AN EFFICIENCY STUDY OF THE VIRGINIA POLYTECHNIC INSTITUTE SEWAGE DISPOSAL PLANT

by

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INTRODUCTION

The Virginia Polytechnic Institute Sewage Disposal Plant is located on Stroubles Creek about two miles south of the campus. The site, adjacent to State Highway No. 657, is approximately five miles from the campus by paved and unpaved roads.

Constructed in the fall of 1947 and the spring of 1948, the plant replaced the old Imhoff-type plant which had been operating under heavily overloaded conditions during the period of increased college enrollments following World War II. The plant is designed to treat one million gallons of sewage per day and at the present time serves both the Virginia Polytechnic Institute and the Town of Blacksburg. The sewer system is of the separate type, and a sixteen inch cast iron pipe line carries the sewage by gravity to the separate sludge digestion type plant. Treatment units consist of a comminutor, two primary settling tanks, a trickling filter, a chlorinator, two secondary settling tanks, a digester, three open sludge drying beds, and three covered sludge drying beds.

The plant was put in operation in July, 1948, and now operates at near design capacity during periods of high sewage flows. Due to decreased college enrollments at summer sessions, summer sewage flows are only approximately one-half of the normal flows.

Although daily records of results and operation reports have been kept over the first three years of operation, to the knowledge of the author no efficiency study of the plant has been previously made. The purpose of this thesis was to study two of the three basic sewage treatment processes, namely, the separation of solids from the liquids and the treatment of the liquids. No study of the treatment of the solids was proposed.

The efficiency of the overall treatment of the liquids was studied by comparison of analytical results of the plant influent and effluent. Analyses were also made of sewage samples taken at other points of the system to study the performance of individual treatment units. These studies were made from January to July, 1951.

REVIEW OF LITERATURE

The current literature is abundant in sewage treatment operating reports and analyses of untreated and treated sewage. This accumulation of results is to a great extent a product of the sewage treatment plant construction "boom" that followed World War II. The studies of these results, which have been obtained from all of the various types of treatment plants in operation, may well determine future changes in design, improvements in operation, and standard methods of efficiency studies.

The selection of proper tests to be used in efficiency studies is a matter of great importance. It is common practice for investigators to use the percent reduction in suspended solids and biochemical oxygen demand as the criteria of efficiency. This practice has been strongly attacked by Riddick and Johnson (28), who state that without a standard procedure of sampling the percent reduction is a meaningless figure, except as applied to the individual plant. These authors have contributed an outstanding article that deserves much attention. They believe that before a plant is considered operating "well" or "poorly" because of the percent reduction obtained, the following items must be considered: (1) the sampling procedure, (2) the theoretical detention time, (3) the suspended solids contained in the raw sewage, and (4) the percent of ground water infiltration. The authors show that a high percentage removal of suspended solids can be obtained simply by sampling when the concentration of the raw sewage is high. A plant with a high concentration and high percentage removal of suspended solids may still impose a great loading of organic matter on a stream because the final effluent remains high in suspended solids content. Other plants may be rated below standard only because the sewage was dilute at the time of sampling and an effluent low in suspended solids content was produced by low percentage removals. In short, Riddick and Johnson think "percent reductions are easy to use and easier to abuse."

Doman (5) states that effective use of percentage removal depends on correlation of such percentages with the parts per million remaining in the effluent. He conducted correlation studies on sedimentation tanks and suggested the use of a sedimentation index, which combined the percent removal of suspended solids with the parts per million of suspended solids in the effluent into one number.

Jones (19) reports that by disregarding percent removals, minimum effluent standards could be set up which should be met at all times.

Norgaard (27) attacks the practice of over-emphasizing the five-day biochemical oxygen demand and suspended solids values, when they alone do not depict the behavior of sewage. The B.O.D. is considered an inconsistent and, to the layman, an incomprehensible measure of pollution, while the suspended solids test fails when the waste contains a large proportion of solids in the dissolved state. He considers the total solids and volatile solids tests as standard measures of strength which should be included in all published data.

Many investigators report that the performance of sedimentation tanks should be measured by settleable solids rather than suspended solids. As with settleable solids, Norgaard (27) considers it desirable and far more realistic to compare the performance of sedimentation tanks on the basis of settleable B.O.D. rather than total B.O.D.; otherwise, it is possible to obtain misleading results where wastes consist almost entirely of soluble materials and yield no reduction through settling.

Some of the common criticisms of the B.O.D. test are the five-day waiting period, the varied methods of procedure, the inability of the test to differentiate between the oxygen demand caused by carbonaceous oxidation and that caused by nitrification, and the deviations from the commonly accepted velocity rate of reaction (k=.1). Norgaard (27) suggests that the latter criticism be overcome by determining the one-day and the five-day B.O.D. because at normal reaction rates the one-day B.O.D. should be thirty percent of the five-day B.O.D. If this relation does not exist, a more thorough investigation of the velocity reaction should be made.

Eckenfelder and Hood (6) (7) (8) (9) (10) have been leaders in evaluating sewage analysis work and establishing fundamental relationships. They state (6) that the accuracy of the B.O.D. test is limited to 5 to 15 percent, and that the validity of the test may be confirmed or denied in some cases by relative stability comparisons. The importance of the dissolved oxygen test is not denied, but it should be remembered that this test does not disclose the quantity of the pollutional load, as several parts per million of dissolved oxygen may be found in a raw sewage with a very high B.O.D. If a sewage is below zero in dissolved oxygen content, the biochemical state or extent of reduction cannot be determined, and it is suggested that a measurement of the oxidation-reduction potential be made.

Eckenfelder and Hood (10) state that "quantities of alkalinity are not controllable and are highly variable in raw sewage." They further state (6) that "the significance of alkalinity in sewage treatment has been to establish the magnitude of the buffer value. This value will vary as the strength and character of the raw sewage and the degree of treatment. Oxidative treatment reduces the alkalinity by the formation of acidic compounds and destruction of the alkaline buffer. Thus, alkalinity values indicate the oxidative effectiveness of the treatment process."

The Federation of Sewage Works Association (12) emphasizes the use of alkalinity tests to determine the effectiveness of treatment. When the alkalinity of primary settled sewage ranges from 150 to 400 parts per million, a reduction of thirty percent or more in the final effluent is considered equivalent to an eighty-five percent or greater removal in B.O.D. and indicates a good effluent.

Metcalf and Eddy (22) state that the determination of the hydrogen-ion concentration of sewage is important in connection with the following three problems: (1) the life processes of bacteria that decompose sewage matters; (2) the coagulation and precipitation of suspended and colloidal matter; and (3) the dewatering of sludge. In connection with the first problem, Eckenfelder and Hood (3) find that the optimum pH of most of the organisms concerned lies in the range from 6.0 to 8.0, and an extremely high or low pH brings biological activity to a standstill. Maximum oxidation is found to occur at a pH from 6.6 to 9.0.

The importance of pH-alkalinity values is shown by Hood (17), who states that pH-alkalinity surveys can be used to advantage in checking the performance of the individual units or the overall sewage treatment plant. Poor efficiency is often the result of high pH-alkalinity values, and results are often affected by upper adjustment of pH-alkalinity values due to returned digester supernatant for treatment. It is mentioned by the author that pretreatment of the supernatant by chlorination is of benefit by causing downward pH-alkalinity adjustment. Hood further states that no constant relation is found to exist between B.O.D. and pH-alkalinity value.

Kellam (20) recognized the effects of the quality and condition of sewage upon arrival at the treatment plant. Poorly designed sewer systems, with resulting septic sewage, will cause disintegration of solids followed by a reduction in settleable material and an increase in non-settleable and dissolved solids. These effects, which also include increased dissolved biochemical oxygen demands, tend to increase the loadings on secondary units and decrease plant efficiency. Other effects are deterioration of pipe lines and equipment by excessive hydrogen sulfide formation and the creation of nuisance conditions.

Free ammonia nitrogen is important in biological treatment processes. It may be oxidized to nitrites and nitrates or serve as a source of nitrogen for microbial oxidation of carbonaceous compounds. Eckenfelder and Hood (9) indicate through experimental evidence at Ridgewood, New Jersey, that free ammonia nitrogen and alkalinity are reduced through a trickling filter in some proportion to the oxidation occurring.

The desirability of nitrification seems to be a matter of controversy. Eliassen (11) states the undesirability of depositing nitrates in streams because they stimulate algal growths and recommends their elimination when possible. Hood (17) considers nitrification important in preserving good stream conditions and vital to the success of treatment processes. Mohlman, Hurwitz, Barnett, and Kramer (23) believe the potential oxygen available in the form of nitrates is an asset to streams in preventing nuisance conditions until the nitrates are utilized; however, since they are not utilized until the dissolved oxygen content is zero, they serve no particular use if the dissolved oxygen to be maintained is 3 to 4 parts per million.

At the Elizabeth Joint Meeting Plant Rudolfs and Decher (29) used seven and one-half years of operation data to determine that the strength of sewage was not related to the rainfall. A fifty-eight percent increase in the average daily rainfall failed to alter the average strength of the sewage, because street washings entered the sewers and the sewers were flushed during storms. The quality of the effluent was also not affected by flows, as the degree of purification remained nearly constant at all times.

Sperry (30) showed that with the exception of Sundays and Mondays sewage flows vary little from day to day of the week, and Kellam (13) found that flow variations on a given system are surprisingly uniform even from hour to hour of a given day of the week. Loads generally increase and decrease with the flow, and flows usually level off after reaching a maximum around noon and remain fairly constant for several hours.

Rudolfs and Decher (29) mention that the general efficiency of a plant is indicated by the neat appearance of buildings, equipment, and grounds. The Federation of Sewage Works Association (12) discussed the importance of technical tests, but emphasized that they should always be supplemented with common observations in evaluating the success or failure of a treatment plant. It is pointed out that "a black, smelly stream below a plant is indicative of failure, just as a clear, clean stream supporting fish life proves the efficiency of plant performance."

Sampling procedures are varied and in need of standardization. Riddick and Johnson (28) express the need of a uniform system of sampling for a true comparison of plant efficiencies. Caster and Hamilton (3) further emphasize the need, stating that comparisons of eight-hour composite samples and twenty-four hour composite samples of raw sewage produced variations of 41 per cent in B.O.D. and 31 percent in suspended solids. The National Research Council (26) observed significant distortion of plant performance where short sampling periods were used and suggests the following minimum requirements: (1) a period of compositing greater than eight hours; (2) sample volumes composited proportional to flow at intervals not greater than two hours; and (3) four composite samples per month.

The Federation of Sewage Works Association (12) believes that analyses of individual catch samples collected at intervals during a twenty-four hour period should be compared with an analysis of the twenty-four hour composite sample. Where this is impossible, it is recommended that a sample taken during maximum flow be examined, and if the results are satisfactory at this period of maximum loading, they should be satisfactory at all times. When catch samples are used to determine the efficiency of a unit, the effluent sample should be collected after the flowing through time has elapsed.

Although composite samples are recommended by the majority of investigators, the Federation of Sewage Works Association warns that mixing of portions can cause marked changes with results that are not typical of the sewage at any time.

The Standard Methods for the Examination of Water and Sewage (1) has been of great aid in standardizing the procedures of sewage analysis work; however, the literature indicates an immediate need for new and improved standard methods before comparisons of efficiency studies can be made on a sound basis.

OBJECT

The purpose of this study was to investigate the efficiency of the separation of the solids from the liquids and the treatment of the liquids at the VPI Sewage Disposal Plant. Essentially, this treatment is accomplished by three units, which are as follows: (1) Two primary sedimentation tanks, (2) a trickling filter, and (3) two secondary sedimentation tanks. The study was proposed to determine the efficiency of the individual units, as well as the overall efficiency of the combined units.

The study was designed to include the establishment of sewage sampling stations at various points in the treatment plant, collection of sewage samples at the sampling stations, and examination of the samples to determine physical and chemical changes through the treatment process. The physical and chemical changes were to be indicated by testing the sewage samples for temperature, hydrogen-ion concentration (pH), dissolved oxygen, biochemical oxygen demand, relative stability, alkalinity, free ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, total solids, total volatile solids, suspended solids, settleable solids, chlorides, and sulfates. The results of these tests were to be studied for efficiency determinations and for possible correlations of degree of efficiency with varying sewage flows.

THE INVESTIGATION

Tests Employed

Quantity of Flow: The amount of sewage flowing through a given system will depend on the time of day, rainfall and infiltration, industrial waste loadings, constant or variable populations, and other factors. The variations in flow caused by these factors may strongly influence the efficiency of the treatment process; therefore, correlation of the flow with plant performance is important in predicting future plant performance.

Temperature: The temperature of sewage is important because it causes changes in the biological activity of treatment processes, induces various degrees of solubility of dissolved oxygen, and affects the viscosity and thus influences sedimentation efficiencies. Temperatures may be influenced greatly by varying amounts of industrial wastes. Domestic sewage temperatures are usually higher than atmospheric temperatures, but the reverse is true during the summer months.

Hydrogen-ion concentration(pH) indicates whether sewage is acid or alkaline. This test is especially important in plant control and has recently been used in combination with alkalinity values to indicate plant performance. Optimum pH values are important for greater activity of organisms in biological processes.

Dissolved Oxygen is the amount of oxygen dissolved in a liquid, and the chief value of the test is its use as a part of the biochemical oxygen demand test. D.O. values represent assets of a stream or effluent, which are reduced or depleted by pollutional loads.

Biochemical Oxygen Demand is defined as the amount of oxygen required to stabilize the organic material of a sample by bacterial action. The test is used to compare the strengths of various wastes, and the reduction in B.O.D. is generally considered the best criterion of effective treatment.

The Relative Stability of sewage is expressed as a percentage and is the ratio of the oxygen available in a sample to the total oxygen demand of the sample. The test has lost much of its significance and has been replaced to a large degree by the B.O.D. test, but it is still used in many small treatment plants.

Alkalinity in sewage is caused by the hydroxides, carbonates, and bicarbonates of various elements, the most common of which are calcium, magnesium, sodium, and potassium. In the past unless abnormal alkalinities were discovered, the test had little significance, but it is now used to some degree in determining the effectiveness of oxidative treatment.

Free ammonia nitrogen is a reduced substance resulting from the bacterial decomposition of organic material. Concentrations are usually high in stale sewages, and when combined with organic nitrogen determinations, the total concentrations serve as a measure of the strength of sewage.

Nitrite Nitrogen is not a stable form of nitrogen, and its presence in sewage indicates that oxidation to nitrate nitrogen or reduction to ammonia nitrogen is occurring.

Nitrate Nitrogen is the most stable form of nitrogen in sewage and large concentrations of nitrates indicate that nitrification has occurred through the oxidation of ammonia nitrogen. The presence of this stable form of nitrogen in sewage plant effluents may or may not be considered desirable.

The Total Solids content, which represents the residue of a sample after evaporation, is one of the oldest indicators of the strength of sewage. Separation of the solids from the liquids is the first basic process of sewage treatment, and the total solids test is important in determining the efficiency of the process.

Volatile Solids furnish a measure of the quantity of organic material in the total solids, the remaining portion consisting of mineral matter. In sewage treatment, the volatile solids are of greater concern than the mineral matter because they undergo decomposition.

Suspended Solids are those that are not dissolved in the liquid and can be removed by filtration. Suspended matter removal values are important in determining sedimentation efficiencies and are used by many investigators along with B.O.D. removals as the usual measures of sewage treatment efficiency.

Settleable Solids are those that will settle to the bottom of settling devices in a given detention time, while non-settleable solids will not settle under any conditions. Settleable solids are most important in determining the efficiency of sedimentation tanks, as it is the purpose of these tanks to separate settleable solids from the liquids.

Chlorides are inorganic ions found in sewage that are not affected by sewage treatment, and the concentrations of the water supply are increased by urine and industrial waste and decreased only by diluting water. Concentrations above those of the water supply may be used to indicate the strength of the sewage.

Sulfates: Sulphur compounds in sewage are readily oxidized to sulfates through the treatment process and sulfates can be reduced in sewage with the formation of the gas, hydrogen sulfide. Tests for sulfates may be used to indicate the effectiveness of the oxidative treatment.

Sampling

In any efficiency study similar to this investigation, the sampling procedure is of utmost importance. Even though the accuracy of the analytical work is good, misleading results will be obtained unless representative samples of the wastes are obtained.

The most common sampling procedure used by investigators is the collection of composite samples over a twenty-four hour period. The composite samples consist of individual samples collected at intervals during the twenty-four hours, with the volume of each individual sample collected proportional to the sewage flow at the time of sampling.

The distance to the treatment plant from the Sanitary Engineering Laboratory and the time and personnel required for composite samples necessitated the use of "catch" samples in this investigation. These "catch" samples were collected during periods of maximum flows, as previous investigations have shown that the strength of sewage, or the loading, is generally greatest when the flow is at a maximum. The assumption was made that satisfactory operation at maximum flows would indicate satisfactory operation at all times.

A study of flow charts at the sewage pumping station revealed that maximum flows for a twenty-four hour period occurred between twelve and one o'clock of each day, with the flow remaining almost constant for several hours before reaching the maximum. Consequently, one o'clock in the afternoon was chosen as the most suitable sampling time. Since the sewage would likely be more concentrated during middle-of-the-week days when a majority of the VPI students were on the campus, most of the sampling was done on a Wednesday or Thursday.

When the time of flow is known, the same "slug" of sewage can be sampled at all of the sampling stations by simply waiting until each of the flow times between stations has elapsed. The time of flow of the sewage through the various treatment units concerned in this study was unknown, and some adjustment of the sampling procedure was desirable to compensate for this factor. The only possible adjustment seemed to be the fact that the sampling time was preceded by several hours of near constant flows. From eight A.M. until one P.M. of each day the flow variations were very slight, and this long period of practically constant flow was assumed ample to allow a sample of near the same strength to be collected at all sampling stations.

Four sampling stations were established as shown in Figure 1. Station Number One was located at Manhole Number One and the sample at this station consisted of the raw sewage influent. Station Number Two was located just beyond the overflow weir of the primary clarifier. Station Number Three was established at the end of the collection channel

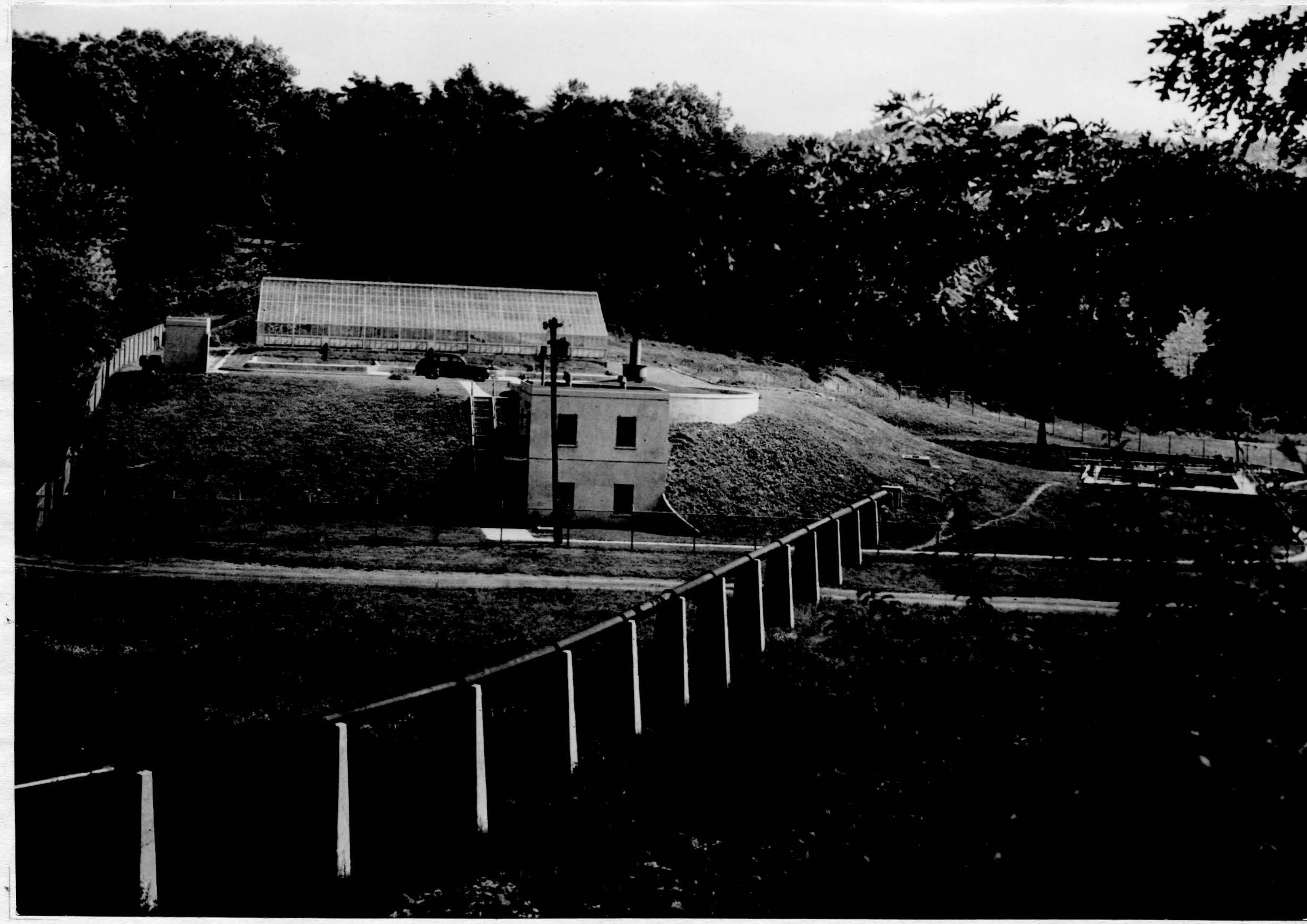


Plate 1. VPI Sewage Disposal Plant

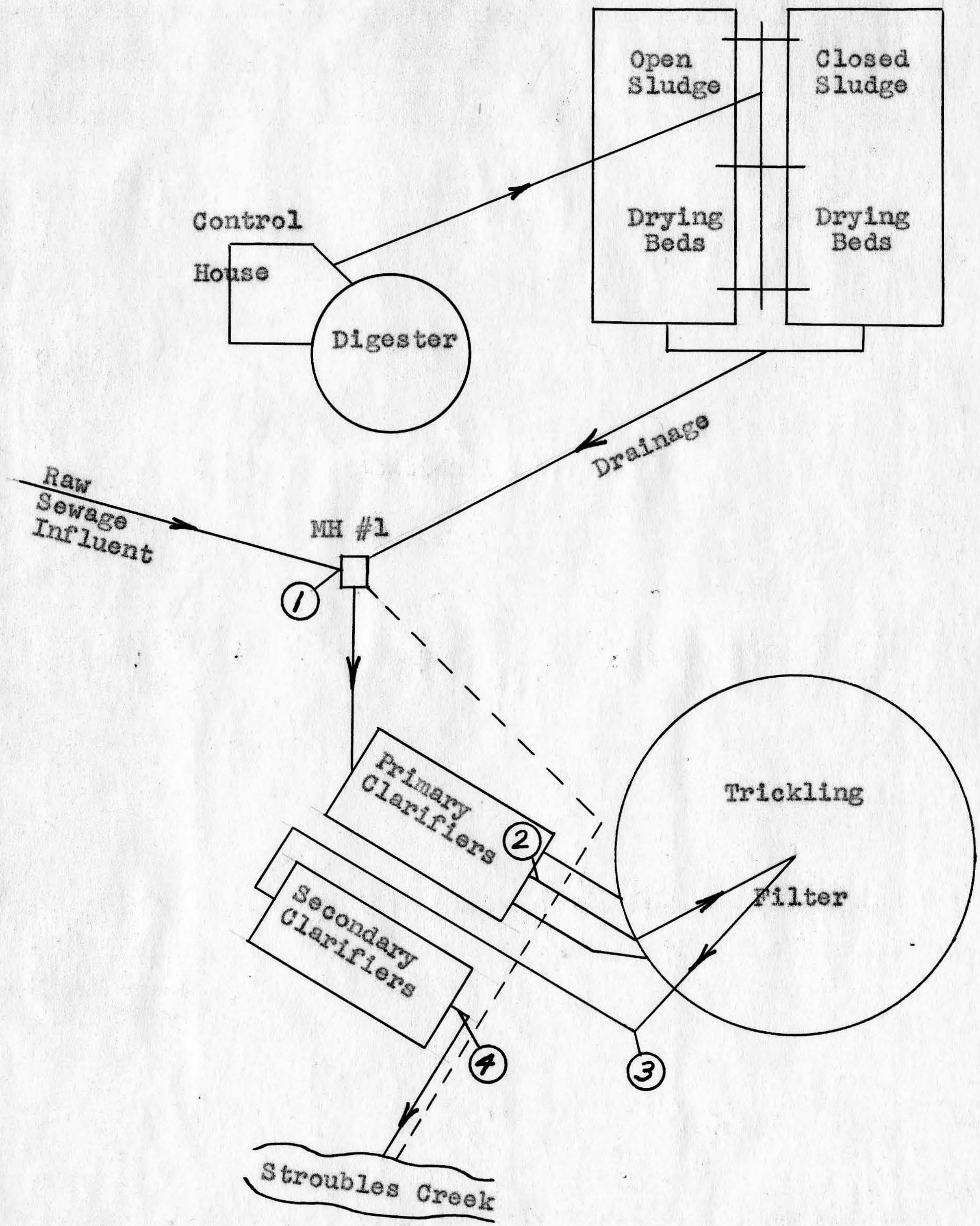
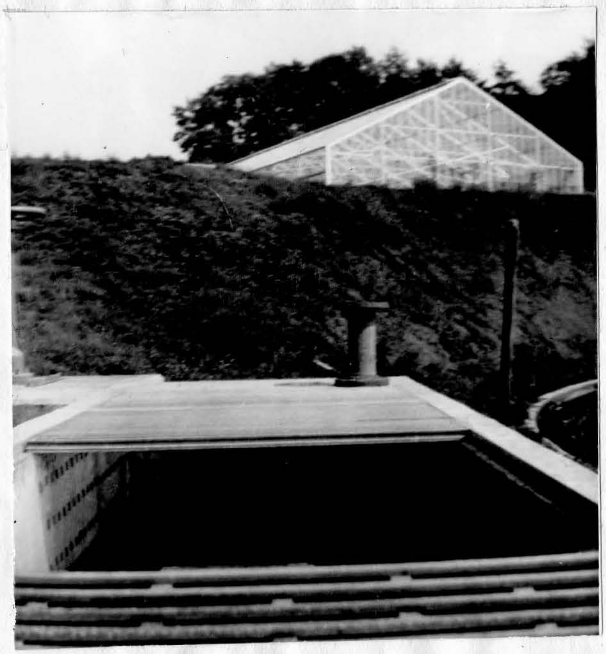


Figure 1. Locations of Sampling Stations.

Station 1



Station 2

Plate 2. Sampling Stations for raw sewage and primary effluent.

Station 3

Station 4

Plate 3. Sampling Stations for trickling filter effluent and final effluent.

of the trickling filter. The final sample consisted of the plant effluent and was collected at Station Number Four in the weir trough of the secondary clarifier. These stations were selected so as to make possible a comparison of raw sewage, primary settled sewage, trickling filter effluent, and final effluent.

At each station one-half gallon of sewage was collected in a wide mouth tin sampler, which was designed for regular use at the disposal plant. These samples were placed in tightly covered glass jars and conveyed to the Sanitary Engineering Laboratory immediately upon collection. Analyses were started upon arrival, and the remaining portions of the samples were preserved by refrigeration at near freezing temperatures. Since all of the analytical work was done by the author, it required several days to complete a single run. The B.O.D. dilutions were made and incubated first, and the solids tests were the last to be completed.

At the same time the jar samples were collected in the field, additional samples were collected for dissolved oxygen and relative stability tests and much care was taken to avoid aeration. As soon as each sample was taken, the reagents for dissolved oxygen and relative stability tests were added to the bottles in the field. They were then conveyed to the laboratory, where the relative stability bottles were incubated and the dissolved oxygen tests were completed.

Test Procedures

Although some modifications were employed, the test procedures used in the analyses were those recommended by The Standard Methods for the Examination of Water and Sewage (1), and the many stock and standard solutions needed for these tests were prepared by the author. Some of the solutions were preserved for only short periods of time and had to be replaced at intervals during the testing period.

The author became familiar with testing procedures by using trial runs before actual test runs began. The necessary modifications, along with time limitations, caused delays in beginning dissolved oxygen, biochemical oxygen demand, and suspended solids tests. This was regretable but unavoidable.

It was felt that the color comparison tests for the various forms of nitrogen were time consuming and difficult to perform accurately by visual comparison; therefore, it was decided to use a Fisher electrophotometer for these determinations. Standard solutions were made containing various concentrations of free ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. The necessary reagents were added to produce the color reactions, and readings were taken on the electrophotometer. These readings were plotted against concentrations to produce calibration curves. In each case it was necessary to make several attempts before a satisfactory curve could be obtained. The electrophotometer was used in all of the sewage examinations, and nitrogen concentrations were obtained from the calibration curves.

Several B.O.D. tests were made using both a standard laboratory dilution water and water from Stroubles Creek, collected just above the entrance of the disposal plant effluent, with the following results:

	B.O.D. Using Creek Dilution Water	B.O.D. Using Laboratory Dilution Water
Sample # 1	208 ppm.	220 ppm.
Sample # 2	144 ppm.	140 ppm.
Sample # 3	42 ppm.	44 ppm.
Sample # 4	40 ppm.	36 ppm.

These differences were considered insignificant and a decision was made to use the creek water in all B.O.D. dilution work. The water always contained a high dissolved oxygen content that stabilized near seven parts per million after a few days storage.

Recording the sewage flow was the initial step of each sampling run. The flow is recorded continuously in the VPI sewerage system at the pumping station, located near the college lake, and is measured in terms of million gallons per day by a Kennison Nozzle meter.

The atmospheric temperature was measured at a height of four feet from the ground.

Hydrogen-ion concentration was determined by the use of a portable Beckman electrometer which was standardized with a buffer solution of pH 7.0 before each run. Electrodes were cleaned before each immersion, and temperature adjustments were made as the pH of the sample was determined.

Dissolved Oxygen was determined by alum flocculation of the collected samples, followed by the sodium-azide modification of the Winkler method. The flocculation was necessary to remove interfering sewage solids in all samples except the final effluent.

Biochemical Oxygen Demand samples were prepared by using the following dilutions: 1.0 and 2.0 percent for Sample No. 1; 3.0 and 3.5 percent for Sample No. 2; and 10.0 and 12.0 percent for Samples No. 3 and 4. The sodium-azide modification of the Winkler method was used for the dissolved oxygen tests, which were run on each dilution and diluting water blank before and after incubation for five days at 20 degrees C. The residual chlorine in Sample No. 4 was so small that dechlorination was not necessary, but it was seeded with one ml. of primary settled sewage.

The alkalinity was always entirely bicarbonate, as phenolphthalein indicator produced no color in the samples.

Ammonia Nitrogen was determined by direct nesslerization rather than distillation.

Nitrate Nitrogen was determined by the phenoldisulfonic acid method.

Settleable Solids were measured by volume in an Imhoff cone.

Results

Flow: Average sewage flows by months during the sampling period are shown in Figure 2 of the results. The maximum average monthly flow occurred during the month of April and the minimum in June, with the values ranging from 1,200,000 gallons per day to 470,000 gallons per day. The average flow over the entire sampling period was 700,000 gallons per day.

The extremely high flows that were recorded in April indicate that flows may possibly be related to rainfall in the VPI sewerage system.

Temperature: The temperatures of the atmosphere and sewage varied as expected, as shown by Figure 3. Great changes in the atmospheric temperatures over the sampling period induced only slight changes of sewage temperatures, and the atmospheric temperatures were less than the sewage temperatures in winter and greater in summer.

Table I - Flow and Temperature Results

Date	Flow (mgd)	Temperature (degrees centigrade) Sample Number				
		Atmosphere	1	2	3	4*
January 10	.52	14	18	15	12	12
17	.57	14	19	14	12	11
24	.61	11	18	15	13	13
31	.75	-3	18	13	11	12
Average	.61	9	18			12
February 7	1.05	0	12	12	11	11
14	.60	23	17	15	14	14
21	.92	12	14	13	13	13
28	.69	8	18	15	13	13
Average	.82	11	15			13
March 7	.75	21	17	16	16	16
April 5	1.05	14	16	14	13	13
12	1.80	10	14	13	13	13
19	1.00	16	17	16	--	--
26	1.00	26	20	18	18	18
Average	1.21	16	17			15
May 3	.85	24	20	19	19	19
10	.72	29	20	20	20	20
17	.65	28	21	20	20	20
Average	.74	27	20			20
June 15	.50	26	21	20	20	20
21	.46	23	22	21	22	22
28	.45	34	24	24	24	24
Average	.47	28	22			22
July 5	.50	22	22	22	22	22
6	.50	--	--	--	--	--
11	.60	27	23	23	22	23
12	.49	27	23	23	23	23
13	.41	28	23	23	23	24
17	.46	30	24	24	23	24
19	.46	32	24	24	24	24
Average	.49	28	23			23

* The sample numbers 1, 2, 3 and 4 indicate raw sewage, primary effluent trickling, filter effluent, and final effluent.

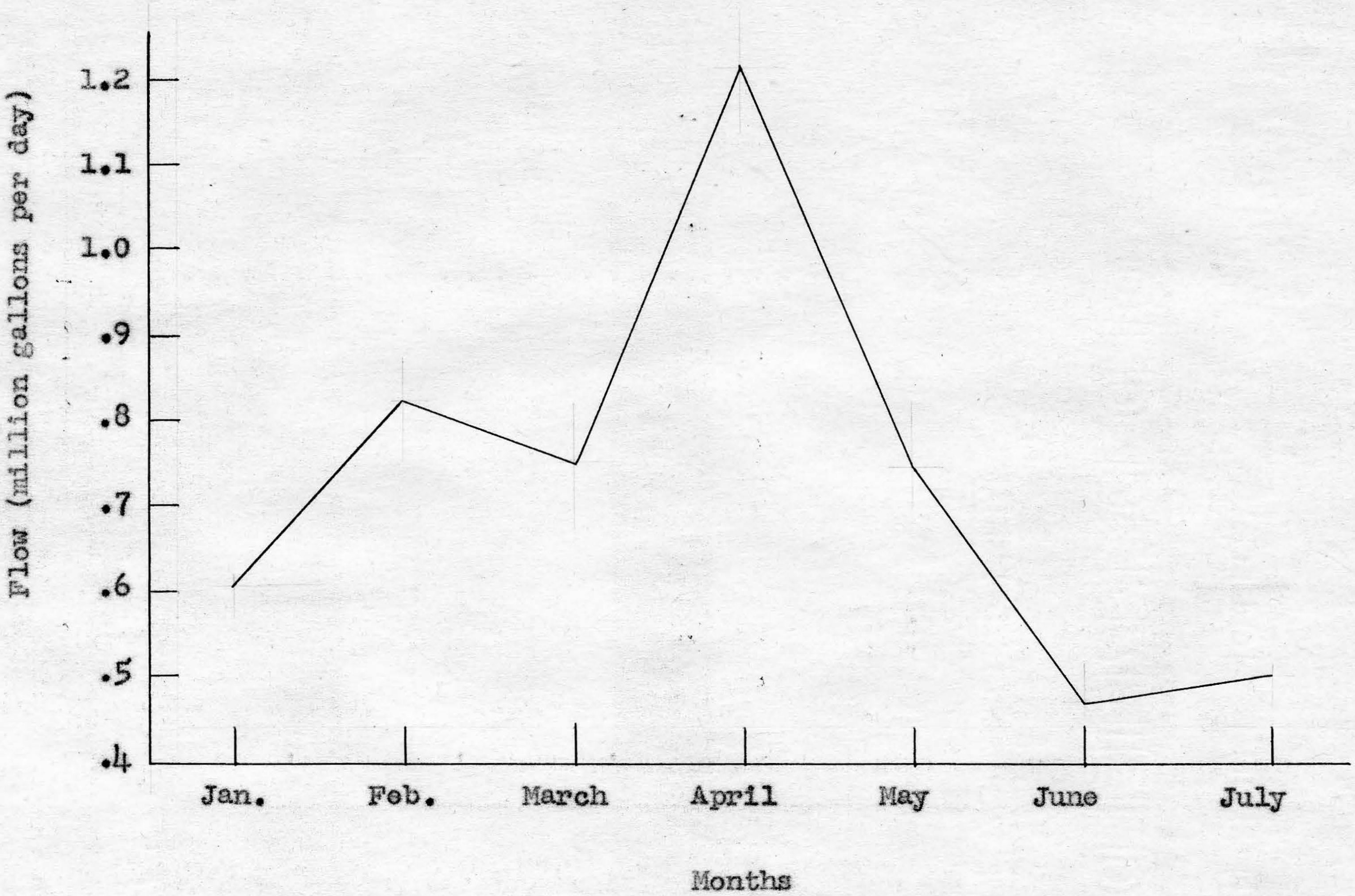


Figure 2. Monthly variation of average SEWAGE FLOWS.

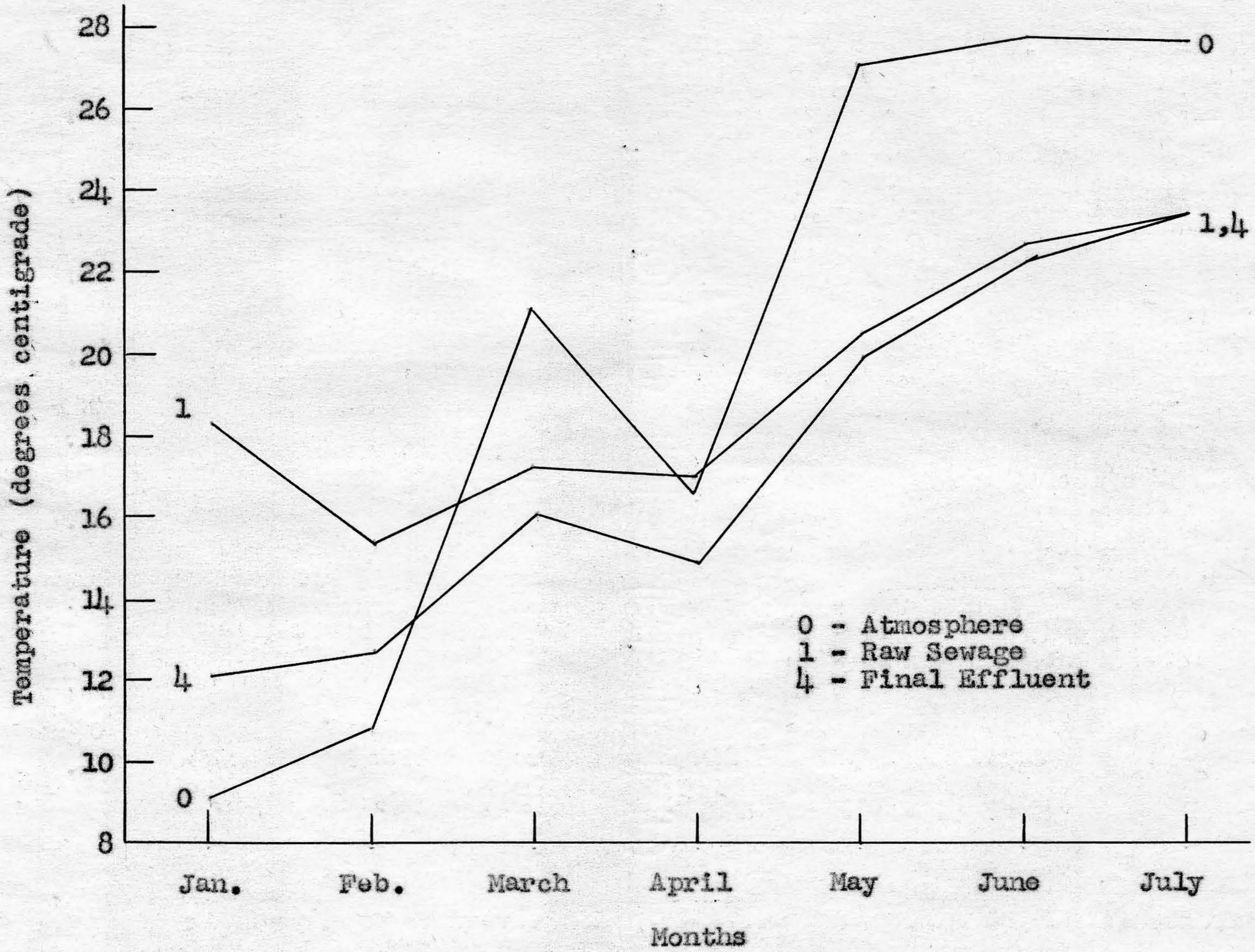


Figure 3. Monthly variation of average TEMPERATURES.

<u>Total</u> <u>Solids</u> <u>and</u> <u>Volatile</u> <u>Solids</u>: Although the value of results in terms of percent reduction is questioned, percent reductions are presented in this investigation for two particular reasons: first, it was anticipated that the variations in percent reductions would indicate the efficiency of the treatment plant at various flows; secondly, the percent reductions may be helpful in future studies of the VPI Treatment Plant.

The results in Table II indicate that approximately one-half of the total solids in the plant influent (Sample 1) are volatile(organic). The reductions that follow were calculated from the average monthly values of total and volatile solids.

Month	Flow (mgd.) (Aver.)	Overall Reduction (%) Total Solids	Overall Reduction (%) Volatile Solids
January	.61	47	74
February	.82	38	84
March	.75	34	75
April	1.21	39	71
May	.74	30	42
June	.47	32	56
July	.49	47	75

Although the average reduction in total solids is only 38 percent, the reduction in volatile solids is much greater, the average value being 68 percent. There appears to be no correlation between the percent reduction and the flow.

The average monthly values of total and volatile solids are plotted in Figures 4 and 5.

Table II - Total Solids and Volatile Solids
(Parts per million)

Date	Flow	Total Solids 1	Total Solids 2	Total Solids 4*	Volatile Solids 1	Volatile Solids 2	Volatile Solids 4*
January 10	.52	750	651	483	353	245	111
17	.57	1223	956	485	435	178	50
24	.61	787	625	604	338	199	154
31	.75	983	536	458	420	201	88
Average	.61	951	689	508	387	206	101
February 7	1.05	970	823	527	620	287	130
14	.60	708	611	497	251	180	39
21	.92	679	654	460	276	225	14
28	.69	740	647	445	299	192	44
Average	.82	774	684	482	362	221	57
March 7	.75	692	617	454	334	174	85
April 5	1.05	684	492	347	350	171	75
12	1.80	558	529	361	176	165	55
19	1.00	629	507	---	294	235	--
26	1.00	586	445	425	190	182	88
Average	1.21	614	493	377	250	189	73
May 3	.85	574	456	405	181	112	119
10	.72	723	636	487	260	182	112
17	.65	682	675	486	272	251	179
Average	.74	660	589	459	238	182	137
June 15	.50	727	617	479	267	171	68
21	.46	725	573	440	315	241	165
28	.45	657	652	513	270	236	142
Average	.47	703	614	477	284	216	125
July 5	.50	725	544	417	372	219	125
6	.50	---	---	---	---	---	---
11	.60	881	519	446	410	192	93
12	.49	730	454	365	377	157	127
13	.41	854	546	468	459	197	57
17	.46	856	466	422	496	140	111
19	.46	737	440	436	296	131	94
Average	.49	797	495	425	401	173	101

* The sample numbers 1, 2 and 4 indicate raw sewage, primary effluent, and final effluent.

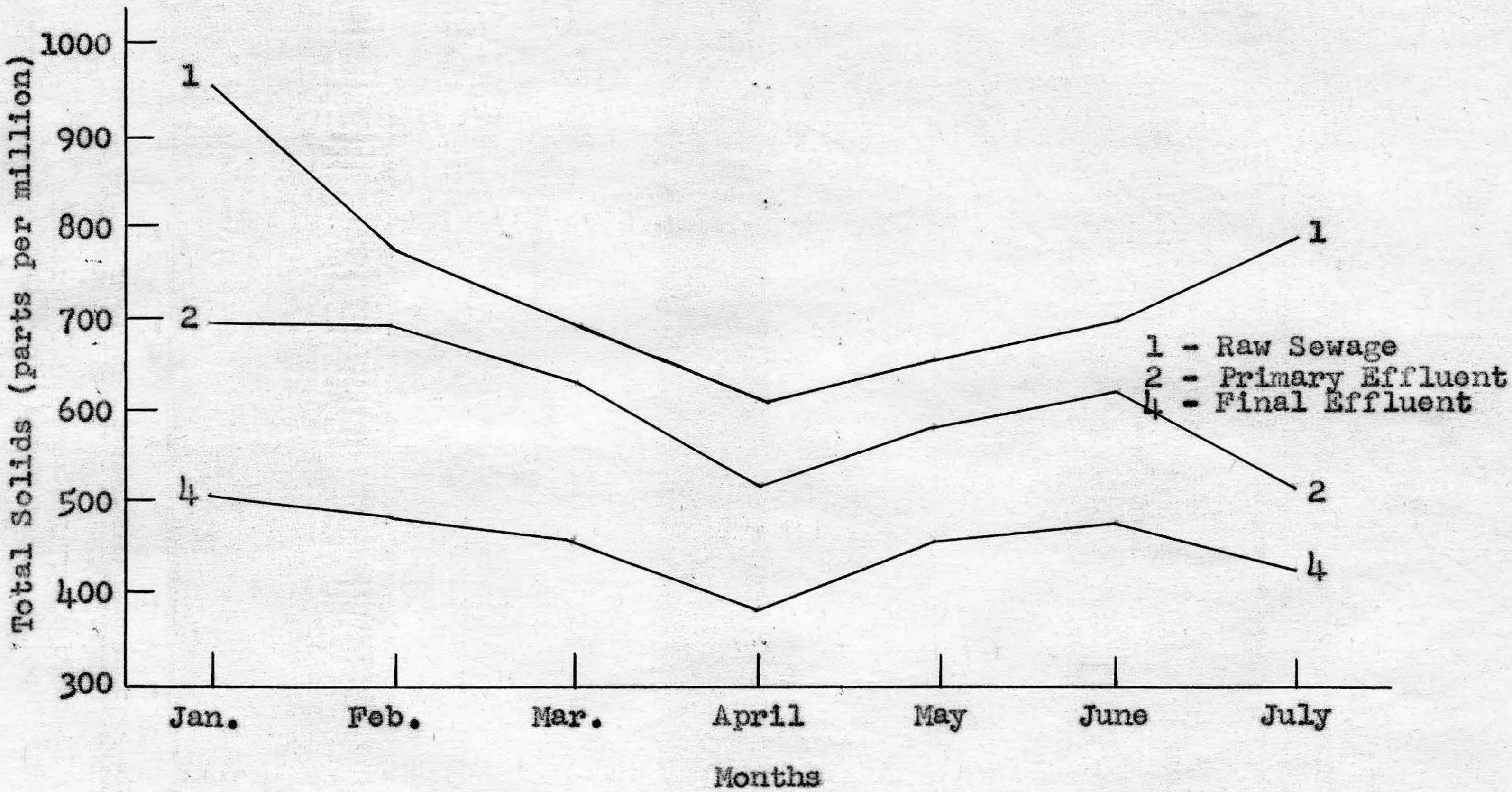


Figure 4. Monthly variation of average TOTAL SOLIDS concentration in Sewage.

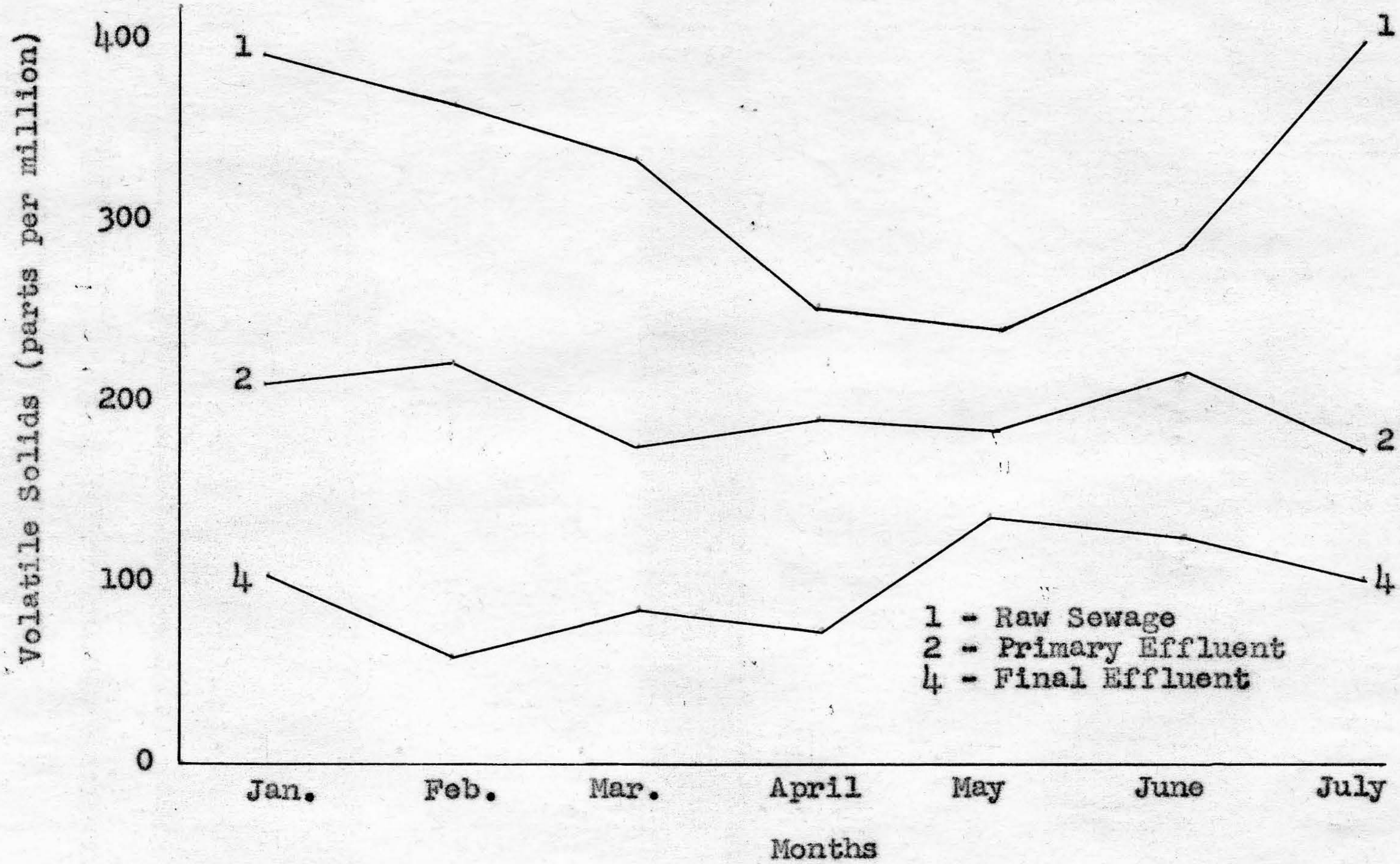


Figure 5. Monthly variation of average VOLATILE SOLIDS concentration in Sewage.

Settleable Solids and Suspended Solids: Imhoff and Fair (18) state that the performance of sedimentation tanks is generally considered satisfactory if the plant effluent contains not more than 0.5 ml. of settleable solids determined by an Imhoff cone. Using this criterion of efficiency, the results of Table III show that the settleable solids content of the final effluent was continually satisfactory and the sedimentation efficiency was exceptionally good during the low summer flows.

The reduction in suspended solids was greater at low flows, as shown by Table III and Figure 7, and superior effluents were produced along with the greater percent removals. The average overall reduction in suspended solids was 84 per cent, and the monthly average reductions are shown by the following figures.

Month	Flow (mgd.) (Aver.)	Overall Reduction(%) Suspended Solids	Reduction through Prim. Clar.
April	1.21	79	32
May	.74	80	30
June	.47	84	33
July	.49	92	59

The "unloading" or "sloughing off" of a trickling filter usually occurs in the spring of the year and is caused by upward temperature changes following long cold periods. Great quantities of solid matter that have been stored in the filter media are released along with the bacterial jelly of the filter. This unloading was observed on May 10 and was responsible for the settleable solids results of the trickling filter effluent on that date.

Table III - Settleable Solids and Suspended Solids

Date	Flow (mgd)	Settleable Solids (ml./liter)				Suspended Solids (ppm.)		
		1	2	3	4*	1	2	4*
January 10	.52	---	---	---	---	---	---	---
17	.57	---	---	---	---	---	---	---
24	.61	9.0	1.4	3.5	.5	---	---	---
31	.75	10.0	0.6	2.0	.3	---	---	---
Average	.61	9.5	1.0	2.8	.4	---	---	---
February 7	1.05	3.0	1.7	0.8	.5	---	---	---
14	.60	6.2	1.0	2.0	.2	---	---	---
21	.92	5.0	1.8	3.0	.5	---	---	---
28	.69	9.0	0.5	3.5	.2	---	---	---
Average	.82	5.8	1.3	2.3	.4	---	---	---
March 7	.75	5.0	1.8	2.0	.5	---	---	---
April 5	1.05	6.0	0.2	0.2	.2	---	---	---
12	1.80	3.0	4.0	0.5	.4	---	---	---
19	1.00	6.0	1.4	---	---	185	131	33
26	1.00	6.5	0.8	0.3	.2	192	124	45
Average	1.21	5.4	1.6	0.3	.3	189	128	39
May 3	.85	8.5	1.2	1.0	.4	174	110	39
10	.72	6.0	1.1	22.0	.2	241	172	43
17	.65	8.0	2.0	0.3	.3	182	136	36
Average	.74	7.5	1.4	7.8	.3	199	139	39
June 15	.50	5.0	3.1	0.6	.6	266	178	34
21	.46	5.5	0.8	0.2	.2	228	158	34
28	.45	6.3	2.7	0.3	.1	190	121	42
Average	.47	5.6	2.2	0.4	.3	228	152	37
July 5	.50	9.0	2.0	0.2	.1	306	162	28
6	.50	---	---	---	---	308	68	12
11	.60	13.0	2.5	0.5	.1	364	278	74
12	.49	11.0	2.5	0.3	.1	332	140	28
13	.41	10.5	0.5	0.2	.1	436	88	16
17	.46	7.0	0.4	0.1	Tr.	308	84	20
19	.46	7.5	2.2	0.3	.1	264	140	12
Average	.49	9.7	1.7	0.3	.1	331	137	27

* The sample numbers 1, 2, 3, and 4 indicate raw sewage, primary effluent, trickling filter effluent, and final effluent.

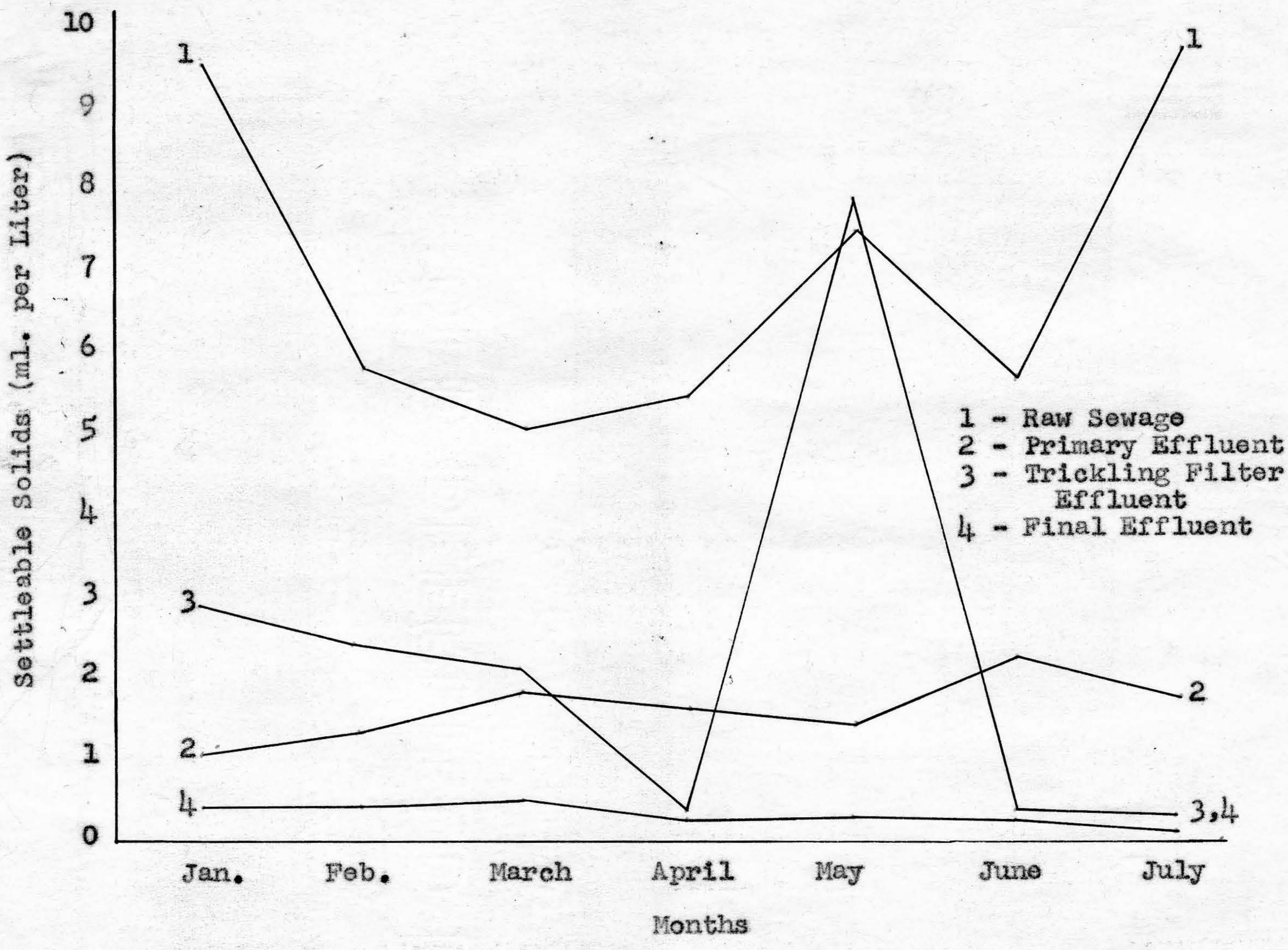


Figure 6. Monthly variation of average SETTLEABLE SOLIDS concentration in Sewage.

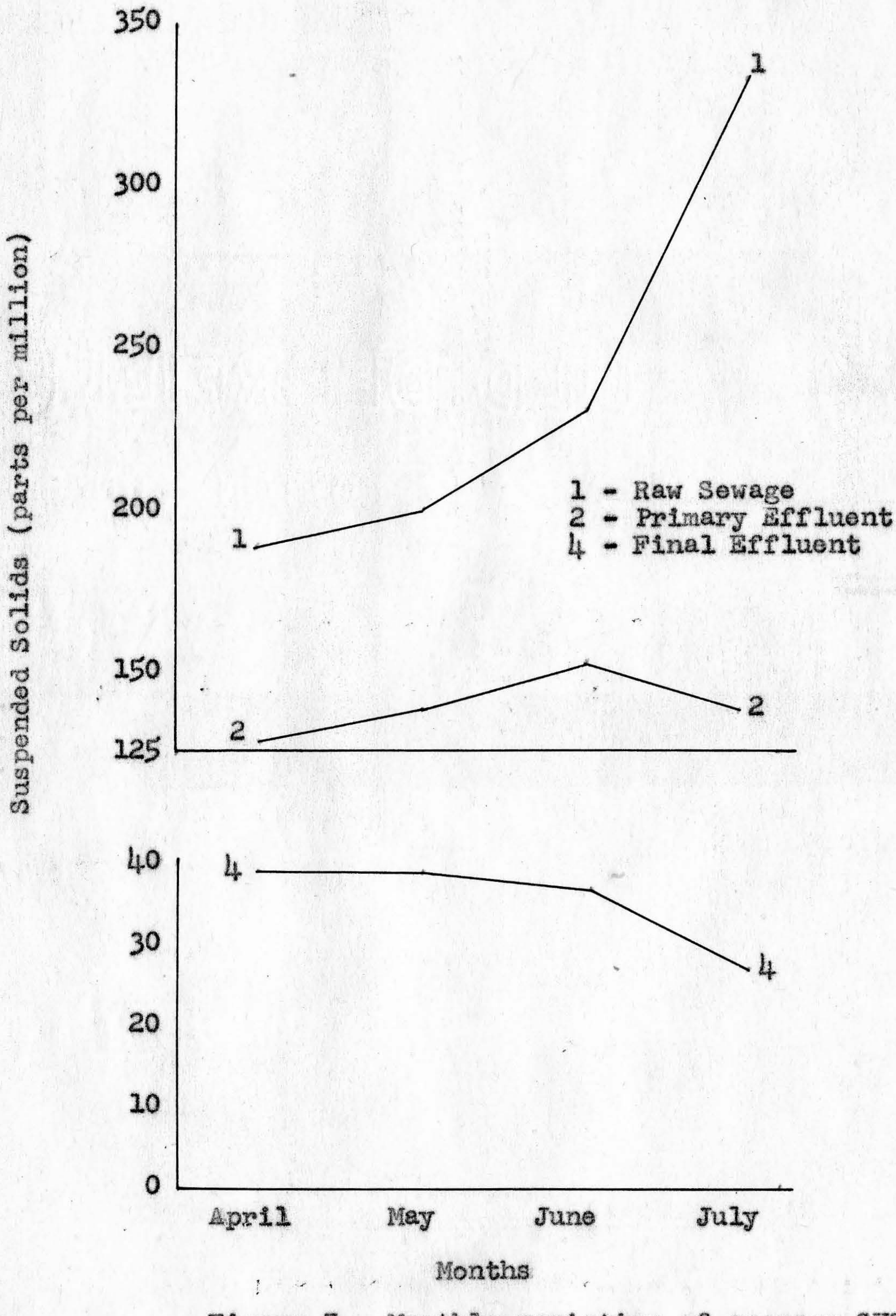


Figure 7. Monthly variation of average SUSPENDED SOLIDS concentration in Sewage.

B.O.D. and Relative Stability: The average reduction in B.O.D. through the primary clarifier was 38 percent, and the average overall reduction was 83 percent. The results shown by Figure 8 indicate that removal efficiency increased as flow decreased, as a superior effluent was produced even though the strength of the sewage was greater. Relative stability results compared very well with corresponding B.O.D. results and Figures 8 and 9 show that the stability of the effluent increased as the B.O.D. removals increased.

The B.O.D. of the trickling filter effluent was very high on May 10, and this high value was probably caused by the "unloading" of the filter on that date. B.O.D. reduction values through primary clarification were very low in the month of May and averaged less than one-half of the same values for June and July.

Month	Flow	Aver. B.O.D. Reduction through P. Clarifier	Aver. Overall B.O.D. Reduction
April	1.21	37%	81%
May	.74	20%	70%
June	.47	47%	89%
July	.49	48%	93%

Table IV - B.O.D. and Relative Stability

Date	Flow (mgd.)	B.O.D. (ppm)				Rel. Stability (%)			
		1	2	3	4*	1	2	3	4*
January 10	.52	---	---	---	---	11	11	30	37
17	.57	---	---	---	---	<11	<11	37	37
24	.61	---	---	---	---	<11	<11	11	21
31	.75	---	---	---	---	<11	<11	37	37
Average	.61	---	---	---	---	<11	<11	29	33
February 7	1.05	---	---	---	---	11	11	21	21
14	.60	---	---	---	---	11	11	21	21
21	.92	---	---	---	---	<11	<11	21	21
28	.69	---	---	---	---	<11	<11	60	63
Average	.82	---	---	---	---	<11	<11	31	33
March 7	.75	---	---	---	---	<11	<11	68	68
April 5	1.05	188	124	72	40	<11	<11	75	80
12	1.80	200	120	44	36	11	11	78	96
19	1.00	175	116	48	25	11	11	--	--
26	1.00	190	118	43	39	<11	<11	80	84
Average	1.21	188	119	52	35	<11	<11	78	87
May 3	.85	173	113	29	25	<11	<11	98	98
10	.72	161	133	181	93	<11	<11	21	21
17	.65	165	150	34	32	<11	<11	68	68
Average	.74	166	132	81	50	<11	<11	62	62
June 15	.50	240	105	32	25	<11	<11	99	99
21	.46	193	110	25	18	<11	<11	99	99
28	.45	218	130	28	25	<11	<11	99	99
Average	.47	217	115	28	23	<11	<11	99	99
July 5	.50	195	126	30	21	<11	<11	99	99
6	.50	256	93	23	13	<11	<11	99	99
11	.60	226	126	38	14	<11	<11	99	99
12	.49	265	131	31	16	<11	<11	99	99
13	.41	246	125	25	16	<11	<11	99	99
17	.46	218	144	45	14	<11	<11	99	99
19	.46	242	117	37	18	<11	<11	99	99
Average	.49	235	123	33	16	<11	<11	99	99

* The sample numbers 1, 2, 3, and 4 indicate raw sewage, primary effluent, trickling filter effluent, and final effluent.

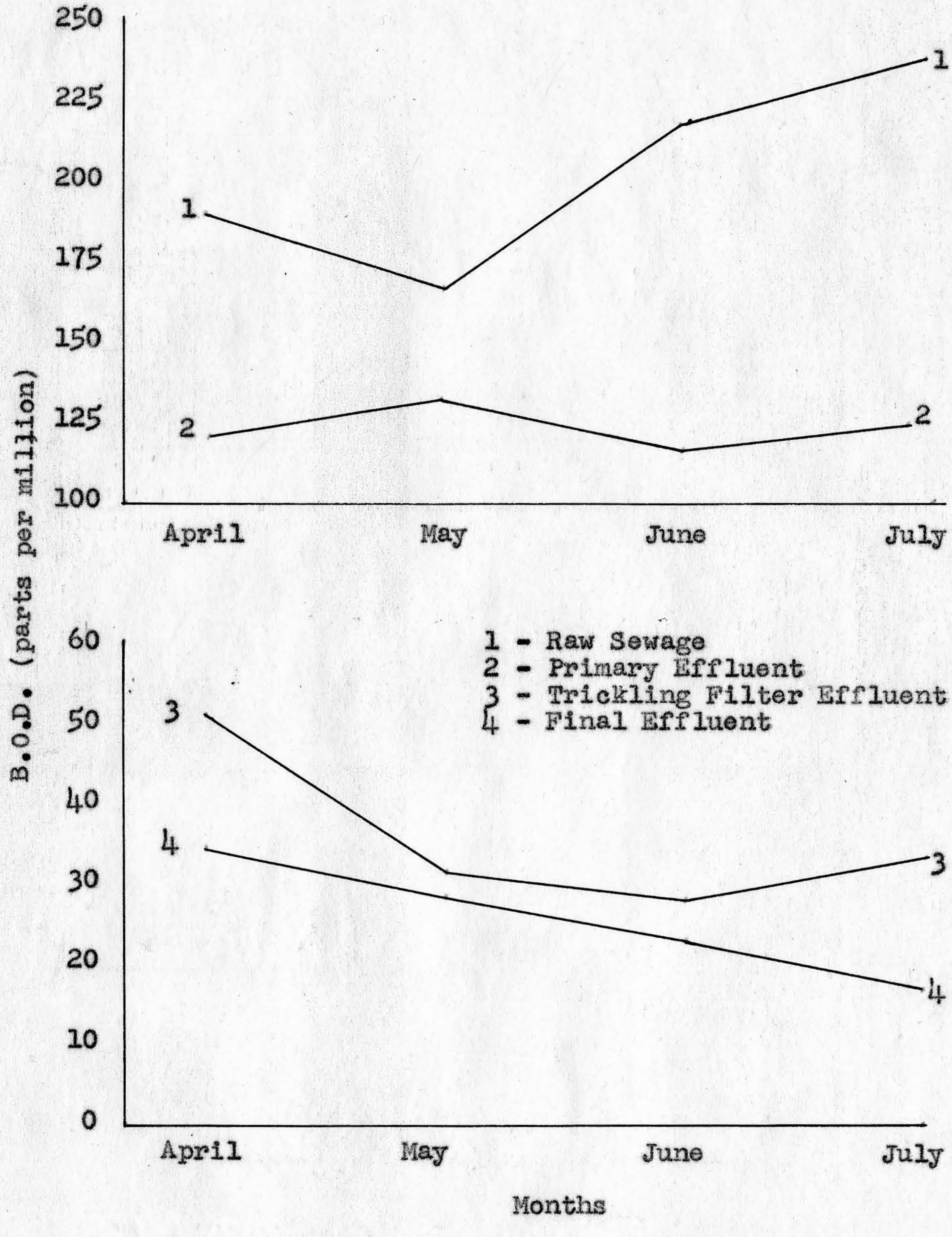


Figure 8. Monthly variation of average B.O.D. of Sewage.

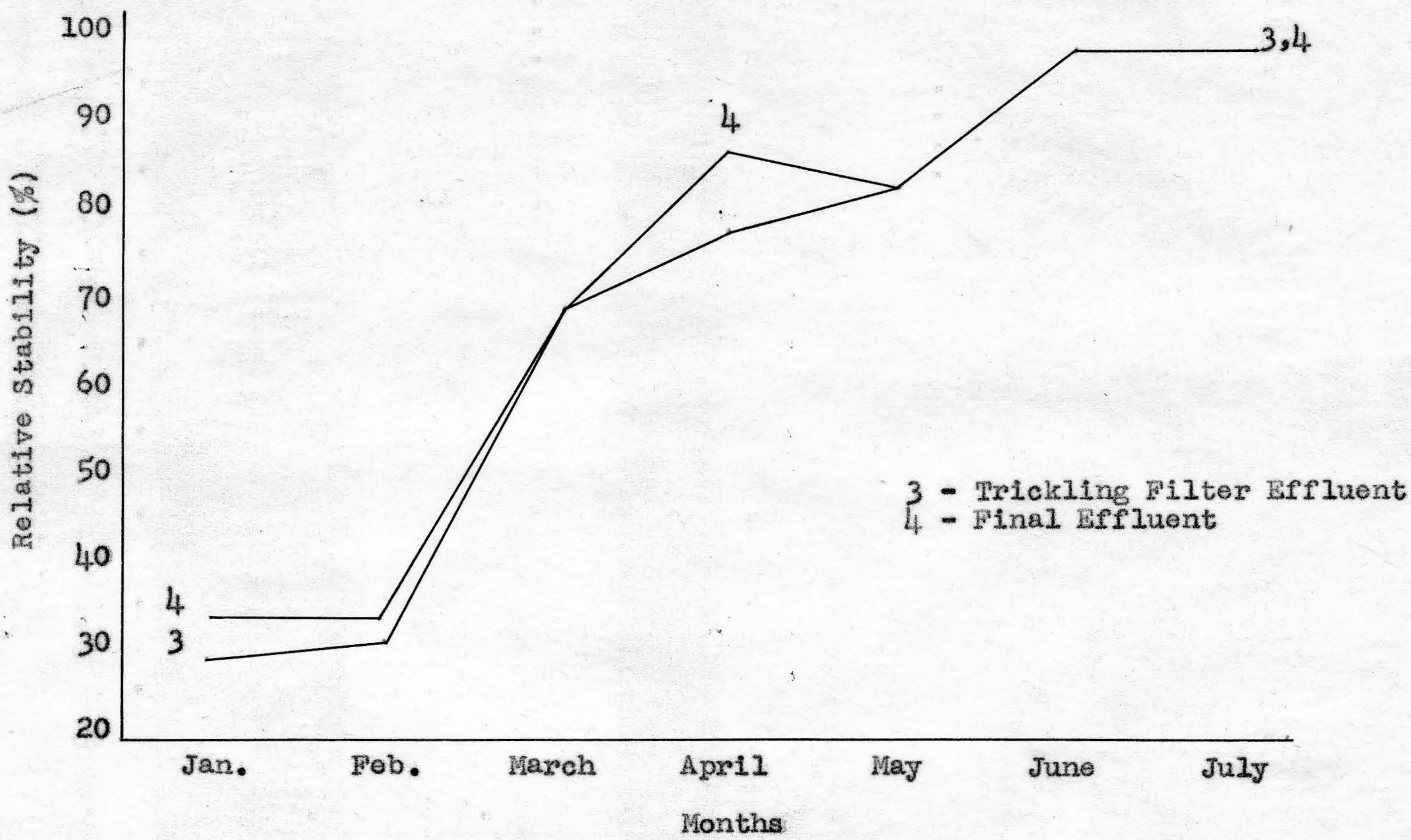


Figure 9. Monthly variation of average RELATIVE STABILITY of sewage.

<u>pH and M.O. Alkalinity</u>: The average pH of the raw sewage was 7.4 and this value increased through the stages of treatment to an average value of 7.7 in the final effluent.

M.O. Alkalinity values of the raw sewage and primary effluent were approximately the same, as were the values of the trickling filter and final effluents. The reduction in alkalinity occurred primarily through the trickling filter, the average value being approximately 19 percent, and the average reductions through the filter by months are shown by the following figures.

Month	Flow (Aver.)	% Alkalinity Reduction through T. Filter
January	.61	13
February	.82	17
March	.75	10
April	1.21	12
May	.74	22
June	.47	25
July	.49	37

Although the values of alkalinity reduction through the trickling filter were much greater at low flows, no definite relation was found to exist between the quantity of flow, and the percent reduction in alkalinity.

Table V. - pH and M.O. Alkalinity

Date		Flow	pH				Alkalinity (ppm. $CaCO_3$)			
			1	2	3	4*	1	2	3	4*
January	10	.52	7.5	7.6	7.7	7.8	430	402	382	374
	17	.57	7.5	7.5	7.7	7.7	441	374	344	324
	24	.61	7.3	7.7	7.8	7.7	376	384	338	342
	31	.75	7.7	7.3	7.4	7.4	402	344	294	330
	Average	.61	7.5	7.5	7.7	7.7	412	376	340	343
February	7	1.05	7.6	7.4	7.6	7.7	290	296	276	269
	14	.60	8.0	8.1	8.2	8.2	342	400	210	354
	21	.92	7.4	7.4	7.6	7.6	306	304	296	224
	28	.69	7.6	7.3	7.5	7.8	380	354	346	330
	Average	.82	7.7	7.6	7.7	7.8	330	339	282	294
March	7	.75	7.6	8.0	8.0	8.1	336	304	290	296
April	5	1.05	7.3	7.3	7.4	7.5	274	274	254	256
	12	1.80	7.1	7.3	7.4	7.4	194	206	194	184
	19	1.00	7.3	7.3	---	---	280	290	---	---
	26	1.00	7.6	7.4	7.7	7.8	302	290	248	234
	Average	1.21	7.3	7.3	7.5	7.6	263	265	232	225
May	3	.85	7.3	7.3	7.4	7.3	298	310	244	222
	10	.72	7.4	7.4	7.5	7.5	320	308	260	296
	17	.65	7.7	7.5	7.7	7.6	320	312	222	226
	Average	.74	7.5	7.4	7.5	7.5	313	310	242	238
June	15	.50	7.4	7.4	7.6	7.7	406	424	286	284
	21	.46	7.4	7.3	7.6	7.7	342	366	300	298
	28	.45	7.5	7.5	7.7	7.7	414	384	298	290
	Average	.47	7.4	7.4	7.6	7.7	387	391	295	291
July	5	.50	7.2	7.3	7.4	7.5	434	396	254	222
	6	.50	---	---	---	---	---	---	---	---
	11	.60	7.4	7.5	7.7	7.8	458	408	260	242
	12	.49	7.2	7.3	7.4	7.6	472	384	246	228
	13	.41	7.4	7.6	7.7	7.7	442	408	268	254
	17	.46	7.2	7.6	7.7	7.7	434	404	256	234
	19	.46	7.4	7.6	7.8	7.7	336	388	262	264
	Average	.49	7.3	7.5	7.6	7.7	429	398	258	240

* The sample numbers 1, 2, 3, and 4 indicate raw sewage, primary effluent, trickling filter effluent, and final effluent.

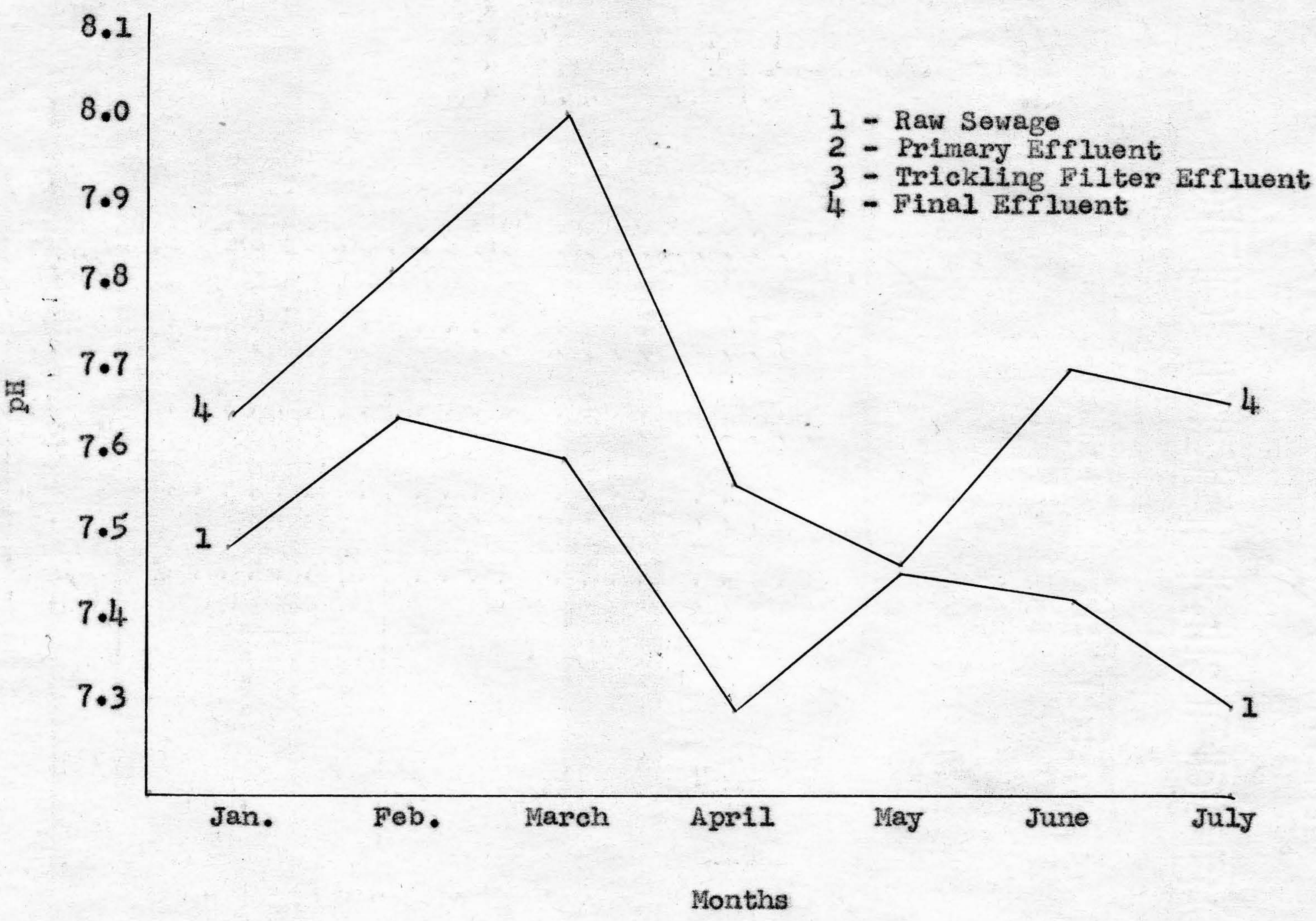


Figure 10. Monthly variation of average pH value of sewage.

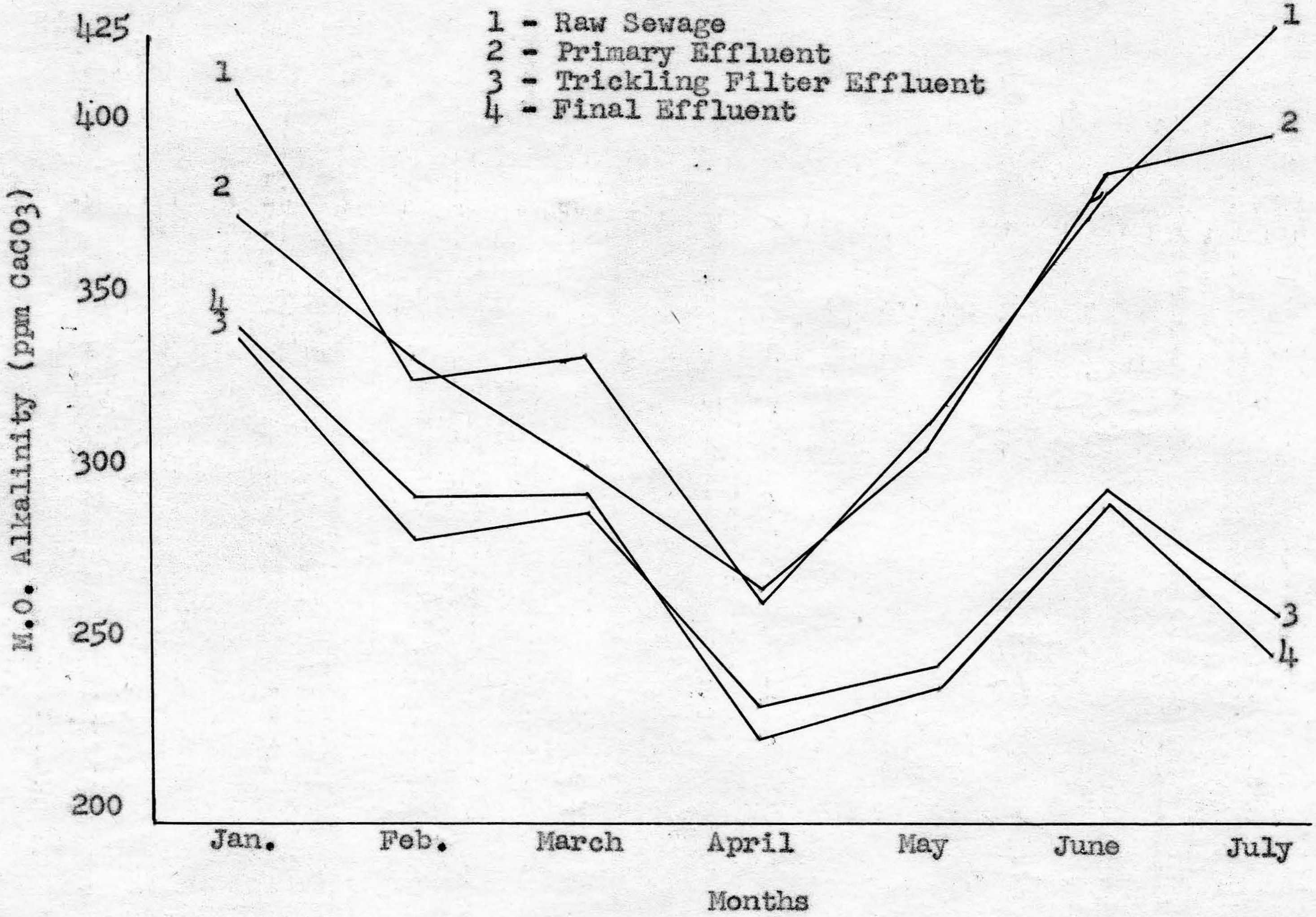


Figure 11. Monthly variation of average M.O. ALKALINITY in sewage.

Ammonia Nitrogen, Nitrite Nitrogen, Nitrate Nitrogen, Dissolved Oxygen, and Sulfates: The results in Table VI and Table VII show that the nitrogen determinations were somewhat irregular, and from a plant efficiency viewpoint little was gained from these tests. The ammonia nitrogen reductions through the treatment plant and the increases in nitrates are illustrated by Figure 12 and Figure 14, and these figures clearly show that nitrification of ammonia nitrogen to nitrates was practically non-existent during the winter months; however, the nitrates were greatly increased and the ammonia nitrogen greatly reduced in the spring and summer months. Since nitrates are considered indicators of stability, the plant effluent was much more stable in the spring and summer than in the winter. This conclusion checks well with the results of relative stabinity tests, which showed great increases in stability from winter to summer.

The tests for nitrites revealed greater concentrations of nitrites than are usually encountered in raw and primary settled sewage, and these concentrations could not be accounted for.

The dissolved oxygen values were the least variable of the test results, but the determinations were made only from April to July. The raw sewage was always depleted of dissolved oxygen, which indicated the sewage was stale, but the final effluent content averaged 4.5 parts per million and was apparently very stable.

The sulfate results seemed very erratic, especially during the months of least efficiency. In June and July the sulfates were increased slightly through the treatment process as sulphur compounds were oxidized to sulfates.

Chlorides: The plant influent and effluent were analyzed for chlorides to determine differences in strength of the sewage. The results of Figure 17 show that the plant influent was continually slightly stronger than the effluent, but the variations were small and a sewage of very nearly the same strength was sampled at all the sampling stations.

Table VI. - Ammonia Nitrogen and Nitrite Nitrogen

Date		Flow	Ammonia Nit. (ppm)				Nitrite Nit. (ppm)			
			1	2	3	4*	1	2	3	4*
January	10	.52	----	----	----	----	---	---	---	---
	17	.57	19.0	16.9	13.8	12.6	.48	.39	.51	.50
	24	.61	21.4	24.0	16.6	20.1	.30	.42	.51	.43
	31	.75	16.5	20.1	12.2	19.4	.21	.20	.35	.23
	Average	.61	19.0	20.3	14.2	17.4	.33	.34	.46	.39
February	7	1.05	9.8	21.1	17.6	16.2	.17	.16	.22	.21
	14	.60	18.7	21.8	20.1	21.8	.21	.22	.38	.33
	21	.92	15.0	22.2	20.1	18.0	.30	.42	.44	.30
	28	.69	22.2	24.0	21.1	19.7	.27	.22	.28	.33
	Average	.82	16.4	22.3	19.7	18.9	.24	.26	.33	.29
March	7	.75	18.0	17.2	16.1	16.6	.27	.27	.30	.27
April	5	1.05	11.8	14.2	12.3	13.4	.34	.49	.45	.40
	12	1.80	4.6	9.8	8.2	8.2	.28	.33	.46	.54
	19	1.00	12.5	15.2	----	----	.32	.34	---	---
	26	1.00	13.0	13.2	7.8	8.2	.42	.47	.59	.53
	Average	1.21	11.0	13.1	9.4	9.9	.34	.41	.50	.49
May	3	.85	14.4	18.6	11.3	12.2	.40	.53	.80	.78
	10	.72	24.0	18.6	7.8	18.4	.20	.37	.85	.56
	17	.65	21.0	19.4	9.4	9.8	.19	.39	.65	.71
	Average	.74	19.8	18.9	9.5	13.5	.26	.43	.77	.68
June	15	.50	12.5	17.6	7.6	6.8	.23	1.22	.59	.57
	21	.46	16.2	13.2	14.2	14.8	.04	.50	.29	.28
	28	.45	21.8	18.6	7.8	8.2	.07	.20	.43	.43
	Average	.47	16.8	16.5	9.9	9.9	.11	.64	.44	.43
July	5	.50	26.0	20.8	4.3	0.8	.05	1.55	.25	.13
	6	.50	----	----	----	----	---	----	---	---
	11	.60	27.5	23.2	6.2	3.1	.09	2.10	.32	.30
	12	.49	26.4	20.8	4.2	2.2	.10	2.00	.34	.30
	13	.41	25.8	20.0	5.6	4.0	.32	2.10	.32	.31
	17	.46	26.5	18.6	4.0	1.9	.13	3.20	.35	.25
	19	.46	12.2	15.8	3.7	4.6	.14	1.16	.50	.50
	Average	.49	24.1	19.9	4.7	2.8	.14	2.02	.35	.30

* The sample numbers 1, 2, 3, and 4 indicate raw sewage, primary effluent, trickling filter effluent, and final effluent.

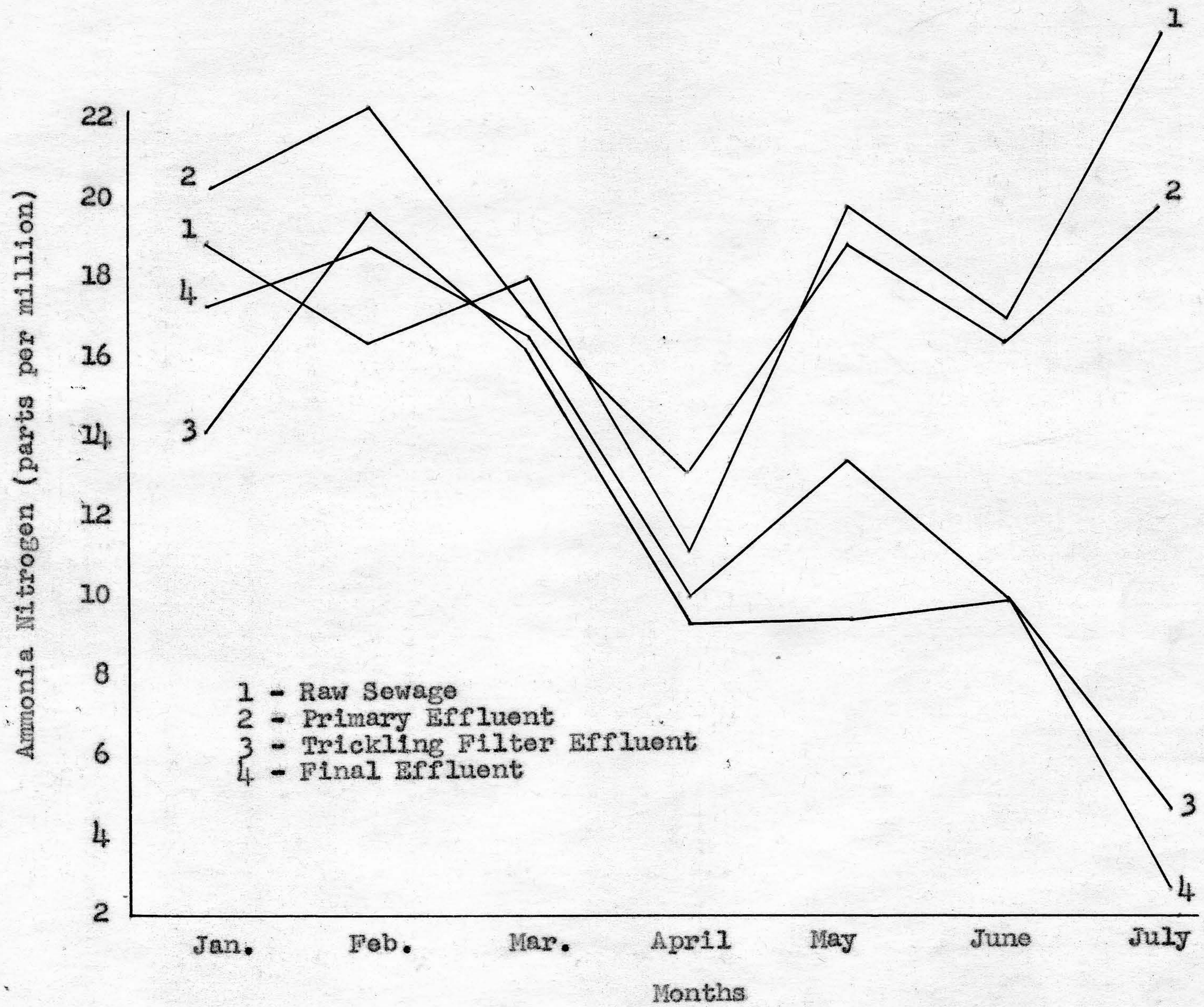


Figure 12. Monthly variation of average AMMONIA NITROGEN concentration in sewage.

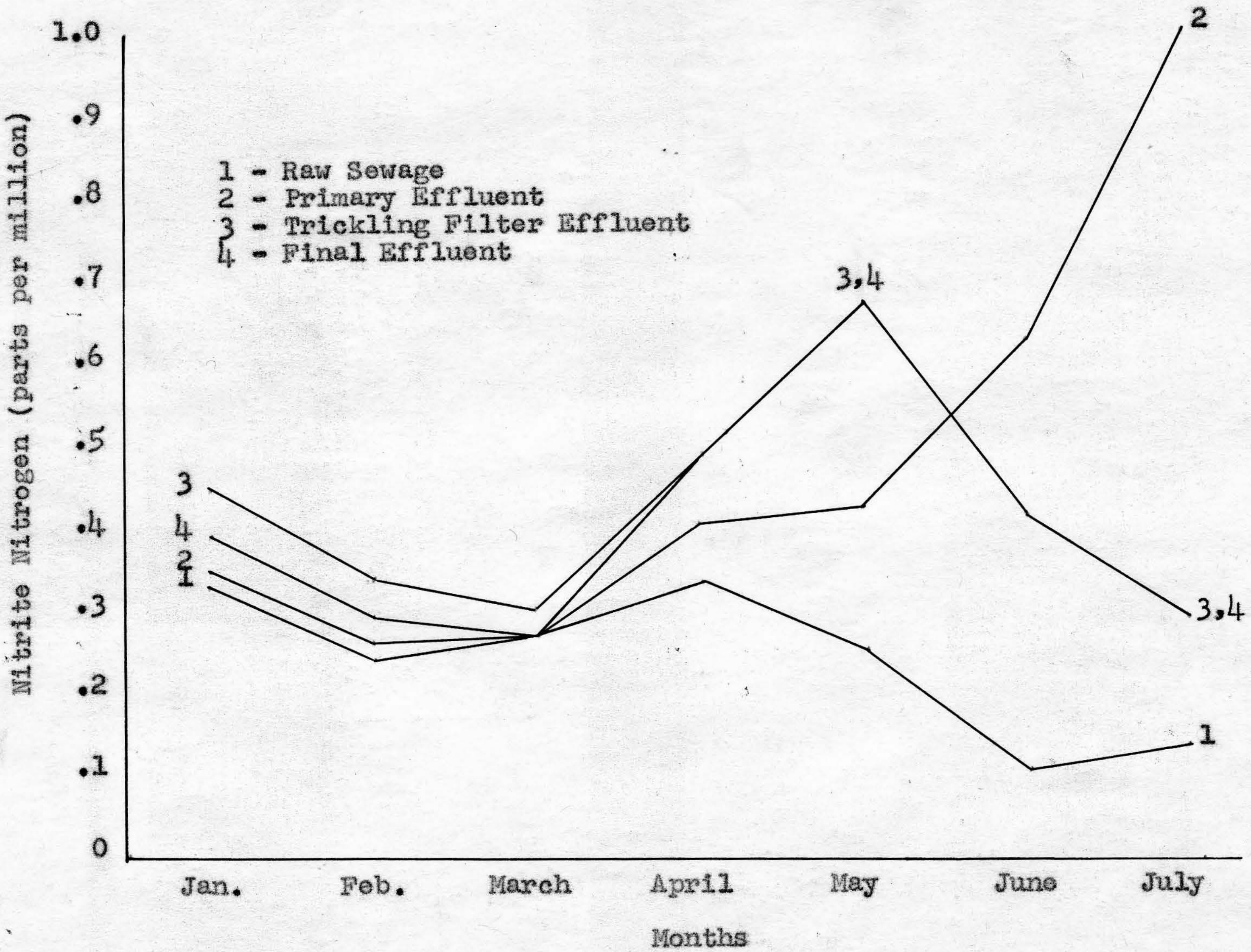


Figure 13. Monthly variation of average NITRITE NITROGEN concentration in sewage.

Table VII - Nitrate Nitrogen and Dissolved Oxygen

Date	Flow	Nitrate Nit.(ppm)				Dissolved Oxygen(ppm)			
		1	2	3	4*	1	2	3	4*
January 10	.52	--	--	--	--	-	--	---	---
17	.57	.38	.65	1.0	1.2	-	--	---	---
24	.61	.30	.45	.85	.15	-	--	---	---
31	.75	.20	.11	.10	.10	-	--	---	---
Average	.61	.29	.40	.65	.48	-	--	---	---
February 7	1.05	.15	.80	.20	1.5	-	--	---	---
14	.60	.80	.60	.20	.30	-	--	---	---
21	.92	.85	.73	.95	.75	-	--	---	---
28	.69	.70	.65	1.2	1.4	-	--	---	---
Average	.82	.63	.70	.64	.98	-	--	---	---
March 7	.75	.73	.55	.20	.18	-	--	---	---
April 5	1.05	.28	.28	.15	1.7	0	.3	3.5	4.1
12	1.80	1.4	1.1	2.0	2.2	0	.7	4.3	4.6
19	1.00	.90	.70	---	---	0	1.5	4.7	4.9
26	1.00	.15	.20	.25	3.3	0	.5	3.9	4.2
Average	1.21	.67	.56	.80	2.4	0	.8	4.1	4.5
May 3	.85	.60	1.2	4.5	4.7	0	.4	4.1	4.3
10	.72	.20	1.3	6.5	6.2	0	.6	4.4	4.8
17	.65	.27	1.0	4.7	5.3	0	.7	3.9	4.3
Average	.74	.36	1.1	5.2	5.4	0	.6	4.1	4.5
June 15	.50	.20	1.8	6.1	6.5	0	.5	4.0	4.5
21	.46	.13	.20	.24	.20	0	.3	3.3	4.5
28	.45	.20	.15	.25	.18	0	.9	3.7	4.2
Average	.47	.18	.71	2.2	2.3	0	.6	3.7	4.4
July 5	.50	.15	.18	.13	5.8	0	.6	4.5	4.7
6	.50	---	---	---	---	0	.7	4.7	4.9
11	.60	.27	.10	.20	.20	0	.5	4.2	4.4
12	.49	.15	.15	5.8	5.7	0	.7	4.1	4.4
13	.41	.25	.15	.35	5.0	0	.4	4.2	4.5
17	.46	.10	.10	6.0	6.1	0	.7	5.0	5.2
19	.46	.10	.10	5.8	5.0	0	.5	4.4	4.4
Average	.49	.17	.13	3.0	4.6	0	.6	4.4	4.6

* The sample numbers 1, 2, 3, and 4 indicate raw sewage, primary effluent, trickling filter effluent, and final effluent.

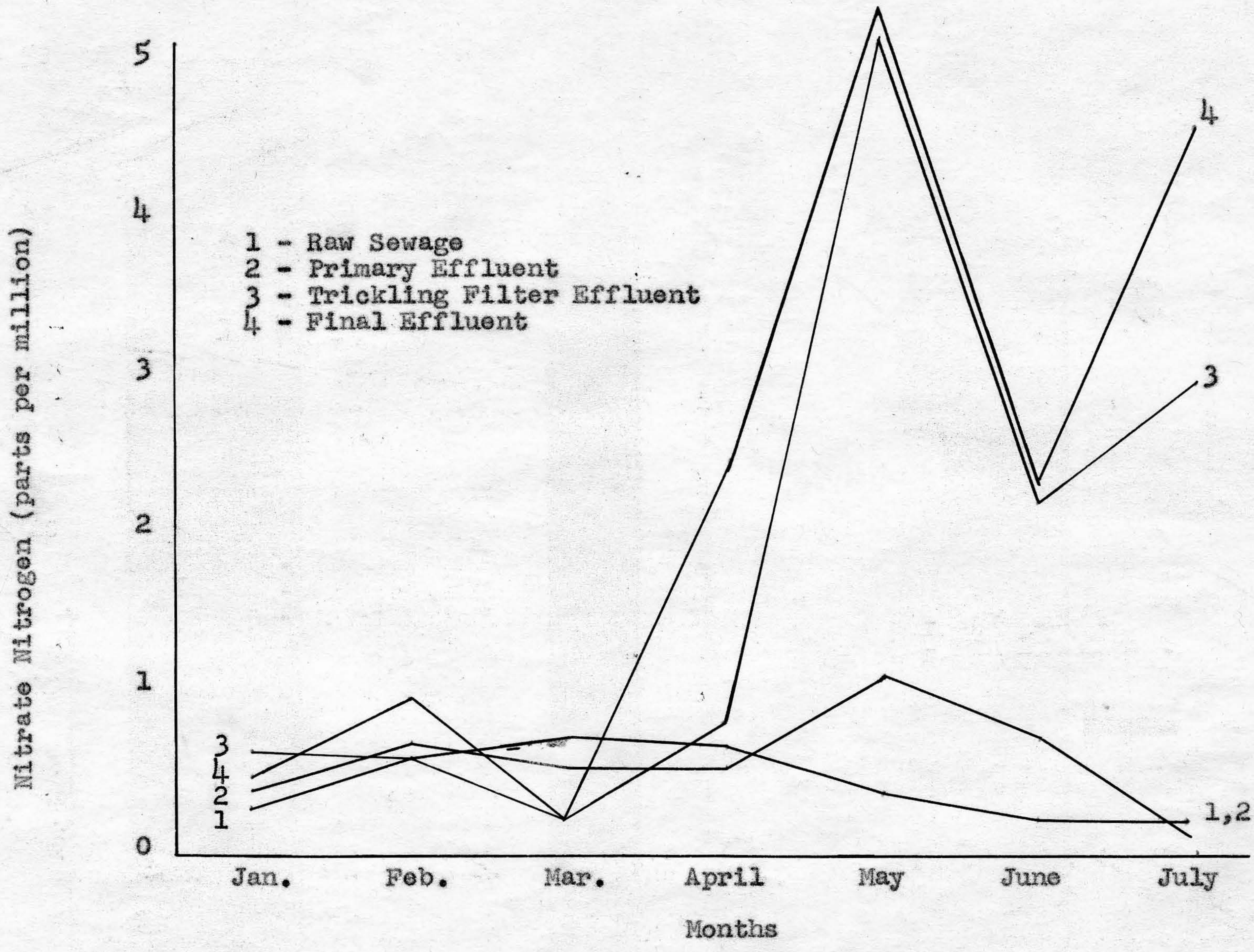


Figure 14. Monthly variation of average NITRATE NITROGEN concentration in sewage.

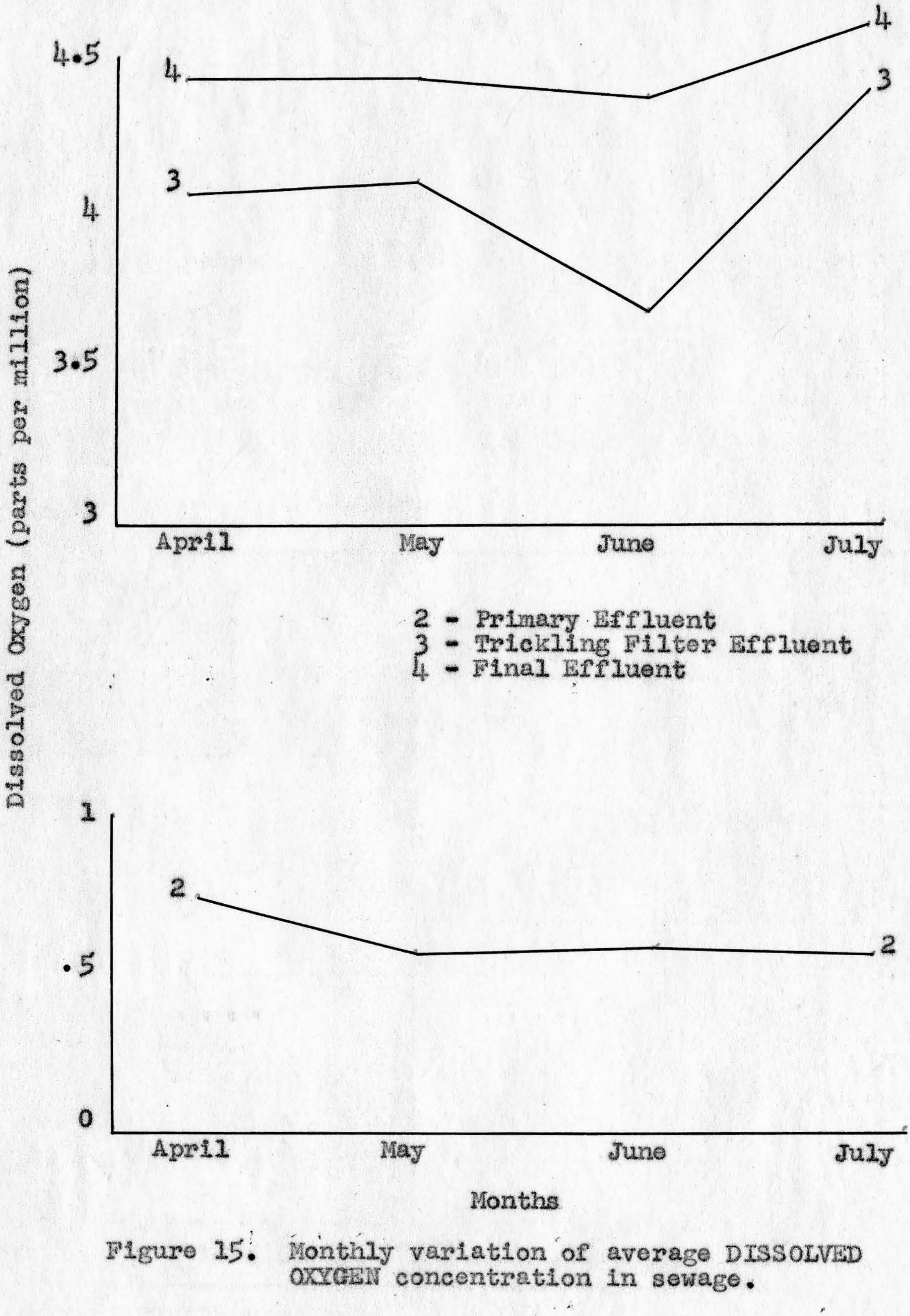


Figure 15. Monthly variation of average DISSOLVED OXYGEN concentration in sewage.

Table VIII - Sulfates and Chlorides

Date	Flow	Sulfates (ppm)			Chlorides (ppm)	
		1	2	3*	1	4*
January 10	.52	22.2	11.4	16.5	20	41
17	.57	34.7	22.2	25.2	51	41
24	.61	31.1	17.1	23.8	46	41
31	.75	32.9	33.0	33.0	75	41
Average	.61	30.0	21.0	25.0	48	41
February 7	1.05	36.8	65.5	26.9	40	38
14	.60	15.3	16.8	16.5	46	33
21	.92	44.0	24.2	22.7	28	22
28	.69	17.8	51.7	28.0	43	27
Average	.82	29.0	40.0	24.0	39	30
March 7	.75	30.5	35.9	26.6	34	28
April 5	1.05	20.4	24.2	31.2	33	23
12	1.80	20.6	15.4	25.9	17	15
19	1.00	33.0	16.9	----	25	18
26	1.00	18.3	14.5	24.6	26	24
Average	1.21	23.0	18.0	27.0	25	20
May 3	.85	41.0	17.6	22.2	32	30
10	.72	21.1	16.5	25.5	36	41
17	.65	15.9	10.4	14.5	35	30
Average	.74	26.0	15.0	21.0	34	34
June 15	.50	15.9	20.6	25.8	27	21
21	.46	13.8	17.4	18.4	70	29
28	.45	12.7	19.3	20.0	30	39
Average	.47	14.0	19.0	21.0	42	29
July 5	.50	13.3	18.4	21.6	26	37
6	.50	----	----	----	--	--
11	.60	19.8	18.1	22.4	77	28
12	.49	12.2	19.1	20.1	31	32
13	.41	16.1	17.4	23.7	33	52
17	.46	24.2	28.6	32.6	26	51
19	.46	13.4	17.0	19.2	46	29
Average	.49	17.0	20.0	23.0	40	38

* The sample numbers 1, 2, 3, and 4 indicate raw sewage, primary effluent, trickling filter effluent, and final effluent.

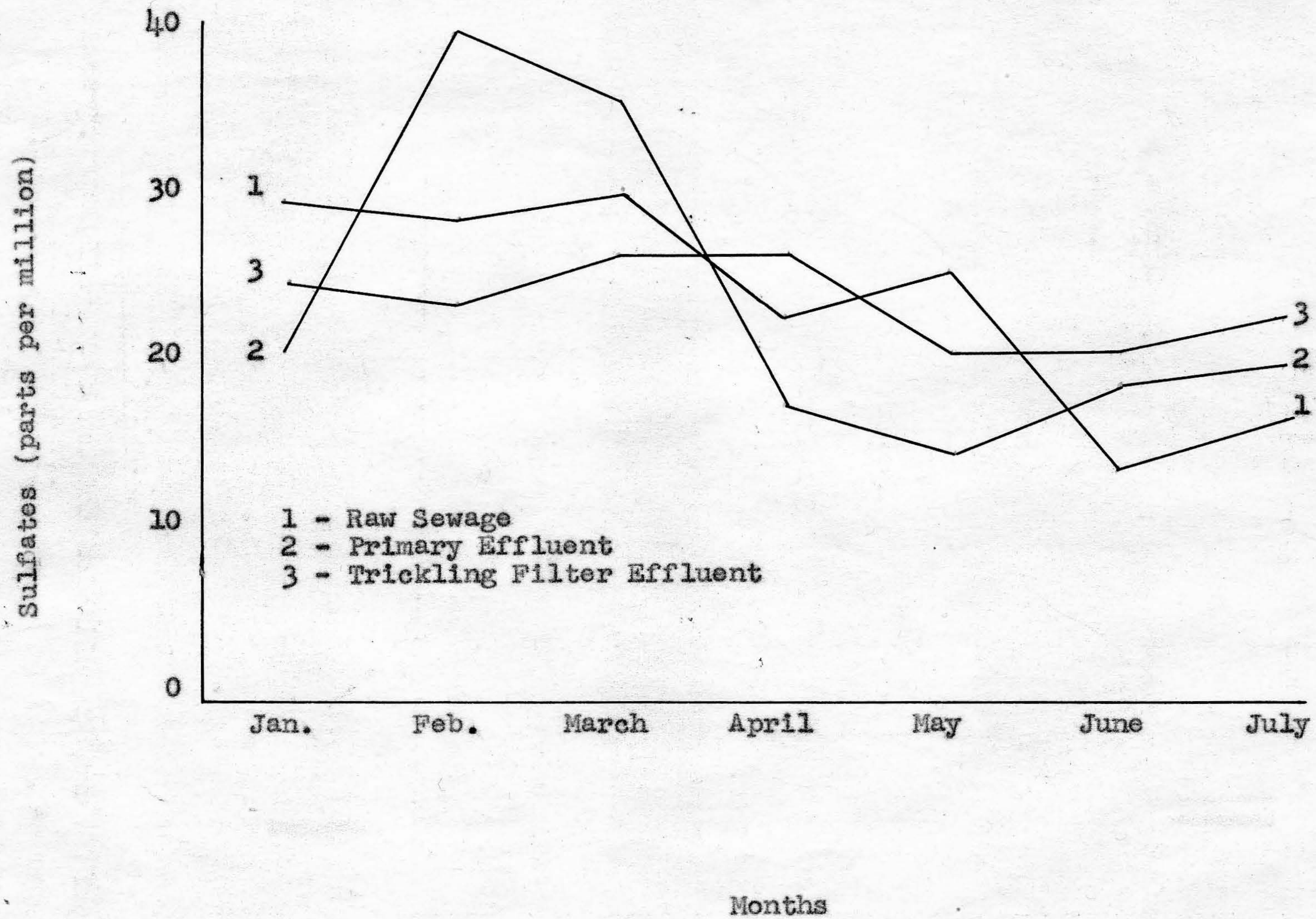


Figure 16. Monthly variation of average SULFATES concentration in sewage.

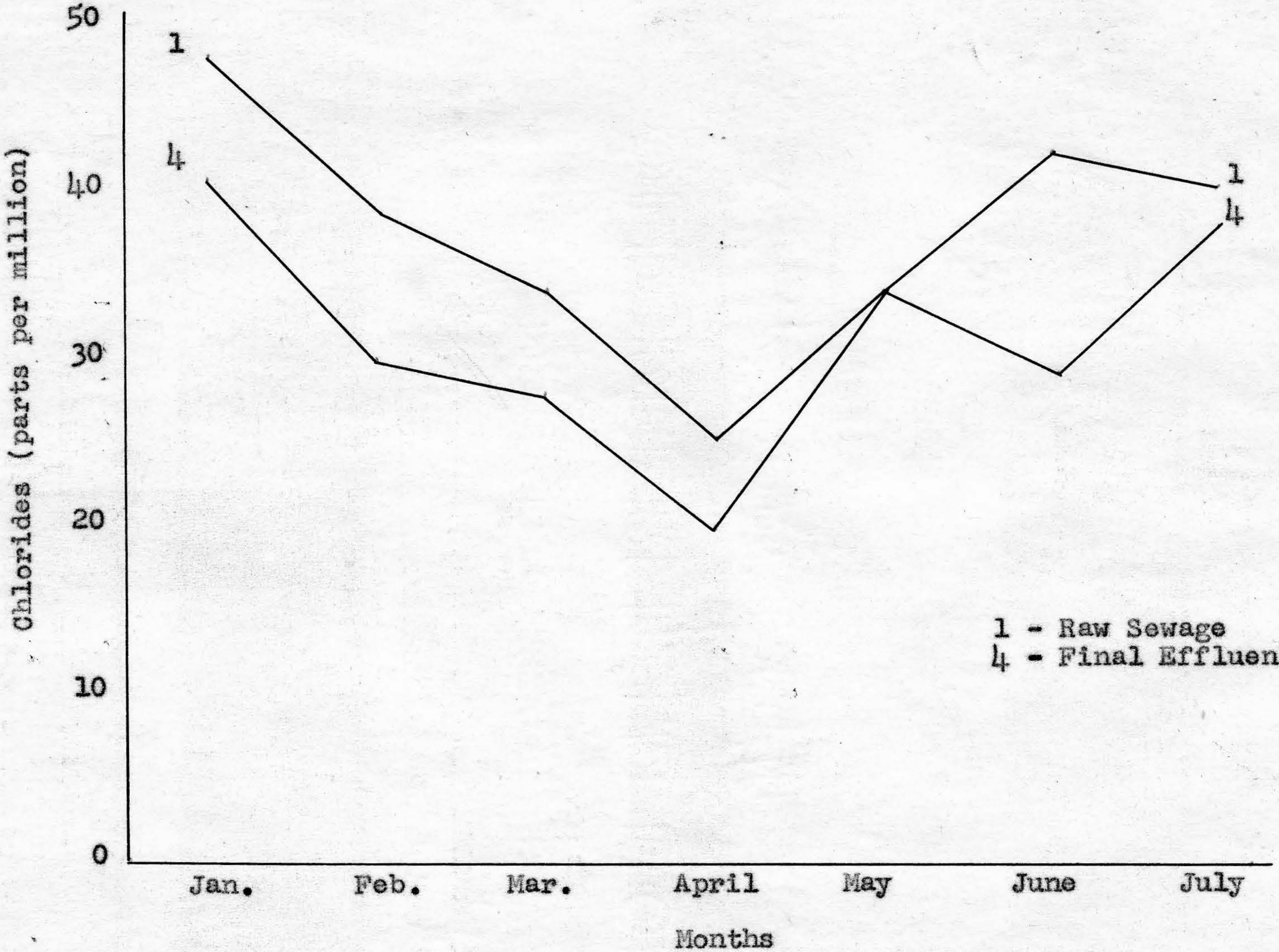


Figure 17. Monthly variation of average CHLORIDES concentration in sewage

Stream and Plant Observations

Several trips were made along Stroubles Creek during the study to observe the condition of the receiving stream, and with one exception the stream appeared as clear below the entrance of the treatment plant effluent as it did upstream. Because of maintenance work on April 19, sewage was being bypassed from the primary clarifier, and a very turbid condition was noted in the receiving stream on that date.

Dissolved oxygen tests were run on the stream, and samples taken above the entrance of the plant effluent were always found to be saturated, while at a distance of seventy-five yards below the entrance of the plant effluent, the average D.O. content of the samples was 7.0 parts per million. On April 19, the D.O. was 5.6 parts per million below the entrance of the plant effluent.

At each observation minnows were present in the stream, although they were observed in much greater numbers upstream.

Maintenance appeared to be very satisfactpry throughout the treatment works, and cleaning, painting, and repairing operations were frequently observed.

DISCUSSION OF RESULTS

The author realizes that even under the best conditions efficiency studies similar to this investigation are subject to many discrepancies and that it is impossible to analyze the previously presented results for exact efficiency determinations of sewage treatment units. Sewage characteristics are quite variable from system to syetem or in a given system, sampling methods are not standardized, standard analysis procedures are not always used, and many of the standard procedures are in need of improvement. These and other factors make it very difficult to reach definite conclusions in investigations of this type.

In spite of these handicaps, however, the author believes that the results of this study can be used to good advantage in obtaining the performance of the units studied. This can be accomplished by the comparison of sewage content reductions with those generally expected through the various units, by comparison of performances with treatment plants similar in design to the VPI plant, and by the use of common observations.

Primary Sedimentation Efficiency

The removal of suspended solids by primary settling is generally expected to range from 45 to 60 percent for domestic sewage. B.O.D. removals vary from 25 percent to a usual maximum of 40 percent, unless detention periods greater than two hours are used, and settleable solids removal values should always exceed 80 percent.

The suspended solids results show that removals were considerably lower than the expected 45 percent for a large part of the study, but they increased with the summer months and reached 59 percent in the month of July, with the lowest percentage removal occurring during the month of May. B.O.D. removal values ranged from 37 to 48 percent with the exception of the month of May, when only a 20 percent removal was attained, and the B.O.D. removals were also highest in the summer months. Settleable solids were reduced by volume a minimum of 93 percent in February and a maximum of 99 percent in July.

Moore, Smith, and Ruchhoft(23) made an efficiency study of a domestic sewage disposal plant at Centralia, Missouri, that employed practically the same treatment process that is used at the VPI plant, and the efficiency of the Centralia plant was considered excellent. Differences in B.O.D. removal through the primary clarifier were slight, and the values ranged from 26 to 50 percent at the Centralia plant as compared with 20 to 48 percent at the VPI plant. Suspended solids removal was exceptionally high at Centralia, with removals of 61 to 74 percent as compared with 30 to 59 percent at VPI.

These results indicate that the primary clarifier was least efficient in April and May, or at flows near or above the design flow, and that the efficiency was very good in

June and July.

Trickling Filter Efficiency

Imhoff and Fair (18) state that low-rate trickling filters that are preceded and followed by settling tanks should remove from 80 to 95 percent of the B.O.D. and from 70 to 92 percent of the suspended solids. The B.O.D. removal was in this range at all times with the exception of the month of May, when a removal of only 70 percent was accomplished, and the removal in July was equal to that accomplished at Centralia. Suspended solids removal values were in the expected range at all times and reached the maximum expected value of 92 percent in July, which was one percent higher than the percentage removal at Centralia.

The alkalinity values reveal the oxidative effectiveness of the trickling filter. The June and July samples, which showed the greatest reductions in alkalinity through the filter, corresponded to the final effluents with the lowest B.O.D. values. Free ammonia nitrogen was greatly reduced through the filter in the summer, indicating greater nitrification and a more stable effluent.

These results indicate excellent trickling filter efficiency in the summer months and satisfactory performance at all other times during the study except the month of May.

Secondary Sedimentation Efficiency

The secondary clarifier operated more efficiently than the other units throughout the sampling period. Flows and temperatures affected it less, and regardless of the loading received from the trickling filter, it continually produced an effluent low in settleable solids. With respect to B.O.D. and Suspended Solids content, the final effluent was equal in quality to the Centralia plant.

Overall Plant Efficiency

The results of the stream and plant observations indicate that the efficiency of the overall plant was good. The receiving stream supported fish life and was in good condition during the sampling period. Maintenance operations appeared to be very satisfactory at all times.

The combined results indicate that the efficiency was greatest during June and July, the months of lowest flow and highest temperatures. It is important to note that this observation of greatest efficiency is not based on the mere fact that the strength of the sewage was greater in June and July and greater reductions in B.O.D., Suspended Solids, etc., were obtained. Instead, it is based on the fact that a superior plant effluent was produced along with the greater reductions.

Apparently, flow and temperature variations have a very definite effect on the efficiency of the plant. The flow variations may be caused by ground water infiltrations, as well as the variable student enrollments at VPI.

The average monthly values of a majority of the test results compare favorably with operating results of a treatment plant very similar to the VPI plant (23), and these results were considered excellent. During the winter and spring months the final effluent was of a lower quality than during the summer months, but considering the condition of the receiving stream, it was certainly of a satisfactory quality.

CONCLUSIONS

The author believes that the following conclusions can be made from this study;

(1) The VPI Sewage Disposal Plant operates more efficiently during the summer months, or periods of low flows and high temperatures.

(2) The overall plant operated satisfactorily during this study and the efficiency was excellent in the month of July.

(3) The primary clarifier was not as efficient as the other units studied and operated poorly in the month of May.

(4) It is possible that ground water infiltration in the VPI Sewerage System decreases the treatment plant efficiency.

(5) The suggested use of reduction in alkalinity (12) could be used to advantage in operation in indicating the quality of the final effluent.

(6) There is a need for a study of the "time of flow" through the VPI plant. Such a study would greatly aid the plant operators, and it should certainly precede any future investigations of this type.

The author sincerely hopes that future similar studies of this magnitude will not be undertaken by a single investigator, as the analytical work was time consuming and limited the scope of the investigation. Composite samples and "flow time" are very desirable factors to be considered, and it would be interesting to compare results secured after thorough consideration of these factors with the results obtained in this study.

SUMMARY

The purpose of this study was to investigate the efficiency of the VPI Sewage Disposal Plant. A proposal was made to study the separation of the solids from the liquids and the treatment of the liquids, which is accomplished essentially by two primary clarifiers, a trickling filter, and two secondary clarifiers. The proposal included an efficiency study of these individual treatment units as well as the overall treatment plant.

The investigation included the establishment of sewage sampling stations at four points of the treatment system where samples were collected of the raw sewage, the primary clarifier effluent, the trickling filter effluent, and the final effluent. Physical and chemical tests were made of each sample for temperature, hydrogen-ion concentration (pH), dissolved oxygen, biochemical oxygen demand, relative stability, alkalinity, free ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, total solids, volatile solids, suspended solids, settleable solids, chlorides, and sulfates. The quantity of sewage flow was recorded each time samples were collected in an attempt to correlate flow with the efficiency of operation. During the sampling period observations were made of the physical condition of the stream and the treatment works.

Time and personnel limitations necessitated the use of

"catch" samples, which were collected during the daily period of maximum loading, the assumption being that satisfactory operation at maximum loadings would indicate satisfactory operation at any other loading. The samples were collected and analyzed over a period from January to July, 1951.

The results of the investigation were studied for efficiency determinations of the individual treatment units and the overall plant by comparisons of the sewage content reductions obtained with those generally expected through the various units, by a comparison of performance with a treatment plant similar in design to the VPI plant, and by use of the common observations made during the sampling period.

The conclusions were made that the overall plant operated satisfactorily during the study, the primary clarifier was not as efficient as the other units, and the overall plant operated more efficiently at low flows and high temperatures.

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