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Minimization of Excess Sludge Production for Biological Waste Water Treatment using Activated Sludge Process

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Abstract

Redox potential technique can be used for minimizing sludge. Redox potential is nothing but any oxidation-reduction (redox) reaction can be divided into two half, one in which another chemical species undergoes reduction. If a half reaction is written as a reduction, the driving force is the reduction potential. If the half-reaction is written as oxidation, the driving force is the oxidation potential related to the reduction potential by a sign change. So the redox potential is the reduction/oxidation potential of a compound measured under standards conditions against a standard reference half-cell. In biological systems the standard redox potential is defined at pH – 7.0 versus the hydrogen electrode and partial pressure of hydrogen = 1 bar. In these project efforts was made to determine the feasibility of activated sludge process (ASP) for the treatment of synthetic wastewater and to develop simple design criteria under local conditions. A bench scale model comprising of an aeration tank and final clarifier was used for this purpose. Synthetic wastewater prepared in the laboratory using Glucose as the main source of carbon and the required nutrients were treated using mixed culture microorganisms on a batch as well as continuous manner. The reduction in COD and the increase in cell production analyzed. The characteristics of the settled sludge were determined by sludge volume index (SVI). The sludge produced during the treatment has separately treated with water having negative redox potential to study the effect on the reduction of the excel production. Known quantity of sludge was mixed with different volumes of redox potential solution to study the percentage reduction with and without stirring as a function of time. The results were used to optimize the time and percentage reduction.

Keywords: Excess sludge, minimization of sludge production, sludge reduction, wastewater treatment, activated sludge process.

Introduction

All industries in general and chemical industries in particular pollute the surrounding environment by discharging solid, liquid and gaseous waste materials which are very harmful to human beings, aquatic life. In the present study, treatment of waste water was investigated to reduce the level of pollution. Usually the extent of pollution is measured in terms of the biological and chemical oxygen demands (COD and BOD) and suspended Solids (SS)[1]. The treatment is divided into three stages primary, secondary and tertiary. In the primary stage coarse materials are separated by using filtration. During the secondary treatment particularly dissolved organic pollutants are removed by aerobic or anaerobic methods using microorganisms (Biological). The treated effluent should have a BOD value of 60 mg/L and a suspended solid content of 30 mg/L. In the third stage the BOD and SS are further reduced to 20 and 10 mg/L respectively by filtering the treated effluent from the secondary stage through sand, charcoal and /or activated carbon[2].

In the case of minimization of sludge reduction oxidations and reductions always go together. They are called redox reactions. Redox potential is nothing but any oxidation-reduction (redox) reaction can be divided into two half, one in which another chemical species undergoes reduction. If a half reaction is written as a reduction, the driving force is the reduction potential. If the half-reaction is written as oxidation, the driving force is the oxidation potential related to the reduction potential by a sign change[3]. So the redox potential is the reduction/oxidation potential of a compound measured under standards conditions against a standard reference half-cell. In biological systems the standard redox potential is defined at pH – 7.0 versus the hydrogen electrode and partial pressure of hydrogen = 1 bar[4]. The metabolic activity of microorganisms depends on many factors, including the redox potential of the culture environment. Measuring the redox potential allows the vessel operator to monitor the addition of reducing agents while ensuring that the potential is in the proper range for initiation of growth. It is also important to monitor the redox potential just before inoculation[5].

Experimental Setup: The general arrangement of an activated sludge process for removing carbonaceous pollution includes the following items: i. Aeration tank where air (or oxygen) is injected in the mixed liquor. ii. Settling tank (usually referred to as "final clarifier" or "secondary settling tank") to allow the biological flocs to settle, thus separate the biological sludge from the clear treated water. This is illustrated in the following diagram:

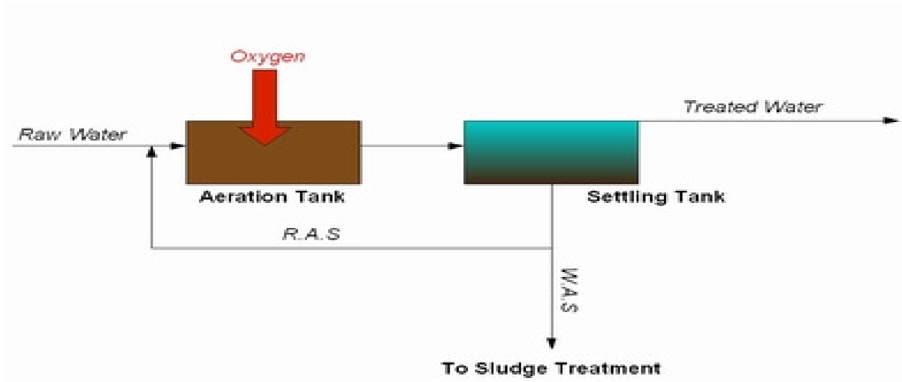

Figure-1
Generalized arrangement of an activated sludge process

A laboratory scale bubble column reactor made up of glass having approximately 15 cm diameter and 1 m height with bottom sealed and top open with a provision of an overflow to hold at least 10 L of waste water was used in this study. It consists of an aeration tank (bucket) of 15 L capacity. One aerator like that of fishpond with very fine bubbles and provision for uninterrupted power supply for aeration was used. The waste water fed as influent to the bubble column reactor was brought from Pentakali Dam, Dist: Buldana, 10Km Chikhli - Mehakar Road.

Material and Methods

Determination of COD and suspended solids were carried out by using $k_2Cr_2O_7$, ferrous ammonium sulphate, H_2SO_4. The COD was calibrated using exactly 1gpl pure glucose solution (add 1gm glucose in distilled water and make up volume 1 liter). Here the data was collected and studied related to COD only.

Composition of Synthetic Wastewater: Following are the composition of synthetic wastewater for mg/l solution: glucose: 1000, urea: 225, magnesium sulfate: 100, potassium phosphate: 1000, calcium chloride: 64, ferric chloride: 0.5.

Chemical Oxygen Demand: Principle: Most of the organic matters are destroyed when boiled with a mixture of potassium dichromate and sulphuric acid producing carbon dioxide and water. A sample is refluxed with a known amount of potassium dichromate in sulphuric acid medium and the excess of dichromate is titrate against ferrous ammonium sulphate. The amount of dichromate consumed is proportional to the oxygen required to oxidize the oxidizable organic matter.

Procedure: Place 0.4g $HgSO_4$ in a reflux tube. Add 20ml or an aliquot sample diluted to 20 ml with distilled water. Mix well, so that chlorides are converted into poorly ionized mercuric chloride. Add 10ml standard $K_2Cr_2O_7$ solution and then add slowly 30 ml sulphuric acid which already containing silver sulphate. Mix well, if the colour turns green, take a fresh sample with smaller aliquot. Final concentration of concentrated H_2SO_4 should always 18N. Connect the tubes to condenser and reflux for 2 h at 150^{o}C. Cool and wash down the condensers with 60ml distilled water. Cool and titrate against standard ferrous ammonium sulphate using ferroin as indicator. Near the end point of the titration color changes sharply from green blue to wine red. Reflux blank simultaneously with the sample under identical conditions.

Calculation

$$\text{COD, mg/l} = \frac{(V_1 - V_2) * N * 8000}{V_0}$$

Where, V_1 = volume of Fe $(NH_4)_2$ $(SO_4)_2$ required for titration against the blank, in ml; V_2 = volume of Fe $(NH_4)_2(SO_4)_2$ required for titration against the sample, in ml; N = Normality of Fe $(NH_4)_2(SO_4)_2$; V_0 = volume of sample taken for testing, in ml.

Total Suspended Solids: Principle: A well-mixed sample is filtered through a weighed standard glass-fiber filter and the residue retained on the filter is dried to a constant weight at 103 to 105°C. The increase in weight of the filter represents the total suspended solids. If the suspended material clogs the filter and prolongs filtration, it may be necessary to increase the diameter of the filter or decrease the sample volume. To obtain an estimate of total suspended solids, calculate the difference between total dissolved solids and total solids.

Calculation:

$$\text{mg total suspended solids/L} = \frac{(A-B) \times 1000}{\text{Sample volume,ml}}$$

Where, A = weight of filter + dried residue, mg, and B = weight of filter, mg.

Sludge Volume Index: The sludge volume index (SVI) is the volume in milliliters occupied by 1 g of a suspension after 30 min settling. SVI typically is used to monitor settling characteristics of activated sludge and other biological suspensions. Although SVI is not supported theoretically, experience has shown it to be useful in routine process control.

Sludge volume index (SVI) is an indication of the sludge settleability in the final clarifier. It is a useful test that indicates changes in the sludge settling characteristics and quality. By definition, the SVI is the volume of settled sludge in milliliters occupied by 1 gram of dry sludge solids after 30 minutes of settling in a 1000 ml graduated cylinder or a settleometer.

A liter of mix liquor sample is collected at or near the outlet of the aeration tank, settled for 30 minutes in a 1 liter graduated cylinder, and the volume occupied by the sludge is reported in milliliters.

The SVI is computed by dividing the result of the settling test in ml/liter by the MLSS concentration in mg/L in the aeration tank times 1000.

Calculations:

$$SVI = \frac{\text{Settled sludge volume (ml/l) X 1000}}{\text{Suspended solids (mg/l)}}$$

Redox Potential Measurements: The redox potential is measured by using redox probes. The potential difference is determined between a metal electrode and a reference electrode whereby both are immersed in the solution to be measured. The redox potential is generated by transfer of electrons from the metal electrode into the solution and vice versa. The net current from this process depends on the redox species, its concentration in solution and the material of the electrode. The redox potential equilibrates where the absolutes of the cathodic and anodic currents are equal and the net cur-rent becomes zero[7]. Net current graphs drawn for different redox couples should theoretically meet at one redox potential. In natural waters, redox couples are usually far from equilibrium. In this case electrodes show mixed potentials. The mixed potential is determined by redox couples with the steepest net current curve. Redox couples with a smaller slope in this curve produce a net current is close to zero over a wide redox potential range, which results in a poor stability as far as the measurements are concerned. Natural waters are usually very dilute solutions in terms of the concentration of redox-sensitive species. Redox probes only respond to processes which quickly and reversibly occur at the metal electrode surface[8].

The sludge produced during the treatment will be separately treated with water having negative redox potential to study the effect on the reduction of the excel production. Known quantity of sludge will be mixed with different volumes of redox potential solution to study the percentage reduction with and without stirring as a function of time. The results will be used to optimize the time and percentage reduction[9].

This is also true that we can use negative redox potential solution for minimization of sludge

But within proper limit because solution contains acidic solution and according to environmental protection agencies norms we cannot discharge more acidic solution in the environment. In order to study the effect of negative redox potential values in sludge minimization process we prepared Solution of one liter water having ¾ drops of HCl which showed -190mv redox potential value[10]. Then by mixing the known quantity of sludge with known quantity of redox potential solution and after continuous stirring at different time intervals we got the following readings[11].

Results and Discussion

In this project effort was made to determine the feasibility of activated sludge process (ASP) for the treatment of synthetic wastewater and to develop simple design criteria under local conditions. A bench scale model comprising of an aeration tank and final clarifier was used for this purpose. Synthetic wastewater prepared in the laboratory using glucose as the main source of carbon and the required nutrients will be treated using mixed culture microorganisms on a batch as well as continuous manner. The reduction in COD and the increase in cell production will be analyzed. The characteristics of the settled sludge were determined by sludge volume index (SVI).

In Activated Sludge Process sludge production is also a problem as the waste activated sludge is to be used for compost or for land filling .Thus this problem of excess sludge production can be solved with the help of redox potential Technique[6].

Table-1
Influence of Time on COD Reduction

S. No.	Time (hrs)	COD (mg/L)	MLVSS (mg/L)
1	0	1337	1120
2	2	1126	1720
3	4	915	1756
4	6	720	1890
5	8	502	2102

We have taken this biological floc of different concentrations in the reactor and then in order to check feasibility of Activated Sludge Process we took readings for different time intervals of COD and Sludge Volume Index by using 1gpl/2gpl methanol synthetic waste water solutions. We have got the following observations.

However the excess production of waste activated sludge in activated sludge production is 50% and 50% of heat generation takes place in aerobic process. This problem of excess sludge production can be solved with the help of Redox potential technique but within a proper limit only. Because negative redox potential solutions are acidic in nature as they are responsible for reduction of sludge but we cannot discharge more acidic solution in the environment according to the norms of environmental protection agencies norms. As we have seen from the result that from 34 percent to 92 percent of sludge can be minimized. This can be a good option in waste treatments.

The activated sludge methods of waste water treatment are the most economical and widely used for removing organic components from waste water. The pollution load was estimated by chemical oxygen demand (COD). Results obtained in this study has indicated that the percentage reduction of COD reached upto 80 percent by using methanol in SWW in case of glucose SWW it can be up to 90 to 95 percent. As we have taken synthetic waste water (SWW) of 1gpl and 2 gpl methanol solution and treated in ASP process to determine the feasibility of process for different MLVSS concentrations Like 1200,1600,1700,2010, 2300, 2700, 3200, mg/lit, we could reduce COD up to considerable extent at proportionate condition of sludge behavior by studding the values of SVI, F/M ratio, hydraulic detention time etc. We could check the optimum values for F/M ration which can be 0.2 to 0.4 where as SVI values which which are 35ml/g to 80ml/g for getting better result.

In activated sludge process the excess sludge production is also a major problem, generally this waste activated sludge can be used to land filling or making fertilizers. But this excess sludge minimization can be done with the help of negative redox potential solutions. We used -190mv solution and at different concentrations we could treat known quantity sludge and we can reduce a excess sludge up to 34 to 92 percent. However with the help of redox potential technique sludge minimization can be done but we can use this technique within proper limit because negative redox potential solution is acidic in nature so by using more concentrated solution means using more acidic solution. According to EPA norms we cannot discharge more acidic solution in the environment. Thus by knowing various sludge characteristics like SVI, F/M ratio, redox potential technique we can optimize the process.

Table-2
COD and SVI with respect to MLVSS and Time of Methanol SWW

Time (min)	Solution SWW (gpl)	MLVSS (gram/L)	COD (mg/li)t	SVI (ml/g)
30	1gpl CH_3OH	1.2	907	61
45			504	67
60			201	70
30	1gpl CH_3OH	1.6	840	67
45			571	50
60			235	67
30	1gpl CH_3OH	2.01	246	41.9
45			192	43.2
60			80	45
30	1gpl CH_3OH	2.7	362	32.3
45			236	44
60			180	48.9
30	1gpl CH_3OH	3.2	348	28.1
45			292	31.8
60			125	40
30	2gpl CH_3OH	1.7	1936	27.6
45			1721	45
60			1337	47
30	2gpl CH_3OH	2.3	1580	35.4
45			1041	35.2
60			470	35.2

Table-3
Sludge Reduction with Redox Potential Solutions w.r.t Times

Time (min)	200ml sludge +200ml HCl (S.S.) in mg/lit	200ml sludge +150ml HCl (S.S.) in mg/lit	200ml sludge +100ml HCl (S.S.) in mg/lit	200ml sludge +50ml HCl (S.S.) in mg/lit
0	1725	1912	----	----
10	1120	996	560	588
20	830	912	556	676
30	824	780	532	508
40	772	824	560	508
50	620	800	672	540

Table-4
Percent sludge reduction with redox potential Solutions w.r.to time (min.)

Time (min)	200ml sludge +400ml HCl SS1% Reduction	200ml sludge +600ml HCL SS2% Reduction	200ml sludge +800ml HCl SS3% Reduction	400ml sludge +100ml HCl SS4% Reduction	400ml sludge +200ml HCl SS5 % Reduction	200ml sludge +200ml HCl SS6 % Reduction	200ml sludge +150ml HCl SS 7% Reduction
10	74.8	84.3	89.7	34.4	54.7	35	47.9
20	85.2	89.3	90.1	42.4	55.1	51.8	52.3
30	85.8	90.6	90.1	46.6	55.1	52.3	59.1
40	87.1	91	90.6	43.4	55.8	55.3	56.9
50	91.4	92	92	42.4	56.3	64	58.1

Conclusion

With the study of this process the feasibility of activated sludge process using synthetic waste water was determined. The reduction in COD and growth of the cell production can be analyzed which helps to study the behaviour of sludge i.e. sludge volume index, F/M ratio, using redox potential technique for minimization of sludge etc .This can help us to optimize the process.

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