A Rapid Centrifuge Method for Determination and Control of Sludge Concentration in Activated Sludge Plants

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Abstract

A simple, fast, inexpensive method of limited accuracy to determine mixed liquor suspended solids (MLSS) for activated sludge plant control is described. It is intended for use at small activated sludge plants to replace the usual half-hour sludge settled volume [SSV (½h)] test currently in use for sludge concentration control. However, the SSV (½h) test should not be discarded entirely since it is required for sludge volume index (SVI) calculations.

Introduction

The "Half hour sludge settled volume" [SSV (½h)] test, using a 1 ℓ cylinder is almost exclusively employed in this country for sludge concentration control in small activated sludge plants and package plants. It is, however, a most unsatisfactory test and operators, who fail to appreciate the pitfalls of bulking sludge, can easily land their plant in trouble, if too much reliance is placed on this test.

Controlling the installations by the mixed liquor suspended solid (MLSS) parameter would bring about a vast improvement in plant control, but the usual method for determining MLSS requires expensive apparatus and a certain degree of skill, which are not normally available at these smaller plants.

It is, therefore, proposed to replace, or at least supplement, the "Half hour sludge settled volume" [SSV (½h)] test with a simple, much more reliable and quicker test for determining the sludge concentration (MLSS). In this test the volume of sludge is determined to which a given solids suspension will compact, when centrifuged for a selected period of time at a given centrifugal force.

The idea of using a centrifuge to determine the MLSS concentration of activated sludge is by no means new and various authors have reported on the method. Setter (1935) proposed that a correlation for suspended solids determinations could be established between the centrifuge and gravimetric techniques. He attempted to display this relationship by a linear plot of centrifuged sludge volume (per cent) versus suspended solids (gravimetric) in mg/ℓ. Setter made no distinction between the various types of sludges (i.e. sludges with varying solids retention times (SRT)), when establishing a correlation for the two methods. Martinson and Deaner (1976), however, maintain that a single correlation for all types of sludges cannot exist. This is accepted as true, but nevertheless, the deviations from a straight line relationship for different types of sludges were found to be by no means as large as those when comparing the half hour sludge settled volume with the MLSS (gravimetric), Fig. 2. So there would be an advantage in this method of sludge concentration control over the former method. The method is in fact being applied in the U.S.A. West, (1974) considers the fact that the centrifuge method is affected by sludge age to be one of the virtues of the test and not a defect. He maintains it provides a realistic measure of effective sludge concentration.

The straight line equation $Y = KX + b$ would in this relationship have the b intercept as zero, which simplifies the equation to $Y = KX$, so that MLSS = K (centrifuge sludge volume), for tests done under standard conditions. The value of K, as determined for a specific sludge at various dilutions for 100 per cent correlation, will be different for each other type of sludge and therefore according to Martinson and Deaner, an all encompassing coefficient K for all sludges does not exist. Although these limitations apply a case can still be made out for adopting the centrifuge method described below to supplement the half hour sludge settled volume [SSV (½h)] test for sludge control on the plant.

Apparatus

The method was standardized for a Hettich Rotofix II – centrifuge with a swing-out head to hold two centrifuge tubes (Pyrex glass or similar) with a conical lower end, marked for 10 mℓ and graduated for readings to 0,1 mℓ accuracy. Each tube is 111 mm long × 17,5 mm in diameter. It can hold 15 mℓ and using pipettes a graduation mark is made at this point. Such tubes are readily obtainable from suppliers of laboratory equipment. Any other suitably sized clinical centrifuge with the same type and size of swing-out head, arm length 140 mm which can be run at 2 000 rpm i.e. supply a centrifugal force of 625 g and which can accommodate the tube size mentioned, can be used.

Method

Fill both tubes to the 15 mℓ mark with well stirred, mixed liquor from the activated sludge plant, place into the centrifuge to balance, switch on at zero time and let it speed up to 2 000 rpm as rapidly as possible. Run for exactly 2 minutes and switch off. Allow the centrifuge to come to rest on its own and immediately take out the tubes and read the sludge levels as accurately as possible and average the readings. If the reading is not taken immediately, the sludge swells a little and the reading will be incorrect. This reading is then multiplied by a factor K, which has been determined experimentally. The tubes have to be cleaned out as soon as possible after use with the aid of a pointed instrument and a strong, fine jet of water.

Experimental Results for Determination of Factor K for MLSS by Centrifuge

Activated sludge samples taken at random from various sources were subjected to the centrifuge test described above; the MLSS was determined by the usual gravimetric method using millipore filters and on some of the samples a sludge settled volume (½h) test was also done. The results are tabulated in Table 1 from which the plots in Figures 1 and 2 were constructed.

TABLE 1

RESULTS AS SHOWN FOR ACTIVATED SLUDGE FROM VARIOUS SOURCES

Source of sludge	Centrifuge Tube reading mℓ	MLSS* mg/ℓ	Sludge settled volume (½h) mℓ/ℓ	Sludge volume Index mℓ/g
Moroka	1,60	5604	–	
Orbal, Daspoort	0,30	1276	–	
Bardenpho Plant	0,65	2124	–	
Expt. Lab. Units 1	0,50	1560	–	
Expt. Lab. Units 2	1,02	3216	–	
Orbal, Daspoort	0,37	1544	160	104
Bardenpho Daspoort	0,60	2188	785	359
Daspoort, Municipal plant	1,30	5440	460	85
Baviaanspoort	1,15	3236	950	293
Expt. Lab. Units 1	1,8	6280	–	–
Expt. Lab. Units 2	1,7	6652	–	–
Orbal, Daspoort	1,05	3816	915	240
Bardenpho, Daspoort	0,55	2236	975	436
Daspoort, Municipal plant	1,30	6232	570	91,5
Baviaanspoort	0,65	2972	870	341
Expt. Lab. Units 1	0,70	3512	–	–
Expt. Lab. Units 2	0,38	1780	–	–
Orbal, Daspoort	0,95	3948	720	182
Bardenpho, Daspoort	0,46	1844	860	466
Heidelberg, Simplex	1,7	4604	1000	–
Heidelberg, Carrousel	1,10	4736	800	169
Bardenpho Pilot plant 1	0,75	3924	220	56,1
Bardenpho Pilot plant 2	0,63	3288	–	–
Daspoort, Municipal plant	1,18	5476	805	147
Bardenpho Pilot plant	0,80	3952	238	60,2
Viviers Lime Floc. plant	0,38	2548	300	118
Daspoort Municipal plant	1,43	6364	900	141,5
Nylstroom, Orbal	0,35	2184	160	74
Phoenix Colliery	0,70	4080	835	205
Bronkhorstspruit (P.D.)	1,10	6260	915	146

*MLSS = mixed liquor suspended solids

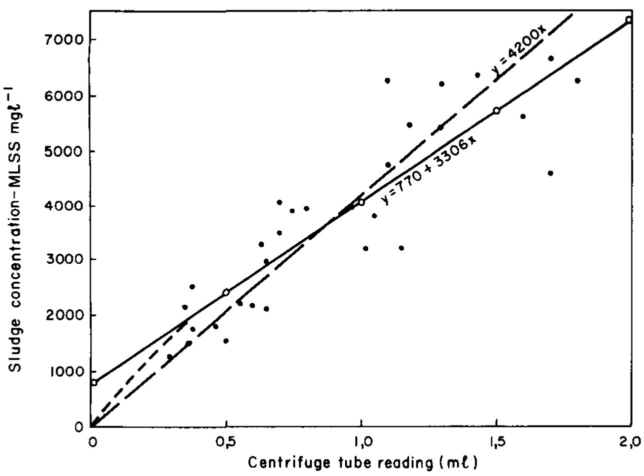

Figure 1
Centrifuge tube reading vs MLSS

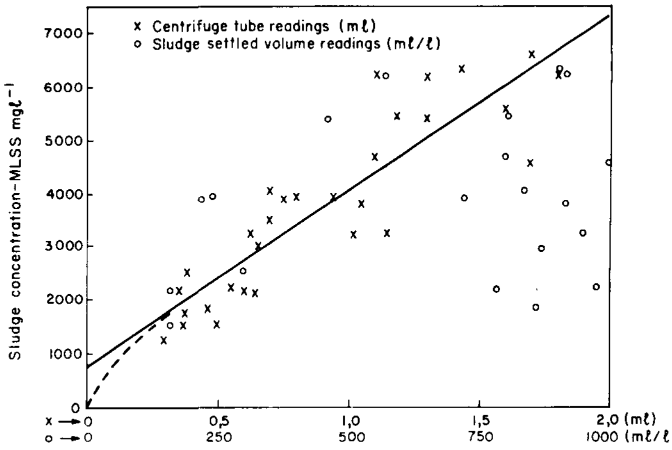

Figure 2
Comparison. MLSS with centrifuge tube and sludge settled volume readings

A regression analysis for the centrifuge tube readings X versus MLSS (Y) gave Y = 770 + 3306 X i.e. the line of best fit for the points. The correlation coefficient 0,78 (n = 30) is quite significant. This line, shown in Figure 1, should actually pass through zero, hence the formula might apply only for centrifuge tube readings above 0,3 mℓ.

Then MLSS = (centrifuge tube reading × 3306 + 770) mg/ℓ

However, in practice, a simpler formula is desirable viz MLSS = 4200 X, which is represented by the dashed line, Figure 1.

It must be realized that the K value of 4 200 is only an approximate average, since in general, as mentioned previously, the K value will vary with the character of the sludge. A laboratory having the facilities could thus determine the K values for different solids retention times (provided these are accurately known) and thus obtain a more reliable centrifuge determination for MLSS.

In Figure 2 it is shown that the centrifuge method of determining MLSS, being a simpler and quicker determination than the gravimetric method, will give a much more reliable indication for activated sludge operation control than the half-hour sludge settled volume test which is at present usually applied at small sewage works. The half-hour sludge settled volume (SSV) readings have a considerably larger scatter than the centrifuge test readings and bear very little relationship to the actual sludge concentration which is the essential parameter. This is because of sludge density variations.

From the results of the two tests, the sludge volume index (SVI) can be calculated.

$$SVI = \frac{\text{½ hour SSV m}\ell/\ell}{\text{MLSS g}/\ell}$$

This gives an indication of the sludge density. It is not a very meaningful parameter and will merely indicate whether mixed liquor sludge characteristics tend towards bulking or not. SVI's of roughly 50 – 150 mg/mℓ indicate a normal sludge. Above 150 it denotes increasingly bulky sludge, which could lead to sludge losses on the plant.

Discussion

The sludge concentration, MLSS, at which a certain plant should be run and controlled depends on many factors, and usually the designer will specify more or less the concentration at which the plant should be operated, at around 20°C at full design loading. Owing to the effect of temperature on the activity of organisms, particularly nitrifiers, the operating sludge concentration should be higher in winter than in summer. For daily control determinations of MLSS the centrifuge method would be an invaluable aid, which more than warrants the purchase of a suitable centrifuge. The determinations of the MLSS by the method are bound to be more accurate when higher centrifuge speeds are used and a longer centrifuging time is chosen. However, a new K value must then be determined. In any case, it would be preferable to determine K for each individual works, if possible.

Conclusion

The determination of the sludge concentration in activated sludge mixed liquors using a centrifuge method is considered sufficiently accurate and more suitable for plant control purposes than the half hour sludge settled volume test. It is recommended that small treatment works which have no control laboratory should at least avail themselves of this method for plant control.

Acknowledgement

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