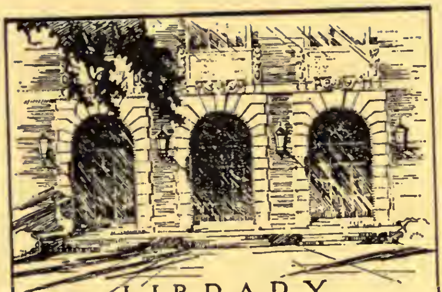

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A STUDY OF FACTORS AFFECTING THE EFFICIENCY AND DESIGN OF FARM SEPTIC TANKS

By E. W. Lehmann, R. C. Kelleher, and A. M. Buswell

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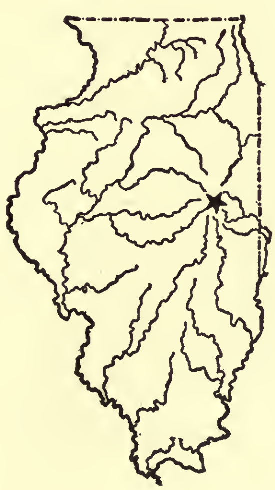

URBANA, ILLINOIS, APRIL, 1928

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This report on "A Study of Factors Affecting the Efficiency and Design of Farm Septic Tanks" is printed also as Bulletin 27 of the Illinois State Water Survey

A STUDY OF FACTORS AFFECTING THE EFFICIENCY AND DESIGN OF FARM SEPTIC TANKS

By E. W. Lehmann, R. C. Kelleher, and A. M. Buswell[1]

With the introduction of modern plumbing into the farm home a demand for a simple and effective means of sewage disposal on the farm was created. The septic tank was found best suited to this disposal problem, and a number of designs of small tanks were developed by various agencies, many of them evolved by more or less "cut-and-try" methods. Because of poor design many of the tanks failed to function properly, and many others were more complicated and more expensive than necessary.

Several investigations concerning septic tanks have been conducted by the experiment stations connected with the state universities, but up to 1922 there was a lack of fundamental data on the factors affecting the design of simple farm septic tanks. In 1922 the Illinois Station, in cooperation with the Illinois State Water Survey, began a study of tanks of simple rectangular design which could be easily constructed by inexperienced workmen. The investigation was continued for five years, and during this time more than 1,100 chemical analyses were made of effluent from experimental tanks.

The purpose of this investigation was to study: (1) the amount and rate of sewage flow that a farm septic tank may be expected to care for; (2) the effect of the size of the tank on its efficiency for a given amount of sewage; (3) the relation of length, width, and depth of tank to efficient operation; (4) the relative efficiency of single-chamber and multiple-chamber tanks.

The results of this study have led to the following conclusions which will be found further elaborated in the following pages:

1. Inasmuch as the flow of sewage per person from farm homes is subject to wide variation, the tank should be so designed as to make an average allowance for sewage flow of 18 to 25 gallons per person per day depending upon the size of the family (page 332).

2. Ordinarily it is not practical to build a tank smaller than the size required for seven people.

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[1]E. W. Lehmann, Chief in Farm Mechanics; R. C. Kelleher, formerly First Assistant in Farm Mechanics; and A. M. Buswell, Chief, Illinois State Water Survey. The authors wish to express to Mr. Harold E. Babbitt, Professor of Municipal and Sanitary Engineering, University of Illinois, and to Mr. Harry F. Ferguson, Chief Sanitary Engineer, Illinois State Department of Public Health, appreciation for valuable suggestions on the interpretation of data. Thanks are extended also to Mr. F. P. Hanson, formerly Extension Specialist in Farm Mechanics, University of Illinois, and to Mr. A. A. Brensky, formerly Assistant Engineer, Illinois State Water Survey, for suggestions and cooperation in the erection of the experimental plant.

3. In a single-chamber tank a 72-hour retention period should be provided (Fig. 24).

4. In a two-chamber tank a 72-hour retention period should be provided in the first chamber and an additional retention period of 36 hours in the second chamber (capacities being in the ratio of 2 to 1, or a total retention period of 108 hours) (Fig. 25).

5. When properly designed the two-chamber tank is more efficient than the one-chamber tank, particularly if the two-chamber tank is provided with 50 percent larger capacity, as recommended above.

I—STUDY OF SEWAGE FLOW FROM FARM HOMES

Method of Measuring Flow

The first step in this study was to determine the amount and rate of sewage flow that a farm septic tank may be expected to care for.

A tipping-bucket meter was constructed and installed at a home on the University farm occupied by three people (Figs. 1 and 2). The

FIG. 1.—TIPPING-BUCKET METER FOR DETERMINING THE QUANTITY AND RATE OF SEWAGE FLOW FROM A FARM HOME

The meter above is shown in the laboratory being calibrated.

home was supplied with University water pressure, and the tenant was not charged for the water used. The sewer connections consisted of a toilet, a kitchen sink, a bathtub, and a laundry drain.

The meter was constructed of sheet copper and reinforced with strap iron. It was fitted with an electrical contact brush for operating the time recorder, so that each tipping of the bucket closed the circuit and operated the recording pen. The tape chart on the time recorder had a paper travel of 6 inches an hour. The amount of discharge per dump was adjusted by changing the position of the counterweight shown at the right end of the tipping-bucket in Fig. 1.

The tipping-bucket was first calibrated while operating in the laboratory. The laboratory calibration was not satisfactory, since the conditions were somewhat different under actual operation. The friction on the bearings was different while operating in the manhole, and a thin film of organic matter covered the inside of the bucket after a week or ten days of operation. The bucket was therefore recalibrated in the manhole after the formation of film had apparently become constant. A water meter, installed in the home and used for this calibration, indicated that the bucket was discharging 1¾ gallons each time it tipped.

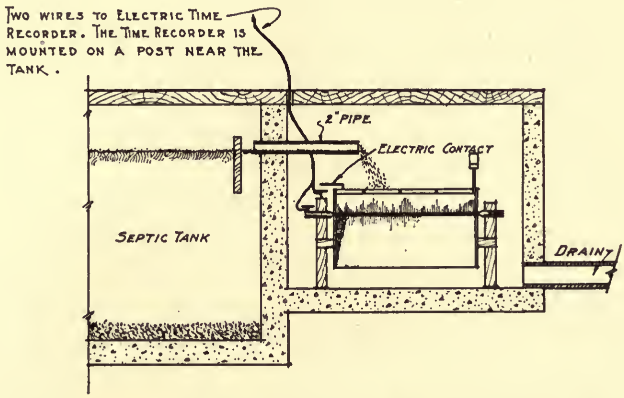

FIG. 2.—THE TIPPING-BUCKET METER SHOWN IN FIG. 1 INSTALLED IN A MANHOLE AT THE OUTLET END OF THE SEPTIC TANK

The quantity and rate of flow of sewage were measured at the septic tank by means of the tipping-bucket meter. The water consumption was measured with an ordinary water meter while the sewage measurements were being made.

Results Obtained

The average hourly rate of flow of sewage from this farm home over a period of 14 days, as recorded by the tipping-bucket meter, is shown in Fig. 3. The average flow over the entire period was 1.42 gallons per capita per hour, or 34.1 gallons per capita per day. The average water consumption at this home during the time the sewage measurements were taken was 39.5 gallons per capita per day. Part of the discrepancy between the water consumption and the sewage flow was due to the fact that some water was used for watering poultry.

The results of this study indicate that in general the water consumption in a home is an approximate index of the sewage flow. Additional measurements of water consumption were then made with water meters at eight other farm homes. These, as well as the first home, were supplied with water under pressure and were equipped with plumbing fixtures and a sewage-disposal system. Each had a kitchen sink, a bathtub, a lavatory, a toilet, and laundry equipment, with the exception of Farms 7 and 8, which had no lavatory. Farms 1 to 6 were equipped with home water-pressure systems. Farms 7, 8, and 9 were supplied with University water pressure and the tenants were not charged for the water used. The data for all nine homes are given

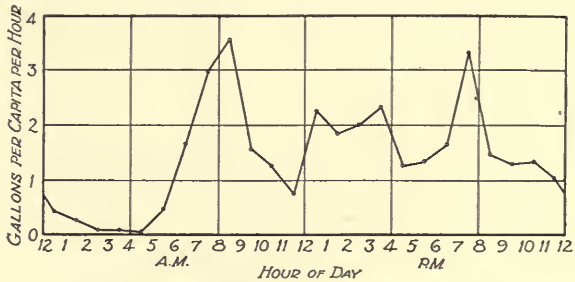

FIG. 3.—RATE OF SEWAGE FLOW FROM A FARM HOME OF THREE PEOPLE

The curve shows the average hourly rate of flow over a 14-day period during April and May. The maximum flow during one hour was 35 gallons, or 11.7 gallons per capita per hour; this large flow occurred one Saturday between 7:00 and 8:00 p. m. The shape of the curve will of course vary from home to home, depending upon the habits of the occupants.

in Table 1. It will be noted that the consumption on Farms 7, 8, and 9 was higher than the average consumption on the other six farms.

The measurements indicated that in general the water consumption was greater during the summer than during the winter.

Conclusions

This study leads to the following conclusions:

1. In farm homes where all of the house supply is used in the home, and where all the house drainage is discharged into the sewer line, the sewage flow is approximately equivalent to the water consumption.

2. The rate of sewage flow varies considerably for different hours of the day.

3. The monthly variations in sewage flow depend to a large extent upon the monthly variation in water consumption. The higher temperatures during the summer months tend to increase water consumption and sewage flow. However, both hourly and monthly variations of flow are affected greatly by the habits of the people and by local conditions.

TABLE 1.—WATER CONSUMPTION AT FARM HOMES EQUIPPED WITH MODERN PLUMBING

Farm No.	Period during which measurements were taken	Number of people	Volume per person per day
			gals.
1	6-5-25 9-4-25	3	47.5
2	6-11-25 7-10-25	3	17.0
3	5-4-26 8-3-26	4	21.1
4	3-1-26 3-1-27	4	30.4
5	6-15-25 12-21-25	7	15.0
6	8-1-25 6-4-26	8	10.0
7[1]	6-19-25 6-19-26	5	38.0
8[1]	6-19-25 6-19-26	5	45.8
9[1]	6-19-25 4-3-26	4	29.0

[1]Farms 7, 8, and 9 were supplied with University water pressure and the tenants were not charged for water used.

4. The quantity of sewage flow from farm homes also varies widely with the habits developed in the use of water.

5. In designing septic tanks for farm homes the following allowance for average sewage flow from homes of different sizes is suggested:

7 people, 25 gallons per capita per day
9 people, 23 gallons per capita per day
12 people, 20 gallons per capita per day
15 people, 18 gallons per capita per day

II—STUDY OF SINGLE- AND MULTIPLE-CHAMBER SEPTIC TANKS: EFFECT OF RETENTION PERIOD ON EFFLUENT

Description of Experimental Tanks

In order to compare different septic tanks while treating the same kind and amount of sewage, an experimental plant was constructed. Three tanks consisting respectively of three chambers, two chambers, and one chamber (A, B, and C, Fig. 4) were built side by side, and dosing apparatus (Fig. 5) was provided so that each tank received the same dose of sewage.

City sewage was used in these tanks because it could be supplied in equal amounts to each, thus affording a comparison of different tanks while operating under the same conditions. Each of the three tanks was dosed at the same time by dividing the flow from a central dosing tank (Fig. 5). The dosing tank was supplied from the Cham-

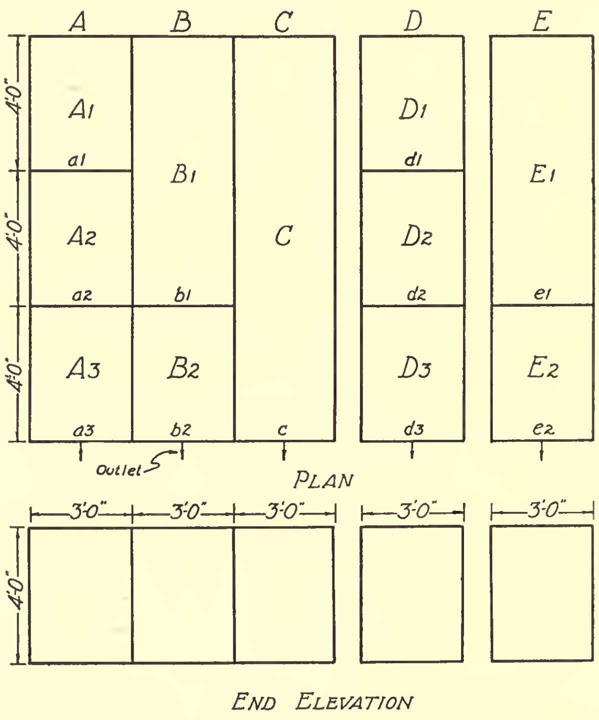

FIG. 4.—PLAN AND END ELEVATION OF EXPERIMENTAL SEPTIC TANKS USED IN STUDY II

Tanks A, B, and C were dosed with city sewage and Tanks D and E were connected with farm homes.

paign city sewer with ordinary domestic sewage practically free from industrial wastes. The city water consumption was about 80 gallons per capita per day.[1]

Each tank was 12 feet long and 3 feet wide, with the sewage standing 4 feet deep in each chamber.

In view of the fact that the three tanks described above were

[1]For further description of the Champaign sewage, see Bulletin 18, Illinois State Water Survey, pages 19 and 48.

dosed with city sewage, which differs from farm sewage, additional septic tanks were constructed on the University farm and connected to farm homes in order to secure data on farm sewage simultaneously with that on city sewage. A two-chamber tank and a three-chamber tank, identical with those which were dosed with city sewage, were connected to farm houses. Plan views of these tanks are shown at D and E, Fig. 4, and the details common to all the tanks in Fig. 6.

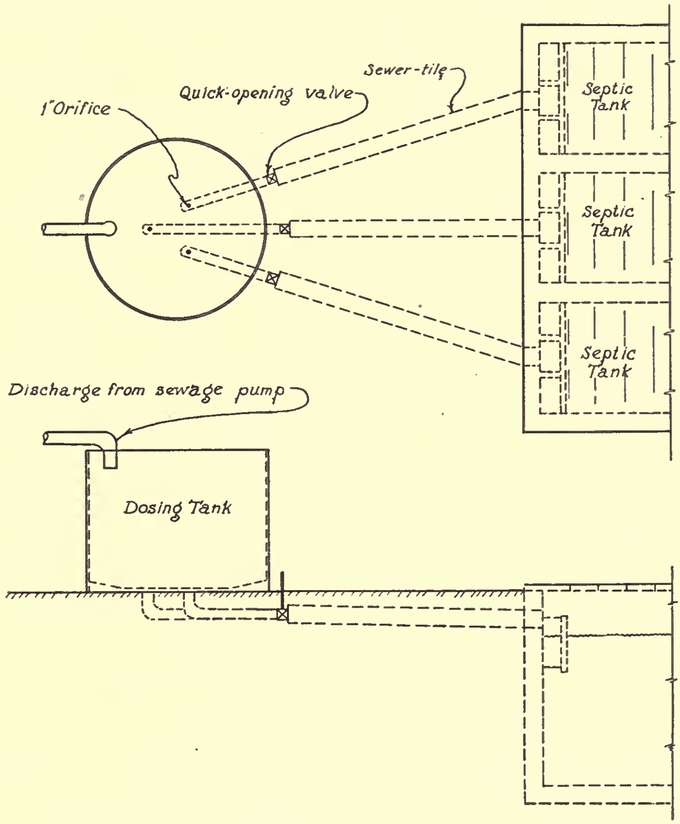

FIG. 5.—PLAN AND ELEVATION OF THE DOSING APPARATUS
This dosing tank was used to divide the flow of sewage into the one-, two-, and three-chamber tanks (A, B, and C) shown in Fig. 4.

The tanks treating city sewage and those at the farm homes were all put in operation about the same time. Since only two septic tanks (two- and three-chamber) were connected at the farm homes during this test, no data were obtained that could be compared with those from the single-chamber tank which treated city sewage.

Dosing Tanks with City Sewage.—The three tanks in which city sewage was used were dosed by an attendant, and a liquid level recorder was installed in the dosing tank as a check. Farm conditions were imitated as nearly as possible by dosing the tank at different times of the day. At each dosing period all tanks were given the same kind and amount of sewage, three orifices of the same size being located in the bottom of the dosing tank in order to divide the sewage. Each orifice was connected to a septic tank, and a quick-opening valve was placed in the sewer line to each tank (Fig. 5).

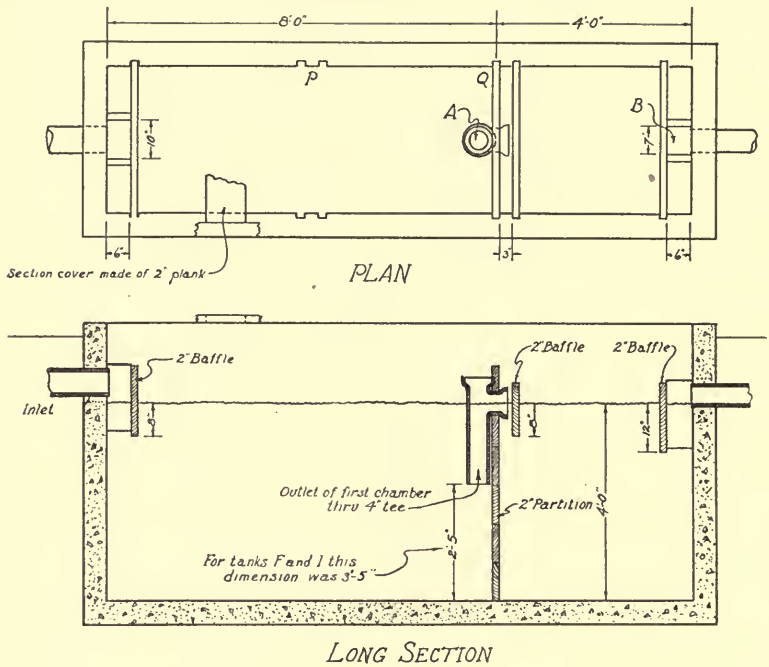

FIG. 6.—GENERAL DESIGN OF EXPERIMENTAL TANKS

All the tanks used in Studies II and III were built after the above design, tho there were certain differences in detail. In Tank C the partition and baffle at *Q* were omitted; in Tanks A and D partitions and baffles were placed at both *P* and *Q*. Tanks F, H, I, and K had differently shaped cross-sections, as shown in Fig. 17.

The tanks were dosed by first pumping a definite depth of sewage into the dosing tank, leaving the valves closed and then opening all valves together. Each tank received the following amounts of sewage daily: 8 a.m., 55.5 gallons; 12 noon, 110.5 gallons; 5 p.m., 110.5 gallons; 10 p.m., 83 gallons; or a total charge to each tank in 24 hours of 359.5 gallons, an equivalent of 48 cubic feet of sewage. This was equal to the volume of the first chamber (A1) of the three-chamber tank. This chamber, therefore, had a retention period of 24 hours of sewage flow; the first chamber (B1) of the two-chamber tank had a retention period of 48 hours; and the single-chamber tank (C) had a retention period of 72 hours. In each case the total retention period of the entire tank was 72 hours.

The maximum tank velocity was produced by the dosings at noon and at 5 p.m., when 110.5 gallons of sewage was admitted to each tank in 4¾ minutes. The rate of flow to the septic tanks was greatest at the beginning of these dosings and gradually decreased as the head on the orifices was reduced. The maximum rate of flow at the beginning of the 110.5-gallon dosing caused a tank velocity of approximately .3 foot a minute.

Flow of Sewage to Farm Tanks.—The two tanks connected to the farm homes received sewage which varied in quality and amount of flow. The water consumption for each home was metered, and the amount used was taken as an index of the sewage flow.

The three-chamber tank (D) received sewage from a home of five people, and the average sewage flow was 140 gallons a day, or 28 gallons per capita per day.

The two-chamber tank (E), which received sewage from a home of five people, had an average sewage flow of 650 gallons a day, or 130 gallons per capita per day. The large flow to this tank was due to a leak in the toilet, which was discovered and stopped March 20, 1924, after the first study on the tank had been completed. The water consumption then dropped from 130 to 40 gallons per capita per day. The fact that during this test the sewage treated by this two-chamber tank was diluted with a large quantity of water should be taken into consideration in making comparisons with the other tanks in Tables 3, 15, and 16.

Collection of Samples.—Samples were collected for chemical analysis from each chamber of each tank every six days. The samples did not actually flow from the chambers, but were collected at the outlets by means of a sampling device. The sampling points are indicated at *a1*, *b2*, etc., in Fig. 4. Two liters of sewage were collected for each sample. The sampling device consisted of a galvanized iron cylinder with an inlet at the bottom for admitting sewage (Fig. 7). The device drew the sample from a depth approximately 17 inches below the sewage level in the tank. In this way samples were obtained free from scum.

The sample was taken by forcing the sampler below the level of the sewage in the tank, pulling on trigger *B* so as to open valve *A*, and allowing sewage to flow into the cylinder and displace air thru the tube *C*. The charge of sewage was then transferred from the sampler to a 2.5-liter bottle.

In collecting samples from the first chambers of the tanks, the sewage sampler was inserted into the vertical tile tee, as shown in plan at *A* in Fig. 6; in collecting samples at the outlet of the last chamber the sampler was inserted between the baffle and the end of the tank, as shown in plan at *B*.[1] Usually there was no scum accumulation at the sampling points; if scum was present, it was avoided while inserting the inlet of the sampling device.

No definite hour of the day was set for collecting the samples from the tanks connected to farm homes. Sometimes effluent would be passing from the tank while the sample was being collected, and at other times there would be none, depending on the flow of sewage

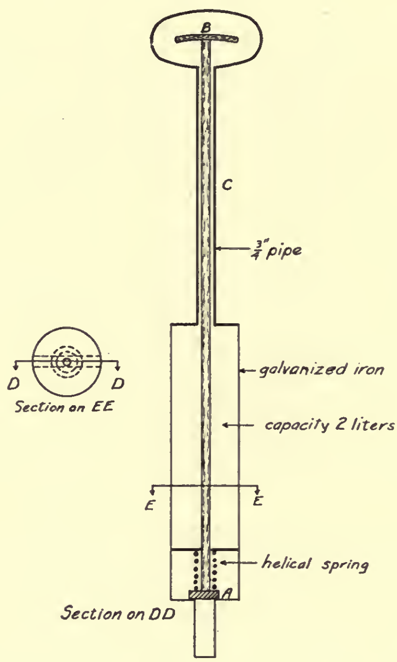

FIG. 7.—SEWAGE SAMPLING DEVICE

from the house to the tank. Likewise, no definite hour of the day was set for collecting the samples from the tank treating city sewage. Samples were not collected, however, while the tanks were being dosed, because of the difficulty of getting all samples at the same stage of the dosing operation.

Altho the above method of collecting samples was not ideal, the samples were representative of effluent from tanks operating under farm conditions. Under ordinary farm service a septic tank operates

[1]In future experimentation the provision of a slight fall between chambers and at the tank outlet will permit the use of a receptacle to collect samples of effluent as they flow from the different chambers.

intermittently—sometimes there is no discharge, sometimes a very slow discharge owing to the contents of the tank being displaced by flow from a lavatory or a kitchen sink, and sometimes a more rapid discharge because of bathtub or toilet drainage. The samples collected from the city-sewage tanks soon after dosing were representative of the effluent from a farm tank which results from bathtub or toilet discharge, and those collected a considerable time after dosing were representative of effluent from a farm tank caused by sink drainage.

The samples from the three tanks in which city sewage was treated were taken every six days. A separate sample was collected from each one of the six sampling points. One sample was collected immediately after the other, all six being taken in 10 to 30 minutes. As the sampling dates were six days apart, each day of the week was represented by the samples. Likewise, the two tanks at the farm houses were sampled at each point every six days. In order to distribute the work of analysis, the two sets of samples, representing city sewage and farm sewage, were collected three days apart.

Analytical Methods.—The following determinations were made on the samples in the laboratories of the State Water Survey: chlorin in chlorids, alkalinity, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, oxygen consumed, turbidity, residue on evaporation, settleable solids (Imhoff cone).

The analytical methods were those prescribed by the American Public Health Association and the American Water Works Association, "Standard Methods for the Examination of Water and Sewage, 1925." Results are reported in parts per million, with the exception of settleable solids, which are reported in cubic centimeters per liter.

Of the determinations made on the samples, those used in judging the relative performance of the different tanks were settleable solids, total residue on evaporation, turbidity, and oxygen consumed from permanganate. The first three determinations give a measure of the suspended and dissolved solids which the tank does not remove. The permanganate test measures the oxidizable material in the effluent, and therefore gives a further measure of its quality.

Measurement of Scum and Sludge.—At the end of the test the total accumulation of scum and sludge was measured in each chamber as follows:

The thickness of the scum was determined by the device shown in Fig. 8, which consists of a metal plate (*D*) mounted on the end of a ⅜-inch pipe so that the plate can be moved from a vertical to a horizontal position (or vice versa) by means of the wire control (*E*). The different positions of the plate are shown by the three views in Fig. 8. The plate (in vertical position) is forced down thru the scum and then turned to the horizontal position. The plate is then raised until it comes into contact with the undersurface of the scum, and the measuring rod is placed in a vertical position with one end in contact with the upper surface of the scum. A reading of the index (*F*) on the measuring rod

(*G*) then gives directly the thickness of the scum. The measuring rod is graduated to feet and hundredths of a foot reading downward from the top.

The surface line of the sludge at the bottom of the tank was located by the use of a small bottle mounted on the end of a graduated rod as shown in Fig. 9. The rod (*A*) is graduated to feet and hundredths of a foot from the top down. The valve at the mouth of the bottle is opened by the handle (*B*). The length of the steel rod (*C*) is such that when one end of it rests on the bottom of the tank, the other end indicates directly on the graduated rod (*A*) the distance between the bottom of the tank and the mouth of the bottle. The sludge line is determined with this device by first taking a sample from the clear liquid above the sludge line and then taking samples a little deeper each time until the bottle is filled with dark liquid. The reading of the upper end of the steel rod (*C*) on the graduated rod (*A*) at this last depth gives directly the depth of sludge in the bottom of the tank.

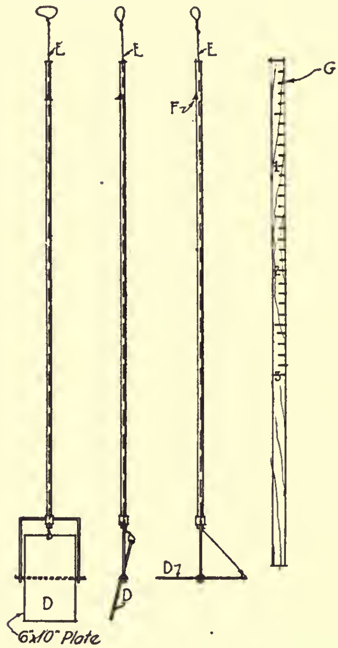

FIG. 8.—DEVICE FOR MEASURING THE THICKNESS OF SCUM

In making the scum and sludge measurements on the chambers which were more than 4 feet long, two or three complete readings were taken and the average used in computing the total scum and sludge for these chambers.

Temperature Records.—The temperature of the sewage in each chamber was taken at the time each sample was taken.

Duration and Conditions of Tests.—The dosing of the three tanks in which city sewage was treated (Tanks A, B, C) started November

22, 1922. There was some leakage from the tanks for a short time until the pores in the concrete became filled; sewage started to flow from the tank outlets December 11, 1922. Effluent samples were collected from December 12, 1922, to December 18, 1923.

The three-chamber tank (D), which treated farm sewage, was connected November 16, 1922. The tank leaked for a considerable time after being put into operation; no effluent flowed over the outlet until February 12, and the sewage level was below the outlet at times

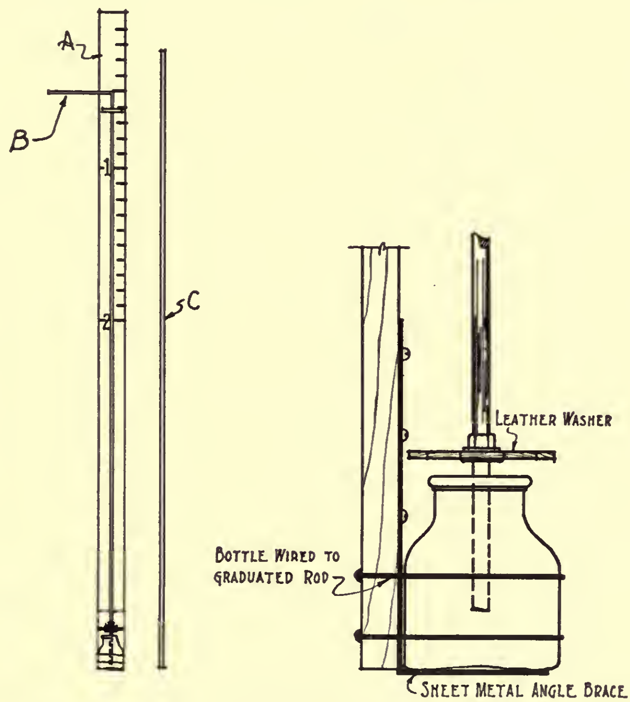

FIG. 9.—DEVICE FOR MEASURING THE DEPTH OF SLUDGE

until March 8, 1923. Samples were collected December 15, 1922, to December 19, 1923. This tank treated sewage from five people, and the sewer connections consisted of a toilet, a kitchen sink, and a bathtub.

The two-chamber tank (E) which treated farm sewage was connected November 18, 1922, and sewage flowed from the outlet November 27. Effluent samples were collected from December 15, 1922, to December 19, 1923. This tank treated sewage from five people, the connections consisting of a toilet, a kitchen sink, a bathtub, and a laundry drain.

During this investigation conditions were abnormal in Tanks D and E, in which farm sewage was treated, the influent to Tank E

TABLE 2.—CONDITIONS DURING COMPARISON OF SINGLE- AND MULTIPLE-CHAMBER SEPTIC TANKS

Tank	Inside dimensions	Number of chambers	Sewage treated: Kind of sewage	Sewage treated: Number of people	Sewage treated: Sewage flow per day	Total retention period	Put into operation	Sampling period	Samples from each sampling point in tank
					gals.	*hours*			
A	12'x3'x4'	3	City	..	359.5	72	11-22-22	12-12-22 12-18-23	54
B	12'x3'x4'	2	City	..	359.5	72	11-22-22	12-12-22 12-18-23	54
C	12'x3'x4'	1	City	..	359.5	72	11-22-22	12-12-22 12-18-23	54
D[2]	12'x3'x4'	3	Farm	5	140[1]	185[1]	11-16-22	12-15-22 12-19-23	51
E[3]	12'x3'x4	2	Farm	5	650[1]	40[1]	11-18-22	12-15-22 12-19-23	51

[1]Average. [2]Tank leaked until March 8, 1923. [3]Sewage diluted by leak from toilet.

TABLE 3.—AVERAGE CHEMICAL ANALYSES OF ALL SAMPLES OF EFFLUENT COLLECTED DURING STUDY OF SINGLE- AND MULTIPLE-CHAMBER SEPTIC TANKS

(Results are reported in parts per million, with the exception of settleable solids, which are reported in cubic centimeters per liter.)

	Average for tanks dosed with city sewage[1]						Average for tanks connected to farm houses[2]				
	3-chamber tank			2-chamber tank		1-chamber tank[3]	3-chamber tank			2-chamber tank[4]	
Chamber No.	A1 (4'x3')	A2 (4'x3')	A3 (4'x3')	B1 (8'x3')	B2 (4'x3')	C (12'x3')	D1 (4'x3')	D2 (4'x3')	D3 (4'x3')	E1 (8'x3')	E2 (4'x3')
Temperature, ° C.	14.2	14.3	14.2	14.2	14.2	14.2	12.1	11.9	11.9	13.6	13.6
Chlorin in chlorids	129	138	139	137	136	136	78.4	77.5	79.0	50.0	53.1
Alkalinity, methyl orange	495	528	544	536	520	544	594	601	627	505	570
Ammonia nitrogen	47.6	48.5	49.6	47.8	48.1	53.0	91.5	92.5	94.5	54.0	63.4
Albuminoid nitrogen	7.26	6.54	5.14	5.97	5.30	5.60	11.51	8.40	7.23	6.84	8.59
Nitrate nitrogen	.80	.61	.55	.69	.58	.61	.77	.68	.67	.60	.58
Nitrite nitrogen	.0396	.0006	.0005	.0006	.0002	.0006	.0003	.0001	.0002	.0006	.0017
Oxygen consumed	47.3	48.0	42.8	48.4	46.2	45.3	60.2	52.4	53.7	42.0	50.7
Turbidity	251	192	140	190	157	177	267	209	175	193	187
Residue on evaporation	1265	1180	1000	1095	1000	1136	966	845	826	785	885
Settleable solids	3.40	2.64	1.18	1.54	1.00	1.97	1.86	.45	.43	1.65	.32
Total scum and sludge, cu. ft.[5]	31.8	46.8	55.2	39.6	45.0	43.6	12.4	18.5	18.5	19.4	24.4

[1]The data for city sewage are averages for 54 samples collected December 12, 1922, to December 18, 1923. Tanks treating city sewage received the same kind and amount of sewage thruout the period, while tanks connected to farm homes received sewage varying considerably in quality and in the amount of flow.
[2]The data for farm sewage are averages for 51 samples collected December 15, 1922, to December 19, 1923.
[3]No single-chamber tank was connected at a farm home.
[4]Owing to a leak in the toilet, sewage treated by this tank was diluted with a large quantity of water.
[5]The data given for scum and sludge represent the total accumulation for the chamber and all previous chambers.

TABLE 4.—AVERAGE ANALYSES OF 54 SAMPLES OF EFFLUENT FROM SEPTIC TANK CHAMBERS OF DIFFERENT RETENTION PERIODS (CITY SEWAGE)[1]

(54 samples, collected December 12, 1922, to December 18, 1923)

Chamber No.	A1 24-hour capacity (4'x3'x4')	B1 48-hour capacity (8'x3'x4')	C 72-hour capacity (12'x3'x4')
Oxygen consumed	47.3	48.4	45.3
Turbidity	251	190	177
Residue on evaporation	1265	1095	1136
Settleable solids	3.40	1.54	1.97
Total scum and sludge, cu. ft.	31.8	39.6	43.6

[1]Comparison of effluents from sampling points *a1*, *b1*, and *c* in Fig. 4. In effect, each chamber functions as a single-chamber tank or as the first chamber of a multiple-chamber tank.

TABLE 5.—AVERAGE ANALYSES OF 54 SAMPLES OF EFFLUENT FROM SINGLE- AND MULTIPLE-CHAMBER SEPTIC TANKS OF 72-HOUR TOTAL CAPACITY (CITY SEWAGE)[1]

(Collected December 12, 1922, to December 18, 1923)

Sampling point	*a3* (3-chamber tank)	*b2* (2-chamber tank)	*c* (1-chamber tank)
Oxygen consumed	42.8	46.2	45.3
Turbidity	140	157	177
Residue on evaporation	1000	1000	1136
Settleable solids	1.18	1.00	1.97
Total scum and sludge,[2] cu. ft.	55.2	45.0	43.6

[1]Comparison of effluents from sampling points *a3*, *b2*, and *c* in Fig. 4.
[2]Total accumulation in all chambers.

TABLE 6.—AVERAGE ANALYSES OF 54 SAMPLES OF EFFLUENT FROM SINGLE- AND MULTIPLE-CHAMBER SEPTIC TANKS OF 48-HOUR TOTAL CAPACITY (CITY SEWAGE)[1]

(Collected December 12, 1922, to December 18, 1923)

Sampling point	*a2* (2-chamber tank)	*b1* (1-chamber tank)
Oxygen consumed	48.0	48.4
Turbidity	192	190
Residue on evaporation	1180	1095
Settleable solids	2.64	1.54
Total scum and sludge, cu. ft.[2]	46.8	39.6

[1]Comparison of effluents from sampling points *a2* and *b1* in Fig. 4.
[2]Total accumulation in all chambers.

being diluted by a leaky toilet and Tank D leaking until the pores in the concrete became filled. However, sufficient data were obtained to justify the drawing of conclusions.

Results Obtained

The data given in Tables 2 and 3, showing briefly the conditions during the study and the average chemical analyses of the effluent over the entire test, make it possible to study the effect of variation in retention period on the efficiency of operation, and the comparative efficiency of single-chamber and multiple-chamber tanks. Information on the functioning of the tanks at two different stages of their operation is given in Tables 15 and 16 in the Appendix.

In making comparisons of data from Tables 3, 15, and 16, it should be remembered that the tanks treating city sewage received the same kind and amount of sewage thruout the period, while the tanks connected to farm houses received sewage which varied considerably in quality and in amount of flow. Direct comparisons therefore can hardly be made of the results obtained from the city sewage and those from the farm sewage.

Tables 4, 5, and 6 are compiled from Table 3, the results secured with chambers of different capacity and retention period being given in Table 4; those secured with one-, two-, and three-chamber tanks of 72-hour total retention period in Table 5; and those secured with one- and two-chamber tanks of 48-hour retention period, in Table 6.

Data on sludge accumulation for the different chambers are shown in Tables 7 and 8. Figs. 10 to 16 show curves with tank temperature, turbidity, residue on evaporation, and settleable solids plotted against time for the following chambers: A1, B1, B2, C, D1, E1, and E2.

Discussion and Conclusions

A study of the data collected in this second investigation revealed the following facts and leads to the conclusions and recommendations indicated.

1. The chamber with a 48-hour capacity (B1) showed a marked improvement over the chamber having a 24-hour capacity, (A1) as indicated by lower turbidity, less residue on evaporation, and less settleable solids (Table 4). As between Chamber C, having a 72-hour capacity, and Chamber B1, having a 48-hour capacity, the 72-hour tank had the advantage of lower oxygen consumption and lower turbidity. On the other hand, the 48-hour tank showed less residue on evaporation, less settleable solids, and a smaller scum and sludge accumulation. These last three points, together with the smaller cost of the 48-hour tank, would give it the advantage for the first year's operation, but would make no provision for sludge storage over a period of years. In the design of a single-chamber tank or of the first chamber of a multiple-chamber tank, an allowance might well be made

for a 48-hour effective retention period with 50 percent additional capacity for sludge storage, or a total retention period of 72 hours. This would insure efficient operation for a longer period without the necessity of cleaning the tank.

2. Of the tanks with a total retention period of 72 hours and with the same dosing of city sewage, the two-chamber tank (B) gave the best results (Table 5). The advantage of the two-chamber tank over the three-chamber tank was evidently due to the fact that the retention

TABLE 7.—SCUM AND SLUDGE ACCUMULATION IN CHAMBERS OF TANKS TREATING CITY SEWAGE DURING STUDY OF SINGLE- AND MULTIPLE-CHAMBER SEPTIC TANKS[1]

Chamber No.	A1 (4'x3')	A2 (4'x3')	A3 (4'x3')	B1 (8'x3')	B2 (4'x3')	C (12'x3')
	ft.	*ft.*	*ft.*	*ft.*	*ft.*	*ft.*
Depth of scum	1.90	.45	.10	1.00	.05	.63
Depth of sludge	.75	.80	.60	.65	.40	.58
Total depth of scum and sludge	2.65	1.25	.70	1.65	.45	1.21
	cu. ft.	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*
Volume of scum and sludge	31.8	15.0	8.4	39.6	5.4	43.5

[1]The tanks were put in operation November 22, 1922, and the above measurements made December 17, 1923.

TABLE 8.—SCUM AND SLUDGE ACCUMULATION IN CHAMBERS OF TANKS TREATING FARM SEWAGE DURING STUDY OF SINGLE- AND MULTIPLE-CHAMBER SEPTIC TANKS[1]

Chamber No.	D1 (4'x3')	D2 (4'x3')	D3 (4'x3')	E1 (8'x3')	E2 (4'x3')
	ft.	*ft.*	*ft.*	*ft.*	*ft.*
Depth of scum	.63	.01	0.00	.21	.02
Depth of sludge	.40	.50	....[2]	.60	.40
Total depth of scum and sludge	1.03	.51	....	.81	.42
	cu. ft.	*cu. ft.*		*cu. ft.*	*cu. ft.*
Volume of scum and sludge	12.4	6.1	....	19.4	5.05

[1]The tanks were put into operation November 16 and 18, 1922, and the above measurements were made December 17, 1923.
[2]The sludge in chamber D3 was less than .4 foot deep and could not be measured conveniently.

period and distribution of scum and sludge in each chamber of the two-chamber tank was most favorable for settlement and digestion of solids by bacterial action. The advantage of the two- and three-chamber tanks over the single-chamber was no doubt due to additional baffling; furthermore, most of the sludge in the two- and three-chamber tanks was stored in the first chambers, and considerable gassing and disturbance was thereby eliminated near the outlet of these tanks (Table 7).

3. With tanks of 48-hour total retention period, the single-chamber tank gave better results than the two-chamber tank, as evidenced by study of effluents from *a2* and *b1* (Table 6 and Fig. 4). The unfavorable results with the small two-chamber tank were probably

due to the fact that after operating for a time, a large part of the first chamber was occupied by scum and sludge, thus reducing the effective capacity and retention period below that required for proper settlement and digestion of solids (Table 7).

With tanks of a 72-hour total capacity there was an advantage in using two chambers, but with tanks having a 48-hour total capacity

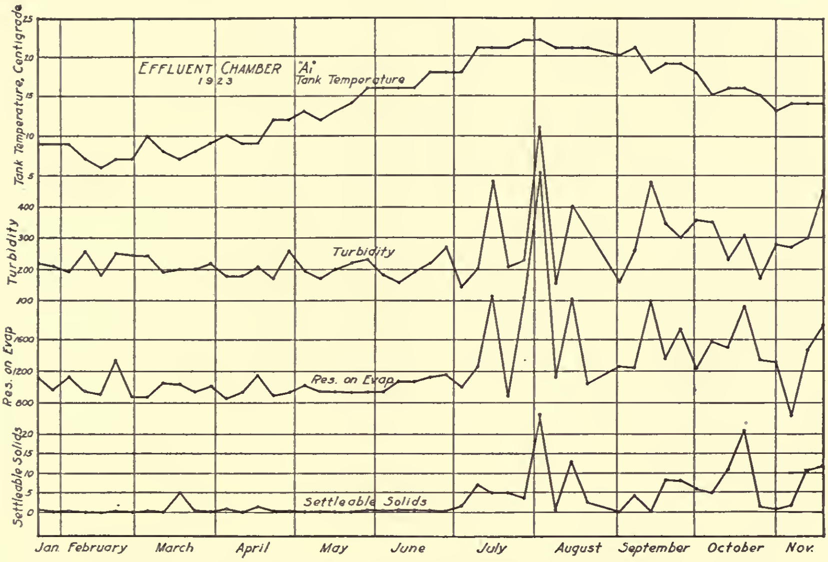

FIG. 10.—VARIATIONS IN EFFLUENT FROM CHAMBER A1, FIRST CHAMBER OF TANK A (FIG. 4): CITY SEWAGE

two chambers were no advantage. In other words, a two-chamber tank is desirable if the tank is of sufficient size to provide a 48-hour capacity, or more, in the first chamber.

4. Each additional chamber produced considerable improvement in the quality of the effluent over that produced by the preceding chamber. Similar results were obtained with both city and farm sewage (Table 3).

5. Curves showing tank temperature, turbidity, residue on evaporation, and settleable solids plotted against time for chambers A1, B1, C, D1, and E1 (Figs. 10, 11, 13, 14, 15) indicate that the effluent was relatively high in solids during the summer months while the tank temperature was high.

6. Curves showing tank temperature and settleable solids plotted against time for chambers A1, B1, B2, and C (Figs. 10 to 13) indicate higher settleable solids after several months' operation even for periods with approximately the same tank temperature. This increase was probably the result of scum and sludge accumulation.

7. Curves with turbidity, residue on evaporation, and settleable solids plotted against time show considerable variation in the quality of the effluent, especially for settleable solids (Figs. 10, 11, 13, 14, 15).

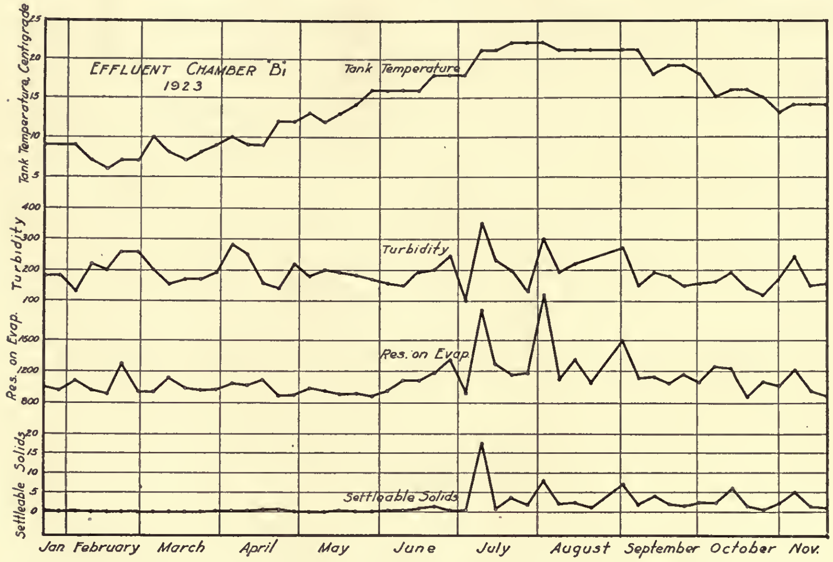

FIG. 11.—VARIATIONS IN EFFLUENT FROM CHAMBER B1, FIRST CHAMBER OF TANK B: CITY SEWAGE

FIG. 12.—VARIATIONS IN EFFLUENT FROM CHAMBER B2, SECOND CHAMBER OF TANK B: CITY SEWAGE

This variation is undoubtedly due to the fact that as sludge accumulates, gassing takes place intermittently and causes the discharge

Fig. 13.—Variations in Effluent From Chamber C: City Sewage

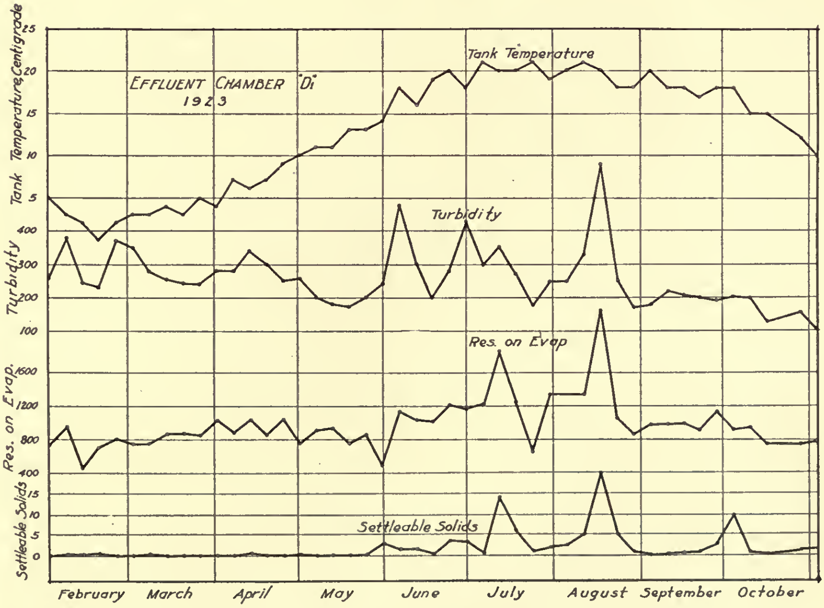

Fig. 14.—Variations in Effluent From Chamber D1, First Chamber of Tank D: Farm Sewage

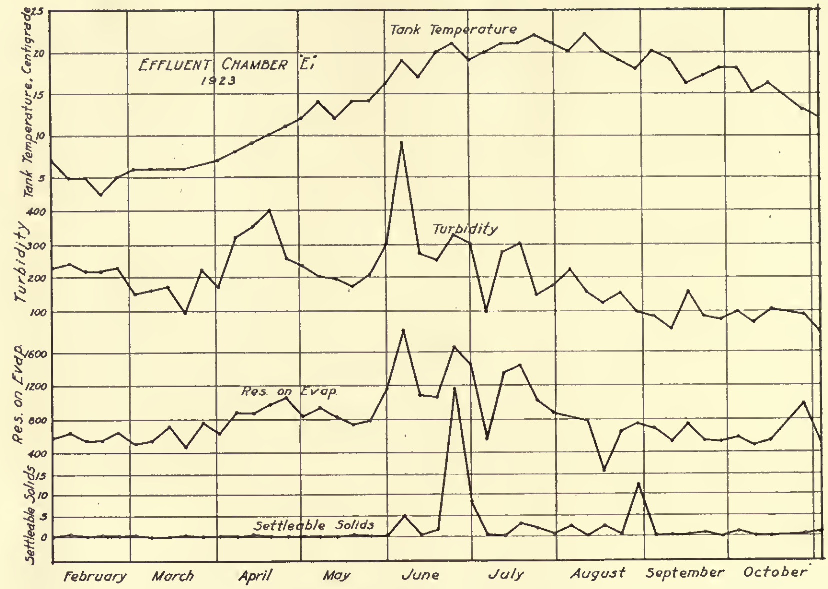

FIG. 15.—VARIATIONS IN EFFLUENT FROM CHAMBER E1, FIRST CHAMBER OF TANK E: FARM SEWAGE

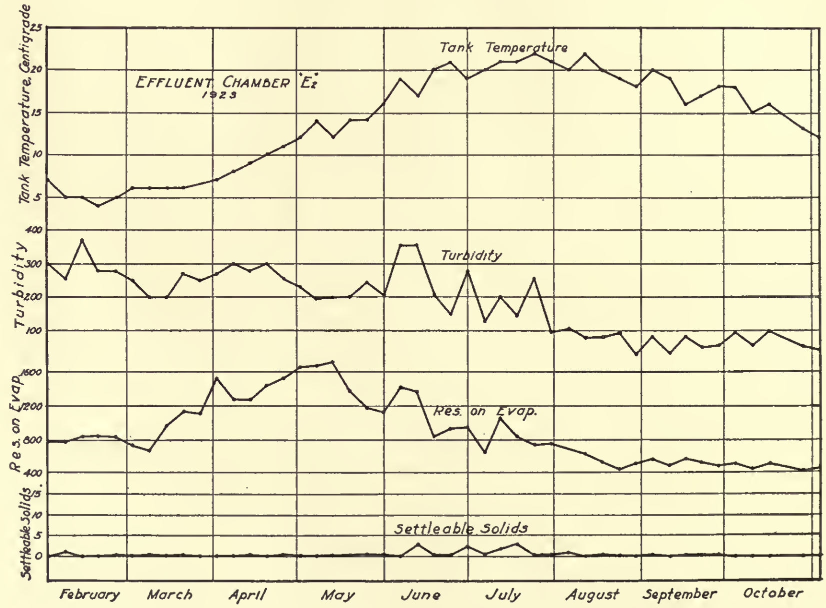

FIG. 16.—VARIATIONS IN EFFLUENT FROM CHAMBER E2, SECOND CHAMBER OF TANK E: FARM SEWAGE

of considerable amounts of flock at one time, thus producing a marked variation in the quality of the effluent.

III—STUDY OF TWO-CHAMBER SEPTIC TANKS HAVING DIFFERENTLY SHAPED CROSS-SECTIONS

The purpose of this third investigation was to secure data on the effect of differences in shape of cross-section on the efficiency of septic tanks and to secure additional data on the performance and behavior of two-chamber septic tanks. Comparisons were made between two-chamber tanks of the same capacity that differed in shape of cross-section.

Description of Experimental Tanks

Three two-chamber septic tanks of different cross-sections were compared while treating city sewage, being dosed with the same apparatus as that used in Investigation No. 2. The two-chamber tank which was used to treat city sewage in the previous study was cleaned out and used again in this test. The other two tanks were rebuilt, so that all three were compared as two-chamber tanks having the same capacity but differing in shape of cross-section. Plan views of the tanks are shown at F, G, and H in Fig. 17, and general details in Fig. 6. A bird's-eye view is given in Fig. 18.

The first chamber of each tank was 8 feet long and the second 4 feet long. The tanks were of the following cross-section: narrow tank, 2.4 feet wide, 5-foot depth of sewage; medium tank, 3 feet wide, 4-foot depth of sewage; wide tank, 4 feet wide, 3-foot depth of sewage. The cross-sectional area and capacity of each tank was, of course, the same.

Three tanks treating farm sewage, identical with those treating city sewage, were included in the study. The two-chamber tank used in the first investigation to treat sewage from one of the farm homes was cleaned out and operated again; the other tank on the University farm was rebuilt; and a third one was constructed and connected to a house on the University farm. Plan views of the tanks are shown at I, J, and K in Fig. 17, and general details in Fig. 6. The three tanks treating city sewage and the three treating farm sewage were put into operation at about the same time.

Dosing Tanks with City Sewage.—Dosing with city sewage was carried on in the same manner as in the previous investigation. A daily charge of 359.5 gallons was made to each tank. This was equivalent to a total retention period in each tank of 72 hours.

Flow of Sewage to Farm Tanks.—The three tanks installed at farm homes received sewage which varied in quality and in amount of flow. The tank of narrow cross-section (I) received sewage from a home of four people, in which the average flow was 95 gallons a day

(23.7 gallons per capita). The medium-width tank (J) received sewage from a home of four to six people (average of five people), in which the average sewage flow was 219 gallons a day (43.7 gallons per capita). The wide tank (K) received sewage from a home of five people, and the average flow was 175 gallons a day (35 gallons per capita).

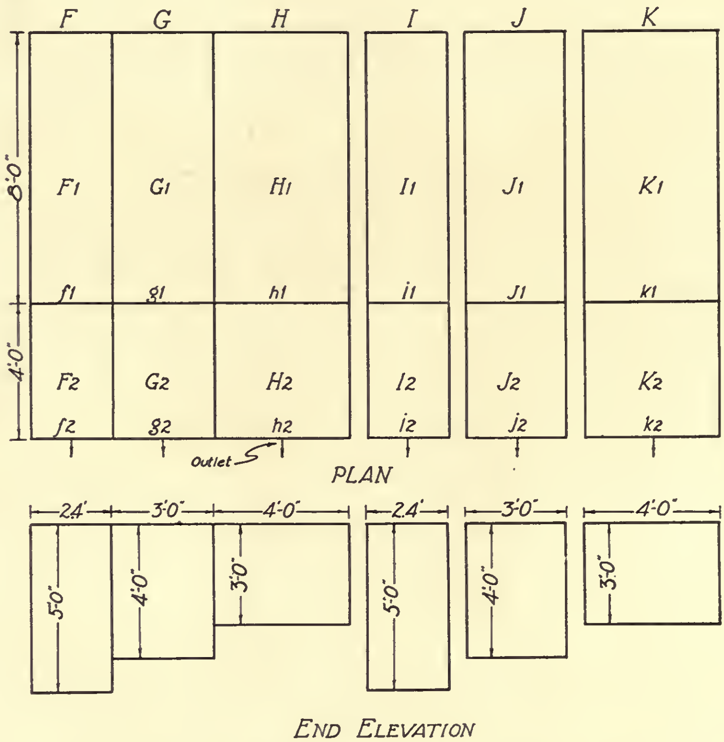

FIG. 17.—PLAN AND END ELEVATION OF EXPERIMENTAL SEPTIC TANKS USED IN STUDY OF DIFFERENTLY SHAPED CROSS-SECTIONS

Tanks F, G, and H were dosed with city sewage and Tanks I, J, and K were connected with farm homes. These tanks differ from those used in Study II (Fig. 4) in the relative shape of cross-section and in the number of chambers per tank. The dimensions indicate inside measurements except those given for depth, which indicate the depth of sewage standing in the tank.

Collecting and Analyzing Samples.—Samples were collected in the same manner as in the study of single- and multiple-chamber tanks, except that they were taken from each sampling point every eight days instead of every six. The sampling dates were for each day of the week in rotation, that is, Sunday, Monday, Tuesday, etc. The method of chemical analysis also was the same.

Measurements of Scum and Sludge.—Scum and sludge measurements were made in the same manner as in the investigation on single- and multiple-chamber tanks except that they were taken at intervals thruout the study in order to secure data on the rate of accumulation. The measurements were continued on the tanks at the farm homes for 14 months after the analysis of effluent was discontinued, in order to secure data over a period of several years.

Duration and Conditions of Test.—During this study of cross-sections the tanks treating both city and farm sewage were discharg-

FIG. 18.—BIRD'S-EYE VIEW OF EXPERIMENTAL SEPTIC TANKS F, G, AND H DOSED WITH CITY SEWAGE

ing from the outlets shortly after being put into operation. The dosing and sampling of the three tanks treating city sewage was started early in July, 1924, and was continued until October 12, 1925, except for a period of 4½ months (from October 30, 1924, to the middle of March, 1925), when no attendant was available to take care of the dosing. Scum and sludge measurements made before the tanks were shut down and at the time they were put into operation again, indicated a partial settlement of scum but little change in the aggregate volume of scum and sludge while the tanks were idle (Fig. 21).

Effluent samples were collected from the tanks treating farm sewage from July 8, 1924, to December 11, 1925, except from October to March while the city sewage tanks were shut down. The tank of narrow cross-section (I), treating sewage from four people in a farm home where the plumbing fixtures consisted of a toilet, a kitchen sink, a bathtub, a lavatory, and a laundry drain, was connected June 4, 1924. The medium tank (J), which treated sewage from four to six people in a farm home where the fixtures consisted of a toilet, a kitchen sink, a bathtub, and a laundry drain, was connected June 12, 1924. The wide tank (K), treating sewage from five people in a farm home where the fixtures consisted of a toilet, a kitchen sink, and a bathtub, was connected June 9, 1924.

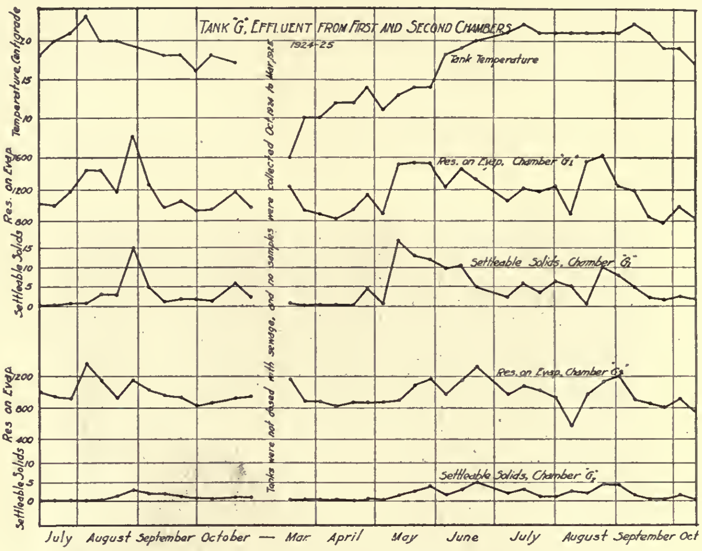

FIG. 19.—VARIATIONS IN EFFLUENT FROM CHAMBERS G1 AND G2 OF TANK G (FIG. 17): CITY SEWAGE

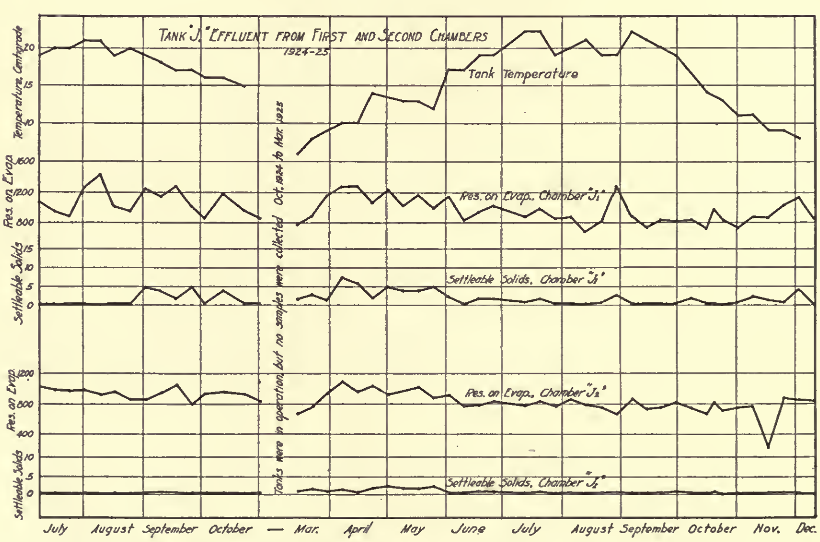

FIG. 20.—VARIATIONS IN EFFUENT FROM CHAMBERS J1 AND J2 OF TANK J: FARM SEWAGE

TABLE 9.—CONDITIONS DURING COMPARISON OF SEPTIC-TANK CROSS-SECTIONS

Tank	Inside dimensions	Number of chambers	Sewage treated: Kind of sewage	Sewage treated: Number of people	Sewage treated: Sewage flow per day	Total retention period	Put into operation	Sampling period[1]	Samples from each sampling point in tank
					gals.	*hours*			
F	12′x2.4′x5′	2	City	..	359.5	72	6–30–24	7–12–24 10–12–25	40
G	12′x3′x4′	2	City	..	359.5	72	6–30–24	7–12–24 10–12–25	40
H	12′x4′x3′	2	City	..	359.5	72	6–30–24	7–12–24 10–12–25	40
I	12′x2.4′x5′	2	Farm	4	95[2]	273[2]	6– 4–24	7– 8–24 12–11–25	50
J	12′x3′x4′	2	Farm	5	219[2]	118[2]	6–12–24	7– 8–24 12–11–25	50
K	12′x4′x3′	2	Farm	5	175[2]	148[2]	6– 9–24	7– 8–24 12–11–25	50

[1]Tanks F, G, and H were not dosed or sampled from October, 1924, to March, 1925. No samples were collected from Tanks I, J, and K from October, 1924 to March, 1925.

[2]Average.

TABLE 10.—AVERAGE CHEMICAL ANALYSES OF ALL SAMPLES OF EFFUENT COLLECTED DURING STUDY OF SEPTIC-TANK CROSS-SECTIONS

(Results are reported in parts per million, with the exception of settleable solids, which are reported in cubic centimeters per liter.)

	Average for tanks dosed with city sewage[1]						Average for tanks connected to farm houses[2]					
	Narrow tank		Medium tank		Wide tank		Narrow tank		Medium tank		Wide tank	
Chamber No.	F1 (8x2.4x5)	F2 (4x2.4x5)	G1 (8x3x4)	G2 (4x3x4)	H1 (8x4x3)	H2 (4x4x3)	I1 (8x2.4x5)	I2 (4x2.4x5)	J1 (8x3x4)	J2 (4x3x4)	K1 (8x4x3)	K2 (4x4x3)
Temperature, ° C.	17.5	17.5	17.5	17.5	17.4	17.4	14.3	14.6	16.0	16.0	16.8	16.8
Chlorin in chlorids	131	123	128	125	130	119	48.8	46.9	61.4	61.2	51.3	49.5
Alkalinity, methyl orange	577	590	578	610	574	584	620	620	630	641	566	575
Ammonia nitrogen	45.3	47.6	49.1	48.0	43.9	44.1	55.2	52.4	59.0	63.0	52.4	54.0
Albuminoid nitrogen	5.20	4.37	5.70	4.86	5.21	5.45	5.78	4.53	8.40	6.26	5.28	4.96
Nitrate nitrogen	.57	.45	.43	.40	.73	.42	1.21	1.04	.66	.56	.69	.59
Nitrite nitrogen	.0031	.0017	.0011	.0011	.0025	.0031	.2280	.2320	.0040	.0005	.0474	.0556
Oxygen consumed	67.0	59.1	72.0	60.6	88.3	58.4	67.0	56.9	70.5	62.7	67.0	45.6
Turbidity	250	164	252	147	211	148	246	157	324	225	234	112
Residue on evaporation	1130	981	1170	981	1030	961	1021	833	985	848	908	685
Settleable solids	2.76	1.72	4.29	1.42	2.79	.92	2.21	.40	1.87	.50	4.34	.50
Total scum and sludge, cu. ft.[3]	46.8	54.0	49.5	56.7	52.5	62.1	15.0	18.8	16.8	19.8	16.7	23.9

[1]The data for city sewage are averages for 40 samples collected July 12, 1924, to October 12, 1925.
[2]The data for farm sewage are averages for 50 samples collected July 8, 1924, to December 11, 1925.
[3]The data given for scum and sludge is the total accumulation for the chamber and all previous chambers.

Results Obtained

A basis for studying the effect of shape of cross-section on the operation of septic tanks may be found in the analytical data summarized in Table 10, which shows average chemical analyses of effluent

TABLE 11.—SCUM AND SLUDGE ACCUMULATION IN CHAMBERS OF TANKS TREATING CITY SEWAGE DURING STUDY OF TANK CROSS-SECTIONS[1]

Chamber No.	F1 (8'x2.4'x5')	F2 (4'x2.4'x5')	G1 (8'x3'x4')	G2 (4'x3'x4')	H1 (8'x4'x3')	H2 (4'x4'x3')
	ft.	*ft.*	*ft.*	*ft.*	*ft.*	*ft.*
Depth of scum	1.13	.05	.88	.05	.61	.05
Depth of sludge	1.31	.70	1.18	.55	1.03	.55
Total depth of scum and sludge	2.44	.75	2.06	.60	1.64	.60
	cu. ft.	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*
Volume of scum and sludge	46.8	7.2	49.5	7.2	52.5	9.6

[1]The tanks were put in operation June 30, 1924, and the above measurements were made October 14, 1925. Tanks were idle October, 1924, to March, 1925.

TABLE 12.—SCUM AND SLUDGE ACCUMULATION IN CHAMBERS OF TANKS TREATING FARM SEWAGE DURING STUDY OF TANK CROSS-SECTION[1]

Chamber No.	I1 (8'x2.4'x5')	I2 (4'x2.4'x5')	J1 (8'x3'x4')	J2 (4'x3'x4')	K1 (8'x4'x3')	K2 (4'x4'x3')
	ft.	*ft.*	*ft.*	*ft.*	*ft.*	*ft.*
Depth of scum	.03	.00	.40	.00	.02	.00
Depth of sludge	.75	.40	.30	.25	.50	.45
Total depth of scum and sludge	.78	.40	.70	.25	.52	.45
	cu. ft.	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*
Volume of scum and sludge	15.0	3.84	16.8	3.0	16.7	7.2

[1]These measurements were taken about three months before analysis of effluent was discontinued. The tanks were put into operation June 4 to 12, 1924, and measurements made September 7, 1925. Scum and sludge measurements were continued for 14 months after the analysis of effluent was discontinued; the results of the latter measurements are shown in Table 13 and Fig. 22.

TABLE 13.—SCUM AND SLUDGE ACCUMULATION FROM FARM SEWAGE DURING A PERIOD OF 2 YEARS 8½ MONTHS

Chamber No.	I1 (8'x2.4'x5')	I2 (4'x2.4'x5')	J1 (8'x3'x4')	J2 (4'x3'x4')	K1 (8'x4'x3')	K2 (4'x4'x3')
Volume of scum and sludge, cu. ft.	20.4	11.2	40.3	6.7	32.3	16.2
Percentage of chamber capacity occupied by scum and sludge	21.2	23.3	42.0	13.9	33.6	33.8

from two-chamber tanks of equal capacity but of narrow-deep, medium, and wide-shallow cross-section. Table 9 outlines the conditions maintained during these tests. Information on the functioning of the tanks at two different stages of their operation may be secured from Tables 17 and 18. In this instance again direct comparisons between the tanks treating city sewage and those receiving farm sewage should not be made, since those treating city sewage received the same kind and amount of sewage, while those treating farm sewage received a sewage flow varying in quality and in amount.

Tank temperature, residue on evaporation, and settleable solids plotted for the first and second chambers of Tank G, are shown in Fig. 19. Fig. 20 shows similar curves for the first and second chambers of Tank J. Table 11 gives the results of scum and sludge

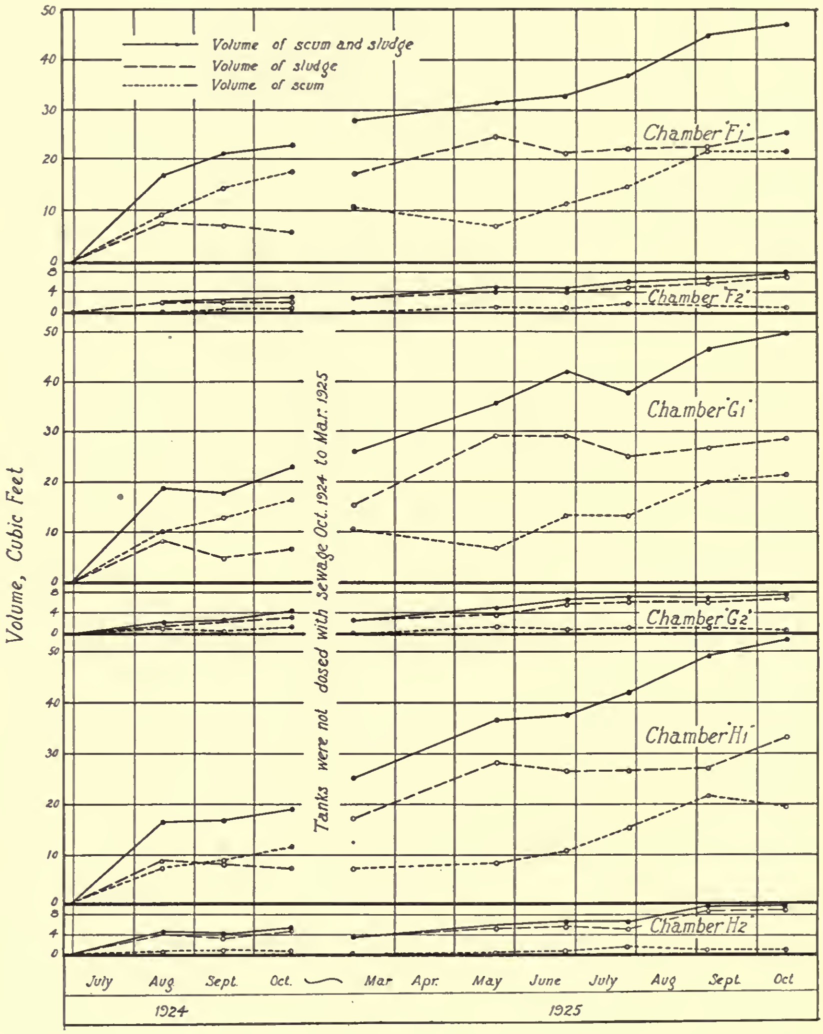

FIG. 21.—RATE OF SCUM AND SLUDGE ACCUMULATION WITH CITY SEWAGE

Comparing the first and second chambers of each tank, the scum and sludge accumulation is consistently greater in the first chamber. Little difference in rate of scum and sludge accumulation occurred for tanks of varying depths. The rate of accumulation was less during June and July because the high tank temperatures resulted in a more complete digestion of the solids. In both Studies II and III the scum and sludge accumulations were greater with city sewage than with farm sewage.

measurements made on tanks treating city sewage, and Table 12 shows results of similar measurements made on tanks treating farm sewage.

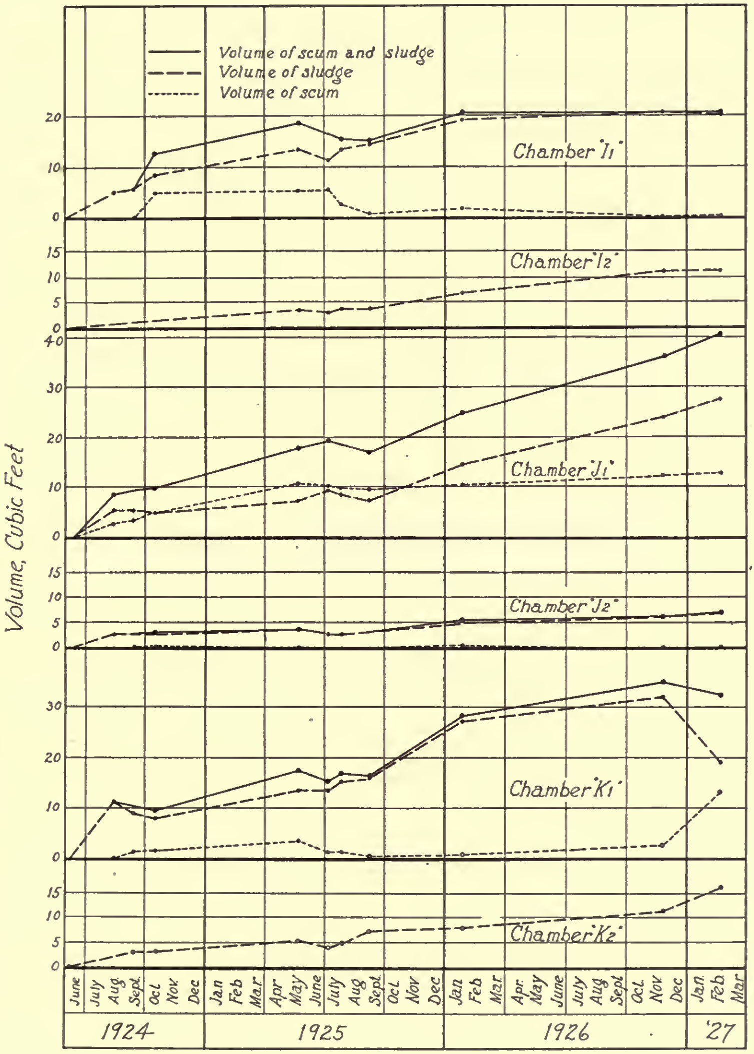

FIG. 22.—RATE OF SCUM AND SLUDGE ACCUMULATION WITH FARM SEWAGE

Only an occasional trace of scum appeared in Chambers I2 and K2, hence the one dotted line for these chambers represents sludge accumulation. No measurements were taken during the summer of 1926, but it is probable that high temperatures at that time caused a somewhat similar reduction of scum and sludge to that observed the previous summer. The tanks were put in operation in June, 1924, and the curves show the accumulation during the period of 2 years 8½ months.

A number of curves are included in Figs. 21 and 22 which show rate of scum and sludge accumulation. The scum and sludge accumulation in Tanks I, J, and K over a period of 2 years 8½ months are shown in Table 13, and Fig. 23 indicates graphically the accumulation in Tank J.

Discussion and Conclusions

A study of the data collected in this investigation revealed the following facts and leads to the conclusions and recommendations indicated:

1. No definite relationship between the shape of cross-section of a septic tank and the efficiency of its operation was discovered (Table

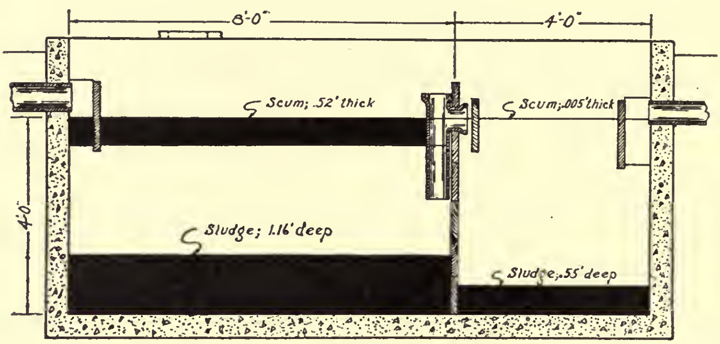

FIG. 23.—LONGITUDINAL SECTION OF TANK J

The black areas indicate scum and sludge accumulations after 2 years, 8½ months. Data on the scum and sludge accumulation of all the tanks used in Study III are shown graphically in Figs. 21 and 22.

10). Since the effective depth gradually becomes less as scum and sludge accumulate, it would seem logical to select a cross-section of reasonable sewage depth (3½ to 4½ feet) which would provide the required capacity with the most economical construction (considering relative costs of floor, walls, reinforced cover, etc.), and at the same time provide a tank length which would be satisfactory for the settlement of suspended material.

2. The effluent from the second chambers of all tanks (with both city and farm sewage) showed a marked improvement over the effluent from the first chambers (Table 10). Similar results were obtained in the investigation of single- and multiple-chamber tanks. Thus in both investigations a comparison of one-chamber tanks with two-chamber tanks of 50 percent larger capacity shows a much better effluent from the two-chamber tanks. The advantage of the two-chamber tanks is probably due partly to additional baffling and reduction of gassing near the outlets, and partly to the additional capacity provided.

3. The narrow, medium, and wide tanks treating farm sewage had an average total retention period of 273, 118, and 148 hours respectively (Table 9). The effluent from the second chamber of each of these tanks showed considerable improvement over that from the first chamber (Table 10). Considering the long retention periods of these tanks, the results indicate that it is good practice to allow ample capacity in the design of farm septic tanks. Some factors to be considered in deciding upon the capacity of the tank are: quality of effluent desired, cost of constructing tank, and cost of maintenance. (The cost of cleaning would be less for a large tank since fewer cleanings are required).

4. The curves for rate of scum and sludge accumulation (Figs. 21 and 22) show in general a gradual increase in combined volume. The decrease during June, July, and August, 1925, in tanks treating farm sewage (Fig. 22) was apparently due to the better digestion of solids which takes place during periods of higher tank temperature, and also to the passing out of more solids with the effluent during periods of high tank temperature. (During the previous study the effluent was high in solids while the tank temperature was high). No scum and sludge measurements were taken during the summer of 1926, but it is probable that a decrease in volume occurred similar to that of the previous summer.

5. Curves for scum and sludge (Fig. 22) indicate an unloading of sludge from Chamber K1 into K2 during December, 1926, and January and February, 1927. This was evidently due to gassing in K1, and the consequent rising of sludge from the bottom of the chamber and an increase in scum volume, the gassing and disturbance increasing the solids carried over into K2. The additional chamber was of special advantage in preventing large amounts of solids from passing into the final disposal tile.

6. In designs for septic tanks allowance should be made for scum and sludge storage in order that efficient operation may be assured for considerable periods without cleaning. The volume of scum and sludge accumulation during a period of 2 years 8½ months for septic tanks treating sewage from three different farm homes is given in Table 13. The average accumulation per tank during this time was 42.36 cubic feet, an equivalent accumulation of 3.35 cubic feet per person per year. During the 2 years 8½ months of operation the average volume of scum and sludge in the first chambers of the three tanks was 31 cubic feet, or 32.3 percent of the capacity of the chamber, and the average volume in the second chambers was 11.36 cubic feet, or 23.7 percent of the capacity of the chamber. These chambers were larger than ordinarily recommended. With tank chambers of the size shown in Fig. 25 a larger percentage of the tank capacity would be occupied by scum and sludge; on the other hand, under normal conditions, with a

concrete slab and earth-fill covering (instead of plank), more favorable temperatures should exist for sludge digestion. With a two-chamber tank 3 feet wide, having a 4-foot depth of sewage and chamber lengths of 6 feet and 3 feet, a similar accumulation of 31 cubic feet would occupy 43 percent of the capacity of the first chamber, and an accumulation of 11.36 cubic feet would occupy 31.5 percent of the capacity of the second chamber.

IV—RECOMMENDATIONS FOR THE DESIGN OF SIMPLE FARM SEPTIC TANKS

The following recommendations for the design of farm septic tanks are based upon the results of the three foregoing investigations:

1. Make allowance for an average sewage flow from different-sized farm homes as follows:

    7 people, 25 gallons per capita per day
    9 people, 23 gallons per capita per day
    12 people, 20 gallons per capita per day
    15 people, 18 gallons per capita per day

2. For a single-chamber tank provide an effective retention period of 48 hours, with an allowance of 50 percent additional capacity for sludge storage, or a total retention period of 72 hours of sewage flow. (Allowance is made for sludge storage in order to make possible longer service without cleaning the tank).

3. For a more efficient plant use a two-chamber tank. Provide a retention period of 72 hours in the first chamber (effective retention period of 48 hours, with a 50 percent additonal capacity for sludge storage) and an additional retention period of 36 hours in the second chamber, or a total retention period of 108 hours.

4. Make the minimum-sized tank large enough for 7 people: (a) in order to maintain ample tank dimensions for proper settlement of solids; (b) to allow for additional people in the house; (c) because the reduction in cost is small for tanks under this suggested minimum; (d) with less than 7 people, the additional capacity insures more efficient operation and less frequent cleaning.

TABLE 14.—SUGGESTED CAPACITY AND DIMENSIONS FOR SEPTIC TANKS TO ACCOMMODATE DIFFERENT NUMBERS OF PEOPLE

Number of people	Sewage flow per person per day	Capacity required in first chamber for 72-hour retention		Effective cross-section	Length for 1-chamber tank or for first chamber of 2-chamber tank[1]	Length for second chamber of 2-chamber tank
	gals.	*gals.*	*cu. ft.*			
7	25	525	70	3'x4'	6'-0"	3'-0"
9	23	620	83	3'x4'	7'-0"	3'-6"
12	20	720	96	3'x4'	8'-0"	4'-0"
15	18	810	108	3'x4'	9'-0"	4'-6"

[1]The lengths given in the sixth column and an effective cross-section measuring 3'x4' provide approximately the capacities given in the fourth column.

5. Use a tank cross-section 3 feet wide with a 4-foot depth of sewage. (This is suggested as an economical cross-section for tanks accommodating 7 to 15 people).

6. Use the data given in Table 14 for the suggested capacities, length of chambers, etc., for different numbers of people.

7. Refer to Fig. 24 for a suggested design for a single-chamber septic tank, and to Fig. 25 for a two-chamber tank with a partition between the chambers designed to retain scum and sludge in the first chamber.

8. A single-chamber tank of the design shown in Fig. 24 has an

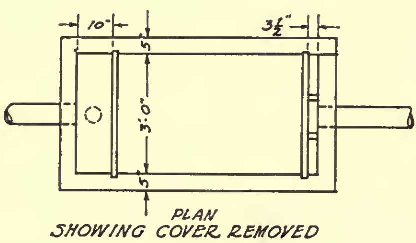

TABLE OF SIZES

NUMBER OF PEOPLE	DISTANCE - C -
7 or less	6'-0"
9	7'-0"
12	8'-0"
15	9'-0"

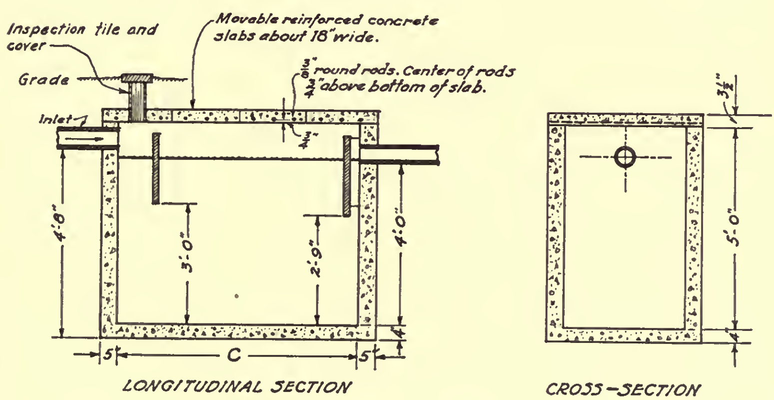

FIG. 24.—SUGGESTED DESIGN FOR A SINGLE-CHAMBER SEPTIC TANK

This single-chamber tank should give reasonably good service where the final disposal of the effluent is not a serious problem.

advantage over a two-chamber tank of the design shown in Fig. 25, in lower cost of construction, but the two-chamber tank has important advantages, as follows: (a) fewer solids pass out with the effluent; (b) there is less danger of clogging the final disposal tile; (c) the tank will operate efficiently for a longer period without cleaning; (d) because of the longer retention period fewer pathogenic organisms pass out with the effluent.[1]

[1]Statement based on results reported by Rockefeller Institute of Medical Research regarding the life of typhoid and dysentery bacilli in septic tanks.

9. Considering the above advantages, the two-chamber tank is recommended for best results and might well be considered for all conditions. However, the single-chamber tank should give reasonably good results where the final disposal of the effluent is not a serious problem. This would generally be true where one or more of the fol-

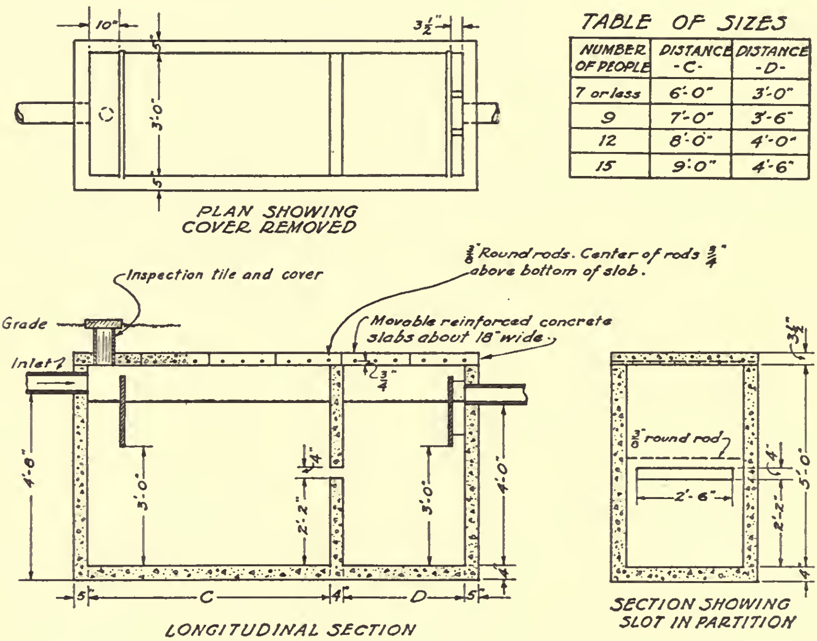

TABLE OF SIZES

NUMBER OF PEOPLE	DISTANCE -C-	DISTANCE -D-
7 or less	6'-0"	3'-0"
9	7'-0"	3'-6"
12	8'-0"	4'-0"
15	9'-0"	4'-6"

FIG. 25.—SUGGESTED DESIGN FOR A TWO-CHAMBER SEPTIC TANK

While more expensive to construct than the one-chamber tank, the above two-chamber tank has important advantages and might well be considered for all conditions. Fewer solids pass out with the effluent; there is less danger of clogging the final disposal tile; the tank will operate efficiently for a longer period without cleaning; and because of the longer retention period fewer pathogenic organisms will pass out with the effluent.

lowing conditions exist: (1) disposal tile located in porous, well-drained soil; (2) plenty of area available for disposal tile; (3) water supply in a well-protected location; and (4) small family using tank (two to four persons).

APPENDIX

TABLE 15.—AVERAGE CHEMICAL ANALYSES FOR FIRST HALF OF SAMPLES OF EFFLUENT COLLECTED DURING STUDY OF SINGLE- AND MULTIPLE-CHAMBER SEPTIC TANKS

(Results are reported in parts per million, with the exception of settleable solids, which are reported in cubic centimeters per liter.)

	Average for tanks dosed with city sewage[1]						Average for tanks connected to farm houses[2]				
	3-chamber tank			2-chamber tank		1-chamber tank[3]	3-chamber tank			2-chamber tank[4]	
Chamber No.	A1 (4'x3')	A2 (4'x3')	A3 (4'x3')	B1 (8'x3')	B2 (4'x3')	C (12'x3')	D1 (4'x3')	D2 (4'x3')	D3 (4'x3')	E1 (8'x3')	E2 (4'x3')
Temperature, ° C.	10.4	10.4	10.4	10.4	10.4	10.4	7.0	6.8	6.7	9.3	9.4
Chlorin in chlorids	135	154	155	152	152	150	73.6	76.0	80.2	44.5	59.0
Alkalinity, methyl orange	454	490	517	501	498	509	577	597	634	557	703
Ammonia nitrogen	33.8	33.2	33.0	32.8	31.0	34.7	70.3	69.0	73.5	52.3	79.0
Albuminoid nitrogen	6.50	6.58	4.51	4.98	4.76	4.65	9.76	7.21	6.98	6.05	10.70
Nitrate nitrogen	1.07	.74	.61	.89	.69	.70	.89	.81	.79	.64	.68
Nitrite nitrogen	.0789	.0011	.0009	.0011	.0003	.0012	.0006	.0003	.0004	.0011	.0035
Oxygen consumed	48.5	46.5	42.0	50.6	47.6	44.0	67.8	57.5	62.4	52.3	72.0
Turbidity	209	176	153	191	166	170	284	230	212	242	263
Residue on evaporation	1020	960	937	954	975	965	843	825	841	780	1133
Settleable solids	.44	.10	.09	.13	.06	.06	.38	.05	.25	.45	.22

[1]The data for city sewage are averages for 27 samples collected December 12, 1922, to June 9, 1923. Tanks treating city sewage received the same kind and amount of sewage thruout the period, while tanks connected to farm homes received sewage varying considerably in quality and in the amount of flow.

[2]The data for farm sewage are averages for 26 samples collected December 15, 1922, to June 12, 1923.

[3]No single-chamber tank was connected at a farm home.

[4]Owing to a leak in the toilet, sewage treated by this tank was diluted with a large quantity of water.

TABLE 16.—AVERAGE CHEMICAL ANALYSES FOR LAST HALF OF SAMPLES OF EFFLUENT COLLECTED DURING STUDY OF SINGLE- AND MULTIPLE-CHAMBER SEPTIC TANKS

(Results are reported in parts per million, with the exception of settleable solids, which are reported in cubic centimeters per liter.)

	Average for tanks dosed with city sewage[1]						Average for tanks connected to farm houses[2]				
	3-chamber tank			2-chamber tank		1-chamber tank[3]	3-chamber tank			2-chamber tank[4]	
Chamber No.	A1 (4'x3')	A2 (4'x3')	A3 (4'x3')	B1 (8'x3')	B2 (4'x3')	C (12 x3')	D1 (4'x3')	D2 (4'x3')	D3 (4'x3')	E1 (8'x3')	E2 (4'x3')
Temperature, ° C.	17.9	18.2	17.9	18.0	17.9	17.9	17.3	17.3	17.3	18.0	18.0
Chlorin in chlorids	122	122	123	123	120	121	83.2	78.7	77.5	56.0	47.3
Alkalinity, methyl orange	436	568	572	574	580	580	610	606	621	450	436
Ammonia nitrogen	61.6	64.0	66.5	62.8	65.5	71.5	113.5	116.4	116.0	56.0	47.1
Albuminoid nitrogen	8.03	6.5	5.76	6.97	5.85	6.58	13.40	9.66	7.46	7.64	6.50
Nitrate nitrogen	.54	.49	.49	.48	.48	.52	.65	.55	.55	.56	.49
Nitrite nitrogen	.0004	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Oxygen consumed	46.1	49.7	43.8	46.4	45.0	46.5	52.5	47.0	44.6	31.5	28.9
Turbidity	294	208	128	188	149	184	250	187	135	142	107
Residue on evaporation	1512	1410	1065	1208	1025	1315	1096	858	810	790	620
Settleable solids	6.38	5.16	2.28	2.96	1.95	3.88	3.40	.87	.61	2.91	.43

[1]The data for city sewage are averages for 27 samples collected June 9, 1923, to December 18, 1923. Tanks treating city sewage received the same kind and amount of sewage thruout the period, while tanks connected to farm homes received sewage varying considerably in quality and in the amount of flow.

[2]The data for farm sewage are averages for 25 samples collected June 12, 1923, to December 19, 1923.

[3]No single-chamber tank was connected at a farm home.

[4]Owing to a leak in the toilet, sewage treated by this tank was diluted with a large quantity of water.

TABLE 17.—AVERAGE CHEMICAL ANALYSES FOR FIRST HALF OF SAMPLES OF EFFLUENT COLLECTED DURING STUDY OF SEPTIC-TANK CROSS-SECTIONS

(Results are reported in parts per million, with the exception of settleable solids, which are reported in cubic centimeters per liter.)

	Average for tanks dosed with city sewage[1]						Average for tanks connected to farm houses[2]					
	Narrow tank		Medium tank		Wide tank		Narrow tank		Medium tank		Wide tank	
Chamber No.	F1 (8x2.4x5)	F2 (4x2.4x5)	G1 (8x3x4)	G2 (4x3x4)	H1 (8x4x3)	H2 (4x4x3)	I1 (8x2.4x5)	I2 (4x2.4x5)	J1 (8x3x4)	J2 (4x3x4)	K1 (8x4x3)	K2 (4x4x3)
Temperature, ° C.	15.9	15.9	16.0	16.0	15.6	15.6	14.2	14.2	15.2	15.2	16.0	16.0
Chlorin in chlorids	114	104	109	103	106	99.7	52.5	49.5	70.5	70.8	61.0	58.0
Alkalinity, methyl orange	568	578	583	599	548	577	578	584	635	650	565	570
Ammonia nitrogen	55.3	57.8	57.6	54.9	50.4	50.8	60.5	54.4	70.4	73.0	60.0	61.2
Albuminoid nitrogen	5.84	5.30	6.86	6.08	6.41	7.10	6.15	5.18	10.37	7.60	6.86	6.93
Nitrate nitrogen	.71	.53	.44	.48	.47	.48	1.88	2.37	.98	.52	.94	.76
Nitrite nitrogen	.0045	.0017	.0002	.0013	.0027	.0042	.4460	.4620	.0066	.0007	.0907	.1107
Oxygen consumed	56.4	55.0	58.9	57.6	56.7	53.9	63.5	59.0	73.7	68.2	70.2	51.5
Turbidity	250	164	243	153	197	168	229	145	366	245	319	140
Residue on evaporation	992	940	1120	979	983	961	1045	900	1077	925	1090	750
Settleable solids	1.61	.52	2.46	.75	1.66	.49	1.42	.34	2.55	.66	6.71	.63

[1]The data for city sewage are averages for 20 samples collected July 12, 1924, to April 27, 1925.
[2]The data for farm sewage are averages for 25 samples collected July 8, 1924, to May 25, 1925.

TABLE 18.—AVERAGE CHEMICAL ANALYSES FOR LAST HALF OF SAMPLES OF EFFLUENT COLLECTED DURING STUDY OF SEPTIC-TANK CROSS-SECTIONS

(Results are reported in parts per million, with the exception of settleable solids, which are reported in cubic centimeters per liter.)

	Average for tanks dosed with city sewage[1]						Average for tanks connected to farm houses[2]					
	Narrow tank		Medium tank		Wide tank		Narrow tank		Medium tank		Wide tank	
Chamber No.	F1 (8x2.4x5)	F2 (4x2.4x5)	G1 (8x3x4)	G2 (4x3x4)	H1 (8x4x3)	H2 (4x4x3)	I1 (8x2.4x5)	I2 (4x2.4x5)	J1 (8x3x4)	J2 (4x3x4)	K1 (8x4x3)	K2 (4x4x3)
Temperature, ° C.	18.8	18.8	18.8	18.8	18.7	18.8	15.0	15.0	16.9	16.8	18.6	18.6
Chlorin in chlorids	148	141	148	148	155	139.5	45.2	44.5	52.5	51.7	41.8	41.1
Alkalinity, methyl orange	588	603	575	624	598	611	661	657	626	630	569	580
Ammonia nitrogen	35.2	37.7	40.9	41.4	37.6	37.4	49.7	50.2	47.2	52.4	44.6	46.8
Albuminoid nitrogen	4.59	3.47	4.55	3.67	4.02	3.80	5.40	3.86	6.35	4.90	3.64	2.94
Nitrate nitrogen	.42	.38	.42	.33	.99	.36	.55	.34	.34	.60	.44	.43
Nitrite nitrogen	.0018	.0018	.0020	.0010	.0023	.0020	.0110	.0014	.0014	.0002	.0040	.0006
Oxygen consumed	77.9	63.5	85.3	63.9	120.0	62.8	70.5	54.8	67.4	57.4	63.8	39.8
Turbidity	251	164	262	140	222	129	263	169	283	206	149	84
Residue on evaporation	1267	1022	1223	984	1076	962	997	764	894	770	730	620
Settleable solids	3.90	2.93	6.13	2.10	3.94	1.36	2.99	.47	1.19	.34	1.95	.37

[1]The data for city sewage are averages for 20 samples collected April 27, 1925, to October 12, 1925.
[2]The data for farm sewage are averages for 25 samples collected May 25, 1925, to December 11, 1925.