1933

A Plant Efficiency Survey and Experimental Plant Results Obtained at The Sioux Falls Sewage Treatment Plant, Sioux Falls, S.D.

Lowell A. Yost

Hans Jepson

Recommended Citation
Yost, Lowell A. and Jepson, Hans, "A Plant Efficiency Survey and Experimental Plant Results Obtained at The Sioux Falls Sewage Treatment Plant, Sioux Falls, S.D." (1933). *Theses and Dissertations*. 1935.
http://openprairie.sdstate.edu/etd/1935

A PLANT EFFICIENCY SURVEY AND EXPERIMENTAL PLANT RESULTS OBTAINED AT THE SIOUX FALLS SEWAGE TREATMENT PLANT, SIOUX FALLS, S. D.

Part I

Report on the Plant Efficiency Survey

Part II

Experimental Plant Results

by

Lowell A. Yost
and
Hans Jepson

A Thesis Submitted to the Faculty

For the Degree of

MASTER OF SCIENCE IN CIVIL ENGINEERING

Approved:

[redacted]

Head of Department

[redacted]

Dean of Engineering

South Dakota State College
Brookings, South Dakota

- 1933 -

PREFACE

The Plant Efficiency Survey of the Sioux Falls Sewage Treatment Plant was conducted jointly by Lowell A. Yost, Instructor in Civil Engineering at South Dakota State College, and Mr. W. W. Towne, Director of the Sanitary Engineering Division, South Dakota State Board of Health, during the summer of 1931, July 1 to October 1. Part I of this thesis is a modification of the Plant Efficiency Survey Report presented to the City of Sioux Falls, December 18, 1931, by the Division of Sanitary Engineering, South Dakota State Board of Health.

Part II, "Experimental Plant Results at the Sioux Falls Sewage Treatment Plant" was obtained by operating an Activated Sludge Experimental Unit and a Chemical Precipitation Experimental Unit from April 1, 1932 until December 5, 1932. The Experimental Plant was operated by the writers, assisted by the regular employees at the Treatment Plant. Joseph B. Estabrook, Treasurer of the Pillsbury Engineering Company, Minneapolis, Minnesota, and Mr. R. E. Bragstad, City Engineer of Sioux Falls, South Dakota, supervised the operation of the Experimental Units.

The writers wish to express their appreciation to Professor Harold S. Carter of the Civil Engineering Department, South Dakota State College, for his many helpful suggestions; to Joseph B. Estabrook, R. E. Bragstad, and W. W. Towne, whose recommendations made the experimental work possible; and to Mr. F. J. Conner, Superintendent of the Sewage Treatment Plant, and his assistants for the very valuable help and information furnished by them. Fred G. Nelson, Sanitary Engineer with the Dorr Company, Chicago, Illinois, made valuable suggestions at numerous times during the experimental period.

TABLE OF CONTENTS

page

I. INTRODUCTION 5

II. A PLANT EFFICIENCY SURVEY OF THE SIOUX FALLS SEWAGE TREATMENT PLANT (Part I) 9
- A. Description of the Sioux Falls Sewage Treatment Plant and the Pre-treatment Works at John Morrell and Company 9
- B. Tests Conducted During the Efficiency Survey 11
  - 1. Purpose of Sewage Treatment 11
  - 2. Steps in the Treatment Process 12
  - 3. B.O.D. Tests and Other Analyses 13
- C. Operating Conditions of the Sioux Falls Sewage Treatment Plant 15
- D. Physical Findings 17
- E. Data and Their Interpretation 19
  - 1. Rate of Sewage Flow 19
  - 2. Bio-chemical Oxygen Demand Data 19
  - 3. Solids Determinations 21
  - 4. Sewage Nitrification Accomplished by the Trickling Filter 26
  - 5. Sludge Analyses 29
  - 6. Stream Pollution Study of the Sioux River 32
  - 7. Stream Flow Record of the Sioux River 33
  - 8. B.O.D. Reduction Tests on Final Settling 35
- F. Summary and Conclusions 37
- G. Recommendations 39

III. EXPERIMENTAL PLANTS RESULTS (Part II) 41
- A. Detailed Description of the Experimental Units 41
  - 1. Activated Sludge Unit 41
  - 2. Chemical Precipitation Unit 43
- B. Control Tests Conducted During the Experimental Period 45
  - 1. Bio-chemical Oxygen Demand Tests 45
  - 2. Suspended Solids Determination 46
  - 3. Other Control Tests 47
- C. Operation of the Main Plant During the Experimental Period 48
  - 1. Averages Computed from Daily Records 48
  - 2. Bio-chemical Oxygen Demand Reduction 48
  - 3. "Suspended Solids" Reductions 50
  - 4. Separate Sedimentation Results 50
  - 5. Decrease in Filter Load Due to Separate Sedimentation 54
- D. Possibilities of Supplementing the Treatment of the Present Main Plant 58
- E. Results of the Activated Sludge Experimental Unit 60
  - 1. Operating Periods 60
  - 2. Averages Computed from Daily Records 60

TABLE OF CONTENTS (Cont.)

page

3. Treatment of Settled Mixed Sewage with Activated Sludge-- 61
4. Treatment of Trickling Filter Effluent with Activated Sludge---------------------------------- 61
5. Operating Remarks-------------------------------- 63

F. Results of the Chemical Precipitation Experimental Unit-- 66
1. Choice of Coagulant----------------------------- 66
2. Operating Periods------------------------------- 67
3. Daily B.O.D. and "Suspended Solids" Reductions-- 68
4. Chemical Precipitation of Settled Mixed Sewage-- 68
5. Chemical Precipitation of Raw Mixed Sewage------ 70
6. Chemical Precipitation of Packing House Waste--- 70
7. Cost Comparisons-------------------------------- 70
8. Reduction in Filter Load due to Chemical Ppt.--- 71
9. Digestion of sludge from the Chemical Ppt. Unit.- 74

G. Pre-aeration Results------------------------------ 76
1. Purpose of Pre-aeration Studies----------------- 76
2. Pre-aeration of Raw Mixed Sewage---------------- 76
3. Pre-aeration of Packing House Waste------------- 78

H. Application of Experimental Data------------------ 80
1. Activated Sludge Plant Placed Between the Clarifiers and the Trickling Filter------------- 80
2. Activated Sludge Plant Placed After the Trickling Filter------------------------------------ 81

I. Summary and Conclusions--------------------------- 86
1. In Regard to the Present Main Plant------------- 86
2. Experimental Plant Findings--------------------- 87
3. Supplementing the Treatment of the Present Main Plant----------------------------------- 88

I. INTRODUCTION

"Sioux Falls, the largest city in South Dakota is situated on a bend in the Sioux River. The flow of this river ranges from a recorded minimum flow of 9 to a maximum flood flow of 500 cu. ft. per second. As originally designed and built the sewage system emptied into the river at three main outlets. In 1910 the City had a population of approximately 14000 people, and during the next decade its population practically doubled. During this period of growth there was added to the industries of the City a large meat packing plant which has been steadily growing and has exercised a marked influence upon the liquid wastes of the City, until at the present time when the waste from this source alone is approximately 50 percent in volume of the total amount of waste produced by the rest of the City.

For several years the volume of flow in the Sioux River had been insufficient to provide adequate dilution for the ever increasing amount of liquid wastes discharged into it. As a result, the river was offensive both to sight and smell for miles below the City, with an absence of fish life, causing much just complaint from the riparian owners down stream. This was the condition which the City faced in the summer of 1925, when the first definite steps were taken to deal with this problem." (1)

In August 1927, the first units of a Sewage Treatment Plant were placed in operation. This plant is known as the separate sludge digestion type with trickling filters and consists of the following units: Coarse bar screen, Dorr Detritor, measuring weir and flow gage, 2 Dorr Clarifiers or sedimentation tanks, 3 heated sludge digestion tanks, 2 sludge pumps, dosing tanks, filter bed and sludge drying bed. The Treatment Plant was

---

(1) From a paper by R. E. Bragstad

designed to handle not only domestic sewage from the City, but also packing house waste from John Morrell and Company after pretreatment, consisting of fine screening and a 30 minute detention period in a Dorr Clarifier.

For several months previous to the spring of 1931 the filter efficiency was apparently decreasing, as evidenced by the darkening color of the plant effluent. The low flow condition of the Sioux River at this time resulted in nusiance conditions downstream below the treatment plant.

Because of the above facts, Mr. R. E. Bragstad, City Engineer of Sioux Falls, requested the State Board of Health to conduct a plant efficiency survey of the disposal plant to determine the quality of effluent being discharged therefrom, and the efficiency of the various units of the Treatment Plant. This survey, conducted jointly by the City and the South Dakota State Board of Health, was completed about December 1, 1931. The report of the survey is given under Part I of this paper.

Following the report of the Plant Efficiency Survey of the Sioux Falls Treatment Plant, submitted to the City of Sioux Falls, Dec. 10, 1931, the City Commission employed the Pillsbury Engineering Company, Consulting Engineers, Minneapolis, Minnesota, to review the data and findings of the Plant Efficiency Survey.

Their recommendations concurred with the above report in addition to the following:

1. Mechanically cleaning the filter beds of their accumulated filth by forking over, or moving the rock and washing it with a high pressure hose stream.

2. The use of chemical coagulants to increase the reduction of suspended solids going over onto the filters, the kind and quantity of

coagulant to be determined by experimental tests.

3. Either a new set of filter beds, equal and similar in every way to the present filters be built or some other method of treatment devised to perform their function. Since a new set of filter beds would cost in excess of $300,000, they recommended that an experimental plant be operated for a time at a cost of about $3000 to develop, if possible, a process which would obviate the necessity for additional filter area.

Following the report of the Pillsbury Engineering Company, the City Commission authorized the construction and operation of an experimental plant. The experimental plant was designed by Mr. J. B. Estabrook of the Pillsbury Engineering Company, Mr. R. E. Bragstad, City Engineer, and Mr. Fred G. Nelson, Sanitary Engineer with the Dorr Company, and built under the direction of Mr. Bragstad.

The Experimental Plant consisted of two units, an activated sludge plant consisting of an aeration tank, clarifier, air blowing and sludge return equipment and a chemical precipitation plant consisting of a chemical feed, mixing basin, and clarifier.

The chemical precipitation unit was started May 4, 1932, while the activated sludge unit was started May 20, 1932. Both units were operated almost continuously until December 5, 1932.

The Experimental Plant was operated by the writers and supervised by Mr. J. B. Estabrook and Mr. R. E. Bragstad. Fred G. Nelson, Sanitary Engineer with the Dorr Company and W. W. Towne, Director of the Sanitary Engineering Division, State Board of Health, gave very valuable help at numerous times during the experimental period. Biochemical Oxygen Demand and "suspended solids" tests were run on the influent and effluent of both experimental units to check their daily operation. Data were also collected on the operation of the main treatment plant, so that data could be correlated with the Experimental Plant results.

II. A PLANT EFFICIENCY SURVEY OF THE SIOUX FALLS SEWAGE TREATMENT PLANT (PART I)

A. DESCRIPTION OF THE SIOUX FALLS SEWAGE TREATMENT PLANT AND THE PRE-TREATMENT WORKS AT JOHN MORRELL & CO.

The pre-treatment works at the packing plant consist of a Dorr revolving fine screen and a Dorr clarifier equipped with grease skimming mechanism. The clarifier has a theoretical detention period of approximately thirty minutes, at an average flow of 2 M.G.D.

The City treatment plant consists of two overflow gates for by-passing storm water directly to the river, three units of grit chambers,[1] two Dorr clarifiers, two Dorr sludge pumps, filter beds, sludge beds and a gas collection and sludge heating system. The grit chambers each have a capacity of 6 M.G.D. The Dorr clarifiers are each 70 ft. square with a depth of 10 ft. 3 in. at the outer wall. These two tanks, operating in parallel, are designed to provide a two and one-half hour retention period for an average flow of 8 M.G.D.

The Dorr digestors are each eighty-five feet in diameter by twenty-five feet deep and are equipped with gas collection facilities and hot water coils for circulating hot water to obtain more favorable temperatures for proper bacterial action. Each tank has an effective sludge capacity of 132,000 cubic feet. The Dorr sludge pumps each have a capacity of 75 G.P.M.

The trickling filter is 4.1 acres in area, 9 feet deep and is provided with Rawn underdrains. The sludge beds are underdrained sand beds

---

[1] Replaced by a Dorr Detritor in May 1932

covering an area of 1.1 acres. The gas collection and sludge heating system consists of gas collection domes and water circulating coils in the digestors, Bryant gas boiler with thermostatic control, water circulating pump, recording thermometer, a flametrap Connersville rotary meter, and two No. 60-A displacement gas meters, for measuring the gas burned.

B. TESTS CONDUCTED DURING THE EFFICIENCY SURVEY

1. Purpose of Sewage Treatment

Before describing the nature of the tests conducted during the survey it might be well to describe the composition of domestic sewage and industrial wastes in general, and what is to be accomplished by passing them through a treatment plant.

Domestic and industrial wastes are composed for the most part of water which serves as the vehicle by which the impurities are carried from their source to the place of disposal. The impurities consist of various forms of organic material in suspension and in solution, which in the natural course of events pass through a process of decomposition whereby they are changed into more stable and inoffensive organic and inorganic substances.

This final result in nature, is accomplished by supplying oxygen to the organic substances which, by a slow process of oxidation and biological and bacterial action, changes the original material into inoffensive substances which are non-oxygen consuming. As long as there is oxygen in contact with the organic material putrefaction will not occur, but when there is not sufficient oxygen present putrefaction starts, resulting in nuisance conditions.

When these wastes are discharged into a stream, the oxygen is supplied by the dissolved oxygen within the water. A given quantity of water at a given temperature can dissolve only a given quantity of oxygen. Thus it is evident that the quantity of organic material which can be discharged into a stream without causing nuisance conditions is dependent upon the stream flow and the amount of oxygen dissolved in the water.

The purpose of sewage treatment is to provide a means whereby the organic material will pass through this oxidation, and bacterial and biological process, within a few hours, which, in nature, might take many days. In but very few treatment works is the purification complete, however, the organic material should be removed to such a degree that the remaining impurities can be satisfactorily disposed of within the stream receiving the treated waste.

2. Steps in the Treatment Process

This treatment process is accomplished by the following steps at the Sioux Falls Sewage Treatment Plant.

The raw sewage passes through two primary clarifiers where the velocity of flow is reduced to such an extent that a large portion of the suspended solids settle to the bottom. The solids or fresh sludge, as they are called, are then pumped to one of three digestion tanks where the sludge passes through a stage of bacterial action known as the digestion period. This bacterial action breaks down the volatile solids into gasses and liquids, and changes the unstable organic material into more stable organic and inorganic substances, after which the remaining solids are drawn onto the sludge beds and dewatered sufficiently to handle.

The liquid passing through the primary clarifiers still carries some suspended solids, and colloidal and dissolved organic material which does not settle out. This is discharged upon the trickling filters and as it passes down through the rocks, which are covered with a gelatinous mass of oxidizing bacteria, as well as larger organisms, it is consumed and oxidized by them, resulting in a by-product of stable organic and inorganic substances. The degree of purification accomplished by the filter, however, is dependent upon the quantity of liquid flowing through the filter at any given time and the amount of organic substance in the liquid.

3. Bio-Chemical Oxygen Demand Tests And Other Analyses

It is evident from the above discussion that a measure of the efficiency of a sewage treatment plant, or any of the individual steps of the treatment process, can be determined by obtaining the amount of organic material removed by the treatment process. This can be determined indirectly by what is known as the biochemical oxygen demand test, which measures the amount of oxygen required to oxidize a given quantity of sewage. This test has become the most common measuring stick in determining the requirements and efficiencies of sewage treatment processes. A detailed description of the Bio-Chemical Oxygen Demand Test is given in Part II of this thesis.

Other analyses consisted of (1) solids determinations which are tests showing reduction in suspended solids content of the sewage as it passes through the Treatment Plant, and (2) nitrogen determinations on the filter influent and effluent which show, to a certain degree, the extent to which the filter changes the unstable forms of nitrogen, such as albuminoid, ammonia, and nitrite nitrogen to the stable form of nitrate nitrogen

Samples of fresh and digested sludge were also analyzed for their volatile and fixed solids content in order to determine the condition of the digested sludge. Dissolved oxygen and biochemical oxygen demand tests were run on the Sioux River at various points above and below the City. These tests show the ability of the stream to oxidize organic material, and the condition of the stream after receiving the effluent from the sewage treatment plant and other sources of pollution within the City of Sioux Falls.

The Bio-Chemical Oxygen Demand Tests and the Solids determinations conducted during the survey were made according to "Standard Methods For The Examination of Water and Sewage", sixth edition, published by the American Public Health Association, New York, N. Y.

C. OPERATING CONDITIONS OF THE SIOUX FALLS SEWAGE TREATMENT PLANT

At the beginning of this survey, July 1, 1931, the sewage treated at the treatment plant consisted of the industrial waste from the packing plant of John Morrell and Company, and the domestic sewage flow from the City of Sioux Falls.

Before entering the City sewer system the packing plant waste received pretreatment consisting of fine screening and clarification. The clarifier has a theoretical detention period of 30 minutes. It is equipped with grease skimming mechanism. Considerable grease is retained in this tank and recovered.

At this time and for several months previous the sludge settling in the Morrell clarifier was pumped back into the clarifier effluent and carried to the city treatment works. Under these conditions the clarifier served only as a grease skimmer, with the disadvantage of adding aged solids to the waste to be treated at the city plant. Very often the solids thus returned were in a state of partial decomposition or even bordered on septic.

In the efficient sedimentation of sewage solids it is imperative that the solids settle and be removed from the sedimentation chamber before septic-action takes place. Otherwise the evolution of gas will carry particles of solids to the surface of the tank and these will escape through the tank outlet. Also solids in which septic action or gas formation has started are buoyed up by the gas and do not settle.

After clarification the packing house waste containing the sludge was pumped to the city treatment plant, and there mixed with domestic sewage before entering the city clarifiers. From here the mixed waste passes through the two primary clarifiers, operating in parallel, and the effluent is dosed intermittently onto the trickling filter.

The sludge settling in the clarifiers was pumped into one of the three heated digestion tanks.

The plant operated under the same conditions throughout the survey with the following exceptions. After August 10, 1931, the packing house sludge from Morrell's clarifier was not pumped back into the effluent, and at various times one of the filter sections was rested from twenty-four to forty-eight hours to try to eliminate ponding on the filters.

D. PHYSICAL FINDINGS

Notes were made regularly on the physical conditions of the plant and its surroundings; particularly when unusual conditions were noted. Following is a compilation of those data.

At the beginning of the survey there was noted on the surface of the liquid in the digestors a considerable amount of scum which had the appearance of paunch and would not settle, nor would it digest.

The scum creates such a load on the stirring mechanisms in the digesters, that it was impossible to keep them operating.

This condition existed until after August 10 when the scum was removed. Its removal so bettered the situation that by the close of the survey the quantity of scum within the digesters was negligible and the overload was reduced to a minimum.

On July 1, the filter effluent was quite highly colored and there was a slight ponding of liquid on the filters.

Different sections of the filter bed were rested as above mentioned with very little apparent benefit.

Ponding increased gradually and became quite general toward the close of the survey. At the time of a visit to the plant in early November, after the close of the survey, ponding was very general over the entire filter bed, at which time chlorination was recommended as a possible remedy.

The effluent from the clarifiers at the beginning of the survey appeared to contain considerable light brown flocculent material.

The above condition was believed to have been remedied slightly after August 10, when the packing plant waste no longer contained the sludge from the Morrell clarifier.

There also seemed to be a slight diminution in the odor intensity after the above date.

The Sioux River was very low throughout this period and had the appearance of being quite heavily polluted.

E. DATA AND THEIR INTERPRETATION

1. Rate of Sewage Flow

Tables 1 and 2 show the rate of flow of the packing plant waste and the city sewage respectively, for a representative week. The average, maximum and minimum flows and the total daily flows are also given. From these tables it will be seen that the average flow from the packing plant is approximately 2.5 M.G.D. and the city 3 M.G.D., making an approximate total of 5.5 M.G.D. of combined packing plant waste and domestic sewage passing through the treatment plant.

Table 3 shows the kill at the packing plant for those days on which samples were collected for biochemical oxygen demand analyses.

2. Bio-Chemical Oxygen Demand Data

The results of the B.O.D. analyses are shown in table 4. There seems to be very little correlation between the packing plant kill and the B.O.D. strength of that waste, which may be partly explained by the fact that other activities, which may influence the character of the waste, are carried on independently of the kill.

These results may also be expressed in pounds of oxygen per day required to oxidize the organic material present in a given quantity of waste. In table 4 we find given the B.O.D. results for the various units of the sewage treatment plant and for the waste from Morrell's clarifier. The average B.O.D. for the packing plant as listed under station number 1 is 1007. The average daily flow of packing plant sewage taken for a typical week from Table 1 is 2,409,263 gallons. The oxygen required per day may then be obtained as follows:

$$\frac{2,409,263 \times 8.33 \times 1007}{1,000,000} = 20,200 \text{ lbs.}$$

Similarly we find for domestic sewage in table 4 under station2 an average B.O.D. of 356. An average daily flow from table 2 is found to be 2,939,609 gallons. Oxygen required is; $\frac{2,939,609 \times 8.33 \times 356}{1,000,000} = 8,700$ lbs./day. In the above computations the value 8.33, which is ordinarily the weight of a gallon of pure water, is taken as the weight of a gallon of sewage. Such an approximation is accurate enough for ordinary computations where the experimental error generally exceeds the limits of approximation.

Continuing our computations for total Oxygen Demands of the wastes through the various units of the treatment plant, we find under station 4, table 4,an average B.O.D. of 491 for clarifier effluent. The flow through the clarifier would be the sum of the domestic and packing house wastes or 5,348,872 gallons. The Oxygen demand then is;

$$\frac{5,348,872 \times 8.33 \times 491}{1,000,000} = 21,850 \text{ lbs./day.}$$

For the filter effluent, station 5, table 4, we find an average B.O.D. of 120. The flow is of course the same as through the clarifiers. The total oxygen demand would be;

$$\frac{5,348,872 \times 8.33 \times 120}{1000,000} = 5,344 \text{ lbs./day}$$

With respect to packing plant wastes an interesting comparison of its strength with that of domestic sewage can be made on the basis of population contributing to domestic sewage flow. Sioux Falls has a population (at the present time) of about 33,400. An average oxygen demand for domestic sewage we found to be 8,700 lbs. The packing house waste had a demand of 20,200 lbs. of oxygen or an equivalent population, as compared with domestic sewage, of; $\frac{20,200 \times 33,400}{8,700} = 77,600$

The Sewage Treatment Plant thus has a contributory population of 76,600 plus 33,400 or 111,000

The requirements and accomplishments of the treatment plant can be briefly summarized as follows:

1. Oxygen required to oxidize the combined raw domestic and packing house waste, 28,900 lbs. per day.

2. Oxygen required to oxidize clarifier effluent, 21,850 lbs. per day.

3. Oxygen required to oxidize filter effluent, 5,344 lbs. per day. This figure also represents the amount of oxygen which must be supplied by the Sioux River in order to avert nuisance conditions.

4. The total equivalent population contributing to the sewage treatment plant is approximately 111,000. (1931)

5. The total efficiency of the treatment plant is (28,900 - 5,344) ÷ 28,900 = 0.815 or 81.5%. The average efficiency of 13 similiar plants was 83.8%. (Bulletin 23, Illinois Water Survey)

3. Solids Determinations

In table 5 is given the solids determinations of the wastes analyzed. It is significant to note that there is but a slight reduction in both total and volatile solids after treatment. It is apparent, however, that the volatile solids in the filter effluent do not have as high a B.O.D. per given quantity as those found in the raw sewage.

The removal of suspended solids corresponds very closely to the B.O.D. reductions. The clarifiers remove 36.2 percent of the total suspended solids and the filter 48.8 per cent, making a total reduction of 85 per cent. The reduction in suspended solids accomplished by tank treatment is not as great as it should be, considering the length of the retention period within the tank. Tank treatment should accomplish about 50 per cent reduction, however, as stated elsewhere, the packing house waste apparently

TABLE 1

MORRELL'S PACKING PLANT DAILY SEWAGE FLOW FOR A TYPICAL WEEK.

July 20, to 26.

HOUR	Flow in gallons per minute for hourly periods						
	July 20 Mon.	July 21 Tues.	July 22 Wed.	July 23 Thurs.	July 24 Fri.	July 25 Sat.	July 26 Sun.
7:00A.M.	1134	1685	2500	1490	2280	2165	675
8:00A.M.	2170	3151	2825	2280	2720	2596	675
9:00A.M.	2500	3035	2825	2596	2935	2825	740
10:00A.M.	2600	3151	2720	2720	3035	2935	600
11:00A.M.	2715	3035	2280	2935	2596	2500	740
12 Noon	2400	2596	2280	2063	2596	2400	675
1:00P.M.	2166	2500	2720	2500	3035	3035	740
2:00P.M.	2820	3260	2935	2935	2935	2825	740
3:00P.M.	2400	2596	2500	2825	2165	2280	675
4:00P.M.	1970	2063	1685	2400	1685	1870.	675
5:00P.M.	1870	1780	1400	1579	1579	1490	675
6:00P.M.	1580	1685	1300	1490	1400	1215	600
7:00P.M.	1400	1400	1215	1300	1300	1134	523
8:00P.M.	1400	1490	1215	1134	1300	1134	523
9:00P.M.	1300	1400	1215	1215	1134	1134	600
10:00P.M.	1300	1300	1215	1215	1060	1060	600
11:00P.M.	1215	1300	1134	1215	900	975	523
12 Midnite	1215	1215	1134	1134	900	975	523
1:00A.M.	1134	1300	1060	1060	900	975	523
2:00A.M.	1134	1215	1060	1060	820	975	523
3:00A.M.	1215	1300	1134	1134	820	1060	523
4:00A.M.	1215	1300	1134	1134	900	975	523
5:00A.M.	1134	1215	1134	1060	1060	975	675
6:00A.M.	1215	1300	1579	1060	1400	820	900
Total flow G.P.D.	3247630	2776320	2531952	2491920	2487312	2419632	910080
Ave. flow G.P.M.	2255	1928	1758	1730	1727	1680	632
Max. flow G.P.M.	3151	3542	3260	3260	3260	3035	1132
Min. flow G.P.M.	1055	1134	1060	1060	820	820	523

Average daily flow for the week 2,409,263 gal.

TABLE 2

DAILY DOMESTIC SEWAGE FLOW FOR A TYPICAL WEEK.

July 20, to 26, 1931

Hour	Flow in gallons per minute for hourly periods						
	July 20 Mon.	July 21 Tues.	July 22 Wed.	July 23 Thurs	July 24 Fri.	July 25 Sat.	July 26 Sun.
7:00 A.M.	1863	1710	1068	1159	1282	1863	1710
8:00 A.M.	2765	2200	1710	1615	1710	2765	2095
9:00 A.M.	3184	n2641	1978	2095	2200	3184	2520
10:00 A.M.	2968	2765	2520	1868	2331	3184	2641
11:00 A.M.	3484	3361	2520	2520	2765	3361	2968
12:00 Noon	3184	2886	2331	2095	2520	3184	2641
1:00 P.M.	2765	2641	2095	1978	2331	2968	2765
2:00 P.M.	2765	2641	2331	1863	2520	2968	2641
3:00 P.M.	2765	2641	2095	2095	2641	2886	2641
4:00 P.M.	2765	2520	2200	1978	2765	2765	2520
5:00 P.M.	2641	2331	1710	1863	2641	2765	2520
6:00 P.M.	2520	2200	1710	1710	2520	2641	2331
77:00 P.M.	2331	1978	1615	1615	2200	2641	2331
8:00 P.M.	2200	2095	1615	1710	2095	2886	2200
9:00 P.M.	2095	1710	1417	1710	1978	2641	2200
10:00 P.M.	2200	1615	1282	1863	1863	2331	2331
11:00 P.M.	2095	1615	1282	1710	1863	2200	2331
12:00 M.Nite	2765	1417	1068	1527	1978	2095	2520
1:00 A.M.	2520	1282	987	1159	2095	1978	2200
2:00 A.M.	2200	1068	897	897	1863	1710	1615
3:00 A.M.	1978	987	809	897	1863	1710	1527
4:00 A.M.	1710	897	809	897	1710	1527	1527
5:00 A.M.	1527	809	718	897	1710	1527	1527
6:00 A.M.	1527	809	809	1068	1527	1527	1710
Total Flow Gal.Per Day	3529008	2808000	2199960	2327040	2920752	3558412	3234096
Ave. Flow Gal.Per Min	2450	1950	1527	1616	2028	2471	2245
Max. Flow Gal.Per Min	3184	3361	2520	2520	2765	3361	2968
Min. Flow Gal.Per Min	1527	809	718	897	1282	1527	1417

Average daily flow for the week: 2,939, 609 gal.

TABLE 3

KILL AT MORRELL'S PACKING PLANT ON DAYS OF B.O.D. ANALYSES

Date	Hogs	Cattle	Sheep	Veal	Total
7-10	3050	401	14	7	3422
7-15	2546	300	86	8	2940
7-17	3053	303	150	18	3524
7-19	None	None	None	None	None
7-24	2584	352	100	24	3060
7-31	2546	301	125	9	2981
8-3	2303	301	56	1	2661
8-4	2270	302	47	14	2633
8-6	2818	300	63	16	3197
8-9	None	None	None	None	None
8-14	2793	325	122	22	3262
8-19	2453	410	72	37	2972
8-21	2911	409	207	10	3537
8-26	2547	450	55	23	3075
8-27	None	None	None	None	None
8-31	2852	349	25	6	3232
9-26	2840	350	78	13	3281

TABLE 4

BIOCHEMICAL OXYGEN DEMAND RESULTS

Note: Station 1 - Morrell's Packing Plant Waste
Station 2 - Domestic Sewage
Station 3 - Clarifier Influent
Station 4 - Clarifier Effluent
Station 5 - Filter Effluent

66

	B.O.D. of waste at Station					Plant Eff. %	Remarks
Date	1	2	3	4	5		
7-10			1380	615			Grab Sample
7-15	1105	261	654	629	120	81.6	24 hr. composite
7-17	748	284	559	295	101	81.9	24 hr. composite
7-19	710	208	548	360	132	75.9	24 hr. composite (Sunday)
7-24	1280	340	690	530	200	71.0	24 hr. composite
7-31	881	361	738	486	112	84.8	Grab Sample - 2 P.M.
8-3	640	536	884	590	170	80.7	12 hr. composite 7 A.M. to 6 P.M.
8-4	1284	515	1189	597	132	88.9	12 hr. composite 7 A.M. to 6 P.M.
8-6	1243	403	981	580	100	90.8	6 hr. composite 10 A.M. to 6 P.M.
8-9	897	171	372	240	36	90.3	12 hr. composite 7 P.M. to 6 A.M. (Sunday)
8-10	Waste from Morrell's did not containe sludge from Clarifier after this date.						
8-14	1162	394	698	385	56	92.0	8 hr. composite 10 A.M. to 6 P.M.
8-19	713	360	596	437	58	90.6	6 hr. composite 10 A.M. to 3 P.M.
8-21	733	338	558	362	73	86.9	8 hr. composite 10 A.M. to 5 P.M.
8-26	1359	341	744	772	193	74.1	10 hr. composite 8:30 A.M. to 5 P.M.
8-27	1116	291	650	540	116	82.2	24 hr. composite
8-31	1562	475	795	502	128	83.9	10 hr. composite 8 A.M. to 5 P.M.
9-26	675	362	590	426	198	66.5	9 hr. composite 9:30 A.M. to 6:30 P..
Average	1007	356	743	491	120	83.8	

contained large amounts of very light flocculent material in suspension which would not settle even in an Imhoff cone. This assumption is further substantiated by Imhoff cone tests on the tank influent and effluent. The average reduction in settleable solids by this test, with a two hour settling period, was approximately 95 per cent, showing high efficiency in the sedimentation of solids which would settle readily.

4. Sewage Nitrification Accomplished by the Trickling Filter

Table 6 shows the nitrification accomplished by filtration. Since it was impossible to run these tests at the treatment plant, these analyses were made by Mr. Guy G. Frary, State Chemist at Vermillion. It was impossible for Mr. Frary to do this work at the start of the survey, but the tests were commenced as soon as possible and were continued for some time after the other analytical work was completed.

One purpose of sewage filtration is to change the unstable forms of nitrogen to the more stable forms. Albuminoid, ammonia and nitrite nitrogen are very unstable, changing very rapidly to the stable form of nitrate nitrogen in the presence of sufficient oxygen.

Inasmuch as a trickling filter is an oxidizing device some knowledge of its efficiency can be obtained by determining to what extent the sewage is nitrified as it passes through the filter.

It will be noted that the first three samples show a marked reduction in total nitrogen in the effluent over the tank effluent. Also the nitrate nitrogen was increased considerably by filtration.

The remaining tests, however, do not show this condition to be as marked, indicating that the oxidizing capacity of the filter has been reduced.

TABLE 5

SOLIDS DETERMINATIONS

Results in P.P.M.

MORRELL PACKING PLANT WASTE

Date	Total	Volatile	Fixed	Dissolved	Suspended
7-15	5170	4750	420	3594	1576
7-19	3676	3068	608	3162	314
8-3	6230	5450	780	4554	1676
8-21	4800	3986	814	3966	834
8-27	4532	3908	624	3230	1302
Average	4881	4232	649	3701	1140

DOMESTIC SEWAGE

Date	Total	Volatile	Fixed	Dissolved	Suspended
7-15	1420	850	570	920	500
7-19	1107	582	525	902	205
8-3	1740	1114	626	1110	630
8-21	1240	618	623	940	300
8-27	1308	656	632	934	374
Average	1363	768	595	961	406

TABLE 5 CONTINUED

SOLIDS DETERMINATIONS

Results in P.P.M.

Date	Total	Volatile	Fixed	Dissolved	Suspended
Mixed Waste and Sewage					
*7-10	5420	4740	680	4630	790
7-15	3300	2546	754	2540	760
7-19	2002	1422	580	1756	246
8-3	3874			2626	1248
8-21	3314	2828	486	2686	628
8-27	2890	2276	614	2294	596
Average	3072	2536	487	2380	696
City Clarifier Effluent					
*7-10	3210	2590	650	3050	190
7-15	2730	2434	296	2056	674
7-19	1940	1422	518	1589	351
8-3	3053	2438	614	2114	438
8-21	2904	2332	584		
8-27	2594	2148	446	2288	305
Average	2644	2155	592	2137	442
Filter Effluent					
7-19				11868	
8-3	2626			2400	226
8-21	2580	2148	432	2468	112
8-27	2304	1846	458	2180	124
Average	2503	1997	445	2349	154

Note: * = Grab sample, not used in averages.

As mentioned elsewhere in this report the filters began ponding about September 1. The ponding seals the surface of the filter, preventing aeration of the bed between doses, which is necessary to the growth of oxidizing bacteria. This explanation seems the only logical conclusion to draw relative to the decreased efficiency of the filter after September 15. The efficiency decrease is also apparent in table 4, when on September 26 the efficiency for that series of tests was 66.5 percent, the lowest recorded. During the survey different sections of the filter bed were rested for periods of from 24 to 48 hours to see what effect it would have on the ponding. There seemed to be a slight decrease in the ponding immediately after the filter was again put in operation, but within a day or two the condition apparently was as bad as ever.

5. Sludge Analyses

Table 7 gives the results of sludge analyses. It is significant to note that during digestion there is considerable volatile matter reduction. The digested sludge analyzed had not passed through as long a digestion period as is customary, due to a breakdown in one digester, and operating difficulties in the other tanks, necessitating sludge withdrawals before the usual time of digestion. However, this sludge was in good condition and showed that very good digestion took place in the tanks.

Another important item to observe is the result of the test on the scum in the digester. The scum had been in the tank for several weeks and it will be noted that there is no reduction in volatile matter comparative to that shown by the sludge, showing that this material, which has the resemblance of paunch from the packing plant, will not digest within reasonable time limit and should not be included in the sewage.

TABLE 7

SLUDGE ANALYSES
SOLIDS DETERMINATIONS ON DRY BASIS

	Solids in P.P.M.			Per cent	Percentage basis	
Date	Total	Volatile	Fixed	Moisture	Volatile	Fixed
South Clarifier, Fresh Sludge						
7-8	116000	82000	33200	88.4	71.4	28.6
8-25	99500	59900	39600	90.0	60.2	39.8
Morrell Clarifier, Fresh Sludge						
7-8	37000			96.3		
7-11	125000	107000	18000	87.5	85.6	14.4
Digester No. 1, Digested Sludge						
7-11	144000	63800	80200	86.6	44.6	55.4
8-27	130200	62100	68100	86.9	47.7	52.3
Digester No. 2, Digested Sludge						
7-22	114000	55200	58800	88.6	48.0	52.0
Scum on Digester No. 3						
7-8	199000	144000	55000	80.1	72.2	27.8

Note: The average pH of the sludge in the digesters during the survey period was 7.5

The average pH of fresh sludge from the clarifiers was 6.8

6. Stream Pollution Study of the Sioux River

Table 8 shows the dissolved oxygen content of the Sioux River at the stations noted, as well as the oxygen demand of the organic material within the water at those points.

The computed averages from table 8 are plotted on figure 1 of this report.

From these data it will be seen that the B.O.D. exceeds the D.O. of the stream even before the effluent from the disposal plant enters the stream. This can be explained by the fact that the waste from the stock yards was discharged untreated into the stream above Station 2, which depleted the oxygen to such an extent that nuisance conditions prevailed.

During this survey construction was started which, when completed. would provide a connection whereby the waste from the stock yards and the Serum Company would pass through the city treatment plant, after pre-treatment consisting of fine screening.

Two sets of samples were analyzed to determine the biochemical oxygen demand of these wastes, the average results being given below.

Stock Yards B.O.D. - 292
Serum Company B.O.D. - 313

It will be seen that these wastes are not as concentrated as the city sewage and as the above samples were grab samples collected during the middle of the day it is to be expected that the average B.O.D. over a period of 24 hours would be less.

After the sewage treatment plant effluent enters the stream the nuisance condition grows steadily worse for a considerable distance down stream and at no place covered by this survey, below station 1, is there a positive oxygen balance. In other words the oxygen required is greater than the oxygen available at all stations below station 1. By the time the polluted stream reaches the Brandon Bridge, we find that sufficient oxygen has been absorbed to support fish life and prohibit general nuisance conditions. In fact on two days the dissolved oxygen content is above the saturation point for those temperatures. This may be attributed to the predominance of green algae in the lower stretches of the stream which supply oxygen to the water. The B.O.D. is also reduced considerably here, but the demand is still considerably greater than the supply, and the dissolved oxygen content would be depleted here also if it were not for the algae and stream reaeration taking place.

When the opportunity for stream reaeration and algae propagation is reduced by ice formation, conditions may be expected to become worse.

7. Stream Flow Record of the Sioux River

Stream flow records (Table 10) which were kept during the latter part of the survey showed the average flow to be 3.29 second feet and only a very few times did the flow exceed that value. These increased flows were due to local showers and continued for only a day or two. By assuming an average stream flow of 3 second feet or 1,944,000 gal. per day we find that the average flow entering the stream from the treatment works was more than two and one half times the stream flow.

Assuming that the average dissolved oxygen content at station 1 represents the amount of oxygen available for oxidizing the treatment plant effluent and with a stream flow of 3 second feed, there would be available 116 pounds of oxygen per day in the stream for this purpose. On that basis it is evident that the B.O.D. of the filter effluent would have to be reduced far below the present figure

TABLE 8

DISSOLVED OXYGEN
and
BIOCHEMICAL OXYGEN DEMAND
Results on the Sioux River

Results in P.P.M.

	Station 1			Station 2			Station 3			Station 4		
Date	Temp C°	D.O.	B.O.D.	Temp C°	D.O.	B.O.D.	Temp C°	D.O.	B.O.D.	Temp C°	D.O.	B.O.D.
7-21	42	3.7	10.9	40		36.5	32	0	45.7	29	11.3	32.9
7-22	40	4.5	10.2	29	1.5	30.2	26	0	34.9			
7-23	41	7.8	9.6		0	19.6	32	0	24.4	29	9.4	24.4
8-1	34	8.1	7.5		0	40.0	27	0	32.8	27	4.4	24.0
8-10	25	5.5	5.8	24	1.7	11.1	24	0.7	19.1	21	2.6	6.0
8-23	32		5.4	30	0	22.0	29	0	14.7	27	2.6	11.6
Average		5.9	7.3		0.6	26.6		0.1	28.6		6.1	19.8

Station 1 - McClellan St. Bridge
Station 2 - Disposal Plant Foot Bridge
Station 3 - McKee Bridge, 2 miles below disposal plant outlet
Station 4 - Brandon Bridge, 9 miles below disposal plant outlet

8. B.O.D. Reduction Tests on Final Settling

Tests for determining the reduction in B.O.D. accomplished by settling the filter effluent for certain periods were carried on with the results as shown in Table 9.

BIOCHEMICAL OXYGEN DEMAND REDUCTION TESTS ON FINAL SETTLING AFTER FILTRATION.

TABLE 9

6

B.O.D.			
Filter Effluent	30 Min.	45 Min.	1 Hour
128	85	78	
132			72

Other tests which were run on this experiment depleted all of the available oxygen in the five day period, therefore, the B.O.D. could not be determined. The experiment was carried on by collecting a sample of filter effluent in an Imhoff cone. B.O.D. tests were made before and after settling for the prescribed time.

It must be remembered that the settling of solids in the above tests took place under quiescent conditions which would not exist in a final clarifier. However, a final clarifier, having a theoretical settling period of any of the above time elements, would no doubt give results similiar to the above, but in all probability, the theoretical retention period would have to be increased over any one time element above to produce the same B.O.D. reduction.

Additional tests should be run on this experiment to substantiate the above results. However, results similiar to these but possibly with lower B.O.D. reductions are what may be expected if further tests are made.

TABLE 10

AVERAGE DAILY FLOW OF THE SIOUX RIVER
At SIOUX FALLS, SOUTH DAKOTA
August 29 to September 25, 1931

Date	Relative Temperature	Average Daily Head in feet	Discharge in ft. /sec. Q.	Discharge in Gal./min.	Discharge in M. G. D.
Aug. 29	cool	0.070	1.281	577	0.830
" 30	"	0.058	0.980	441	0.635
" 31	warm	0.100	2.195	989	1.422
Sept. 1	"	0.075	1.435	646	0.930
" 2	"	0.082	1.624	732	1.053
" 3	"	0.090	1.869	840	1.211
" 4	"	0.100	2.195	989	1.422
" 5	"	0.075	1.435	646	0.930
" 6	"	0.075	1.435	646	0.930
" 7	"	0.075	1.435	646	0.930
" 8	"	0.100	2.195	989	1.422
" 9	"	0.100	2.195	989	1.422
" 10	"	0.075	1.435	646	0.930
" 11	"	0.075	1.435	646	0.930
" 12	"	0.050	0.772	347	0.501
" 13	"	0.019	0.178	80	0.115
" 14	cool	0.025	0.279	126	0.181
" 15	"	0.048	0.728	328	0.472
" 16	warm	0.075	1.435	646	0.930
" 17	"	0.100	2.195	989	1.422
" 18	cool	0.100	2.195	989	1.422
" 19	warm	0.300	11.500	5,180	7.450
" 20	"	0.113	2.52	1,135	1.632
" 21	cool	0.100	2.195	989	1.422
" 22	"	0.100	2.195	989	1.422
" 23	"	0.316	12.50	5,625	8.100
" 24	"	0.533	27.00	12,150	17.500
" 25	"	0.125	3.25	1,462	2.108
AVERAGE			3.29	1,473	2.131

F. SUMMARY AND CONCLUSIONS

The important findings brought to light in this survey may be summarized as follows:

(1) The treatment plant is treating approximately equal volumes of packing house waste and city sewage, the total flow averaging 5,349,000 gallons per day.

(2) The packing plant has an equivalent population of 76,000, based on the B.O.D. of the city sewage and the population of Sioux Falls. The total population contributing to the treatment plant, including the packing house equivalent, is 110,000.

(3) The clarifiers are not over loaded in capacity, but due to the character of the sewage, the removal of suspended solids is not as great as is desired.

(4) The result of carrying over of suspended solids onto the filter has led to ponding on the filter, resulting in decreased efficiency.

(5) The filter is being dosed at the rate of 1.3 million gallons per acre per day, which is a low rate on a gallon basis, but the liquid being discharged onto the filter is 1.38 times as strong as the raw domestic sewage.

(6) The filter is considerably over loaded under the present operating conditions, and cannot be expected to deliver a desirable effluent unless more efficient sedimentation is obtained.

(7) Sedimentation of the filter effluent will accomplish some additional purification, but it is believed that the reductions in B.O.D. on a plant size scale will not be as great as the experimental work shows.

(8) Better nitrification and B.O.D. reductions can be obtained by eliminating ponding.

(9) The stomach paunch from the packing plant interferes with the proper operation of the digestion tanks and it will not digest within reasonable length of time.

(10) The flow in the Sioux River is the lowest recorded.

(11) The raw sewage from the stock yards and the Serum Company caused nuisance conditions above the sewage treatment plant outlet and depleted the oxygen content of the water below that required to sustain fish life.

(12) The stream, after receiving the plant effluent, is in worse condition than before, but begins to better itself before reaching Brandon. When the stream freezes over conditions will probably become worse farther down stream.

(13) The present grit chambers retain large amounts of organic material which, when discharged into the stream with the grit, form sludge banks in the stream resulting in septic action and a very unsightly condition.

(14) The resting of the filters for periods of 24 to 48 hours did not seem to eliminate ponding for any great period of time.

G. RECOMMENDATIONS

The writers wish to submit the following recommendations:

(1) The main treatment plant, and especially the filter unit, is receiving a much greater load of organic material than it is capable of treating to the required degree of purification. More efficient sedimentation of the packing house waste must be accomplished or additional filter area provided.

Of the two suggestions offered it is recommended that experimental studies be made to determine the most economical means of reducing the strength of the packing house waste by more efficient sedimentation of the organic material.

(2) Final settling of the filter effluent will better the quality of the liquid discharged into the Sioux River as well as remove a large amount of the solids which cause very unsightly conditions down stream, especially during low ~~flow~~ stream flows. For these reasons we recommend that the city install final clarification.

(3) The organic material settling in the grit chamber and gaining access to the stream when these chambers are cleaned should be eliminated. It is recommended that the city install a mechanically operated detritor which will remove only the heavier inorganic substances.

(4) We are of the opinion that the efficiency of the trickling filter can be increased by eliminating ponding. We would recommend chlorination of the filters to accomplish this. It is known that chlorine will also, to a small extent, reduce the biochemical oxygen demand of sewage which would mean a better filter effluent. In addition chlorination has been proved an effective odor control for which the chlorination apparatus

could be used when necessary.

(5) Another possible method of lessening the filter lead would be Activated Sludge Treatment of the clarifier effluent, the effluent from this treatment to be discharged in the filters. The activated sludge type of treatment has been successfully used in other places where the trickling filter was overloaded.

(6) It is recommended that the sludge pumps be operated frequently for short intervals, pumping only as long as is necessary to remove accumulated fresh sludge. This will tend to reduce the quantity of return supernatant liquid from the digestors which is advisable as the solids in this liquid do not settle readily.

(7) At no time in the future should the sludge from the Morrell Clarifier be discharged into the waste flowing to the city treatment plant.

III. EXPERIMENTAL PLANTS RESULTS (PART II)

A. DETAILED DESCRIPTION OF THE EXPERIMENTAL UNITS

1. Activated Sludge Unit

In the treatment of sewage by the activated sludge process the sewage enters an aeration tank after it has received preliminary treatment consisting of coarse screening and grit removal. As it enters the aeration tank it is mixed with 20 to 30% of its volume of activated sludge. The sewage passes through the aeration tank in from two to twenty hours, depending upon the strength of the sewage and the method of aeration. While in the tank, air is blown through the sewage or it is mechanically agitated or both. The effluent from the aeration tank passes to a sedimentation tank to permit sedimentation or settling of the activated sludge. The supernatant liquid from the sedimentation tank may be treated further but usually passes to a point of final disposal. A portion of the sludge removed from the sedimentation tank is returned to the influent of the aeration tank to seed the incoming sewage with the aerobic bacteria that oxidizes it as it passes through the aeration tank. The remainder of the sludge is usually disposed of by burning or by digestion in sludge digestion tanks. The activated sludge proper consists of a spongy mixture of aerobic bacteria and suspended organic solids including those of a colloidal nature. To keep the sludge active air must be supplied continuously to the mixture of sewage and sludge.

Since the first full size Activated Sludge Unit was installed in Milwaukee in 1915 the activated sludge process has established itself as a standard sewage treatment method.

The Sioux Falls Activated Sludge Unit consisted of an aeration tank, sedimentation tank or clarifier, air blowing and sludge return equipment. Figure 2 is a photograph of the activated sludge unit in operation. The aeration tank was 5 ft. wide, 6 feet deep and 20 feet long. Drop pipes carried air from the main air header pipe to porous tubes resting on the bottom of the areation tank. The 5 ft. x 5 ft. x 6 ft. deep clarifier was located at the effluent end of the aeration tank. It was equipped with sludge removal equipment similar to a large Dorr Clarifier. Air was furnished by means of a blower driven by an electric motor. The return sludge was pumped from the bottom of the clarifier to the influent end of the aeration tank by means of a centrifugal pump. A shed attached to the side of the aeration tank housed the air blowing equipment, sludge return equipment, and an air meter that measured the amount of air delivered to the aeration tank.

With a sewage flow of 5 gallons per minute plus a 25 per cent sludge return the aeration tank provided an aeration period of 12 hours while the theoretical sedimentation period in the clarifier was 3 hours.

2. Chemical Precipitation Experimental Unit

The chemical precipitation unit consisted of an orifice box, mixing basin, and sedimentation tank. The orifice box was calibrated to deliver a 5 gallon per minute sewage flow to the mixing basin where the Ferric Chloride solution was introduced from a 5 gallon carboy setting above the mixing tank. The mixing tank was 20 inches wide, 18 inches deep, and 5 feet long, and provided a mixing period of 20 minutes. It was equipped with a chain driven paddle to thoroughly mix the chemical with the sewage. The sedimentation tank or clarifier was an exact duplicate of the activated sludge clarifier. The sludge removal equipment of both clarifiers was driven by the same shaft.

Referring to figure 2, the chemical Precipitation Unit is located to the right of the Activated Sludge Unit

FIGURE 2

B. CONTROL TESTS CONDUCTED DURING THE EXPERIMENTAL PERIOD

1. Bio-Chemical Oxygen Demand Tests

Since the purpose of sewage treatment processes is the removal or stabilization of the organic matter present in the sewage, the efficiency of a sewage treatment plant,or any of the individual steps of the treatment process, can be determined by the amount of organic material removed by the treatment process. This can be determined indirectly by what is known as the bio-chemical oxygen demand test. The bio-chemical oxygen demand of sewage is the oxygen in parts per million by weight required to oxidize or stabilize its organic matter by aerobic bacterial action. Thus the bio-chemical oxygen demand value of a sewage is a measure of its organic strength. The B.O.D. test has become a standard measuring stick in determining the requirements and efficiencies of sewage treatment processes. Detailed instructions for the performance of bio-chemical oxygen demand tests have been drawn up by the American Public Health Association and the United States Public Health Service.

The Rideal-Stewart modification of the Winkler Method as given in part I and part II of "Detailed Instructions for the Performance of the Dissolved Oxygen and Biochemical Oxygen Demand Tests" by Emery J. Theriault, Chemist, U. S. Public Health Service, was followed in all B.O.D. analysis performed at the Sioux Falls Sewage Experimental Plant. Enough B.O.D. tests were made to check the daily operation of the Experimental Units. Sufficient data was collected on the operation of the Main Treatment Plant to correlate that data with experimental plant results.

Samples for B.O.D. analysis were collected every hour for 8 hours during the day and composited. At the end of the sample period a representative sample was taken from the composite, diluted with dilution water in the proper proportions and incubated for 5 days at a temperature of

" 18	Chem. Precip. Again started	813	62	92.4	813	575	29.3	62	89.1	575	133.0		76.9	970	507			47.6
" 22	Chem. Infl. = Raw Pack. H.	955	85	91.1	955	682	28.5	85	87.5	682	45.0		93.4	1125	490			56.5
" 23		1022	94	90.7	1022	762	25.4	94	87.6	762	128.0		83.1	1175	480			59.1
" 25		753	75	90.0	753	622	17.4	75	87.9	622	105.0		83.1	915	477			47.8
" 29	Filter Effl. = Aer. Infl.	634	71	88.8	634	560	11.7	71	87.4	71		23.0	67.6	895	370			58.7
" 30		943	219	76.8				219	72.7	219		41.0	81.3					
Sept. 2		803	66	91.9	803	747	7.0	66	91.2	66		24.0	63.9	800	505			36.9
" 6	Chem. Feed to 50 p.p.m.	1010	234	76.8	1010	817	19.1	234	71.3	234		78.0	66.6	1440		823		42.9
" 8														920		475		48.5
" 9		860	138	83.9	860	775	9.9	138	82.2	138		30.0	78.3	1215		725		40.3
" 12		720	71	90.1	720	487	32.4	71	85.4					940		507		45.9
" 13	No Chem. Added	605	38	93.7				38	93.6					725			557	23.2
" 14	Dom. Sew. By-passed	1080	77	92.7	1080	827	23.4	77	90.5					1060		No	727	31.4
" 15	Do	1000	39	96.1	1000	670	33.0	39	94.2					1000		Chem.	660	34.0
" 16		955	82	91.4	955	637	33.3	82	87.0					890			607	31.8
" 19	Domestic Sew. only	417	53	87.2	417	137	67.2	53	61.0					960				
" 23										122		38.0	68.9			494		48.6
" 26	Split Flow	443	25	94.3	443	303	31.6	25	91.8									
" 27		667	115	82.7	667	560	16.1	115	61.6	115		16.0	86.0					
Oct. 1		757	230	69.5	757	567	25.0	230	59.4	230		31.0	87.4					
" 3		569	56	90.2	569	390	31.4	56	85.6	56		13.0	77.6					
" 8		653	121	81.5	653	560	14.3	121	78.2	121		25.5	79.0					
" 10		761	158	79.3	761	452	40.6	158	66.5	158		30.0	81.1					
" 15		683	248	63.8				248	67.4	248		36.0	85.4	~Pre-Aeration Clarifier~				
" 17		541	160	70.3	541	325	39.9	160	55.8	160		23.0	85.7	Infl.	30 min	% Red.	3 hrs.	% Red.
" 29	Pre-Aerat Clarif.									1165		258.0	77.8	1165	730	37.4		
" 31	Pre-Aer. Infl. = Raw Pack. H.									830		177.0	78.7	830	595	28.3		
Nov. 4										1375		273.0	80.1	1375	843	38.7		
" 5										1402		277.0	80.2	1402	861	38.6		
" 7					1378	705	48.9							1378	849	38.4		
" 12		629	273	56.6	629	500	20.5	273	56.6									
" 14		687	260	62.2	687	441	35.8	260	41.0					835	770	7.8	553	33.8
" 18					1310	1049	19.9							1310	987	24.6	783	40.2
" 25		952	352	63.0	952	562	41.0	352	45.4					1474	870	41.0	747	49.4
" 26														1580	1360	13.9	1059	33.0
" 30														1810	1214	32.9	1200	33.7
Dec. 2					1755	975	44.4							1755			1154	34.2
" 3					1575	1135	27.9							1575			955	39.3
" 5		950	350	63.2	950	613	35.5	350	52.4					1260			810	35.7

TABLE NO. 11

B.O.D. (in p.p.m.) for Various Units of the Sioux Falls Sewage Treatment and Experimental Plant

Spring + Summer of 1932	Miscellaneous ----- Notes	Main Plant			Dorr Clarifiers			Filter		Activated Sludge Plant				Chemical Precipitation Plant				
		Infl.	Effl.	% Red	Infl.	Effl.	% Red	Effl.	% Red	Infl.	Effluent Air 3-4 ft^3/gal.	Air 3/4 ft^3/gal.	% Red	Infl.	Effluent $FeCl_3$ 25 p.p.m.	$FeCl_3$ 50 p.p.m.	$FeCl_3$ 35 p.p.m.	% Red
Column	Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
April 2								116	57.0									
" 6								73	68.3									
" 8		732	172	76.8	732	438	40.2	172	60.7									
" 11		805	181	77.5	805	406	49.5	181	55.4									
" 14		712	185	74.0	712	394	44.6	185	53.0									
" 15		789	320	59.5	789	554	29.9	320	42.3									
" 19		830	312	62.4	830	545	34.3	312	42.6									
" 21		683	201	70.6	683	356	47.9	201	43.6									
" 25		730	165	77.4	730	329	55.0	165	49.8									
" 28		795	177	77.8	795	436	45.1	177	59.4									
May 2		780	234	70.0	780	427	45.3	234	45.1									
" 3	Chem. Infl. = Clarif. Effl.													392			228	41.7
" 4														450			277	38.6
" 5														483			362	24.9
" 6		825	272	67.1	825	565	31.5	272	51.9					565			412	27.1
" 9		790	201	74.6	790	424	46.4	201	52.6					424			295	30.4
" 10		755	297	60.7	755	330	56.4			625	50.5		90.2	625			363	41.8
" 13														330			314	4.8
" 17	Chem. Infl. = Raw Sew.													1067			378	64.6
" 18						330		118	64.3									
" 19											17.5			683			224	67.0
" 20		953	217	77.4	953	594	37.7	217	63.4	594	35.8		94.0	953			372	61.0
" 21											116.0			807			345	57.2
" 23					745	352	52.6			352	15.8		95.8	745	266			64.2
" 24					565	445	21.2			445	34.1		92.4	565	374			51.5
" 27		972	291	70.2	972	612	36.7	291	52.5	612	113.0		81.5	972	550			43.4
" 31	Chem. Feed to 50 p.p.m.	928	343	63.0	928	652	29.8	343	47.4	652	29.9		95.5	928		387		58.3
June 1					1090	717	34.2			717	75.8		89.5	1090		484		55.5
" 6	Activ. Plant at 4 ft^3/gal.	960	133	86.2	960	357	62.8	133	62.7	357	67.4		81.1	960		345		64.1
" 7					851	549	35.5							851		465		45.4
" 9										514	44.7		91.4					
" 10	25 p.p.m $FeCl_3$ 5 " $NaAlO_2$	861	101	88.2	861	592	31.0	101	83.0	592	101.3		83.0	861	445			48.3
" 16	Chem. Effl = Act. Pl. Infl	422	76	81.8	422	340	19.3	76	77.5	326	23.0		93.0	422	326			22.6
" 17		548	180	67.2	548	438	20.1	180	59.0	287	116.0		59.6	548	287			47.6
" 20		594	36	93.9	594	343	42.3	36	89.5	237	50.9		78.5	594	237			60.0
" 21	N. Clarifier Chlorinated				595	332	44.2											
" 23		586	84	85.8	586	479	18.1	84	82.7	485	21.5		95.5					
" 24		1003	57	94.2	1003	571	43.0	57	90.0	590	45.0		92.5					
" 27		584	65	89.0	584	405	30.7	65	84.0	269	10.0		96.2	584	269			53.9
" 30		674	33	95.0	674	443	34.3	33	92.4	296	28.2		90.4	674	296			56.1
July 1	Changed to Dry Feed	617	108	82.4	617	553	10.2	108	80.5	467	33.3		92.9	617		No Chem.	467	24.2
" 5		927	143	84.6	927	600	35.3	143	76.1	534	39.1		92.8	927			534	41.3
" 6		520	176	66.2						632	88.1		86.0					
" 9					1064	684	35.7									Aeration Tower Infl.	Effl.	% Red.
" 12	Clar. Infl. = Aer. Infl.	871	111	87.3	871	466	46.5	111	76.1	466	15.6		96.6					
" 14	Aer. Tower Started	820	82	90.0	820	520	36.6	82	84.0	520	11.7		97.6			820	372	54.6
" 15		940	115	87.8	940	585	37.8	115	80.4	585	12.0		98.0			940	550	41.5
" 19	N. Clarif. Cut out	740	166	77.6	740	627	15.3	166	73.4	627	34.7		94.2			740	522	29.5
" 21		724	63	91.3	724	565	22.0	63	88.8	565	25.0		95.7			724	352	51.3
" 22		584	45	92.3	584	437	25.0	45	89.8	437	5.0		98.8			584	417	28.5
" 25		599	58	90.4	599	362	39.6	58	83.9	362	118.0		67.5			599	275	54.2
" 26		693	130	81.3	693	650	6.3	130	80.0	650	55.0		91.6			693	457	34.1
" 29		610	90	85.2				90	86.7	675	21.6		96.7			610	405	33.6
August 3		1025	178	82.7	1025	765	35.1	178	76.8							1025	475	53.6
" 5	Aer. Tank Deepened	671	48	92.7														
" 9		700	91	89.9	700	550	21.4	91	83.3							700	230	67.2
" 11		467	54	88.4				54	87.9							467	210	55.0
" 13		443	70	84.4				70	83.6							443	212	52.2
" 15		690	88	87.3	690	590	14.5	88	85.1	590	39.0		93.4			690	352	48.9
" 16		927	119	87.1	927	787	15.1	119	84.8	787	55.0		93.0			927	510	45.0
" 18	Chem. Precip Again Started	813	62	92.4	813	575	29.3	62	89.1	575	133.0		76.9	970	507			47.6
" 22	Chem. Infl = Raw Pack. H.	955	85	91.1	955	682	28.5	85	87.5	682	45.0		93.4	1125	490			56.5
" 23		1022	94	90.7	1022	762	25.4	94	87.6	762	128.0		83.1	1175	480			59.1
" 25		753	75	90.0	753	622	17.4	75	87.9	622	105.0		83.1	915	477			47.8
" 29	Filter Effl. = Aer. Infl.	634	71	88.8	634	560	11.7	71	87.4	71		23.0	67.6	895	370			58.7
" 30		943	219	76.8				219	72.7	219		41.0	81.3					
Sept. 2		803	66	91.9	803	747	7.0	66	91.2	66		24.0	63.9	800	505			36.9
" 6	Chem. Feed to 50 p.p.m.	1010	234	76.8	1010	817	19.1	234	71.3	234		78.0	66.6	1440		823		42.9
" 8														920		475		48.5
" 9		860	138	83.9	860	775	9.9	138	82.2	138		30.0	78.3	1215		725		40.3
" 12		720	71	90.1	720	487	32.4	71	85.4					940		507		45.9
" 13	No Chem. Added	605	38	93.7				38	93.6					725		No Chem.	557	23.2
" 14	Dom. Sew. By-passed	1080	77	92.7	1080	827	23.4	77	90.5					1060			727	31.4
" 15	Do	1000	39	96.1	1000	670	33.0	39	94.2					1000			660	34.0
" 16		955	82	91.4	955	637	33.3	82	87.0					890			607	31.8
" 19	Domestic Sew. only	417	53	87.2	417	137	67.2	53	61.0					960				
" 23										122		38.0	68.9			494		48.6
" 26	Split Flow	443	25	94.3	443	303	31.6	25	91.8									
" 27		667	115	82.7	667	560	16.1	115	61.6	115		16.0	86.0					
Oct. 1		757	230	69.5	757	567	25.0	230	59.4	230		31.0	87.4					
" 3		569	56	90.2	569	390	31.4	56	85.6	56		13.0	77.6					
" 8		653	121	81.5	653	560	14.3	121	78.2	121		25.5	79.0					
" 10		761	158	79.3	761	452	40.6	158	66.5	158		30.0	81.1					

20 degrees centigrade. By determining the amount of oxygen remaining in the dilution water at the end of the 5 day period and multiplying that value by the proper dilution factor the 5 day Bio-Chemical Oxygen Demand of the composite sample was obtained.

Table No. 11 of part 2 is a record of the daily B.O.D. reductions through every unit of the main treatment plant and experimental plants.

The percent reduction in the organic strength or the B.O.D. value of a sewage as it passes through a treatment unit is obtained by multiplying the difference in the influent and effluent B.O.D. values of the sewage by 100 and dividing by the influent value. By this procedure the efficiency of a particular treatment unit in reducing the organic strength of a sewage may be found.

2. Suspended Solids Determinations

Suspended solids in sewage or industrial wastes are the visible solid particles in the sewage as contrasted to the dissolved material which is not visible. Under the influence of gravity a large portion of these solid particles will settle out when the sewage is subjected to quiescent conditions. The remaining suspended solids that have a specific gravity value very close to unity do not settle readily, but tend to remain in colloidal suspension.

The purpose of a sedimentation or settling tank in the treatment of a sewage is to allow the heavier suspended solids to settle out by reducing the velocity of the sewage passing through the tank to a small value. The efficiency of a sedimentation unit in reducing the suspended solids in sewage may be found in the following manner: "Suspended solids" values of representative samples of the influent and effluent are determined by gravimetric chemical analysis. The difference in the influent and effluent values gives the reduction through the unit. By multiplying this difference by 100 and dividing by the influent value the per cent reduction of suspended solids through the unit is obtained.

Table No. 12, "Suspended Solids in parts per million for various units of the Sioux Falls Sewage Treatment and Experimental Plant" gives the daily "Suspended Solids" reductions through each unit of the Main Plant and Experimental Plant for the entire experimental period.

The determination of Suspended Solids by the "Gooch Crucible Method" as given on page 26 of Standard Methods for the examination of Water and Sewage", 6th Edition (Published by the American Public Health Association) was followed at the Sioux Falls Experimental Plant.

3. Other Control Tests.

Other tests conducted during the experimental period included the hydrogen ion concentration or pH test to determine the acidity or alkalinity of a sewage or sludge, the dissolved oxygen test to determine the amount of dissolved oxygen in a treatment effluent and the Imhoff cone "settleable solids" test.

Valuable control information was obtained in the operation of the Activated Sludge Unit by catching a sample of the aeration tank effluent in a graduated cylinder and observing the action, color appearance, and time of settling of the sludge.

C. OPERATION OF THE MAIN PLANT

DURING THE EXPERIMENTAL PERIOD

1. Averages Computed from Daily Records

During the operation of the Experimental Units enough B.O.D. and "Suspended Solids" data were collected on the operation of the Main Treatment Plant so the writers could correlate that data with the experimental plant results. Columns 1 to 8 inclusive of Table No. 11 (Bio-Chemical Oxygen Demand Tests) and Table No. 12 (Suspended Solids Determinations) deal with daily tests of the various units of the main plant. Table No. 13 consists of computed average "B.O.D.". and "Suspended Solids" values taken from Tables 11 and 12 for various periods during the operation of the experimental plant. Data for charts 1 to 7 inclusive have been taken directly from Table 13

2. Bio-Chemical oxygen Demand Reductions

Chart No. 1 shows the Bio-Chemical Oxygen reductions of raw mixed sewage (mixed packing house and domestic) through the present plant. The raw mixed sewage enters the clarifiers with a B.O.D. strength of 791 parts per million. The clarifiers reduce the strength 32.9% to 531 P.P.M. which is the sewage strength as it is dosed on the sprinkling filters. The 77.5% reduction through the filters further reduces the B.O.D. strength of the final effluent to 132 P.P.M. considering the main plant as one unit, the 83.3% plant efficiency compares favorably with the efficiencies of other plants of this type. The average efficiency of 13 similar plants taken from bulletin 23 of the Illinois Water Survey was 83.8%.

															760		142		81.2
"	9		336	126	62.5	336	196	41.7	126	35.7	126		129		822		232		71.8
"	12		436	126	71.2	436	254	41.8	126	50.4	126		132		705		144		77.6
"	13	No Chem. Added	522	98	81.2	522	175	66.5	98	44.0	98		100		360			(154	57.2
"	14	Dom. Sew. By-passed	756	70	90.7	756	234	68.1	70	70.0					506	Plain Sed		138	72.7
"	15	"	766	124	83.9	766	214	72.1	124	42.0					686	No Chem		194	71.8
"	16	"	732	24	96.7	732	294	59.8	24	91.9					781	added.		248	68.2
"	19	Dom. Sew.	418	110	73.7	418	76	81.7											
"	20	"				378	34	91.0							870		176		79.8
"	26	Split Flow	692	188	72.8	692	238	65.7	188	21.0									
"	27	" "	576	148	74.3	576	298	48.3	148	50.4									
"	29	" "	478	96	80.0	478	168	64.9	96	42.8	96		24	75.0	912	176			80.7
"	30	" "	526	96	81.8	526	210	60.2	96	54.3	96		48	50.0	1488	256			82.8
Oct.	1	" "	456	80	82.5	456	160	65.0	80	50.0	80		32	60.0	1024	168			83.5
"	3	" "	602	72	88.0	602	154	74.4	72	53.2	72		16	77.8					
"	7	" "	486	80	83.6	486	176	63.8	80	54.5	80		40	50.0					
"	8	" "	480	56	88.5	480	168	65.0	56	66.7	56		8	75.8					
"	10	" "	696	112	83.9	696	208	70.1	112	46.1	112		56	50.0					
"	14	" "	526	88	83.3	526	212	59.8	88	58.5	88		48	45.4					
"	15	" "	600	120	80.0	600	196	67.4	120	38.7	120		64	46.7					
"	17	" "	606	136	77.6	606	240	60.4	136	43.3	136		40	70.5	~Pre-Aeration			Clarifier~	
"	21	" "	464	88	81.0	464	244	47.4	88	63.9	88		24	72.7	Infl.	30 mi.	% Red.	3 hrs.	% Red.
"	29	Pre-Aerat. Clarifier									1216		152	87.5	1216	376	69.0		
"	31	Pre-Aer. Inf. = Raw Pack. H									1104		144	87.0	1104	456	58.7		
Nov.	4										1120		184	83.5	1120	464	58.6		
"	5										1104		192	82.6	1104	616	44.2		
"	7					912	316	65.4							912	416	54.3		
"	10					512	264	48.4							512	328	35.9	244	52.3
"	11					1016	520	48.8							1016	472	53.6	344	66.2
"	12	Split Flow	672	112	83.3	672	388	42.2	112	71.1					796	432	45.7	304	61.8
"	14	" "	704	128	81.8	704	288	59.1	128	55.6					808	652	19.3	404	50.0
"	17	" "				832	604	27.4							832	464	44.2	448	46.2
"	18	" "				944	840	11.1							944	592	37.3	452	52.1
"	21	" "				1152	628	45.4							1212	472	61.0	748	38.3
"	25	" "	568	120	788	568	232	59.2	120	48.3					768	296	61.4	352	54.1
"	26	" "				1120	464	58.6							1104	344	68.9	312	71.7
"	30	" "				1072	508	52.6							1104			296	73.1
Dec.	2	" "				976	400	59.0							1072			256	76.2
"	3	" "				1440	528	63.4							1376			360	73.8
"	5	" "	864	224	74.1	864	368	57.4	224	39.1					1024			296	71.0

TABLE NO. 12

Suspended Solids (in p.p.m.) for Various Units of the Sioux Falls Sewage Treatment and Experimental Plant

Spring + Summer of 1932	Miscellaneous ----- Notes	Main Plant			Dorr Clarifiers			Filter		Activated Sludge Plant				Chemical Precipitation Plant				
		Infl.	Effl.	%Red	Infl.	Effl.	%Red	Effl.	%Red	Infl.	Effluent Air 3-4 ft^3/gal.	Effluent Air 3/4 ft^3/gal.	%Red	Infl.	Effluent FeCl$_3$ 25 p.p.m.	Effluent FeCl$_3$ 50 p.p.m.	Effluent FeCl$_3$ 35 p.p.m.	%Red.
Column	Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
May 2	Chem. Infl. = Clar. Effl.	854	226	73.7	854	410	52.0	226	44.9					361			336	6.9
" 4														275			76	72.0
" 5														376			334	11.3
" 7														342			140	59.1
" 9														406			212	47.8
" 11														322			126	60.9
" 12														422			204	51.7
" 14														406			104	74.5
" 16														598			222	62.9
" 19	Chem. Infl. = Raw Mix. Sew													905			258	71.5
" 20														260			112	57.0
" 23	Chem. Feed to 25 p.p.m.													554	140			74.8
" 24														598	150			75.0
" 25					598	304	49.2											
" 26	Aer. Infl. = Clarif. Effl.				816	424	48.1			424	320		24.5	816	194			76.2
" 27					472	234	50.4			234	102		56.5	472	200			57.6
" 31	Chem. Feed to 50 p.p.m.				554	224	59.6			224	84		62.5	554		122		78.1
June 1														698		136		80.5
" 6					544	88	83.8							544		310		43.0
" 10	Chem. Feed 25 FeCl$_3$ and				684	244	65.2			244	78		68.1	684	88			87.2
" 13	5 Na$_3$AlO$_3$				550	146	73.5							550	105			80.9
" 16	Chem. Effl. = Activ. Infl.	616	200	67.5	616	412	33.1	200	51.4	194	116		40.0	616	194			68.5
" 17		513	162	68.4	513	432	15.1	162	62.5	116	35		69.8	513	116			77.4
" 20		778	236	69.8	778	404	48.1	236	41.6	87	38		56.3	778	87			88.9
" 23		738	210	71.5	738	374	49.4	210	43.9	304	126		58.6					
" 24		386	222	42.5				222	55.1	578	54		90.6					
" 27		386	163	57.8	386	178	53.9	163	8.4	204	134		34.3	386	204			47.2
" 30		504	126	75.0	504	181	64.2	126	30.2					504	116			77.0
July 1	Changed to Dry Feed	436	74	83.2	436	265	39.2	74	72.1	156	48		69.3	436	Plain Sedimentation. No Chemical added		156	64.2
" 5		581	236	59.4	581	254	56.3	236	7.1	184	72		60.9	581			184	68.4
" 6		480	182	62.1	480	175	63.5							480			286	54.7
" 7		632	88	86.1	632	298	52.9	88	70.5	286	230		19.6	632			150	68.8
" 8					600	312	48.0								~Aeration Tower~			
" 11					518	223	56.9								Infl.	Effl.	%Red.	
" 14	Aer. Tower Started	532	135	74.6	532	300	41.8	135	55.0	300	268		9.4		532	214	59.8	
" 15	Aer. Infl. = Clar. Infl.	522	184	64.8	522	224	57.4	184	17.9						522	236	54.8	
" 18		568	214	62.3	568	224	60.6	214	4.5	224	160		28.6		568	230	52.3	
" 19	N. Clarif. Cut Out	482	152	68.5	482	256	46.9	152	40.6	256	156		39.1		482	230	52.3	
" 21		476	184	61.4	476	196	58.9	184	6.1	196	140		28.6		476	128	73.2	
" 22		382	220	42.4	382	188	50.8			188	128		31.9		382	182	52.4	
" 25		438	144	67.2	438	242	44.8	144	40.5						438	194	55.7	
" 26		406	150	63.2	406	180	55.6	150	16.7						406	162	60.2	
" 28		420	124	70.5	420	224	46.7	124	44.6	224	4		97.4		420	226	46.2	
" 29		444	106	76.1	444	222	50.0	106	52.3	222	196		11.7		444	166	62.7	
August 1		542	226	58.3	542	278	48.7	226	18.7						542	224	58.7	
" 5	Aer. Tank Deepened	462	196	57.5	462	230	50.2	196	14.8									
" 9		596	62	89.7	596	132	77.9	62	53.0						596	208	65.2	
" 11		412	98	76.2	412	187	54.6	98	47.6						412	196	52.4	
" 12		476	62	87.0	476	241	49.4	62	74.3						476	190	60.1	
" 15		458	98	78.6	458	214	53.4	98	54.2	214	90		58.0		458	232	49.4	
" 16		460	166	63.9	460	202	56.1	166	17.8	202	128		36.6		460	208	54.9	
" 18	Chem. Plant Again Started	492	120	75.6	492	252	48.8	120	52.4	252	202		19.9	694	164			76.4
" 22	Chem. Infl. = Raw Pack. H.	392	100	74.5	392	108	72.5	100	8.0					308	132			57.2
" 23		438	113	74.2	438	182	58.5	113	37.9	182	120		34.1	424	116			72.7
" 25		488	197	59.8	488	250	48.9	197	21.2					436	124			71.6
" 29	Filt. Effl. = Aer. Infl.	494	154	68.7	494	183	62.9	154	15.9					532	156			70.6
" 30		480	156	67.5	480	242	49.6	156	35.5					488	182			62.7
Sept. 1														618	168			72.8
" 2		359	156	56.5	359	236	34.2	156	33.9	156		170	Neg.	802	210			73.8
" 6	Chem. Feed 50 p.p.m.													982		248		74.7
" 7		579	98	83.1	579	262	54.7	98	62.3	98		120	"	740		164		77.8
" 8														760		142		81.2
" 9		336	126	62.5	336	196	41.7	126	35.7	126		129	"	822		232		71.8
" 12		436	126	71.2	436	254	41.8	126	50.4	126		132	"	705		144		77.6
" 13	No Chem. Added	522	98	81.2	522	175	66.5	98	44.0	98		100	"	360	Plain Sed No Chem. added.		154	57.2
" 14	Dom. Sew. By-passed	756	70	90.7	756	234	68.1	70	70.0					506			138	72.7
" 15	"	766	124	83.9	766	214	72.1	124	42.0					686			194	71.8
" 16	"	732	24	96.7	732	294	59.8	24	91.9					781			248	68.2
" 19	Dom. Sew.	418	110	73.7	418	76	81.7											
" 20	"				378	34	91.0							870		176		79.8
" 26	Split Flow	692	188	72.8	692	238	65.7	188	21.0									
" 27	" "	576	148	74.3	576	298	48.3	148	50.4									
" 29	" "	478	96	80.0	478	168	64.9	96	42.8	96		24	75.0	912	176			80.7
" 30	" "	526	96	81.8	526	210	60.2	96	54.3	96		48	50.0	1488	256			82.8
Oct. 1	" "	456	80	82.5	456	160	65.0	80	50.0	80		32	60.0	1024	168			83.5
" 3	" "	602	72	88.0	602	154	74.4	72	53.2	72		16	77.8					
" 7	" "	486	80	83.6	486	176	63.8	80	54.5	80		40	50.0					
" 8	" "	480	56	88.5	480	168	65.0	56	66.7	56		8	75.8					
" 10	" "	696	112	83.9	696	208	70.1	112	46.1	112		56	50.0					
" 14	" "	526	88	83.3	526	212	59.8	88	58.5	88		48	45.4					
" 15	" "	600	120	80.0	600	196	67.4	120	38.7	120		64	46.7					
" 17	" "	606	136	77.6	606	240	60.4	136	43.3	136		40	70.5	~Pre-Aeration Clarifier~				
" 21	" "	464	88	81.0	464	244	47.4	88	63.9	88		24	72.7	Infl.	30 mi.	%Red.	3 hrs.	%Red.
" 29	Pre-Aerat. Clarifier									1216		152	87.5	1216	376	69.0		
" 31	Pre-Aer. Inf = Raw Pack. H.									1104		144	87.0	1104	456	58.7		
Nov. 4										1120		184	83.5	1120	464	58.6		
" 5										1104		192	82.6	1104	616	44.2		
" 7					912	316	65.4							912	416	54.3		
" 10					512	264	48.4							512	328	35.9	244	52.3
" 11					1016	520	48.8							1016	472	53.6	344	66.2
" 12	Split Flow	672	112	83.3	672	388	42.2	112	71.1					796	432	45.7	304	61.8
" 14	" "	704	128	81.8	704	288	59.1	128	55.6					808	652	19.3	404	50.0
" 17	" "				832	604	27.4							832	464	44.2	448	46.2
" 18	" "				944	840	11.1							944	592	37.3	452	52.1
" 21	" "				1152	628	45.4							1212	472	61.0	748	38.3
" 25	" "	568	120	788	568	232	59.2	120	48.3					768	296	61.4	352	54.1
" 26	" "				1120	464	58.6							1104	344	68.9	312	71.7
" 30	" "				1072	508	52.6							1104			296	73.1
Dec. 2	" "				976	400	59.0							1072			256	76.2
" 3	" "				1440	528	63.4							1376			360	73.8
" 5	" "	864	224	74.1	864	368	57.4	224	39.1					1024			296	71.0

TABLE 13

B.O.D. AND SUSPENDED SOLIDS REDUCTIONS THROUGH THE MAIN TREATMENT PLANT

SIOUX FALLS SEWAGE TREATMENT PLANT
-1932-

Averages computed from Tables 11 and 12

Treatment Unit	Influent	Period Dates Inclusive	Biochemical Oxygen Demand			Suspended Solids		
			Ave. Inf.	Ave. Eff.	% Reduct.	Ave. Inf.	Ave. Eff.	% Reduct.
Total Plant Columns 1,2,3, of Tables 11 and 12	Raw Mixed Sewage	May 25 to Sept.19	791	132	83.3	522	142	72.8
	Separate Sedimentation Pack. House Waste thru S. Clarifier Domestic thru N. Clar.	Sept.26 to Dec. 5	690	196	71.6	587	114	80.6
Dorr Clarifiers Columns 4,5,6, of Tables 11 and 12	Raw Mixed Sewage	May 25 to Sept.19	791	531	32.9	522	232	55.5
	Pack. House Waste	Sept.14 to Dec. 5	1168	768	34.3	798	365	54.3
	Raw Domestic	Sept.19 to Dec.5	459	219	52.3	480	115	76.0
Trickling Filter Columns 7,8, of Tables 11 and 12	Normal Clarifier Effluent	June 16 to Sept. 16	536	132	75.4	232	142	38.8
	Separate Sedimentation Pack.House thru S.Clar. Domestic thru N.Clar.	Sept 26 to Dec.5	609	196	67.9	232	114	50.9

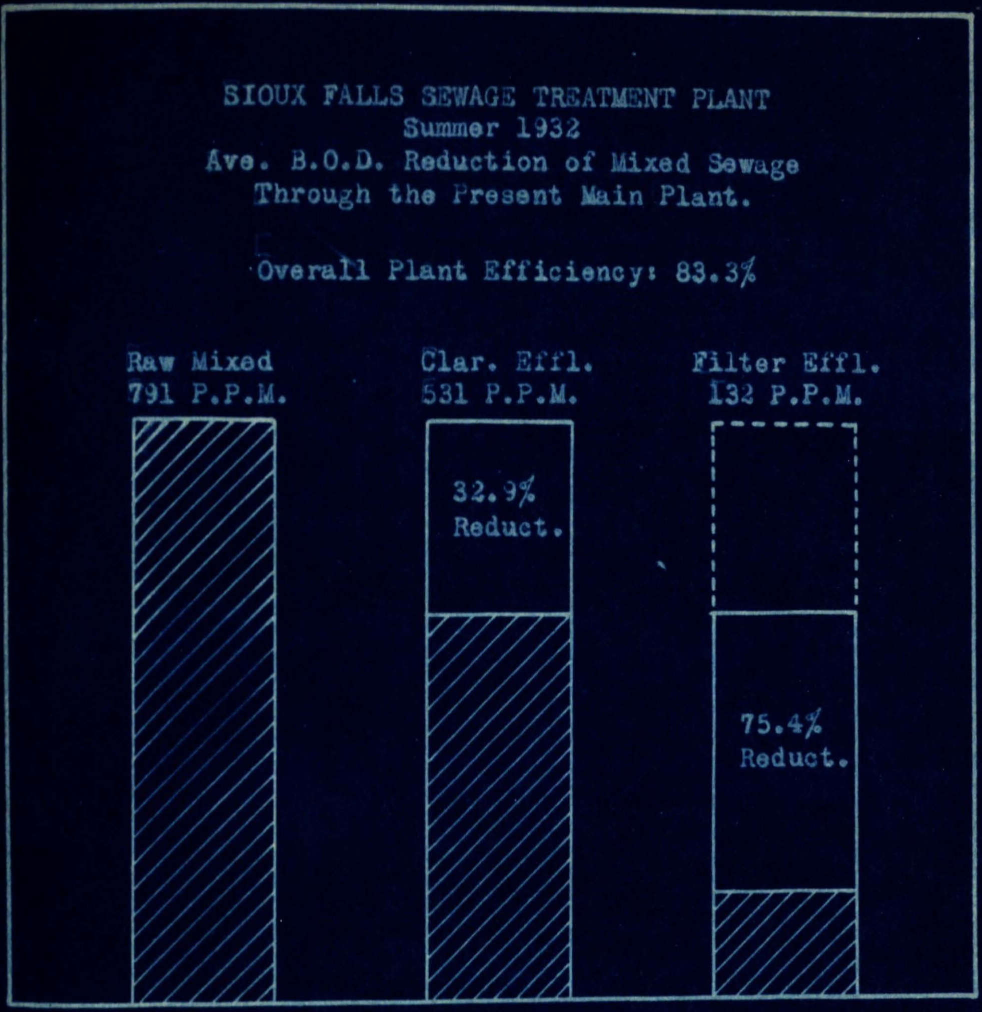
However, due to the effect of the packing house waste the organic strength of the filter effluent is still too high, approaching the strength of average raw domestic sewage. The relatively small amount of dilution water available in the Sioux River, in which the filter effluent is discharged, is depleted of dissolved oxygen and nuisance conditions exist for several miles below the Treatment Plant during low flow conditions of the river (page 32). During the summer of 1931 the sewage flow from the Treatment Plant was two and one half times greater than the river flow about the plant (page 33).

3. "Suspended Solids" Reductions

The average "Suspended Solids" reduction of the raw mixed sewage for the same period as above is shown on Chart No. 2. The 55.3% reduction of "Suspended Solids" through the clarifiers indicates that the remaining 44.7% of the original " Suspended Solids" present in the raw mixed sewage is dosed onto the filter beds. This results in a gradual clogging of the filters with suspended solids. The gradual clogging necessitated the machanical cleaning of the entire filter bed during the spring of 1932 at a cost of $10,000. One of the main objectives of the experimental work was to find, if possible, some economical method of reducing the load of suspended solids going over onto the filters.

4. Separate Sedimentation Results

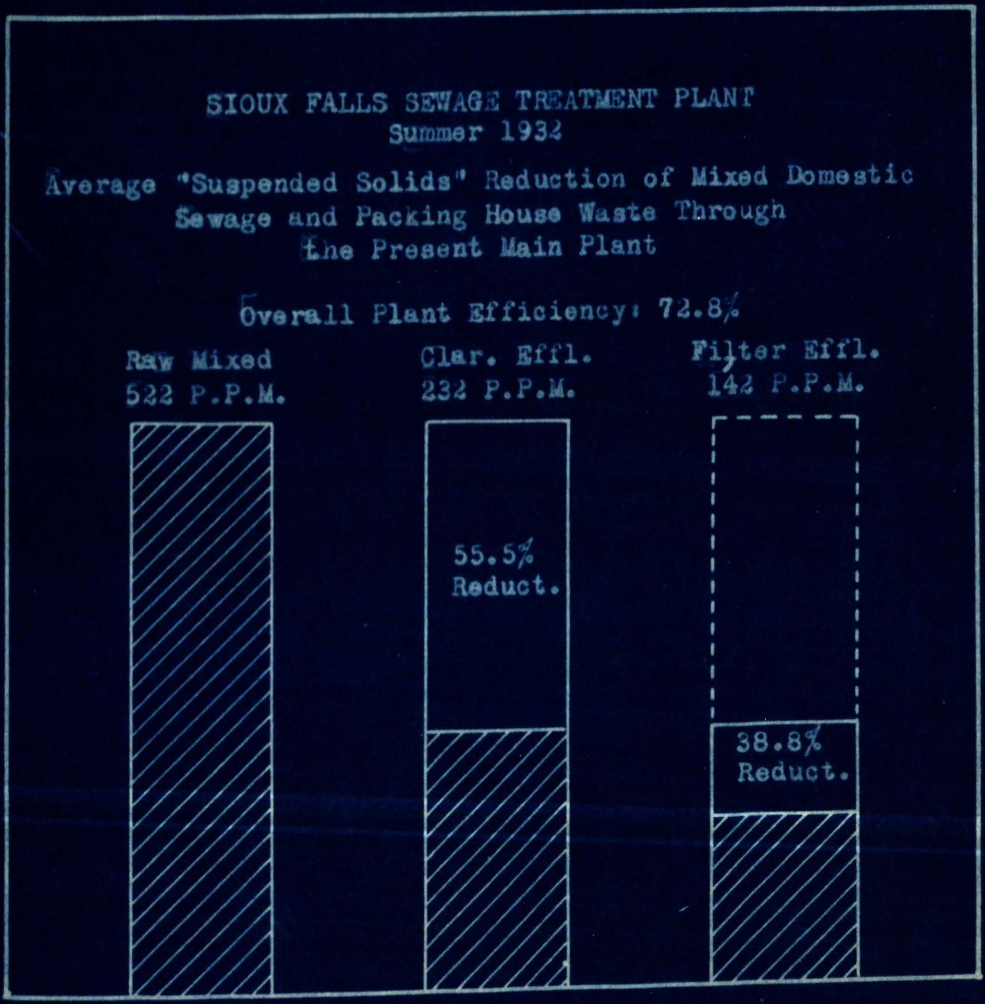
In the normal operation of the Sioux Falls treatment plant the domestic sewage from the city and the waste from the packing house are mixed in the influent channel leading to the two clarifiers. Thus the flow through the clarifiers consists of approximately equal volumes of



SIOUX FALLS SEWAGE TREATMENT PLANT
Summer 1932
Ave. B.O.D. Reduction of Mixed Sewage
Through the Present Main Plant.

Overall Plant Efficiency: 83.3%

CHART
NO. 1



SIOUX FALLS SEWAGE TREATMENT PLANT
Summer 1932

Average "Suspended Solids" Reduction of Mixed Domestic
Sewage and Packing House Waste Through
the Present Main Plant

Overall Plant Efficiency: 72.8%

CHART
NO. 2

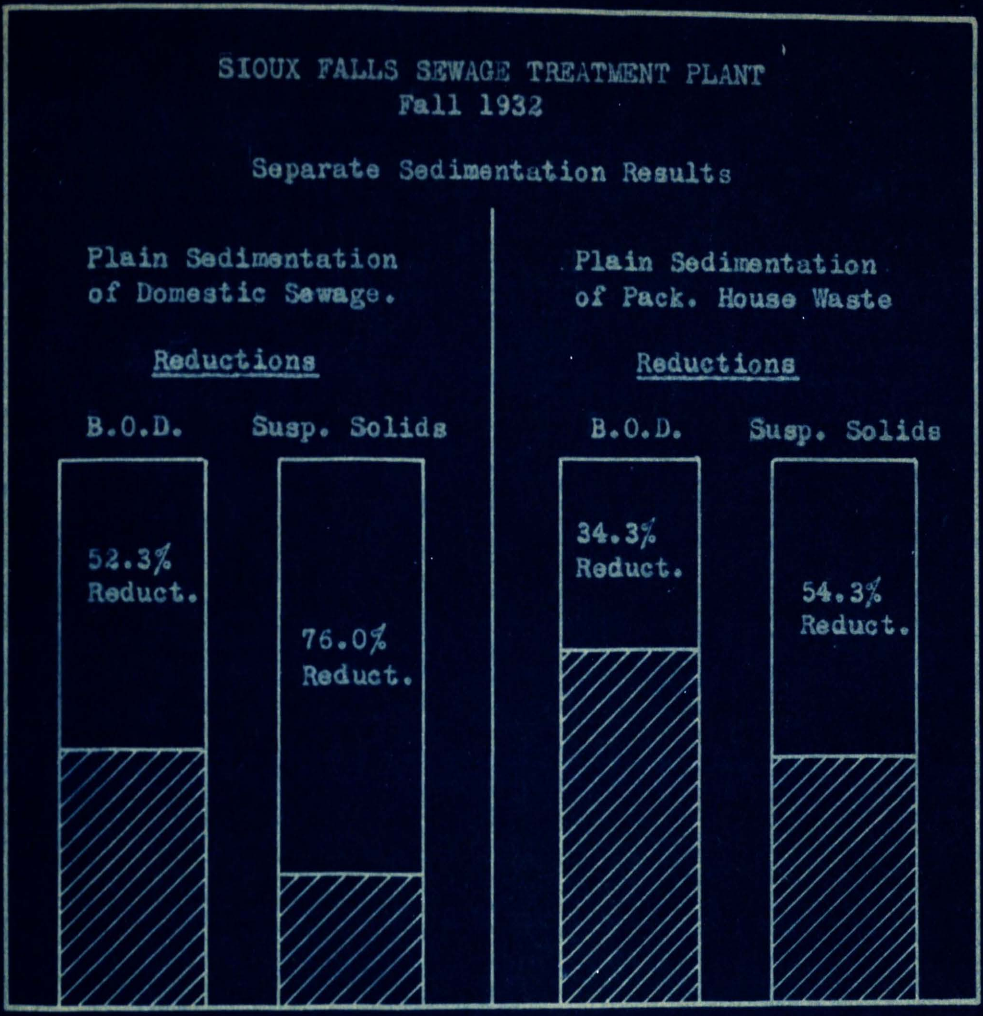
mixed domestic sewage and packing house waste. By placing a wood diaphragm wall in the influent channel, the packing house waste was kept separate from the domestic sewage and diverted through the south clarifier, while the domestic sewage flowed through the north clarifier. Separate sedimentation or split flow studies of each type of waste could then be made.

Chart No. 3 shows the plain sedimentation of domestic sewage compared with the plain sedimentation of the packing house waste. The B.O.D. reduction of domestic sewage by sedimentation was 52.3%; the suspended solids reduction 76.0%. The B.O.D. reduction of the packing house waste 34.3%; the reduction in the suspended solids 54.3%. It must be kept in mind in this comparison that the packing house waste receives preliminary treatment at the packing plant consisting of fine screening, 30 minutes of sedimentation and grease removal before it enters the city treatment plant.[1]

Using the above figures, an interesting comparison of the B.O.D. strength and "suspended solids" content of the two wastes can be made. Chart No. 4 compares the two wastes before sedimentation in the clarifiers. The packing house waste with a B.O.D. strength of 1168 P.P.M. is 1168 ÷ 459 or 2.54 times stronger than the domestic sewage while the suspended solid content is 798 ÷ 480 or 1.66 times greater than the domestic sewage. Chart No. 5 indicates their relative strengths after sedimentation, thus showing a comparison of the two wastes as they are dosed onto the filters. The B.O.D. strength of the settled packing house waste compared to settled domestic is now the ratio of 768 to 219 or 3.5 times stronger than the settled domestic sewage. The suspended solids content of the settled

---

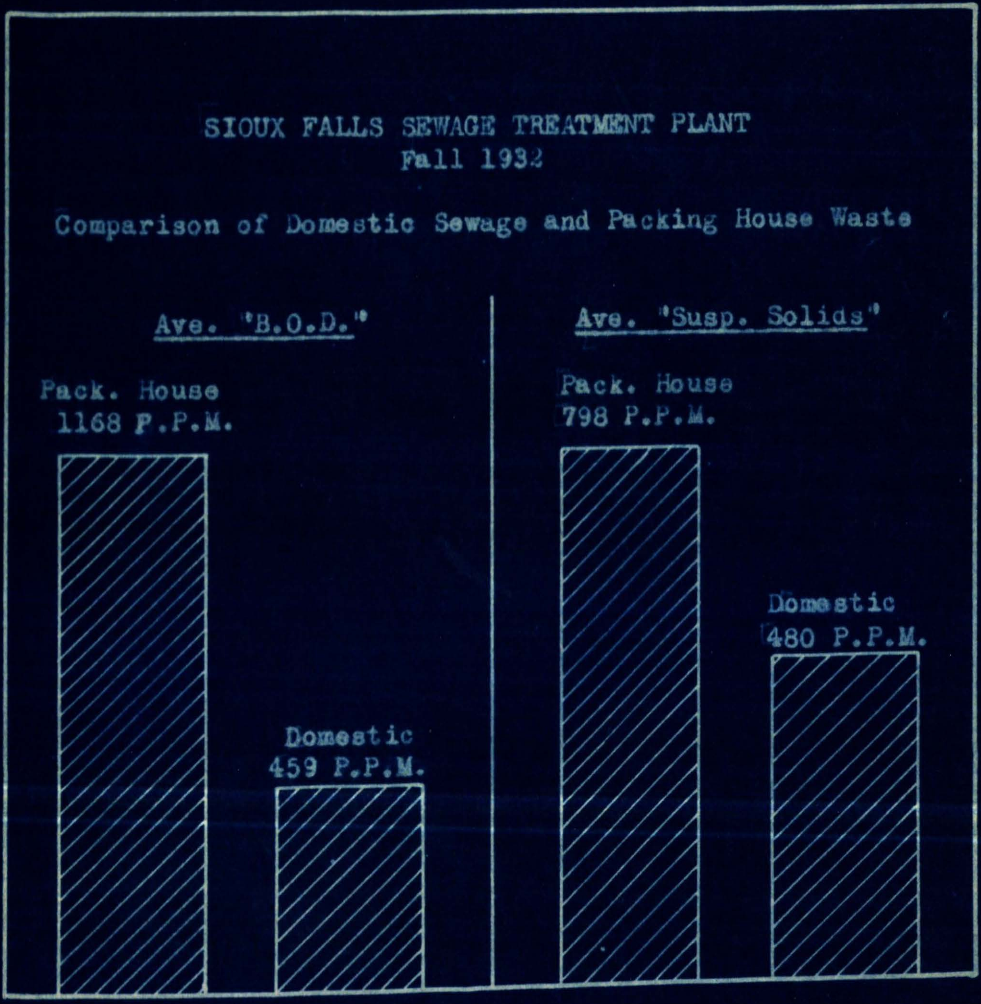
[1] The term, Packing House Waste, as used in this thesis refers only to the screened, settled waste from the John Morrell & Co., as received at the Sioux Falls Sewage Treatment Plant.



SIOUX FALLS SEWAGE TREATMENT PLANT
Fall 1932

Separate Sedimentation Results

CHART
NO. 3



SIOUX FALLS SEWAGE TREATMENT PLANT
Fall 1932

Comparison of Domestic Sewage and Packing House Waste

CHART
NO. 4

packing house waste is now 365 P.P.M. compared to 115 P.P.M. of the domestic sewage, or 365 divided by 115 or 3.17 times greater. Thus, roughly, two-thirds of the B.O.D. strength and three-fourths of the suspended solids load going over onto the filters are due to the packing house waste.

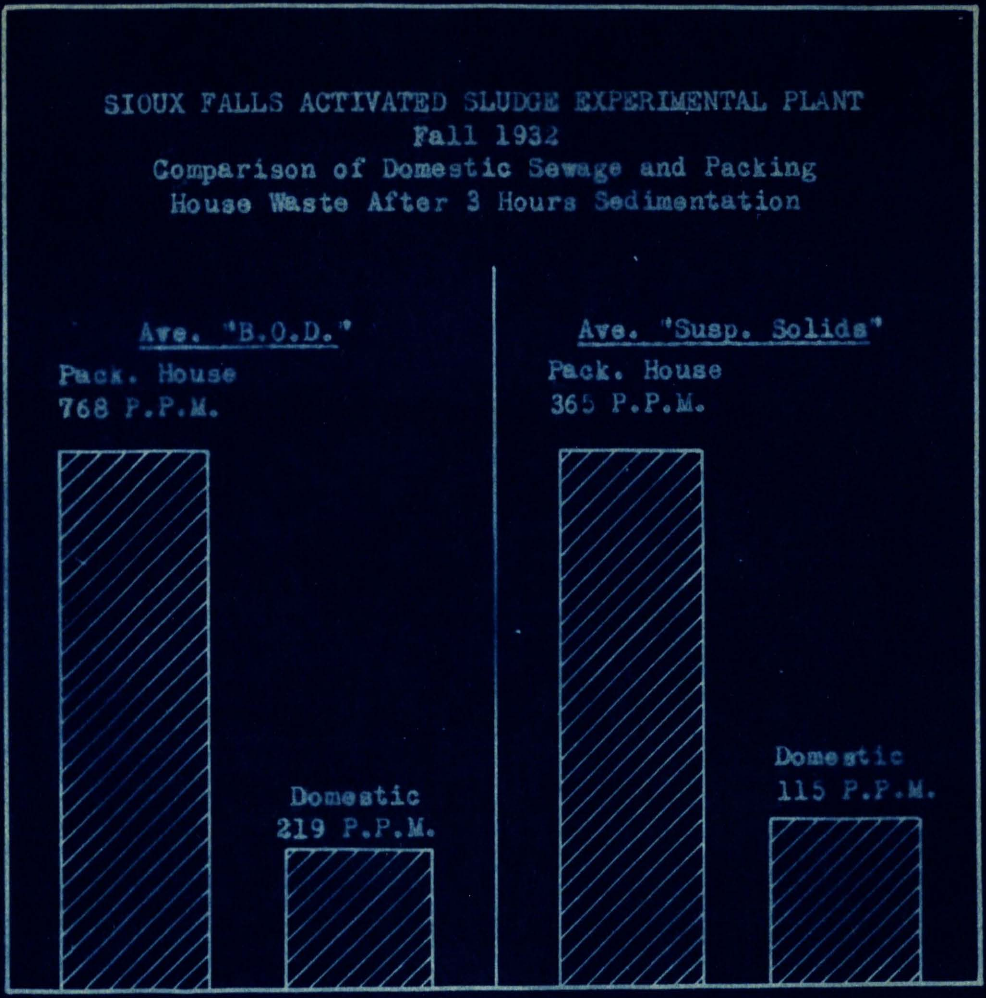
Another significant discovery was the fact that a better B.O.D. and "suspended solids" reduction took place with separate sedimentation of each waste as compared with the sedimentation of the mixed packing house waste and domestic sewage which was the normal procedure.

Referring to Chart No. 1, the B.O. D. reduction through the clarifier with mixed sedimentation was 32.9%. With separate sedimentation Chart No. 3 indicates that the packing house waste was reduced 34.3% while the domestic sewage reduction was 52.3%. Assuming equal amounts of each waste, which is approximately correct, the average reduction of both wastes would be the sum of 34.3% and 52.3% divided by 2, or 43.3%. This comparison is indicated graphically on Chart No. 6.

Chart No. 2 shows a 55.5% "suspended solids " reduction of mixed domestic sewage and packing house waste through the clarifiers. Chart No. 3 indicates that with separate sedimentation of each type of waste the Domestic sewage was reduced 76.0% while the packing house waste reduction was 54.3%. The average reduction of both wastes would then be 76.0% plus 54.3% divided by 2 or 65.1% as shown on Chart 7. This represents an increase in the "suspended solids" reduction of 65.1 - 55.3 or 9.8% due to keeping the two wastes separate through the clarifiers.

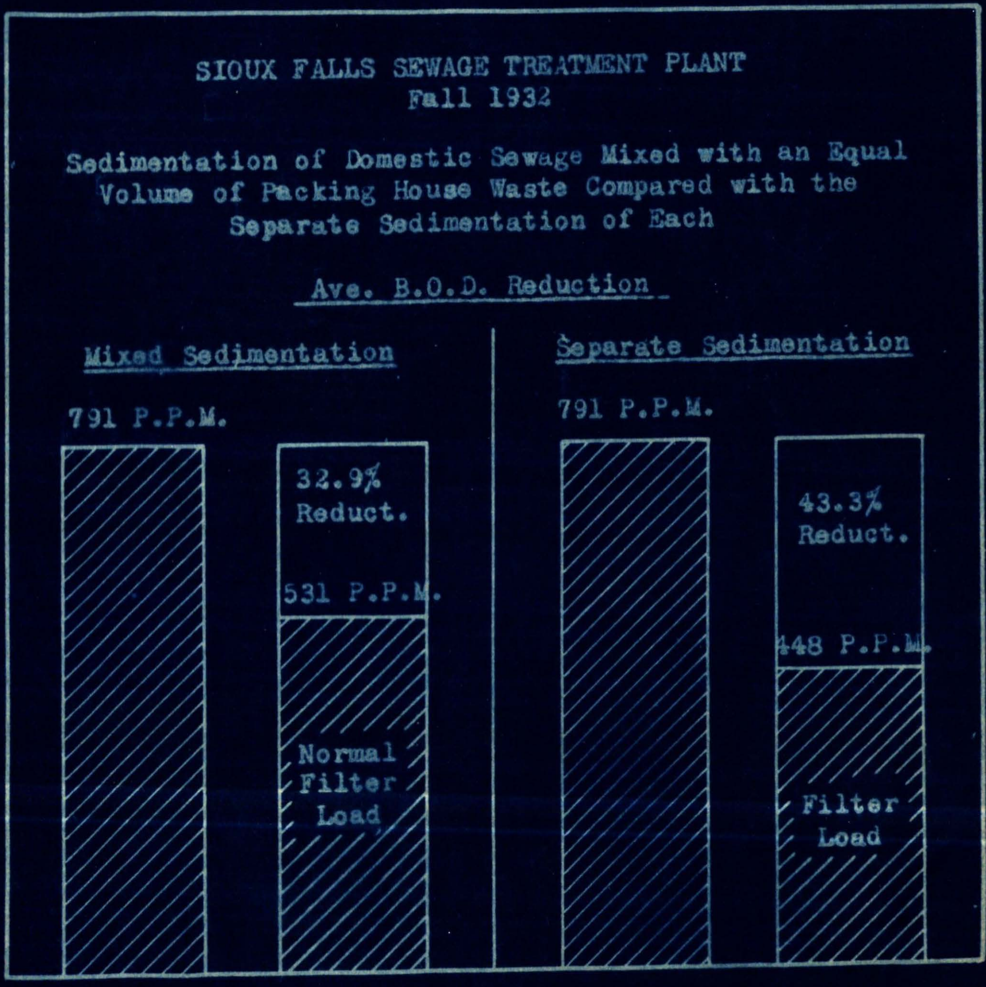
5. Decrease in filter load due to separate sedimentation

Chart No. 6 indicates that with mixed sedimentation the normal B.O.D. filter load is 531 P.P.M. Under separate sedimentation this load



SIOUX FALLS ACTIVATED SLUDGE EXPERIMENTAL PLANT
Fall 1932
Comparison of Domestic Sewage and Packing House Waste After 3 Hours Sedimentation

CHART
NO. 5



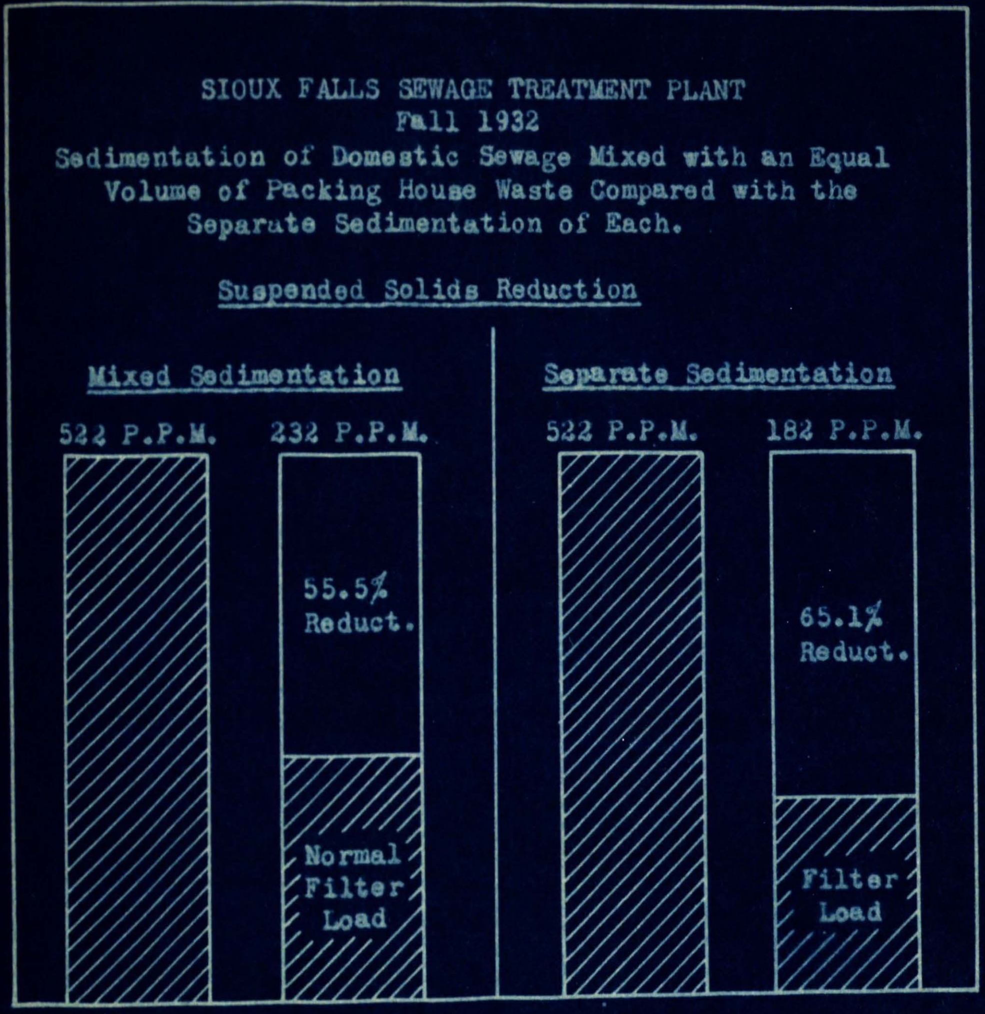
SIOUX FALLS SEWAGE TREATMENT PLANT
Fall 1932

Sedimentation of Domestic Sewage Mixed with an Equal Volume of Packing House Waste Compared with the Separate Sedimentation of Each

CHART
NO. 6

is reduced to 448 P.P.M. The represents a reduction in the normal B.O.D. filter load of (531 - 448) divided by 531 or 15.6%. The normal filter load of "Suspended Solids" as shown on Chart No. 7 is 232 P.P.M. Separate sedimentation reduces this load to 182 P.P.M. representing a percentage reduction of 232 - 182 divided by 232 or 21.5%.

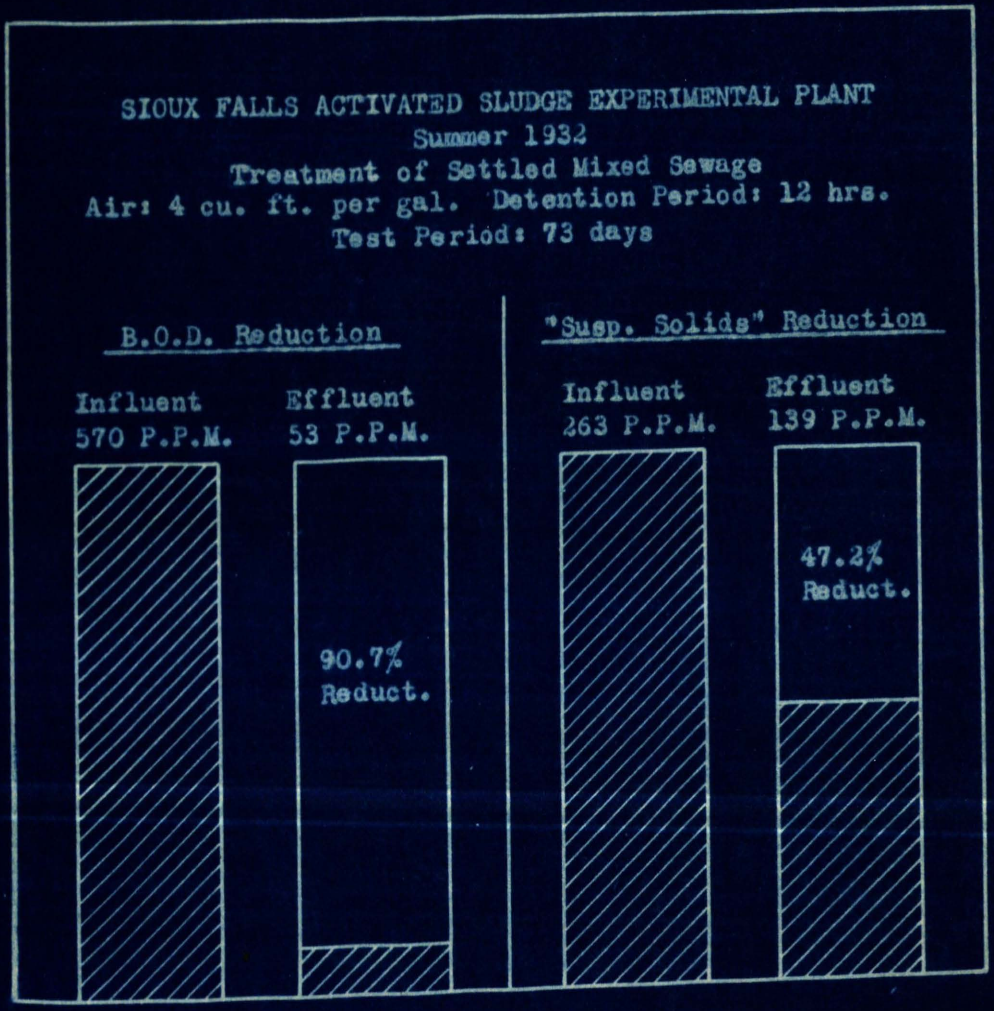
Thus, by an expenditure of some $20 in labor and material for the diaghragm wall the B.O.D. and "Suspended Solids" filter loads were reduced 15.6% and 21.5% respectively.



SIOUX FALLS SEWAGE TREATMENT PLANT
Fall 1932
Sedimentation of Domestic Sewage Mixed with an Equal Volume of Packing House Waste Compared with the Separate Sedimentation of Each.

Suspended Solids Reduction

CHART
NO. 7



SIOUX FALLS ACTIVATED SLUDGE EXPERIMENTAL PLANT
Summer 1932
Treatment of Settled Mixed Sewage
Air: 4 cu. ft. per gal. Detention Period: 12 hrs.
Test Period: 73 days

CHART
NO. 8

D. POSSIBILITIES OF SUPPLEMENTING THE TREATMENT OF THE PRESENT MAIN PLANT

In planning the methods of procedure in operating the Experimental Units at the Sioux Falls Sewage Treatment Plant with the limited amount of time and money that was available the two main objectives that had to be accomplished in supplementing the treatment of the present main plant were continually kept in mind. The two objectives were as follows: (1) To reduce the B.O.D. strength of the final effluent discharged into the Sioux River in order to correct nuisance conditions and to protect the riparian owners downstream. (2) To appreciably reduce the load of suspended solids discharged on to the filter beds in order to prevent their periodic clogging and the necessity of expensive mechanical cleaning.

Two types of treatment suggest themselves: (1) Activated sludge, (2) chemical precipitation. The several possibilities are as follows:

1. Pass all or a part of the clarifier effluent through an activated sludge plant before it is dosed onto the filters.

2. Chemical precipitation of the raw mixed sewage or of the clarifier effluent to secure better sedimentation of suspended solids in the clarifiers, thus reducing the load of suspended solids going onto the filters.

3. Treatment of the present filter effluent by the activated sludge process before discharging it into the river.

4. Keeping the packing house waste and domestic sewage flows separate through the clarifiers, treating the packing house waste only, with chemical to secure better precipitation of the packing house waste.

5. Combinations of the above possibilities.

For an activated sludge process to be economically feasible, cheap power must be available. Early in this investigation Mr. R. E. Bragstad called attention to the fact that enough excess sewage gas from the digestors was available to at least operate a 100 K.W. generator. Further investigation revealed that the present amount of excess gas would produce approximately 335 H.P. With the increased amount of sludge that would be available with an activated sludge plant, enough gas should be produced to furnish all the power necessary in the operation of an activated sludge plant.

E. RESULTS OF THE ACTIVATED SLUDGE EXPERIMENTAL UNIT

1. Operating Periods

The Activated Sludge Experimental Unit (Fig. 2) was started May 4, 1932 and operated with settled mixed sewage as influent until June 15. From June 16 until July 11 the effluent from the Chemical Precipitation Unit was used as Activated Sludge influent. From July 12 until Aug. 3 Clarifier effluent was again used as influent.

At this time the dimensions of the Aeration Tank were changed from 5 ft. wide, 5 ft. deep and 20 ft. long to 5 ft. wide, 10 ft. deep and 10 ft. long. It was thought that the air would be more effective if it were introduced 10 ft. below the surface of the sewage instead of 5 ft. Also since large activated sludge plant installations have a sewage depth of from 10 to 15 ft. over the porous plates, the operating conditions of the experimental unit with the deepened tank would be more comparable to a full size unit. However, no marked difference in operation or results was observed after deepening the Aeration Tank.

The Activated Sludge Unit with the altered aeration tank was again placed in operation Aug. 15 and operated until Aug. 25 with settled mixed sewage (clarifier effluent) as influent. From Aug. 26 until Oct. 17 the Activated Sludge Unit was operated with trickling filter effluent as aeration tank influent. After Oct. 17 the plant was operated somewhat intermittantly as a Pre-aeration Unit until Dec. 5, 1932.

2. Averages Computed from Daily Records

In Table No. 11 column 9 gives the daily B.O.D. value of the Activated Sludge influent, columns 10 and 11 the daily effluent value for air feeds of 3 to 4 cu. ft. per gallon and $\frac{3}{4}$ cu. ft. per gallon respectively, while column 12 gives the daily percentage B.O.D. reduction through the activated sludge unit. Likewise in Table No. 12 the daily "Suspended Solids" influent value is listed in column 9, the daily effluent value in columsn 10 and 11, and the daily percent reduction in column 12. Table No. 14 consists of averages computed from Tables 11 and 12 for the various test periods.

Charts No's. 8 and 9 are based upon data taken from Table No. 14.

3. Treatment of Settled Mixed Sewage with Activated Sludge.

Chart No. 8 shows the results obtained by treating clarifier effluent (settled mixed sewage) with Activated Sludge. Using 3 to 4 cubic feet of air per gallon of sewage with a 12 hour detention period the B.O. D. value of the influent was reduced 90.7% while the "Suspended Solids" value was reduced 47.2%. Inexperience on the part of the plant operators and some mechanical difficulties during the early part of the experimental period accounts for the low "Suspended Solids" reduction of 47.2%. This high "Suspended Solids" content of the final effluent was due largely to the fact that rising sludge in the clarifier passed over the clarifier weir with the effluent.

With a 12 hour detention period air supplied at less than 3 cubic feet per gallon produced an under-aerated sludge that was difficult to settle in the clarifier while over 4 cubic feet of air per gallon produced but slightly better results and would not be feasible in a large size plant because of the large supply of air necessary. (Page 80)

The amount of sludge return was varied with the density of the sludge. It averaged approximately 25%. to here

4. Treatment of Trickling Filter Effluent with Activated Sludge.

The results of treating the sprinkling filter effluent with

TABLE 14

B.O.D. AND SUSPENDED SOLIDS REDUCTIONS THROUGH THE ACTIVATED SLUDGE UNIT FOR THE VARIOUS TEST PERIODS

SIOUX FALLS SEWAGE TREATMENT PLANT

-1932-

Averages Computed from Tables 11 and 12

Air Feed and Detention Period	Influent	Period Dates Inclusive	Biochemical Oxygen Demand			Suspended Solids		
			Ave. Inf.	Ave. Eff.	% Reduct.	Ave. Inf.	Ave. Eff.	% Reduct.
Air 3 to 4 cu.ft./gal. 12 hrs. Detention	Clarifier Effluent	May 26 to June 10 July 14 to Aug. 23	570	53	90.7	263	139	47.2
Air 3 to 4 cu.ft./gal. 12 hrs. Detention	Chemical Plant Effluent	June 16 to June 20 and June 27 to July 7	381	48	87.4	175	96	45.1
Air 3/4 cu. ft. /gal.	Filter Effluent	Aug. 29 to Oct. 21	149	31	79.3	93	36	61.3
Air 1½ cu. ft. /gal. 12 hrs. Detention	Packing House Waste	Oct. 29 to Nov. 5	1191	246	79.2	1137	168	85.2

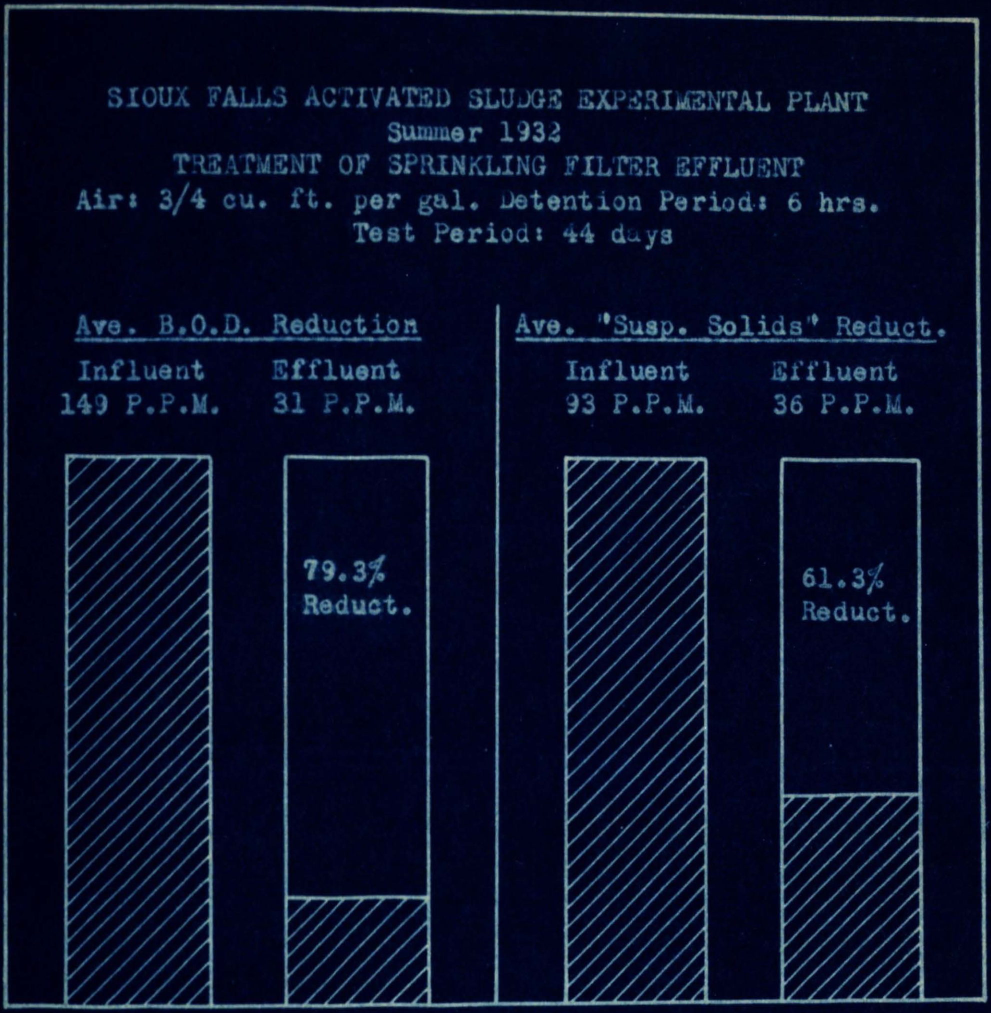
Note: The amount of return sludge was varied according to the density of the sludge but averaged approximately 25%.

Activated Sludge are indicated on Chart No. 9 with a detention period of 6 hrs. and air supplied at the rate of three-fourths of a cubic foot pr. gallon of sewage the average B.O.D. reduction was 79.3%. The "Suspended Solids" reduction of 61.3% was improved during the latter part of the experimental period by placing a shallow baffle in front of the effluent weir of the Activated Sludge clarifier. It was also found that if the effluent from the activater sludge clarifier was passed through a second clarifier nearly complete removal of the suspended solids resulted. This discovery was gratifying because the principle could be easily applied to a full sized plant by using two clarifiers connected in series.

With a 6 hour detention period air supplied in any amount less than three-fourths of a cubic foot per gallon produced an under-aerated sludge. The amount of sludge returned to seed the incoming sewage averaged 25% but was varied with the density of the sludge.

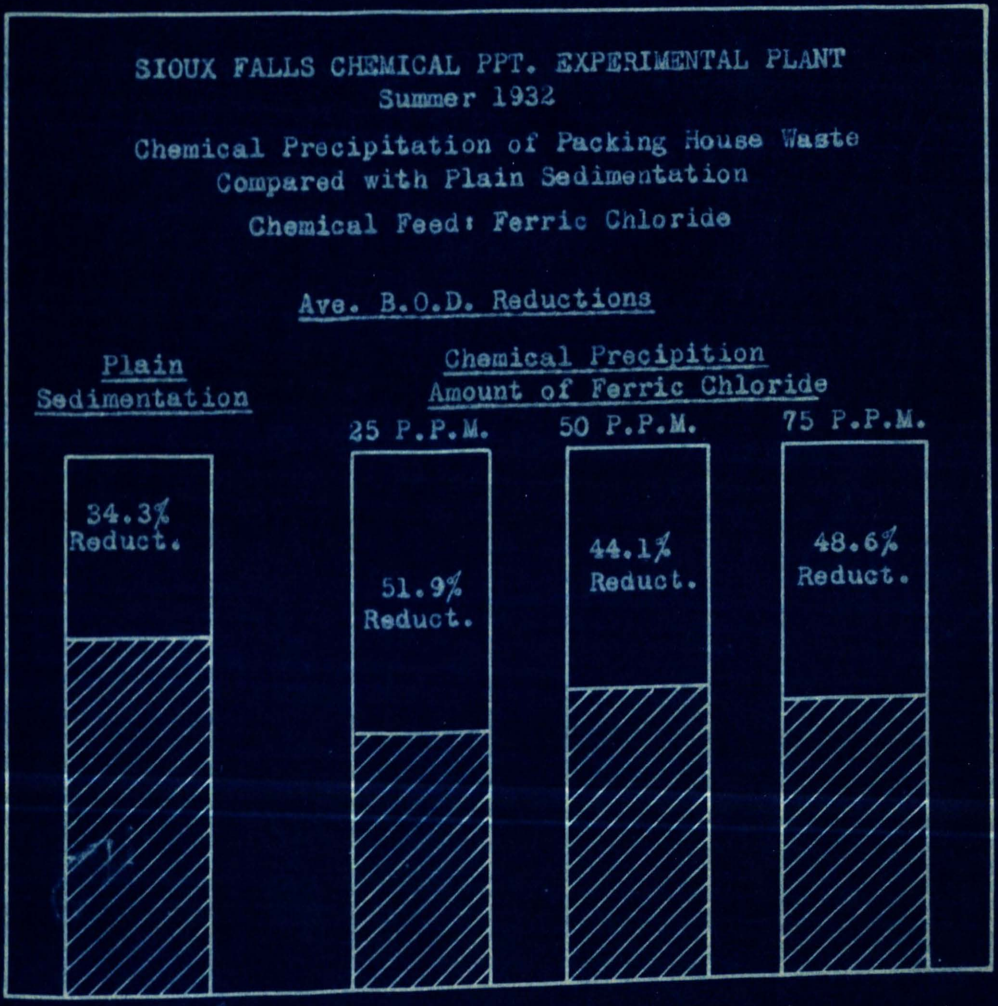
5. Operating Remarks.

The successful operation of an activated sludge unit requires a reasonable amount of operating experience with that particular type of treatment process. This experience was lacking on the part of the writers during the early part of the experimental period. Sewage flow, the amount of air supplied, and the percent of sludge returned to seed the incoming sewage are all variables that require adjustment relative to the changing conditions of the plant, which are judged by the appearance of the influent and effluent, color, appearance and density of the return sludge and the sludge in the clarifier. Catching a sample of the sewage in a graduated cylinder as it leaves the aeration tank and observing the action and appearance of the activated sludge as it settles provides valuable control information.



SIOUX FALLS ACTIVATED SLUDGE EXPERIMENTAL PLANT
Summer 1932
TREATMENT OF SPRINKLING FILTER EFFLUENT
Air: 3/4 cu. ft. per gal. Detention Period: 6 hrs.
Test Period: 44 days

CHART
NO. 9



SIOUX FALLS CHEMICAL PPT. EXPERIMENTAL PLANT
Summer 1932
Chemical Precipitation of Packing House Waste
Compared with Plain Sedimentation
Chemical Feed: Ferric Chloride

CHART
NO.10

F. RESULTS OF THE CHEMICAL PRECIPITATION EXPERIMENTAL UNIT.

1. Choice of Coagulant

Chemical precipitation of sewage consists in adding to the sewage such chemicals as will, by reaction with each other and with the constituents of the sewage, produce a flocculant precipitate and thus hasten sedimentation. The advantage of this process over plain sedimentation is a more rapid and thorough removal of the suspended matter. Its disadvantages include the accumulation of a large amount of sludge, the necessity for skilled attendance and the expense for chemicals. The process is not in extensive use as the conditions under which the advantages outweigh the disadvantages are unusual. The greatest field for usefulness seems to be in the treatment of industrial wastes.

The most commonly used chemicals are a combination of lime and copperas, lime alone and alum alone. Lately Ferric Chloride has been used to a limited extent. Laboratory tests indicated that among the few chemicals it would be economically feasible to use at Sioux Falls, Ferric Chloride was the most logical. It is a powerful coagulant and its cost compares favorable to lime.

In the operation of the Chemical Precipitation Unit Ferric Chloride was used exclusively with one exception. A mixture of 25 P.P.M. of Ferric Chloride and 5 P.P.M. of Sodium Aluminate was tried but gave only slightly better results than the 25 P.P.M. of Ferric Chloride used alone. The small increase in "Suspended Solids" reduction together with the high comparative cost of the Sodium Aluminate did not warrant its use.

The Ferric Chloride used at the Experimental Plant was a syrupy solution of Ferric Chloride and water containing 50% available Ferric Chloride. 1335 grams of the solution was mixed in 5 gallons of water and applied with gravity feed equipment from a 5 gallon carboy on a platform located just above the chemical mixing tank. The rate of chemical feed was checked at 30 minute intervals and corrected when necessary. All chemical feed rates are given as available Ferric Chloride in parts per million by weight. In Fig. 2, page 44, the Chemical Precipitation Unit may be seen just to the right of the Activated Sludge Unit.

2. Operating Periods

The Chemical Precipitation was started May 4, 1932 with settled mixed sewage as influent and a chemical feed of 35 P.P.M. of Ferric Chloride. On July 15 the influent was changed to Raw Mixed Sewage (approximately equal volumes of Raw Domestic and Packing House Waste) with a chemical feed of 35 P.P.M. On May 23 the chemical feed was reduced to 25 P.P.M. The plant operated at that rate until May 31 when the chemical feed was increased to 50 P.P.M. From June 8 until June 30 the Chemical feed rate was kept at 25 P.P.M.

The Chemical Precipitation Plant was operated as a control unit from July 1 to July 8. Raw Mixed Sewage was passed through the unit but no chemical was added to the mixing tank, that is, the unit was operating as a plain sedimentation tank or clarifier. The difference in the B.O.D. and "Suspended Solids" reductions obtained without the use of the chemical and the reduction with the use of the chemical gave the increased reduction obtained by the use of the Ferric Chloride.

The Chemical Plant was not operated from July 7 until Aug. 18 since during that period the Chemical Precipitation Unit clarifier was used as a part of the Aeration Tower equipment.

The last period of operation of the Chemical Precipitation Unit was from Aug. 18 until Oct. 1. The influent was Packing House Waste as received at the Treatment Plant and the Chemical feed was 25 P.P.M. of Ferric Chloride with the exception of a control period from Sept. 13 to Sept. 16 when no chemical was added. The purpose of the control test was to determine the B.O.D. and "Suspended Solids" reductions of Packing House Waste without treating it with chemical.

3. DAILY B.O.D. AND "SUSPENDED SOLIDS" REDUCTIONS.

The daily B.O.D. and "Suspended Solids" reductions of the various types of waste are given in Tables 11 and 12 respectively. Table 15 consists of the computed averages for the various test periods, taken from Tables 11 and 12. Data for Charts No. 10, 11, 12, 13, and 14 were taken directly from Table 15.

4. CHEMICAL PRECIPITATION OF SETTLED MIXED SEWAGE

Referring to Table 15, the average results obtained by treating settled mixed sewage (effluent from the Dor Clarifiers) with 35 P.P.M. by weight of available Ferric Chloride was a 34.1% reduction in B.O.D. and a 53.0% reduction in "Suspended Solids". A rate of 35 parts per million would be 35 lbs. of Ferric Chloride to 1,000,000 lbs. of sewage.

Since the application of this method to the Main Plant would require the installation of another clarifier it was discontinued after a short test period. Later, it was found that the same results could be obtained by treating the Packing House Waste only, with but half the cost for chemical.

TABLE 15

B.O.D. AND SUSPENDED SOLIDS REDUCTIONS THROUGH THE CHEMICAL PRECIPITATION UNIT FOR THE VARIOUS TEST PERIODS

SIOUX FALLS SEWAGE TREATMENT PLANT

-1932-

Averages Computed from Tables 11 and 12

CHEMICAL FEED	Influent	Period Dates Inclusive	Biochemical Oxygen Demand			Suspended Solids		
			Ave. Inf.	Ave. Eff.	% Reduct.	Ave. Inf.	Ave. Eff.	% Reduct.
25 P.P.M. of Ferric Chloride	Raw Mixed	May 23 to June 30	663	339	48.9	588	145	75.3
Columns 13-14-17	Packing House Waste	Aug. 18 to Oct. 1	980	472	51.9	702	169	75.9
35 P.P.M. of Ferric Chloride	Settled Mixed Sewage	May 4 to May 14	490	323	34.1	364	171	53.0
Columns 13-16-17	Raw Mixed Sewage	May 16-19 and 20	877	329	62.5	588	197	63.8
50 P.P.M. of Ferric Chloride	Raw Mixed Sewage	May 31 to June 6	957	420	56.2	599	189	68.4
Columns 13-15-17	Packing House Waste	Sept. 6 to Sept. 12	1129	633	44.1	802	186	76.9
75 P.P.M. of Ferric Chloride[1]	Packing House Waste	Sept.23	960	494	48.6	870	176	79.8
Dry Feed No Chemical Used	Raw Mixed Sewage	July 1 to July 7	772	501	35.1	532	194	63.5
Columns 13-16-17	Raw Packing House	Sept.13 to Sept. 16	919	638	30.6	583	184	68.5

---

[1] Not included in Tables 11 and 12.

5. Chemical Precipitation of Raw Mixed Sewage.

The left half of Chart No. 12 indicates the results obtained by treating the mixed Domestic Sewage and Packing House Waste with 25 P.P.M. of Ferric Chloride. The B.O.D. reduction was 48.9% while the reduction in "Suspended Solids" was 75.3%.

The fact that separate sedimentation studies showed a 52.3% B.O.D. and a 76.0% "Suspended Solids" reduction by plain sedimentation of the Domestic Sewage indicated that the chemical might be put to better use by treating packing house waste only.

6. Chemical Precipitation of Packing House Waste.

Chart No. 10 shows the average B.O.D. reductions of Packing House Waste with Chemical feed rates of 25, 50, and 75 P.P.M. Ferric Chloride at 25 P.P.M. gave a 51.9% B.O.D. reduction which was better than any other rate of feed that was tried. This was a considerable improvement over the plain sedimentation reduction of 34.3%.

The "Suspended Soldis" reduction of Packing House Waste for the above rates of chemical feed compared to plain sedimentation is shown on Chart No. 11. It is interesting to note that doubling the rate of chemical feed to 50 P.P.M. increased the Suspended Solids reduction only 1.0% while tripling the rate to 75 P.P.M. increased the reduction only from 75.9 to 79.8 or 3.9%. This would indicate that in using a chemical feed rate above 25 P.P.M. the results would not justify the added cost.

7. Cost Comparisons

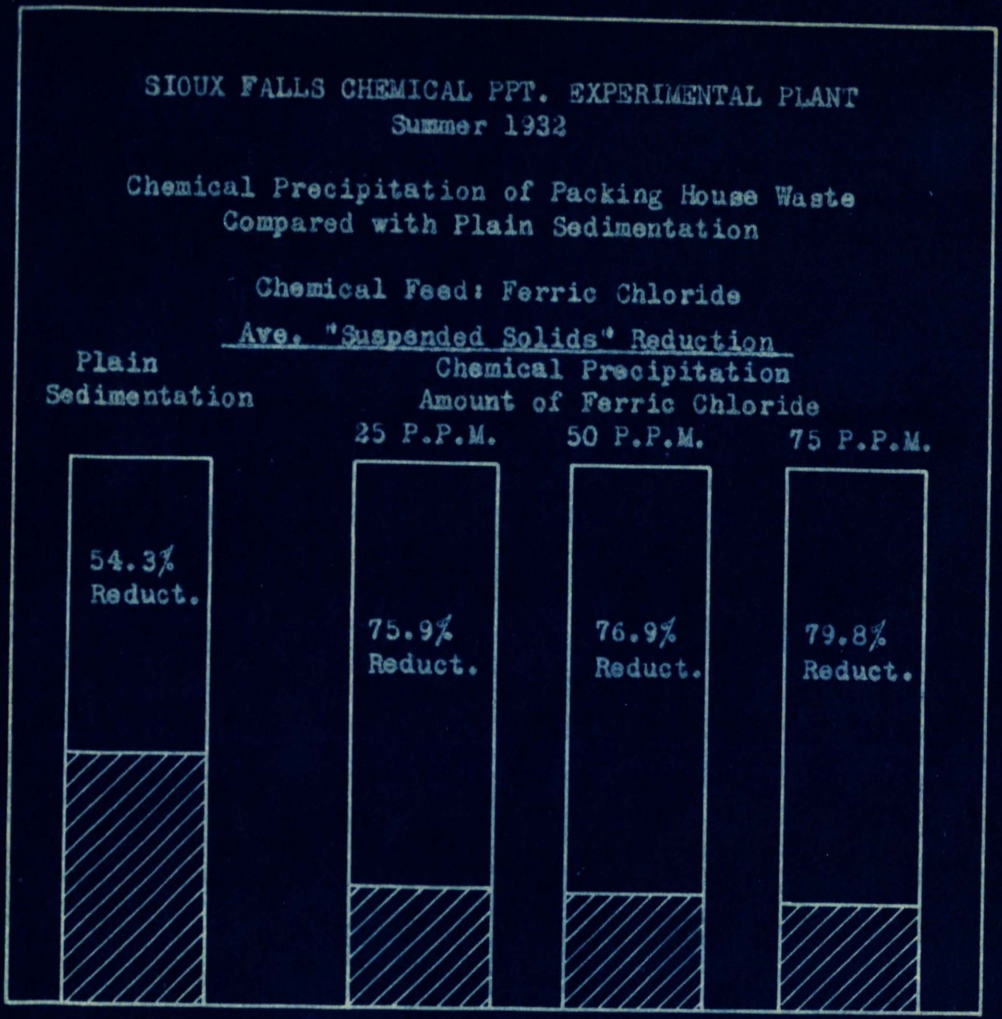
Chart No. 12 compares the chemical precipitation of mixed Domestic Sewage and Packing House Waste with the separate treatment of each, that is, chemical precipitation of Packing House waste only and plain sedimentation of the Domestic Sewage.

The data for the left half of Chart No. 12 is obtained directly from Table 15. The data for the right half of Chart No. 12 is obtained indirectly in the following manner: according to Table 15 the B.O.D. and "Suspended Solids" reductions obtained by treating packing house waste with 25 P.P.M. of Ferric Chloride was 51.9% and 75.9% respectively. Referring to Table 13 it may be noted that plain sedimentation of Domestic Sewage resulted in a 52.3% B.O.D reduction and a 76.0% reduction in Suspended Solids. Since the volumes of Packing House Waste and Domestic Sewage are approximately equal the average B.O.D. reduction of the total volume of the domestic Sewage and Packing House Waste would be the average of 51.9% and 52.3% or 52.1%. Similiarly, the average Suspended Solids' reduction of the total volume of Domestic Sewage and Packing House Waste would be the average of 75.9% and 76.0% or 76.0%.

Thus slightly better results are obtained by treating the Packing House Waste only with but one half the amount of chemical since the Packing House flow is only one half the amount of the total mixed flow. The supply of Ferric Chloride necessary to treat the 5,000,000 gallon daily flow of the mixed waste at the rate of 25 P.P.M. would cost from $30 to $40 per day at present chemical prices while the Packing House Waste flowing at the approximate rate of 2,500,000 gallons per day could be treated with chemical at the same rate of feed at one half that expense. In both cases the reduction of the B.O.D. and "Suspended Solids" filter load would be practically the same.

8. Reduction in Filter Load due to Chemical Precipitation of Packing House Waste.

Chart No. 13 illustrates the reduction in the normal filter



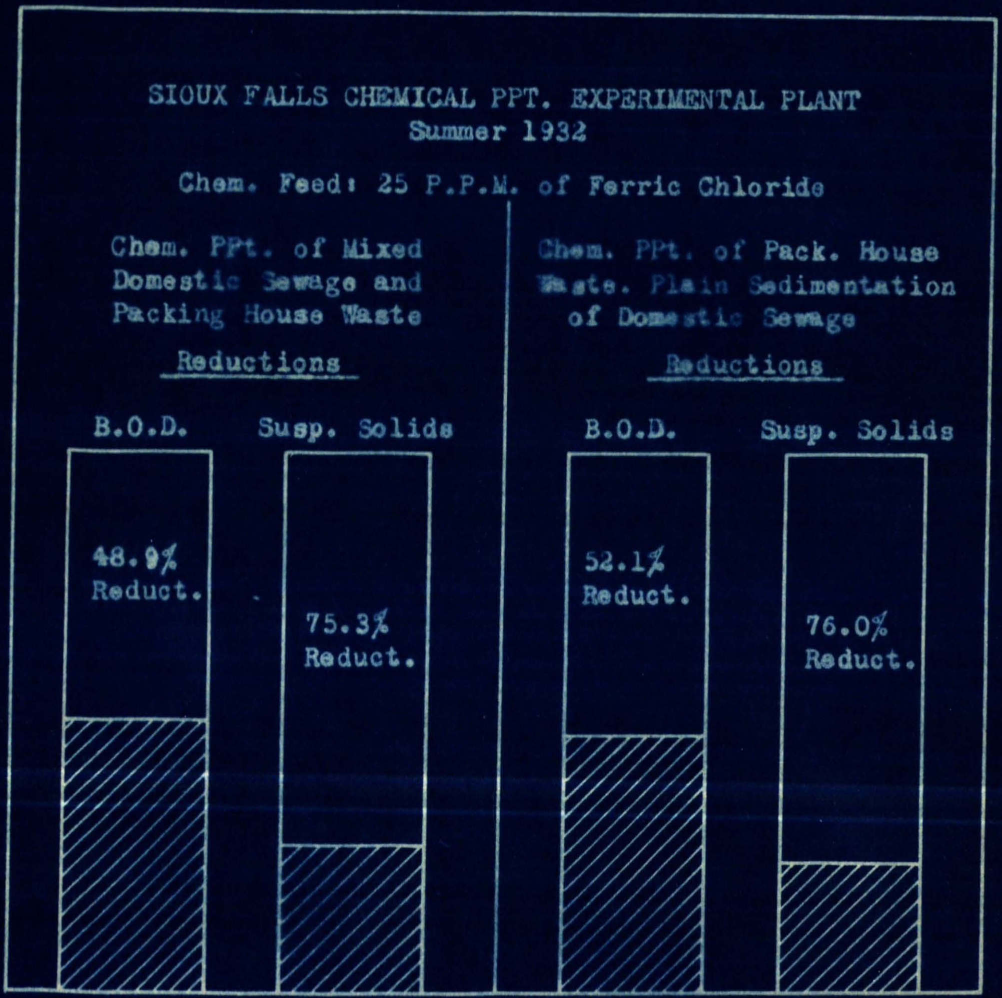
SIOUX FALLS CHEMICAL PPT. EXPERIMENTAL PLANT
Summer 1932

Chemical Precipitation of Packing House Waste
Compared with Plain Sedimentation

Chemical Feed: Ferric Chloride

Ave. "Suspended Solids" Reduction

CHART
NO.11



SIOUX FALLS CHEMICAL PPT. EXPERIMENTAL PLANT
Summer 1932

Chem. Feed: 25 P.P.M. of Ferric Chloride

CHART
NO.12

load of suspended solids by precipitating the packing house waste with 25 P.P.M. of Ferric Chloride.

The data for chart No. 13 is obtained in the following manner: Referring to Chart No. 2 the normal filter load of suspended solids, i.e., the parts per million of suspended solids in the clarifier influent when the plant is in normal operation is 232 P.P.M. On the basis of a 5,000,000 gallon daily mixed sewage flow the normal filter load in pounds of suspended solids would be (5,000,000 x 8.33 x 232) ÷ 1,000,000 or 9,650 lbs. per day.

According to Table 13 the "suspended solids" content of settled domestic sewage is 115 P.P.M. The "suspended solids" content of packing house waste according to the same table is 798 P.P.M. Chart No. 11 indicates the "suspended solids" reductions in packing house waste that may be expected with various rates of chemical feed. Using the above figures and considering the packing house flow and domestic sewage flow each equal to 2,500,000 gallons per day, the "suspended solids" filter loads for the various amounts of chemical feed would be as follows:

Ferric Chloride in P.P.M.	Computations		Filter Load
25	(75.9 x 798 + 115) 2.5 x 8.33	=	6,390 lbs.
50	(76.9 x 798 + 115) 2.5 x 8.33	=	6,230 lbs.
75	(79.8 x 798 + 115) 2.5 x 8.33	=	5,780 lbs.

The reduction in the normal filter load of suspended solids due to chemical precipitation of the packing house waste may be expressed on a percentage basis. Using 25 P.P.M. the percentage reduction would be (9650 - 6390) ÷ 9650 or 33.8%. Making similar computations, the reduction in filter load using 50 P.P.M. of Ferric Chloride would be 35.5% and by using 75 P.P.M. the reduction would be 40.1%.

9. Digestion of sludge from the Chemical Precipitation Unit.

In the treatment of a sewage with Ferric Chloride an acid sludge is produced. An acid sludge may cause foaming when introduced into digestion tanks.

With as low a chemical feed as 25 P.P.M. of Ferric Chloride the Chemical Precipitation Unit produced a sludge of pH 6.2 to 6.4. To be certain that this sludge would digest properly without lime treatment a large wooden barrel was rigged up to serve as a digestion tank. At various intervials during the day sludge was drawn from the clarifier and a portion added to the small digestion tank. pH tests indicated that the acid sludge changed rapidly to a pH of 7.2 to 7.4 and digested properly without foaming.

The acid sludge was also mixed with activated sludge in the small digestor to observe the digesting qualities of the mixture. The mixture digested in a normal manner.

SIOUX FALLS SEWAGE TREATMENT PLANT
Fall 1932

Reduction in Filter Load of Suspended Solids
due to Chemical PPt. of Packing House Waste

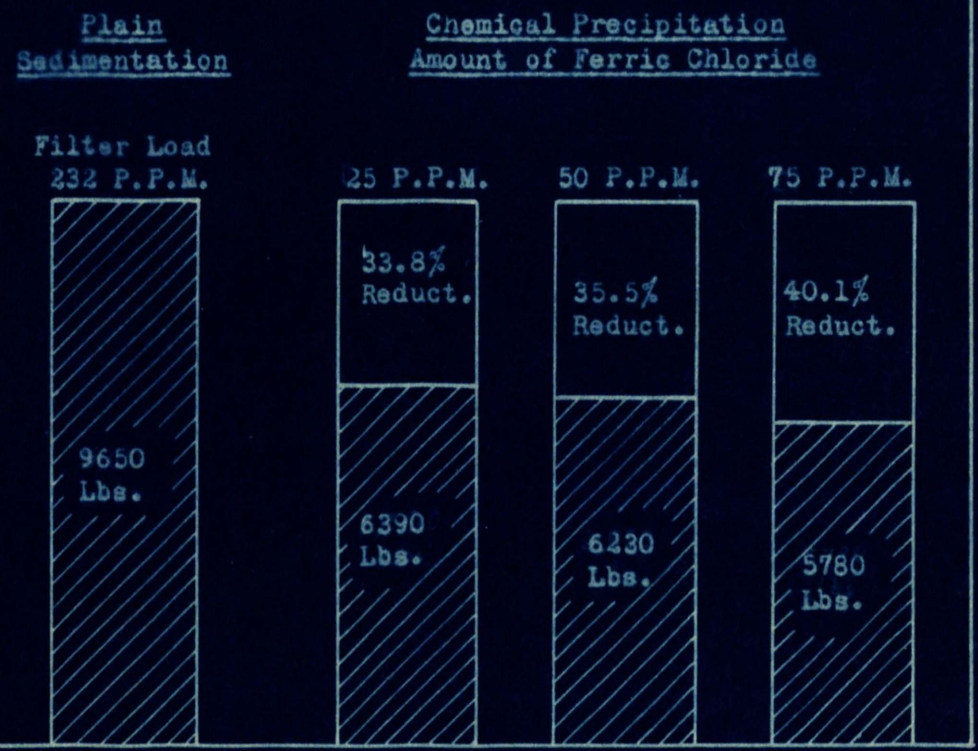


CHART NO.13

SIOUX FALLS SEWAGE TREATMENT PLANT
Fall 1932

Average B.O.D. and Suspended Solids Reductions of
Packing House Waste Through the Pre-Aeration Units

Influent: Raw Packing House

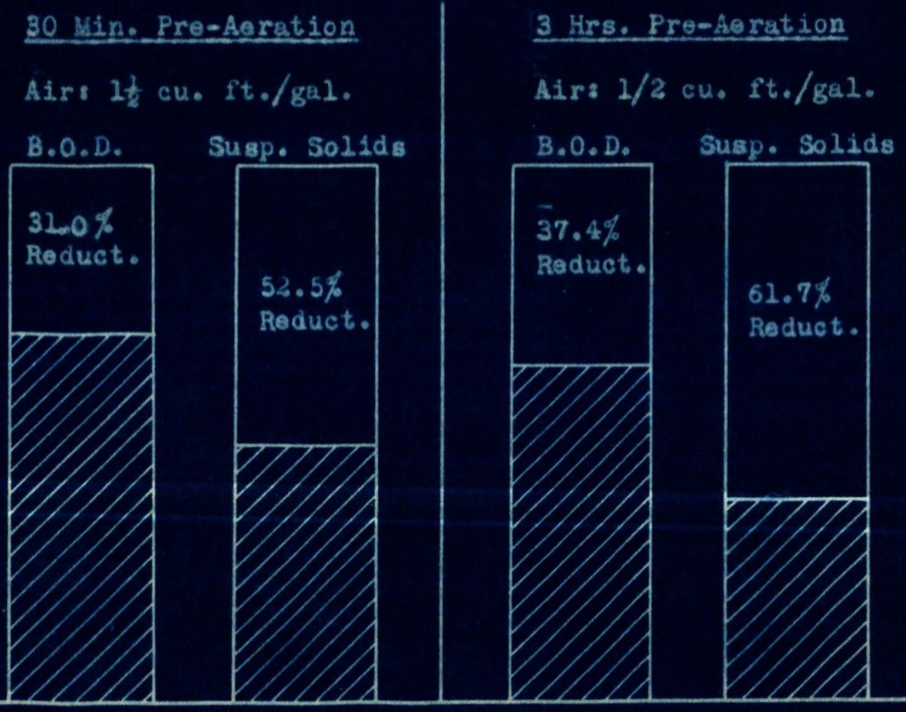


CHART NO.14

G. PRE-AERATION RESULTS

1. Purpose of Pre-aeration Studies

Pre-aeration consists in subjecting a sewage to a relatively small period of aeration by either mechanical or diffused air methods before settling it in a sedimentation tank or clarifier. It differs from the activated sludge process in that the amount of air supplied is less, the detention period is shorter and no sludge is returned from the clarifier to seed the incoming sewage. Pre-aeration of certain types of waste followed by sedimentation produces a better reduction in suspended solids than plain sedimentation alone.

Pre-aeration of both the Raw Mixed Sewage and Packing House Waste was tried on an experimental scale at the Sioux Falls Sewage Treatment Plant. It was hoped that the reduction in Suspended Solids by pre-aeration methods would produce results comparable to chemical precipitation and at a lower cost.

2. Pre-aeration of Raw Mixed Sewage

Settled mixed sewage was pre-aerated by flow through an aeration tower similar to water cooling towers used in power plants. The tower was of wood construction, 4 ft. square and 20 ft. high. The interior was equipped with several tiers of sloping boards. The sewage was aerated by pumping it to the top of the aeration tower and allowing it to flow down over the tiers of sloping boards in thin sheets. By recirculating several times a high degree of aeration could be secured. After being circulated through the tower, the sewage was allowed to settle in the experimental clarifier originally a part of the chemical precipitation unit.

The daily B.O.D. and "Suspended Solids" reductions are given in Tables 11 and 12 respectively. Table 16 contains computed averages taken

TABLE 16

B.O.D. AND SUSPENDED SOLIDS REDUCTIONS THROUGH THE AERATION TOWER

SIOUX FALLS SEWAGE TREATMENT PLANT

-1932-

Averages Computed from Tables 11 and 12

Number of Times Re-Circulated	Influent	Period	Biochemical Oxygen Demand			Suspended Solids		
		Dates Inclusive	Ave. Inf.	Ave. Eff.	% Reduct.	Ave. Inf.	Ave. Eff.	% Reduct.
Seven	Raw Mixed Sewage	July 14 to Aug. 3	748	426	43.1	474	199	58.0
Fifteen	Raw Mixed Sewage	Aug. 9 to Aug. 16	646	303	53.1	490	215	56.2

TABLE 17

B.O.D. AND SUSPENDED SOLIDS REDUCTIONS THROUGH THE PRE-AERATION UNITS

SIOUX FALLS SEWAGE TREATMENT PLANT

-1932-

Averages Computed from Tables 11 and 12

Detention Period and Air Feed	Influent	Period	Biochemical Oxygen Demand			Suspended Solids		
		Dates Inclusive	Ave. Inf.	Ave. Eff.	% Reduct.	Ave. Inf.	Ave. Eff.	% Reduct.
30 Min. Pre-Aeration. 1 cu.ft/gal.	Raw Packing House	Oct.29 to Nov.26	1316	908	31.0	961	456	52.5
3 hr. Pre-Aeration ½ cu.ft/gal	Raw Packing House	Nov.10 to Dec. 5	1450	907	37.4	967	371	61.7

from Tables 11 and 12. Referring to Table 16, recirculating the sewage 7 times gave a B.O.D. reduction of 58% and a "Suspended Solids" reduction of 43.1% while recirculating 15 times gave a B.O.D. and "Suspended Solids" reduction of 56.2% and 53.1% respectively.

Although the B.O.D. reductions were favorable, the "Suspended Solids" reductions were far too low for the Aeration Tower to receive further consideration.

3. Pre-aeration of Packing House Waste

The Activated Sludge Plant was modified to serve as a diffused air type of pre-aeration unit by enlarging the influent orifice to discharge 20 G.P.M. and disconnecting the return sludge equipment. A flow of 20 G.P.M. provided a theoretical detention period of 3 hours.

Treating Packing House Waste with air supplied at a rate of one-half of a cubic foot per gallon followed by sedimentation, the average B.O.D. and Suspended Solids Reductions as given in Table 17 were 37.4% and 61.7% respectively.

The chemical precipitation unit was also modified to pre-aerate packing house waste by diffused air. By placing porous tubes in the bottom of the chemical mixing tank and decreasing the size of the influent orifice a pre-aeration period of 30 minutes was provided. Table 17 gives the average results obtained by pre-aerating packing house waste for 30 minutes with 1 cubic foot of air per gallon followed by sedimentation. The B.O.D. and Suspended Solids reductions were 31.0% and 52.5% respectively. The results of pre-aerating packing house waste are shown graphically on Chart No. 14. The data was taken directly from Table 17.

The low B.O.D. and Suspended Solids reductions obtained by pre-aeration indicated that pre-aeration of the packing house waste would not produce results comparable to the treatment of the packing house waste with Ferric Chloride.

H. APPLICATION OF EXPERIMENTAL DATA TO THE MAIN PLANT

1. Activated Sludge Plant Placed Between the Clarifiers and the Trickling Filter

The possible methods of supplementing the treatment of the present main plant were outlined in Section D, Part II of this paper. In general, these methods served as a guide during the experimental period in the operation of the various treatment units. With the experimental data analyzed, the possibilities and limitations of the various treatment methods as applied to conditions at the Sioux Falls Treatment Plant may be discussed.

In the treatment of clarifier effluent with Activated Sludge it was found that an air supply of 3 to 4 cubic feet per gallon with a detention period of 12 hours was necessary. To treat a 6,000,000 gallon daily flow with 4 cubic feet of air per gallon would probably exceed the power possibilities of the digestor gas produced at the plant. In addition, the economic feasibility of treating the entire sewage flow would be questionable because of the aeration tank capacity required for a 12 hour detention period. However, it would be feasible to reduce the filter load by treating half of the clarifier effluent with Activated Sludge.

Chart No. 15 indicates the B.O.D. results that may be expected by placing an Activated Sludge Plant between the clarifiers and Trickling Filters of the present main plant and treating half of the clarifier effluent. With separate sedimentation of the Domestic Sewage and Packing House Waste, the B.O.D. reduction through the clarifiers would be 43.3% with a 448 P.P.M. B.O.D. strength of the clarifier effluent. (Chart No. 6).

Treating half of the clarifier effluent with Activated Sludge would reduce that portion of the clarifier effluent 90.7% to a B.O.D.

strength of 448 x 9.3% or 42 P.P.M. The B.O.D. strength of the remixed portions of the filter influent in the dosing tanks would then be the average of 448 and 42 or 245 P.P.M. This represents a reduction of 45.4% between the clarifiers and the filters.

According to Chart No. 1 the expected B.O.D. reduction through the filter would be 75.4%. Thus the B.O.D. strength of the final effluent as it would discharge into the Sioux River would be 245 x 24.6% or 60 P.P.M. This represents an overall plant efficiency of (791 - 60) ÷ 791 or 92.5% as compared to a 83.3% overall plant efficiency of the present main plant. If additional power was available treatment of a greater portion of the clarifier effluent would, of course, increase the overall plant efficiency.

Chart No. 16 indicates the probable "Suspended Solids" reductions that would be obtained by placing an Activated Sludge Plant between the clarifiers and the filter, treating half of the clarifier effluent. The data for the above chart is taken directly from Chart Numbers 2, 7, and 8 while the computations are made in the same manner as for Chart No. 14.

The filter influent suspended solids value of 182 P.P.M. compares with a normal filter load of 232 P.P.M. This represents a reduction in the normal filter load of (232 - 139) ÷ 232 or 40% by separate sedimentation through the clarifiers with activated sludge treatment of one-half the flow from the Dorr Clarifiers.

2. Activated Sludge Plant Placed after the Trickling Filter

Operation of the Activated Sludge Unit indicated that for the proper treatment of trickling filter effluent an aeration period of 6 hours with ¾ cubic foot of air per gallon was required. (Chart No. 9)

SIOUX FALLS SEWAGE TREATMENT PLANT
FALL 1932

Activated Sludge Plant Placed Between the Clarifiers and the Trickling Filter Treating Half of the Clarifier Effluent

Average B.O.D. Reductions
Based on Experimental Plant Results

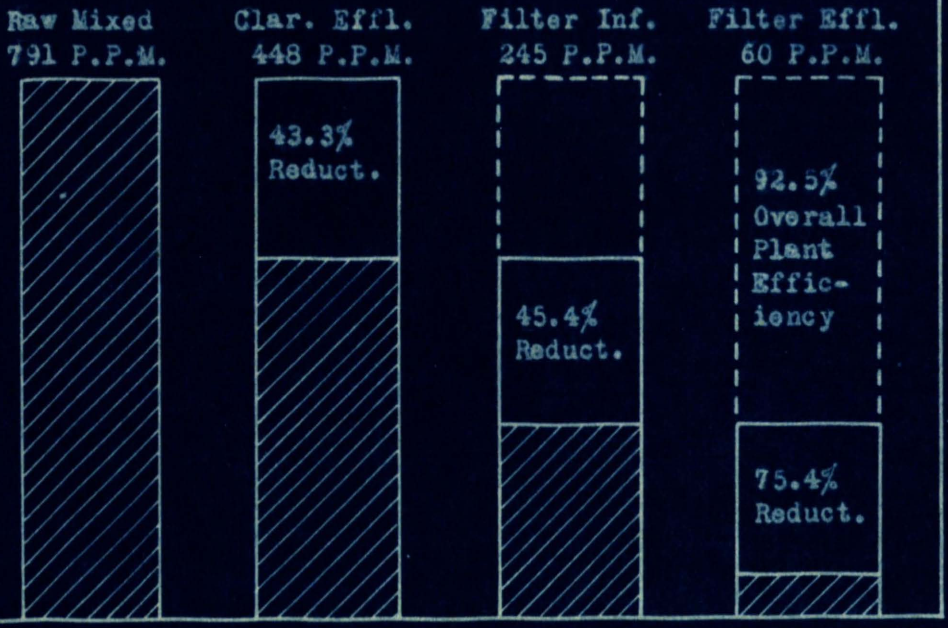


CHART NO.15

SIOUX FALLS SEWAGE TREATMENT PLANT
Fall 1932

Activated Sludge Plant Placed Between the Clarifiers and the Trickling Filter Treating Half of the Clarifier Effluent

Ave. Suspended Solids Reductions
Based on Experimental Plant Results

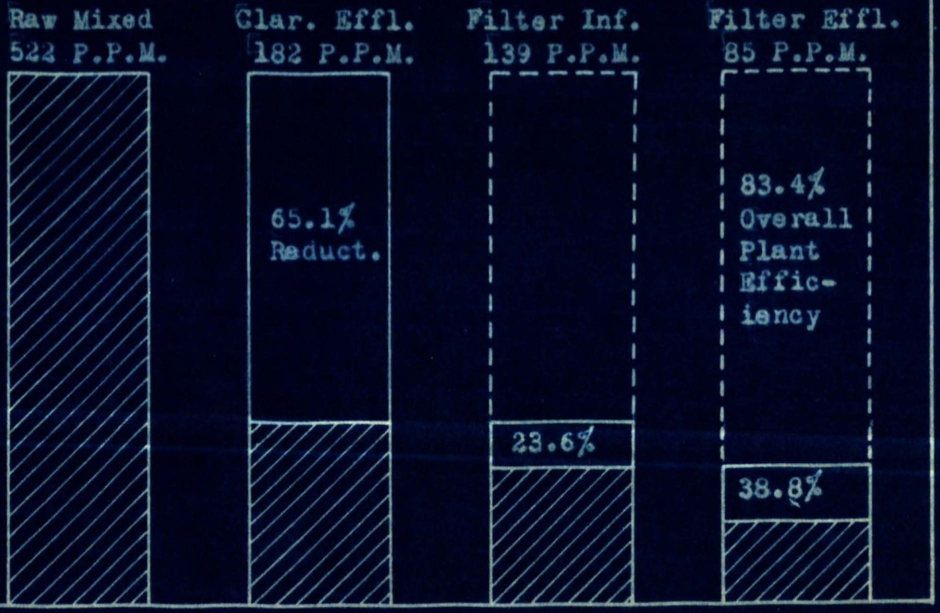


CHART NO.16

Since Activated Sludge Treatment of the filter effluent would not reduce the "Suspended Solids" filter load, some other treatment method would be used for that purpose. The experimental work indicated that the treatment of the Packing House Waste with 25 P.P.M. of Ferric Chloride would reduce the normal filter load 33.8% (Chart No. 13).

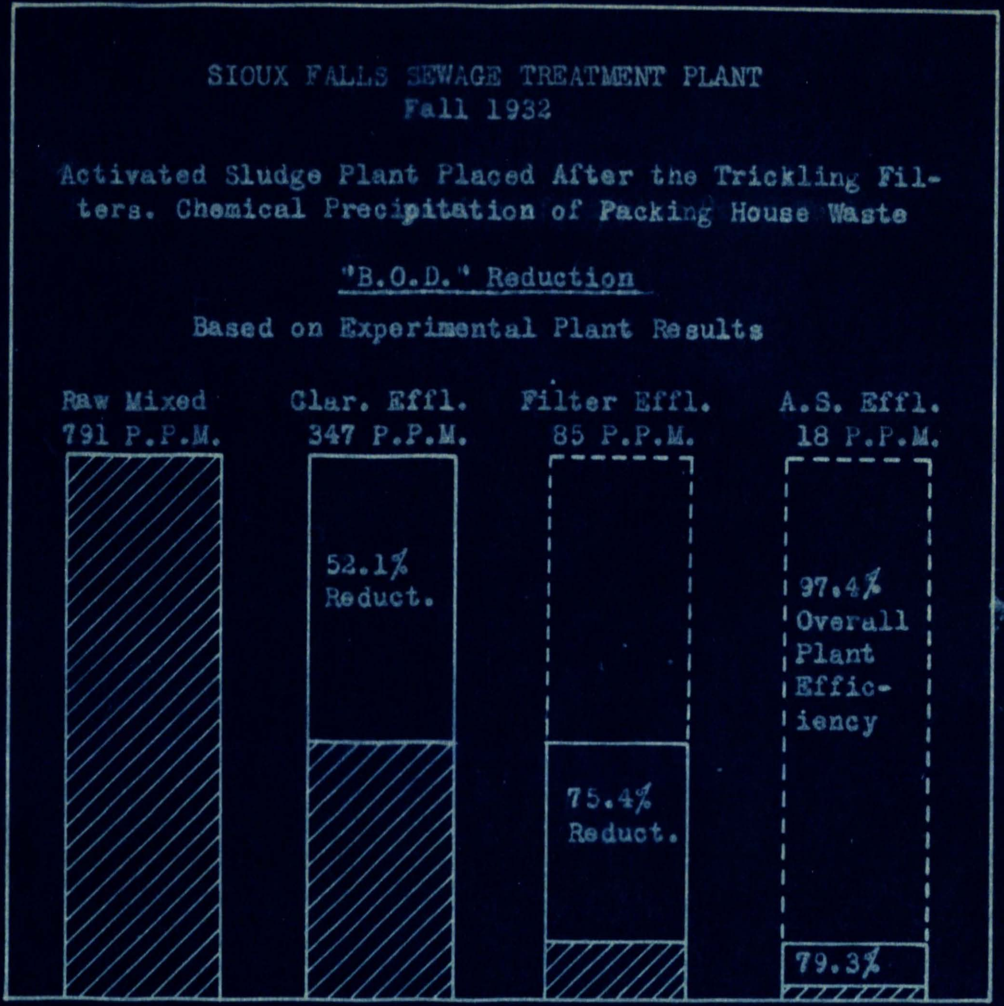
Chart No. 17 indicates the results of supplementing the treatment of the present main plant by treating the Packing House Waste with 25 P.P.M. of Ferric Chloride with an Activated Sludge Plant placed after the trickling filter treating the entire filter effluent.

The packing house waste and the domestic sewage would be kept separate through the clarifiers. According to Chart No. 1 the average B.O.D. strength of the two wastes would be 791 P.P.M. The average B.O.D. reduction through the clarifiers would be 52.1% (Chart No. 12). Thus the B.O.D. strength of the effluent from the clarifiers would be (791 x 47.9%) or 347 P.P.M.

Since the normal reduction through the filter is 75.4%, the B.O.D. strength of the filter effluent entering the Activated Sludge plant would be 347 x 24.6% or 85 P.P.M.

The expected reduction through the Activated Sludge Plant would be 79.3% (Chart No. 9). Thus the Activated Sludge Plant effluent would enter the river with a B.O.D. strength of 18 P.P.M. This represents an overall plant efficiency of (791 - 18) ÷ 791 or 97.4% on a B.O.D. basis

Chart No. 18 shows the "suspended solids" reductions that would be obtained with chemical precipitation of the Packing House Waste and Activated Sludge Treatment following the filters. The data for Chart No. 18 is taken in order from Chart Numbers 2, 12, 2, and 9 while the computations are similar to Chart No. 17. As will be noted, the overall plant efficiency on a "Suspended Solids" basis is 94.3%. According to experimental plant results, two Activated Sludge plant clarifiers hooked in series would increase the overall plant efficiency to some extent. (page 63).



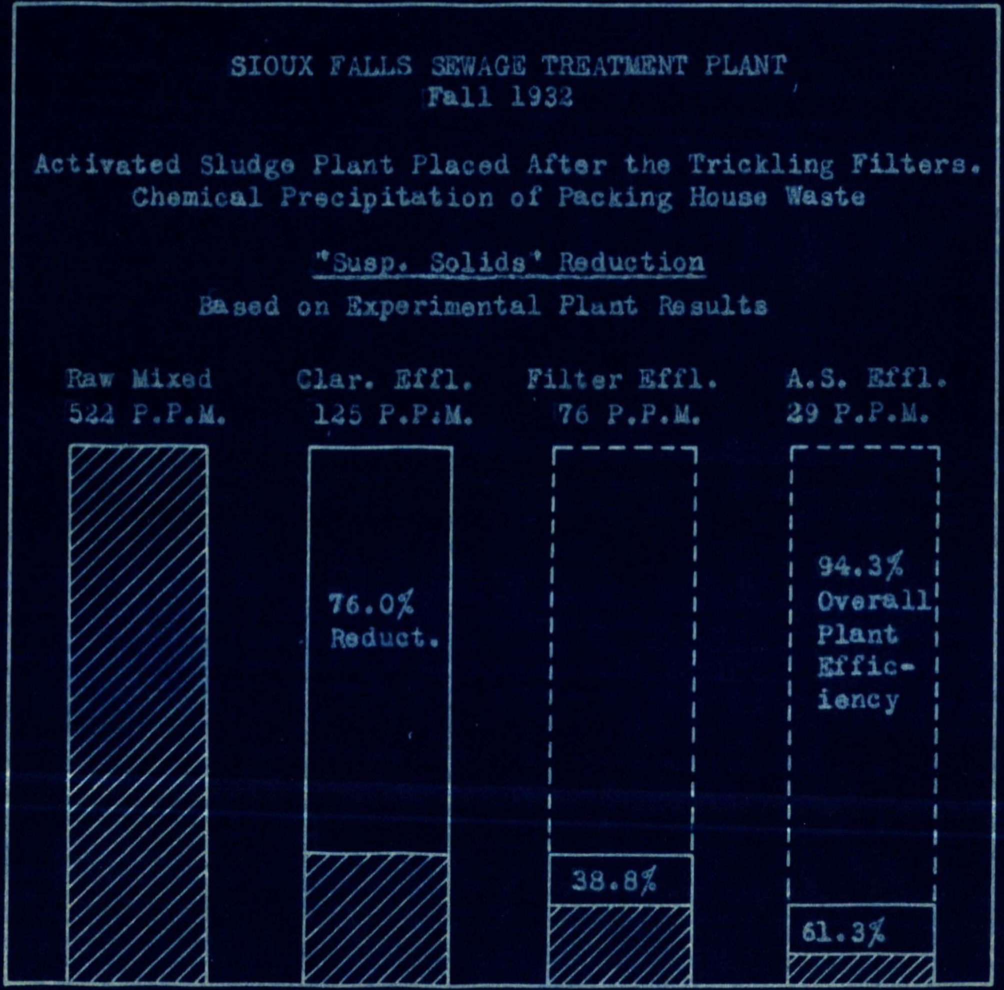
SIOUX FALLS SEWAGE TREATMENT PLANT
Fall 1932

Activated Sludge Plant Placed After the Trickling Filters. Chemical Precipitation of Packing House Waste

"B.O.D." Reduction

Based on Experimental Plant Results

CHART
NO.17



SIOUX FALLS SEWAGE TREATMENT PLANT
Fall 1932

Activated Sludge Plant Placed After the Trickling Filters.
Chemical Precipitation of Packing House Waste

"Susp. Solids" Reduction

Based on Experimental Plant Results

CHART
NO.18

I. SUMMARY AND CONCLUSIONS

The findings and results of the experimental investigations at the Sioux Falls Treatment Plant may be summarized as follows:

1. In regard to the present main plant:

(a) The present Treatment Plant is operating as efficiently as other plants of its type. However, the suspended solids in the Packing House Waste load the trickling filter causing a gradual clogging of the filter beds. Only a considerable reduction in the filter load will prevent the need for expensive mechanical cleaning.

(b) In order to prevent nuisance conditions in the Sioux River below the Treatment Plant during periods of low river flow, the B.O.D. strength of the final effluent must be reduced to as low a value as 20 P.P.M. This can be accomplished in the most economical manner by supplementing the treatment of the present main plant with an Activated Sludge Unit as discussed later in item III of Summary and Conclusions.

(c) Two-thirds of the B.O.D. filter load and three-fourths of the "Suspended Solids" filter load are due to the Packing House Waste.

(d) The present "Suspended Solids" filter load may be reduced 15 to 20% by placing a diaphragm wall in the influent channel leading to the main plant to keep the Domestic Sewage flow and Packing House flow separate through the clarifiers. Thus the Packing House waste would be diverted through the south clarifier while the domestic sewage would flow through the north clarifier. However, this decrease in filter loading does not appear sufficient to prevent the gradual accumulation of suspended solids in the filter bed.

(e) The excess digestor gas produced at the main plant could be utilized to produce approximately 335 H.P. This power would be available for any supplementary treatment process.

(f) The sludge digestors of the present main plant have enough excess capacity to digest the sludge from an Activated Sludge Plant.

2. Experimental Plant Findings

(a) In the treatment of clarifier effluent by the Activated Sludge Method, an air supply of 3 to 4 cubic feet per gallon with a detention period of 12 hours is required.

(b) The Activated Sludge Treatment of trickling filter effluent requires ¾ cubic feet per gallon of air with a 6 hour detention period.

(c) In the Activated Sludge Method of treatment double clarification of the aeration tank effluent, i.e., passing the aeration tank effluent through two clarifiers connected in series produced better results than the use of one clarifier only or of two clarifiers in parallel.

(d) Enough excess digestor gas would be available at the Main Plant to treat all of the trickling filter effluent or at least half of the clarifier effluent by the Activated Sludge Process.

(e) Results obtained by pre-aerating Packing House Waste and Raw Mixed Sewage before sedimentation were to low to justify the pre-aeration method of supplementary treatment.

(f) Treatment of the Raw Mixed Sewage with 25 P.P.M. of Ferric Chloride before sedimentation will reduce the present "Suspended Solids" filter load from 30 to 35%. However, the same results can be obtained with one-half the amount of chemical by treating the Packing House Waste only with 25 P.P.M. of Ferric Chloride followed by sedimentation in the south clarifier, and allowing the Domestic Sewage to pass through the north clarifier without chemical treatment.

(g) The use of Ferric Chloride in amounts above 25 P.PM. in the treatment of Raw Mixed Sewage or Packing House Waste does not justify the extra cost for chemical.

(h) Treating the effluent from the clarifiers with Ferric Chloride produced no better results than treating the Raw Mixed Sewage. Since the application of this method to the main plant would require another unit of clarifiers, it would not be feasible.

3. Supplementing the treatment of the present main plant.

(a) The economic feasibility of treating the entire flow of clarifier effluent by the Activated Sludge Process is questionable because the large amount of power required would greatly exceed the power possibilities of the digestor gas that can be produced at the plant. (b) However, it would be feasible to pass half of the clarifier effluent through an Activated Sludge Plant. The "suspended solids" filter load would then be reduced 40% while the strength of the filter effluent entering the river would be reduced about 50%. This would reduce the B.O.D. strength of the final effluent to approximately 60 P.P.M.

(c) The entire trickling filter flow could be passed through an Activated Sludge Plant before discharging it into the river. This treatment would reduce the B.O.D. strength of the final effluent entering the river to approximately 20 P.P.M., which is sufficiently low to prevent nuisance conditions in the Sioux River below the Main Plant.

The above method obviously would not reduce the "suspended solids" filter load. This load could be reduced by treating the Packing House Waste with 25 P.P.M. of Ferric Chloride before sedimentation in the south clarifier.

(d) The most economical manner of preventing nuisance conditions down stream from the disposal plant appears to be a combination of b and c given above. An Activated Sludge Plant could be built in such a manner that either one-half of the clarifier effluent or the total flow of trickling filter effluent could be treated. During normal stream flow conditions, treatment of one-half of the clarifier effluent would prevent nuisance conditions downstream.

During low flow conditions the entire trickling filter effluent could be passed through the Activated Sludge Plant. During the passage of the filter effluent through the Activated Sludge Plant the "suspended solids" filter load could be reduced by treating the Packing House Waste with Ferric Chloride.

APPROVAL

This thesis is approved as a study of sufficient merit to be accepted for the Masters Degree. Approval of particular statements made or conclusions drawn herein is not to be inferred.

V. S. Carter

In charge of thesis

G. L. Brown

For Committee on Advanced Degrees