Activated Sludge Control With a Settlometer and Centrifuge

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There have been many articles written on the control of activated sludge plants. Nemke[1] recently published a good article summarizing many of the key observation and theoretical control techniques that are used for operating activated sludge plants. One area, however, that has not received much attention in the literature is the use of the settlometer and centrifuge. This paper will attempt to lay out a systematic procedure for utilizing some very simple tests to produce an operating control plan. This procedure has been successfully used by EPA personnel in Region VIII on many occasions to operate and control activated sludge plants.

The system presented here is essentially derived from the concepts presented by Al West[2]. Bob Hegg[3] also discussed the use of these control tests and their relation to basic kinetics. The tests described in these articles provide the basic information for establishing a material balance around various components of the activated sludge system and for monitoring the activated sludge quality. The material balance provides a systematic procedure for the operator to monitor sources, location, and production of solids. Control parameters such as sludge age are really just a spin-off of one aspect of the material balance information.

Sludge quality is a much more difficult parameter to monitor but is the real key to any successful activated sludge operation. A series of graphs and trend charts will be developed which the operator can use to visually observe and predict changes in sludge quality. Experience has shown that changes in these trends are more sensitive to predicting changes in sludge quality than the use of a numerical parameter such as sludge age.

CONTROL TESTS

The process control procedures used at plants are designed to provide sufficient information regarding the status of the plant process in order to make appropriate operational changes. (i.e. adjustment of return sludge flow rates, adjustment of quantity of activated sludge to be wasted, adjustment of dissolved oxygen concentrations, etc.) These tests are discussed in detail elsewhere so this paper will only briefly summarize the tests.[2,4]

The control tests initiated are dissolved oxygen determinations, centrifuge tests, turbidity analyses, settleability tests and sludge blanket depth determinations. Tests are usually conducted at least two times per day, seven days per week or once per operating shift, and all tests except sludge settleability are usually conducted five times per day.

Dissolved oxygen (D.O.) tests are used to monitor the availability of D.O. in the aeration basins.

Centrifuge tests are conducted on samples of mixed liquor, on samples of return sludge, and on samples of waste sludge to determine average concentrations throughout the day. The centrifuge test values are expressed in percent solids by volume. Although it is not necessary for control, a correlation between percent solids by volume and solids by weight can be made.

Turbidity tests are performed on samples of settled effluent from the final clarifier. Test results are used to monitor the ability of the activated sludge to remove colloidal material from sewage. Although turbidity may not be directly related to BOD_5, results provide a responsive indicator for monitoring the quality of the activated sludge.

Settleability tests are conducted on samples of the mixed liquor collected in the aeration basin near the point of discharge to the secondary clarifier, and run in a standard Mallory Settlometer. Settleability tests are used to evaluate sludge settling characteristics, floc formation, and to provide information on return sludge rates.

Sludge blanket depth determinations are made on the final clarifier with either an electronic device or a site glass, flashlight and an aluminum pipe. Results are used to monitor changes in the depth of the blanket and to determine the amount of sludge that is accumulating in the final clarifier.

Data obtained from the various control tests can be used to perform calculations and develop various graphs. The results of the calculations and the trends from the graphs are then used to interpret plant performance and control plant operations.

MATERIAL BALANCE

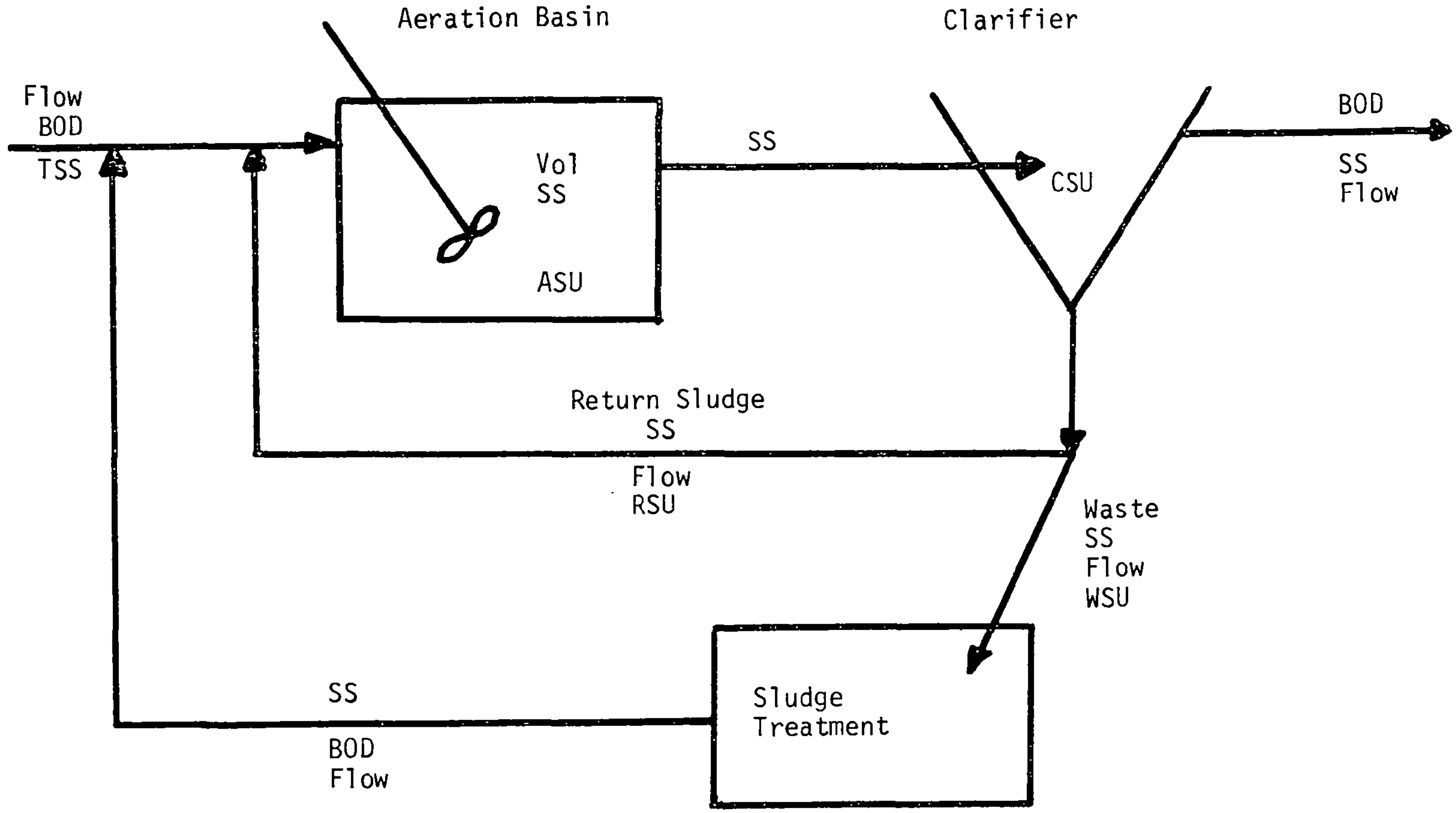
A material balance is a measurement of some specific material (i.e. BOD & SS) in a manner which will account for all sources, removals, storage, and generation of that material. Figure I shows a schematic of an activated sludge plant and the minimum information that should be collected for making a basic material balance around an activated sludge plant.

The material balance can provide the operator with much useful information of what is happening or not happening in his plant. He will be able to determine the impact of sludge waste and sludge return flows, the generation or growth of the activated sludge, and the quantitative change of any BOD and SS through the plant.

Many process control parameters make use of only a part of total material balance information. F/M ratio, for example, uses only BOD of the influent and suspended solids of the aeration tank. Sludge age uses only the suspended solids of the aeration tank and the quantity of sludge wasted. At times of good operations and when the plant is running at "steady state" conditions, one of these control parameters may be all that is needed. However, the operator needs to know what is happening to all areas of his plant so that when a problem does arise, he can tell which segment of plant operations is out of line.

Figure I

MATERIAL BALANCE INFORMATION



THE SLUDGE UNIT SYSTEM

One means of making a material balance is the sludge unit system. This is a method involving simple tests and measurements which can be used for describing a material balance around an activated sludge system. The only extra equipment needed is a centrifuge for measuring the concentration of sludge. Volume and flow measurements are done by typical metering and known dimensions. The centrifuge is used to measure sludge concentration because it saves time over the regular suspended solids test. When sludge separates in the centrifuge, the amount is measured as percent of the total volume.

Some examples show how this system can be used. Take for instance an aeration tank. We need to know how many microorganisms are in the total tank. Since the microorganisms cannot be easily measured in the tank, a representative sample is taken from the tank and placed into the centrifuge. A 15 minute spin reveals that the level of separated sludge is 1.0 percent of the volume in the centrifuge tube. However, before the microorganisms measured can be compared to the microorganisms in the aeration tank, we must have a system to calculate this quantity. Looking at our aeration tank system we see that the centrifuge reads 1.0 percent and the tank volume is 1.0 MG (million gallons). Therefore, this quantity of microorganisms is defined as 1.0 sludge unit, or as shown in the formula:

$$1.0\% \times 1.0 \text{ MG} = 1.0 \text{ Sludge Unit}$$

To see how this system works, let's look at a couple more examples:

1. Suppose the same aeration tank had twice as many microorganisms present. Now, when we run the sample on the centrifuge we

find that the separated sludge reads 2.0%. Now, the sludge units are calculated to be:

2.0% x 1 MG = 2 Sludge Units

which shows twice as many microorganisms as before.

2. Let's also consider what would happen if we had two aeration tanks instead of one. If both aeration tanks had a reading of 1 percent sludge, then the sludge units would calculate to:

1st tank - 1% x 1 MG = 1.0 Sludge Unit

2nd tank - 1% x 1 MG = 1.0 Sludge Unit

Total Sludge Units = 2.0

We now have a system which can be used to measure the quantity of microorganisms in the plant which only involves two numbers. The first number is the percent reading taken from the centrifuge and the second number is the volume of the aeration tank (in million gallons). Since the volume of the tank usually stays the same, all that is needed to determine the quantity of microorganisms is a reading from the centrifuge, and this reading only takes a few minutes to determine. The time saved using this procedure can be used for doing other necessary work at the plant.

If we wanted to we could convert the Sludge Units to pounds of sludge. All that is needed for this is to run a suspended solids (SS) test and a spin test on the sample. For the previous example which had a spin of 1%, the SS were found to be 1000 mg/l. This gives a spin ratio of 1000 mg/l / 1%. To calculate pounds use the following formula:

lbs = % spin x spin ratio x 8.34 x Vol (million gallons)

So, as in the previous example where the tank volume was 1 MG and the spin ratio was 1000 mg/l / 1%, we have:

$$\text{lbs} = 1\% \times \frac{1000 \text{ mg/l}}{1\%} \times \frac{8.34 \text{ lbs}}{\text{gal}} \times 1 \text{ MG}$$

Therefore:

$$\text{lbs} = 8340 \text{ lbs}$$

The sludge unit system may sound a little different at first and may sound like more work, but it actually provides the plant operator with a tool that can be used over and over and in many different ways with relatively little time involved. Also, as will be shown later, the use of these units and data obtained from the settlometer provides the operator with very useful data for controlling return sludge rates.

Some of the ways we can use the sludge unit system are outlined below. Refer to Appendix A for a summary of definitions.

1. Aeration Sludge Units - ASU

This is a measurement of the amount of sludge found in the aeration tanks. ASU's are calculated by multiplying the aeration tank volume in millions of gallons (AVG) by the daily average aeration tank concentration (ATC). The formula used for this calculation is:

$$\text{ASU} = \text{AVG} \times \text{ATC}$$

Example:

Vol = 1 MG
ATC = 3%

ASU = 1 MG x 3%

ASU = 3 units

2. <u>Clarifier Sludge Units</u> - CSU

This is a measurement of the amount of sludge found in the clarifier. CSU's are calculated by multiplying the volume of sludge in the clarifier in millions of gallons (CVG) by the average concentration of the sludge in the clarifier. The volume of sludge in the clarifier is found by finding the fraction of the total clarifier volume that is filled with sludge.

The percent of sludge is determined by the following forula and defining CVG as volume of clarifier and DOB as the measured distance from the water surface to the top of the sludge blanket.

Now:

$$\text{Percent Sludge} = \left[\frac{\text{Average depth of Clarifier - DOB}}{\text{Average depth of Clarifier}}\right] \text{CVG}$$

The average sludge blanket concentration is found by assuming the concentration at the top of the blanket is equal to ATC and the concentration at the bottom of the blanket is equal to RSC. These assumptions are made since we know the sludge is compacting at the bottom of the clarifier, but we can't really measure the average concentration. The average concentration is then assumed to be:

$$\text{Average Sludge Concentration} = \frac{\text{ATC + RSC}}{2}$$

Now in order to find the total clarifier sludge units, multiply the percent sludge by the average sludge concentration. Clarifier sludge units is then determined by:

$$\text{CSU} = \text{CVG} \left[\frac{\text{Average depth of the clarifier - DOB}}{\text{Average depth of the clarifier}}\right] \left[\frac{\text{ATC + RSC}}{2}\right]$$

Example: CVG = 0.70 MG
ATC = 3%
RSC = 12%
DOB = 8 ft
Average clarifier depth (ACD) = 10 ft

$$CSU = \left| CVG \left| \frac{ACD-DOB}{ACD} \right| \frac{RSC+ATC}{2} \right| = .7\ MG \left[\frac{10 - 8}{10}\right]\left[\frac{3 + 12}{2}\right]$$

CSU = 1.05 units

3. <u>Total Sludge Units</u> - TSU

This is the measurement of the total amount activated sludge in the system. Other techniques developed in the literature have been presented but they do not account for varying amounts of sludge in the clarifier. Total sludge units are calculated by:

TSU = ASU + CSU

Example: TSU = 3.0 + 1.05

TSU = 4.05 units

4. <u>Return Sludge Units</u> - RSU

This is the measurement of the daily average of sludge returned from the clarifier to the aeration tank. Return sludge units are calculated by:

RSU = RSC x RSF

Where: RSC = average concentration of return sludge

RSF = average flow of return sludge in mgd

Example: RSF = 2 MGD
RSC = 12%

RSU = 2 MGD x 12%

RSU = 24 units/day

5. Waste Sludge Units - WSU

This is the measurement of the total quantity of sludge wasted from the system each day. Sludge wasting can occur intentionally by pumping sludge to a digester or it can occur unintentionally by being carried over the clarifier weirs. Usually the amount of sludge lost over the clarifier weirs is small in comparison to that which is intentionally wasted. However, to check this out or to measure the quantity of the sludge unit system, we can make use of the spin ratio.

Effluent sludge units (ESU) is calculated by measuring the total suspended solids in the effluent, dividing by the spin ratio, and multiplying by the plant daily average flow. The formula is given as:

$$ESU = \frac{(TSS)\ (Flow)}{Spin\ Ratio}$$

Example:

TSS = 30 mg/l
Flow = 4 MGD
Spin Ratio = 1000 mg/l / 1%

$$ESU = \frac{(30\ mg/l)\ (4\ MGD)}{1000\ mg/l\ /\ 1\%}$$

ESU = .120 units

Intentional sludge wasting (XSU) is calculated by taking the daily average concentration of sludge wasted (WSC) and multiplying the volume (in millions of gallons) of sludge wasted (WSF). Intentional waste sludge units are calculated by:

XSU = WSC x WSF

Example:

WSC = 15%
WSF = 0.05 MG

XSU = 15% x 0.05 MG

XSU = .75 units

Total sludge wasted (WSU) is now calculated by adding the effluent sludge units to the intentional sludge units, or:

WSU = ESU + XSU

Example: ESU = .12
XSU = .75

WSU = .12 + .75

WSU = .87 units

(Note that ESU $<$ XSU)

6. Sludge Age - Age

Sludge Age or mean cell residence time has been used by many authors as an operational tool. The purpose is to define an average time that activated sludge stays in the plant. To find sludge age we need only to devide the total sludge units by the total sludge wasted per day, or:

Age = TSU / WSU/day

Age = 4.05/.87

Age = 5.0 days

7. Sludge Detention Time in the Clarifier - SDTc

This is a measurement of the average time that the activated sludge actually spends in the clarifier at any given time. SDTc is found by dividing the clarifier sludge units by the average daily return sludge units and multiplying by 24 hrs/day to obtain the time in hours, or:

SDTc = CSU/RSU x 24 hrs/day

Example: CSU = 1.05
RSU = 24

SDTc = 1.05/24 x 24 hrs/day

SDTc = 1.05 hours

8. Sludge Detention Time in the Aerator - SDTa

This is the measurement of the average time that the activated sludge actually spends in the aerator. This measurement is different than the theoretical hydraulic residence time or the mean sludge residence time (sludge age) in a very important aspect. The hydraulic residence time defines the average time the raw sewage spends in the aeration tank during the day. The sludge age defines the average time the sludge spends in the system. The sludge detention time (SDTa) defines the average time that the microorganisms are in contact with the raw sewage at any given time. The important point here is that the operator can control or change his sludge detention times by changing return rates; whereas, the hydraulic residence time is controlled by design and the sludge age is controlled by wasting. The sludge detention time affects the efficiency of the organisms to absorb and make use of the BOD by changing the contact time with the BOD. A comparison of sludge detention times in the aeration tank to the clarifier also provides important information for controlling sludge quality. This will be discussed in more detail later in this paper in the discussion on sludge quality.

SDTa is found by dividing the aeration sludge units by the sludge units being sent to the clarifier per day, and multiplying by 24 hrs/day. The sludge flow to the clarifier is found by adding the plant flow (Q) to the return flow (RSF) and multiplying by the concentration (ATC). Therefore, the formula used to calculate SDTa is:

$$SDTa = \frac{ASU}{(Q + RSF)\ ATC} \times 24\ \text{hrs/day}$$

Example: ASU = 3.0
Q = 4 MGD
RSF = 2 MGD
ATC = 3%

$$SDTa = \frac{3.0}{(4+2)\ 3\%} \times 24\ hrs/day$$

SDTa = 4 hrs

The eight cases just presented provide good examples of how a material balance of the activated sludge can be used to provide useful information for plant operations. These same principals can be used by an operator to balance clarifier suction ports sludge streams in and out of digester, and many other uses.

SLUDGE QUALITY

Sludge quality is the real key to having an activated sludge plant provide a high quality effluent. Parameters such as sludge age, MLSS, food loading, and oxygen uptake all affect sludge quality; yet they all require some indifinite measurement of the biological solids in the system. The state of the art for measuring these parameters is improving rapidly, but there still remains the problem of measuring the "active biomass". Even if the analytical procedures could be improved, there is still a lag in the measurement of physical parameters to the change in the biological system. For example, if an operator was maintaining a sludge age of 5 days, but decided to increase to 8 days, he would need to operate at the new level for at least one sludge age (8 days) to physically change all the sludge to a residence time of 8 days. This, however, does not guarantee that the numerous biological populations have all adjusted equally to the new equilibrium point.

A system has been developed to provide an operator with a more timely indicator of the changing sludge quality. This system involves sludge settling tests and the observation of trends of the various process parameters developed earlier. This system utilizes the following major elements:

1. Settlometer

The settlometer is the key indicator for observing sludge quality. Diligent use of the settlometer can provide an experienced operator with days advance warning of an impending disruption or change in process control. This advance warning provides the operator with valuable time to make appropriate process changes. The settlometer information can also be instrumental when recovering from an unavoidable operational upset. In this case the advanced indicators can guide the operator through a series of process adjustments without wasting excess time waiting for results from process changes or without trying to make a major adjustment in too short a time.

The first things an operator should look at when running the settlometer test are the floc formation and the blanket formation. Through experience, an operator will soon learn that within a few minutes he can detect certain characteristics which will describe the sludge quality. Is the floc granular, compact, fluffy or feathery? Does the floc settle individually or does it first form a blanket? Is the blanket ragged and lumpy, or uniform on the surface?

After the operator has looked at these characteristics he then should observe settling rates and compaction characteristics. Is the blanket settling uniformly, or are segments settling faster than others? Is the blanket entrapping the majority of the material or are straggler floc escaping? Is the sludge compacting and squeezing out water, or is it maintaining a constant density throughout? By this time the operator should also realize how important a large diameter settlometer is in order to reduce the effects of a narrow cylinder. Many of these observations would not be noticeable in a 1000 ml graduated cylinder.

Observations such as these are important to the operator. They are not easily translated to numbers so he should make appropriate notes on his data sheet for future reference. There are, however, numerical observations which can be made. Appendix B shows a typical data sheet which can be used to record appropriate sludge settling parameters. Observations and recordings are made every 5 minutes for the first half hour, and then every 10 minutes for the second half hour. More observations are made in the first half hour to ensure that the operator is taking the time to observe the floc formation and blanket characteristics.

If the operator also measures the concentration from the original sample with the centrifuge (ATC) he can make some informative calculations from the data.

The calculation of interest is the conversion of the sludge settling volume (SSV) to sludge settling concentrations (SSC). This is done by the following formula at any given time(t) of settling:

$$SSC_{(t)} = \frac{ATC \times 1000}{SSV_{(t)}}$$

An example of a settling test and appropriate calculations is shown in Appendix B. One calculation taken from the example is:

$$ATC = 3.4\%$$

$$SSV_{30} = 680 \text{ (at 30 min.)}$$

$$SSC_{30} = \frac{3.4\% \times 1000}{680}$$

$$SSC_{30} = 5\%$$

This means that after 30 minutes the sludge has settled to a concentration of only 5%.

SSC's can be calculated for various times and be plotted corresponding to the time and day they were observed. When several days of data have been plotted, a trend will have been developed which graphically relates to the settling characteristics observed in the settleometer. Usually it is found that the 5 minute, 30 minute, and 60 minute SSC's adequately represent the settling characteristics.

The 5 minute SSC is an indicator of the critical floc and blanket formation stage. Here the operator's observations and notes are very important for future reference.

The 30 minute SSC correlates to the settling test used in the sludge volume index measurement. Also, the majority of the settling occurs before the 30 minute reading, so that the distance settled reflects the settling rate of the sludge. For example, a SSV_{30} of 200 would indicate a fast settling sludge. A SSV_{30} of only 600 would represent a very slow settling sludge.

The 60 minute SSC represents the level of compaction that can be expected from the sludge. This concentration, therefore, relates to the return sludge concentration that is actually observed in the plant. These numbers will seldom be the same due to flow characteristics and other physical differences found in the clarifiers. The important criteria, however, is that the settleometer characteristics are reproducible for similar sludge quality characteristics. This then enables the operator to make some decisions on return sludge flows from settlometer data.

Before any operational decisions can be made, it is useful to make some assumptions about the settlometer and the clarifier. It needs to be added, though, that these assumptions do not necessarily have to be accurate because we are primarily interested in the trends that develope from day to day. These assumptions are:

(1) The sludge settling concentrations found at any given time relate to the return sludge concentration if the sludge had stayed in the clarifier for the same time.

(2) The clarifier does not have any unusual flow patterns, short circuiting, coning from return intakes, or other factors which would make the clarifier not operate as expected.

(3) Sludge detention time in the clarifier should be greater than 30 minutes to provide time for compaction. Any time less than 30 minutes will usually require a high return rate which will reduce the sludge detention time in the aerators. (See discussion of SDTa.)

(4) The sludge detention time in the clarifier should be less than 60 minutes to preserve an "active biomass".

Assumption #1 has been found to be reasonably reliable and in several instances where the data appeared to be out of line, a problem with the clarifier as described in #2 was found to be the limiting factor.

Now with these assumptions in mind, we can compare the measured return sludge concentration to the 60 minute and the 30 minute SSC. A rule of thumb is then evident which says,

If RSC is $>$ SSC_{60}, increase return sludge rates.

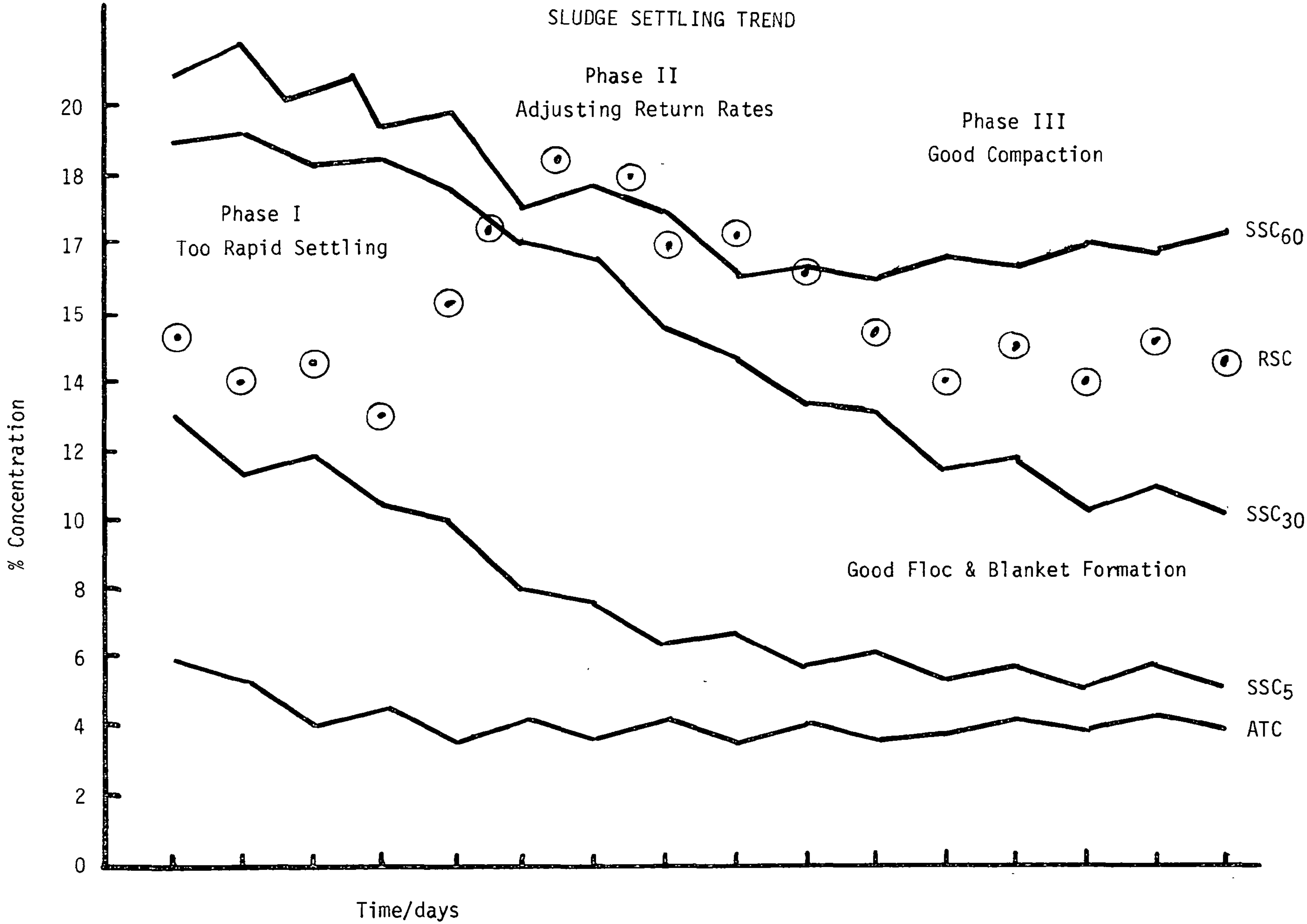
If RSC is $<$ SSC_{30}, decrease return sludge rates.

Like all rules of thumb, other plant conditions have to be considered such as return rate flexibility, aeration detention time, etc.

The information derived from the settling test can be summarized in the graph shown in Figure II. This is a graph of several days data which reflects improved floc and blanket formation and good settling characteristics. The RSC and ATC values are also added to

Figure II

SLUDGE SETTLING TREND



the graph to add a visual relationship of settling characteristics to process numbers. Fluctuations in the graph also represent typical variances in day to day data. Note on the graph that the sludge was settling very rapidly during Phase I. Also during this phase the return sludge concentrations were much less than the 30 minute settling concentration ($RSC < SSC_{30}$). During Phase II the operator reduced his return rates. This reduction in return rates increased the return sludge concentration and probably also increased the sludge detention time in the aeration tank. The settling characteristics started to change as a result of process adjustments until Phase III, where the operator determined that he had a good quality sludge by observing his floc and blanket formation and the clarity of the effluent. Note that during this phase the RSC was inbetween the 30 minute and the 60 minute settling concentrations ($SSC_{30} < RSC < SSC_{60}$). Also note that the initial settling at 5 minutes was very slow and that the 5 minute settling concentration was not much greater than the aeration tank concentration ($ATC < SSC_5$). At this point the return rates and wasting rates would be held constant.

2. Solids Balance

Much has been written about the importance of sludge age, mean cell residence time, or other similar parameters; but often too much attention has been given to the number and not to what they really mean. These terms are mathematical expressions of a system which has been operating in a "steady state" period. Steady state implies that all relative parameters have not changed. This uncertainty of steady state, or even the uncertainty of the specific number, can be partially overcome by graphing the results of the sludge unit calculations. Sludge age is included in the graph but the important information in process control is to find what parameters are changing. An example of such a graph is shown in Figure III.

Graphing the data also allows the operator to visualize the effects of daily changes and gradual trends. Through this type of understanding the operator will be in a better position to determine the magnitude and type of process adjustments that may be needed.

As noted in Figure III, daily calculation of sludge age does not always make sense. On days when no wasting occurs, the sludge age approaches infinity. This response is shown by the broken lines. This information, however, does provide the operator with a valuable rule of thumb.

"It is better to waste a little every day than a lot at one time."

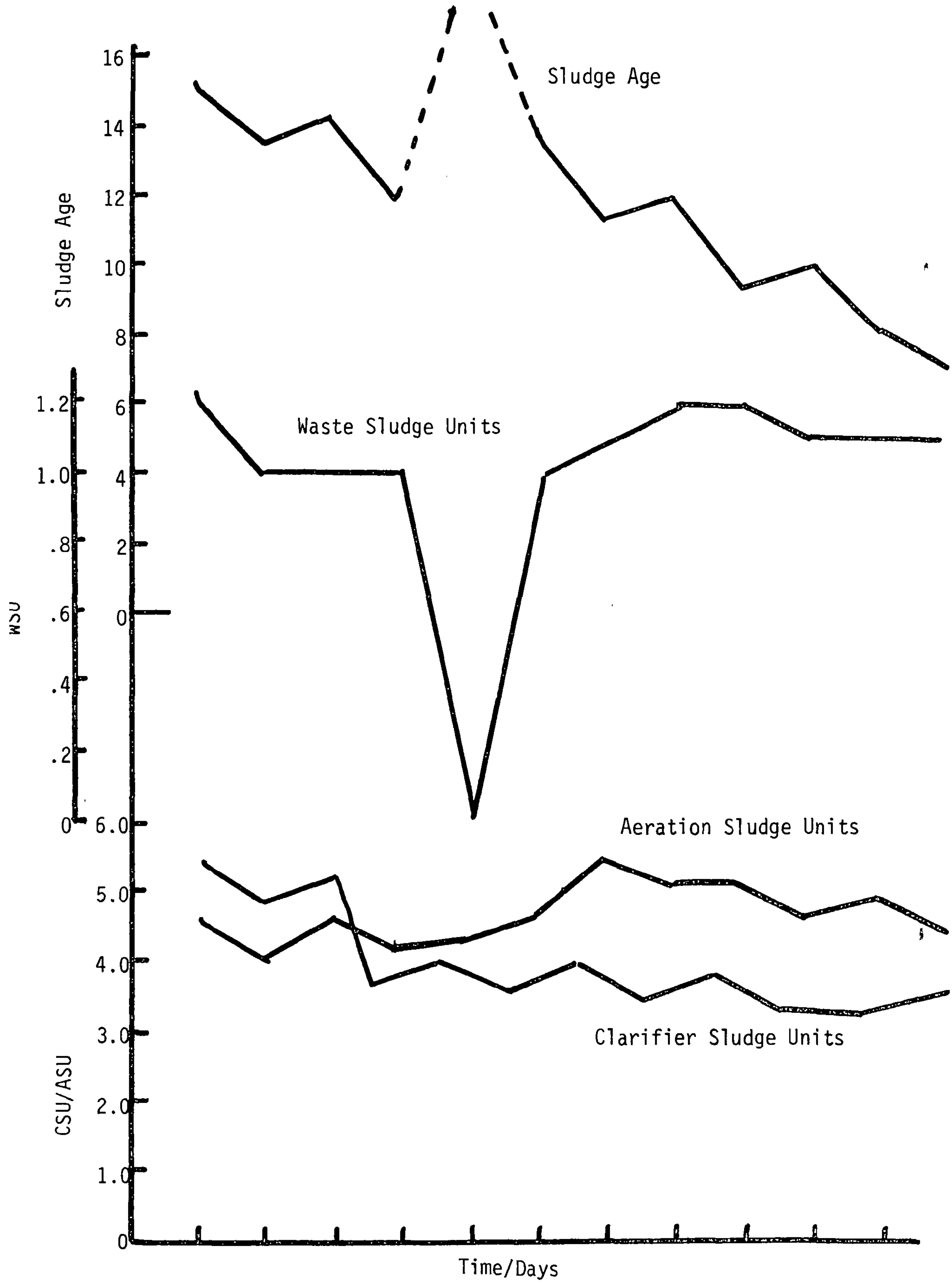
When the operator follows this rule, he will be able to provide a much smoother graph; but more importantly, the control and operation of his plant will likewise be much smoother. Note in Figure III the response to the aeration sludge units. The amount of sludge under aeration changed rapidly after the period of no wasting.

Another rule of thumb has been developed which relates the sludge detention time in the aeration tank to the detention time in the final clarifier:

$$SDTa/SDTc > 1$$

This rule of thumb is based on observations of sludge quality in various plants where it has been noticed that as SDTa becomes closer to SDTc, that sludge quality is much more difficult to control.

Figure III SOLIDS BALANCE TRENDS

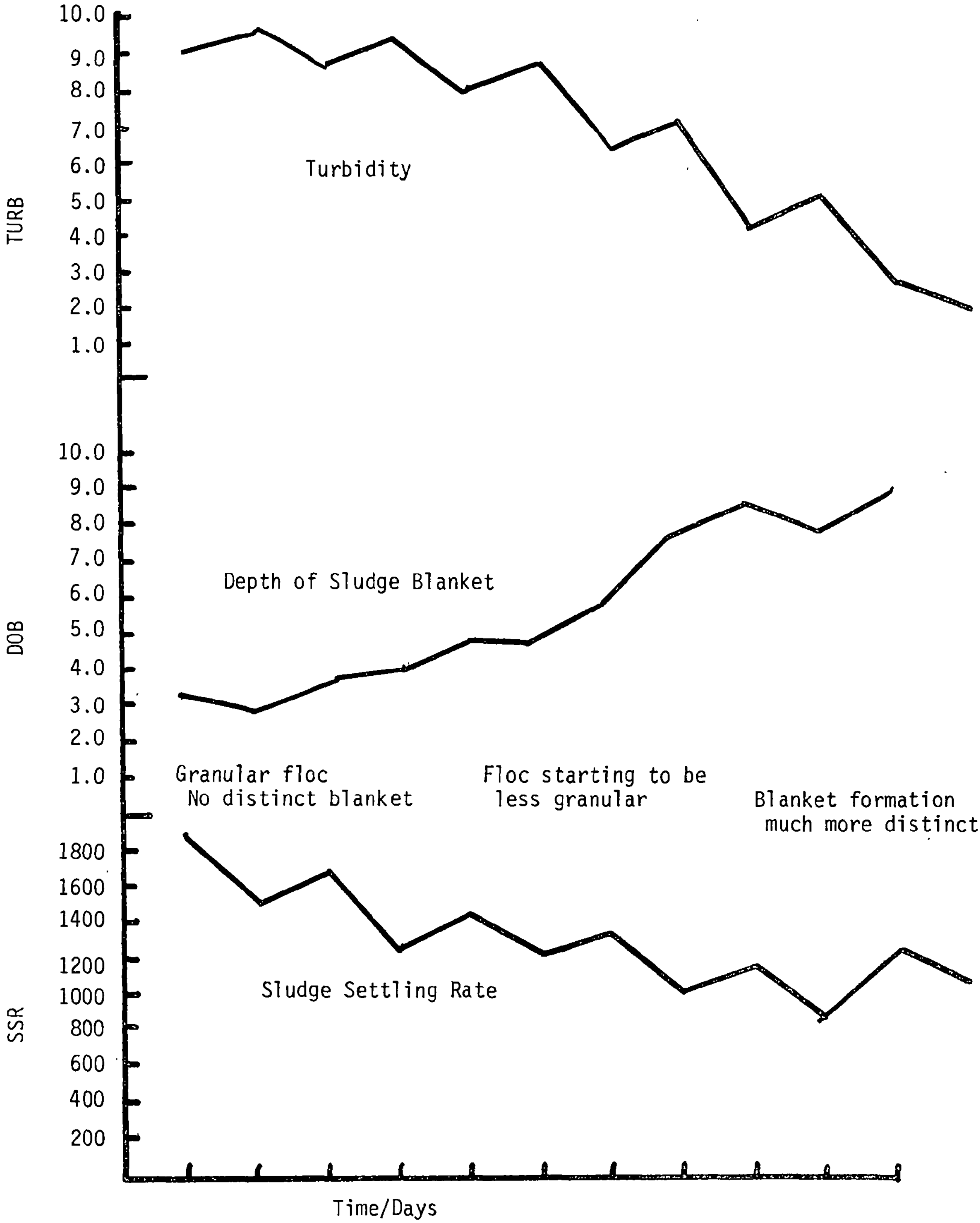


Tank geometry, especially in some complete mix plants, may limit the ability of the operator to control this ratio above one, but this still should be a goal of plant operations.

3. Other Process Variables

Other process variables can also be plotted in trend charts to aid the operator in maintaining control of his facility. Some of the more useful ones include turbidity, depth of sludge blanket, and sludge settling rates. Plots of typical values are shown in Figure IV.

Figure IV PROCESS VARIABLE TRENDS



TURBIDITY

Turbidity is the operator's handle on the performance of his activated sludge system. A well performing activated sludge plant should be producing an effluent with a settled turbidity of less than 3 units and sometimes down to 1 unit. Turbidity measurements can also be used to measure the degree of severity of pin floc or other solids scouring problems. Short term variations due to these type problems may be attributable to hydraulic problems in the clarifier rather than actual sludge quality deterioration.

DEPTH OF BLANKET, DOB

Depth of blanket measurements are important for an operator so he can have early warning to clarifier malfunctions and to problems associated with long storage times in the clarifier. An average value for each clarifier is usually sufficient for process control, but measurements should be periodically made at various locations in the clarifier to detect any localized problems. Coning or plugging of suction ports can lead to areas in the clarifier where the sludge blanket will build. Sludge blanket depths refer to the distance between the water surface and the sludge surface in the clarifier.

SLUDGE SETTLING RATE, SSR

Sludge settling rates can be used by the operator to numerically relate one set of sludge characteristics to another. These settling rates can be used by the operator to describe a rate of settling for which the plant provides a good quality effluent. Generally this rate will fall between 400 and 1200. This corresponds to a 30 minute reading on the settleometer of 400 to 800 milliliters. As mentioned before, this information should always be accompanied by notes which relate to the more important, but not quantitative, data of floc and blanket formation.

Conclusion

The key to having an activated sludge plant put out an excellent effluent day after day is to monitor and regulate the sludge quality. Sludge quality cannot be defined by any one magic number, so the operator must make use of all the information available to him. Changes in sludge quality can be most readily indentified by observing trends of various process parameters. The system presented here has been utilized at many treatment plants successfully. The tests required for this system are simple to perform, quick to run, and responsive to changes in the system. If time and background is available, this information can be converted to kinetic relationships. Also, more sophisticated use of this information has been published which provides the operator with additional process control information. Most important, however, is that by looking at the settlometer, the operator can visualize the sludge quality in his plant.

Appendix A

Column No.	Symbol	Symbol Meaning	Explanation
1	Day	Self Explanatory	For convenience use 8:00 AM to 8:00 AM
2	Date	Self Explanatory	
3	ATC	Aeration Tank Concentration	=Average of values recorded during the day
4	ASU	Aerator Sludge Unit	Total Aeration Tank Volume in million gallons (AVG) Times the ATC from Column 1 =(AVG) (ATC) =(______MG) (ATC)
5	DOB	Depth of Blanket	=Average of values recorded during the day of the distance from the water surface to the sludge surface
6	CSU	Clarifier Sludge Unit	=(Volume of the clarifier (CVG)X(Percentage of the clarifier filled with sludge)X(Average concentration of the sludge in the clarifier) $=(CVG)X\frac{(\text{Average depth of the clarifier-DOB})}{(\text{Average depth of the clarifier})} X \frac{(ATC+RSC)}{2}$ $=(\_\_\_\_MG)\ \frac{(\_\_\_ft - \_\_\_DOB)}{\_\_ft}\ \frac{(ATC+RSC)}{2}$
7	TSU	Total Sludge Unit	=(ASU + CSU)
8	RSC	Return Sludge Concentration	=Average of values recorded during the day
9	RSF	Return Sludge Flow	=Average return sludge flow rate for that day (Note: time period for determining this rate should be the same as the time period used for determining daily sewage flow rate, eg. 8:00 AM to 8:00 AM)
10	RSU	Return Sludge Unit	=(RSF) (RSC)
11	TURB	Turbidity	=Average of values recorded during the day
12	ESU	Effluent Sludge Unit	=Quantity of sludge lost in effluent each day =(Effluent Total Suspended Solids Concentration) (Flow) ÷ (Ratio of TSS Concentration to percent by volume)

Column No.	Symbol	Symbol Meaning	Explanation
12	ESU	(cont.)	$=\frac{(TSS)\ (Flow)}{\text{Ratio of TSS to \%}}$ $=\frac{(TSS)\ (Flow)}{mg/l\%}$
13	XSU/ day	Intentional Waste Sludge Unit	=Quantity of sludge intentionally wasted from the system each day =Total for the day (Note: time period for determining this quantity should be the same as the time period used for determing daily sewage flow rate, eg. 8:00 AM to 8:00 AM) =WSC X WSF
14	WSU/ day	Total Waste Sludge Unit	=ESU + XSU
15	AGE	Sludge Age (# of Days)	=Average length of time a given quantity of sludge remains in the system =TSU/WSU/Day
16	SDTc	Sludge Detention Time in the Clarifier(s)	=Average length of time a given quantity of sludge remains in the clarifier =(CSU) (24 hr/day) /RSU
17	SDTa	Sludge Detention Time in the Aerator	=Average length of time a given quantity of sludge remains in the aerator $=\frac{\text{Volume Aer. Tank X ATC X 24 hr/day}}{(Q + RSF)ATC}$ $=\frac{ASU\ (24)}{(Q + RSF)\ ATC}$
18	Q	Average Daily Sewage Flow	=Sewage flow for a given time period eg. 8:00 AM to 8:00 AM
19	$SSV_{(t)}$	Sludge Settling Volume	=The volume of settled sludge as determined from the settleometer at any time (t).
20	$SSC_{(t)}$	Sludge Settling Concentration	=The concentration of settled sludge at any time (t). $=\frac{ATC\ X\ 1000}{SSV_{(t)}}$

Column No.	Symbol	Symbol Meaning	Explanation
21	SSR	Sludge Settling Rate	=The increase in sludge concentration per hour $= \frac{1000 - SSV_{30}}{\frac{1}{2}\ hr}$

Appendix B

ACTIVATED SLUDGE PLANT

DAILY DATA SHEET

Facility Clear Creek

Day Saturday

Date 6/12/73

SETTLEOMETER TEST INFORMATION

Time of test								
Time	SSV cc/l	SSC* %	Time	SSV cc/l	SSC* %	Time	SSV cc/l	SSC* %
0	1000	3.4	0	1000	2.8	0	1000	
5	950	3.58	5	910	3.08	5		
10	890	3.82	10	820	3.42	10		
15	830	4.10	15	740	3.79	15		
20	770	4.42	20	670	4.18	20		
25	720	4.73	25	620	4.52	25		
30	680	5.00	30	570	4.92	30		
40	620	5.48	40	490	5.72	40		
50	570	5.97	50	430	6.52	50		
60	520	6.54	60	380	7.38	60		

ATC RSC DOB TURB & FLO INFORMATION

TIME	ATC—%	RSC—%	DOB—Ft	Turb—JTU	INF FLO
900a	3.4	8.6	6.0	3.2	1.5
100p	2.8	9.0	3.0	3.7	
500p	3.0	9.1	3.5	3.5	
1000p	3.1	9.0	4.5	3.0	
Sub-Tot.					
Total					
Aver.	3.1	8.9	4.2	3.3	1.5

WASTING INFORMATION

Time Wasting Began	Time Wasting Ended	Total Time Wasted (min)	Flow Rate (GPM)	Gallons Wasted (GAL)	WSC Began (%)	WSC Ended (%)	Average WSC (%)	Sludge Units Wasted (GAL X %)
700a	200p	300	90	27,000	9.2	10.0	9.6	.26
							Total	

RSF INFORMATION

Time Began	Time Ended	Total Time (min)	RSF (GAL/min)	Total * (GAL)
800a	800a	1440	1000	1.4
			Total	1.4MG

BOD5 TEST INFORMATION

Parameter							BLK
Bottle #							
% Dilution							
Initial D.O.							
Final D.O.							
D.O. Deplet.							
Factor							
mg/l BOD_5							

MISC. INFORMATION

TSS & VSS TEST INFORMATION

Parameter					
Time					
Tare #					
Tare & Solids WT.					
Tare WT.					
Dry Solids WT					
Ash WT.					
Volatile WT.					
Vol. of Sample					
TSS mg/l					
VSS mg/l					
% VSS					

*SSC = $\frac{ATC \times 1000}{SSV}$

NOTE: Normal Data period is from 0800 on the date shown and continues for 24 hrs.

References

1. Jim Nemke, "Visual Observations Can Be Process Control Aids," Deeds & Data, WPCF, September 1975.

2. Al West, "Operational Control Procedures for the Activated Sludge Process," Part I, II, III-A, III-B, Return Sludge Control and Appendix, National Field Investigations Center, U.S.EPA, Cincinnati, Ohio.

3. Bob A. Hegg and John R. Burgeson, "Activated Sludge Operations - Integrating Control Testing and Basic Kinetics," Deeds & Data, WPCF, August 1975.

4. "Procedures Used in Conducting Selected Activated Sludge Control Tests," U.S.EPA, Region VIII, Denver, Colorado.