DOCUMENT RESUME

ED 156 469 SE 024 421

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TITLE Operational Control Procedures for the Activated Sludge Process, Part I - Observations, Part II - Control Tests.
INSTITUTION Environmental Protection Agency, Washington, D.C. Office of Water Programs.
PUB DATE May 74
NOTE 31p.; For related documents, see SE 024 422-424; Contains occasional light type; Photographs may not reproduce well

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS *Environment; *Instructional Materials; *Job Skills; Laboratory Training; Management; Measurement Techniques; Pollution; *Post Secondary Education; Waste Disposal; *Water Pollution Control
IDENTIFIERS Activated Sludge; *Waste Water Treatment; Water Quality

ABSTRACT

This is the first in a series of documents developed by the National Training and Operational Technology Center describing operational control procedures for the activated sludge process used in wastewater treatment. Part I of this document deals with physical observations which should be performed during each routine control test. Part II discusses the control tests that are used to directly identify process performance and to dictate process control adjustments. Included are centrifuge tests, effluent turbidity tests and dissolved oxygen tests. (CS)

NATIONAL TRAINING AND OPERATIONAL TECHNOLOGY CENTER

OPERATIONAL CONTROL PROCEDURES
for the
ACTIVATED SLUDGE PROCESS

PART I - OBSERVATIONS

PART II - CONTROL TESTS

MAY 1974

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF WATER PROGRAM OPERATIONS

NATIONAL TRAINING AND OPERATIONAL TECHNOLOGY CENTER

OPERATIONAL CONTROL PROCEDURES
FOR THE
ACTIVATED SLUDGE PROCESS

PART I - OBSERVATIONS

PART II - CONTROL TESTS

by

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MAY 1974
(Revised Mar., 1978)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF WATER PROGRAM OPERATIONS

FOREWORD

The National Training and Operational Technology Center is developing a series of pamphlets describing Operational Control Procedures for the Activated Sludge Process. This series, describing the "NTOTC Procedures", will include Part I OBSERVATIONS, Part II CONTROL TESTS, Part III CALCULATION PROCEDURES, Part IV SLUDGE QUALITY, Part V PROCESS CONTROL and an APPENDIX. Each of these individual parts will be released for distribution as soon as it is completed, though not necessarily in numerical order. The original five-part series may then be expanded to include case histories and refined process evaluation and control techniques.

This pamphlet has been developed as a reference for Activated Sludge Plant Control lectures I have presented at training sessions, symposia, and workshops. It is based on my personal conclusions reached while directing the operation of dozens of different activated sludge plants. This pamphlet is not necessarily an expression of Environmental Protection Agency policy or requirements.

Parts I and II were originally printed as separate pamphlets dated April 1973. The May 1974 printing combines the two Parts which includes some revision concerning use of the centrifuge and dilution settlometer tests.

The mention of trade names or commercial products in this pamphlet is for illustrative purposes and does not constitute endorsement or recommendation for use by the Environmental Protection Agency.

Alfred W. West

PART I

OBSERVATIONS

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OBJECTIVES

Aeration tanks and final clarifiers are studied perceptively for informative physical characteristics that help identify sludge quality and process status. They are scrutinized for clues that indicate the kind of control adjustments needed to achieve optimum plant performance. The inferences of such physical findings are used to supplement the results of other more specific control tests that dictate the direction and magnitude of the essential control adjustments.

INTRODUCTION

Much can be learned from simple but perceptive sensory observation of process features such as the type, color, and extent of foam on the aeration tank surface and the presence or lack of scums and rising floc particles in the final clarifiers. From such observations, a skilled operator usually can determine the basic phase his process is moving towards or is locked into. Such observations will make him aware of more generalized long-term requirements. They will help him reach proper conclusions from the results of other more specific control tests that are used to calculate process demands and to determine the type and extent of control adjustments that are actually needed.

The entire series of physical observations described in this section should be made each time the routine control tests are performed. The appearance of the final effluent and the aeration and clarifier tank contents should be examined at least once during each operator's eight-hour shift.

AERATION TANKS

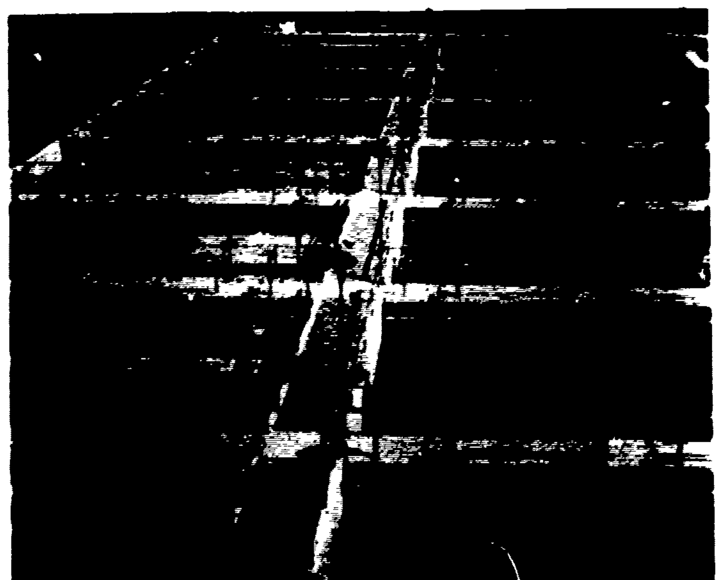
TURBULENCE

The operator should observe the entire aeration tank surface for turbulence. Though some of his conclusions will be subjective and based on past experience, the extent of surface turbulence will indicate whether or not all sewage, return sludge, and mixed liquor are thoroughly mixed throughout the entire aeration tank. Observable surface

COMPRESSED AIR - SPIRAL FLOW
Showing Diffuser Socks

COMPRESSED AIR - SPIRAL FLOW
In Use

PRESSED AIR - CROSS ROLL
Showing Diffuser Socks



COMPRESSED AIR - CROSS ROLL
In Use

characteristics will imply whether or not dead spots or insufficiently mixed core areas may exist within the aeration tanks. The operator should maintain, increase, or decrease air discharge rates according to the conclusions he reaches from the results of such observations and from supplementary dissolved oxygen determinations.

He should reproportion air flow through headers or individual subheaders to correct any dead spots, unequal air distribution, or inadequately tapered aeration intensity that may have been observed.

If serious mixing deficiencies prevail despite corrective air distribution adjustments, he should attempt to determine which structural, mechanical or design deficiencies may be responsible for the difficulties. If normal air balancing procedures fail to correct evident defects, he should be prepared to recommend the maintenance or modification procedure that may be necessary to eliminate the problems.

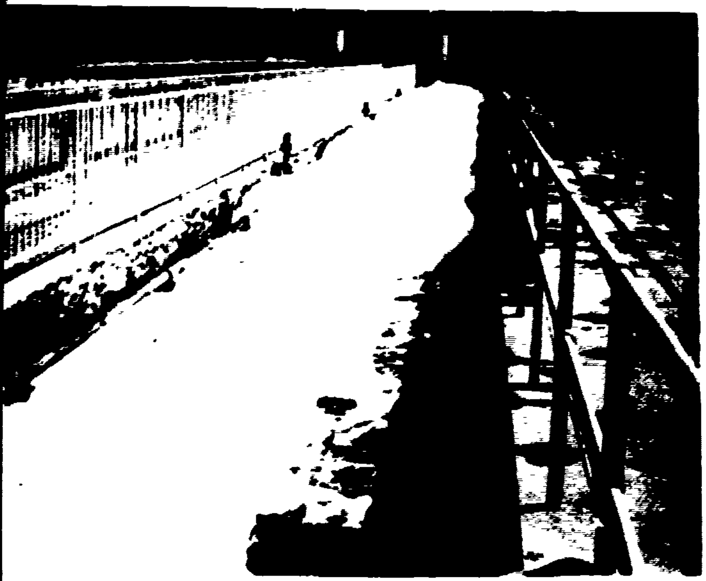
In many cases, aeration deficiencies can be corrected by routine diffuser cleaning or by replacing existing diffusers with more effective maintenance free units. In some cases, major mechanical alterations may be required to relocate and increase the number of diffusers to mix and aerate the tank contents thoroughly. Overall process performance has been improved at some plants by replacing the single run of diffusers that extended along one side wall with multiple parallel runs of diffusers extending either longitudinally or across the tank bottom.

SURFACE FOAM AND SCUM

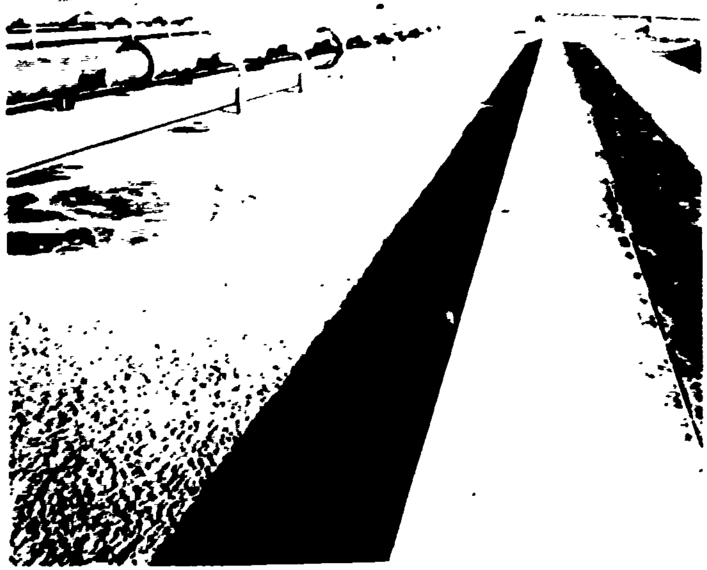
The type of foam or scum, if any, accumulated over the aeration tank surface, and to a lesser extent, the color of the mixed liquor sludge reveal process status and indicate generalized long-term sludge wasting requirements.

Fresh Crisp White Foam

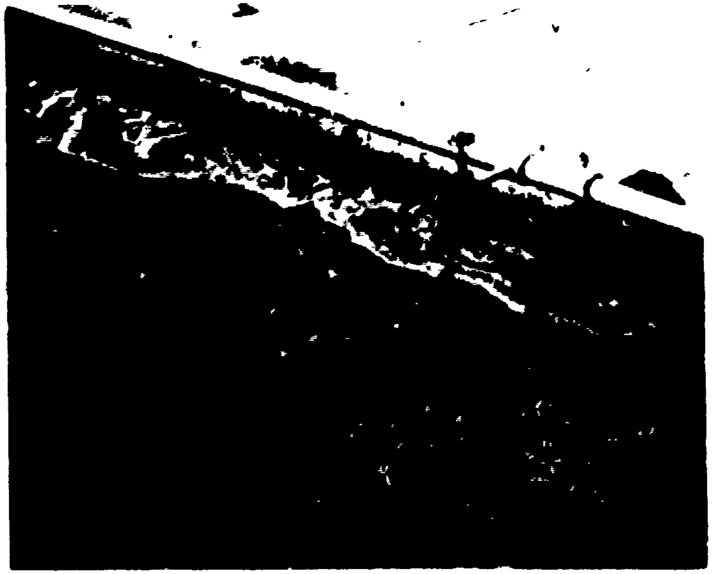
Only a modest accumulation of white, or at least light colored, crisp appearing foam is usually evident on aeration tank surfaces when an excellent final effluent is produced by a properly balanced activated sludge process. Under such circumstances the operator should continue his successful



BILLOWY WHITE FOAM
(Young Sludge)



THICK DARK TANK FOAM
(Old Sludge)



DARK FOAM, BAD ODOR
(Septic Sludge)

control policies until the physical characteristics or the results of other control tests diverge from optimum.

Excessive Billowing White Foam

If the aeration tanks are covered by thick voluminous billows of white sudsy foam, the operator can be quite certain that the sludge is too young and that sludge age should be increased by reducing the sludge wasting rate.

Sludge age, which is controlled by the sludge wasting rate, indicates the approximate number of days that the activated sludge remains in the system before being discarded. Prolonged excessive sludge wasting will reduce sludge age by increasing the proportionate amount of newly developed floc in the system. Conversely, unduly low wasting rates will increase the number of days the sludge is retained in the system and will increase the proportionate amount of older sludge.

Sludge wasting rates should be decreased only gradually on a day-to-day basis to correct the process imbalance that was revealed by the excessive white foam. Best results are usually obtained by reducing the wasting rate approximately twenty percent on each successive day until all observations and tests reveal an improving trend. When positive improvement is noted, the operator should maintain the lowered wasting rate for about three more days while the improving trends are confirmed. He should, of course, continue to plot and review process control and response trends which will alert him to subsequent control adjustment policy that may become necessary. As implied previously, wasting usually should not be discontinued completely. Exceptionally low sludge settling rates and classic bulking that can accompany this type of foam generation may be corrected by reducing air discharge rates to lower the mixed liquor dissolved oxygen concentration to the 0.5 to 1.0 mg/l range.

Thick, Scummy, Dark Tan Foam

At the other extreme, the operator may observe a more dense and somewhat greasy scummy layer of deep tan to brown foam covering the entire aeration tank surface. Such a foam almost always indicates that the sludge is too old and possibly over oxidized. The obvious answer is to increase sludge wasting rates. Here again, the sludge wasting rate should usually be increased modestly, possibly twenty percent per day, on a day-to-day basis while observing trend lines to determine the maximum wasting rate that should be maintained until the difficulties are overcome and the process is restored to proper balance.

SLUDGE COLOR AND ODOR

At times a poor quality extremely dark brown-colored sludge, sometimes almost black, releasing hydrogen sulfide odors, may be observed in the aeration tanks. It does not take much experience to recognize this problem. Most operators would logically increase air discharge rates immediately to provide 2 - 3 mg/l DO throughout the tank contents. In severe cases, when such color and odor persists, despite proper control measures, they should question the adequacy of the aeration devices installed at their plants. Under such circumstances, the operator should clean or replace the existing diffusers and recommend appropriate mechanical modifications as discussed in the section on turbulence and mixing.

The operator should also observe the final effluent and the clarifier water surface critically for additional clues to indicate process phase and balance, and to supplement the results of other control tests to determine sludge wasting and air control requirements.

FINAL EFFLUENT APPEARANCE

If the final effluent appears clear and attractive, or is improving day by day, obviously the operator should continue his present control policy if all control measurements are in the proper range.

Conversely, if it appears turbid or contains noticeable solids, he should modify his operational control policies and procedures. Though observation of poor effluent quality alone will not reveal specific control requirements, it signals the need for judicious review of control and response trends and for revised operating policies. Specific control adjustments will be dictated by the results of other control tests.

FINAL CLARIFIER SURFACE APPEARANCE

Sludge Bulking

Operators who have experienced true classic sludge bulking find it all too easy to remember and identify. Such conditions are evidenced by a homogeneous appearing sludge blanket that extends throughout the entire clarifier, and can be observed at the water surface while the mixed liquor solids pour out over the final effluent weirs. Though at times induced by shock loadings, and aided and abetted by ineffective aeration devices, classic sludge bulking usually is caused by improper operational control rather than by inadequate plant capacity. Furthermore, impending bulking usually can be recognized from the trend charts (Appendix) and by judicious use of the sludge depth blanket finder (Part II Control Tests) many days before it actually occurs.

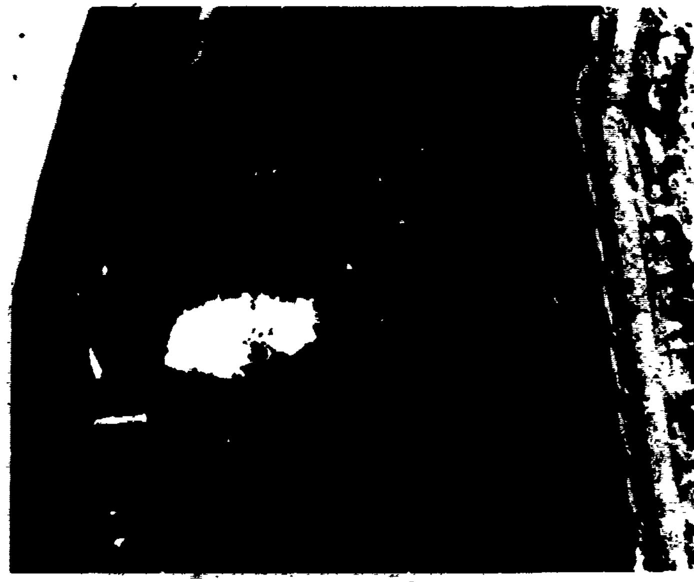
This type of bulking, which is practically always associated with young sludge, usually can be eliminated by reducing sludge wasting rates, increasing return sludge flow rates, and reducing air discharge down to the minimum rates that will maintain aerobic conditions in the aeration tanks. Where appropriate flexibility has been designed into plants, bulking has also been eliminated by changing the process mode from conventional plug flow to step flow by introducing the primary effluent into the second or third bay of the aeration tank.

In some cases where such control adjustments have failed, emergency chemical treatment has cured classic sludge bulking. Some operators have successfully applied polymers and ferric chloride or alum to the mixed liquor entering the final clarifier without destroying desirable sludge characteristics. Laboratory jar tests should be performed to indicate the type of chemical, the dosage rate, and the pH range that will be most effective. If the chemical additives do not cure actual bulking in the final clarifiers, even though the sludge samples settled and compacted in the laboratory jar tests, the chemicals should be added at different points between the aeration tanks and the final clarifiers until best results are obtained. It is usually best to apply chemicals to the wet well preceding, or the pipe line leading to, the final clarifier.

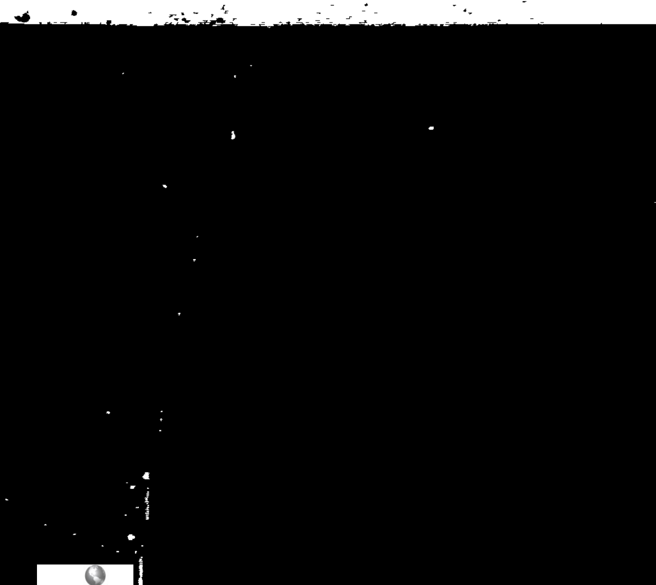
Sludge Solids Washout

Excessive sludge washout over the final effluent weirs, when the upper surface of the sludge blanket is more than

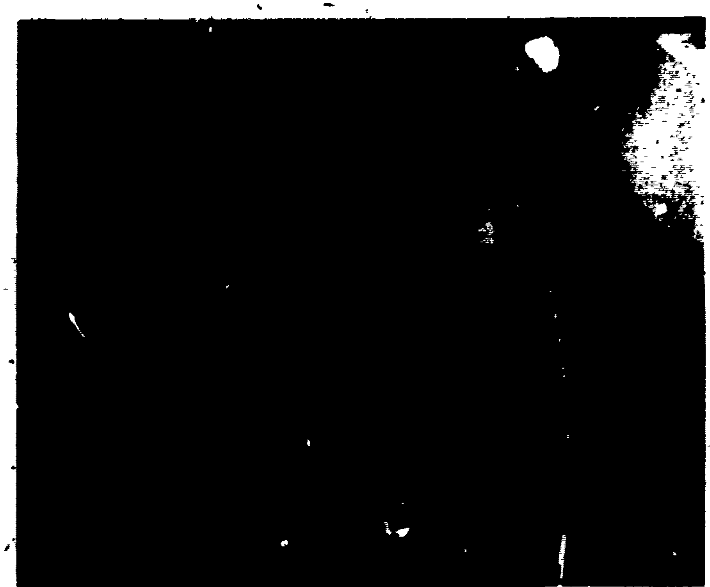
CLASSIC SLUDGE BULKING



SOLIDS WASH OUT



RISING CLUMPS



FLOATING ASH

three feet below the clarifier water surface and when sludge settles properly in the laboratory, should not be confused with classic sludge bulking. At times this type of severe effluent degradation has been observed while the settlometer test revealed excellent sludge quality. In many multiple clarifier plants this has been caused by unequal mixed liquor flow into, or by unequal return sludge removal from, individual final clarifiers. Under such circumstances, where excessive velocity currents are induced, every effort should be made to balance flows into and out of the clarifiers.

Solids washout has also been caused by hydraulic overloading, by improper clarifier inlet port arrangements, and by faulty final effluent weir locations. Differing from classic sludge bulking, this type of problem is more frequently caused by hydraulic overloads or inappropriate final clarifier design rather than by operational control procedures.

Clumping and Ashing

At times, large masses of sludge, possibly as large as one foot in diameter, may be seen rising, then bursting, and finally spreading over the clarifier surface. This has sometimes been called "clumping". At other times, smaller sludge particles, usually deep brown to gray in color, may rise and then spread over the tank surface. Some operators call this "ashing". This problem usually occurs when sludge age has been permitted to increase beyond the optimum equilibrium requirement of the process cycle and it can usually be eliminated by increasing sludge wasting rates. Reducing air discharge rates to the minimum levels that will still maintain aerobic conditions in the aeration tanks has also been helpful.

Straggler Floc

At times, small, almost transparent, very light fluffy, buoyant sludge particles (one-eighth to one-quarter inch in diameter) may be observed rising to the clarifier surface near the outlet weirs. This condition is usually intensified in a shallow clarifier and may be especially noticeable at high return sludge flow rates. When this type of straggler floc is observed while the final effluent is otherwise exceptionally clear, and particularly if it prevailed even during relatively low surface overflow rates, it implies that sludge age should be increased moderately towards optimum. Since this type of straggler floc usually occurs at relatively low mixed liquor solids concentrations and is usually intensified during the early morning hours, it is believed that these particles are fresh, low density portions of new sludge that have been built up over night. Straggler floc formation can be minimized, by reducing sludge wasting rates moderately to increase sludge age while return sludge and air discharge rates are controlled to meet process demands that are calculated from other control tests.

Pin Floc

At other times, very small compact pin floc, usually less than one-thirty-second of an inch in diameter, may be observed suspended throughout moderately turbid final clarifier tank contents. This is a strong indication that sludge age has been increased unduly, and the sludge has become overoxidized. This will be confirmed by the settlometer test if rapidly settling discrete sludge particles appear granular rather than flocculant, and accumulate rather than compact while forming a settlometer sludge blanket. In essence, granular sludge particles were falling through a turbid liquor rather than compacting and squeezing out a clear final effluent.

When these final clarifier characteristics are confirmed by the settlometer test, the sludge wasting rate should be increased while return sludge flow is adjusted to meet other control test demands.

PART II

CONTROL TESTS

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OBJECTIVES

Control tests, that can be run as frequently as needed throughout each 24-hour cycle, reveal sludge quality, process status, and final effluent quality.

Results of the settlometer, centrifuge and final clarifier sludge blanket level tests are used to calculate solids distribution ratios between the aeration tanks and the final clarifiers, sludge detention time in the final clarifiers and other factors influencing process performance.

The coordinated results of the full test series, including flow records, turbidity, and dissolved oxygen test data, are ultimately used to determine the return sludge flow, excess sludge wasting and air discharge rates needed to maintain or restore excellent final effluent quality.

INTRODUCTION

Practically all information needed to define sludge quality and process status and to calculate control adjustment requirements can be determined from the results of a few relatively simple tests. The entire series of settlometer, centrifuge, sludge blanket depth, effluent turbidity and dissolved oxygen tests can be completed in about ninety minutes and can, therefore, be run as frequently as needed throughout each 24-hour cycle. The complete test series should be run at least once every eight-hour operating shift. The sludge blanket and the fifteen minute centrifuge tests should be run more frequently whenever rapidly changing process characteristics demand more critical scrutiny and control. Though simple, informative, and too frequently neglected, these tests are neither new nor difficult. They were, in fact, proposed by E. B. Mallory more than thirty years ago. Though the testing techniques and some of the data processing methodology includes that proposed by Mallory, the procedures and calculations for determining control adjustment requirements, as discussed in these pamphlets, were developed by me.

These discussions include only those control tests that are used directly to identify process performance and to dictate process control adjustments. Other important monitoring type tests, such as BOD, COD, etc., are not included in these discussions.

METER READINGS

Each control test series should be started by reading plant meters to record flow data that are needed to determine process requirements.

Flow records specifically related to control of the activated sludge process include:

AERATION TANKS

Total influent waste water flow to aeration tanks
Return sludge flow to aeration tanks
Total air to aeration tanks

FINAL CLARIFIERS

Mixed liquor flow to clarifiers
Sludge removed from clarifiers

EXCESS SLUDGE TO WASTE

Mixed liquor wasted
Return sludge wasted

The extent of additional flow data needed to evaluate and control total plant performance will vary from plant to plant. Other waste streams that should also be measured could include:

Raw sewage flow
Plant drainage recycled to primaries
Primary sludge flow
Sludge thickener flows
Sludge filtrate flows
Digester supernatant flow
Sludge removed from plant
Plant drainage recycled to aeration tanks
Final effluent reuse
Final effluent flow

The following discussion is limited specifically to the activated sludge portion of the treatment plant. For multiple tank plants, having three aeration tanks and three final clarifiers, for example, the operator should also routinely maintain equal hydraulic loading to each of the parallel operating units.

The following flow rates should be determined during each test period and the 24-hour totalized value of each should be recorded every day.

SEWAGE FLOW INTO EACH AERATION TANK

Frequently overall treatment is impeded when aeration tank loadings cannot be, or are not, balanced properly between the parallel aeration tanks. The better treatment provided by an underloaded tank unit will not compensate fully for the poorer treatment provided by the overloaded unit.

RETURN SLUDGE FLOW INTO EACH AERATION TANK

Maldistribution of return sludge flow, especially when coupled with unequal sewage flow loading between parallel aeration tanks, can further distort the proportionate purification pressures (mixed liquor concentration and detention times) and reduce treatment capability.

AIR DISCHARGE TO EACH AERATION TANK

Here, again, unequal distribution as well as inadequate or excessive total air flow can degrade sludge quality and purification. The basic indicating, recording, and totalizing meters should be used to measure and control air flow to each aeration tank. Simple indicating meters should be observed to assure proper air distribution to the main air headers feeding each bay or compartment of individual aeration tanks.

MIXED LIQUOR FLOW INTO EACH FINAL CLARIFIER

The influent flow to each clarifier should be determined during each test period so that the surface overflow rates and the solids loadings can be distributed properly to each clarifier. This is especially important during troublesome times when rising sludge blankets warn that classic sludge bulking may be imminent.

If the clarifier flows are not balanced properly at such times, mixed liquor sludge can be forced out over the final weirs of the overloaded clarifier, while the sludge blankets in the other clarifiers may remain low enough to produce a clear effluent. Unfortunately, this may occur when proper flow distribution could otherwise have held the sludge blankets safely below the water surface of all clarifiers.

SLUDGE REMOVED FROM EACH CLARIFIER

These meters, one for each tank, should also be read at each test period and the totalized value should be recorded each day. Here again, the need to balance sludge removal from all clarifiers to maintain proper sludge blanket level control is obvious.

EXCESS SLUDGE FLOW TO WASTE

This meter, or meters, should be read at every test period and whenever the wasting rate is changed.

Procedures to use flow data and other control test results to determine return sludge, waste sludge, and other process requirements will be discussed in other parts of this pamphlet series.

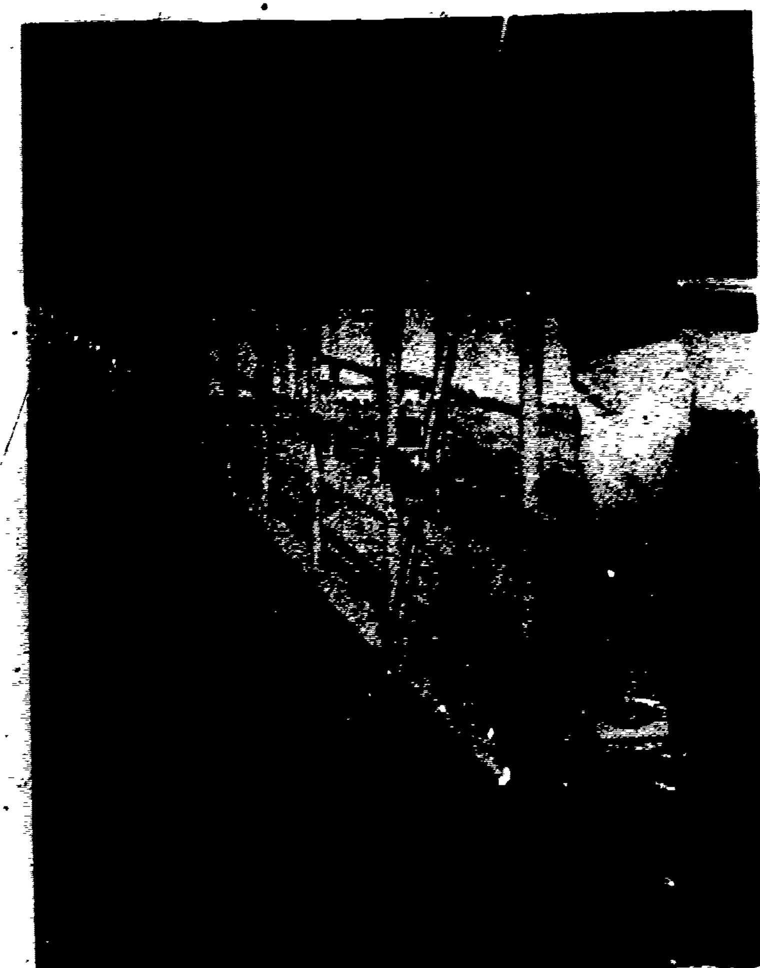
DEPTH OF SLUDGE BLANKET

After checking the meters, an operator following a logical test schedule should move on to determine final clarifier characteristics. He should determine the depth of the sludge blanket that has accumulated within the clarifier and observe conditions at and near the water surface.

Various types of sludge blanket depth finders are used. The type described in the Appendix can be constructed simply and used conveniently; and when handled properly, it becomes a valuable, reliable operational control tool. At least two sludge blanket finders should be provided to assure continuity of test results, especially when one is being repaired. One should be long enough to reach from the bridge to the tank bottom. The other shorter one should only be long enough to extend about half way down into the tank.

Two other types of blanket finders are wands with photo-electric cell actuated buzzers and a series of small

SLUDGE BLANKET FINDER
LIGHT AND SIGHT GLASS



OPERATOR STARTING
DEPTH OF BLANKET TEST

airlift pumps extending down to different measured depths within the final clarifier. The operator should use the type he finds most convenient, but it is suggested that the reliable pipe and sight glass type be provided, at least as a back-up instrument.

It takes a little practice for an operator to use a blanket finder, or, more exactly, to know what he is looking for, but after the first few diligent attempts he will be surprised at how accurately and easily blanket depths can be determined.

A cross section of most clarifiers containing a reasonably good sludge solids distribution balance may reveal a zone of discrete straggler floc particles settling down to form the blanket. Somewhat farther than half-way down into the tank, there will usually be a distinct plane of demarcation between the individual settling sludge particles and the relatively thin, but quite homogeneous, upper surface of the accumulated sludge blanket. Then the concentration of this sludge blanket will usually increase in density down to the zone of maximum compaction at the very bottom of the tank.

Here are two precautions - which will only be resolved by practice. Do not stop the downward movement of the blanket finder when the individual discrete sludge particles are observed. Secondly, do not force the blanket finder down to the point where the denser sludge within the blanket actually obscures the light. Instead, move the blanket finder down at a rather rapid uniform rate through the clear liquor, then continue down through the zone containing individual floc particles, and finally stop when the upper surface of the definite homogeneous sludge mass is observed. Take your reading at this point; you have reached the upper surface of the sludge blanket.

The blanket reading station should be located at a point where the single measurement will approximate the average depth of the entire sludge blanket. A station on the final clarifier bridge, about one-third of the tank radius in from the outer tank wall, will usually satisfy this requirement. The selected station should be marked so that blanket depths are always measured at the same location.

SAMPLE COLLECTION

Samples for the control tests and other laboratory work must be collected on time, from appropriate locations, and according to approved procedures; and they certainly must be representative. These elementary principles can not be violated without cost.

CENTRIFUGE TEST SAMPLES

After observing the clarifiers, return sludge samples should be collected for the centrifuge test. Selection of the sampling station for collecting samples that truly represent the actual quality of the entire return and waste sludge flow is most important. It is best to collect the sample from the point where the thoroughly mixed return sludge from all clarifiers enters the aeration tanks. If such location is inaccessible, the sample should be taken from a tap off the return sludge pump discharge header. The sample pipe should obviously be flushed out thoroughly before each sample is collected. Since mixing may be inadequate, sampling from deep wet wells should be avoided if at all possible.

In addition to the sample collected for basic plant control, individual return sludge samples should be collected from each final clarifier to check or to balance multi-tank performance.

At times, samples should be collected from each of the individual sludge draw-off tubes in each final clarifier. This series of samples need be collected only as frequently as required to assure uniform sludge withdrawal from the entire clarifier floor area. Ordinarily, such "trim spin" samples are collected about once each week.

The samples collected for the settlometer test, as described in a following section, will also be used to determine the centrifuged concentration of the mixed liquor solids.

TURBIDITY TEST SAMPLES

Special samples should also be collected from the final clarifier to determine the turbidity of the treated waste. These samples for turbidity should be collected deliberately from the clearest area of the final clarifier water surface that contains the least surface sludge or scum that may be present. When collected in this manner, these samples will indicate specific process performance, undistorted by clarifier or other equipment defects that may need correction. Other 24-hour composite samples collected for plant monitoring (BOD, COD, TSS, etc.) will be used to determine net process performance.

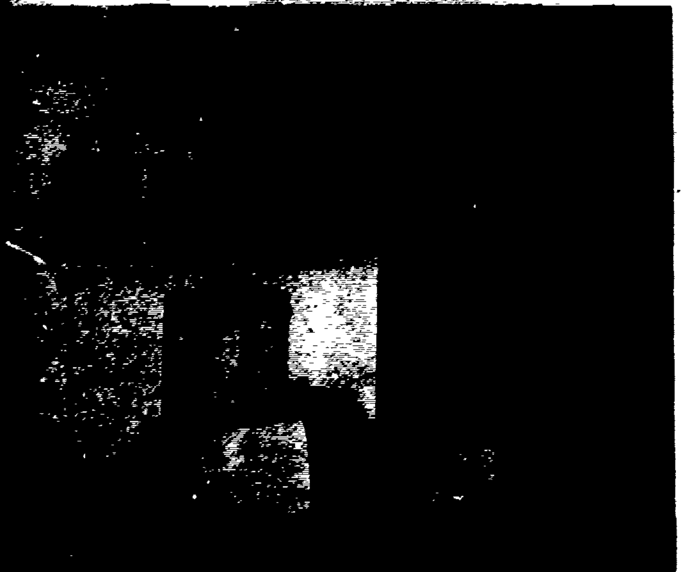
SETTLOMETER TEST SAMPLES

The mixed liquor sample for the settlometer test should be collected last of all. This sample, which should represent the average quality of all mixed liquor flowing out of all aeration tanks, will also be used to determine solids concentration both by centrifuge and by weight. Preferably, this sample should be collected from the common discharge flume that contains all mixed liquor flowing from the outlet of all active aeration tanks. If the common discharge header is inaccessible, equal volumes of mixed liquor should be collected from the outlet end of each aeration tank and composited into a single representative sample for the settleability and solids concentration tests.

The necessity for collecting mixed liquor samples in wide-mouthed containers, rushing the samples to the laboratory, and starting the settlometer test immediately, can not be over emphasized. After collection, the samples should be subjected to the absolute minimum amount of agitation and aeration. Improper sample handling, such as violent shaking or splashing, or unwarranted delay between the time that the sample is collected and the time it is poured into the settlometer, can alter sludge settling characteristics and induce erroneous settlometer test results.

SETTLOMETER TESTS

Preferably, mixed liquor sludge settleability tests should be determined in a clear glass cylinder with a larger diameter and a lesser depth than the standard 1,000 cc graduated cylinder that is frequently used for this test. A glass cylinder shaped similar to the standard two-liter beaker, but with better graduations and without the rounded bottom edge, would be satisfactory. Many operators now prefer the five inch diameter, six inch graduated depth, two-liter Mallory settlometer that is graduated in tenths and hundredths of the settlometer volume. Satisfactory settlometers can also be fabricated from five inch diameter clear plexiglass cylinders.



TEST SET-UP

5 MINUTE READING

1 HOUR APPEARANCE

1 HOUR READING

SETTLOMETER TEST

The mixed liquor sludge sample should be stirred and then poured into the settlometer carefully and rapidly and with the least possible amount of additional aeration or disturbance. The settlometer contents should then be stirred gently to assure thorough mixing; then all swirling should be dampened immediately with a wide paddle (four inch sheet aluminum works well) before the timer is started.

The volume of the settlometer occupied by settled sludge should be read and recorded at every five-minute interval for the first thirty minutes and then every ten-minute interval for the second thirty minutes of the one hour settlometer test. This is the standard test duration.

When sludge settles extremely slow, or when bulking actually occurs, the settlometer test period should be extended beyond the one hour reading. By returning to observe the settled sludge volume after 2, 3, 4, etc. hours, the operator will be able to determine ultimate sludge compaction for a more thorough process evaluation.

Running simultaneous multiple settlometer tests on diluted specimens of slowly settling mixed liquor can help the operator decide whether to increase or decrease the sludge wasting rate. At least two dilutions should be made. One settlometer should contain undiluted mixed liquor, one should contain about 75% mixed liquor diluted with 25% final effluent, and a third settlometer should contain half mixed liquor and half final effluent.

Though this expanded multiple dilution test need be run only once per day while the slow settling problem persists, it should follow the previously stated standard procedures. If confirmed by other control test results, these multiple settlometer test results can reveal the following control adjustment needs.

If the diluted samples settle much more rapidly than the undiluted sample (especially during the first 10 minutes), the system contains too many fair to good quality mixed liquor solids and sludge wasting should most probably be increased.

If the diluted samples settle at the same rate, or only slightly faster than the undiluted mixed liquor sample (especially during the first 10 minutes), the mixed liquor sludge is truly bulky. This has been caused frequently by excessively heavy wasting which reduced sludge age way below the optimum. Sludge wasting should usually be reduced (but not down to zero) modestly, day by day, to develop a sludge that can concentrate more.

Operators who set up a test cylinder, walk away, and then return for only one single observation after thirty minutes, miss most of the information that actually defines sludge quality. A single thirty-minute test, to determine SVI, is somewhat like a five-day BOD, in that it reveals only one point in a progressive reaction and it will not help an evaluator who is really interested in reaction rates and the full impact of ultimate demands.

The first five-minute reading is one of the two most important observations for this test. During this first five minutes the conscientious operator will critically observe how the sludge particles agglomerate while forming the blanket. He will see whether the sludge compacts slowly and uniformly while squeezing clear liquid from the sludge mass, or whether tightly knotted sludge particles are simply falling down through a turbid effluent. He will also observe how much and what type of straggler floc, if any, remains in the supernatant liquor above the main sludge mass.

The importance of conscientious, perceptive observation during the first five minutes can not be over emphasized. During these first five minutes the operator will acquire additional insight into sludge character and quality, and will be in a much better position to evaluate what the settlometer test reveals.

The sixty-minute reading is the second most important observation. It provides a check on final clarifier sludge blanket characteristics and is used to compute process equilibrium indices and operational control adjustment requirements.

After the tests are completed, the settlometers should remain undisturbed for at least four hours. The time at which previously compacted sludge starts to swell and rise to the surface is another important indicator of sludge quality. Settled sludge should not remain down forever, any more than it should gasify and pop to the surface during the sixty-minute test cycle. Well-oxidized sludge will frequently begin to swell somewhat after ninety minutes and will usually float to the surface within two to four hours after the test was started.

A portion of the sample collected for the settlometer test should be saved for solids determinations.

CENTRIFUGE TESTS

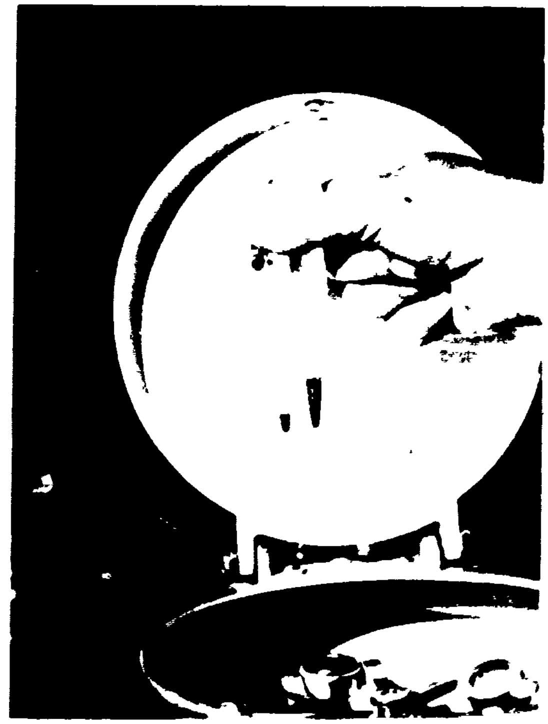
The centrifuge permits rapid determination of mixed liquor and return sludge solids concentrations for immediate use in calculating solids distribution ratios, effective return sludge percentages, solids concentration rates, clarifier sludge detention times, and a host of other process relationships used to determine operational control demands.

The use of 12.5 ml API (American Petroleum Institute) centrifuge tubes in a clinical centrifuge, with a six place horizontal head, revolving at full speed (position 7 on the International No. 428, for example) has been found convenient and appropriate for sewage plant control testing. The mixed liquor and return sludge specimens should be centrifuged for a standardized fifteen minute interval to assure consistent compaction and to avoid discrepancies that can be introduced by slight variations in testing time when shorter intervals (say from one to three minutes) are used. Shorter time intervals may be used for "trim spins" and other special tests when many specimens are centrifuged to determine the solids balance in multiple aeration tanks or clarifiers.

The centrifuge is an exceedingly useful and convenient tool for searching out and correcting unbalanced sewage or return sludg flow distribution as well as unequal mixed liquor and return sludge solids concentrations in multiple tank plants. It has also been used effectively to determine return sludge percentages in the all too many cases where flow meters have been missing or were in error. Mixed liquor and return sludge concentration data frequently are plugged into the mixing formulas, described in Part IIIA. It is then possible to determine either the primary effluent flow rate into the aeration tanks or the sludge withdrawal rate from the final clarifiers when either of the meters for these two locations is missing or inoperative.

Some operators question the use of the centrifuge for sludge concentration determination because such tests results can not always be correlated with suspended solids determinations by the laboratory balance. The variation in the ratio of mixed liquor suspended solids concentration determined by the laboratory balance to that determined by

PROPER SAMPLE HANDLING FOR TURBIDITY TEST



CENTRIFUGED SLUDGE SAMPLES

TURBIDITY READING

the centrifuge is affected by sludge age and oxidation and is, therefore, one of the virtues of the centrifuge test; not a defect. Furthermore, the centrifuge test result, because it is influenced by the specific gravity and the surface area of the sludge mass, provides a realistic measure of effective sludge concentration.

EFFLUENT TURBIDITY TESTS

Two turbidity determinations should be made on the sample collected from the final clarifier. A photo-electric activated readout type turbidimeter with results expressed in Jackson Turbidity Units (JTU) or Formazin Turbidity Units (FTU) is recommended. The turbidity of excellent final effluents usually ranges between 1.0 and 3.0 JTU. Final effluent turbidities greater than 3.0, and especially those exceeding 10.0 JTU, indicate that the full purification capability of the activated sludge process has not been achieved.

The first turbidity determination should be made shortly after the settlometer and centrifuge tests have been started. The sample should be stirred (only for the first test) before it is poured into the turbidimeter test vial. The vial exterior should always be wiped clean and dry before insertion into the turbidimeter. This precaution will protect the internal components and enhance accuracy.

The final effluent sample should then be put aside for a one-hour settling period to permit gravity separation of extraneous floatable scums and settleable solids that may be attributed to flow overloads or inappropriate final clarifier features. At the end of this time interval, the turbidity of the subnatant liquor in the settled final effluent sample should be determined.

Special additional precautions should be observed while pouring the "settled" specimens into the turbidimeter test vial. The specimen container should be carefully lifted from the work bench and any accumulated surface scum should be poured to waste before the settled liquid (free from any sludge that may have settled to the bottom of the container) is poured into the test vial. The pouring operation must be gradual and continuous to avoid creating air bubbles and to eliminate surface scums or settled solids that might otherwise cause erroneous interpretation of the test results.

When performed properly, the turbidity test will reflect process performance. If the final effluent contains excessive suspended solids, for example, differences in the turbidity test results on settled versus unsettled effluent specimens will indicate whether the problem was created by improper process control, hydraulic overloads or by defective final clarifiers. In other words, if the final clarifiers lack scum baffles and skimmers or have inappropriately placed final effluent launders, or if the tank geometry induces unnecessary velocity currents, the turbidity of the settled specimen will reveal the true effect of control adjustments on sludge characteristics and process equilibrium. Many times the final effluent produced by good sludge at proper process equilibrium contains unnecessarily high concentrations of solids that are needlessly forced out of the clarifiers by inappropriate or malfunctioning equipment. The object of this turbidity test is to define process response and control requirements rather than to document built-in, and usually not immediately correctable, plant defects.

Turbidimeter calibration and use should follow manufacturer's instructions. Where multiple turbidity standards are supplied with the equipment, the turbidimeter should be calibrated with the standard closest to the anticipated effluent turbidity. If, for example, 1.0, 10.0, and 100.0 FTU standards were provided, and the equipment had been calibrated with the 100 FTU standard, but the effluent turbidity read out at less than 10 FTU; the meter should be recalibrated with the 10 FTU standard and reread.

DISSOLVED OXYGEN TESTS

At least once per day, and preferably once during each eight hour shift, dissolved oxygen concentrations should be determined at the inlet and at the outlet ends of each "pass" or compartmented area of the aeration tanks. Additional dissolved oxygen determinations should be made more frequently at "one" or "a single" aeration tank sampling station to reveal dissolved oxygen variations throughout each 24-hour cycle. These additional tests usually are run once every four hours and should be scheduled to include the intervals when influent loads increase in the early afternoon and decrease in the early morning hours. A battery-operated dissolved oxygen field probe is much more convenient to use and provides more accurate mixed liquor DO values than the Winkler Method.

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