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Dewatering Rates for Digested Sludge in Lagoons

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DEWATERING RATES FOR DIGESTED SLUDGE IN LAGOONS *

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Digested sludge lagoons were originally considered temporary sludge storage devices; however, it was found that with prolonged storage a lagoon became an effective drying unit. Since they provide one of the more economical methods of dewatering digested sludges, they are being used frequently in place of other dewatering methods. Research is expected to improve methods of design and operation and minimize the disadvantages associated with digested sludge lagoon operation.

Some of the questions confronted in lagoon design concern lagoon area, depth, drying time, and loading rates. The main factors investigated in this study were the effects of depth of sludge layers on the ultimate dewatering rates by drainage, and the effects of transpiration on sludge drying rates. Previous investigators, including Downes (1), Babbitt (2), Rudolfs and Cleary (3), Haseltine (4), Bubbis (5), Lundesguaard (6), Neuspiel (7), and Al-Ani (8), studied factors affecting dewatering rates of sludge supported on sand and soils.

Effect of Sludge Depth on Dewatering Rates

The effects of sludge depth and the permeability of the previously deposited sludge on dewatering rates were investigated in the laboratory lagoons shown in Figure 1. Sheet metal pipes were used as the lagoons. Piezometers were placed at various levels and were used in certain of the tests. Plastic bag covers and the selected water table maintained by the siphon and siphon breaker, were used to prevent evaporation from the top and bottom of the sludge layer, respectively. The lagoons were operated at the constant sludge depths and with the supporting materials listed in Table I.

Lagoons 57–62 were used in the transpiration studies, constituting another phase of the study to be discussed later.

The normal procedure in treatment plant operation is for digested sludge to be loaded on a lagoon at regular time increments, as determined by the solids accumulation in the digester. Each incremental layer of sludge added to the lagoon is exposed continuously to drainage and evaporation. During severe winter months, however, it is possible that sludge loaded on the lagoon will freeze and accumulate, and when it thaws the dewatering rate reflects the condition of a lagoon initially loaded with sludge to the frozen depth. To simulate this condition in the laboratory, relatively large initial sludge depths were used, and the lagoons were operated as constant head lagoons at these depths. They were loaded

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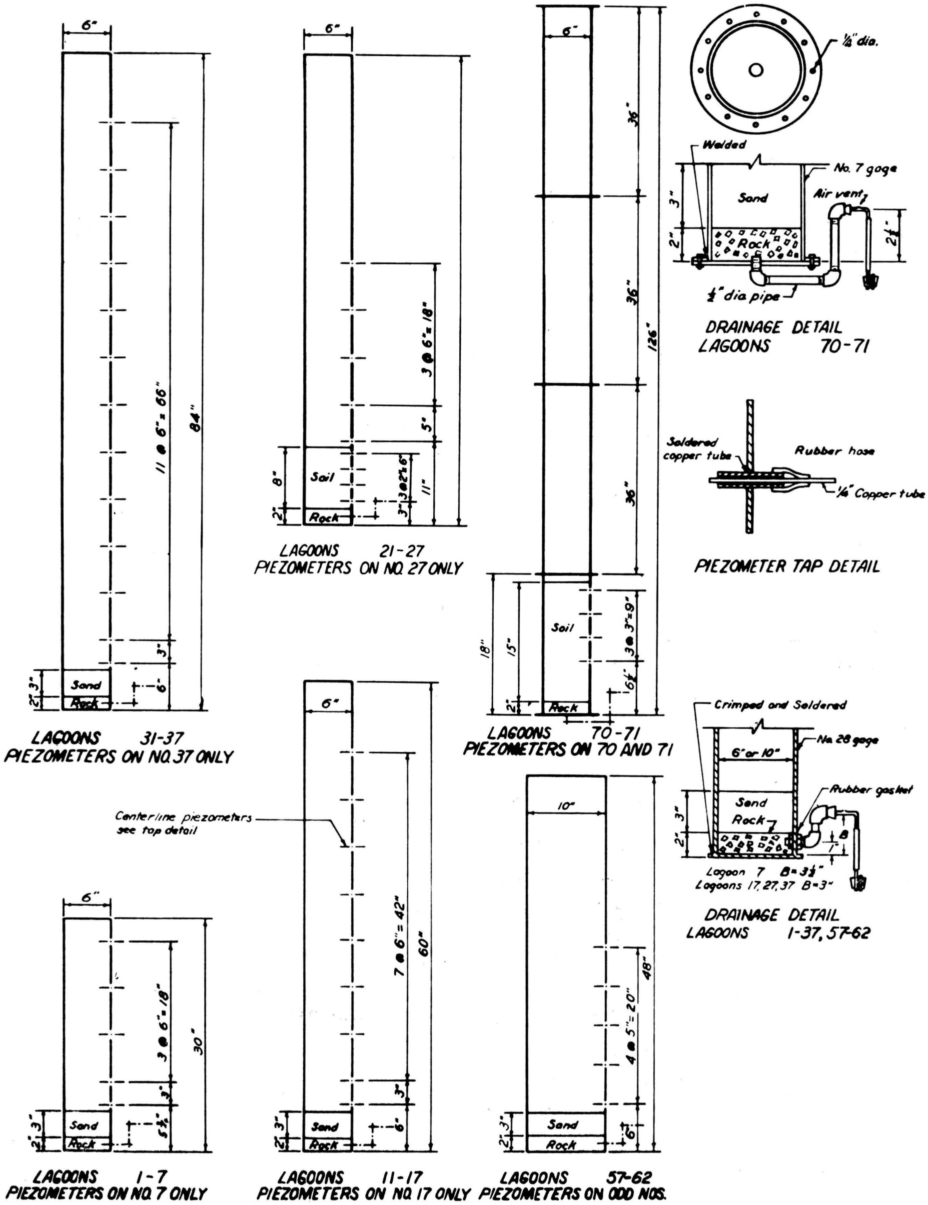

FIGURE 1.—Details of units used as laboratory sludge lagoons.

TABLE I.—Details of Sludge Lagoons

Lagoon No.	Supporting Material	Sludge Depth (in.)
1–7	Sand	22
11–17	Sand	52
21–27	Disturbed soil	47
31–37	Sand	76
57–62	Sand	40

initially on June 13, 1957, to the depths listed in Table I. On June 24, they were loaded to the same depth, and weekly thereafter until August 24, 1957, after which they were loaded every other week for the remainder of the run. Sludge from the Iowa City, Iowa, secondary digester was used for the first two months' operation, and from the Cedar Rapids, Iowa, secondary digester for the duration of the run. A record was maintained of the weight of dry solids added to each lagoon, and of the quantity of liquid discharged during each loading period. Total and volatile solids analyses were made on the sludge according to "Standard Methods" (9).

Results

The average discharge rates obtained at each depth for each loading period are shown in Figure 2. Each point is the average rate for the seven lagoons in the series. The rates are erratic during the first three weeks of operation, except for the 2-ft depth series. Thereafter, they reduce at a decreasing uniform rate and maintain their positions relative to depth. After 35 weeks of operation, the curves become practically straight horizontal lines.

When the units for these curves are converted to drainage rates per foot of sludge depth and are plotted on log-log paper, they appear as in Figure 3. The curve in this figure indicates that after the first 20 days of operation, the drainage rate is proportional to depth. After 250 days of operation, the discharge rates remain proportional to depth, but their variation with time is not the same. The cause of this change in slope is not known, but its influence is reflected in all three depths.

The relative importance of the first three weeks' drainage is apparent when it is noted that the average recorded discharge for Lagoons 31 to 37 was 23.8 l during the first 27 days of operation and 28.5 l for the following 175 days. The discharge then, during the first 27 days, was 46 per cent of the total discharge for 200 days.

The total average quantity of sludge added to each lagoon during the first year's operation was proportional to depth. Actually, 2.4 ft of wet sludge was added per foot of lagoon depth at 2-, 4-, and 6-ft lagoon depths. This is for a constant head, sand-supported lagoon, with no evaporation, using a sludge of approximately 8-per cent total solids. The soil-supported lagoons (21–27), operated over the same time period, and accommodated 90 per cent as much sludge as did the sand-supported lagoons.

Transpiration

The effect of transpiration was determined by measuring the difference in the moisture removed from lagoons with and without plant growth. To-

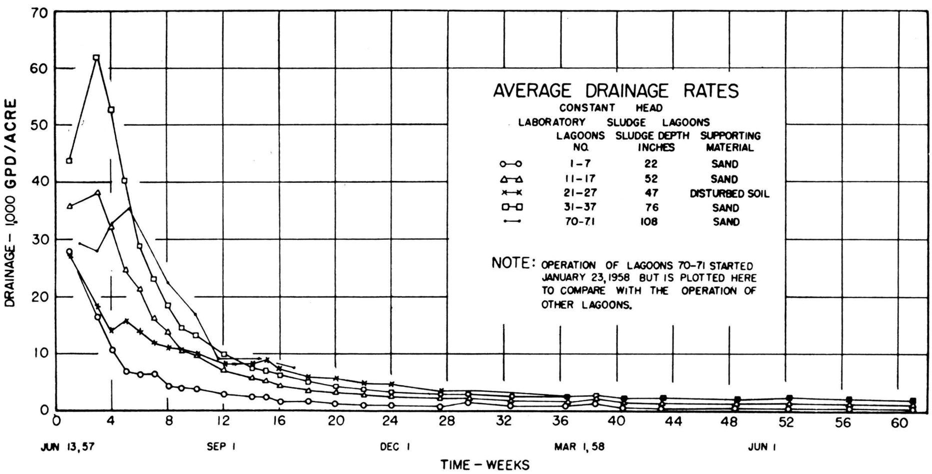

FIGURE 2.—Average discharge rates for various depths during first 40 weeks of operation.

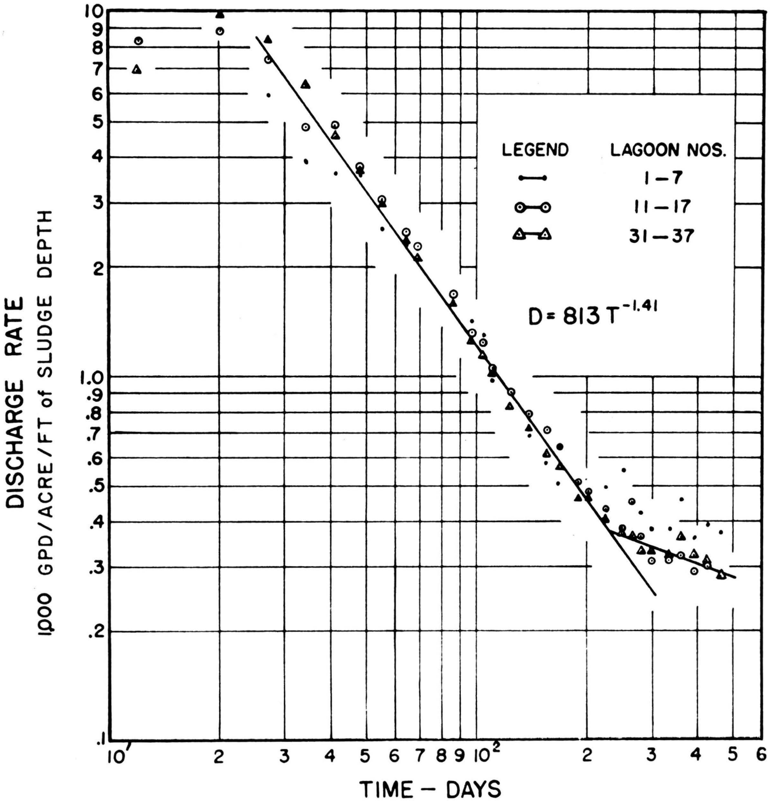

FIGURE 3.—Average discharge rates per foot of sludge depth.

mato plants were used in this study for two reasons: (*a*) tomato seeds are not destroyed in the digestion process, and as a result they usually grow abundantly the first summer of sludge drying, and (*b*) tomato plants have a deep root system. Doneen and McGillivray (10) reported that over a 4-month period from June 15 to October 23, in an unirrigated plot, a total of 21 in. of water was removed by a tomato crop. Most of the water had been removed by early October, but by October 23, the roots had penetrated to and were removing water from a 12-ft soil depth. The average soil moisture in this instance was approximately 2 in. of water per foot of soil depth. The moisture content of sludge is much greater than this, and correspondingly smaller sludge depths will support growth.

Lagoons 57 to 62 (Figure 1) were loaded with sludge on June 13, 1957, and treated identically with the other lagoons (1 to 37) until November 2, 1957, when they were loaded with sludge for the last time. Dewatering by drainage was allowed until May 6, 1958, to produce a sludge dry enough to support plant growth. On May 6, four lagoons (59–62) were placed in a sunny location, and the plastic bag covers were removed to allow evaporation. Lagoons 57 and 58 were retained as control lagoons with no evaporation. On June 6, tomato seedlings were planted in Lagoons 61 and 62. A crust had formed at the surface of these lagoons, and it was necessary to add water so the plants could survive the initial growth period. Equal quantities of water were added periodically to all lagoons. This was continued until the root growth had developed and could supply the plants with moisture from the sludge. A continuous record was maintained of the quantity of liquid discharged during the run, and of the water added during the summer months.

The growth at its best could not be termed luxuriant. The tomatoes grew to 1 to 1½ in. in diameter. On September 2, the experiment was ended and sludge samples were taken from each quarter section of each sludge column for total and volatile solids analyses. At the same time, root penetrations and terminal sludge depths were noted.

The results of this experiment are illustrated graphically in Figure 4. The solid line in the figure is the variation of moisture content computed from a material balance. For the lagoons with no evaporation it was computed to be 74 per cent on September 2, and by sampling it was determined to be 77 per cent. The average terminal moisture content of the pair of lagoons with evaporation was 60 per cent, and 45 per cent for the pair of lagoons with evaporation and transpiration. The lines for Lagoons 59–62 are dotted from May 6 to September 2, because the daily loss of moisture to the atmosphere by evapo-transpiration was not known. By a material balance, however, the net moisture lost to the atmosphere by evaporation and transpiration was computed to be 11.4 and 6.7 in., respectively. The total evaporation from a "free water surface" over the same period was 25.73 in. according to the United States Weather Bureau weather station located on the grounds of the Iowa City treatment plant. The 11.4 in. was 44 per cent of the free water surface evaporation. This is more than the 30-per cent figure reported by Lundesguaard (6), but the increased surface area of the cylindrical lagoons probably produced more than normal evaporation rates, and accounts for this difference.

Figure 5 shows the variation of terminal moisture content with depth. It indicates that drainage alone produces a sludge mass of uniform moisture content and that evaporation effects are restricted primarily to the upper 6 in. of sludge, below which the

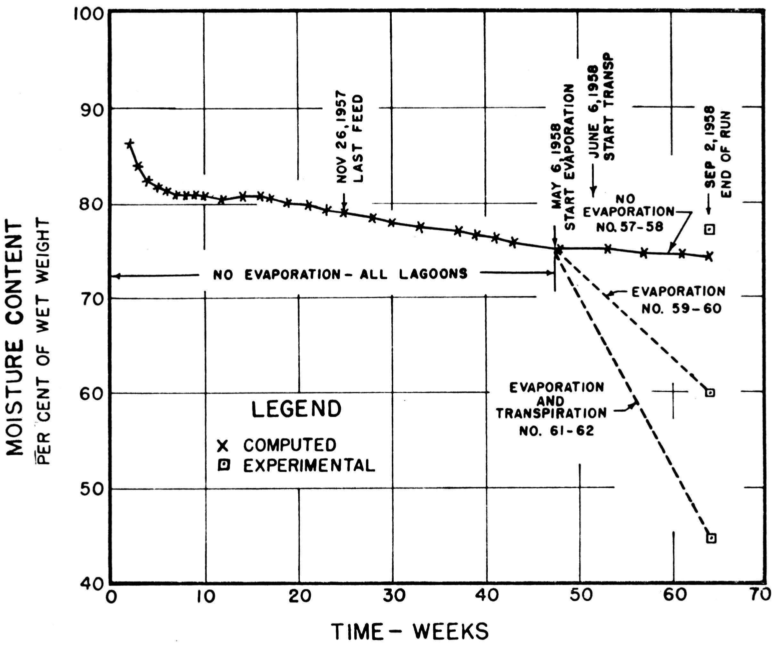

FIGURE 4.—Variation of moisture content with time and the effect of evapo-transpiration on moisture content.

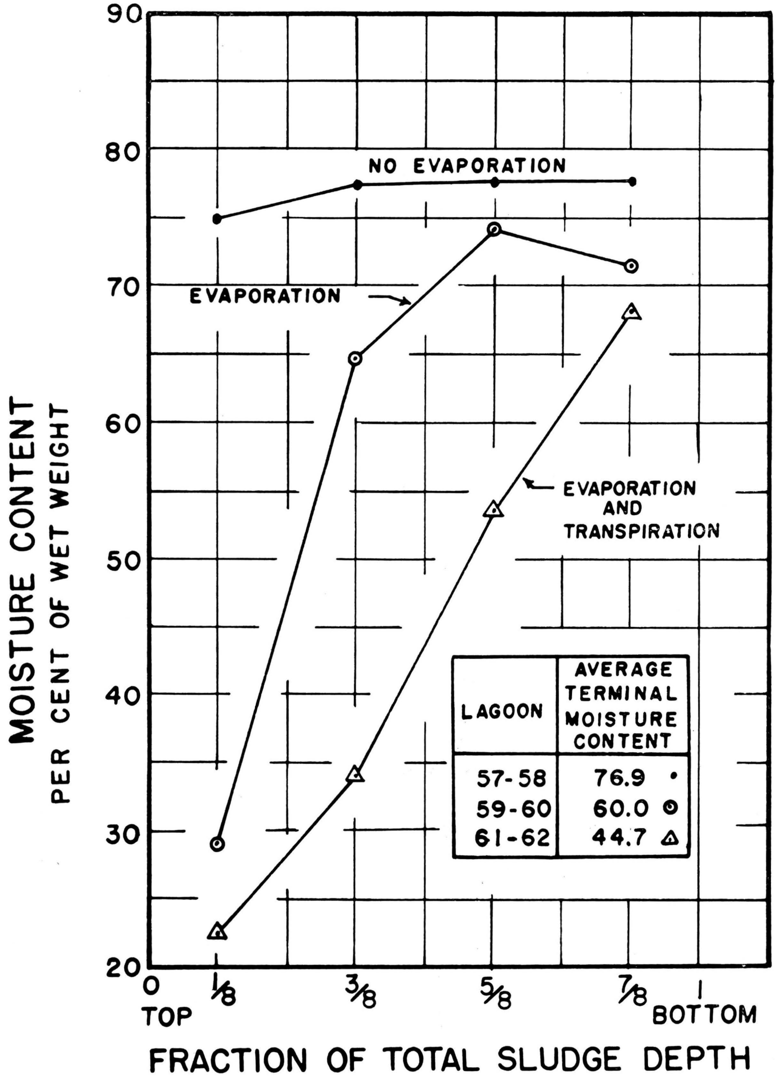

FIGURE 5.—Terminal moisture content.

moisture content increases rapidly with depth. The lagoons subjected to evaporation and transpiration were drier at every depth. From the moisture contents indicated in Figure 5, the quantity of water removed by transpiration may be expressed as a per cent of the total water removed by evapo-transpiration. These percentages are 5, 46, 77, and 29 per cent at the 1/8, 3/8, 5/8, and 7/8 depths respectively. These percentages are inherent, in the data given in Figure 5.

The loading for all lagoons is the same; 2.4 lb of dry solids per square foot per 30 days of lagoon operation (based on 60 weeks of operation). This is comparable to the loading data given by Haseltine (4) and Downes (1).

Discussion

Tomato plant growth more luxuriant than that attained in this investigation would remove more moisture; perhaps even more significant results could be obtained by using plants of the grain family, such as alfalfa, which have a relatively high transpiration ratio. A need for more research along these lines is indicated.

To make the necessary computations certain conditions must be supposed to exist in the field. One condition is existence of pervious supporting material. Native soils may be improved by providing interconnecting sand-filled trenches which may include underdrains. Liquor drained from these trenches has a high BOD (11) and should be treated accordingly.

Another condition is satisfactory geometric design. The lagoon width should be limited to twice the casting radius of the drag line that is to be used for excavation, so that it will be unnecessary for heavy equipment to enter the lagoon during the sludge removal operations. The general shape of the lagoon and the method of entry should be arranged for uniform sludge distribution. Placement of a decanting manhole at the end of the lagoon opposite the inlet is advisable so that supernatant may be drained off.

The proposed operation of a digested sludge lagoon involves a three-year cycle commencing in November. The lagoon is loaded for a year, allowed to dry 18 months, cleaned, and then the supporting material is "rested" for 6 months. This necessitates the use of 3 lagoons and provides ample operating flexibility. The loading is started in November, so that after a year's loading, sufficient time remains for the sludge to dewater to a solids concentration that will support growth by the following spring.

For an example, let 20,000 cu ft of digested sludge, at 8-per cent total solids, be discharged to a lagoon each month. Assuming a specific gravity of 1.0, there are 100,000 lb of dry solids added to the lagoon each month. The loading is to start in November, and continue through October. Assume that at the end of this period, the moisture content has been reduced to 80 per cent by drainage only. Evaporation is ignored, even though the moisture removed may be 30 per cent of that removed from a free water surface over the same period. The terminal volume is then computed using a specific gravity of 1.0, which is a conservative figure.

The desired lagoon length and area are obtained by assuming a desired sludge depth at the end of the first year's operation. With the depth, width, terminal volume, and moisture content given, the length and area of the lagoon may be computed, as well as the inches of water remaining in the sludge. By assuming no evaporation in designing this lagoon, any evaporation that does occur results in the development of a free board that may be considered a safety factor.

Through the following year, to October, evaporation will remove approximately 30 per cent of the moisture evaporated from a free water surface. The latter figure may be obtained from the U. S. Weather Bureau. During this period, transpiration will account for the removal of at least 6 in. of water, or more for luxuriant plant growth.

The water remaining in October can be computed, and since the weight of the dry solids initially added to the lagoon remains practically constant, the terminal moisture content can be computed.

Following through the steps listed above, the actual calculations are made and the lagoon dimensions become 50 × 480 × 4 ft. Equivalent water depth is 38 in. Assuming an average annual evaporation rate of 40 in., during the first year 12 in. would be removed by this means and 6 in. or more would be removed by transpiration.

At the end of the second year moisture content is 67.5 per cent and the depth is 2 ft. At this time, the sludge may be removed or it may be desirable to retain it in the lagoon until spring, at which time the loading would be 1.4

lb dry solids per square foot per 30-day loading period.

Summary and Conclusions

The conclusions from these two phases of the investigation are:

1. For constant-head, digested-sludge lagoons which are operated identically except for depth, the discharge rate at any time after the first 20 days of operation is proportional to depth.
2. The ultimate practical loading when dewatering only by drainage is approximately 2.4 ft of wet sludge per foot of lagoon depth for a sludge with 8-per cent total solids.
3. Residual moisture contents resulting from gravity drainage alone indicate that constant head lagoons 2 to 6 ft deep dry to 80-per cent moisture or less over a year's time.
4. Transpiration may account for the removal of at least 6 in. of water where there is tomato plant growth.

Acknowledgments

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