matter is not organic nor putrefactive. Part is inorganic and a portion of the organic matter is in a stable condition.

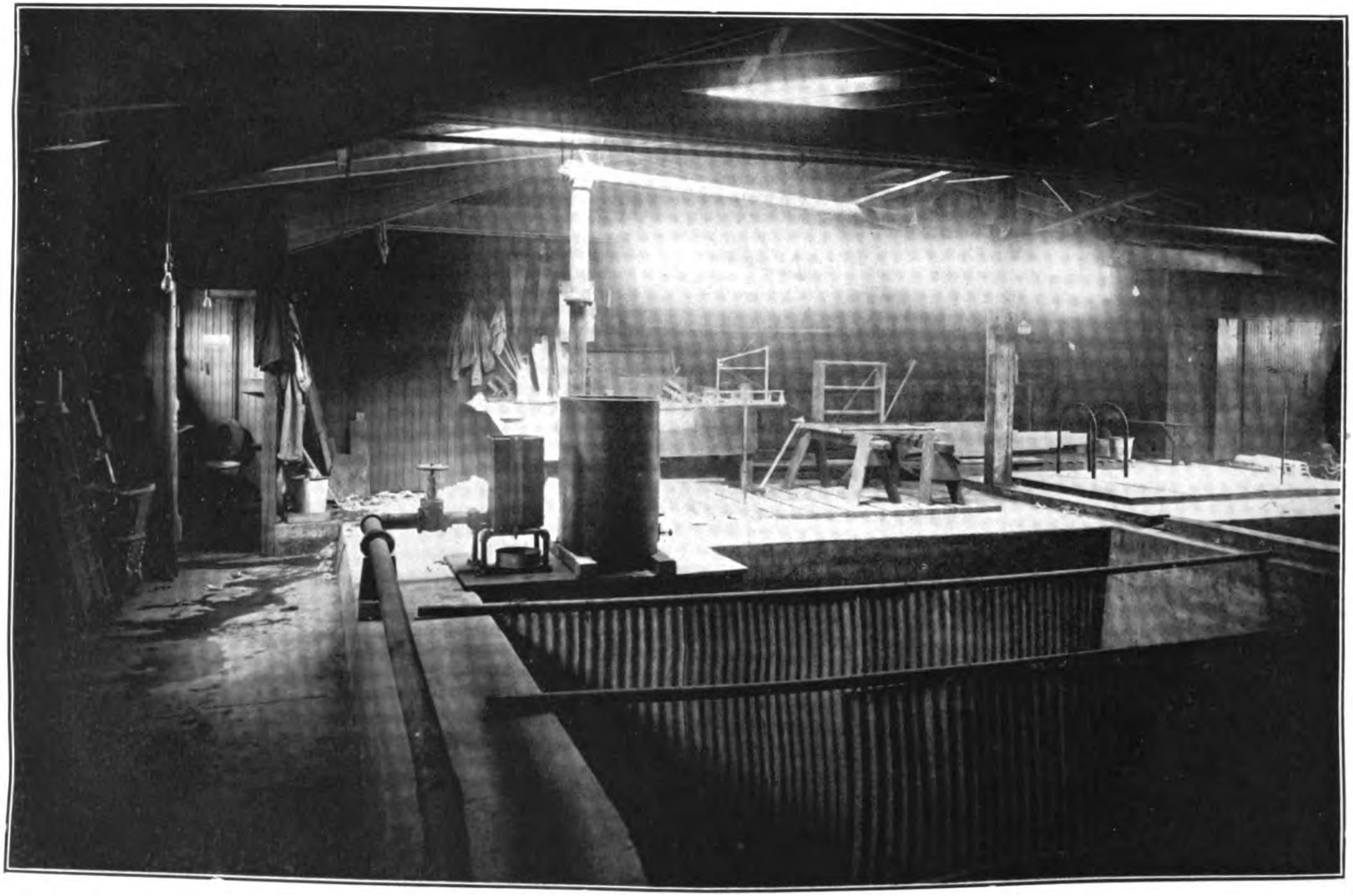
The dissolved matters are most easily acted upon by bacteria. The ease with which purification is effected increases as the sizes of the solids decrease. Mr. Emil Kuichling in his Report on Disposal of the Sewage of Rochester, 1907, states that double the dilution is required by the "suspended solids" as by the "dissolved matters."

If, therefore, the suspended solids, or even part of them, are removed before the sewage is dischargd into a river, the amount of such treated sewage that can be added without producing an offensive condition would be much greater than of crude sewage.

But the mere settling of sewage prior to its purification by dilution does not sufficiently remove bacteria to insure the safe use of the river for water supply. It has previously been shown that fresh settled sewage can be disinfected and thus eliminate that danger.

It was therefore desirable to determine by a large size experiment the maximum proportion in which fresh sewage could be purified inoffensively by dilution.

The dilution tank No. 50, heretofore described, was therefore operated, using sewage in the first experiments (funds were exhausted before the completion of the original program of experiments), from which, by preliminary treatment, the suspended solids, at least larger than 1 mm., had been removed by fine mesh screening or



Dilution Tank.—Station No. 50.

sedimentation, and a substantial destruction of pathogenic bacteria by the use of calcium hypochlorite had been accomplished.

**Criterion.**

It was not expected that after the addition of the screened and disinfected sewage to the river water flowing through the dilution tank, that its chemical or bacteriological analysis would indicate a potable water, and a special standard was, therefore, required to determine the condition of the water after the addition of the polluting sewage. The criterion adopted was that, although not potable, the water should continue to improve chemically and bacterially (as relating to pathogenic germs); that the dissolved oxygen should not be depleted below 50 per cent. saturation, the limit set by the English Royal Commission for major fish life; that it should always be stable as indicated by the methylene blue test, and inoffensive to sight and smell.

This criterion was in accordance with the definition of a perfect effluent as proposed by Mr. J. D. Watson, Engineer of the Birmingham, etc., Drainage Board. "A perfect effluent is not an ideal one; the ideal is to obtain by natural means an effluent which will not putrefy, **and which will continue to improve when it is discharged into a stream.**"

## RESULTS OF EXPERIMENTS IN THE DILUTION TANK WITH DISINFECTED SEWAGE.

### Preliminary Statement.

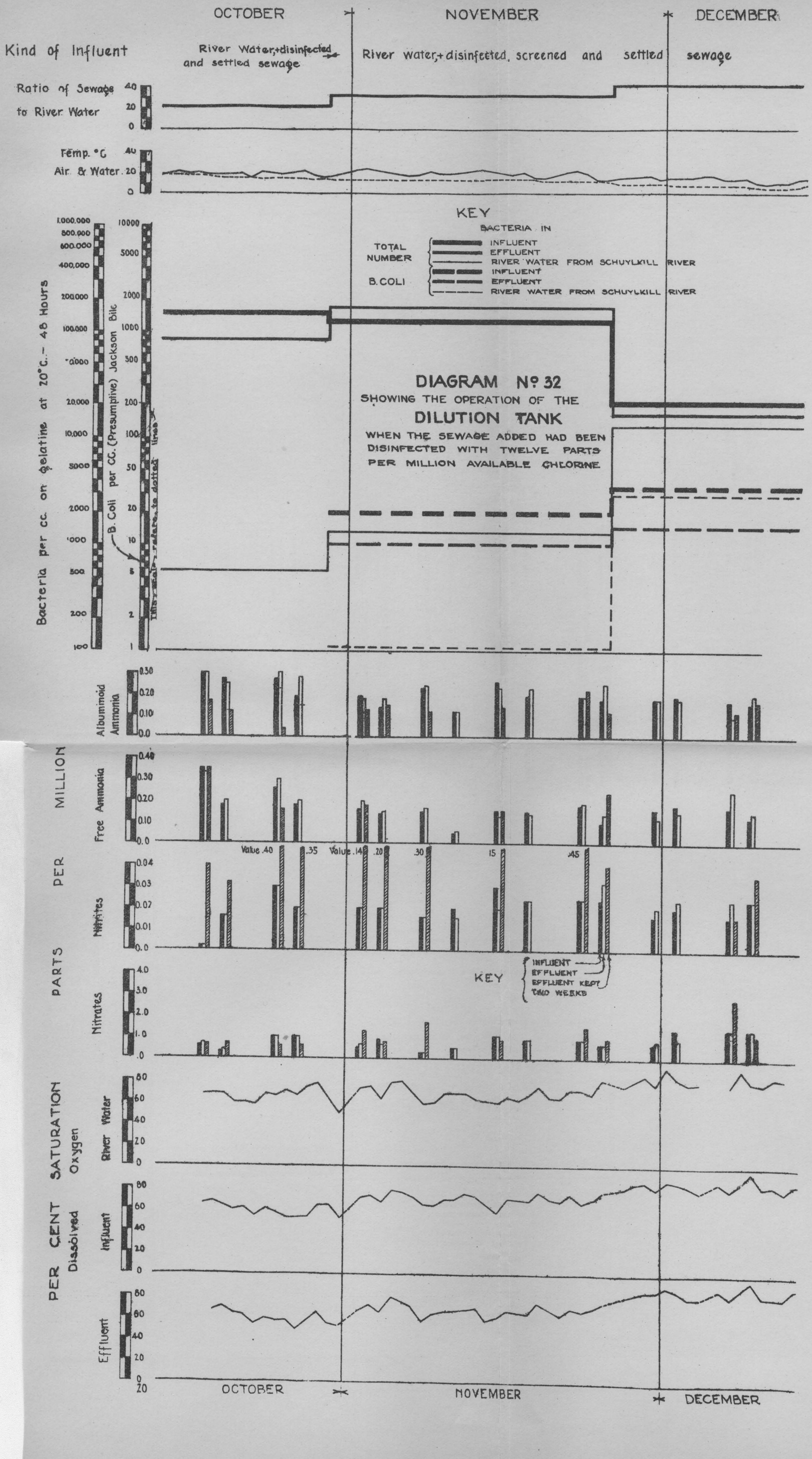
Before discussing the data obtained from the dilution tank, certain conditions of operation must be explained. First, during the warm weather, when studies would have been of the greatest value, the Schuylkill river was at such a low stage, due to an unprecedented drought, that it was impossible (with the existing pipe lines) to pump river water to the testing station, and it was not until September, 1909, that the experiments could be satisfactorily commenced. Second, the disinfection tanks were situated at such a distance from the dilution tank that detrimental chemical and bacteriological changes probably occurred in the sewage during transit from the disinfection tank to the dilution tank. Third, the suction of the pump which forced the river water to the testing station was located in a 48-inch pipe extending into the river. As the amount of water used per day in the dilution tank was a small part of the contents of this pipe, sedimentation occurred therein and consequently the bacterial content of the river water used in the tests was lower than that observed by the Bureau of Water at Belmont intake. Fourth, in examining samples of water for B. Coli. the Jackson presumptive test was used and numbers reported as the reciprocal of the highest dilution yielding gas. Had confirmatory tests been carried on, it is reasonable to expect that the numbers shown would have been materially reduced. Fifth, prior to February, 1910, the samples of the effluent which were kept for two weeks were stored in the laboratory at about 20° C.; subsequent to that date they were hung in the tank and, therefore, at the same temperature as the water.

**History of the Experiment.**

The details of operation of the dilution tank are shown in diagram No. 32 and the average chemical analysis for periods in Table No. 54.

For most of November the ratio was 1 to 30, and according to the standard set purification was affected, indicated by the formation of nitrates, no exhaustion of dissolved oxygen, and the decrease in B. Coli.

During the first part of December the highest dilution


OCTOBER
NOVEMBER
DECEMBER
Kind of Influent
River Water, + disinfected and settled sewage
River water, + disinfected, screened and settled sewage
Ratio of Sewage to River Water
Temp. °C Air & Water
KEY
BACTERIA IN
TOTAL NUMBER
INFLUENT
EFFLUENT
RIVER WATER FROM SCHUYLKILL RIVER
B. COLI
INFLUENT
EFFLUENT
RIVER WATER FROM SCHUYLKILL RIVER
DIAGRAM No 32
SHOWING THE OPERATION OF THE
DILUTION TANK
WHEN THE SEWAGE ADDED HAD BEEN DISINFECTED WITH TWELVE PARTS PER MILLION AVAILABLE CHLORINE
Bacteria per cc. on gelatine at 20°C. - 48 Hours
B. Coli per CC. (Presumptive) Jackson Bile
Albuminoid Ammonia
Free Ammonia
Nitrites
Nitrates
PARTS PER MILLION
KEY
INFLUENT
EFFLUENT
EFFLUENT KEPT TWO WEEKS
PER CENT SATURATION Dissolved Oxygen
River Water
Influent
Effluent

(1 to 40) was in progress; the effect upon the water was not very great and the purification of the sewage accomplished. The number of bacteria in the effluent of the tank being but slightly higher than in the river water as used and only one-fourth as many as in the river water at Belmont Intake (as reported by the Bureau of Water) with this dilution (1 to 40), the presumptive test showed only one-half as many gas formers in the effluent of the tank as in the applied river water.

From the middle of January to the middle of March, 1910, the operation of the dilution tank, judged by the standard heretofore described, was successful. The water continued to improve in quality as it grew older, and the bacterial content of the effluent was lower than the influent and markedly lower than the raw river water at Belmont Intake as reported by the Bureau of Water for similar periods; the amount of dissolved oxygen in the effluent was but slightly lower than in the raw river water. During this period the dilution was at the rate of 1 to 20, 1 to 15, and 1 to 10, as may be seen in detail in Table No. 54 and on diagram No. 32.

Beginning in the middle of March and until the end of the experiments on April 30, 1910, the ratio of disinfected screened sewage to river water was made 1 to 7 and the results, as expected, were not as favorable as previously. On the diagram the higher amounts of nitrogen as albuminoid ammonia, free ammonia and nitrites, the lower amounts of nitrates, the high bacterial content of the water, and the heavy reduction of dissolved oxygen during the period all show that the limit of efficient purification by dilution had been passed. However, this condition was not in any sense offensive pollution.

During the entire experiment there was never the slightest evidence of offensive pollution to sight or smell; the effluent was of higher turbidity than a potable water, but the preliminary treatment of the sewage used had removed all solids of such size as to be visible to the eye. Every day samples of the influent and effluent ends of the tank were incubated at 20° C. with methylene blue, and with no exception retained their original bright color for at least 10 days, after which time they were removed from the incubator.

It can, therefore, be safely said that at no time was the tank in putrefactive state, even when it was one-seventh sewage.

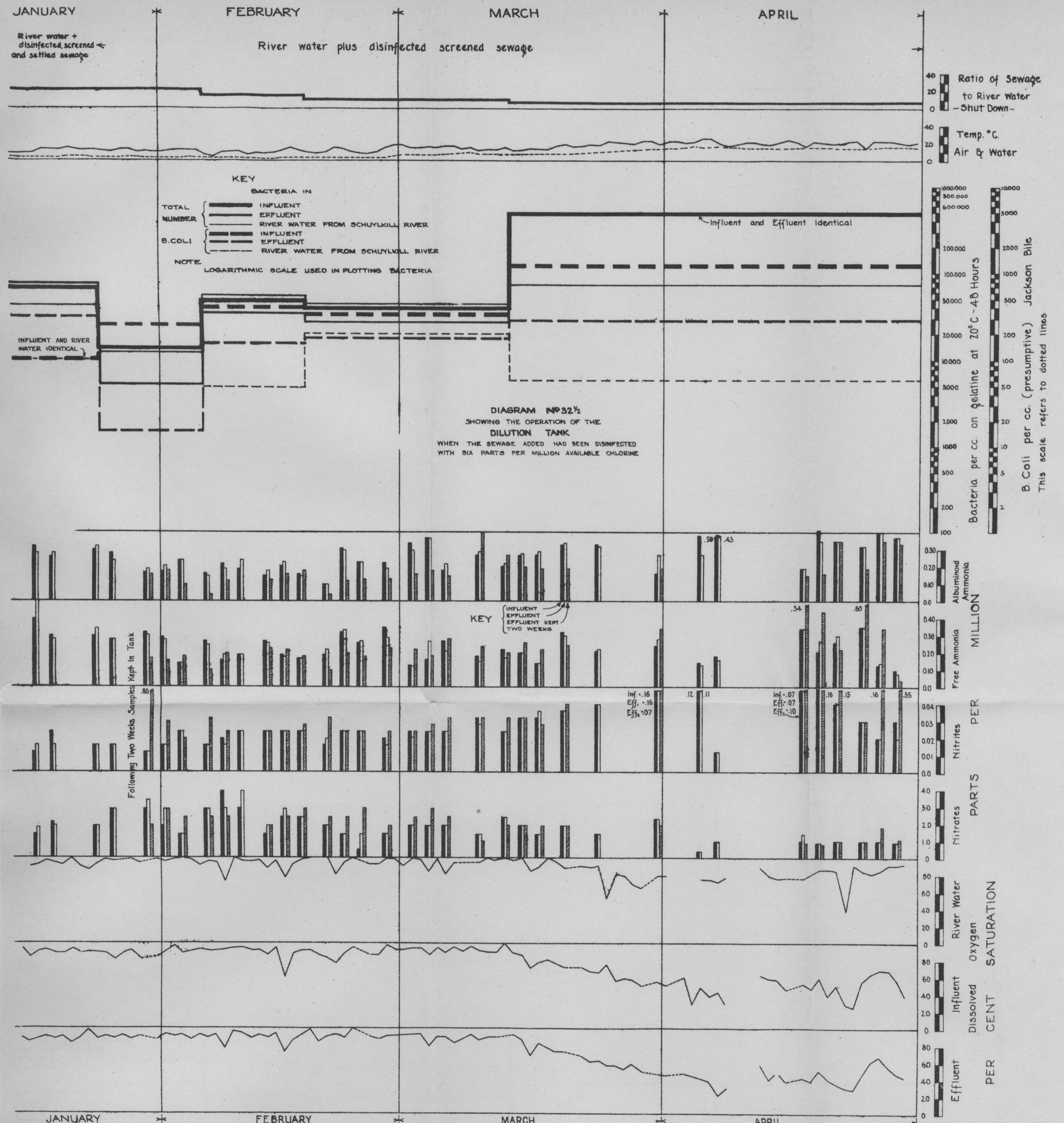
During March the sewage added to the tank was sampled at the same time the water samples were taken and the "pounds" of various constituents added to the tank may be seen in Table No. 55.

Analyses of the Schuylkill river water collected at Belmont Intake (up stream from the Spring Garden Pumping Station), made by Dr. Geo. Edw. Thomas, Chemist, Belmont Laboratory, Bureau of Water, are shown in Table No. 56, with the kind permission of Mr. Fred C. Dunlap, Chief Engineer, Bureau of Water.

## Conclusions on Dilution of Disinfected Sewage.

Having in mind the conditions set forth in the introductory remarks on dilution, and using the standard determined upon, the experiments above described showed that if fresh, crude sewage was passed through a fine mesh screen to remove its larger solids or satisfactorily settled, and then disinfected with 6 parts per million available chlorine and was added to river water in amounts up to one-tenth of the volume of the river water, its purification was accomplished without offense to sight or smell and the depletion of the dissolved oxygen of the river water was not carried below 50 per cent. saturation.

The cost per annum of the disinfecting material alone for thus treating only one million gallons of sewage per day would be approximately $910.



JANUARY
FEBRUARY
MARCH
APRIL
River water + disinfected, screened and settled sewage
River water plus disinfected screened sewage
Ratio of Sewage to River Water
-Shut Down-
Temp. °C. Air & Water
KEY
BACTERIA IN
TOTAL NUMBER
INFLUENT
EFFLUENT
RIVER WATER FROM SCHUYLKILL RIVER
B. COLI
INFLUENT
EFFLUENT
RIVER WATER FROM SCHUYLKILL RIVER
NOTE
LOGARITHMIC SCALE USED IN PLOTTING BACTERIA
Influent and Effluent Identical
INFLUENT AND RIVER WATER IDENTICAL
DIAGRAM Nº 32½
SHOWING THE OPERATION OF THE
DILUTION TANK
WHEN THE SEWAGE ADDED HAD BEEN DISINFECTED WITH SIX PARTS PER MILLION AVAILABLE CHLORINE
Bacteria per cc. on gelatine at 20°C - 48 Hours
B. Coli per cc. (presumptive) Jackson Bile
This scale refers to dotted lines
KEY
INFLUENT
EFFLUENT
EFFLUENT KEPT TWO WEEKS
Following Two Weeks Samples Kept in Tank
Albuminoid Ammonia
Free Ammonia
Nitrites
Nitrates
PARTS PER MILLION
Inf. - .16
Eff. - .16
Eff.₂ - .07
Inf. - .07
Eff. .07
Eff.₂ - .10
River Water
Influent
Effluent
Dissolved Oxygen
PER CENT SATURATION

Owing to a lack of funds the experiments on dilution were not completed.

It is the purpose to extend the experiments so as to determine the amount of dilution necessary for the treatment without disinfection of raw, screened or settled sewage.

# Table No. 54.

*Average Analyses of the Water in the Dilution Tank.*

| Dates. 1909-1910. | Daily Average Temperature. Air. | Daily Average Temperature. Water. | Ratio Sewage to River Water, 1 to — | Hours Flow in Tank. | Source of Sewage—Station Number. See Below. | Parts per Million. Nitrogen as— Album. Amm. Influent End. | Album. Amm. Effluent End. | Album. Amm. Effluent Sample Kept Two Weeks. | Free Amm. Influent End. | Free Amm. Effluent End. | Free Amm. Effluent Sample Kept Two Weeks. | Nitrites. Influent End. | Nitrites. Effluent End. | Nitrites. Effluent Sample Kept Two Weeks. | Nitrates. Influent End. | Nitrates. Effluent End. | Nitrates. Effluent Sample Kept Two Weeks. | Chlorine. Effluent End. | Dissolved Oxygen. River Water. | Dissolved Oxygen. Influent End. | Dissolved Oxygen. Effluent End. | Per Cent. Saturation. River Water. | Per Cent. Saturation. Influent End. | Per Cent. Saturation. Effluent End. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 27 to Oct. 7 | 21. | 20. | 10. | 21½ | 42. | .29 | .29 | .19 | .23 | .24 | .04 | .019 | .022 | .102 | .72 | 1.18 | 1.32 | 17. | 5.58 | 4.11 | 3.30 | 60.2 | 44.3 | 35.5 |
| Oct. 18 to Oct. 29 | 19. | 14. | 20. | 21½ | 43. | .26 | .28 | .084 | .24 | .26 | .13 | .017 | .017 | .28 | .70 | .75 | .65 | 17. | 6.79 | 6.15 | 6.21 | 65.1 | 58.9 | 60.1 |
| Oct. 29 to Nov. 25 | 19. | 12. | 30. | 16.3 | 42. | .18 | .20 | .19 | .13 | .14 | .19 | .022 | .021 | .213 | .81 | .81 | 1.18 | 19. | 7.38 | 7.59 | 7.08 | 67.6 | 70.8 | 68.2 |
| Nov. 25 to Dec. 13 | 13. | 7. | 40. | 12. | 42. | .17 | .16 | .14 | .15 | .17 | ------ | .016 | .016 | .25 | 1.22 | 1.12 | 1.95 | 16. | 9.82 | 10.2 | 10.0 | 81.2 | 89.6 | 85.3 |
| Jan. 15 to Jan. 24 | 12. | 4. | 20. | 24. | 42. | .32 | .29 | ------ | .33 | .37 | ------ | .017 | .016 | ------ | 1.80 | 1.90 | ------ | 11. | 12.3 | 11.9 | 11.5 | 93.0 | 90.2 | 89.5 |
| Jan. 25 to Feb. 1 | 11. | 3. | 20. | 24. | 41. | .21 | .21 | .17 | .29 | .29 | .16 | .015 | .015 | .055 | 2.5 | 3.1 | 2.4 | 12. | 12.9 | 11.5 | 11.9 | 97.3 | 86.8 | 90.4 |
| Feb. 2 to Feb. 6 | 11. | 3. | 20. | 24. | 41. | .20 | .19 | .07 | .20 | .19 | .14 | .020 | .020 | .026 | 2.1 | 2.1 | 2.4 | 11. | 12.9 | 12.4 | 11.7 | 96.8 | 92.2 | 90.9 |
| Feb. 7 to Feb. 17 | 11. | 3. | 15. | 24. | 41. | .18 | .20 | .15 | .19 | .20 | .21 | .024 | .024 | .025 | 2.6 | 2.9 | 2.4 | 12. | 12.4 | 12.1 | 12.1 | 91.3 | 89.1 | 88.8 |
| Feb. 18 to March 13 | 14. | 5. | 10. | 24. | 41. | .24 | .24 | .18 | .23 | .22 | .20 | .024 | .023 | .028 | 1.7 | 1.7 | 2.2 | 9. | 12.4 | 11.5 | 11.5 | 93.2 | 92.1 | 89.5 |
| March 14 to March 31 | 18. | 10. | 7. | 33. | 41. | .27 | .30 | .19 | .22 | .22 | .26 | .060 | .061 | .042 | 1.8 | 1.8 | 1.9 | 9. | 9.9 | 8.2 | 7.9 | 77.0 | 59.5 | 56.6 |
| April 1 to April 30 | 13. | 17. | 7. | 33. | 41. | .36 | .33 | .25 | .21 | .22 | .36 | .040 | .040 | .160 | .89 | .95 | 1.10 | 9. | 8.2 | 5.0 | 4.5 | 82.2 | 57.1 | 52.5 |

41 equals fine screened sewage disinfected. 42 equals screened and settled sewage disinfected. 43 equals settled sewage disinfected.

## Table No. 55.

*Amount of Organic Matter Added to the Dilution Tank.*

| Date—1910. | Analysis of the Contaminating Sewage. | | | Ratio of Water to Sewage. | Pounds of Constituent Added per | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 24 Hours. | | | Million Cubic Feet Water. | | |
| | Nitrogen as— | | | | Nitrogen as— | | | Nitrogen as— | | |
| | Organic. | Free Amm. | Total Oxygen Consumed. | | Organic. | Free Amm. | Oxygen Consumed. | Organic. | Free Amm. | Oxygen Consumed. |
| February 24 | 0.8 | 2.4 | 74. | 10 | ---------- | .065 | 2.600 | ---------- | 13.65 | 52.50 |
| March 6 | 5.2 | 3.2 | 32. | 10 | .140 | .086 | .865 | 29.40 | 18.10 | 18.20 |
| March 10 | 7.0 | 2.2 | 72.4 | 10 | .189 | .060 | 1.950 | 39.70 | 12.60 | 41.00 |
| March 13 | 2.8 | 3.0 | 32. | 10 | .076 | .081 | .865 | 16.00 | 17.00 | 18.20 |
| March 15 | 5.6 | 2.4 | 72. | 7 | .151 | .065 | 1.945 | 43.40 | 18.65 | 55.80 |
| March 20 | 5.2 | 4.0 | 26. | 7 | .141 | .108 | .704 | 40.50 | 31.00 | 20.20 |
| March 22 | 5.0 | 3.0 | 59.2 | 7 | .135 | .081 | 1.600 | 38.80 | 23.20 | 45.80 |
| March 31 | 5.4 | 3.0 | 59.2 | 7 | .146 | .081 | 1.600 | 42.00 | 23.20 | 45.80 |
| April 5 | 6.6 | 2.6 | 71.2 | 7 | .178 | .070 | 1.920 | 51.10 | 20.05 | 55.10 |

# Table No. 56.

*Analyses of the Schuylkill River Water. Data furnished by Fred C. Dunlap, Chief, Bureau of Water.*

| Official Date. | PARTS PER MILLION. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Appearance. | | | | | Nitrogen as— | | | | | | | | |
| 1909. | Temperature, Degrees Fahr. | Sediment. | Turbidity. | Color. | Total Solids. | Suspended Matter. | Total Organic and Ammonium. | Nitrites. | Nitrates. | Oxygen Consumed. | Chlorine. | Iron. | Sulphuric Acid (SO3). | Alkalinity. | Total Hardness. |
| September 20 | ------ | V. slight | 17 | 10+ | 240 | 8 | .50 | .020 | .66 | 2.45 | 11.9 | .48 | -------- | 85 | 158 |
| September 27 | ------ | " | 20 | 10— | 226 | 6 | .54 | .024 | .74 | 2.15 | 11.8 | .54 | -------- | 85 | 160 |
| October 4 | ------ | " | 18 | 10— | 235 | 8 | .45 | .025 | .84 | 2.35 | 11.8 | .44 | -------- | 85 | 161 |
| October 11 | ------ | " | 14 | 10— | 240 | 8 | .50 | .020 | .78 | 2.30 | 11.2 | .46 | -------- | 80 | 179 |
| October 18 | ------ | " | 12 | 10— | 223 | 7 | .53 | .020 | .74 | 2.50 | 10.6 | .34 | -------- | 85 | ------ |
| October 25 | ------ | " | 24 | 5+ | 227 | 11 | .48 | .016 | .84 | 2.40 | 11.0 | .88 | -------- | 84 | 164 |
| November 1 | ------ | " | 21 | 10— | 245 | 11 | .43 | .014 | .99 | 2.50 | 9.6 | .68 | -------- | 80 | 170 |
| November 9 | ------ | " | 22 | 10 | 238 | 10 | .53 | .016 | .92 | 2.80 | 10.6 | .70 | -------- | 76 | 167 |
| November 15 | ------ | " | 26 | 10 | 233 | 11 | .50 | .019 | .84 | 2.65 | 10.3 | .90 | -------- | 81 | 173 |
| November 22 | ------ | " | 19 | 10 | 240 | 7 | .53 | .019 | .84 | 2.70 | 10.4 | .60 | -------- | 83 | 170 |
| November 29 | ------ | " | 20 | 15— | 225 | 8 | .53 | .018 | 1.02 | 3.45 | 9.8 | .66 | -------- | 79 | 176 |
| December 6 | ------ | " | 14 | 10 | 221 | 6 | .42 | .017 | .98 | 2.55 | 9.6 | .62 | -------- | 76 | 155 |
| December 13 | ------ | " | 17 | 10+ | 221 | 7 | .53 | .019 | 1.14 | 2.90 | 9.6 | .78 | -------- | 83 | 164 |
| December 20 | ------ | Slight | 110 | 15 | 183 | 66 | .83 | .012 | 1.49 | 5.25 | 5.2 | 3.2 | -------- | 27 | 91 |
| December 28 | ------ | V. slight | 14 | 10 | 156 | 6 | .48 | .012 | 1.61 | 1.75 | 5.9 | .62 | -------- | 39 | 103 |
| 1910. | | | | | | | | | | | | | | | |
| January 3 | ------ | " | 9 | 10 | 178 | 5 | .49 | .012 | 1.35 | 2.40 | 7.2 | .56 | 49 | 49 | 125 |
| January 10 | ------ | " | 10 | 10+ | 160 | 4 | .42 | .010 | 1.11 | 2.15 | 5.4 | .48 | -------- | 48 | 112 |
| January 17 | ------ | " | 10 | 10+ | 175 | 3 | .49 | .011 | 1.19 | 2.60 | 6.1 | .54 | -------- | 45 | 122 |
| January 24 | ------ | Heavy | 450 | 20— | 487 | 410 | 2.22 | .007 | 1.17 | 16.0 | 3.2 | 19.8 | 25 | 20 | 58 |
| January 31 | ------ | V. Slight | 18 | 10— | 141 | 10 | .33 | .008 | 1.27 | 1.45 | 4.2 | .84 | -------- | 28 | 91 |
| February 7 | ------ | " | 6 | 5+ | 152 | 4 | .30 | .010 | 1.29 | 1.45 | 5.0 | .46 | -------- | 40 | ------ |
| February 14 | ------ | " | 7 | 10— | 158 | 6 | .39 | .011 | 1.43 | 1.65 | 5.4 | .44 | -------- | 42 | 109 |
| February 21 | ------ | Slight | 40 | 10 | 122 | 33 | .50 | .008 | 1.07 | 3.15 | 3.4 | 1.42 | -------- | 28 | 64 |
| February 28 | ------ | V. slight | 28 | 10 | 138 | 32 | .38 | .006 | 1.47 | 1.95 | 3.6 | 1.46 | -------- | 31 | 70 |
| March 7 | ------ | " | 28 | 5 | 121 | 23 | .28 | .005 | 1.26 | 1.65 | 3.2 | 1.20 | -------- | 23 | 88 |
| March 14 | ------ | " | 6 | 5 | 116 | 6 | .23 | .006 | 1.23 | 1.15 | 3.8 | .36 | -------- | 30 | 82 |
| March 21 | ------ | " | 5 | 10— | 145 | 4 | .30 | .008 | 1.11 | 1.25 | 4.3 | .32 | -------- | 36 | 100 |
| March 28 | ------ | " | 7 | 5+ | 158 | 7 | .34 | .013 | .99 | 1.80 | 4.9 | .50 | -------- | 46 | 93 |
| April 4 | ------ | " | 20 | 5 | 163 | 11 | .39 | .018 | .62 | 2.00 | 4.9 | .50 | -------- | 53 | 102 |
| April 11 | ------ | " | 17 | 5 | 173 | 9 | .42 | .011 | .71 | 2.40 | 5.6 | .38 | -------- | 54 | 104 |
| April 18 | ------ | " | 28 | 5+ | 181 | 21 | .50 | .014 | .79 | 2.75 | 6.0 | 1.12 | -------- | 56 | 110 |
| April 25 | ------ | Slight | 30 | 5+ | 155 | 54 | .41 | .006 | .83 | 2.50 | 3.4 | 2.56 | -------- | 26 | 61 |
| Average | ------ | ---------- | 21 | ------ | 187 | 13 | .45 | .014 | 1.04 | 2.36 | 7.3 | .73 | -------- | 57 | 122 |

## Table No. 57.

*Showing the Bacterial Averages from the Dilution Tank Experiments.*

| Dates—1909-1910. | Total Number of Bacteria per C. C. | | | | B. Coli. (Presumptive). | | |
|---|---|---|---|---|---|---|---|
| | River Water at Belmont Intake as per Bureau of Water. | River Water Used in the Dilution Tank. | Influent. | Effluent. | River Water Used in the Dilution Tank. | Influent. | Effluent. |
| September 20 to September 26 | 3,600 | 750 | 85,000 | 47,000 | ---- | ---- | ---- |
| September 27 to October 7 | 29,000 | 700 | 21,000 | 26,000 | ---- | ---- | ---- |
| October 18 to October 29 | 12,000 | 580 | 150,000 | 85,000 | ---- | ---- | ---- |
| October 29 to November 25 | 54,000 | 1,300 | 120,000 | 170,000 | 1 | 20 | 10 |
| November 26 to December 13 | 66,000 | 13,000 | 22,000 | 16,500 | 30 | 35 | 15 |
| January 15 to January 24 | 230,000 | 42,000 | 67,000 | 73,000 | 100 | 100 | 320± |
| January 25 to February 6 | 35,000 | 12,000 | 13,500 | 5,000 | 150 | 250 | 15 |
| February 7 to February 17 | 140,000 | 50,000 | 50,000 | 34,000 | 50 | 400 | 150 |
| February 18 to March 13 | 45,000 | 43,000 | 39,000 | 27,000 | 200± | 340 | 170 |
| March 14 to March 31 }<br>April 1 to April 30 } | 53,000 | 72,000 | 480,000 | 480,000 | 60 | 1,250 | 300 |

## Table No. 58.

*Results of Bacteriological Examination of Small Samples of the Effluent of the Dilution Tank which were Hung in the Tank for a Period of 2 Weeks. Influent—Disinfected Screened Sewage.*

| Dates. 1910. | Ratio of River Water to Sewage. | Initial Bacteria per C. C. | Final Bacteria per C. C. |
|---|---|---|---|
| February 21 | 10—1 | 30,000 | 400,000 |
| February 23 | 10—1 | 300,000 | 290,000 |
| February 25 | 10—1 | 37,000 | 470,000 |
| February 28 | 10—1 | ---------- | 420,000 |
| March 2 | 10—1 | ---------- | 93,000 |
| March 4 | 10—1 | 300,000 | 120,000 |
| March 7 | 10—1 | ---------- | 190,000 |
| March 9 | 10—1 | ---------- | ---------- |
| March 11 | 10—1 | 230,000 | 100,000 |
| March 14 | 10—1 | 1,200,000 | 129,000 |
| Averages | 10—1 | 350,000 | 230,000 |

| Dates. 1910. | Ratio of River Water to Sewage. | Initial Bacteria per C. C. | Final Bacteria per C. C. |
|---|---|---|---|
| March 16 | 7—1 | 770,000 | 50,000 |
| March 18 | 7—1 | 2,600,000 | 70,000 |
| March 21 | 7—1 | 3,400,000 | 21,000 |
| March 23 | 7—1 | 5,300,000 | 100,000 |
| March 25 | 7—1 | 1,400,000 | ---------- |
| April 1 | 7—1 | 700,000 | 75,000 |
| April 6 | 7—1 | 1,100,000 | ---------- |
| April 8 | 7—1 | ---------- | 85,000 |
| April 18 | 7—1 | 310,000 | ---------- |
| April 20 | 7—1 | 625,000 | ---------- |
| April 22 | 7—1 | 300,000 | ---------- |
| April 25 | 7—1 | ---------- | 104,000 |
| April 27 | 7—1 | ---------- | 28,600 |
| Averages | 7—1 | 1,650,000 | 60,000 |

# SLUDGE.

## IMPORTANCE OF STUDIES.

In the operation of a sewage disposal works, the liquid portion of the sewage can be handled in an inoffensive and economical manner, being ultimately disposed of by discharge into a natural water course. One of the most important reasons for constructing these works is to keep the solid portion, which is mechanically removed by screening or sedimentation, out of the water course. The sludge obtained is a dark, generally foul mass, very watery in composition, and consequently bulky. The proper handling to insure in an economic manner its sanitary disposal has been a problem worthy of much study.

There are two conditions of sludge which are of the greatest importance in investigations:

First, the percentage moisture. A cubic yard of sludge (Sp. Gr. 1.02) would weigh 1,720 pounds if the moisture amounted to 90 per cent.; then 10 per cent. of the weight of the wet mass, or 172 pounds, would be dry residue; if the moisture amounted to 95 per cent., then only 5 per cent. of the weight of the wet mass, or 86 pounds, would be dry residue, only one-half the amount in 90 per cent. moisture sludge.

Therefore, when a certain amount of dry residue is settled from sewage the bulk of the resulting sludge is determined by the percentage moisture thereof, and as the volume of the wet mass increases very rapidly with slight increase of percentage moisture above 90 per cent., any design of tank or process which will yield a sludge low in moisture is an advance.

Secondly, the offensive odor of sludge. This is caused by the putrefaction under anaerobic condition of the organic compounds. Freshly deposited or thoroughly digested sludge is not offensive, but as ordinarily removed from sedimentation basins and run into lagoons to dry, whereby a large area is exposed to the air, the emanation may be offensive. Therefore the determination of such a process as will produce inodorous sludge is of equal importance to the low moisture feature.

TABLE No. 59.

*Average Analyses of Sludge.*

| Source of Sludge. | Wet Sludge. | | Per Cent. of Dry Residue. | | | |
|---|---|---|---|---|---|---|
| | Specific Gravity. | Per Cent. Moisture. | Volatile. | Fixed. | Nitrogen. | Fat. |
| Sedimentation of screened sewage in Tank No. 12 Horizontal flow. | 1.086 | 90. | 49. | 51. | 1.3 | 8.1 |
| Sedimentation of crude sewage in Tank No. 13 Horizontal flow. | 1.053 | 86.1 | 48. | 52. | 1.4 | 7.4 |
| Sedimentation of crude sewage in Tank No. 17 Horizontal flow. | 1.043 | 87.7 | 50. | 50. | 1.3 | 7.2 |
| Sedimentation of crude sewage in the Emscher Tank Vertical sedimentation. | 1.065 | 82.5 | 38. | 62. | 1.2 | 6.5 |
| Sedimentation of the effluent of the outside sprinkling filters Horizontal flow. | 1.034 | 91.5 | 46.5 | 53.5 | 1.8 | 6.4 |

Emscher tank falls into the sludge chamber, where diges-
tion and condensation materially reduced the bulk of
sludge produced. Based upon the last run in the Em-

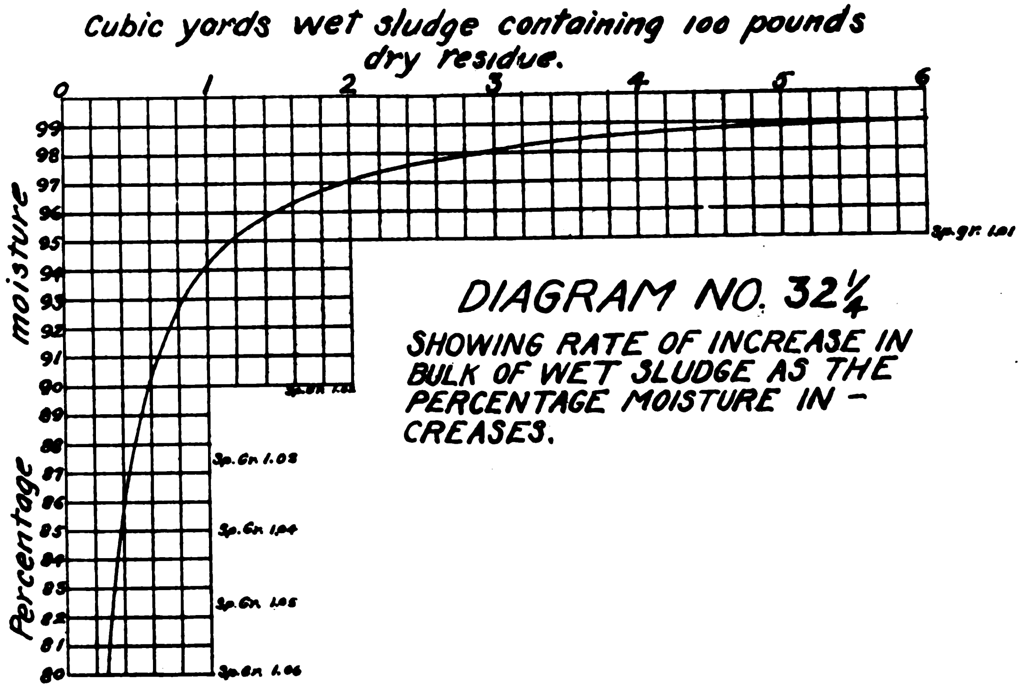



DIAGRAM NO. 32¼

SHOWING RATE OF INCREASE IN BULK OF WET SLUDGE AS THE PERCENTAGE MOISTURE IN-CREASES.

## AMOUNT OF SLUDGE PRODUCED.

### Horizontal Flow in Sedimentation Tanks.

The amount of sludge found in the testing station tanks at the end of a run did not follow any definite law, so that it was not possible to derive a formula whereby, knowing the suspended solids in the influent and percentage removal, the number of cubic yards of wet sludge produced could be anticipated. This may have been due to the large percentage of trade wastes in the sewage used.

Considering average figures, it was found that in a horizontal flow sedimentation tank (No. 13) with sloping bottom toward the inlet end, baffle and scum board at mid length, and operated at from three and one-half to six hours storage, 4.07 cubic yards of sludge, 86.1 per cent. moisture, were deposited from each million gallons of crude sewage settled.

In a horizontal flow sedimentation tank with level bottom (No. 17), divided into three compartments by baffles and scum boards, and operated at from four to ten hours storage with crude sewage, 6.31 cubic yards of sludge, 87.7 per cent. moisture, per million gallons was deposited.

When the fine mesh screened sewage was settled in sedimentation tank (No. 12) having a sloping bottom, baffle and scum board at mid length and operated at from three and one-half to six hours storage, 4.65 cubic yards of sludge, 90 per cent. moisture, were deposited per million gallons of sewage.

### Vertical Flow in an Emscher Tank.

The sludge formed in the sedimentation chamber of the Emscher tank falls into the sludge chamber, where digestion and condensation materially reduced the bulk of sludge produced. Based upon the last run in the Emscher tank, it would appear that sludge was withdrawn at the rate of 0.9 cubic yards of sludge, 82.6 per cent. moisture, per million gallons sewage.

**Slate Beds.**

Based upon loss of capacity of the slate bed during the second experiment, the deposit upon the surface of the slates amounted to 1.17 cubic yards of about 54 per cent. moisture per million gallons crude sewage treated in the bed.

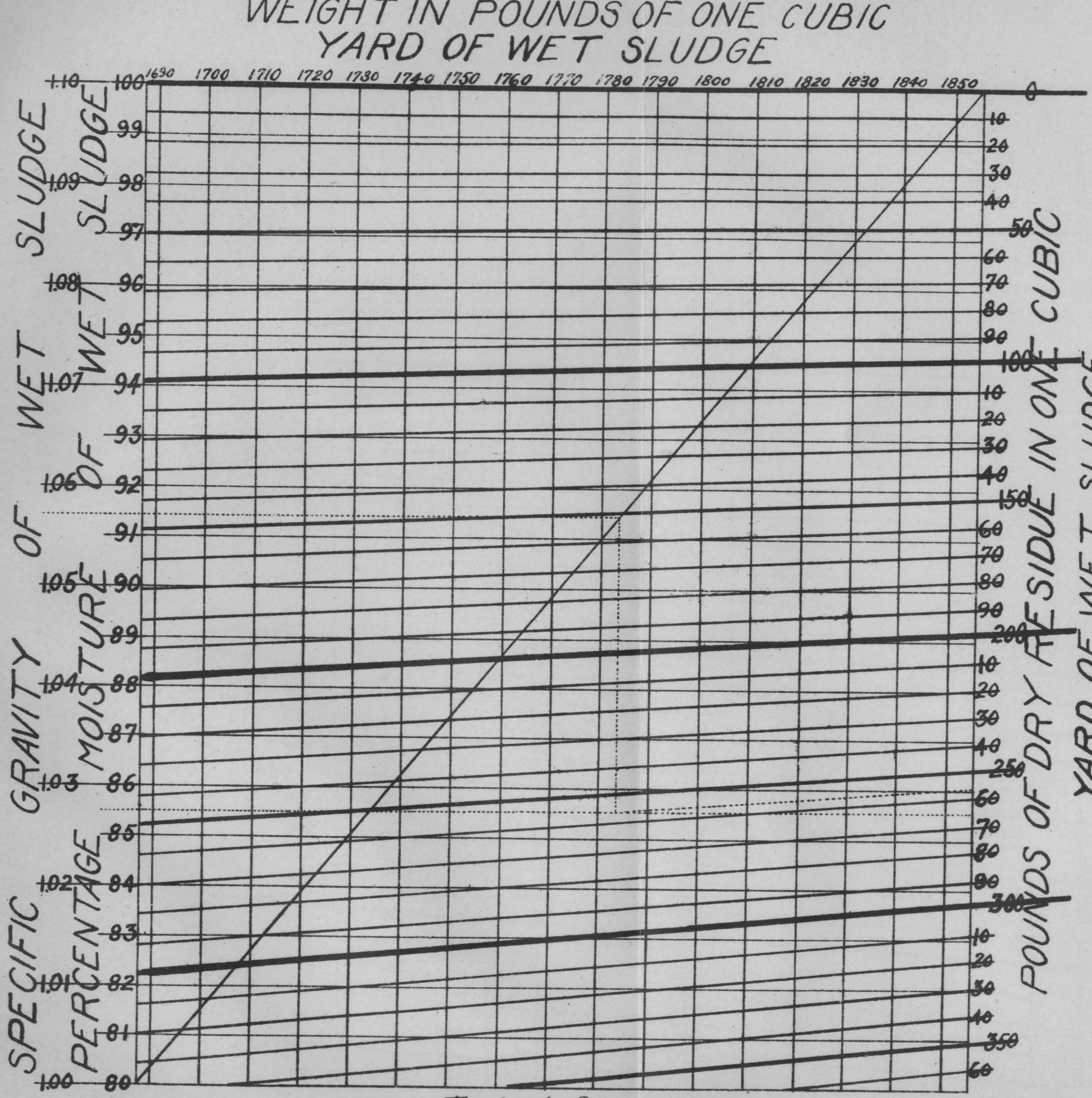
**Settlement of Sprinkling Filter Effluents.**

Microscopical examination of the applied sewage and the effluent from a mature sprinkling filter revealed the cause of the marked change in appearance of the suspended matter. In crude sewage the suspended solids are mostly structural, that is, the meat fibres, hair, bits of vegetables, etc., are determinable by their appearance, and their organic origin is further indicated by the mucilagenous appearance. On the other hand, most of the solids in the effluent were amorphous and appeared friable, having lost their sticky nature, the most noticeable variation being the presence of worms and worm casts. This is probably the reason that the suspended matter in the effluent from a sprinkling filter is more amenable to sedimentation than that in unpurified sewage, and it naturally follows that, regardless of the amount present in the influent to such a settling basin, the effluent from the settling basin will be uniform in character. Therefore, the quantity of sludge deposited depends almost entirely upon the settling solids in the influent of the settling basin. During a time when the filters are storing, the amount of sludge deposited in the settling basins from a million gallons would be small and when the filters unload large.

Under the first condition the effluent from the outside

# DIAGRAM NO. 32¾

SHOWING RELATION BETWEEN SPECIFIC GRAVITY, PERCENTAGE MOISTURE, AND DRY SOLIDS IN ONE CUBIC YARD OF WET SLUDGE.




Typical Case.

Specific Gravity = 1.057 Percentage Moisture = 85.5

Therefore 1 Cu. Yd. such wet sludge would contain 258 pounds dry solids.

sprinkling filters in passage through a plain settling basin deposited sludge, 90.2 per cent. moisture, at the rate of 2.2 cubic yards per million gallons settled, and under the second, when the filters are unloading, 5.3 cubic yards, 91.5 per cent. moisture.

## PERCENTAGE MOISTURE.

### Horizontal Flow in Sedimentation Tanks.

The average figure for moisture in the sludge deposited from crude sewage in sedimentation tank No. 13, with sloping bottom and baffle at mid length, was 86.1 per cent., and in tank No. 17, level bottom, 2 baffles and scum boards, it was 87.7 per cent. Usually sludge from sedimentation basins in which septic action is not permitted to develop contains about 90 per cent. moisture; the lower figure obtained in these tests is parallel to the observations on sedimentation conducted at Cologne, Germany, where it was found that a ten-fold increase in the velocity of the sewage during sedimentation produced a smaller quantity of dried sludge; containing, however, almost the same quantity of dry residue as at the low velocity.

When the sewage was passed through a fine mesh screen prior to sedimentation, the sludge produced was much thinner than from crude sewage, averaging 90 per cent. moisture.

### Vertical Flow in an Emscher Tank.

The sludge withdrawn from the Emscher tank was lower in moisture than that from any other sedimentation process, averaging 82.6 per cent., the minimum figure being 75 per cent. It must be remebered that the amount of sludge withdrawn at one time was but a small part of the contents of the sludge chamber, and coming from the apex of the conical bottom had the lowest percentage moisture. If the supernatant liquor in the Emscher tank had been withdrawn, as in horizontal flow tanks, the percentage moisture in the entire mass of sludge would have been much higher, for samples of the sludge taken at different depths in the tank showed a gradation from thin, watery sludge at the surface to the thick, concentrated sludge in the bottom. It is reasonable to suppose that in a practical tank, say 30 feet deep, the digestion and concentration would be more effective and the sludge as withdrawn would not exceed 75 per cent. moisture, which figure is confirmed by the results obtained from installations of these tanks in the Emscher district.

### Slate Bed.

The deposit on the slates resembled mud in its consistency and the average of three examinations is 54.4 per cent. moisture. This deposit would not flow like sludge, but required to be scraped off the slates to obtain a sample.

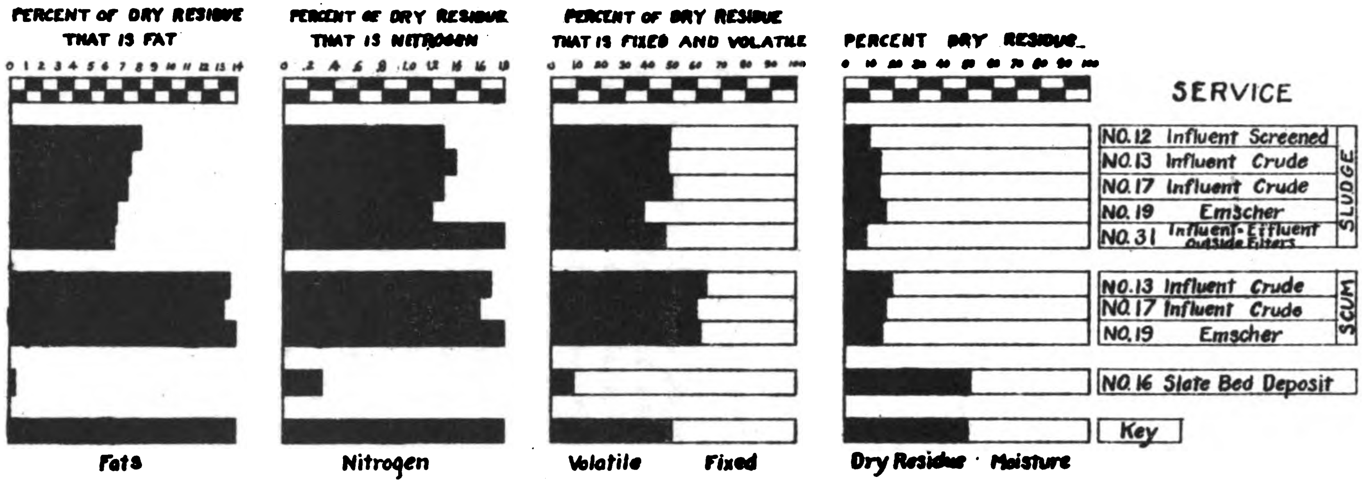
## COMPOSITION OF THE DRY RESIDUE.

### Horizontal Flow in Sedimentation Tanks.

There is shown in Table No. 59 and on diagram No. 33 the average composition of various sludges. It will be seen that the dry residue deposited in the three horizontal flow tanks was similar in composition, slightly less than one-half being volatile or organic, only 1.3 per cent. being nitrogen and between 7 and 8 per cent. fat.

### Vertical Flow in an Emscher Tank.

After the Emscher tank became mature, the fermentation of the sludge was almost constantly evidenced by the "boiling" of the ventilating funnel. The gas produced was perfectly inodorous and inflammable; it is said to be mostly methane or marsh gas. Daily observa-




# DIAGRAM NO. 33

SHOWING THE AVERAGE COMPOSITION OF SLUDGES AND SCUMS tion made of the condition in the sludge chamber would indicate that the sludge contained therein is in an agitated condition. An examination of the lower part of diagram No. 9 will show how the sludge expanded and contracted. In addition to the automatic movements, the sludge was disturbed and violently agitated each time a portion was withdrawn, as evidenced by the excessive ebullition of gas through the ventilating opening at that time.

The digestion of the organic portion of the dry residue is shown by the fact that in average Emscher sludge 38 per cent. of the dry residue was volatile; while from sedimentation tanks in which the sludge was withdrawn before septic action had developed 50 per cent. was volatile.

**Slate Bed.**

The aerobic treatment of the sludge deposited in the slate bed produced a deposit of which less than 12 per cent. of the dry residue was volatile or organic, the nitrogen only amounted to 0.35 per cent of the dry residue and fats to 0.55 per cent. As the deposit contained innumerable worms, part of the above figures must be attributed to the living organic matter.

To show the change occurring in the solids when deposited in the slate bed, on October 21, 1909, four layers of slates were carefully removed and a sample of the surface of the deposit upon the fifth slate taken. Another portion of the deposit exclusive of the surface was taken. The result of the analysis is shown in Table No. 60.

TABLE No. 60.

*Deposit on the Slates.*

| Source. | Wet Sludge. | | Per Cent. of the Dry Residue That Is— | | | |
|---|---|---|---|---|---|---|
| | Specific Gravity. | Per Cent. Water. | Volatile. | Fixed. | Nitrogen. | Fats. |
| Top of deposit | 1.28 | 50.4 | 30.9 | 69.1 | 0.4 | 0.9 |
| Mass of deposit | 1.40 | 49.9 | 8.6 | 91.4 | 0.3 | 0.2 |

Pounds of Various Constituents in One Cubic Yard of the Deposit.

| Source. | Weight of One Cubic Yard. | Dry Residue. | Volatile Matter. | Fixed Matter. | Nitrogen. | Fats. |
|---|---|---|---|---|---|---|
| Top of deposit | 2,160 | 1,070 | 330 | 740 | 4.28 | 9.63 |
| Mass of deposit | 2,360 | 1,180 | 100 | 1,080 | 3.54 | 2.36 |

## CONDITION OF THE SLUDGE.

### Horizontal Flow in Sedimentation Tanks.

The sludges deposited in sedimentation tanks No. 13 (sloping bottom) and 17 (level bottom) from crude sewage were similar in appearance. Not having been allowed to septicize, the resistant suspended matters were found in their original state, and in pumping out the wet mass trouble was caused by wool fibres clogging the diaphragm pump. The sludge from tank No. 12, in which fine mesh-screened sewage was settled, was a uniform, homogeneous mass containing no particle larger than 1 mm. It flowed freely, whereas that from tanks No. 13 and No. 17, which contained wool, hops and other substances, was more sluggish.

When the supernatant liquor was withdrawn from these tanks and the sludge deposit disturbed, the ventilation of the building was insufficient to carry away the odors, which at such times were offensive, and it is but reasonable to expect that in large installations of similar tanks odors may be expected.

**Vertical Flow in an Emscher Tank.**

The condition of the sludge as withdrawn from the Emscher tank was different from any other. Although crude sewage was settled in this tank, the fermentation in the sludge chamber had broken down even resistant bodies and the resultant sludge was fine, granular, and homogeneous; considering its dryness, it flowed freely and did not have an offensive odor. When withdrawn from the sludge outlet the odor was decidedly "tarry," and after a few days the dried mass was inodorous. It is reported by sanitary experts who inspected installations of these tanks in Germany that the sludge as withdrawn and discharged upon sludge beds is entirely inoffensive, thus confirming on a large scale the observations made at the testing station.

Another marked peculiarity of this sludge was the gas (probably methane or marsh gas) contained in it. As the sludge laid in the bottom of the tank it was under pressure due to the hydrostatic head; when withdrawn from the sludge outlet the gas expanded to form bubbles, so that the mass, after standing a few hours, resembled "rising" bread dough in consistency. This is a great advantage, as it facilitates the drying of the mass.

When examined microscopically fresh Emscher sludge appeared to be composed of granular, structureless masses, indicating the complete digestion of the solids.

**Slate Bed.**

The deposit upon the slates was an inodorous mud, even gritty when rubbed between the fingers, and microscopic examination revealed large amounts of sandy matter. When heated in a dish to obtain the dry residue, the worms came to the surface and their activity showed the aptness of the term "living earth."

## FORMATION OF SCUM.

### Horizontal Flow in Sedimentation Tanks (Crude Sewage)

When the crude sewage was settled in horizontal flow tanks without scum boards, the formation of scum was irregular. At times it would form in patches and after moving about finally disappeared.

After the introduction of baffles and scum boards in such tanks, the formation of scum at the inlet end of the tank always commenced soon after the tank was put in service, and by the end of the run had attained serious thickness, being tough and tenacious, and covered with a leathery, impervious skin upon which, in several cases, small plants began to grow.

#### Composition.

Analyses of typical scum is shown in Table No. 61. The high specific gravity seems inconsistent with a floating mass, but it is held up by entrained gas bubbles which are liberated in sampling.

The scum was much more organic in composition than sludge, as may be seen in the diagram No. 33.

#### Condition.

When the scum was removed from a tank prior to sludging the same, the entrained gas was liberated, and caused much offense, due to its foul odor.

TABLE No. 61.

*Analyses of Scum.*

| Date. | Source Influent Crude Sewage. | Wet Sludge. | | Dry Residue. | | | |
|---|---|---|---|---|---|---|---|
| | | Specific Gravity.—Gas bubbles expelled before determination. | Per Cent. Moisture. | Percentage. | | | |
| | | | | Volatile. | Fixed. | Nitrogen. | Fats. |
| December 24, 1909 | Sedimentation Basin Number 13. | 1.07 | 81.9 | 55.6 | 44.4 | 2.2 | 14.3 |
| March 10, 1910 | Sedimentation Basin Number 13. | 1.05 | 81.8 | 65.9 | 34.1 | 1.4 | 18.6 |
| May 3, 1910 | Sedimentation Basin Number 13. | ------- | 79.4 | 59.7 | 40.3 | 1.6 | 7.7 |
| January 6, 1910 | Sedimentation Basin Number 17. First Compartment. | 1.05 | 85.2 | 56.4 | 43.6 | 1.7 | 8.0 |
| March 11, 1910 | Sedimentation Basin Number 17. First Compartment. | 1.04 | 83.7 | 65.4 | 34.6 | 1.9 | 21.7 |
| May 2, 1910 | Sedimentation Basin Number 17. First Compartment. | ------- | 78.8 | 57.4 | 42.6 | 1.3 | 10.0 |
| March 21, 1910 | Emscher Tank Number 19. | 1.05 | 87.2 | 61.8 | 38.2 | 1.9 | 14.3 |
| Average | ------------------------ | 1.05 | 82.5 | 60.5 | 39.5 | 1.7 | 13.5 |

The solids forming the scum remained in their original structural condition, the entire mass being bonded together by the wool fibres.

## Horizontal Flow Tanks Using Screened Sewage.

On tank No. 12, the influent of which was fine mesh screened sewage, a scum such as is described above never formed.

Probably due to the violent agitation of the sewage in the screen, a frothy material was generally present on the inlet end of the tank. It never formed a layer of more than two inches in thickness and ought not to exist on an actual installation.

### Vertical Flow Sedimentation Tank.

During the early operation of the Emscher tank no scum formed upon its surface, but later, as on all the crude sewage tanks, a thick scum formed on the area inside the baffle and later a thin, fatty scum formed between the baffle and the outlet weir.

The ventilating opening always contained a scum, which was continually broken up, however, by the gas bubbles. In a tank of this type for actual use, an increased size of the ventilator over the six inches used in the experimental tank would prevent its clogging and subsequent passage of the gases of fermentation through the settling chamber.

## THE EFFECT OF DESIGN OF THE TANK UPON THE SLUDGE PRODUCED.

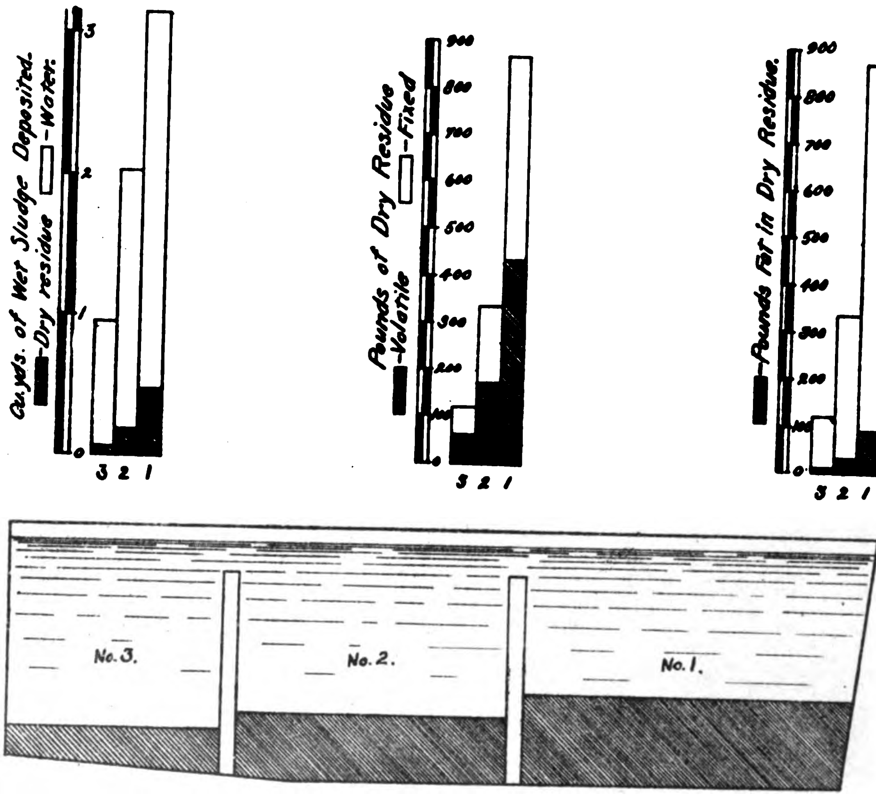
### Horizontal Flow Tanks.

When sedimentation tanks No. 12, 13 and 17 had level bottoms and were unbaffled it was observed that the majority of the sludge was deposited at the inlet end of the tank, and that the sludge at the inlet end contained more dry residue of a fixed or inorganic nature than that found at the outlet end.

The construction of baffles and scum boards, in addition to improving the efficiency of sedimentation, also restrained the sludge at the inlet end, thereby keeping the outlet compartment freer from sludge or scum liable to be carried away with the effluent.

The successful accomplishment of this is shown in diagram No. 34; in this particular case two-thirds of the sludge was deposited in the first part, one-fourth in the second and one-twelfth in the third.

When the sloping bottoms were built in sedimentation tanks No. 12 and 13 it was expected that as sludge formed




0.95 cubic yards wet sludge 92.9 per cent moisture equals 120 pounds dry residue of which 60 pounds are volatile matter and 13 pounds are fat.

2.03 cubic yards wet sludge 90.7 persent moisture equals 335 pounds dry residue of which 172 pounds are volatile matter and 30 pounds are fat.

3.16 cubic yards wet sludge 84.5 per cent moisture equals 870 pounds dry residue of which 435 pounds are volatile matter and 90 pounds are fat.

# DIAGRAM NO. 34

## SHOWING THE EFFECT UPON DEPOSITION OF SLUDGE BY BAFFLES.

upon the bottom of the tank, it would continually slip along the smooth inclined (16° to the horizontal) bottom into the deepest part at the inlet end. During the operation of the tanks this did not occur to as great an extent as hoped for, but when the supernatant liquor was withdrawn the sludge assumed a level surface, leaving the sloping bottom exposed as the sludge was pumped out, so that no manual labor would have been required to push the sludge to an outlet point.

### Vertical Flow Sedimentation Tanks.

The device for removing sludge from the Emscher tank by utilizing the hydrostatic head of water proved successful, even when the sludge was very compact.

In case the sludge at the bottom of the tank should become so dry as not to flow through the sludge pipe, or to prevent, during the maturing of the tank, the liberation of excessively large volumes of entrained gas in the sludge, whereby it might be carried up into the settling chamber, it is the practice in Germany to run a lead pipe provided with numerous outlets down the side of the tank, circling it near the bottom with a branch to the apex of the bottom; through this water under pressure can be forced into the sludge to thin it.

## SLUDGE DIGESTION.

### First Experiment.

When the supernatant liquor in sedimentation tank No. 17 was withdrawn on July 16, 1909, the sludge was driven by a stream of water from a fire nozzle into a concrete basin, which it filled to a depth of about 15 inches. It was expected that the sludge would settle and the water used to drive it could be drawn off the top. In 24 hours, however, the reverse occurred, the thin watery mass separated into three layers, on the bottom sludge, on the surface scum, with a layer of water between. Gas bubbles continually rose, some times breaking through the scum, but generally entrained therein, maintaining it at the surface. When the scum was disturbed the liberated gas was offensive. No diminution of sludge was noted.

**Second Experiment.**

The next time tank No. 17 required cleaning, on August 23, 1909, the supernatant liquor was withdrawn and the sludge pumped to a concrete tank 50 square feet in area and 5 feet deep. Through a by-pass a very small quantity of settled sewage was allowed to flow over the sludge from time to time. A thick, leathery scum formed on the surface, beneath which the mass continued to grow thinner and watery, at least partly due to the settled sewage passing over it. After two weeks the entire content was thorough stirred and pumped to a lagoon. (For drying see later.)

**Third Experiment.**

On September 22, 1909, fresh sludge was again available from tank No. 17 and 4.08 cubic yards were placed in the sludge digestion tank. No sewage was added, the sludge only being disturbed when sampled.

After the tank was filled with sludge, it was stirred so that the sample taken for analysis represented the entire contents. In two days stratification commenced and in eight days it was pronounced, the surface appeared like the typical leathery scum of a septic tank, being 78 per cent. moisture while the sludge at the bottom was 88.3 per cent. moisture. On October 4, 1909, 2.18 cubic yards of fresh sludge was added; this sunk beneath the scum which rose as the fresh sludge was added. Four days later the bottom of the tank contained 95.5 per cent.

## Table No. 62.

*Showing Sludge Data from the Digestion Tank.*

| Date—1909. | Wet Sludge. | | Percentage of Dry Residue. | | | | Remarks. |
|---|---|---|---|---|---|---|---|
| | Sp. Gr. | Per Cent. Moist. | Volatile. | Fixed. | Nitrogen. | Fats. | |
| September 22 | 1.02 | 88.5 | 46.3 | 53.7 | 1.8 | 9.8 | 4.08 cubic yards sludge from No. 17. |
| September 24 | 1.06 | 82.8 | 43.6 | 56.4 | 1.8 | 9.7 | Top. |
| | 1.06 | 83.0 | 45.2 | 54.8 | 1.8 | 9.9 | Middle. |
| | 1.04 | 84.5 | 43.7 | 56.3 | 1.7 | 9.8 | Bottom. |
| September 30 | 1.10 | 78.0 | 44.3 | 55.7 | 1.7 | 10.2 | Top. |
| | 1.10 | 80.3 | 43.2 | 56.8 | 1.8 | 8.5 | Middle. |
| | 1.06 | 88.3 | 42.5 | 57.5 | 1.8 | 8.9 | Bottom. |
| October 4 | 1.06 | 89.5 | 41.6 | 58.4 | 1.7 | 8.6 | 2.18 cubic yards sludge added. |
| October 8 | 1.08 | 78.0 | 45.2 | 54.8 | 1.9 | 10.1 | Top. |
| | 1.07 | 84.9 | 40.7 | 59.3 | 1.8 | 8.5 | Middle. |
| | 1.02 | 95.5 | 48.8 | 51.2 | 2.1 | 8.5 | Bottom. |
| October 15 | 1.09 | 74.1 | 41.7 | 58.3 | 1.8 | 9.0 | Top. |
| | 1.08 | 79.0 | 41.8 | 58.2 | 1.6 | 10.3 | Middle. |
| | 1.07 | 84.7 | 39.8 | 60.2 | 1.2 | 10.5 | Bottom. |
| October 21 | 1.04 | 90.2 | 40.0 | 60.0 | 1.4 | 8.1 | 100 gallons sludge added. |
| October 21 | 1.09 | 79.7 | 43.9 | 56.1 | 1.8 | 8.6 | Top. |
| | 1.06 | 81.9 | 41.9 | 58.1 | 1.5 | 7.8 | Middle. |
| | 1.08 | 83.9 | 41.8 | 58.2 | 1.5 | 9.2 | Bottom. |
| November 3 | 1.12 | 72.9 | 40.8 | 59.2 | 2.2 | 6.9 | Top. |
| | 1.08 | 84.3 | 40.0 | 60.0 | 1.7 | 9.8 | Middle. |
| | 1.06 | 84.9 | 41.9 | 58.1 | 1.8 | 9.5 | Bottom. |
| November 4 | 1.04 | 90.2 | 40.0 | 60.0 | 1.4 | 8.1 | 478 gallons foul water removed. 52 gallons thin sludge removed. |
| November 4 | 1.05 | 84.5 | 50.0 | 50.0 | 1.7 | 10.3 | 4.1 cubic yards sludge added. |
| November 11 | 1.08 | 72.2 | 41.8 | 58.2 | 1.5 | 6.6 | Top. |
| | 1.04 | 82.8 | 61.8 | 38.2 | 1.8 | 8.3 | Middle. |
| | 1.01 | 94.2 | 48.5 | 51.5 | 1.8 | 7.7 | Bottom. |
| November 18 | 1.10 | 70.7 | 43.4 | 56.6 | 1.2 | 6.8 | Top. |
| | 1.08 | 75.0 | 41.3 | 58.7 | 1.5 | 10.3 | Middle. |
| | 1.015 | 96.3 | 50.0 | 50.0 | 1.4 | 8.7 | Bottom. |
| November 26 | 1.04 | 76.7 | 47.0 | 53.0 | 1.5 | 9.1 | Top. |
| | 1.06 | 81.1 | 49.8 | 50.2 | 1.8 | 8.8 | Middle. |
| | 1.017 | 94.8 | 49.3 | 50.7 | 1.8 | 8.5 | Bottom. |
| December 3 | 1.08 | 75.2 | 49.8 | 50.2 | 1.2 | 10.0 | Top. |
| | 1.08 | 79.4 | 48.3 | 51.7 | 1.6 | 9.6 | Middle. |
| | 1.016 | 95.2 | 50.0 | 50.0 | 1.4 | 9.2 | Bottom. |
| December 9 | 1.09 | 73.1 | 53.2 | 46.8 | 0.6 | 10.3 | Top. |
| | 1.07 | 82.1 | 50.0 | 50.0 | 1.7 | 10.7 | Middle. |
| | 1.024 | 94.7 | 47.8 | 52.2 | 1.0 | 10.1 | Bottom. |
| December 16 | 1.10 | 73.9 | 44.6 | 55.4 | 1.4 | 6.9 | Top. |
| | 1.07 | 77.3 | 53.3 | 46.7 | 1.5 | 10.4 | Middle. |
| | 1.017 | 96.5 | 48.9 | 51.1 | 1.4 | 9.7 | Bottom. |

moisture. On October 21, 100 gallons of a thin sludge were added and, as before, sunk, the scum remaining intact. On November 4th a diaphragm pump was set up and the suction placed at the bottom of the digestion tank; expecting to get thin sludge, it was arranged to discharge upon a sand bed, but upon pumping only a strong, foul water was obtained, which was analyzed with the following results.

PARTS PER MILLION.

| Suspended Solids. | | | Nitrogen as— | | Oxygen Consumed. | | | | Fats. |
|---|---|---|---|---|---|---|---|---|---|
| Total. | Fixed. | Volatile. | Organic. | Free Amm. | Total. | In Suspension. | As Colloidal. | In Solution. | |
| 2,032 | 856 | 1,176 | 36 | 20 | 264 | 135.6 | 82 | 46.4 | 325 |

Four hundred and seventy-six gallons of this water were removed from the bottom of the tank, when suddenly the character of the material pumped changed to a thin sludge, showing that there must have existed a fairly sharp plane of separation between the water and the sludge in the tank. Only 52 gallons of this thin sludge had been pumped when it became quite like normal sludge and the pumping was stopped.

On the same day 4.1 cubic yards of wet sludge were added to the digestion tank, which broke a hole in the tough scum covering and sank to the bottom. At frequent intervals up to the end of the tests attempts were made to withdraw water from the bottom of the tank, but only thin, offensive sludge could be obtained, and although there was liquifaction and gasification during the early part of the experiment it seemed to cease entirely when cold weather set in and did not redevelop in the following spring.

Sludge Drying in Earth Lagoons.

The collection of samples was difficult, and it is highly probable that in withdrawing samples from the lower parts of the tank, some contamination from the dry surface scum occurred.

Bacterial examination during the early part of the test showed that 1.4 per cent. of the total number of bacteria in the scum were liquifiers, 4.2 per cent. at mid depth and 8.8 per cent. in the lower stratum.

As an actual example of a similar condition on a large scale, there may be seen at Birmingham, in England, lagoons of sludge five to six feet deep upon which a thick strong crust has formed, beneath which the sludge remains in its original condition with no apparent loss in amount, and Mr. Watson says: "Continued to give off foul odor irrespective of age or density."

As a result of this experiment and the above mentioned examples it would seem that the placing of sludge in open water-tight tanks is not an advantageous means of disposal.

## THE AIR DRYING OF SLUDGE IN EARTH LAGOONS.

### Description of Lagoons.

The testing station was situated on a hill of rocky formation with a thin covering of micaceous soil, in which four lagoons were excavated to a depth of three feet, 8 feet by 12 feet in plan or .0022 acre. In the first one used, a drainage base was made consisting of a three inch layer of one inch to three inch slag covered by ⅜-inch slag screenings to such a depth that the surface was even, and over that a thin layer of slag screenings from ⅛-inch to dust. From the lowest corner ran a three inch iron pipe as a drain.

The other three lagoons had plain earth bottoms.

**Action of a Coarse Drainage Floor.**

On August 20, 1909, three and one-half cubic yards of wet sludge, 82.8 per cent. moisture from sedimentation basin No. 12 (influent screened sewage), was pumped into the lagoon having the slag base and formed a mass 12 inches deep.

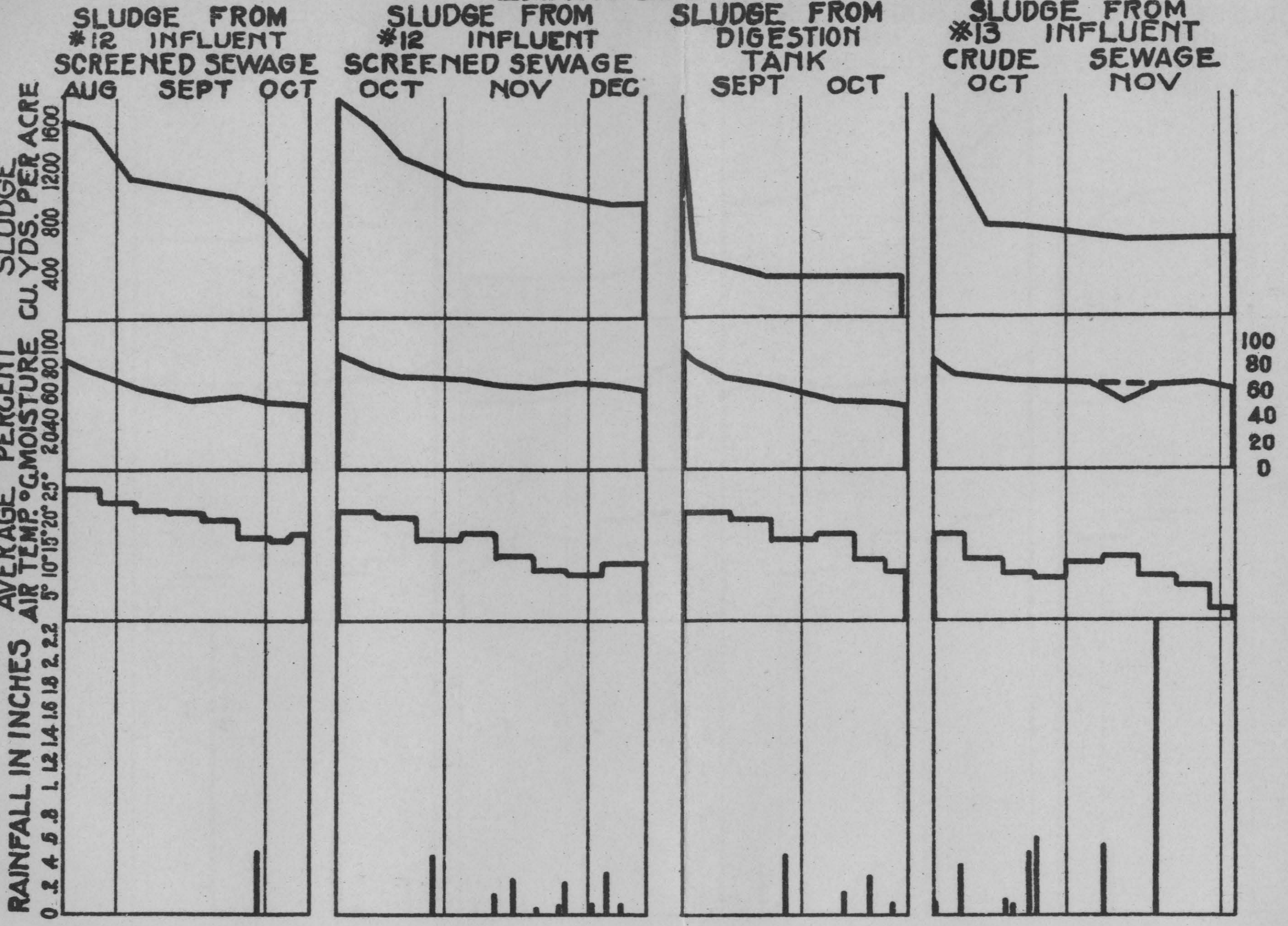
The first sludge filled the broken slag drainage floor at once and ran out of the three inch pipe, which had to be plugged up to stop the flow.

In three weeks the sludge had dried to a consistency fit to remove, but was allowed to remain in the lagoon to watch its action. The screened influent to this tank contained almost no wool fibers nor materials which would bond the sludge as it dried. The mealy nature of the sludge became evident as soon as the surface was dry enough to crack, the cracks gradually developed into fissures extending to the bottom of the layer of sludge, which facilitated the drying by increasing the area exposed to the air. When removed, the lumps piled on the side of the lagoon were not offensive, although the fresh sludge was.

**Action of Plain Earth Lagoons.**

On October 4, 1909, 3.55 cubic yards of sludge from sedimentation basin No. 13 (influent crude sewage) was pumped to a lagoon and filled it to a depth of 12 inches with a mass 88.7 per cent moisture. In four days the surface had dried sufficiently to crack, but the cracks never reached the bottom, as in the case of sludge from the screened sewage. This sludge dried slower than in the preceding case, probably due to the lower temperature, and when finally removed was much more difficult to handle, due to the bonding together of the mass of wool fibers.

## DIAGRAM NO 35
### SHOWING THE CONTRACTION OF SLUDGE WHEN DRIED IN EARTH LAGOONS



**Drying of Emscher Sludge.**

Only 30 gallons of Emscher sludge was usually withdrawn at one time and a small earth lagoon was therefore made, more to obtain samples of dried Emscher sludge than to determine its rate of drying. It was found that when freshly drawn Emscher sludge was placed in this lagoon, the entrained gas expanded so that the surface became convex. As the moisture evaporated or was absorbed into the earth, this arch collapsed and cracked, admitting air to the mass below. When dry it was very porous and spongy. The tarry odor decreased during drying, so that the material removed from the lagoon was an inert, odorless and unobjectionable substance.

**Drying of Sludge From the Digestion Tank.**

On September 7th the stirred up contents of the sludge digestion tank (heretofore described) were pumped to one of the plain earth lagoons. Practically a fluid mass, (96.5 per cent. moisture) filled the lagoon to a depth of 12 inches. After 24 hours the moisture had been absorbed so that the sludge was about four inches deep and 85 per cent. moisture, resembling ordinary sludge when first placed in a lagoon. In three weeks the surface cracked and was firm; when removed from the lagoon it was an inodorous, felt-like mass.

**Drying Sludge in Furrows.**

Two furrows were dug, 2 feet wide at the top, 10 inches at the bottom, 1 foot deep; one 17 feet, the other 23 feet long, the idea being that the larger area required by furrowing would be more than compensated for by the rapid absorption of the moisture by the soil. On September 17, 1909, sludge from the plain sedimentation tank, supplying the outside filters with sewage, was run into these furrows; it contained 87 per cent. moisture and required until October 21st to dry to 60 per cent. moisture, when it was removed. As the sludge dried and its surface assumed a concave form all rain water was caught and absorbed, thereby maintaining the sludge at a higher moisture figure than in plain lagoons.

TABLE No. 64.

*Showing Results of Air Drying Sludge in Earth Lagoons.*

| Source of Sludge. | Time in Days. | Depth in Inches. | Cubic Yards in Lagoon. | Per Cent. Moisture in Sludge. | Rainfall in Inches. | Cubic Yards of Sludge per Acre. |
|---|---|---|---|---|---|---|
| Sedimentation Tank No. 12. Influent screened sewage | 0 | 12.20 | 3.60 | 82.8 | 0 | 1,600 |
| | 26 | 7.67 | 2.50 | 57.0 | 0 | 1,000 |
| | 49 | 3.50 | 1.04 | 51.6 | 0.43 | 470 |
| Sedimentation Tank No. 12. Influent screened sewage | 0 | 18.50 | 4.00 | 90.1 | 0 | 1,800 |
| | 62 | 7.00 | 2.10 | 61.0 | 3.14 | 950 |
| Contents of the sludge digestion tank in first experiment | 0 | 12.00 | 3.50 | 96.5 | 0 | 1,600 |
| | 23 | 2.67 | 1.80 | 60.4 | 0.43 | 360 |
| | 44 | 2.67 | 1.80 | 51.6 | 0.82 | 360 |
| Sedimentation Tank No. 12. Influent crude | 0 | 12.00 | 3.50 | 83.7 | 0 | 1,600 |
| | 59 | 4.70 | 1.40 | 62.8 | 2.59 | 640 |

**Effect of Winter Weather Upon Sludge Exposed in Lagoons.**

On October 8, 1909, when sedimentation tank No. 12 was cleaned, 3.9 cubic yards of wet sludge was placed in one of the earth lagoons. At the end of four weeks it was in a fit condition to remove, but was allowed to remain until December 9th. Upon the sides of the lagoon there

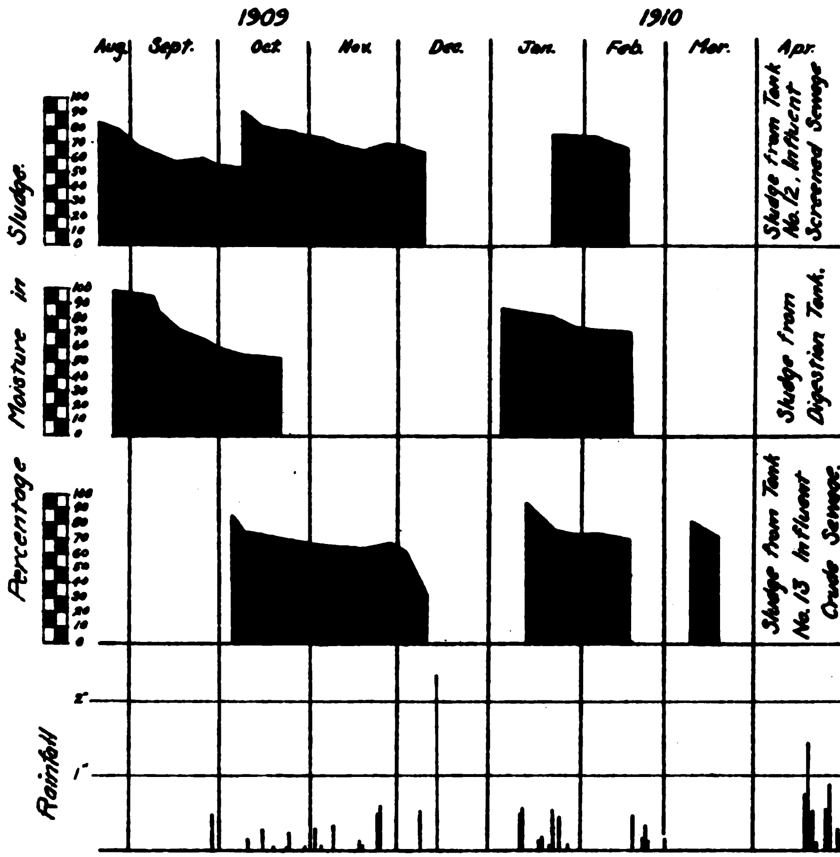



DIAGRAM NO. 36

SHOWING THE AIR DRYING OF SLUDGE IN EARTH LAGOONS stood piled lumps of similar sludge which were exposed to the same conditions as the contents of the lagoon. When snow fell it laid upon the broad, exposed surface of the lagoon and when melted slowly was absorbed, maintaining a high percentage moisture.

On the other hand, the lumps piled upon the side presented less area to the snow and when it melted it ran down and away, so that the lumps remained quite dry all winter.

### General Conclusions Upon Lagooning Sludge.

Sludge was run on the lagoons to a depth of 12 inches or at a rate of 1,600 cubic yards of wet sludge per acre. In moderate weather the sludge would dry to a consistency of say, 60 per cent. moisture, and be fit to remove before the six weeks usually intervening between sludging tanks, and the amount of sludge removed was about 0.4 of that applied. While the sludge was drying in the lagoons samples were taken at weekly intervals and subjected to a complete analysis in the hope that certain methods would be found superior to others by the loss of organic and increase of mineral constituents. But, while fats and nitrogen generally tended to decrease, the data were not uniform enough to form any laws.

## EXPERIMENTS TO DETERMINE THE BEST MATERIAL FOR SLUDGE BEDS.

### Data Sought.

A sewage disposal plant is sometimes located where the soil is of such a character that a natural earth lagoon would be inefficient for drying sludge, and it is necessary to construct an artificial drying bed. The following experiments were conducted to determine the best media for this purpose and its most efficient arrangement.

## Table No. 65.

*Analyses of Sand Used in Experimental Sand Sludge Bed.*

| Number of Compartment in Bed. | | Number of Sieve. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 200 | 100 | 74 | 50 | 40 | 30 | 20 | 10 | 10 |
| | Width of opening in inches | .00265 | .00550 | .00776 | .01100 | .01475 | .02108 | .03535 | .07300 | Per Cent. of Sand Retained on |
| | Width of opening in millimeters | .067 | .140 | .197 | .279 | .375 | .535 | .898 | 1.854 | |
| 1 | Per cent. of sand passing | 0.3 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 1.1 | 9.0 | 91. |
| 2 | Per cent. of sand passing | 0.3 | 0.5 | 0.7 | 1.0 | 1.2 | 3.2 | 4.7 | 6.0 | 94. |
| 3 | Per cent. of sand passing | 0.0 | 0.1 | 0.4 | 7.1 | 21.6 | 57.3 | 90.2 | 9.8 | 0 |
| 4 | Per cent. of sand passing | 0.2 | 5.0 | 14.4 | 32.4 | 43.6 | 56.7 | 86.1 | 99.1 | 0.9 |
| 5 | Per cent. of sand passing | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.7 | 0.7 | 0.7 | 99.3 |
| 6 | Per cent. of sand passing | 0.0 | 0.2 | 0.3 | 0.4 | 0.5 | 0.7 | 7.1 | 48.6 | 51.4 |

## Sand.

### Apparatus Used.

A wooden box was built, 12 feet long, 2 feet wide and 12 inches deep, divided into six equal compartments. The bottom was made of fine mesh wire cloth supported by a heavy screen.

### Coarse vs. Fine Sand.

In the bottom of each compartment was first placed a six inch layer of screened clinker, one-half inch in diameter, and upon it a three inch layer of sand, as shown in Table No. 65. On November 24, 1909, fresh sludge 90 per cent. moisture, from sedimentation basin No. 12 (influent screened sewage). was placed three inches thick upon the sand. It remained on the sand (under cover at an average temperature of 4° C.) for nine days, when the dried mass was carefully removed and determination made of the moisture and amount of media adhering to the dry sludge. Results shown in Table No. 66.

The coarse sand was very unsatisfactory, as the sludge seemed to penetrate into the larger voids and consequently more of the medium was embedded in the cake as removed.

The fine sand did not permit this and probably removed a part of the moisture by capillary attraction.

Assuming that the same amount of medium would be removed by a 12-inch layer of sludge, 1,000 cubic yards of wet sludge would remove:

21.8 tons of coarse sand.
8.6 tons of fine sand.
7.9 tons of rice coal.

TABLE No. 66.

(See Diagram No. 37.)

*Showing Studies on Sludge Bed.*

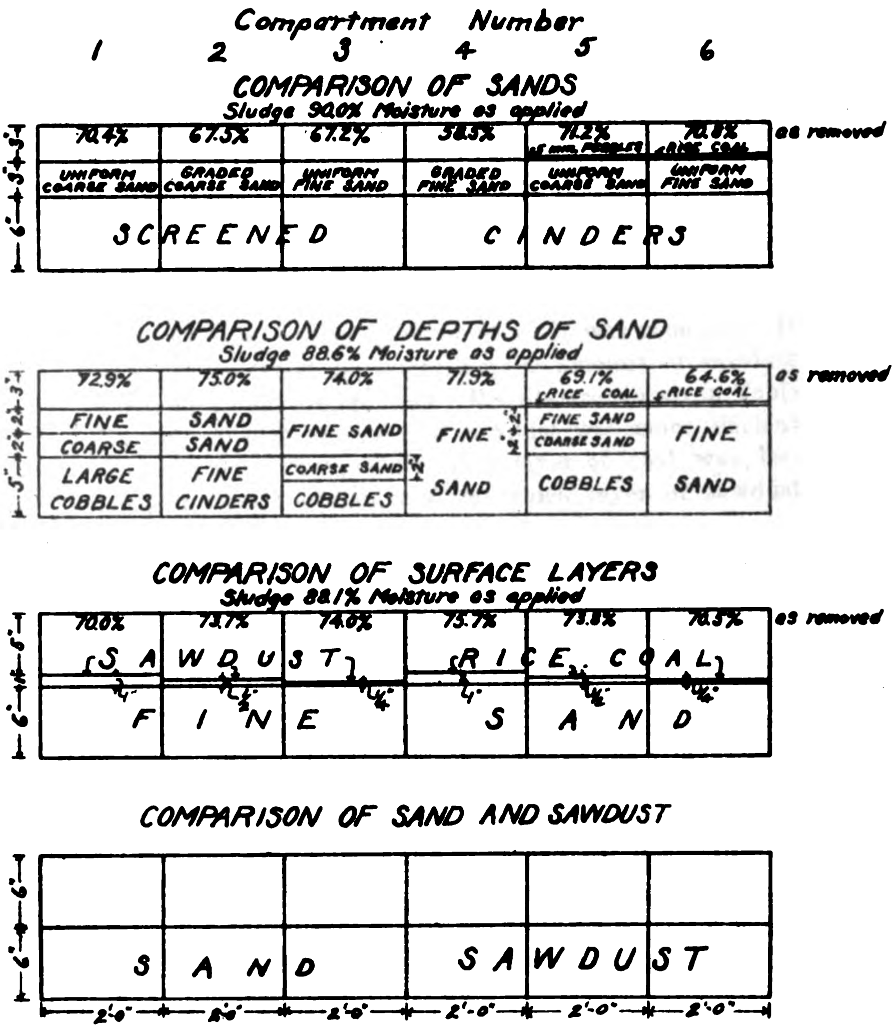
| Test Number. | Number of Compartment | Per Cent. Moisture in Sludge as— Applied. | Removed. | Tons per Acre of Media Adhering to Sludge When it Was Removed. |
|---|---|---|---|---|
| 1 | 1 | 90 | 70.4 | 34.9 |
| | 2 | | 67.5 | 34.9 |
| | 3 | | 67.2 | 13.4 |
| | 4 | | 58.5 | 14.2 |
| | 5 | | 71.2 | 35.2 |
| | 6 | | 70.8 | 12.7 |
| 2 | 1 | 88.6 | 72.9 | 9.1 |
| | 2 | | 75.0 | 16.1 |
| | 3 | | 74.0 | 11.0 |
| | 4 | | 71.9 | 9.3 |
| | 5 | | 69.1 | 8.6 |
| | 6 | | 64.6 | 10.3 |
| 3 | 1 | 88.1 | 70.0 | ........ |
| | 2 | | 73.7 | ........ |
| | 3 | | 74.0 | ........ |
| | 4 | | 75.7 | 19.5 |
| | 5 | | 73.8 | 16.5 |
| | 6 | | 70.7 | 15.9 |

**Depth of Sand.**

The medium was removed and at varying depths layers of fine sand were placed, as shown in diagram No. 37. Sludge 88.6 per cent. moisture from a sedimentation basin (influent crude sewage) was placed upon the sand on December 29, 1909, and after 13 days, at an average temperature of 6.5° C. removed; results shown on Table No. 66. It will be seen that the deeper layer of sand proved

# DIAGRAM NO. 37

*Showing various construetions of the apparatus used to determine best media for sludge drying.*



more efficient than the shallow layers, confirming the theory of capillary attraction; also that the covering of rice coal did not interfere with the action of the sand.

**Sawdust and Coal Surface Layers.**

The medium was again removed and the bottom layer in all compartments made six inches of fine sand. Upon three of the compartments varying thicknesses of sawdust were placed and upon the others rice-size anthracite coal. On January 13, 1910, a six inch layer of sludge, 88.1 per cent. moisture, from a sedimentation tank (influent screened sewage) was placed; after seven days at an average temperature of 8° C. it was removed. It was not practical to determine the amount of sawdust adhering to the sludge cake. Results are shown in Table No. 66. The thick layer of sawdust was more efficient than the thin, whereas the thick layer of coal was less efficient than the thin, and the thick layer of sawdust equally efficient to the thin layer of coal.

**Sawdust vs. Sand.**

The contents of the compartments were changed to six inches of sawdust in three of them, and six inches of fine sand in the remainder. Seven tests were made to compare the sand and sawdust and to find if the sawdust would become saturated with moisture.

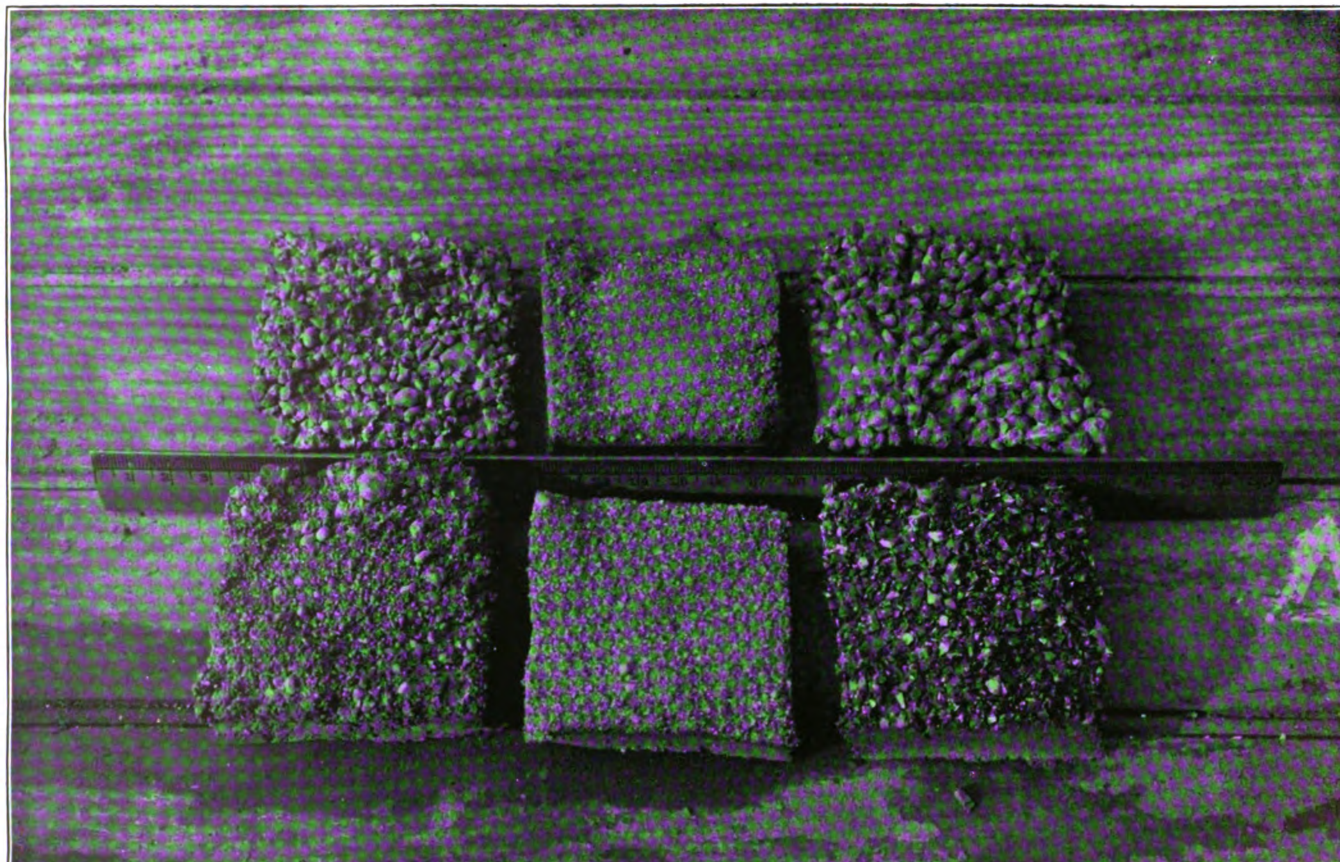
The sludge was allowed to remain on the media an average of six days and an average of two days of rest. The details are shown on Table No. 67, wherein it will be seen that the sawdust was equal to sand and did not at all lose its power to absorb the water from the sludge.

Before recommending the use of sawdust for an artificial sludge lagoon, however, larger scale experiments ought to be conducted to confirm the results here shown.

# TABLE No. 67.

## *Showing Comparative Efficiency of Sand and Sawdust as a Medium to Dry Sludge Upon.*

| Dates Sludge Was Applied, 1910. | Dates Sludge Was Removed, 1910. | Elapsed Time in Days. | Average Air Temperature, Degrees Cent. | Per Cent. Moisture in Applied Sludge. | Compartment Number. | Per Cent. Moisture in Sludge as Removed. | Per Cent. Moisture in Sludge as Removed. Average Value On Sand. | Per Cent. Moisture in Sludge as Removed. Average Value On Sawdust. |
|---|---|---|---|---|---|---|---|---|
| February 1 | February 10 | 9 | 7.3° | 91.9 | 1 | 75.8 | 75.5 | |
| | | | | | 2 | 75.7 | | |
| | | | | | 3 | 74.9 | | |
| | | | | | 4 | 74.2 | ------ | 74.7 |
| | | | | | 5 | 74.4 | | |
| | | | | | 6 | 75.6 | | |
| February 17 | February 19 | 2 | 8.7° | ------ | 1 | ------ | 75.9 | |
| | | | | 92.6 | 2 | 75.7 | | |
| | | | | 91.3 | 3 | 76.0 | | |
| | | | | 90.2 | 4 | 76.6 | ------ | 75.1 |
| | | | | 92.3 | 5 | 75.6 | | |
| | | | | 92.3 | 6 | 73.0 | | |
| February 21 | February 25 | 4 | 9.5° | 92.5 | 1 | 76.0 | 77.0 | |
| | | | | | 2 | 77.4 | | |
| | | | | | 3 | 77.5 | | |
| | | | | | 4 | 76.8 | ------ | 76.6 |
| | | | | | 5 | 76.4 | | |
| | | | | | 6 | 76.7 | | |
| February 28 | March 4 | 4 | 14.3° | 91.8 | 1 | 66.3 | 75.5 | |
| | | | | | 2 | 75.5 | | |
| | | | | | 3 | 75.6 | | |
| | | | | | 4 | 75.4 | ------ | 75.3 |
| | | | | | 5 | 75.5 | | |
| | | | | | 6 | 75.0 | | |
| March 8 | March 14 | 6 | 11.3° | 93.4 | 1 | 73.7 | 73.8 | |
| | | | | | 2 | 74.6 | | |
| | | | | | 3 | 73.0 | | |
| | | | | | 4 | 74.3 | ------ | 73.5 |
| | | | | | 5 | 73.0 | | |
| | | | | | 6 | 74.2 | | |
| March 14 | March 19 | 5 | 10.3° | 90.4 | 1 | 76.6 | 76.5 | |
| | | | | | 2 | 75.9 | | |
| | | | | | 3 | 77.0 | | |
| | | | | | 4 | 76.4 | ------ | 76.0 |
| | | | | | 5 | 75.5 | | |
| | | | | | 6 | 76.1 | | |
| March 21 | April 1 | 11 | 17.4° | 90.7 | 1 | 72.7 | 72.5 | |
| | | | | | 2 | 73.5 | | |
| | | | | | 3 | 71.4 | | |
| | | | | | 4 | 73.0 | ------ | 72.5 |
| | | | | | 5 | 72.8 | | |
| | | | | | 6 | 71.6 | | |
| Averages | ------ | 6 | 11.2° | 91.8 | ------ | ------ | 75.2 | 74.8 |



Adherence of Various Media used in Drying Sludge.

## DRYING SLUDGE UPON SLUDGE BED UNDER COVER.

### Description.

After the abandonment of the contact system, the secondary bed, consisting of three feet of hard furnace clinker, one-half inch in diameter, .00585 acre in area and enclosed by concrete walls, was covered with a layer of fine sand to a depth of six inches.

Its first use was to dry the contents of the tank in which sludge digestion was first studied; on October 5, 1909, the very thin sludge, 98.2 per cent. moisture, was pumped upon this bed; the water that drained through the bed was cloudy and full of large suspended solids, worms and worm casts; these evidently came from the media of the contact bed. In three days it was a thin, dry cake and could easily have been removed, but there being no immediate need for the bed, it was allowed to remain. When, on November 4th, it was removed analysis showed it to contain only 11 per cent. moisture, but the sand adhered to the dry cake at the rate of 17½ tons per acre. On the same day the 486 gallons of foul water from the bottom of the sludge digestion tank were discharged upon this bed and later the 56 gallons of thin sludge from the same source.

This formed a thin cake which quickly dried, so that on November 18th it was a dry, hard cake of only 6.2 per cent. moisture, and was removed.

Both of these experiments were on too small a scale to draw any conclusions from.

### Operation.

On November 24th wet sludge from a sedimentation tank was run upon the bed, 89.6 per cent. moisture, to a depth of 18 inches. At first the drains carried off a little water, but the flow soon ceased and the sludge began to separate into two layers, the upper almost water, and the lower thick sludge that so clogged the pores of the sand that the supernatant liquor could not drain off. The bed was needed, so on December 8th the supernatant liquor was baled off and the sludge, which was found to be 85.5 per cent. moisture, dried for a few days and then hauled to an earth lagoon outside the building, where in the low temperature it immediately froze.

To prevent the water forming on top of the layer of sludge the sides of the sand lagoon were made of sand with a slope of one on one, so that any water collecting on top could be absorbed as fast as it collected. Also to prevent the waste of sand in removing the dry sludge and in case it is burnt to prevent the formation on the grate bars of a silica glass, the surface of the sand was covered with fine sawdust on one-half and bituminous coal on the other.

On January 12, 1910, when No. 12 tank was cleaned, the sludge was placed on this lagoon to a depth of 12 inches. After 12 days under cover in the cold winter weather the moisture had sunk from 95.6 per cent. to 72.4 per cent., and the sludge could have been removed but was allowed to remain to watch its further action. The loss of moisture was very slow after this, and on February 11th, or after one month, the dry sludge was removed. It was found that the half on sawdust was slightly drier and easier to handle than that on coal, the former 68.4 per cent. moisture, the latter 69.2 per cent., and soft coal was removed with the sludge cake at the rate of 40 tons per acre.

**Description of Second Sludge Bed.**

North of the testing station was a sand washer, the hoppers of which were built in a concrete pit. The sand-washing apparatus was removed and a small wall broken down; this left a water-tight pit 9 feet by 17 feet in plan and 4 feet 6 inches deep, covered by a leaky roof about six feet above the top and exposed on three sides. On the floor three lines of perforated three-inch tile were laid leading to a drain, large pieces of broken concrete pavement were filled in to a depth of two feet, then six inches of one-half inch to three inches gravel, over this a two inch layer of sand. This foundation resembled the character of ground, as shown by borings, on the site of a proposed sludge lagoon near Pennypack Creek. One-half inch to three inches gravel was now placed to a depth of six inches and finally six inches of fine sand.

The surface of this lagoon was divided into small areas by 12-inch boards, so that there were four areas each 3′ 10″ x 4′ 3″, six areas each 2′ 10″ x 2′ 10″ and eight areas each 2′ 1½″ x 1′ 11″.

If equal volumes of sludge were placed in these compartments they would fill them respectively 3″, 6″ and 12″.

**Operation.**

This lagoon was only used in cold winter weather, but it served to show that the rate of drying was a function of the depth applied to the lagoon.

Emscher sludge was used in filling the compartments, and it was found that in the winter weather sludge 12 inches deep was fit to remove in 12 days, although it still contained 68 per cent. moisture and had been frozen on the surface. The six inch layers dried in 10 days to 64 per cent. moisture; and a three inch layer in 10 days had only 60 per cent. moisture. These results were obtained in cold winter weather, and at the end of the time specified the sludge was not removed, but observed weekly. It was found that after the first rapid loss of moisture noted above that very little change occurred in the sludge. The result of these experiments would indicate that on an artificial lagoon Emscher sludge 12 inches deep could be dried to a consistency fit to remove in two weeks even in winter weather. Later in the winter and early spring one inch of sawdust was placed over the sand and it was found to facilitate drying slightly, but the freezing weather and snow prevented the complete drying obtained in summer, and in the operation of Emscher tanks, where sludge can be removed in small quantities at frequent intervals, it would be advantageous to withdraw sludge only in favorable weather, so that it could be removed from the lagoon before freezing. Under summer conditions the sludge could be removed sooner.

**Artificial Bottom in the Earth Lagoons.**

In two of the earth lagoons at first described artificial bottoms were placed; in one, six inches of sand, in the other, six inches of sawdust.

Scum 81.9 per cent. moisture was removed from sedimentation tank No. 13 (influent crude sewage) on December 24, 1909, and placed in an earth lagoon having six inches of fine sand in the bottom.

Slight changes occurred, due to the constant freezing temperature (see diagram No. 14), up to January 18th; the succeeding rise in temperature caused a reduction in the percentage moisture, but a snowstorm later restored most of it. After nearly two months the scum contained 85 per cent. moisture.

An almost identical history is recorded of sludge from the same tank which on January 4th was placed upon six inches of sawdust in an old earth lagoon. In seven weeks, due to cold and snowstorms, it had only lost moisture from 87.6 per cent. to 71 per cent.

On January 12th sludge from sedimentation tank No. 12, influent screened sewage, was placed upon six inches of sawdust in an old lagoon; it initially contained 95.6 per cent. moisture. Shortly after the weather moderated and in nine days the mass of sludge contained 78 per cent. moisture, after that it dried slowly, due to the same climatic causes already described.

# INTIMATE MIXTURE OF SLUDGE AND COAL.

## Preliminary Studies.

Under a later heading there will be described the burning of air-dried sludge and coal in alternate layers. Those tests indicated that the fires could be kept in a better condition if the sludge and coal was a more intimate mixture.

To find the best method of accomplishing this, some small size experiments were conducted in mixing various sizes of coal and wet sludge. From these it was found that the addition of an amount of rice-size anthracite coal equal in weight to a unit volume of wet sludge produced a mixture the volume of which was 57 per cent. greater than the original sludge and with specific gravity of 1.29.

Upon exposure in a lagoon it was observed that as the wet sludge of the mixture dried, its residue formed a coating about each piece of coal and the dried mixture could be handled like ordinary rice coal.

## The Air Drying of an Intimate Mixture of Rice Coal and Wet Sludge.

When the sedimentation tanks, No. 12, 13 and 17 were sludged in the early part of March, a portion of the wet sludge was mixed with an equal weight of rice-size white ash coal and placed in lagoons having six inches of sawdust in the bottom.

The analysis of the plain wet sludge used was as follows:

| Source. Sedimentation Tank No. | Wet Sludge. | | Per Cent. Dry Residue. | | | |
|---|---|---|---|---|---|---|
| | Sp. Gr. | Per Cent. Moist. | Vol. | Fixed. | Nit. | Fats. |
| 12 Influent screened sewage | 1.045 | 91.0 | 72.2 | 27.8 | 1.1 | 9.0 |
| 13 Influent crude sewage | 1.045 | 80.5 | 52.6 | 47.4 | 1.2 | 8.5 |
| 17 Influent crude sewage | 1.084 | 91.6 | 51.1 | 48.9 | 1.1 | 6.5 |

It was found that to effect a good mixture of the sludge and coal it had to be handled similarly to making concrete, but the tough, tenacious nature of scum made its mixture with coal by hand impracticable.

The addition of coal, almost moisture free, to the wet sludge, at once lowered the percentage moisture in the mixture made of sludge from sedimentation tank No. 12 (influent screened sewage) from 91 per cent. to 48.5 per cent., and when placed in the lagoon 12 inches deep the mixture was firm enough to support 150 pounds per square foot.

Twenty-four hours later, at an average air temperature of 4° C. in clear weather, samples were taken at top, middle and bottom and per cent. moisture found to be:

| | |
|---|---|
| Top | 25.8 per cent. |
| Middle | 27.0 per cent. |
| Bottom | 30.0 per cent. |

Nine days later, during clear weather, at an average air temperature of 3° C., the mixture contained 22.5 per cent. moisture.

On the same day a mixture of coal and sludge from sedimentation tank No. 17 (influent crude sewage), which had been drying for six days on the artificial sludge lagoon under cover, was found to contain 23.8 per cent. moisture.

The dry mixtures were removed from both sources and placed in piles at the boiler house, as shown in the photograph.

**Conclusions.**

One cubic yard of wet sludge from sedimentation tank No. 12, as used in this experiment, weighed 1,763 pounds. Based upon the figure obtained in the preliminary studies the addition to a cubic yard of sludge of an equal weight of coal would produce a volume of 1.5 cubic yards and the resulting mixture would weigh 2,350 pounds per cubic yard and be composed as follows:

| Constituent. | Per Cent. | Pounds per Cubic Yard. |
|---|---|---|
| Coal | 50. | 1,175 |
| Moisture | 45.5 | 1,069 |
| Dry residue of the sludge | 4.5 | 106 |
| | 100. | 2,350 |

After ten days in the lagoon and standing in a pile under cover one month moisture had evaporated so that, although the volume had not changed, the weight had decreased from 2,350 pounds to 1,340 pounds per cubic yard. This indicates a percentage moisture of 9.7 and a loss during drying of 940 pounds of water per cubic yard of the mixture.

The small samples submitted to coal analysis still further dried, as shown in Table No. 70.

Having in mind that of the original mixture, the coal and the dry residue of the sludge remain unchanged and the change in weight is due to the drying out of the mixture, the deduction may readily be made from the above, that since each cubic yard (with moisture partially expelled), as delivered at the boiler house, must have been composed of two-thirds cubic yards of the original sludge and of 1,175 pounds of rice coal, the weight of the mixture being 1,340 pounds per cubic yard, each ton of 2,000 pounds was derived from one cubic yard of wet sludge and contained 1,760 pounds of coal.

## THE ULTIMATE DISPOSAL OF SLUDGE BY BURNING WITH COAL.

### Preliminary Studies.

Broadly speaking, the valuable constituents of a fuel are the "volatile combustible" and the "fixed carbon," the detrimental parts being the "moisture," "ash" and "sulphur." When the source of sludge is considered, and the presence therein of fats and cellulose, it is reasonable to expect that dry sludge would have some fuel value. An examination of Table No. 59 will show that but little less than one-half of the dry residue of sludge (except the digested sludge from the Emscher tank which is much less) is volatile.

A sample of old dry sludge (from the sludge digestion tank) was analyzed and tested with the following results:

| Wet Sludge. | | Per Cent. of Dry Residue That Is | | | |
|---|---|---|---|---|---|
| Per Cent. Moisture. | B. T. U. | Volatile. | Fixed. | Nitrogen. | Fats. |
| 51.8 | 3,768 | 34.8 | 65.2 | 1.3 | 5.2 |

The English Royal Commission on Sewage Disposal in its Fifth Report cites the instance of Huddersfield, where pressed sludge was mixed with coke breeze and burnt in quantities as large as 5,421 tons per annum.

Several cities in Germany have attempted to dispose of their sludge by burning, both with and without coal.

## Test to Determine the Practicability of Burning Sludge.

### Description of Sludges.

The sludges used were "E," (as designated on table 69) from sedimentation basin No. 12 (influent screened sewage), which had been air dried in an earth lagoon with a slag underdrain. This sludge contained no coarse particles, such as wool, hops, or other inflammable bodies. Adhering to its under side was considerable slag from the lagoon.

"H" was sludge from the sedimentation basin No. 10, supplying the outside sprinkling filters, which had been air dried in trenches. This sludge contained all the solids of the sewage.

"G" was sludge originally deposited in tank No. 17 (influent crude sewage), which had been acted upon in the first experiment in the digestion tank, whereby much organic matter was removed; it was then air dried in an earth lagoon and was very light and porous.

"M" was sludge which also was originally deposited in tank No. 17, had been subjected to digestion and air dried on an artificial sand lagoon. It was in very thin cakes, dry, and considerable sand adhered to it. Samples of the above sludge prior to burning and of the coal used were analyzed in the Testing Laboratory and results are shown in Table No. 68.

Table No. 68.

*Analyses of Coal and Sludges Burnt at the Spring Garden Pumping Station.*

| Coal. | As Received. | Dry Coal. | Sludge as Described in the Text of the Report. | B. T. U. | |
|---|---|---|---|---|---|
| | | | | Dry Sample. | As Burnt. |
| Moisture | 2.55 | ---------- | | | |
| Volatile combustible | 6.70 | 6.86 | | | |
| Fixed carbon | 74.46 | 76.25 | | | |
| Ash | 16.49 | 16.89 | E | 2,780 | 1,877 |
| Total | 100. | 100. | G | 1,864 | 1,216 |
| Sulphur | 0.85 | 0.87 | H | 3,668 | 2,165 |
| B. T. U. | 12,065 | 12,356 | M | 1,596 | 1,360 |

In the adjacent pumping station an internal combustion tubular boiler of the Codman type was used for the test. The four coal fires were put into as nearly identical condition as possible. The dry sludges had been broken into lumps about two inches in diameter and 3.08 cubic feet of each broken sludge was simultaneously burned, coal being added to each fire when it was needed.

**Results.**

The detailed results attained are set forth in Table No. 69.

TABLE NO. 69.

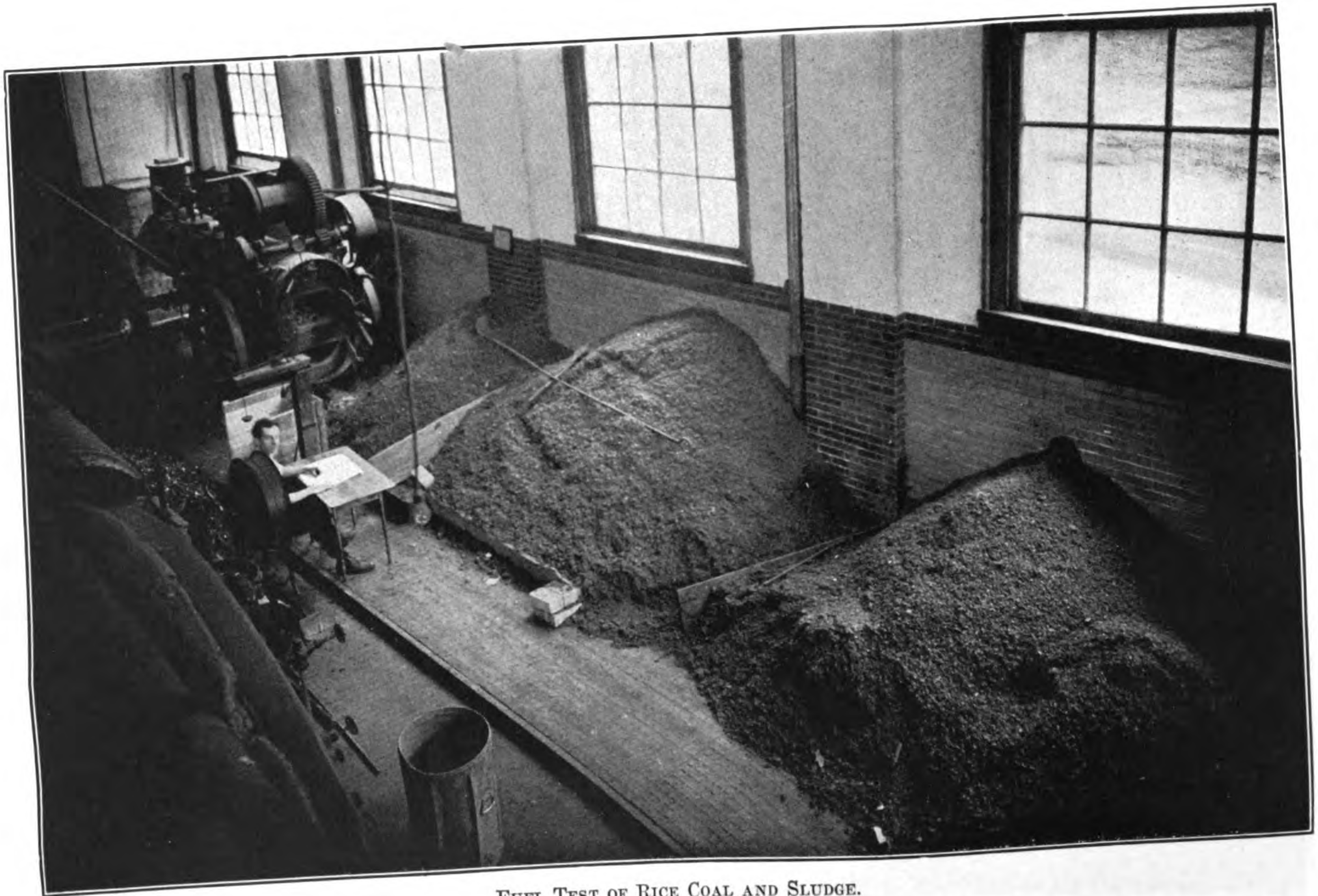
*Results of Burning Air-Dried Sludge with Coal.*

(For description of fuel see Table No. 68 and text.)

| | E. | H. | G. | M. |
|---|---|---|---|---|
| Pounds of wet sludge burnt | 344. | 282. | 283. | 239. |
| Weight in pounds per cubic yard of broken sludge | 1015. | 835. | 840. | 710. |
| Percentage of water in sludge | 32.2 | 40.2 | 35.8 | 15.3 |
| Percentage of the dry residue volatile | 30. | 28.3 | 29.2 | 24.5 |
| Pounds of water in sludge used | 111. | 114. | 101. | 37. |
| Pounds of dry residue in sludge used | 233. | 168. | 182. | 202. |
| Pounds of volatile matter in sludge used | 70. | 48. | 53. | 50. |
| Pounds of fixed matter in sludge used | 163. | 120. | 129. | 152. |
| Pounds of coal burnt with sludge | 285. | 192. | 212. | 214. |
| Minutes required for sludge to burn | 107. | 68. | 83. | 90. |
| Minutes required for fire to need coal | 110. | 80. | 83. | 99. |
| Pounds of wet sludge burnt per minute | 3.22 | 4.15 | 3.41 | 2.66 |
| Pounds of dry residue burnt per minute | 2.18 | 2.47 | 2.19 | 2.24 |
| Pounds of volatile matter burnt per minute | .655 | .705 | .636 | .555 |
| Pounds of coal burnt per one pound of | | | | |
| Wet sludge | .83 | .68 | .75 | .895 |
| Dry residue | .817 | .875 | .86 | .945 |
| Volatile matter | .246 | .25 | .25 | .232 |

At the end of the tests the fires were examined and it was found that the slag from "E" sludge and the sand from "M" sludge had fused and formed a molten glassy substance upon the grate bars. If this had not been removed at once, but had chilled in the grates, it would have seriously injured them.

With this exception the experiment showed that dried



Fuel Test of Rice Coal and Sludge.

sludge could readily be burnt under boilers, and that probably some economy in coal could be realized; how much was not determined, owing to certain limitations of the experiment.

## TEST TO DETERMINE THE FUEL VALUE FOR STEAM PRODUCTION OF MIXTURES OF EQUAL WEIGHTS OF PEA COAL AND DRY SLUDGE.

Having determined that the sewage produced a sludge that it was practicable to burn, attention was next directed to the determination more accurately of the fuel value for steam production of mixtures of sludge and coal.

A portable boiler of the locomotive type was connected by a flue to the large main stack of the pumping station and the same methods used as in determining boiler efficiency.

### Description of Sludges.

The sludges used were from sedimentation tanks No. 12 (influent screened sewage) and No. 17 (influent crude sewage), both dried in earth lagoons and having stood in piles through the winter on the ground; and from the Emscher tank No. 19 dried on an artificial sand lagoon covered with a surface layer of sawdust.

### Methods of Firing.

At first the pea-size white ash coal was mixed just before firing with an equal weight of the partially dried sludge and fed into the fire as required.

A serious difficulty developed in the deadness of the fire when cleaned, and this was overcome by adding an excess of coal before and after cleaning and an excess of sludge between cleanings. In this way the fires were kept in good condition and equal weights of coal and sludge were burnt by the end of the experiment.

**Results.**

The details of the tests are given in the four lower lines of Table No. 70, wherein it may be seen that the caloric value of the sludge as indicated by its pro rata B. T. U. figure was not realized in the amount of water evaporated.

No trouble was experienced in the formation of the molten glass aforementioned, as the dried sludge contained no vitreous material from its drying lagoon.

## TESTS TO DETERMINE THE FUEL VALUE FOR STEAM PRODUCTION OF THE DRIED INTIMATE MIXTURE OF EQUAL WEIGHTS OF RICE COAL AND WET SLUDGE.

**Description of Material.**

There has been previously described the mixing of rice coal and wet sludge, its drying in lagoons, and hauling to the boiler house.

The mixtures used were equal weights of rice-size anthracite coal and sludge from sedimentation tank No. 12 (influent screened sewage) and from sedimentation tanks No. 13 and No. 17 (influent crude sewage). The drying out of the moisture in the wet sludge very materially lowered the percentage of sludge in the mixture as burnt.

**Results.**

In the upper four lines of Table No. 70 there is shown the detailed results of the tests, during which several matters developed. The fine rice coal fell through the grate bars when the fires were cleaned, so that part of the ash shown in the table is really unconsumed fuel. Also the

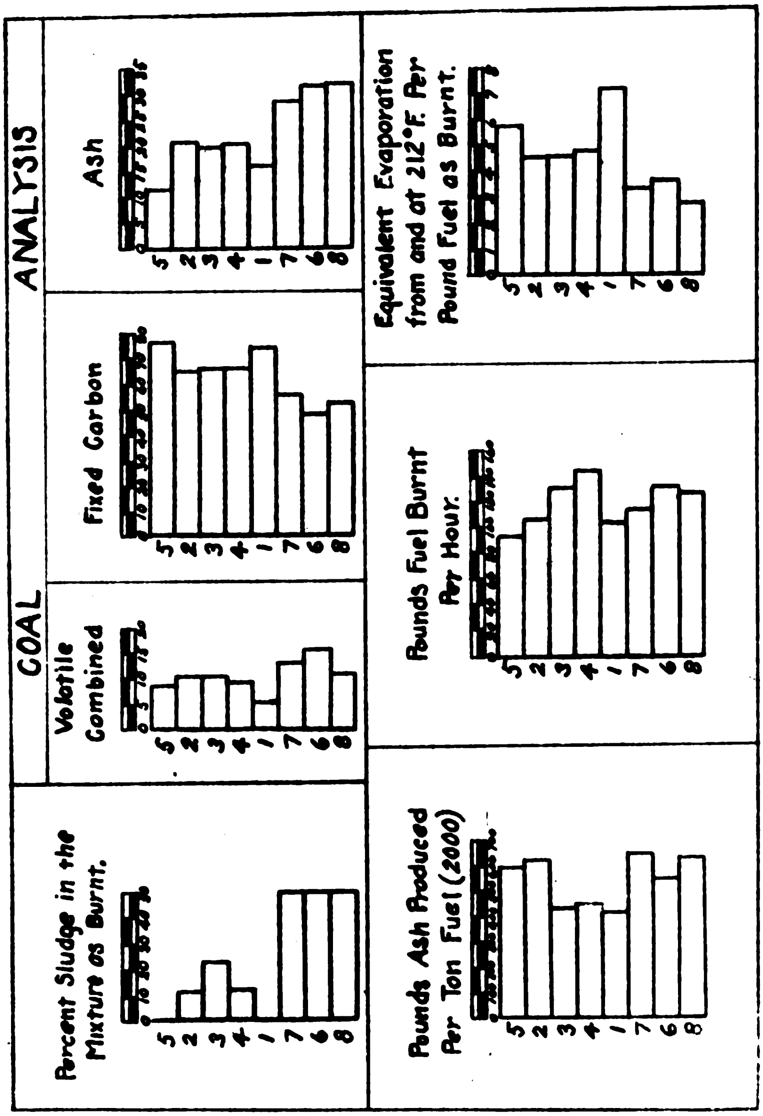
## Table No. 70.

*Results of Tests to Determine the Fuel Value for Steam Production of Mixtures of Sludge and Coal.*

| Fuel. | Source of Sludge. | Number of Test. | Per Cent. of Wet Sludge in Mixture as Burnt. | Analysis of Fuel Prior to Burning. Moisture. | Volatile Combustible. | Fixed Carbon. | Ash | Sulphur. | B. T. U. | Duration of Test in Hours. | Total. Pounds of Fuel Burnt. | Pounds of Water Evaporated in Boiler. | Pounds of Ash Produced. | Unit. Pounds Water Evaporated per Pound of Fuel Burnt. | Pounds of Ash Produced per Pound of Fuel Burnt. | Pounds of Fuel Burnt per Hour. | Average Temperature of Feed Water in Degrees F. | Heat in B. T. U. In the Steam. | In the Feed Water. | Difference. | Factor of Evaporation $\frac{\text{Difference}}{966}$ | Equivalent Evaporation from and at 212 Degrees F. per Pound of Fuel. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rice coal | ------ | 5 | --------- | 1.54 | 8.84 | 77.01 | 12.61 | .85 | 12,519 | 6 | 566 | 2998 | 168½ | 5.30 | .298 | 94.3 | 120 | 1147 | 88.2 | 1058.8 | 1.096 | 5.81 |
| Intimate mixture of equal weights of rice coal and wet sludge after the mixture dried. | 12 | 2 | 12.4 | 3.70 | 10.90 | 64.15 | 21.25 | .63 | 10,700 | 6 | 627 | 2634 | 193 | 4.20 | .308 | 104.5 | 122 | 1147 | 89.8 | 1057.2 | 1.094 | 4.60 |
| | 13 | 3 | 22.9 | 3.87 | 10.89 | 64.98 | 20.26 | .62 | 11,008 | 6 | 795 | 3398 | 176½ | 4.28 | .222 | 132.5 | 126 | 1147 | 94.3 | 1052.7 | 1.091 | 4.68 |
| | 17 | 4 | 12.6 | 2.75 | 9.56 | 66.46 | 21.23 | .94 | 11,252 | 6 | 866 | 3900 | 197 | 4.50 | .227 | 144.3 | 122 | 1147 | 90.4 | 1056.6 | 1.094 | 4.92 |
| Pea coal | ------ | 1 | --------- | 2.83 | 5.53 | 73.68 | 17.96 | .89 | 11,887 | 5¾ | 598 | 3969 | 125½ | 6.64 | .210 | 104.0 | 130 | 1147 | 98.5 | 1048.5 | 1.085 | 7.20 |
| Mixture of equal weights of pea coal and dry sludge | 12 | 7 | 50.0 | 1.73 | 13.50 | 56.62 | 28.15 | .83 | 9,318 | 6 | 700½ | 2114 | 229 | 3.02 | .327 | 116.7 | 122 | 1147 | 91.1 | 1055.9 | 1.093 | 3.30 |
| | 17 | 6 | 50.0 | 2.03 | 15.77 | 48.81 | 33.39 | .45 | 8,875 | 6 | 789½ | 2619 | 218½ | 3.32 | .277 | 131.5 | 122 | 1147 | 90.2 | 1056.8 | 1.094 | 3.63 |
| | 19 | 8 | 50.0 | 1.15 | 11.72 | 52.58 | 34.55 | .84 | 8,832 | 6 | 772 | 2060½ | 243½ | 2.67 | .315 | 128.7 | 119 | 1147 | 87.5 | 1059.5 | 1.097 | 2.92 |

DIAGRAM NO. 38.

*Illustrating Table No. 70 in the Burning of Mixture of Coal and Sludge.*



sludge-coated rice coal, while it did not fuse together, formed a denser mass and required a stronger draft than was needed when pea coal was used, a condition which would have occurred had coal alone been burnt. It was found imperative to burn wood in the bottom of the large stack to increase the draft.

In these tests, even less realization of the caloric value of sludge, as determined by its B. T. U. figure, was noted than when equal weights of pea coal and dried sludge were burnt.

**Final Conclusions.**

Laboratory investigations indicate that there is caloric value in sludge, but from the tests it appears that this value is not realized in quantity of water evaporated by its burning.

The tests are not final nor conclusive, as some conditions were not identical with actual working conditions and unknown factors may have prevented the development of the real latent caloric value of the sludge. Nevertheless, if considered in no other way, the very small percentage of coal needed to incinerate the sludge is justified because of the saving of several dollars per ton required in other methods of sludge disposal.

Sewage disposal plants in Germany have demonstrated the feasibility of utilizing sludge for the manufacturing of producer gas, so that it is probable that in this manner larger economies could be realized than in steam production.

# APPENDIX No. 1.

## COMPARISON OF SEWAGE USED IN THESE EXPERIMENTS WITH THAT USED AT OTHER TESTING STATIONS.

The sampling of crude sewage at a testing station is so much more thorough than at a purification works, that for comparison it is best to use average figures from such sources.

Such data is shown in Table No. 71, wherein the great differences in sewage are well shown and justify the operation of a testing station before the design of large works.

## COMPARISON OF THE SEWAGE USED IN THESE EXPERIMENTS WITH THAT FROM TYPICAL DRAINAGE AREAS OF PHILADELPHIA.

In May, 1910, samples of sewage composed of small portions taken over as long a time as practicable were collected and analyzed at the testing station.

The results shown in Table No. 72 and on diagram No. 39 and 40.

Based upon the above analyses and the flow in each sewer sampled, there is shown in Table No. 73 an attempt to anticipate the character of sewage which would be delivered at a works treating the sewage of the entire city. The similarity of the average sewage used at the testing station is marked.

## Table No. 71.

*Showing the Average Composition of Sewage used in other Experiment Stations.*

| Dates. | Location. | PARTS PER MILLION. | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | | | | | | | | |
| | | Total. | Fixed. | Volatile. | Organic Nitrogen | Free Ammonia. | Nitrite. | Nitrate. | Total. | Suspended. | Settling. | Colloidal. | Dissolved. | Alkalinity. | Chlorine. | Fats. | | | |
| 1903-05 | Mass. Inst. Tech. (a) | ...... | ...... | ...... | ...... | 18.5 | 0.19 | 0.10 | 43.1 | 19.3 | ...... | ...... | 23.8 | ...... | ...... | ...... | | | |
| 1905-07 | Mass. Inst. Tech. (b) | 135 | 44 | 91 | 9.1 | 13.9 | 0.00 | 0.20 | 56.0 | 13.0 | ...... | ...... | 43.0 | ...... | ...... | ...... | | | |
| 1904-05 | Columbus (c) | 209 | 130 | 79 | 9.0 | 11.0 | 0.09 | 0.20 | 51.0 | 25.0 | ...... | ...... | 26.0 | ...... | 65 | 25 | | | |
| 1905-06 | Waterbury (d) | 165 | 50 | 115 | 14.8 | 7.8 | 0.14 | 1.52 | 46.0 | 20.0 | ...... | ...... | 26.0 | 41 | 48 | 26 | | | |
| 1908-09 | Cloversville (e) | 406 | 177 | 229 | 23.0 | 12.0 | 0.38 | 0.87 | 95.0 | 50.0 | ...... | ...... | 45.0 | 217 | 158 | 48 | | | |
| 1909-10 | Philadelphia | 189 | 59 | 130 | 6.3 | 4.0 | 0.23 | 1.00 | 76.0 | ...... | 15.6 | 20.0 | 40.4 | 128 | 39 | 28 | | | |

(a) Contribution from the Sanitary Research Laboratory. Vol. II, page 114. O. C.
(b) Contribution from the Sanitary Research Laboratory. Vol. IV, page 410. O. C. equals 30 minutes on bath at 100 degrees C.
(c) Report of Geo. A. Johnson. O. C. equals 5 minutes at 100 degrees C.
(d) Furnished by Wm. Gavin Taylor.
(e) Furnished by Harrison P. Eddy. O. C. equals 5 minutes at 100 degrees C.

## Table No. 73.

*Showing a Weighted Average Composition of Philadelphia Crude Sewage from Outlets Gauged and Shown on Table No. 72.*

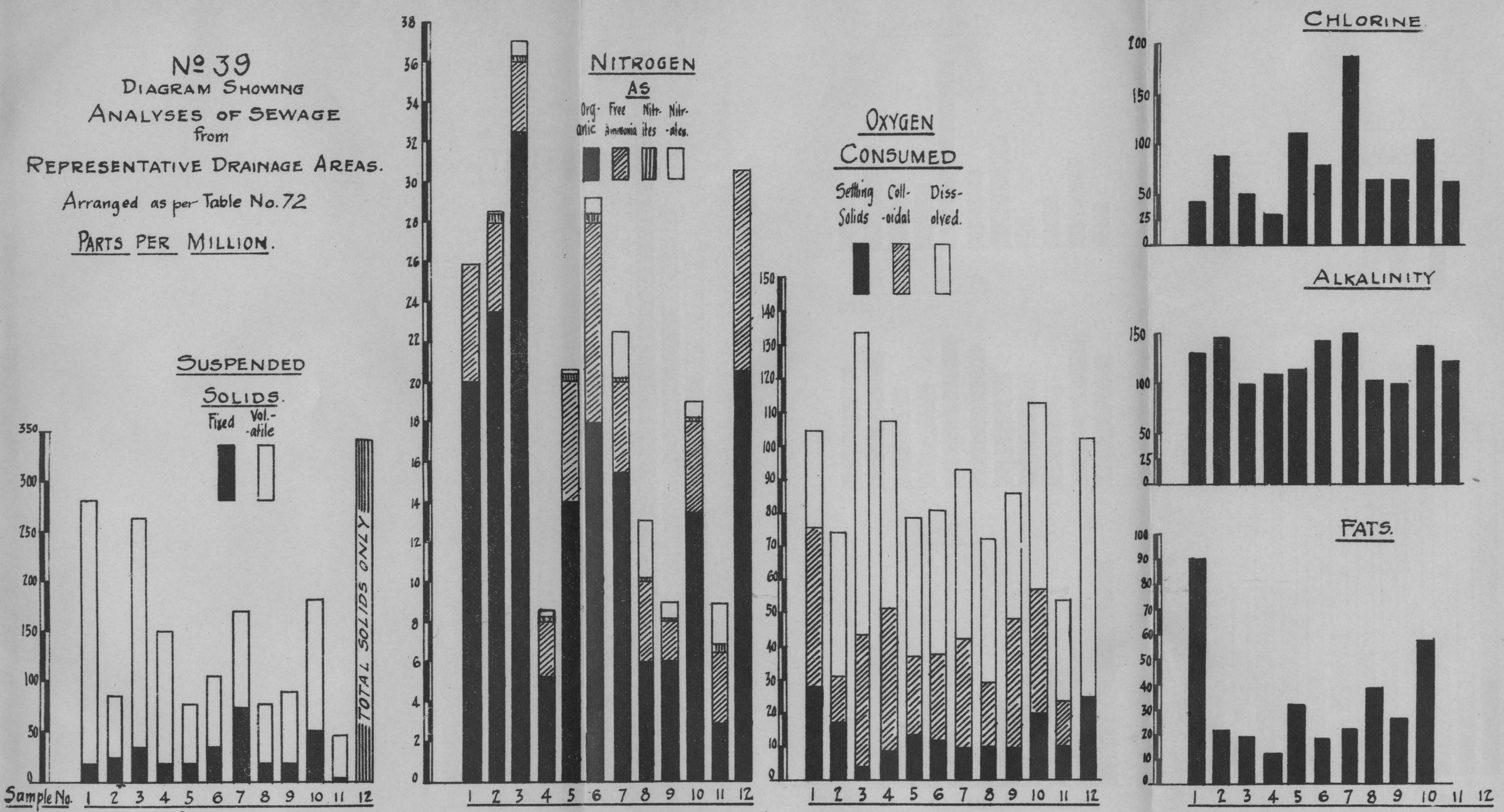
| | PARTS PER MILLION. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Suspended Solids | | | Nitrogen as— | | | | Oxygen Consumed. | | | | | | |
| | Total. | Fixed. | Volatile. | Organic. | Free Amm. | Nitrites. | Nitrates. | Total. | Settling. | Colloidal. | Dissolved. | Chlorine. | Alkalinity. | Fats. |
| Average composition of Philadelphia sewage | 160 | 35 | 125 | 15 | 4 | 0.2 | 1.0 | 100 | 15 | 35 | 50 | 80 | 125 | 40 |
| Average composition of sewage used at the testing station, 1909 and 1910 | 189 | 59 | 130 | 6.3 | 4 | 0.23 | 1.0 | 76 | 15.6 | 20 | 40.4 | 89 | 128 | 28 |

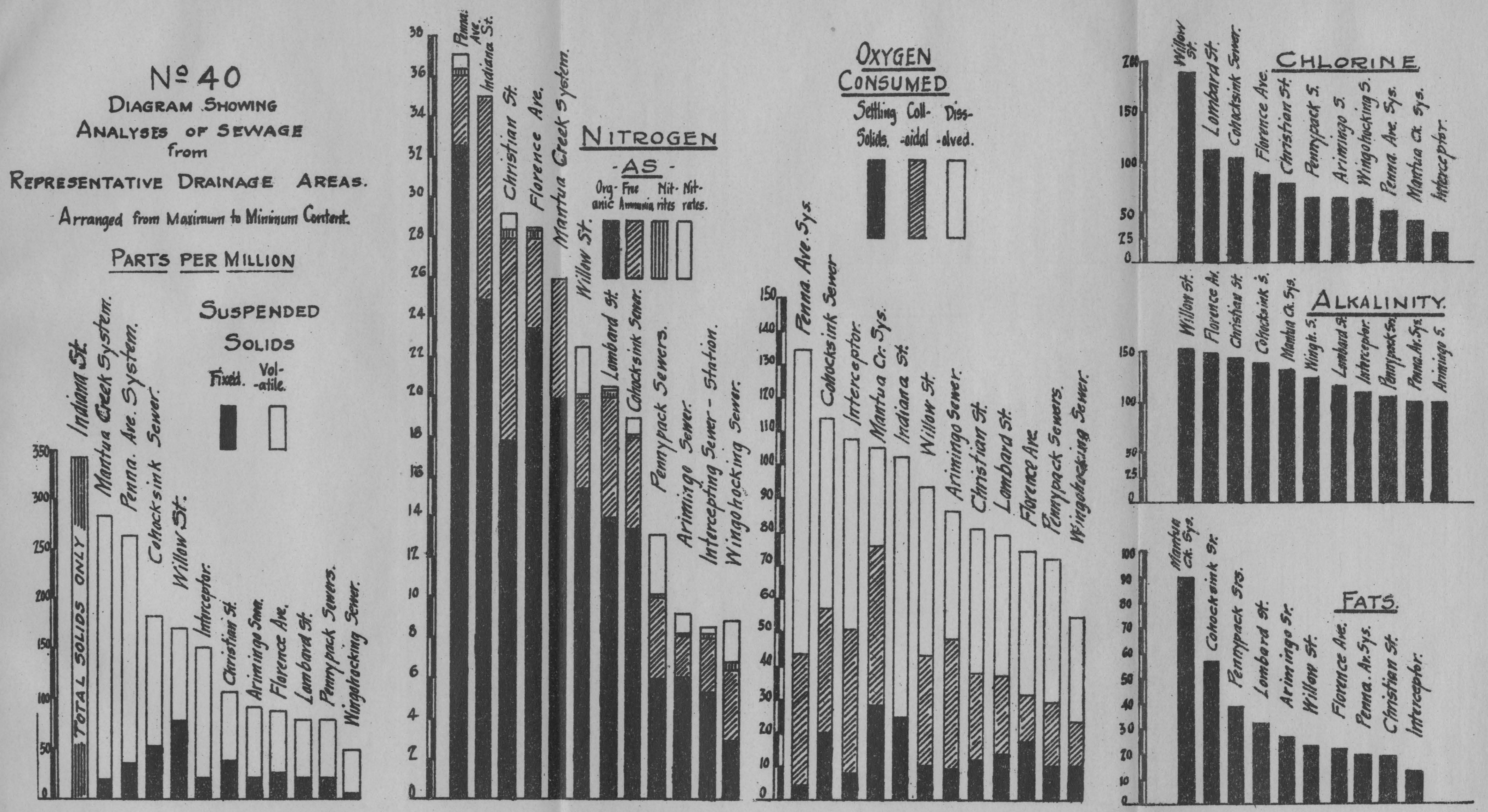
## TABLE NO. 72.

*Analyses of Sewage from Representative Drainage Areas of Philadelphia.*

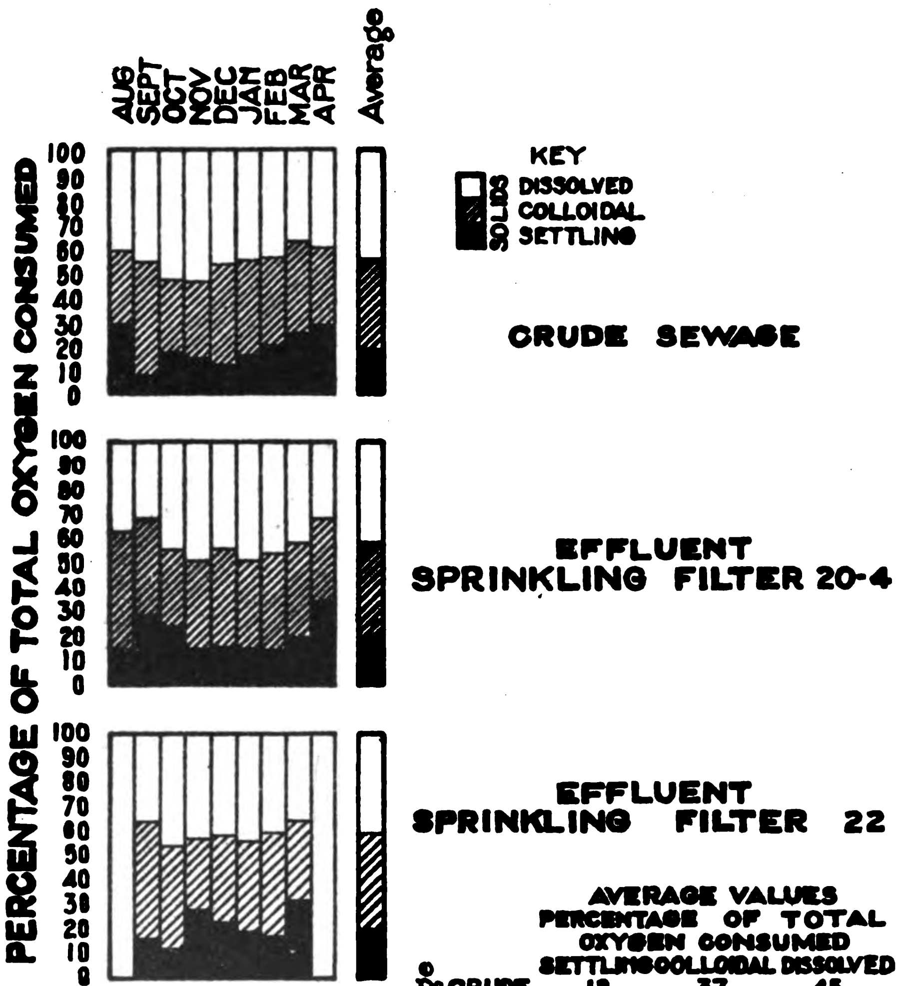
| Sample Number. | Location of Sample. | Date—1910. | | Suspended Solids. | | | Nitrogen as— | | | | Oxygen Consumed. | | | | Chlorine. | Alkalinity. | Fats. | Approximate Discharge in Cubic Feet per Second. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total. | Fixed. | Volatile. | Organic. | Free Amm. | Nitrites. | Nitrates. | Total. | Settling. | Colloidal. | Dissolved. | | | | |
| 1 | Mantua Creek system outlet | May 12 | 9.30 A. M. | 284 | 20 | 264 | 20.0 | 6.0 | 0.0 | 0.0 | 104.8 | 28.0 | 47.6 | 29.2 | 42 | 132 | 90.4 | 12.6 |
| 2 | Florence avenue outlet | May 13 | 9 A. M. to 4 P. M. | 88 | 24 | 64 | 23.5 | 4.5 | 0.40 | 0.14 | 74. | 17.2 | 13.6 | 43.2 | 88 | 148 | 21.6 | 8.05 |
| 3 | Pennsylvania avenue system outlet | May 13 | 7.20 A. M. to 11.40 A. M | 266 | 36 | 230 | 32.5 | 3.5 | 0.28 | 0.70 | 134. | 4.0 | 39.2 | 90.8 | 52 | 100 | 19.2 | 41.09 |
| 4 | Intercepting sewer at pump well for the testing station (a) | May 13 | 10 A. M. | 152 | 20 | 132 | 5.2 | 2.8 | ------- | ------- | 107.2 | 8.0 | 43.2 | 56.0 | 30 | 110 | 12.4 | 18.0 |
| 5 | Lombard street at Second street, M. H | May 13 | 1.15 P. M. to 2.15 P. M. | 80 | 20 | 60 | 14.0 | 6.0 | 0.30 | 0.20 | 78.8 | 13.6 | 23.2 | 42.0 | 112 | 116 | 32.0 | 7.3 |
| 6 | Christian street at Front street, M. H | May 13 | 9 A. M. to 10.30 A. M. | 108 | 36 | 72 | 18.0 | 10.0 | 0.45 | 0.75 | 80.8 | 12.0 | 25.6 | 43.2 | 80 | 144 | 18.4 | 12.0 |
| 7 | Willow street at Second street, M. H | May 13 | 8.45 A. M. to 11 A. M. | 172 | 76 | 96 | 15.5 | 4.5 | 0.15 | 2.3 | 93.2 | 9.6 | 32.8 | 50.8 | 188 | 152 | 22.4 | 25.4 |
| 8 | Weighted composite sample of sewage for Pennyp'k plant | May 16 | 9.15 A. M. to 12 M. | 80 | 20 | 60 | 6.0 | 4.0 | 0.15 | 2.9 | 72.0 | 10.0 | 18.8 | 43.2 | 64 | 104 | 38.8 | 1.5 |
| 9 | Aramingo sewer at Dyott street outlet | May 16 | 1.30 P. M. to 5.30 P. M. | 92 | 20 | 72 | 6.0 | 2.0 | 0.10 | 0.90 | 86.0 | 9.2 | 38.8 | 38.0 | 64 | 100 | 26.4 | 30.0 |
| 10 | Cohocksink sewer at Allen street | May 16 | 12.30 P. M. to 4 P.M. | 184 | 52 | 132 | 13.5 | 4.5 | 0.15 | 0.85 | 113.6 | 20.0 | 37.2 | 56.4 | 104 | 140 | 56.4 | 42.0 |
| 11 | Wingohocking sewer, Fifth and Annsbury | May 20 | 10 A. M. to 1 P. M. | 48 | 4 | 44 | 2.9 | 3.5 | 0.35 | 2.1 | 54. | 10.4 | 13.2 | 30.4 | 62 | 124 | ------- | 35.0 |
| 12 | Indiana street (b) | May 6 to 13, 1909. | Daytime, every ½ hr. | 342 | ------- | ------- | 24.8 | 10.0 | ------- | ------- | 102.4 | 24.6 | ------- | 77.8 | ------- | ------- | ------- | ------- |

(a) Intercepting sewer sample too highly colored with dye to do nitrites, nitrates or alkalinity. Figures given from testing station data.
(b) By filtration through paper.


Nº 39
Diagram Showing
Analyses of Sewage
from
Representative Drainage Areas.
Arranged as per Table No. 72
Parts per Million.
Suspended Solids.
Fixed
Vol.-atile
Total Solids Only
Sample No.
Nitrogen as
Org-anic
Free Ammonia
Nitr-ites
Nitr-ates.
Oxygen Consumed
Settling Solids
Coll-oidal
Diss-olved.
Chlorine
Alkalinity
Fats.



Nº 40
DIAGRAM SHOWING
ANALYSES OF SEWAGE
from
REPRESENTATIVE DRAINAGE AREAS.
Arranged from Maximum to Minimum Content.
PARTS PER MILLION
SUSPENDED SOLIDS
Fixed. Vol-atile.
TOTAL SOLIDS ONLY
Indiana St.
Mantua Creek System.
Penna. Ave. System.
Cohocksink Sewer.
Willow St.
Interceptor.
Christian St.
Arimingo Sewr.
Florence Ave.
Lombard St.
Pennypack Sewers.
Wingohocking Sewer.
NITROGEN
-AS-
Org-anic
Free Ammonia
Nit-rites
Nit-rates.
Penna. Ave.
Indiana St.
Christian St.
Florence Ave.
Mantua Creek System.
Willow St.
Lombard St.
Cohocksink Sewer.
Pennypack Sewers.
Arimingo Sewer.
Intercepting Sewer - Station.
Wingohocking Sewer.
OXYGEN CONSUMED
Settling Solids.
Coll-oidal
Diss-olved.
Penna. Ave. Sys.
Cohocksink Sewer
Interceptor.
Mantua Cr. Sys.
Indiana St.
Willow St.
Arimingo Sewer.
Christian St.
Lombard St.
Florence Ave.
Pennypack Sewers.
Wingohocking Sewer.
CHLORINE.
Willow St.
Lombard St.
Cohocksink Sewer.
Florence Ave.
Christian St.
Pennypack S.
Arimingo S.
Wingohocking S.
Penna. Ave. Sys.
Mantua Cr. Sys.
Interceptor.
ALKALINITY.
Willow St.
Florence Av.
Christian St.
Cohocksink S.
Mantua Cr. Sys.
Wingh. S.
Lombard St.
Interceptor.
Pennypack Sn.
Penna. Av. Sys.
Arimingo S.
FATS.
Mantua Ck. Sys.
Cohocksink Sr.
Pennypack Srs.
Lombard St.
Arimingo Sr.
Willow St.
Florence Ave.
Penna. Av. Sys.
Christian St.
Interceptor.




AVERAGE VALUES
PERCENTAGE OF TOTAL
OXYGEN CONSUMED

| Average | SETTLING | COLLOIDAL | DISSOLVED |
|---|---|---|---|
| CRUDE | 18 | 37 | 45 |
| 20-4 | 20 | 40 | 40 |
| 22 | 20 | 39 | 41 |

# DIAGRAM NO.41

SHOWING
RATIO BETWEEN THE
PHYSICAL DIVISIONS OF
CARBONACEOUS MATTER

# APPENDIX No. 2.

## REMOVAL OF HYDROGEN SULPHIDE.

It is sometimes found necessary to locate a sewage disposal plant adjacent to residences, and to eliminate objectionable odors produced by stale sewage. It has been suggested to collect, by a ventilating system, the gases from tanks and covered sprinkling filters, and pass them through some porous media, the surface of which would be covered with ferric oxide.

The following experiments were conducted to determine the durability of the process and the maximum rate at which deodorization could be accomplished.

### Apparatus Used.

The dilutions of hydrogen sulphide were made in a four-liter bottle having a two-hole stopper.

Through one, water could be admitted at varying rates to force the gas out through the other hole. A pipe conducted the gas to a sealed glass tube, 0.59-inch inside diameter and containing 30 inches of excelsior impregnated with ferric oxide.

The gas, after passage through the tube, entered a Bunsen side-neck filtering flask, upon the bottom of which lay a piece of lead paper, the gas, entering the flask one-eighth of an inch above the bottom and passing out through the side-neck, bubbling up through water.

Two criterions were adopted—first, the blackening of the lead paper; second, the presence of odor when the stopper of the Bunsen flask was removed.

**Lowest Dilution Susceptible to Deodorization.**

In Table No. 74 is shown the result of six experiments wherein it was found that a mixture of air and hydrogen sulphide in ratio of 1-200, which was very offensive, was rendered inodorous by passage through 30 inches of so-called "ferric oxide" at a velocity of 2.5 feet per minute.

**Endurance Test.**

To find how long the action would continue, an endurance test was made, the details of which are shown in Table No. 75 wherein it will be seen that 2.58 cubic feet of a mixture of air and hydrogen sulphide, in ratio of 1-200, passing at a velocity of 2.5 feet per minute through the "ferric oxide," in nine hours' actual service exhausted beyond recovery the ability of the "ferric oxide" to deodorize hydrogen sulphide.

**Removal of Hydrogen Sulphide by Passage Through a Solution of Calcium Hypochlorite.**

Experiments were conducted to determine the practicability of deodorizing hydrogen sulphide by passing it through a solution of calcium hypochlorite. Two hundred cc. of a 1 per cent. solution of dry bleaching powder was used, the diluted gas bubbling one inch below the surface, and the same means used to detect efficiency. A mixture of air and hydrogen sulphide in ratio of 1-250 was used. Each bottle contained four liters of the mixture.

The results accomplished at two rates are shown in Table No. 76, from which it will be seen that one cubic foot of a mixture of air and hydrogen sulphide at a rate of 0.37 cubic feet per hour through 200 cc. of a 1 per cent. solution of calcium hypochlorite exhausted its ability to remove the odor and used 2,550 parts per million available chlorine per cubic foot gas or ¾-liter 1 per cent. bleach solution.

### Table No. 74.

*Removal of Hydrogen Sulphide by Passage Through "Ferric Oxide."*

| Degree of Dilution. | Approximate Rate of Flow, Feet per Minute. | $H_2S$ Detected by | |
|---|---|---|---|
| | | Lead Paper. | Odor. |
| 1:10 | 2.5 | + | + |
| 1:50 | 2.5 | + | + |
| 1:100 | 2.5 | + | + |
| 1:150 | 2.5 | + | + |
| 1:200 | 2.5 | + | — |
| 1:250 | 2.5 | — | — |

### Table No. 75.

*Endurance Test on "Ferric Oxide" in the Removal of Hydrogen Sulphide, Using 4 Litres of 1:250 Dilution per Bottle.*

| Number of Bottle. | Time of Passage of Gas in Minutes. | Rate of Passage of Gas in Feet per Minute. | Remarks. |
|---|---|---|---|
| 1 | 21 | 3.6 | |
| 2 | 22 | 3.4 | |
| 3 | 10 | 7.4 | |
| 4 | 20 | 3.7 | Trace on lead paper. |
| 5 | 16 | 4.7 | |
| 6 | 15 | 4.9 | |
| 7 | 18 | 4.1 | Trace on lead paper. |
| 8 | 37 | 2.0 | |
| 9 | 15 | 4.9 | |
| 10 | 20 | 3.7 | |
| 11 | 21 | 3.6 | Trace on lead paper. |
| 12 | 26 | 2.9 | |
| 13 | 57 | 1.3 | Trace on lead paper. |
| 14 | 69 | 1.1 | Trace on lead paper. |
| 15 | 35 | 2.1 | |
| 16 | 31 | 2.4 | ½ bottle in 6 minutes gave + by lead paper. |
| 17 | 43 | 1.7 | |
| 18 | 51 | 1.5 | + by lead paper; very slight odor. |
| 19 | 13 | 1.4 | + by lead paper; odor strong. |

Length of material in tube equals 20 inches diameter.

# Table No. 76.

## *Deodorization of Hydrogen Sulphide by Passage Through a Solution of Calcium Hypochlorite.*

**Average rate of flow of a 1-250 dilution gas through the bleach equals 0.23 cubic feet per hour.**

| Number of Bottle. | Minutes Required for Four Litres of the Diluted Gas to Pass Through the Solution. | Parts per Million Available Chlorine. | | Remarks. |
|---|---|---|---|---|
| | | Strength of Solution. | Used by the Passage of One Litre of the Diluted Gas. | |
| 0 | 0 | 3408 | ---------------- | |
| 1 | 27 | 2540 | 109 | |
| 2 | 59 | 2180 | 90 | |
| 3 | 30 | 1844 | 84 | Tinge to lead paper. |
| 4 | 38 | 1278 | 142 | |
| 5 | 26 | 852 | 107 | |
| 6 | 40 | 710 | 71 | + no odor. |

**Average rate of flow of a 1-250 dilution gas through the bleach equals 0.37 cubic feet per hour.**

| Number of Bottle. | Minutes Required for Four Litres of the Diluted Gas to Pass Through the Solution. | Strength of Solution. | Used by the Passage of One Litre of the Diluted Gas. | Remarks. |
|---|---|---|---|---|
| 0 | 0 | 3408 | ---------------- | |
| 1 | 27 | 3069 | 81 | + no odor. |
| 2 | 28 | 2734 | 89 | + no odor. |
| 3 | 22 | 2414 | 80 | + no odor. |
| 4 | 17 | 2180 | 71 | + no odor. |
| 5 | 20 | 1811 | 80 | + no odor. |
| 6 | 15 | 1314 | 124 | + no odor. |
| 7 | 28 | 887 | 107 | + slight odor. |