Aerobic digestion efficiency for mixed sludge (primary and secondary) of West Ahvaz wastewater Treatment plant in Batch reactor

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Abstract

Introduction: To stabilize organic matter of sludge, aerobic digestion is commonly applied for small wastewater treatment plants (0.2 m^3/s), but recently it has also been used for large scale wastewater treatment plants. Digested sludge is readily dewatering and for use in agriculture.

Methods and Materials: Aim of this Bench scale study is determination of aerobic digestion performance for mixed sludge of west Ahwaz sewage treatment plant by batch reactor. In this study cubic glacial bioreactor with (33×15×21) dimensions has been used. Then 7 liter of mixed sludge (3L from primary and 4 Lfrom secondary sludge) loaded. Aeration was carried out in 25 day by aquarium aerators.COD, VSS, TVS, TSS, TS,OUR tests examined in bioreactor.

Results: Results showed that after 12 days 38% of TVS reduced. This meets the environmental standards. After 19 days detention time in the bioreactor, COD, VSS, TVS, TSS, TS, were 40 ,56, 54.5, 50.4, 44.7 percent respectively. K_d coefficient was,0.173day^{-1}.

Conclusions: aerobic digestion was useful for mixed sludge of west Ahwaz sewage treatment plant.

Keywords: Aerobic digestion, Mixed sludge, sludge stabilization, VSS, OUR.

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Introduction

Huge sludge is produced in biological wastewater treatment that is biodegradable. Therefore, it is necessary to stabilize it for disposal and safely reuse. Aerobic digestion is one of sludge stabilization methods. (13)

Aerobic digestion of sludge is biological oxidation of organic matter under aerobic conditions. Aerobic digestion of organic sludge is commonly used for small wastewater treatment plants with 2 m^3/s capacities, but in recent years it has been used in larger plants. (3, 11)

This process is similar to activated sludge process and aeration equipment of aeration tank. Most active microorganisms in this process are facultative, however, some absolute aerobic bacteria, such as nitrifying bacteria also exit.

Following sludge types were successfully treated by Aerobic digestion:

1-Excessive active sludge, 2- Excessive activated sludge with primary sludge, 3- Clarifier sludge of trickling filter (humus) and 4 -primary and secondary sludge of trickling filter (humus).

Raw sewage may cause environmental pollution, so USEPA regulations banned its disposal without treatment and stabilization. One of the main goals of wastewater treatment is to stabilize sludge. The main objectives of sludge stabilization are removal of nuisance odors; reduction of pathogenic microorganisms, total solids and sludge volume and sludge biodegradability. Although anaerobic digestion has a long history, for many reasons, such as high initial investment cost, Sensitivity and incomplete digestion, frequent and common problems and failures in operation & maintenance; thus, now there is more attention on aerobic digestion and in Future seems to be more attractive to engineering consultants.

Advantages of aerobic digestion include:

1- Reduction of volatile solids in aerobic digestion is similar to anaerobic digestion.
2- A BOD concentration is less in supernatant liquid.
3- Produces final products, without smell, like humus and environmentally sustainable.
4- Recover more fertilizer matters from sludge.
5- Relatively easy for operation & maintenance.
6- Needs low initial investment.(3, 12)

This study aimed to determine kinetics coefficient of aerobic digestion and evaluation of COD, VSS TVS, TSS, TS, and OUR parameters on mixed sludge in west Ahvaz sewage treatment plant (WASTP) and design parameters calculation for aerobic digestion as corrective method to stabilizing sludge. The plant installed anaerobic digestion system is not working. Also biogas system failed due to lack of proper operation and high sensitivity. Therefore necessity of using aerobic digestion is obvious.

Methods and Materials

This study is an experimental and laboratory study. A cubic glass Bioreactor was built with dimensions of 33 cm length, 15 cm width, and 21 cm height, with10 liters volume.

The reactor was instrumented by 3 aquarium stones with 15 cm length, 2 cm width, and 2 cm height dimensions which connected to aquarium air pump (CX-0078 CHAMPION, made in china). In this study, 7 liters mixed sludge was taken of WASTP with ratio of 3 liters from primary sludge and 4 liters of secondary sludge. The sludge was immediately brought to WASTP laboratory, well mixed and added to the Bioreactor. Then, before starting system aeration, raw with increasing digestion time. These variations initially increased rapidly and over time the variation was less.

In terms of environmental regulations, it is required at least 38 percent reduction in total volatile solids (TVS), as it is shown 38% reduction in volatile solids has occurred.

Endogenous respiration coefficient (k_d)

To determine Endogenous respiration coefficient**,** it is necessary to calculate non-biodegradable solids from volatile suspended solids (VSS), which results in 25to 30days of aeration showed in Table (1). We calculated it as following:

time	remainingVSS	OUR
23	2631	4.3
26	2485	2.5
?	x	0

$$\frac{x-2485}{2485-2631}=\frac{0-2.5}{2.5-4.3}$$

X=2688 mg/L no biodegradable VSS

The amount of non-biodegradable volatile suspended solids is equal to2688 (2688 = Xn) (10). Revealing the amount of non-biodegradable suspended solids in Bioreactors, residual biodegradable volatile suspended solids can be calculated through the equation (1-1) and (1-2) which results showed in third column of table 2.

$$(X_d)_e=(X_e-X_n) \quad (1\text{-}1)$$

$$(X_d)_e=(x_0-x_n) \quad (1\text{-}2)$$

Xe = total output remaining at time t, mg / l VSS

X_0 = total initial at time zero, mg/l VSS

sludge was analyzed for total solids (TS), total suspended solids (TSS), total volatile solids (TVS), Volatile suspended solids (VSS), chemical oxygen demand (COD), Oxygen Uptake Rate (OUR), PH and temperature based on Standard methods for the examination of water and wastewater proposed methods, which was published by America Public Health Association (APHA) (8).Total solids and volatile solids were measured by weight evaluation. OUR was calculated by measuring dissolved oxygen meter (DR/2500); also COD was measured by (DR/2500). Then the air pumps were turned on, aeration and mixing started. Also, in primary days a mechanical stirrer was used to avoid creating foam because of aeration.

To assess aerobic digestion process and determination design parameters extended aeration and mixing was applied for 26 days. Sampling and analysis was carried out 2 days per week from Bioreactors contents. Samples Volume was 300 ml for dissolved oxygen (DO) and 100 ml for suspended solids. Total Samples for testing of all parameters were 69 samples.

Results

Results of TS, TSS, VSS, VS, OUR, COD, PH and temperature parameters in raw mixed sludge are shown in Table 1.

Figure (1) shows the changes in biochemical parameters during aerobic digestion batch reactors.

Initial high slope of the curves shows high reduction of the parameters in initial aeration times in the bio-reactor. Then parameters with time shows steady state and curves are parallel to the time axis. It means that sludge is more stabilized.

Figure 1 - COD, VSS, TVS, TSS and TS variation in aerobic digestion of mixed sludge for West Ahvaz Sewage Treatment Plant (WASTP).

Figure 2 shows the reduction percent for each parameter in the reactor. As it is shown the percentage increases in these parameters

indicating K_e (based on e) value (2). Figure3 shows the fit.
k (Based e) value is equal 0.1497. Considering average temperature of bioreactor in digestion reaction, that was 23 ° C, with correction factor for determined temperature K_d based on the following equation is equal to: (6)

$$K(T) = K_{20^\circ C}.\theta^{(T-20)}$$

$$K_{۲۳} = ۰/۱۴۹۷ \times (۱/۰۵)^{(۲۳-۲۰)}$$

$$k_{۲۳} = ۰/۱۷۳ \ \text{day}^{-1}$$

Xn = non-biodegradable portion of VSS, assumed constant throughout aeration period mg / l(6)

To estimate Adams model parameters, using Excel software with regard Xn as percentage of various initial volatile suspended solids, linear regressions for non-continues Bioreactors was based on Ln (Xe-Xn) / (Xo-Xn). For various Xn, Ln (Xe-Xn) / (Xo-Xn) graph was plotted against time. Volatile suspended solids were based on best fit of regression coefficient, R^2. Best fit slope,

Table 1: Aerobic digestion of sludge mixed Parameters for West Ahvaz Sewage Treatment Plant (WASTP)

Degree ^{0}C	PH	OUR (mg/l-h^{-1})	VSS (mg/l)	TS (mg/l)	TVS (mg/l)	TSS (mg/l)	COD (mg/l)	Aeration time (Day)
23	7.7	44	6382	9156	6775	8663	5740	Zero
23	7.5	44	6262	8963	6571	8489	----	1
23	7.3	26	5009	7887	5782	6960	5290	4
22	7.1	22	4407	7077	4625	6382	4840	7
22	6.7	17.5	4010	6581	4236	5990	4539	10
23	6.3	13.4	3609	5982	3846	5607	4239	13
24	6.1	9.8	3208	5533	3461	4878	3816	16
23	5.8	7.5	2807	5062	3080	4292	3435	19
23	5.6	4.3	2631	4505	2887	3776	2945	23
23	5.4	2.5	2485	3964	2713	2385	2690	26

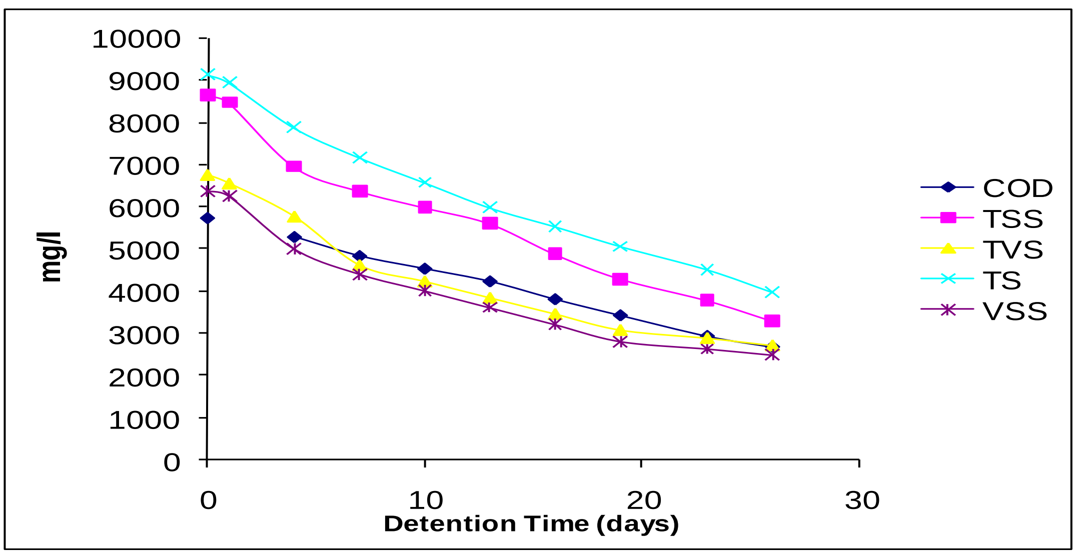

Figure 1: COD, VSS, TVS, TSS and TS variation in aerobic digestion of mixed sludge for West Ahvaz Sewage Treatment Plant (WASTP)

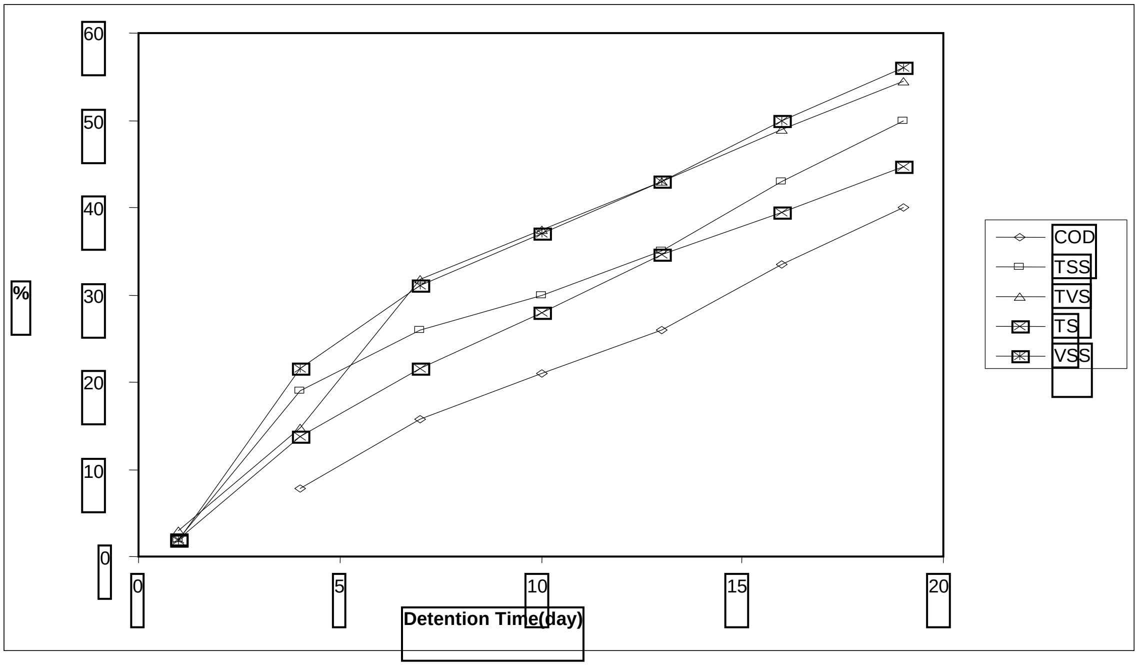

Figure 2: reduction percent of the parameters for West Ahvaz Sewage Treatment Plant (WASTP)

Table 3: Data used to determine the response rate (kd) of mixed sludge

VSS %Destroyed	VSS Degradable Remaining(mg/l)	VSS Remaining(mg/l)	Aeration Time (day)
----	3694	6382	zero
1.9	3574	6262	1
21	2321	5009	4
31	1719	4407	7
37	1322	4010	10
43	921	3609	13
50	520	3208	16
56	119	2807	19

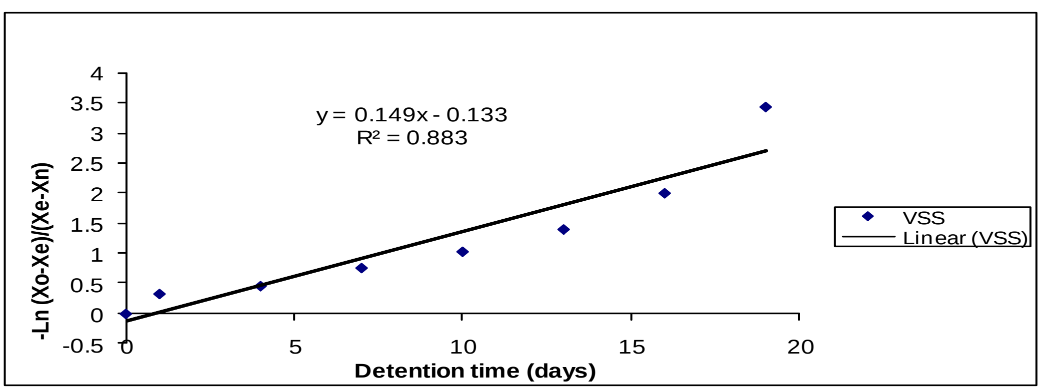

Figure 3: Reaction coefficient k_d determination of mixed sludge based on Adams model

Discussion

PH:

Results obtained in this study indicate that during aerobic digestion in Bioreactor pH levels decreased from 7.7 to5.4, that was because of carbon dioxide action as well as nitrification. Studies by Lawton and hung reported pH losses during aerobic digestion from 8 to 5 are consistent with the current study (9).

TS ‹ TSS ‹TVS‹ COD, and VSS Variation:

Findings of this study showed that aerobic digestion can reduce sludge volume and stabilize it by oxidizing organic matter and biomass. Reductions in organic matter and little amounts of inorganic materials lead to reducing sludge volume, TS and TSS. By the way, the relationship between TS and TSS values were strong and direct. Thus losses in any of them, related to reduction in other. TS and TSS removal percentage during 19 days of aerobic digestion in Bioreactor was, 44.7 and 50.4 percent respectively. These results are consistent with the study results conducted by Mesdaghinia and colleagues (45. 22 and 49.3 percent). As was mentioned, reduction in organic matter content TVS, COD, VSS, can determine the progress of digestion. Reduction percent in COD, VSS, TVS after 19 days of digestion in Bioreactors was 54.5, 56 and 40 percent respectively which is similar to results of Mesdaghinia and colleagues that were 52.36, 52.28, and 43.03 percent respectively. Also, results of other researches, including Hung and Henry are consistent and indicated that aerobic digestion reactor was effective and meet environmental standards (EPA). (4)

Oxygen Uptake Rate (OUR):

One of the indicators for stabilized sludge is oxygen concentration required to stabilize sludge organic matter. According to the results of this study, oxygen consumption rate after 19 day detention time of aerobic digestion in the Bioreactors reduced from 44 to 7.5 milligrams per liter per hour ($mg/l\text{-} h^{-1}$). Studies performed by Eckenfelder and Adams Corresponds that oxygen consumption rate decreased from 42 to 8 mg per liter per hour ($mg/l\text{-}h^{-1}$). Reduction in oxygen consumption during aerobic digestion of sludge stabilization in Bioreactors showed that this reduction trend initially was high, but in the end of the digestion period it reduced. (6)

Endogenous respiration coefficient K_d:

Reaction or decomposition Constant K_d depends on nature of sludge, solids concentration and temperature. Excess activated sludge which is easily decomposed has high K_d value reported by several researchers, including Banhardt and Raynolds, K_d value was reported about 0.28 to 0.71(day-1) reported (5). K_d is less for mixed sludge with respect to mixture of activated sludge which degraded easily and primary sludge which its degradation is not easy. Values of K_d decreases By increasing sludge concentration. studies conducted by Banhart reported K_d equal to 0.14(day^{-1}) and by Javersky equal to 0.18 (day^{-1}) (7).

The results obtained in this study show that the coefficient rate for mixed sludge Khvdkhvry day-1) 0.173 the temperature is 23 degrees Celsius, which is consistent with the results of other investigations.

Conclusions

1 - All parameters measured during the aerobic digestion process (Table 1) in Bioreactors are indicating sludge stabilization.

2- As shown in (Figure 1) at the beginning of digestion period stabilization rate was more and by completing digestion over time, the rate decreases.

3 - Results of batch bio-reactor (Figure 2) after 12 days showed reduction of total volatile solids of 38 percent that in terms of environmental regulation is necessary.

4 - Reaction rate constant of mixed sludge was less than activated sludge that was reported by others, due to the high initial solids concentration.

Results of this study showed that mixed sludge of WASTP stabilized successfully. Detention time of aerobic digestion was least (12 days) and 38% reduction in total volatile that is required by EPA regulation, has happened. So considering problems of operation and maintenance of anaerobic digesters, and suitable weather in Ahwaz, and other benefits , we recommend aerobic digestion for sludge stabilization.

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