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*Research Article*

# Secondary Settling Tanks Enhancement using Effective Microorganisms

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***Abstract***

*Improving the settling properties of sludge is one of the main consultations in order to help enhancement the effluent quality to fit in the standards. In this research paper effective microorganisms (EM) were tested to improve the settling properties of aeration tank effluent. EM were tested as an additive in two different ways –instantaneous and continuous addition- and was investigated based on zone settling velocity, sludge volume index, final sludge concentration and limiting solid flux. Results were compared with the corresponding properties of a control sludge sample. Using of EM improved the settling properties of activated sludge and continuous EM addition was more effective than the instantaneous EM addition as the zone settling velocity, final sludge concentration and limiting solid flux values increased, while the sludge volume index decreased. The cost of using EM was primary estimated and compared to the cost of other additives.*

***Keywords:*** *EM, Sludge settling, solid flux, SVI, zone settling velocity.*

## 1. Introduction

Solid-liquid separation process is the final step of the activated sludge process, in which by gravitational settling the denser solid phase (the activated sludge mass) is separated from the liquid phase (Henze *et al.*, 2008). Tanks used for this process called Secondary settling tanks (S.S.T), these tanks not only separates the mixed liquor suspended solids (MLSS) but also designed for thicken of the settled sludge to maintain a continuous underflow concentrated sludge for recirculation to the biological reactor before returning it to the aeration process or to wasting (WAS) (Ekama *et al.*, 1997), (WEF, 2005).

Sufficient understanding of the settling processes of Activated sludge is required for proper design and operational control of SST (Mines Jr. *et al.*, 2001; Jin *et al.*, 2003). Suspended solids settling behavior vary among different regions in the SST and are governed by the sludge concentration and its flocculation tendency. Based on the latter two factors, Ekama *et al.* (1997) classified the settling behavior in four settling regimes which all occur simultaneously in the clarifier.

- Discrete non-flocculent settling
- Discrete flocculent settling
- Zone settling or hindered settling
- Compressive settling

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Design and operation of S.S.T is commonly based on the solid flux theory, the basic data required for the application of this theory can be obtained from multiple batch tests by which the stirred zone settling velocities (V) over a range of sludge concentrations(X) are measured (dilution experiment) (Vanderhasselt and Vanrolleghem, 2000).

Depending of batch settling test two main approaches may be used the 1st one is the Vesilind approach using zone settling velocity(Vzs) data, the 2nd one is Cho et al. method (direct parameter estimation) relying on a single batch settling curve, Vanderhasselt and Vanrolleghem (2000) compared these two approaches and declared that the Vesilind model is superior to the Cho et al. model in describing the relationship between Vzs and X, while the Cho et al. model is better in describing complete settling curves.

The performance of the S.S.T can be compromised by four different reasons (foaming, pin-point flocs, viscous bulking and filamentous bulking), while "filamentous bulking" which defined as the excessive development of filamentous bacteria in the sludge, is the most common cause of poor settling (Seka *et al*, 2001), (Mamais *et al*, 2011).

Several possible solutions exist to overcome these problems (assuming that the hydraulic conditions are favorable). One of these potential solutions is the addition of suitable amounts of additives to S.S.T influent. Different organic and inorganic additives have been tested and reported; Seka *et al*, (2001) used a multi-compound additive consisting of a synthetic cationic polymer, a weighting agent (alumino–silicate in the form of a talc powder), and a biocide (quaternary ammonium compound) to treat sludge from industrial treatment plants. Farid (2007) investigate the effect of using different cations on bio flocculation in terms of flocs disintegration when exposed to shear forces and found that using these chemicals increase the biofloculation and enhance the settling properties.

Al-Jasser (2009) studied the effect of using seven chemicals as additives to improve the settling properties of secondary sedimentation tanks, based on the characterization parameters tested in his study Zetage-7563 surpassed the other tested additives.

Mamais et al, (2011) evaluate the efficiency of different coagulants (ferric chloride, ferrous chloride, polyaluminium chloride, hydrated aluminum sulphate, cationic polymer) to solve filamentous foaming and bulking problems, and found that Polyaluminium chloride and cationic polymer proved to be the most efficient among the coagulants investigated.

The main problem associated with the use of chemicals additives in the treatment process was the increase in the sludge production; Mamais *et al*, (2011) reported an increase in total suspended solids concentration before and after inorganic chemicals addition by approximately 3.3 (gr.SS/gr.$Al^{3+}$) and 2.0 (gr.SS/gr.$Fe^{3+}$) added, respectively, while no measurable increase in solids concentration was obtained with organic polymer addition.

EM technology was primarily focused on improving productivity in agriculture but then came to prove to have important role to play in wastewater treatment processes, as it was used in the treatment of polluted rivers and streams (Wood *et al*, 2001), in septic tank systems, lagoons, activated sludge systems and UASB (El karamany *et al*, 2011), in the onsite sanitations septic tanks as EM decreased the volumes of sludge produced, with the benefits of reduced sludge handling, and consequently lower costs and decreased impacts upon the environment (Szymanski and Patterson, 2003), in the treatment of aerobic sewage sludge (Namsivayam *et al*, 2011), (Saleh, 2013), anaerobic sewage sludge (Ahmed *et al*, 2013). EM has effectively improved sludge digestion in mesophilic digesters receiving a mixture of primary and secondary sludge for batch digesters (El Monayeri *et al*, 2013), and for the semi-continuous digesters (Aboulfotoh A.M., 2013), and also improved the dewaterability of sewage sludge (Shihab M.S., 2015).

The goal of this research paper was to study the improvement in sedimentation properties produced by the addition of effective microorganisms to effluent from the aeration tank of a conventional activated sludge process. EM were tested as an additive using a dose of (1/1000) per volume, this addition were tested in two different ways –instantaneous and continuous addition- zone settling velocity, sludge volume index, final sludge concentration and limiting solid flux were the parameters investigated in this study. The results were compared with the corresponding properties of a control sludge sample.

## 2. Materials and methods

The experimental work related to this research took place at the environmental engineering laboratory, faculty of engineering, Zagazig University, Zagazig, Egypt.

### *2.1 Waste Activated Sludge*

Waste activated sludge used in this study was produced from two pilot activated sludge systems, the first system was conventional activated sludge, the second system consists of aeration tank and secondary settling tank continuously treated by addition of EM. Sludge from the first system was used as control sludge and also to investigate the effect of the instantaneous addition of EM, while sludge from the second system was used to determine the effect of the continuous addition of EM on the settling characteristics of sludge.

### *2.2 Batch settling tests*

The batch settling tests were done in a glass column of 400 mm height and 61 mm diameter, the column was filled by a sludge sample at a certain solids concentration, then sludge was allowed to settle during which the position of the suspension/liquid interface is measured at different time instants. By conducting a number of stirred settling tests at different concentrations ranging between 1 and 12 (g/l) (at least 6) the Vzs at different X values is obtained (Anna Stypka, 1998). So in this study 7 different initial sludge solid concentrations were tested (10, 8, 6, 4.5, 3, 2, 1.5 (g/l)) each initial concentration was tested at least twice.

To ensure that the linear part of the settling curve is captured accurately, the height of the sludge blanket is measured at a higher time resolution during the first 10 minutes of the test. During the following part of the test, the settling velocity reduces and hence the frequency of measurements is also decreased. The height of the solid/liquid interface is measured at following time instants: 0, 1, 2, 3, 5, 7.5,10, 15, 20, 25, 30, 35, 40, 45, 60, 80, 100 and 120 min.

### *2.3 Sludge volume index (SVI)*

SVI is the volume (in mL) occupied by 1 g of a suspension after 30 minutes settling (Eaton *et al*., 1995). The SVI provides information on the settleability of the sludge. For the determination of the SVI, sludge sample with known solid concentration was introduced in a graduated cylinder with a volume of 1 L. After 30 min, the volume occupied by the sludge is read from the graduated cylinder (in mL/L).

SVI can then be calculated from Equation 1, where X is the initial concentration of the sludge in g/L.

$$SVI = \frac{\text{settled sludge volume}}{X} \quad (1)$$

*2.4 EM source and activation*

Effective microorganisms (EM) used in this study was obtained from the Egyptian Ministry of Agriculture and Land Reclamation; it was in a sealed container and needs to be activated. The activation of EM steps is as follow:

1) Plastic bottle 1000 ml was used.
2) 800 ml tab water, 150ml of molasses and 50ml of EM was placed in the bottle.
3) The bottle was then shacked in order to dissolve the molasses.
4) Then the bottle was caped tightly and kept in a warm place.

Activated EM is ready to use, 4 - 7 days after preparing it, when the pH drops below 4.0 (ideally it has a pH between 3 - 3.5), and when it has a sweet-sour smell and has changed color from black to reddish brown.

*2.5 EM addition*

Instantaneous addition of EM was measured by the addition of (1/1000) by volume of the activated EM to the control sludge and then gentle mixing for 30 minutes before starting of the batch settling tests, while for continuous addition of EM the same dose of (1/1000) was continuously added to the influent flow of the aeration tank.

## 3. Results and discussion

*3.1 Sludge batch settling curves*

Figure (1) shows the settling test curve for control sludge, instantaneous EM addition, and continuous EM addition, the settling curves for the control sludge are complying with the results of Balemans (2014) who conducted a series of settling test on activated sludge and found that for each set of batch settling test, a clear distinction between the shape of the settling curves at low (below 5g/l) and high (above 5g/l) initial concentration is observed. These results also comply with the results of Chen *et al.* (1996) and Janczukowicz *et al.* (2001). EM addition improved the settling of sludge as at any given time the sludge interface height for treated sludge is lower than that of the untreated sludge for the same initial concentration, continuous addition of EM have a higher effect than the instantaneous addition.

Final concentration of the sludge by EM addition (figure 2) and the increased percent ranged from 5 to 15 % and from 15 to 50% for instantaneous and continuous EM addition respectively. The maximum final concentration was reported for initial sludge concentration of 3 (g/l) and reaches 22.22 (g/l), Hanel (1988) reported that in well settling sludge, at very long sedimentation time, sludge concentration can rise even to 25.00 (g/l). However, it can only reach from 1.00 to 2.00 (g/l) in bulking sludge.

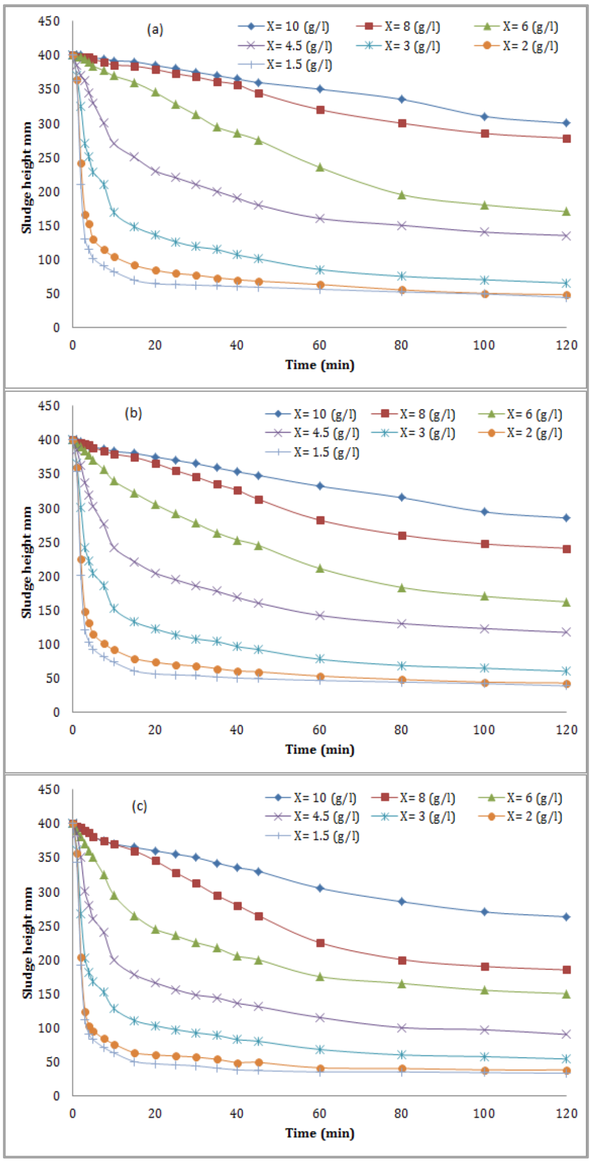


**Fig.1** Settling curves for (a) control sludge (b) instantaneous EM addition and (c) continuous EM addition

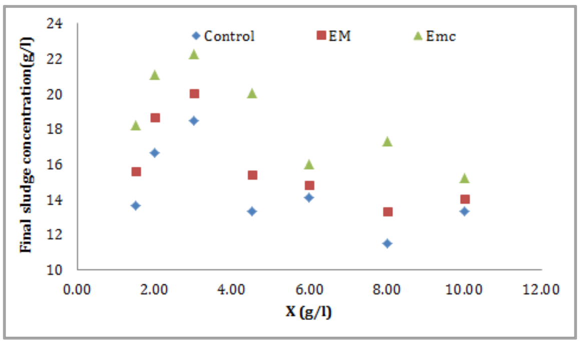


**Fig.2** Relation between X (initial sludge concentration) and final sludge concentration

*3.2 Sludge zone settling*

Zone settling velocity is determined as the slope of the linear part of sludge batch settling test (which in the calculations is defined as the steepest slope in the curve). The obtained data points were used to estimate the zone settling parameters of the settling function of Vesilind (1968). Figure (3, a, b, and c) show the relation between $V_{zs}$ and sludge concentration for control sludge, instantaneous and continuous EM treated sludge respectively.

The two parameters describing the function are $V_0$ and n. $V_0$ is the initial settling velocity derived from the extension of the curve to zero concentration intercept, and n is the hindered settling parameter in liter per gram or m$^3$/kg (Ekama *et al*, 2006).

$$V_{zs} = V_0 \times e^{-nX} \quad (2)$$

**Table 1** Vesilind velocity parameters

| Sludge type | $V_0$ (m/d) | n (m$^3$/kg) | Correlation coefficient |
|---|---|---|---|
| Control | 280.2 | 0.601 | 0.9602 |
| Instantaneous EM | 306.18 | 0.579 | 0.9739 |
| Continuous EM | 352.33 | 0.531 | 0.9871 |

These values show that the activated sludge used in this research is a well-settling according to Ekama *et al*., 1997 how concluded that well-settling sludge have $V_0$ values around 13 m/h and low n values around 0.25 m3/kg whereas poorly-settling sludge have low $V_0$ values around 5 m/h and high n values around 0.5 m3/kg, on the other hand Vanderhasselt and Vanrolleghem (1999) in there study defined the well-settling sludge based on the same $V_0$ values proposed by Ekama but neglect the effect of n values. Using EM increased the $V_0$ values by 9.3% and 25.74% for instantaneous and continuous EM treated sludge respectively.

These results comply with the results of Al-Jasser (2009) he found that using Zetage-7563 with a dosage of 20 (g/m$^3$) is the best additive and reported a zone settling velocity for the treated sludge of 28.8 (m/d) while in this research and for the same sludge concentration the zone settling velocity is 16.93 (m/d) and 24.77 (m/d) for the instantaneous and continuous EM addition of dosage (1/1000) by volume. Based on intial solid concentration of 2 (g/l) the zone settling velocity will be 84.24 (m/d), 96.18 (m/d) and 121.84 (m/d), so the hydraulic loading rate will be 42.12 (m/d), 48.09 (m/d) and 60.92 (m/d) for control, instantaneous and continuous EM treated sludge respectively. These values comply with the hydraulic loading rate of the WEF (1998, 2005) Metcalf & Eddy (2003) which ranged between 16 and 28 (m/d) at average flow rate and may vary between 40 and 64 (m/d) at peak flow.

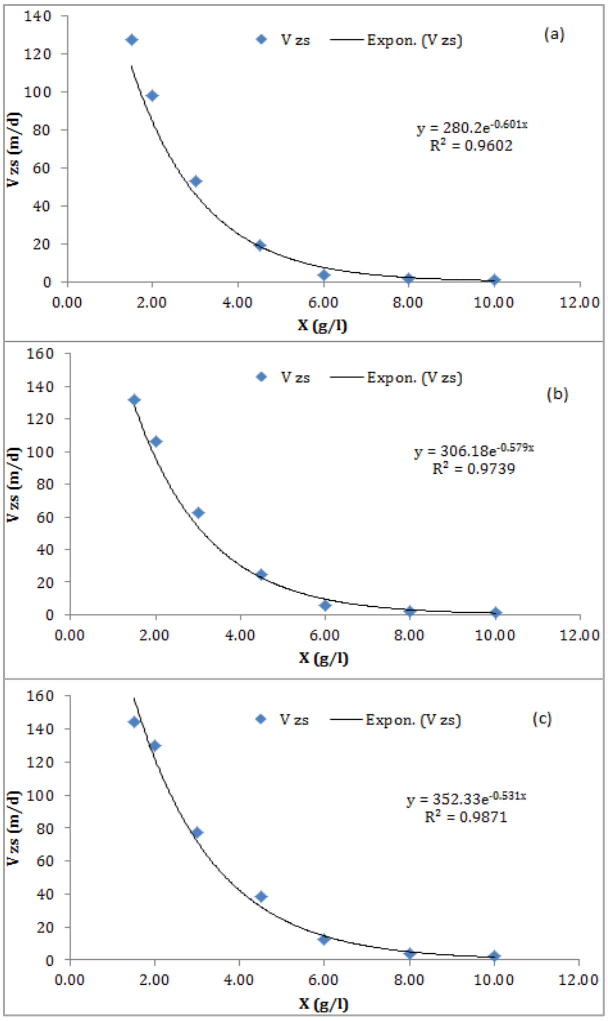


**Fig.3** Relation between $V_{zs}$ and sludge concentration (a) control sludge (b) instantaneous EM addition and (c) continuous EM addition

*3.3 Sludge volume index*

Sludge volume index was in the range of 93.75 - 130 (ml/g), 84.50 – 115.50 (ml/g) and 71.00 – 97.50 (ml/g) for control, instantaneous and continuous EM treated sludge respectively. According to WEF- (1998) the optimum SVI of the activated sludge process may be varying between 100 and 150 (ml/g).

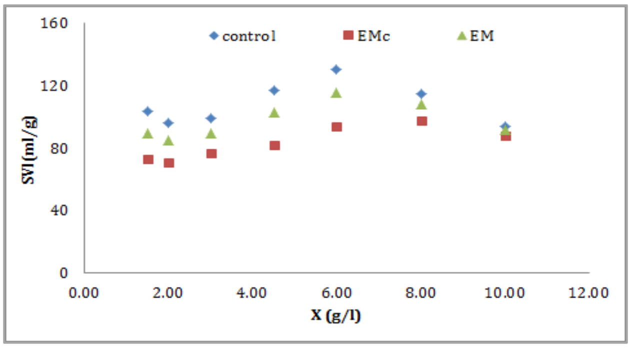


**Fig.4** Relation between SVI and initial sludge concentration (X)

Pipes (1979) reported that high SVI is usually the result of filamentous microorganisms presence in the sludge and that higher SVI usually produces a lower effluent TSS. And sludge with a SVI > 150 (ml/g) is generally considered as bulking. Wanner *et al*. (1998) discovered that the relationship between the abundance filaments and settling properties expressed in terms of SVI was rather loose. Low SVIs were related more with good activated sludge floc properties then with the absence of filaments. On the other hand, a very high abundance of filaments always resulted in bulking or foaming.

*3.4 Limiting solid flux*

Figure (5) show the solid flux curves for control sludge, instantaneous and continuous EM treated sludge; the solid flux curve of the two treated sludges is higher than control sludge which implies that the using of EM could increase the solid loading of the secondary settling tanks. Based on a final required solid concentration of 8 (g/l) the limiting solid flux will be 86.41 ($kg/m^2/d$), 128.15 ($kg/m^2/d$) and 283.1 ($kg/m^2/d$), for control, instantaneous and continuous EM treated sludge respectively. These values comply with the optimum sludge loading rate (solid flux) of the WEF (2005) which ranged between 100 and 150 ($kg/m^2/d$). While according to Metcalf & Eddy (2003) the solid loading may vary between 96 and 144 ($kg/m^2/d$) at average flow rate and at peak flow must be less than 196 ($kg/m^2/d$).

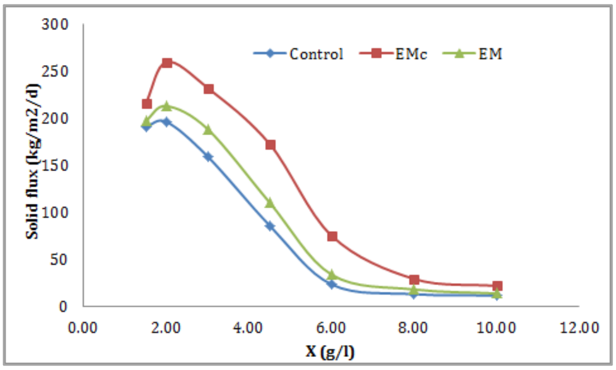


**Fig.5** Relation between solid flux and initial sludge concentration (X)

*3.5 Additional Sludge Production and predicted cost*

No additional sludge production related to the use of EM instantaneous and/or continuous, this result complies with the results of Mamais *et al* (2011) study as they contribute that no measurable increase in solids concentration was obtained when using organic polymer as an addition.

From an economic point of view, the cost of EM addition for a dose of (1/1000) by volume is almost \$200 for each 1000 ($m^3$) wastewater, this cost almost the same cost reported by Al-Jasser (2009) as he calculated a cost ranged between \$202 and \$275 per 1000 ($m^3$) of wastewater. But he did not consider the additional cost due to the increase in the produced sludge volume.

## Conclusions

Based on the experiments results obtained in this study using of EM improved the settling properties of waste activated sludge and continuous EM addition was more effective than the instantaneous addition as the zone settling velocity increased by an average value of 123% and 188%, sludge volume index decreased from an average value of 107.63 to 97.26 and 83.14 (ml/g), the final sludge concentration increased by an average value of 110% and 140% and limiting solid flux values increased from 86.41 ($kg/m^2/d$) to 128.15 ($kg/m^2/d$) and 283.1 ($kg/m^2/d$), for the instantaneous and continuous EM addition respectively.

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