RESEARCH BULLETIN 682 OCTOBER, 1958

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
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Field Tests of a Pond Water Treating System

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(Publication authorized October 6, 1958)

COLUMBIA, MISSOURI

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The work reported in this bulletin was done under Department of Agricultural Engineering Research Project 155, "Farm Water Supplies". This project is a part of North Central Regional Project NC-9 on Farm Housing Research and is partially financed by funds authorized by Section 9b3, Title I, of the Research and Marketing Act of 1946.

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T. O. Hodges, J. E. Edmondson, and M. D. Shanklin

INTRODUCTION

In many areas of Missouri and other states, ground water supplies are inadequate to meet the needs of rural families. In these areas, surface water collected in farm ponds is often used as the domestic water supply. Laboratory tests indicate that water filtered through a slow-sand filter and then treated by chlorination will yield water satisfactory for human consumption, or for use on Grade A dairy farms.

This publication reports results of a study of a slow-sand filtering installation under actual field operating conditions. The treating system was built in the spring of 1957 and the period of testing was from July 1, 1957, to May 3, 1958. The primary objectives of the study were to determine:

a) the effectiveness of a slow-sand filter in reducing the turbidity of pond water
b) the effectiveness of a slow-sand filter in reducing bacteria population of pond water
c) the relationship between bacteria kill and chlorine level
d) general water quality characteristics such as hardness, pH, and chlorides
e) general management requirements of a water treating plant of this type.

DEFINITIONS

Certain terms are widely used in describing water quality and water treatment. Definitions of these terms are given below.

Bacteria of the Coliform group are bacteria which have the characteristic of producing acid and gas from a lactose medium. No attempt was made in these studies to differentiate between the coliform bacteria indicative of fecal contamination and those of non-fecal contamination.

Turbidity. Turbidity is an expression of the optical property of a sample which causes light rays to be scattered and absorbed rather than transmitted in straight lines through the sample. The turbidity of water is caused by the presence of suspended matter, such as clay, silt, finely divided organic matter, plankton, and other microscopic organisms.

Hardness. The theoretical hardness of water is the sum of the concentrations of all metallic cations other than cations of the alkali metals, expressed as equivalent calcium carbonate concentration. The hydrogen ion, being nonmetallic, is excluded from the definition. As used in this publication, "hardness" means total hardness, as determined by a variation of the EDTA* titration method, and reported as parts per million (p.p.m.) calcium carbonate equivalent.

Chlorine demand. The chlorine demand of water is the difference between the amount of chlorine applied to a supply and the amount of free, combined, or total available residual chlorine remaining at the end of a specified contact time. The estimated minimum contact for this system is 30 minutes.

Chlorine residual. As used here, chlorine residual shall include free or combined available chlorine as determined by orthotolidine tests described under "testing methods."

Effective size. The effective size of a sample of sand is defined as the size of grain that is larger than 10 percent of the particles in the sample and smaller than 90 percent of them. (Fig. 6)

Uniformity coefficient is defined as the ratio of the size of grain which has 60 percent of the sample finer than itself to the size which has 10 percent finer than itself.

SIGNIFICANCE OF THE TESTS

Many factors affect the quality of water for human consumption. This study included only those factors which were deemed of primary importance in treating pond water for domestic use, considering that good care would be given to the watershed and to the pond. These were turbidity, hardness and bacteria.

Typhoid fever, dysentery (both amoebic and bacillary), gastro-enteritis and asiatic cholera are the important water-borne diseases. All of these diseases are transmitted by the intestinal and urinary discharges of sick persons and carriers. This source of contamination, prevalent in surface waters, must be controlled, usually with chlorine treatment.

Bacteria of the E. coli group, which have the characteristic of forming acid and gas during growth in a suitable lactose medium, may be from fecal or nonfecal sources. Gas formation casts suspicion upon the water because it indicates contamination of water with wastes from human or animal sources. A positive test as used here indicates only that bacteria of the E. coli group were present.

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*Ethylenediamentetetraacetic and its sodium salts.

The method does not provide for detection, isolation or enumeration of pathogenic bacteria in the water.

The United States Public Health Service has certain standards governing bacteriological requirements for drinking water. Those applicable to this study follow:

1) Of all the standard ten milliliter (10 ml) portions examined per month, not more than 10 percent shall show the presence of organisms of the coliform group.
2) Occasionally three or more of the five equal 10 ml. portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than:
    a) Five percent of the standard samples when twenty or more samples have been examined per month.
    b) One standard sample when less than twenty samples have been examined per month.

A primary function of the filter unit is the removal of suspended matter in the water to make it acceptably clear for drinking and for chlorination. Turbidity tests of samples of water before and after filtration were considered a satisfactory measure of the effectiveness of the filter in performing this function. An exact limit on the permissable turbidity of water for human consumption is not defined, but it is believed by some authorities that the upper limit should be about 10 turbidity units when determined by the "Jackson Candle Method."**

Definite upper limits for many chemical factors have been established by the U. S. Public Health Department for drinking water (1). The upper limits for those factors considered in this study follow:

a) chlorides, 250 mg. per liter†
b) sulfates, 250 mg. per liter
c) pH, about 10.6 at 25° C due to the limitations of phenolphthalein alkalinity, as $CaCO_3$, to 15 mg. per liter plus 0.4 times the total alkalinity
d) total alkalinity, mg. per liter as $CaCO_3$, 400 at pH of 8.0 to 160 at pH of 10.6 at a temperature of 25° C
e) pH, about 10.6 due to alkalinity considerations in (d) above.

Specific conductance measurements give an indication of the total concentration of the ionized constituents of natural water.

DESCRIPTION OF THE SYSTEM

The pond water system on which these tests were conducted is located approximately 14 miles east of Columbia, Missouri. It supplies all the household water for a family of four plus occasional relatives and friends. Also, some water

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**See "Methods of Testing", pg. 11.

†Approximately equivalent to p.p.m. as used in this publication.

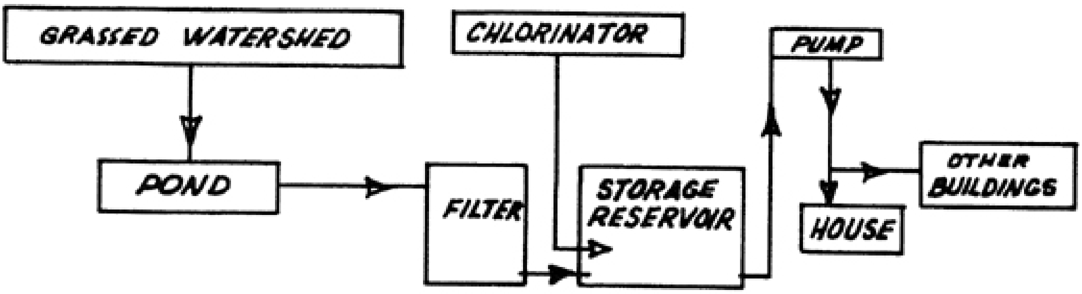

Fig. 1—Flow diagram of water system.

for livestock is drawn from the system.

There are six fundamental components in the system, plus a few special features to permit sampling. Essentially, the system consists of a grassed watershed, a pond, a vertical slow-sand filter, a storage reservoir for treated water, a chlorinator, and a shallow-well pressure system. A flow diagram of these components is shown in Fig. 1.

The watershed contains approximately two acres sodded with grass. It is used for occasional pasturing of livestock, but over-grazing is avoided. Fig. 2 shows typical cover on the watershed.

The pond has a maximum capacity of about 70,000 cubic feet and a maximum depth of 8 feet. Because of limited watershed size the pond has never been full since it was built in 1954. During the period of these tests, the depth varied from 3 feet to a maximum of 8 feet. Twenty-five pounds of agricultural gypsum were put in the pond in 1956 to floculate and clear the pond. The pond, which is stocked with game fish and is used for fishing by the family, is fenced to keep livestock away. A picture of the pond is shown in Fig. 3. The vertical pipe

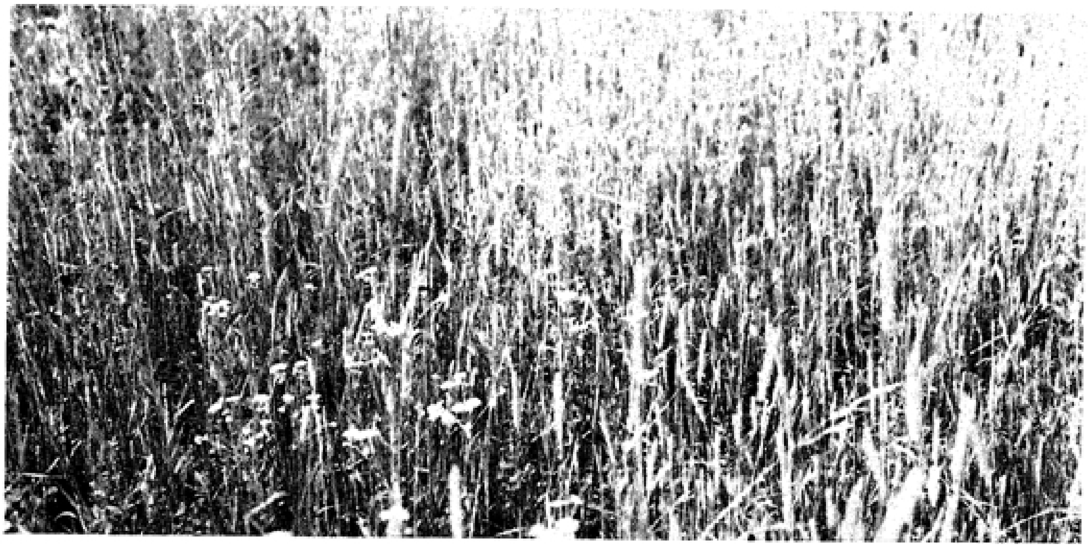

Fig. 2—View of watershed in June, 1958.

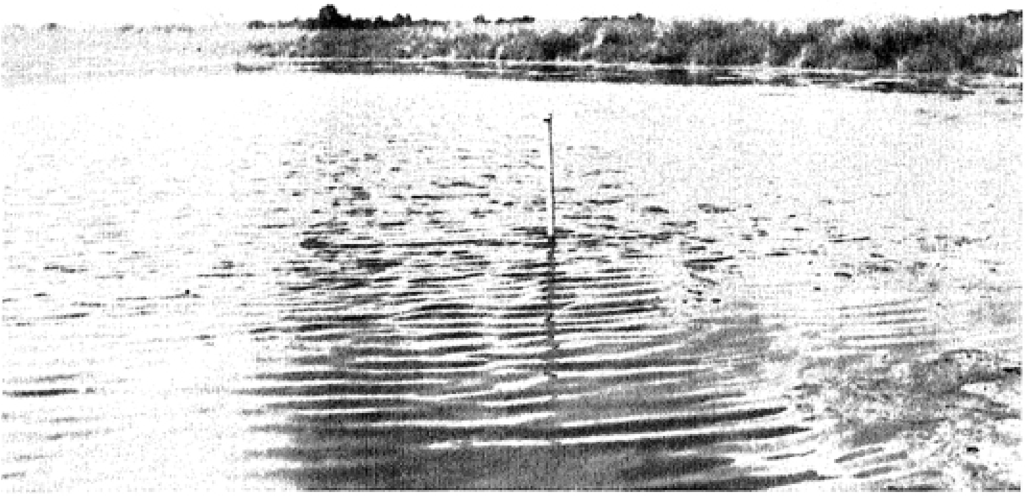

Fig. 3—View of pond used in the filtering study.

shown in the picture has small holes drilled at random in it to collect water from the pond. A better method of water collection would have been to use a float-type pick-up so that all water would have been taken from near the water surface. The vertical pick-up pipe was installed before the beginning of this experiment, however, and no changes were made.

Water from the pond flows by gravity to the vertical slow-sand filter, where the water level is controlled by a float valve (Fig. 4). Previous laboratory work and studies of municipal water treating systems have shown that approximately 70 gallons of water can be filtered each 24 hours per square foot of filter surface area in slow-sand filters. The inside plan dimensions of this filter are 3 feet by 4 feet, or 12 square feet of filter area, which could be expected to yield approximately 840 gallons of water per day. Other dimensions of the system are shown in Fig. 4.

The construction of the functional filtering unit in the concrete shell was as follows:

The assembled pipe underdrain, as shown in Fig. 5, was placed on a layer of 1-inch gravel, 2 inches thick, with the perforations downward. On top of the underdrain was placed a 12-inch layer of gravel, graded from 1-inch size next to the underdrain to ¼-inch (pea) size at the top. The filter sand was then placed on top of the ¼-inch gravel to a depth of approximately 3½ feet, leaving a depth of water approximately 3 feet above the filter sand.

The filter sand was obtained by screening Missouri river sand through an 18-mesh screen and using only the portion which passed through the screen. The effective size of the sand was 0.26 and the uniformity coefficient was 2.04. A plot of the sieve analysis of this sand is shown in Fig. 6. Each point on the curve is

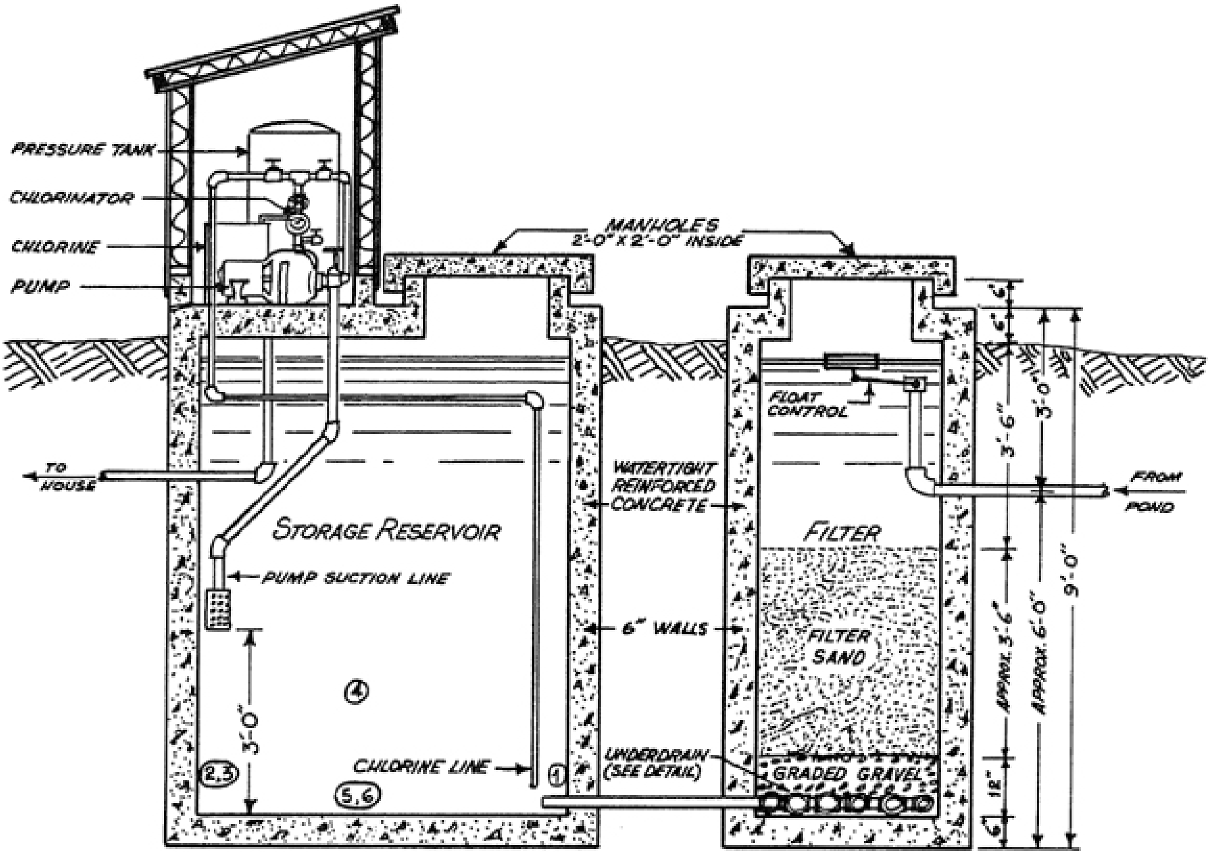

Fig. 4-A—Section through filter and storage reservoir.

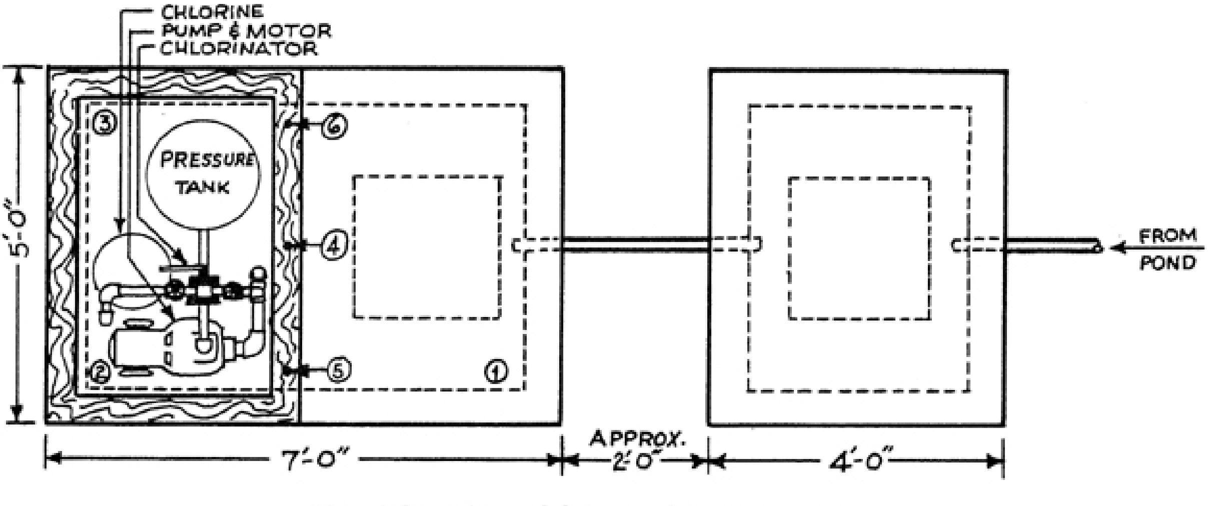

Fig. 4-B—Plan of filter and storage reservoir.

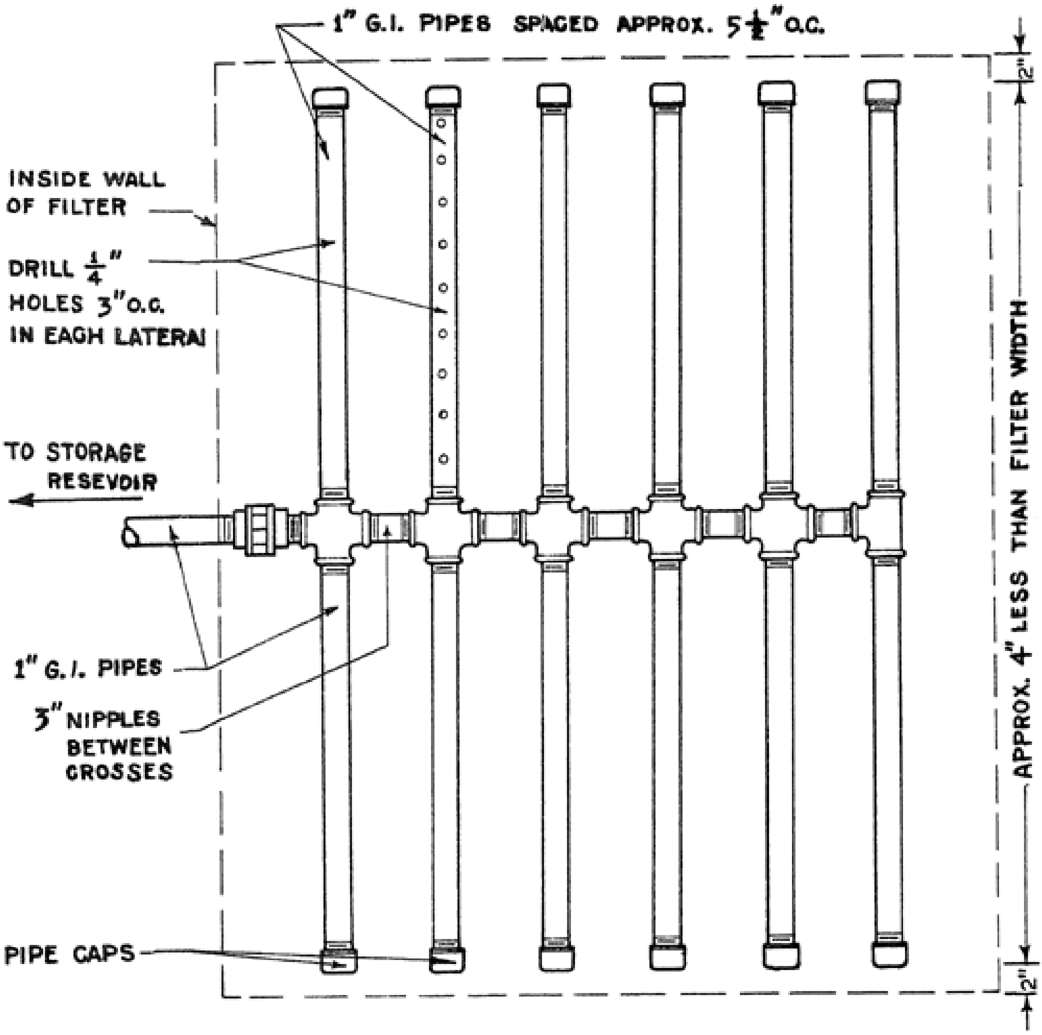

Fig. 5—Underdrain as viewed from bottom.

an average of six samples drawn at random from the filter sand.

The storage reservoir has a capacity of about 2350 gallons. The relatively shallow depth and large plan dimensions prevent a rapid drawdown of water in the reservoir, and thereby control to some extent the rate of filtration.

The pump house and pumping equipment are located directly over the storage reservoir. A shallow-well centrifugal pump and pressure tank are used. The maximum pumping capacity is approximately 5 gallons per minute against a pressure of 40 pounds per square inch.

The chlorinator used in these tests is an experimental piston displacement pump, hydraulically powered by by-passing a small portion of the water from the centrifugal pump through the chlorinator unit. This unit is located directly

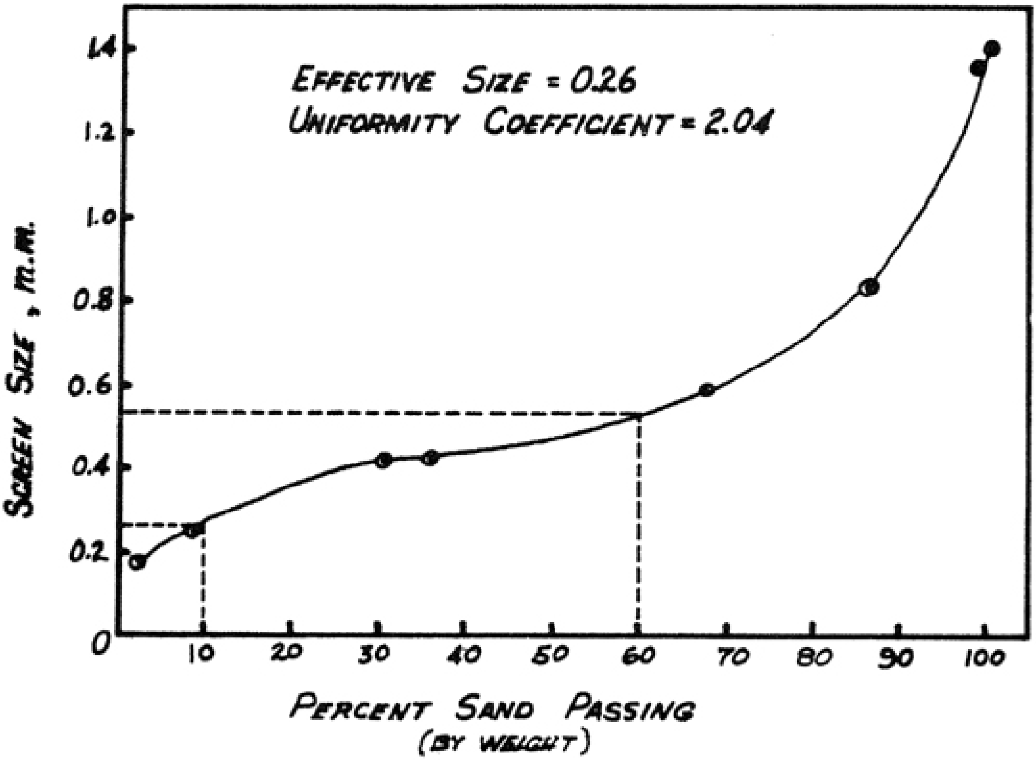

Fig. 6—Sieve analysis of filter sand.

above the water pump and electric motor (Fig. 7). Chlorine from a bottle is pumped by the chlorinator into the stream of water which powers the hydraulic unit and then the chlorinated water passes through a pipe and is ejected into the storage reservoir near the point where the water from the filter enters (Fig. 4).

The pump suction line terminates 3 feet from the bottom of the storage reservoir to prevent lowering the water level below 3 feet and thus to insure adequate retention time for the chlorinated water. The suction line is placed opposite the chlorine line to prevent short-circuiting of the highly chlorinated water.

The chlorinator injects chlorine into the storage reservoir each time the water pump operates. The amount of chlorine injected is controlled by adjusting either the strength of the chlorine solution, the length of the chlorinator piston stroke, the pressure drop across the hydraulic pump, or any combination of these. Attempts were made to keep the unit regulated so that a chlorine residual above 0.2 p.p.m. was maintained at the house.

A water meter was installed in the water line between the pressure tank and the dwelling (Fig. 8) to measure the amount of water used.

Ten ⅛-inch copper tubes, (Figs. 9, 10) were located at various points in the

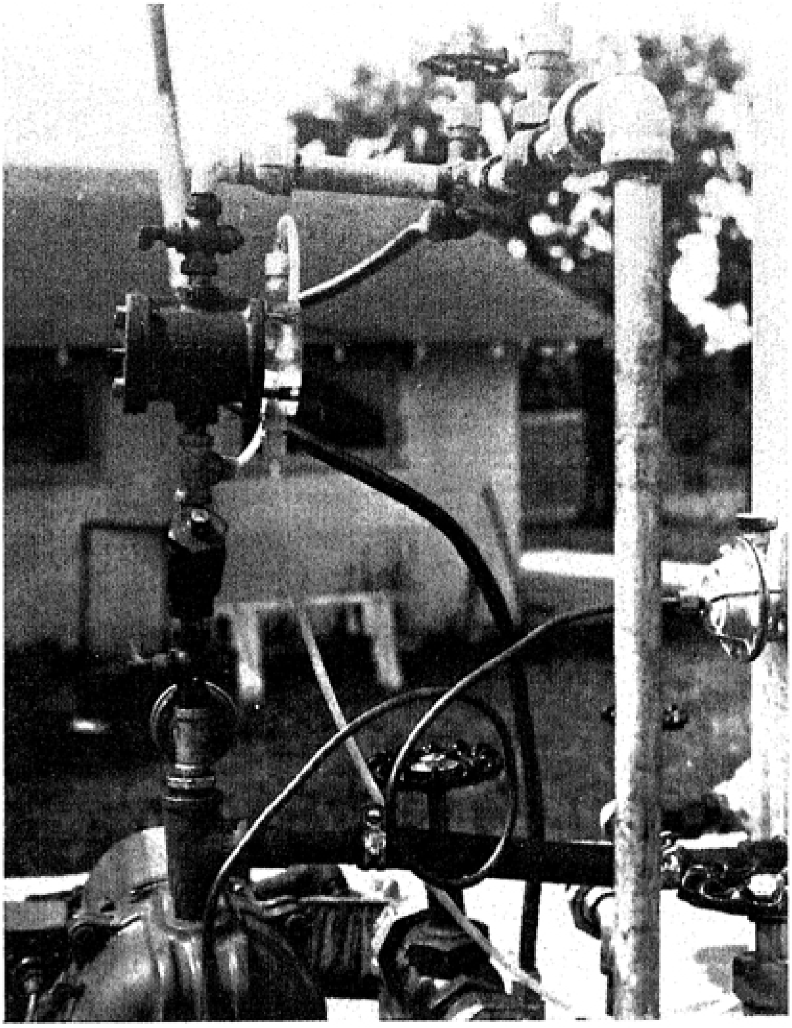

Fig. 7—View showing hydraulically operated chlorinator located above water pump.

system so that water samples could be collected. Only seven of the tubes were actually used in the tests. Six of them were numbered from 1 through 6 and located at points in the reservoir as shown in Fig. 4. The seventh copper tube was inserted into the underdrain effluent pipe so that water samples of filtered, unchlorinated water could be collected.

METHODS OF TESTING

Water samples were collected from the pond, from the filter underdrain, from point 4 in the storage reservoir, and from a house faucet, and were analyzed for bacteria of the coliform group, for turbidity, and for chlorine residual where ap-

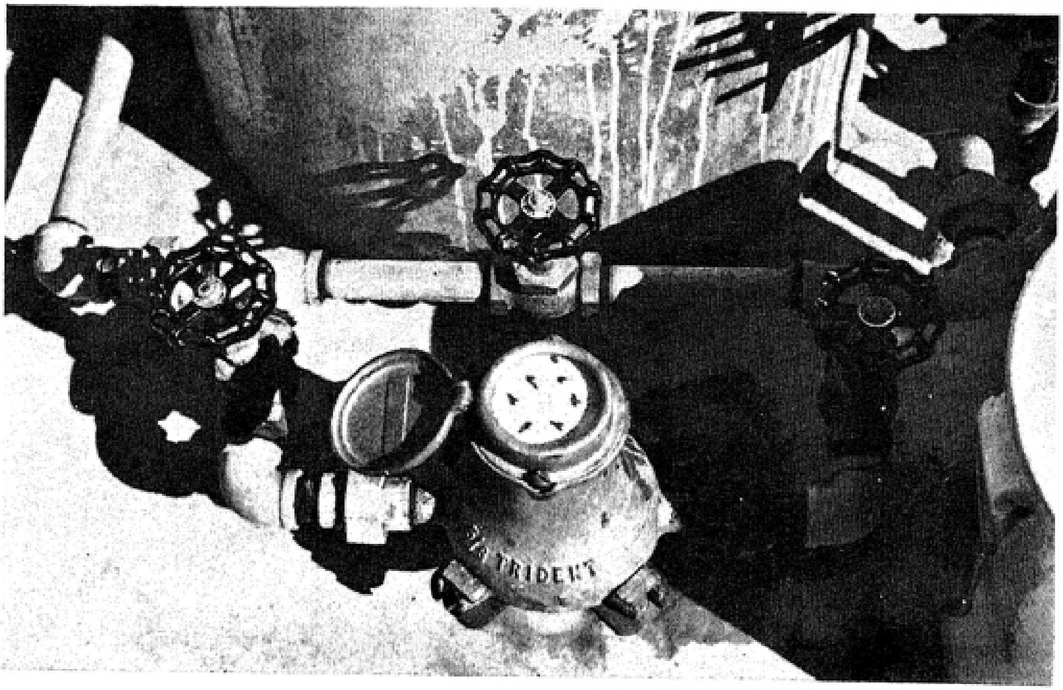

Fig. 8—View showing water meter located in water line between pressure tank and house.

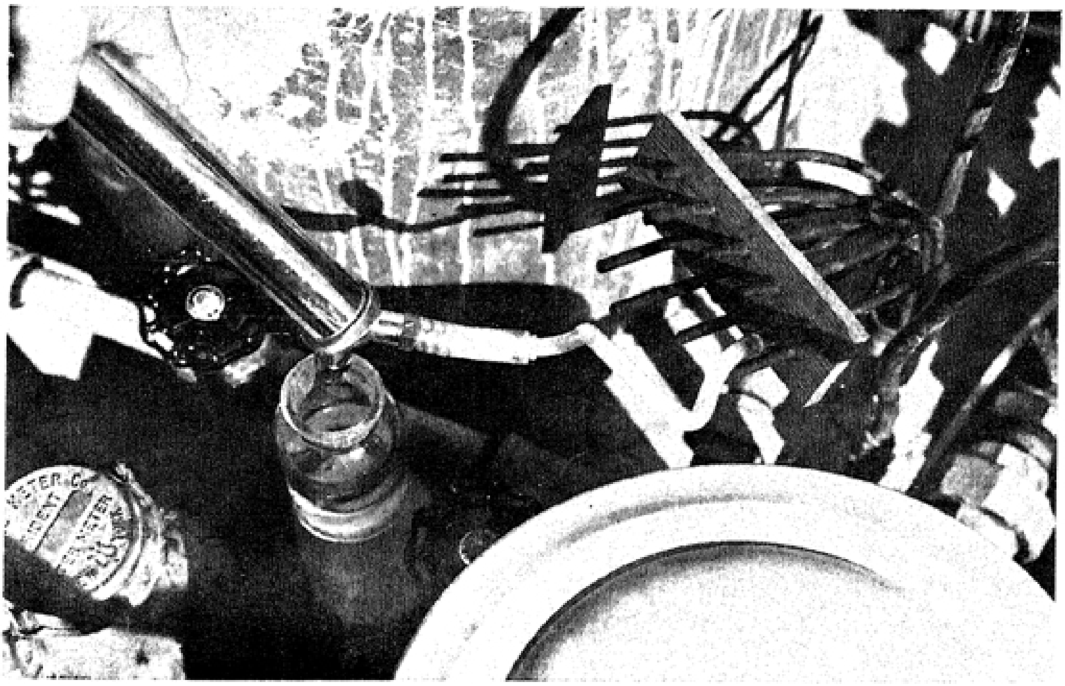

Fig. 9—View showing water samples being collected in sterile glass bottle for bacteriological determinations.

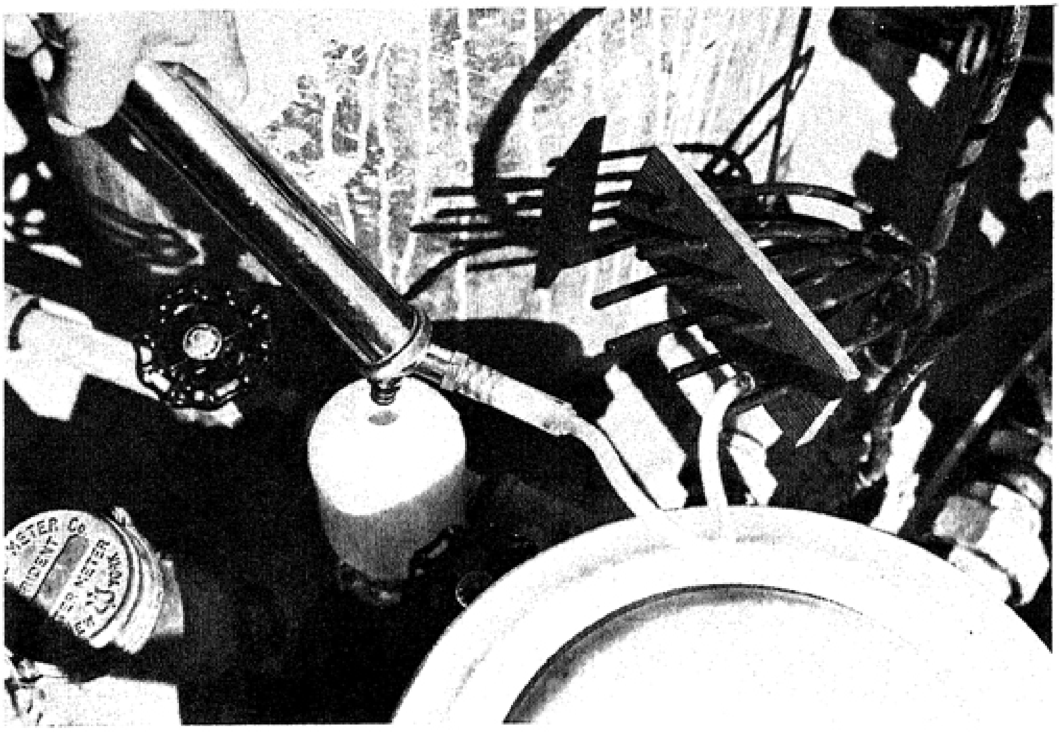

Fig. 10—View showing water samples being collected in polyethelene bottle for chemical determinations.

plicable. During the first six months these determinations were made three times weekly, and during the next three months they were made two times weekly. Water meter readings were made on the same schedule. In addition to these tests, samples were collected frequently from points 1, 2, 3, 4, 5 and 6 and checked for chlorine residual to try to determine how well the chlorine was dispersed throughout the reservoir (Table 1). Also, monthly determinations were made of pH, chlorides, sulfates, and conductivity from samples collected from the pond, the underdrain, point 4 and a house faucet.

All samples collected from the filter underdrain and from the storage reservoir were drawn through the ⅛-inch copper tubes by means of a hand-operated suction pump. Fig. 9 shows water for bacteriological analysis being pumped into a sterilized glass bottle and Fig. 10 shows a sample collection in a polyethelene bottle for determinations other than bacteriological. When the suction pump was connected to a copper tube for collection of a sample from a certain location, about a pint of water was pumped and discarded before the water was collected to be tested. This was to minimize contamination from previous collections.

Samples of pond water were collected by plunging the sample bottles directly into the pond.

All bacteriological sample bottles contained sodium thiosulfate as a dechlornating agent. The sodium thiosulfate was added before sterilization at a rate of 0.1 ml. of a 10 percent solution for each 4 oz. capacity.

The bottles of water for bacteriological tests were taken from the field to the laboratory and placed in a refrigerator, usually within an hour after the samples were collected, where they remained until analyzed. All samples were examined within four hours after collection. The bacteriological tests were performed according to procedures in "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes" (5).

All water samples were inoculated in a five-tube series of lactose broth fermentation tubes. All primary fermentation tubes showing any amount of gas at the end of a 24 or 48 hour incubation period were subjected to a confirmed test. Brilliant green lactose bile broth was used as the medium for confirmed testing. The formation and presence of gas in any amount in brilliant green lactose bile broth fermentation tube any time during the 48-hour incubation constitutes a positive confirmed test.

At regular intervals during the testing period, positive confirmed fermentation tests were further checked for presence of typical coliform organisms by using the completed test. The brilliant green lactose bile broth fermentation tubes showing gas were streaked on eosin methylene blue agar plates. After incubation at 35° C for 24 hours, plates showing typical coliform colonies were designated as positive for the completed test. These results were then considered as positive for the presence of coliform organisms as shown by the presumptive, confirmed and completed standard tests.

Turbidity determinations were made by measuring the percent transmittance of light rays of a certain wave length by the use of an electronic colorimeter which was calibrated against a standard Jackson Candle Turbidimeter (3, pg. 51; 5, pg. 207).

Chlorine residuals were made first in the field by using standard orthotolidine methods and visual color comparisons, and then in the laboratory by using orthotolidine in conjunction with an electronic colorimeter (3, pg. 13). While some leaching of the chlorine undoubtedly occurred while transporting the samples to the laboratory, the time between sample collection and testing was usually only about thirty minutes. Also, the water samples were carried in closed, polyetheylene bottles and protected from direct sun light.

Conductivity determinations were made with a standard conductivity cell, and pH measurements were made with a battery operated pH meter which utilizes a glass electrode in combination with a saturated calomel electrode (5, pgs. 90-161).

Chloride determinations were made by titrations using the mercuric nitrate method (5, pg. 61).

Methyl Orange (total) alkalinity, as p.p.m. calcium carbonate, was determined by titration methods (2, pg. 2).

Sulfates were determined by titration with standard barium perchlorate in conjunction with an indicator (2, pg. 14).

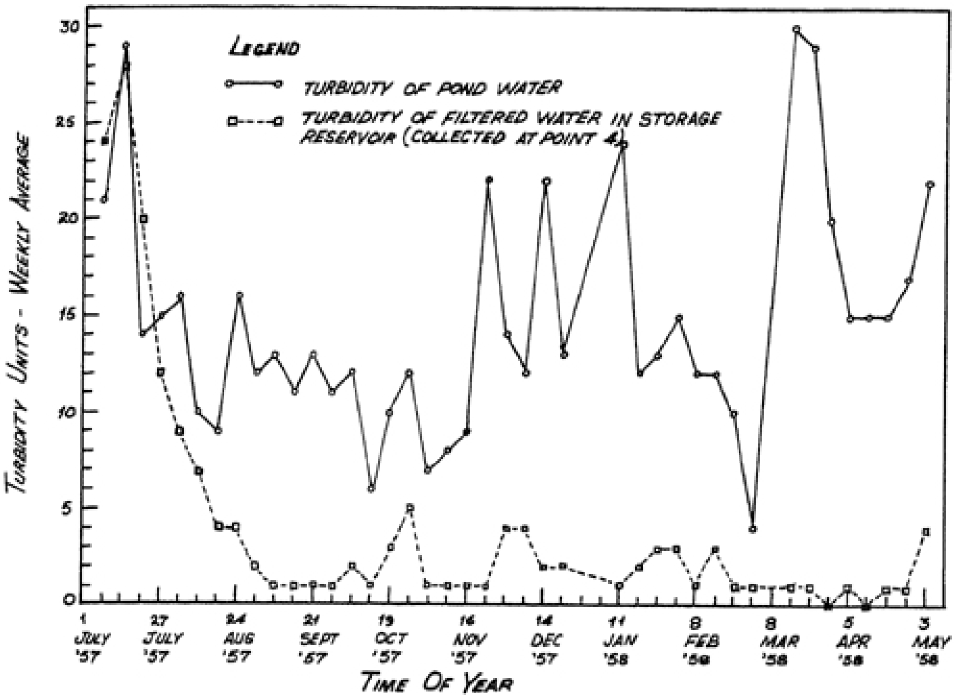

Fig. 11—Turbidity reduction of pond water by slow-sand filter as related to time filter in operation.

RESULTS

Turbidity reduction as related to time filter in operation.

Fig. 11 shows the turbidity reduction of the pond water by the slow-sand filter from July 1, 1957, to May 3, 1958. Each plotted point represents the average turbidity of two or three samples of water collected on different days during the week. During the first three weeks of operation, there was a slight increase in turbidity as the pond water passed through the filter. This was due to the silt in the sand.

After the third week of use, the efficiency of the filter increased to where the turbidity of the filtered water was always below 5 turbidity units, which is a very clear water. The turbidity of the pond water was lowest during the summer and fall months from late July to November and was highest during the winter and early spring. It is important to note that the maximum turbidity of the pond water was only 30 turbidity units. This was due to strict control of the watershed and to the gypsum treatment used for floculation. Obviously, attempts to filter highly turbid water would lead to early clogging of the filter.

Turbidity reduction as related to quantity of water filtered.

Fig. 12 shows turbidity reduction as related to the quantity of water filtered.

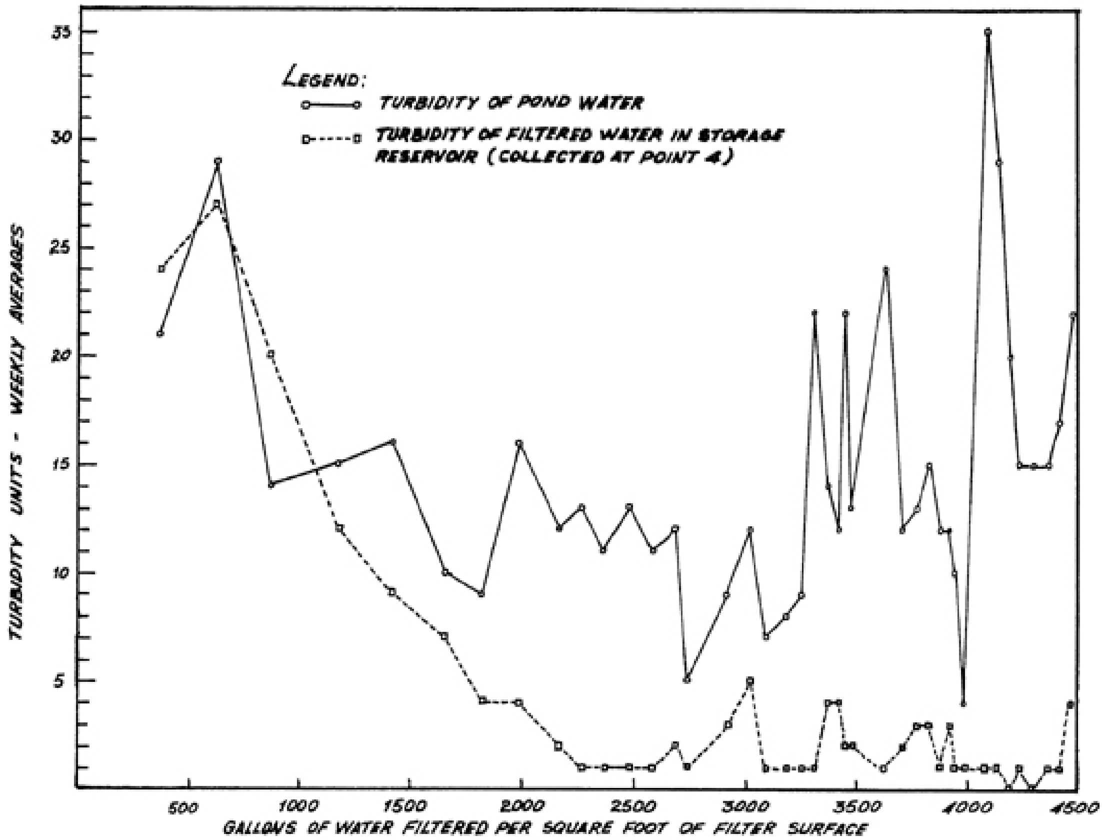

Fig. 12—Turbidity reduction of pond water by slow-sand filter as related to quantity of water filtered.

Reduction of turbidity began after about 1100 gallons of water per square foot of filter surface had passed through the filter. The turbidity of the filtered water was never higher than 5 turbidity units after 1800 gallons of water per square foot of filter surface had filtered and it was usually only 2 to 3 units. The filter was cleaned by scraping about ½ inch of silt from the surface of the filter sand after 2750 gallons of water per square foot of filter surface had been filtered. The efficiency of filtering was reduced by this scraping; the reduction was for a very short time, however (Fig. 12).

Maintenance requirements of the filter.

The filtering rate became very slow after about 2750 gallons of water per square foot had been filtered, so that the silt was removed from the filter surface. This was after four months of operation. About 4500 gallons of water per square foot of filter surface had been filtered at the end of the test period reported here and no further servicing was required.

Chlorides and Chlorine Residual.

The amount of chlorides in treated pond water depends upon the amount present in the raw pond water and upon the amount of chlorine added to the filtered water, which in turn depends upon the chlorine demand of the water. The upper limit of chlorides permissable in water for human consumption is 250 mg. per liter, which is approximately 250 p.p.m. Fig. 13 shows that the chlorides in the raw pond water were usually about 3 p.p.m., ranging from 2.25 to 4.5 p.p.m. and that chlorides in the chlorinated water ranged from 3.5 to 15 p.p.m. depending upon the chlorine residual and the chlorine demand of the water.

The chlorine residual of the chlorinated water in the storage reservoir is also shown in Fig. 13. The plotted points on this curve represent an average from six locations in the storage reservoir sampled either two or three times per week. Much variation occurred in chlorine residual; the range was from about 0.05 to 1 p.p.m. The lower value of 0.05 is not significant since techniques of measurement are not accurate enough to warrant considering this value as a significant residual. Some of the variation in chlorine residual might be attributed to changing chlorine demands of the water, but most of it was due to mechanical problems of injecting chlorine. The speed of piston displacement in the hydraulically-powered chlorinator varied, depending upon the pressure drop across the

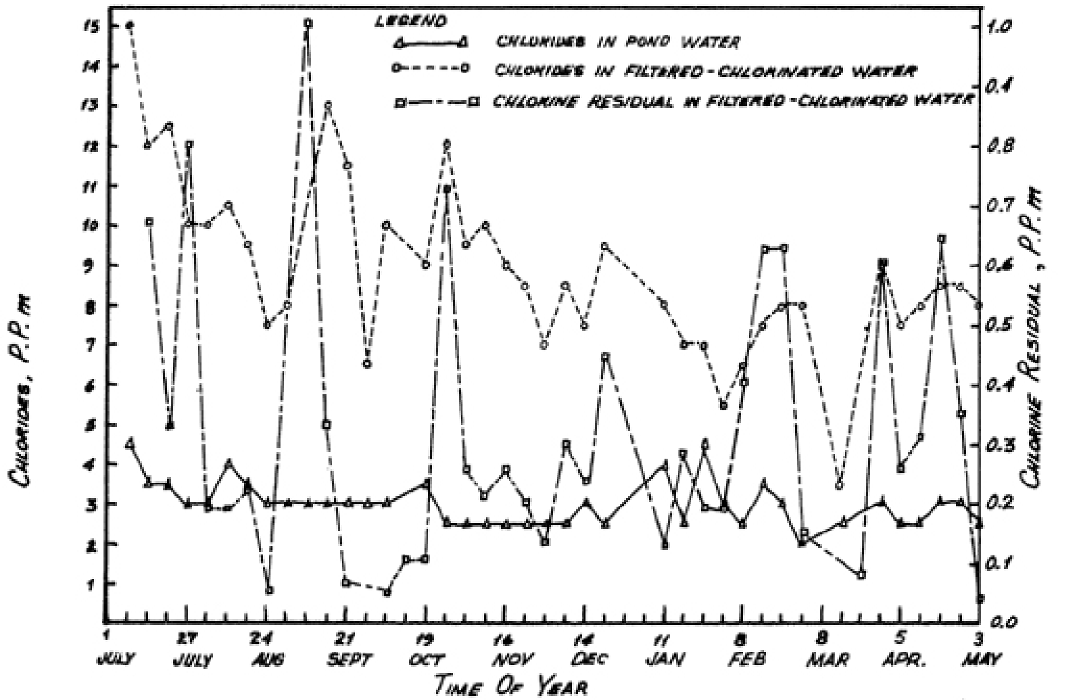

Fig. 13—Chlorides in pond water and in chlorinated water and chlorine residual in chlorinated water.

unit and upon how well the unit was serviced. It should be pointed out that the problems which occurred with this experimental model chlorinator have not been encountered on other systems using electrically-powered positive displacement chlorinators. Improvements are being made in the experimental chlorinator and it is expected that greater consistency of operation can be obtained.

Mixing of Chlorine in Reservoir.

Table 1 shows chlorine residuals of water samples collected from the filter underdrain, from six locations in the storage reservoir, and from a faucet in the house. It was thought that there might possibly be insufficient dispersion of chlorine throughout the system when chlorine was injected at a point as it was in this system. However, as shown by Table 1, while there was much daily variation, there was no definite indication of failure to mix properly.

TABLE 1--CHLORINE RESIDUAL, p.p.m. AT VARIOUS LOCATIONS IN WATER SYSTEM.

	Location in System							
Date	Underdrain	1	2	3	4	5	6*	House
7-12-57	0.00	0.53	over 1.6	0.66	0.065	0.05	0.068	0.018
7-13-57**		1.0	1.0	1.0	0.8+	0.7	0.7	0.2
7-15-57	0.00	0.048	0.00	0.025	0.018	0.025	0.00	0.00
7-16-57**	0.00	1.0+	1.0+	1.0+	1.0+	1.0+	1.0+	
7-17-57	0.00	0.01	0.042	0.22	0.29	0.15	0.12	0.22
7-19-57	0.01	0.078	0.068	0.081	0.17	0.40	0.30	0.17
7-23-57	0.002	0.58	0.58	0.71	0.66	0.71	0.64	0.64
7-24-57	0.00	0.26	0.26	0.42	0.19	0.28	0.35	0.50
7-27-57	0.00	1.3	1.6	1.6	1.6	over 1.6	over 1.6	over 1.6
7-26-57	0.00	0.66	0.80	0.95	0.66	0.69	0.60	0.57
7-29-57	0.018	0.26	0.31	0.49	0.055	0.048	0.065	0.12
7-30-57	0.00	0.34	0.53	0.49	0.45	0.47	0.50	0.38
7-31-57	0.005	0.038	0.038	0.028	0.04	0.09	0.09	0.11
8- 1-57	0.012	0.055	0.065	0.086	0.048	0.068	0.065	0.048
8- 2-57	0.018	0.24	0.30	0.38	0.05	0.05	0.065	0.055
8- 5-57	0.00	0.23	0.33	0.17	0.16	0.23	0.24	0.26
8- 6-57	0.00	0.37	0.37	0.43	0.33	0.30	0.31	0.39
8- 7-57	0.00	0.06	0.086	0.065	0.18	0.086	0.11	0.055
8- 9-57	0.00	0.10	0.042	0.068	0.078	0.10	0.12	0.072
8-12-57	0.00	0.11	0.065	0.093	0.065	0.10	0.093	0.11
8-13-57	0.00	0.018	0.040	0.028	0.050	0.050	0.048	
8-14-57	0.00	0.58	1.3	1.05	0.081	0.086	0.086	0.072
8-15-57	0.00	0.11	0.11	0.14	0.068	0.060	0.055	0.02
8-16-57	0.00	0.39	0.69	0.95	0.081	0.10	0.11	0.042
8-19-57	0.00	0.018	0.010	0.012	0.042	0.078	0.038	0.028
8-20-57	0.00	0.025	0.012	0.025	0.068	0.10	0.090	0.11
8-21-57	0.00	0.038	0.010	0.002	0.078	0.090	0.068	0.040
8-22-57	0.01	0.086	0.081	0.093	0.090	0.11	0.11	over 1.6
8-30-57	0.00				0.002			0.005
9- 4-57	0.00				over 1.6			over 1.6

TABLE 1--CONTINUED

Date	Underdrain	Location in System						
		1	2	3	4	5	6*	House
9- 6-57	0.00	over 1.6	over 1.6	over 1.6	over 1.6	over 1.6	over 1.6	over 1.6
9- 9-57	0.00	0.081	0.18	0.12	0.31	0.29	0.35	0.27
9-11-57	0.00	0.57	0.21	0.41	0.41	0.40	0.43	0.47
9-13-57	0.00	0.35	0.38	0.35	0.35	0.35	0.38	0.30
9-16-57	0.00	0.22	0.11	0.19	0.15	0.16	0.12	0.081
9-18-57	0.00	0.068	0.048	0.050	0.055	0.072	0.12	0.11
9-21-57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10- 2-57	0.00	0.048	0.086	0.042	0.086	0.086	0.055	0.065
10- 4-57	0.00	0.055	0.020	0.078	0.038	0.060	0.040	0.050
10- 7-57	0.00	0.13	0.22	0.11	0.14	0.10		0.068
10-18-57	0.00	0.055	0.086	0.16	0.14	0.18	0.14	0.38
10-21-57	0.00	1.6	1.6	1.6	1.6		1.6	1.6
10-23-57	0.00	0.53	0.47	0.45	0.43	0.53	0.50	0.66
10-25-57	0.01	0.086	0.078	0.072	0.068	0.068	0.11	0.23
10-28-57	0.00	0.21	0.24	0.18	0.31	0.13	0.17	0.49
10-30-57	0.00	0.068	0.090	0.12	0.042	0.11	0.11	0.14
11- 1-57	0.00	0.45	0.45	0.50	0.50	0.47	0.49	0.53
11- 4-57	0.00	0.26	0.34	0.37	0.31	0.28	0.30	0.47
11- 6-57	0.00	0.14	0.24	0.26	0.26	0.31	0.32	0.66
11- 8-57	0.00	0.090	0.065	0.078	0.072	0.081	0.093	0.43
11-11-57	0.00			0.005				0.005
11-13-57	0.00	0.31	0.14	0.26	0.50		0.042	0.64
11-15-57	0.00	0.50	0.49	0.37	0.13	0.25	0.26	over 1.6
11-18-57	0.00	0.40	0.43	0.46	0.52	0.45	0.43	0.90
11-20-57	0.00	0.11	0.11	0.072	0.068	0.10	0.11	0.50
11-22-57	0.00	0.032	0.05	0.048	0.06	0.06	0.048	0.21
11-25-57	0.00	0.028	0.018	0.040	0.018	0.038	0.028	0.040
11-27-57	0.00	0.24	0.23	0.24	0.24	0.22	0.28	0.16
12- 2-57	0.00	0.16	0.17	0.17	0.12	0.11	0.16	0.24
12- 4-57	0.00	0.24	0.26	0.28	0.14	0.31	0.24	0.50
12- 9-57	0.002	0.43	0.31	0.35	0.24	0.31	0.37	0.47
12-11-57	0.00	0.17	0.18	0.18	0.17	0.14	0.23	

TABLE 1--CONTINUED

	Location in System							
Date	Underdrain	1	2	3	4	5	6*	House
12-13-57	0.00	0.15	0.21	0.22	0.18	0.25	0.23	0.46
12-16-57	0.00	0.47	0.50	0.58	0.57	0.64	0.58	0.77
12-18-57	0.00	0.37	0.31	0.33	0.29	0.40	0.34	0.025
1- 6-58	0.00	0.060	0.081	0.065	0.065	0.11	0.11	0.21
1- 8-58	0.00	0.018	0.018	0.018	0.020	0.012	0.018	0.018
1-10-58	0.005	0.29	0.33	0.30	0.33	0.33	0.28	0.050
1-13-58	0.01	0.23	0.20	0.24	0.19	0.26	0.28	0.032
1-15-58	0.00	0.39	0.47	0.49	0.40	0.43	0.43	0.47
1-17-58	0.00	0.17	0.16	0.18	0.22	0.19	0.19	0.060
1-20-58	0.00	0.048	0.040	0.048	0.048	0.042	0.060	0.040
1-24-58	0.005	0.31	0.35	0.27	0.33	0.31	0.37	0.060
1-27-58	0.00	0.042	0.038	0.050	0.042	0.050	0.050	0.018
1-29-58	0.00	0.95	0.26	0.52	0.093	0.028	0.038	0.002
2- 3-58	0.00	1.6	0.66	1.6	0.21	0.020	0.025	0.012
2- 5-58	0.005	0.093	0.13	0.10	0.13	0.16	0.13	0.048
2-10-58	0.00	0.71	0.77	0.64	0.74	0.62	0.77	0.17
2-12-58	0.00	0.49	0.49	0.52	0.57	0.55	0.58	0.42
2-17-58	0.00			0.77	0.80	0.80	0.90	0.60
2-19-58	0.002		0.47	0.47	0.55	0.50	0.53	0.26
2-26-58	0.002	0.14	0.15	0.16	0.17	0.15	0.15	0.47
3-14-58	0.00							
3-17-58	0.002	0.010	0.010	0.005	0.010	0.010	0.005	0.018
3-19-58	0.00	0.13	0.16	0.17	0.16	0.20	0.15	0.028
3-24-58	0.00	0.71	0.66	0.69	0.71	0.69	0.74	0.74
3-26-58	0.00	0.46	0.53	0.52	0.55	0.55	0.45	0.41
3-31-58	0.00	0.24	0.25	0.26	0.24	0.30	0.33	0.018
4- 2-58	0.00	0.26	0.28	0.27	0.26	0.26	0.32	0.18
4- 9-58	0.00	0.26	0.35	0.29	0.37	0.29	0.33	0.36
4-14-58	0.00	0.60	0.62	0.69	0.66	0.62	0.69	0.90
4-16-58	0.00	0.69	0.60	0.69	0.60	0.60	0.64	0.21
4-21-58	0.00	0.33	0.32	0.31	0.31	0.36	0.37	0.74
4-23-58	0.00	0.40	0.45	0.43	0.32	0.38	0.31	0.13
4-28-58	0.0002	0.04	0.04	0.032	0.042	0.060	0.072	0.35

TABLE 1--CONTINUED

	Location in System							
Date	Underdrain	1	2	3	4	5	6*	House
4-30-58	0.00	0.25	0.028	0.025	0.020	0.025	0.032	0.018
5- 5-58	0.00							
5- 7-58	0.00	0.26	0.28	0.24	0.18	0.065	0.078	0.02
5-12-58								
5-14-58	0.00	0.18	0.17	0.16	0.09	0.18	0.26	0.018
5-19-58	0.00	0.60	0.62	0.69	0.55	0.35	0.24	0.090
5-21-58	0.00	0.41	0.45	0.45	0.33	0.46	0.45	0.090
5-26-58	0.00	0.57	0.52	0.49	0.52	0.46	0.50	0.57
5-28-58	0.00	0.39	0.46	0.42	0.53	0.55	0.46	0.64
6- 2-58	0.00	0.33	0.32	0.37	0.36	0.38	0.35	0.33
6- 4-58	0.00	0.95	0.95	0.95	1.3	1.3	0.90	1.60

* Numbers represent locations in the storage reservoir as shown in Figure 4.

** Values obtained on these dates were measured by field color comparator.

■ ■ ■

Other Factors.

Total hardness of the pond water as p.p.m. calcium carbonate equivalent, varied from 26 to 60, with the average of monthly samples for 10 months being 44.

The pH of the pond water varied from 8.4 to 9.4, with the average of samples collected weekly for 10 months being 9.1.

Alkalinity, as p.p.m. $CaCO_3$, varied from 50 to 90, with the average of samples collected monthly for 10 months being 74.

The conductivity of the pond water varied from 125 to 215 mhos. per cubic centimeter with the average being 150 for 97 samples collected during 10 months at a rate of two or three per week. For the same number of samples, collected from a house faucet, the conductivity of the chlorinated water ranged from 148 to 291 mhos. per cubic centimeter with the average being 210.

Bacteria.

Table 2 shows the monthly summary of the coliform tests on water samples from the pond, underdrain, reservoir and house. Using drinking water standards of the U.S.P.H.S., the months of October, December, January, and April failed to meet the requirements for a satisfactory water supply at the house. According to this standard, not more than 10 percent of all 10 ml. portions examined per month shall show the presence of the coliform group. However, if one examines the data on the reservoir, November is the only month that the water supply did not comply with the standard. This would indicate that recontamination may have occurred in the lines or more probably at the house faucet at the time of sampling.

TABLE 2--NUMBER OF 10 ML. PORTIONS OF WATER TESTED POSITIVE FOR BACTERIA OF THE COLIFORM GROUP AT DIFFERENT LOCATIONS IN WATER SYSTEM GROUPED BY MONTH.

Month	No. of 10 Ml. Portions Tested	No. 10 Ml. Portions Tested Positive			
		Pond	Underdrain	Reservoir	House
July '57	55	40	32	1	0
Aug. '57	65	30	17	6	3
Sept.'57	55	35	8	0	2
Oct. '57	55	31	14	4	7
Nov. '57	60	38	19	11	2
Dec. '57	45	25	11	2	5
Jan. '58	50	13	6	1	11
Feb. '58	35	8	3	2	1
Mar. '58	30	13	1	3	2
Apr. '58	40	13	8	1	6
Totals	490	246	119	31	39

Reference to Table 1 shows that the residual chlorine content of the water on many tests was below the recommended minimum of 0.4 p.p.m. Usually when the number of positive coliform tests exceeded 10 percent per month, the chlorine content of the water was below standard. When the chlorine content was above the recommended level, the water should be safe for human consumption.

Table 3 shows the presumptive and confirmed test for the presence of coliform organisms in the water samples from different sources. The data from the confirmed test is most accurate and should be used for determining the safety of the water supply. The presumptive test is used only as a screening test, since organisms other than the coliform group will give positive results. The residual chlorine content is given for the water samples taken at the house. For residual chlorine data at other sources, see Table 1.

TABLE 3--NO. OF 10 ML. PORTIONS OF WATER SHOWING PRESENCE OF COLIFORM GROUP OF BACTERIA.

Slow-sand Filter

(5-10 ml. portions examined from each sample of water)

Date	No. Days After System in Operation	Pond		Underdrain		Reservoir		House		
		P	C	P	C	P	C	P	C	R
7- 8-57	8	3	3	5	5	0	0	0	0	----
7-10-57	10	5	5	5	5	5	0	5	0	----
7-12-57	12	4	4	4	2	5	0	3	2	0.018
7-15-57	15	4	4	5	5	5	0	5	0	0.00
7-17-57	17	3	3	5	5	4	1	3	0	0.22
7-19-57	19	5	5	5	4	0	0	3	0	0.17
7-22-57	22	0	0	4	1	5	0	4	0	0.64
7-24-57	24	2	2	5	1	2	0	2	0	0.50
7-26-57	26	5	4	5	1	4	0	2	0	0.57
7-29-57	29	5	5	5	3	5	0	5	0	0.12
7-31-57	31	5	5	4	0	5	0	0	0	0.11
8- 2-57	33	3	3	3	2	5	0	5	0	0.055
8- 5-57	36	0	0	4	1	5	1	1	0	0.26
8- 7-57	38	-	-	-	-	2	0	3	0	0.055
8- 9-57	40	4	4	2	0	2	0	4	0	0.072
8-12-57	43	3	3	5	2	5	1	4	0	0.11
8-14-57	45	2	1	2	2	4	0	5	1	0.072
8-16-57	47	3	3	5	3	5	0	3	1	0.042
8-18-57	49	5	5	4	3	3	0	5	0	0.028
8-21-57	52	3	3	4	0	4	0	5	1	0.04
8-22-57	53	0	0	4	0	3	0	2	0	1.6
8-26-57	57	2	2	3	2	5	2	5	0	----
8-28-57	59	2	2	5	2	4	2	2	0	----
8-30-57	61	4	4	3	0	5	0	5	0	0.005
9- 5-57	66	5	5	5	1	0	0	3	0	1.6
9- 6-57	68	4	4	3	0	2	0	2	0	1.6
9- 9-57	71	3	3	4	2	2	0	4	0	0.27
9-11-57	73	2	2	5	2	4	0	3	0	0.47
9-13-57	75	1	1	3	0	5	0	3	0	0.47
9-16-57	78	5	4	-	-	3	0	2	0	0.081
9-18-57	80	3	3	4	2	5	0	5	0	0.11
9-21-57	83	5	5	3	0	5	0	5	1	0.00
9-23-57	85	3	3	5	1	4	0	4	1	----
9-27-57	89	5	4	2	0	4	0	5	0	----
9-30-57	92	2	1	5	0	4	0	4	0	----
10- 2-57	94	1	1	5	2	5	0	4	0	0.065
10- 4-57	96	5	2	3	0	5	0	5	1	0.05
10- 7-57	99	3	0	5	0	3	0	2	0	0.068
10-11-57	103	1	0	3	0	5	0	2	0	----
10-14-57	106	4	4	3	2	5	1	3	3	----
10-16-57	108	5	5	0	0	0	0	-	-	----
10-18-57	110	4	3	4	3	1	0	4	0	0.38
10-23-57	115	5	5	5	0	5	3	4	2	0.66
10-25-57	117	4	4	5	4	5	0	3	0	0.23
10-28-57	120	5	5	5	2	5	0	5	1	0.49
10-30-57	122	5	2	5	1	5	0	5	0	0.14
11- 1-57	124	3	2	5	1	3	0	4	1	0.53
11- 4-57	127	3	2	5	1	5	0	5	0	0.47

TABLE 3--CONTINUED

Date	No. Days After System in Operation	Pond		Underdrain		Reservoir		House		
		P	C	P	C	P	C	P	C	R
11- 6-57	129	4	3	5	1	5	0	5	0	0.66
11- 8-57	131	4	4	5	2	5	0	5	1	0.43
11-11-57	134	5	1	5	1	5	3	5	0	0.005
11-13-57	136	5	5	5	5	5	4	5	0	0.64
11-15-57	138	3	3	4	0	4	0	4	0	1.6
11-18-57	141	5	4	5	0	4	1	5	0	0.90
11-20-57	143	4	4	5	3	5	0	2	0	0.50
11-22-57	145	5	5	5	1	5	0	4	0	0.21
11-25-57	148	5	2	5	1	5	2	4	0	0.04
11-27-57	150	3	3	5	3	5	1	5	0	0.16
12- 2-57	155	5	5	5	4	5	0	5	1	0.24
12- 4-57	157	5	4	5	3	5	2	5	2	0.50
12- 6-57	159	5	1	5	0	5	0	4	0	0.64
12- 9-57	162	5	3	5	0	4	0	4	0	0.47
12-11-57	164	5	4	5	0	4	0	-	-	----
12-13-57	166	5	2	5	4	5	0	5	0	0.46
12-16-57	169	5	1	5	0	5	0	3	0	0.77
12-18-57	171	4	1	4	0	2	0	2	2	0.025
12-20-57	173	5	4	5	0	4	0	5	0	----
1- 6-58	190	5	0	5	0	5	0	4	3	0.21
1- 8-58	192	5	2	5	0	5	0	3	1	0.018
1-10-58	194	3	1	5	0	4	0	3	0	0.05
1-13-58	197	2	1	5	0	3	0	1	0	0.032
1-15-58	199	3	2	5	1	2	0	2	0	0.47
1-17-58	201	4	0	5	2	2	0	1	1	0.06
1-20-58	204	2	1	5	2	2	0	3	1	0.04
1-24-58	208	5	1	4	0	5	0	5	3	0.06
1-27-58	211	5	3	5	0	2	0	0	0	0.018
1-29-58	213	5	2	5	1	5	1	3	2	0.002
2- 3-58	218	3	1	5	0	4	0	5	0	0.012
2- 5-58	220	5	0	5	0	3	0	1	1	0.048
2-10-58	225	5	1	1	0	1	0	1	0	0.17
2-12-58	227	5	0	5	0	3	0	0	0	0.42
2-17-58	232	1	0	3	1	5	1	0	0	0.60
2-19-58	234	4	2	5	2	0	0	0	0	0.26
2-26-58	241	5	4	4	0	3	1	1	0	0.47
3-14-58	257	5	1	5	1	5	3	5	2	----
3-17-58	260	5	4	5	0	4	0	5	0	0.018
3-19-58	262	5	4	5	0	3	0	1	0	0.028
3-24-58	267	5	2	5	0	2	0	1	0	0.74
3-26-58	269	5	0	5	0	1	0	1	0	0.41
3-31-58	274	5	2	4	0	1	0	1	0	0.018
4- 2-58	276	5	0	5	0	2	0	1	0	0.18
4- 9-58	283	4	4	2	0	2	0	5	5	0.36
4-14-58	288	5	0	5	3	2	1	0	0	0.90
4-16-58	290	5	1	3	0	1	0	0	0	0.21
4-21-58	295	5	2	5	0	1	0	1	1	0.74
4-23-58	297	-	-	5	5	0	0	0	0	0.13
4-28-58	302	4	2	4	0	3	0	2	0	0.35
4-30-58	304	4	4	3	0	1	0	0	0	0.018

Letters "P", "C", and "R" stand for presumptive, confirmed, and chlorine residual respectively.

From 98 samples originating at the house tap, 490 plantings of 10 ml. each were made to check for the presence of the coliform group. Only 39 tubes out of the 490 planted showed the presence of the coliform microorganisms. This is 8 percent positive tubes, which is lower than the 10 percent allowable by the U.S.P.H.S. drinking water standards. Of the 98 samples of house water tested, 24 samples showed the presence of the coliform group. Fifteen of the 24 positive samples showed only one positive tube out of the five planted from each sample. This may be considered within the error of the testing procedure. Further examination of the reservoir samples on the same day the positive samples were found at the house shows that only six samples were positive at both sources. This would further indicate that most of the positive samples were not due to improper chlorination of the water supply. The chlorine content of the water samples showing the presence of the coliform group was below the recommended 0.4 p.p.m. residual on 17 of the 24 positive house water samples.

Additional analysis of the data shows that only 31 of the 98 samples tested had a chlorine residual of 0.4 p.p.m. Results indicate that under conditions of this test, safe water was supplied even though the chlorine content was below the recommendation of the U.S.P.H.S. This is probably due to the fact that the contact time was sufficient to bring about destruction of the microorganism when the residual chlorine was lower than that recommended.

CONCLUSIONS

The tests of this water treating installation indicate that:

1) A properly constructed and maintained slow-sand filter will provide a clear water (usually less than 5 turbidity units when the turbidity of the pond is less than 30 turbidity units).
2) Only an uncertain fraction of the bacteria in raw water is removed by slow-sand filtration. This conclusion was also drawn in previous research (4).
3) Proper chlorination (about 0.4 p.p.m. residual) should be maintained in the storage reservoir to insure safe water bacteriologically.
storage reservoir to insure safe water bacteriologically.
4) Scraping of the filter surface should not be too frequent if the unit is properly sized and the turbidity of the pond water is maintained below about 30 turbidity units,
5) Good management and proper maintenance of all components of the system are necessary to insure a high quality water.
6) A system of this type should satisfactorily supply the water needs of rural families in areas where it is not feasible to obtain good well water.

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