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Aktif Çamur Ünitesi İşletimine Ön Çökeltim Ünitesi Varlığının Etkileri

Effects of Primary Settler on Activated Sludge Operation

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Öz

Bu çalışmada ön çökeltim ünitesinin aktif çamur ünitesi üzerine etkileri araştırılmıştır. Bu amaçla ön çökeltim ünitesi varlığı ve yokluğu durumları için teorik hesaplamalara göre evsel atıksu arıtımı yapan aerobik aktif çamur prosesleri tasarlanmıştır. Ön çökeltim varlığı ve yokluğu durumları için sırası ile 650 ve 530 mg/L'lik toplam biyolojik parçalanabilir KOİ esas alınmıştır. Ön çökeltim ünitesi mevcudiyetinin, aktif çamur sistemindeki toplam fazla çamuru (ortalama %33), sistemdeki toplam kütleyi (%34) reaktör hacmini (%34) ve oksijen gereksinimini (%23) azalttığı hesaplanmıştır. Ön çökeltim atıksudaki KOİ'nin bir kısmının giderimini sağlarken bu sayede aktif çamur ünitesi üzerindeki yükün azalmasını sağlar.

Effects of Primary Settler on Activated Sludge Operation

In this study, the effects of pre-precipitation unit on activated sludge unit were investigated. An aerobic activated sludge processes treating domestic wastewater designed on the basis of theoretical calculations for two different case – in the presence and absence of primary settler. A domestic wastewater containing 650 and 530 mg/L total and biodegradable COD treated in an activated sludge process in the presence and absence of primary settling respectively. It is calculated that presence of primary settling decreased the total excess sludge (an average 33%), total mass in the system (34%) reactor volume (34%) and oxygen requirement (23%) in the activated sludge system. Presence of primary settler removes a portion of total COD in the influent and therefore it decreases the COD loading to activated sludge process.

1. INTRODUCTION

Many domestic wastewater treatment plants consist of a primary and secondary treatment unit. Inflow to a treatment plant first treated in the primary treatment units and then treated in secondary treatment units where dissolved matter in the wastewater is removed. Primary treatment units consists of screening, grit removal, flow equalization fat and grease removal and primary settlers. Most of settleable particles in the wastewater precipitated in the primary settler (PS) including biodegradable and non-biodegradable particulate matters. This settling has a great effect on the subsequent secondary treatment units [1]

Domestic wastewater treatment by means of simultaneous carbon removal and nitrification is one of the major specific properties of activated sludge systems. Activated sludge system is an aerobic process where organic content of wastewater oxidized by heterotrophic biomass in the aeration volume and biomass in the reactor settled in the subsequent settling tank. A portion of influent biodegradable substrate (C_{S1}) is converted to biomass and the rest oxidized by oxygen and removed from the system as CO_2. Biomass fraction of influent biodegradable substrate removed from the system as daily excess sludge [2].

Particulate fractions of total COD precipitates in the PS. This precipitated portion includes a fraction of biodegradable organic matter (X_{S1}) and therefore there will be a decrease in the biodegraded amount of organic matter in the activated sludge system. So, utilized oxygen amount, reactor sizes, daily sludge

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production, HRT as well as recycle ratio are affected by the presence of PS. According to oxidized organic matter amount, reactor oxygen requirement and therefore energy need also affected by the presence of PS. Therefore it could be noted that presence of PS has a great effect on reactor operational.

The aim of this study is to demonstrate how PS affects the activated-sludge operational conditions. Variations in the system design parameters investigated. The importance of PS existence and its effect on sludge production, oxygen requirement, reactor size etc. is demonstrated upon the theoretical calculations for different sludge ages. To do that, two activated sludge system designed in the presence and absence of PS for the sludge ages between 2 and 23.

2. MATERIALS and METHOD

2.1. Model Parameters and Assumptions

In this study, importance of the PS is investigated according to theoretical calculations and results compared with the literature. Firstly, all biodegradable COD content in the wastewater is assumed to be degraded. Additionally, all particulate COD components (particulate biodegradable and particulate non-biodegradable) assumed as precipitated in the PS with 100% efficiency. Total population related to this treatment plant is accepted as 25000 capita by assuming q = 200 L/day.N. Also, for both presence and absence of PS, some assumptions related to kinetic and stoichiometric coefficients as well as wastewater characteristics done. These assumptions can be seen in the following Table 1.

Table 1. *Wastewater composition and kinetic - stoichiometric coefficients.*

Kinetic - Stoichiometric Coefficients			
Parameter	**Unit**	**Value**	
Q	m^3/d	5000	
Y_H	g cellCOD/g COD	0.64	
f_X	gcellCOD/gVSS	1.42	
b_H	d^{-1}	0.15	
f_{EX}	-	0.15	
f_{ES}	-	0.05	
X_{SS}	mg/L	4000	
I_{SS},COD	kg SS/kg COD	0.90	
Wastewater Composition			
	Unit	**Raw Sewage**	**Settled Sewage**
C_{T1}	mg COD/L	650	450
C_{S1}	mg COD/L	530	410
S_{I1}	mg COD/L	40	40
X_{I1}	mg COD/L	70	30
X_F	mg COD/L	80	25

2.1. Model Parameters and Assumptions

In order to design the activated-sludge system, following equations are used.

Table 2. *Formulas used to design activated-sludge system*

Description	Equation	Abbreviations
Observed Growth Yield (g cell COD/g COD)	$Y_{NH} = \frac{Y_H}{1 + b_H.\theta_X}$	Y_H= Net growth yield (g cell COD/g COD) b_H = Endogenous decay coefficient (d^{-1}) θ_x= Sludge age (d)
Heterotrophic Biomass in excess sludge (kg/d)	$P_{XH} = Q.C_{S1}.Y_{NH}$	C_{S1}= Total biodegredable COD in the inflow (mg/L)
Particulate Microbial Products in Excess Sludge (kg/d)	$P_{XP} = P_{XH}.f_{EX}.b_H.\theta_X$	F_{EX} = Fraction of endogenous biomass converted into particulate inert products.
Particulate Inert Matters in Excess Sludge (kg/d)	$P_{XI} = X_{I1}.Q$	X_{I1}= Particulate inert COD in the influent (mg/L)
Total excess sludge (kg/d)	$P_{XT} = P_{XH}+P_{XP}+P_{XI}$	
Suspended Solid Amound in Excess Sludge (kgSS/d)	$P_{SS} = P_{XT}.i_{SS,COD}$	$İ_{SS}$= Suspended solid fraction in excess sludge (kg SS/kg COD)
Total mass in the reactor (kg COD)	$M_{XT} = P_{XT}.\theta_x$	
Total heterotrophic biomass in the reactor (kg COD)	$M_{XH} = P_{XH}.\theta_x$	
Total Suspended Solid in the Reactor (kg)	$M_{SS} = M_{XT}.\ i_{SS,COD}$	
Reactor Volume (m^3)	$V_R = \frac{M_{SS}}{X_{SS}}$	
Oxygen Requirement (kgO_2/day)	$OR = Q.C_{S1}.[1 - Y_{NH}(1 + b_H.f_E.\theta_X)]$	f_E= Microbial product fraction

3. RESULTS and DISCUSSION

3.1. Role of Primary Settler

In the result of calculations, two different activated sludge systems are designed. Each parameter under effect of the presence of PS (total excess sludge, oxygen requirement etc.) is evaluated and results are evaluated. In the PS, 1000 kg/day total COD could be precipitated. While 600 kg/day of this mass is composed of biodegradable fraction, rest 400 kg/day is inert particulate matter. When O_2 equivalent is calculated for biodegradable fraction by assuming 0.659 kg O_2 necessary for oxidizing each kg COD, it could be noted that 395 kg O_2/day equivalent sludge could be removed and therefore, 263 kWh/day power as electricity saved (0.05kWh/m^3.day). In other words, each kg particulate biodegradable COD enters the activated sludge system without capturing by a PS, costs as a power requirement as 0.44 kWh.

In the case of the absence of PS, this biodegradable part initially hydrolyzed and subsequently oxidized in the aeration tank with the oxygen amount mentioned above. Therefore presence of PS affects the whole activated sludge system.

3.2. Total Daily Excess Sludge (P_{XT}) and Total Mass in the System (M_{XT})

Total daily excess sludge (P_{XT}) in the system is the sum of daily rate of viable excess biomass (P_{XH}), daily rate of particulate inert microbial product generation (P_{XP}) and the daily rate of discharge of influent particulate inert organics (P_{XI}). Each gram biodegredable particulate COD enters to the treatment plant is either removed during the PS or oxidized and turned into biomass and CO_2 to particulate or to evaporate[1]. Particulate fraction here, (P_{XH}) increases as the inflow biodegradable COD increased. The more P_{XH} means the more P_{XP} as it also increase accordingly to P_{XH}.

According to calculations, total excess sludge in the absence of PS calculated as an average of 1175 kg/day (0.235 kg/m^3.day) whereas same value for the presence of PS was 788 kg/day (0.157 kg/m^3.day). Presence of PS decreased the P_{XT} value by 33%. When the amounts of excess sludge produced per day in the activated sludge system is evaluated, Table 3 is obtained. Note that, in the absence of PS P_{XH} and P_{XP} is 39% and 35% increased from the same values in the presence of PS respectively.

This case is also for the inert sludge as well. Inert sludge disposal is increased by 134% in the absence of PS. Disposal of this inert fraction in the activated sludge system rather than PS indicates that 200 kg/day particulate inert biomass is transported in vain. All this unnecessary transportations for biologically degradable and non-degradable particulate COD fractions could increase the pumping costs of the treatment plant.

Table 3. *Fractions of daily excess sludge in the presence and absence of PS*

In the presence of PS			In the absence of PS		
PXH (kg/d)	PXP (kg/d)	PXI (kg/d)	PXH (kg/d)	PXP (kg/d)	PXI (kg/d)
519	114	150	671	154	350

For different sludge ages, variations upon total daily excess sludge are shown in Figure 1. below.

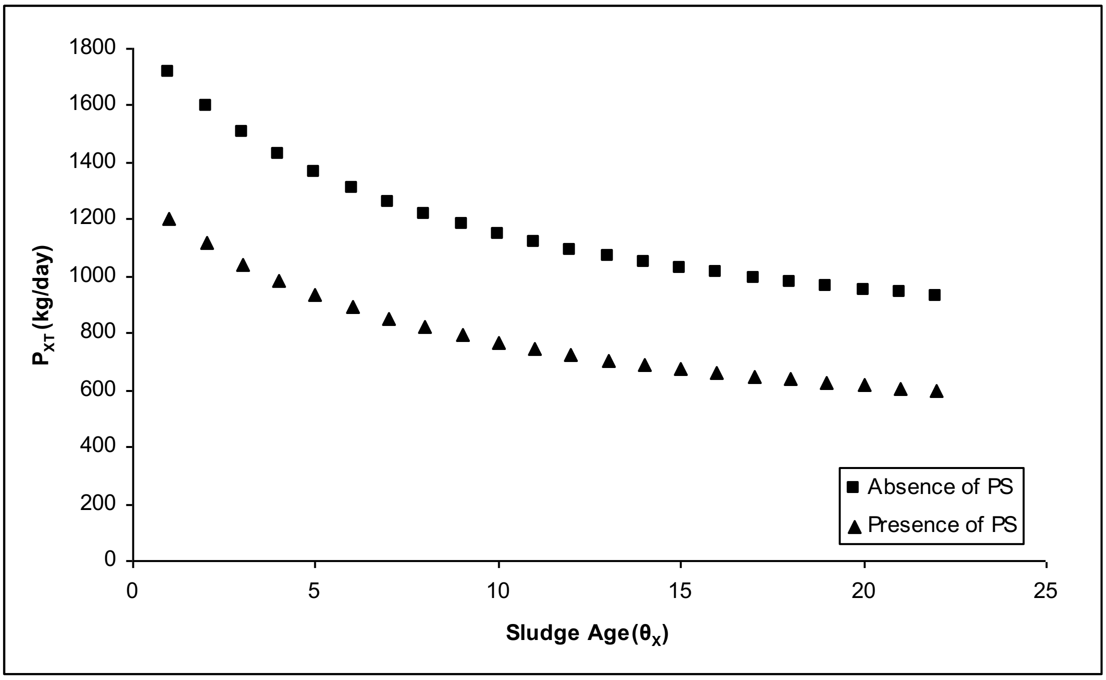

Figure 1. *Variations of total excess sludge with sludge age for both situations*

Total mass in the system is also affected from the presence of PS. Total excess sludge times sludge age gives the total mass (heterotrophic biomass, particulate microbial products and particulate inert COD) in the system (Eq. 7). Although total excess sludge decreases with the increasing sludge age, according to Eq. 7, M_{XT} increases (Fig. 2).

$$M_{XT} = P_{XT}.\theta_X \qquad \text{(Eq. 7)}$$

Since it is assumed that a portion of biodegradable fraction of COD removed in the PS, lesser C_{S1} remained to the heterotrophs in the activated sludge system. Therefore P_{XH} produced in the absence of PS calculated as 671 kg/d (0.134 kg/m^3.d) which is higher than that of calculated in the presence of PS - 519 kg/d (0.104 kg/m^3.d). Same expression can be done for the particulate inert microbial products and particulate inert COD as well (Fig 2). Presence of PS decreased the total mass by 34% when compared with the absence of PS.

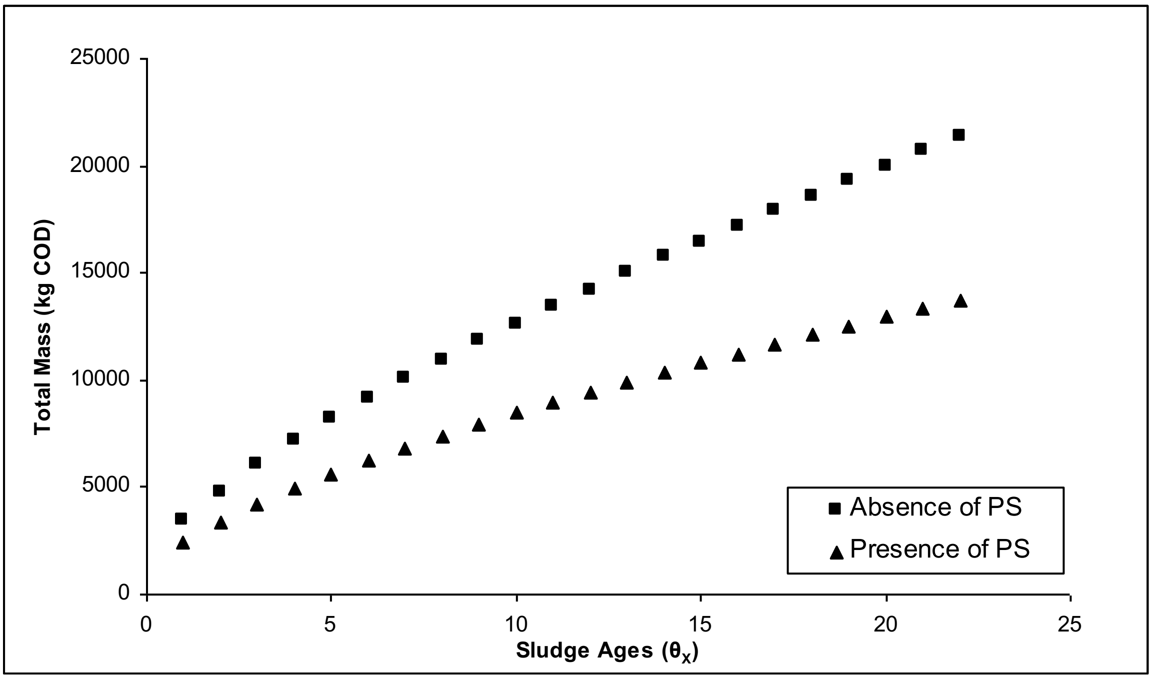

Figure 2. *Changes in M_{XT} on the basis of sludge age*

Increased SS mass in the aeration tank, causes an increase in the reactor volume. This situation is explained in the following section.

3.3. Reactor Volume (V_R) and Hydraulic Retention time (θ_H)

In order to calculate the reactor volume, initially total suspended solid concentration (X_{SS}) in the reactor selected. In order to accomplish better settling, this value needed to be selected below 5000 mg/L [1,8]. Reactor volume is a ratio of M_{SS} to X_{SS} as can be seen in the Table 1. Therefore it could be noted that M_{XT} affects the reactor volume. Approximately 771 and 4804 m^3 required for the sludge age of 2 and 23 respectively in the absence of PS. In case of PS applied, these values became 542 and 3092 m^3 for the same sludge ages. Variations upon the presence of PS with different sludge ages are shown in Figure 3.

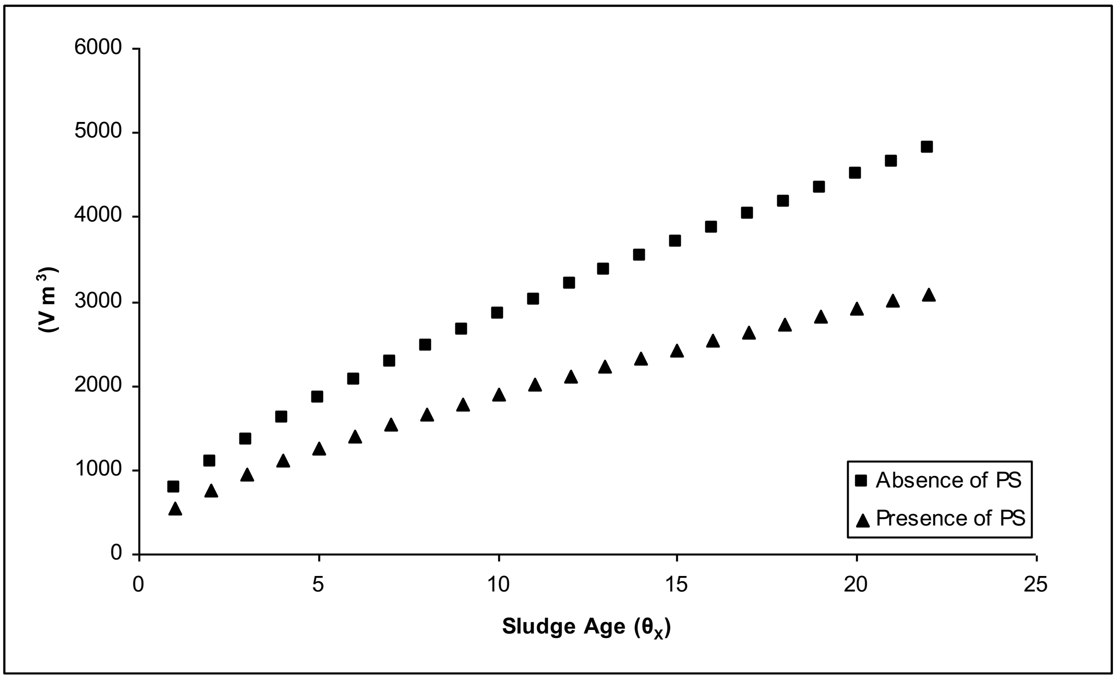

Figure 3. Changes in reactor volume on the basis of sludge age

According to calculations, application of PS decreased the total aeration volume as an average value of 34% (from 3006 to 1986 m^3). Another operational parameter is hydraulic retention time (θ_H). Hydraulic retention time is a function of the reactor volume and flow rate. As the reactor volume increases, duration of water in the reactor increases and therefore high hydraulic retention time calculated in the high sludge age. In case of PS applied, hydraulic retention time increased up to 0.96 from 0.15 day, when sludge age increased from 2 to 23 day. Same values for absence of PS were 0.62 and 0.11 respectively.

3.4. Oxygen Requirement (OR)

In the activated sludge system, oxygen supply to the aeration tank has a great importance since the heterotrophic microorganisms uses oxygen to oxidize organic pollutants. Also as a general approach, aeration related electricity consumption covers the 80% of total electricity consumption. Therefore an evaluation oxygen requirement is crucial for optimum operational [3].

Oxygen requirement (OR) in the activated sludge depends on the biodegradable COD to be oxidized [4]. In the case of the presence of PS, a portion of particulate biodegradable COD removed and less COD flows to the activated-sludge system. This affects the oxygen requirement on a large scale. According to calculations, in the presence of PS 980 kg/day oxygen required when sludge age set as 2 days. However when sludge age increased to 23 days OR calculated as 1552 kg O_2/day. These values also calculated as 1267 and 2006 for the sludge ages 2 and 23 respectively in the absence of PS. As an average value 1774 and 1372 kg O_2/day (0.355 and 0.274 kgO_2/m^3.day) are required in the absence and presence of PS. This indicates absence of PS increases total oxygen requirement by 29% than that of in the presence of PS. The variations on oxygen requirements in the presence and absence of PS for different sludge ages are given in the following Figure 4.

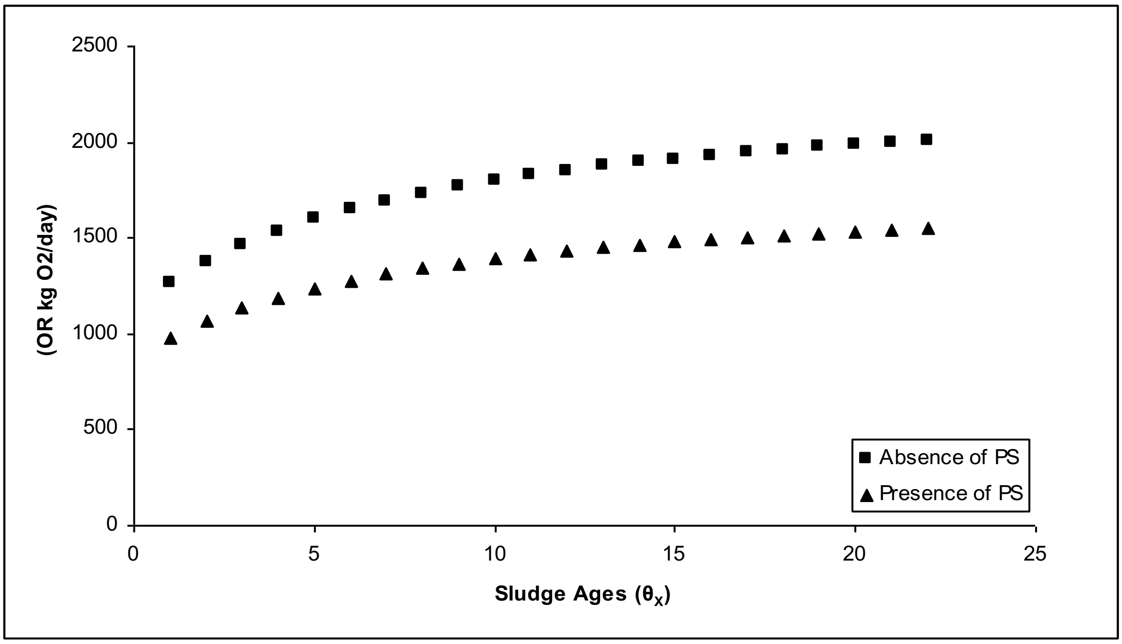

Figure 4. *Changes in oxygen requirement on the basis of sludge age*

Biodegradable particulate organic pollutants are either removed during the PS without oxidizing or oxidized in the aeration tank and evaporated as CO_2 and removed as excess sludge. In case of the absence of PS, this fraction of total COD, come up with an oxygen demand in activated sludge system. The more biodegradable COD in the aeration tank, the more oxygen demand to oxidize it. In other words, the more power requirement to supply necessary oxygen. Providing oxygen to the aeration tank covers more than 50% of the power requirements of the total costs associated with wastewater treatment plant operation [5]. It was reported that oxygen transfer yields varies between 0.6 – 4.2 kg O_2/kWh [6]. Also, according to EPA-Wastewater Treatment Manuals, Table 4 shows the variations on oxygen transfer rate per kWh electricity. During the calculations here, an average value of 1,5 kg O_2/kWh accepted as transfer rate. (Predicted from Table 4).

Table 4. *Performance of various aeration devices*

Aeration Device	**Oxygen Transfer Rate, kg O_2/kWh**
Fine bubble diffusers	2.0 – 2.5
Coarse bubble diffusers	0.8 – 1.2
Vertical shaft aerators	Up to 2.0
Horizontal shaft aerators	Up to 2.0

When presence of PS evaluated with energy demand, absence of PS may increase the total aeration costs of activated sludge system around 30%. 1182 and 915 kWh/day are the energy requirements when PS absent and present respectively. When it expressed as unit wastewater treated, 0.24 and 0.18 kWh/m^3 wastewater treated for the absence and presence of PS. Following table shows the energy requirements for different sludge ages.

***Table 5.** Energy and oxygen requirements for different sludge ages.*

	In the absence of PS							In the presence of PS					
	Q	**C_{S1}**	**OR**		**Power Requirement**		**Removal Rate**	**C_{S1}**	**OR**		**Power Requirement**		**Removal Rate**
	m^3/day	kg/m^3	kgO_2/day	kgO_2/m3	kWh/m^3	kWh/day	kgCOD/kg O_2	m^3/day	kg/m^3	kgO_2/day	kgO_2/m3	kWh/m^3	kWh/day
2	5000	0.53	1267	0.253	0.169	845	2.091	0.41	980	0.196	0.131	653	2.091
3	5000	0.53	1375	0.275	0.183	917	1.927	0.41	1064	0.213	0.142	709	1.927
4	5000	0.53	1463	0.293	0.195	975	1.812	0.41	1132	0.226	0.151	754	1.812
5	5000	0.53	1535	0.307	0.205	1024	1.726	0.41	1188	0.238	0.158	792	1.726
6	5000	0.53	1597	0.319	0.213	1064	1.660	0.41	1235	0.247	0.165	823	1.660
7	5000	0.53	1649	0.330	0.220	1099	1.607	0.41	1276	0.255	0.170	850	1.607
8	5000	0.53	1694	0.339	0.226	1129	1.564	0.41	1311	0.262	0.175	874	1.564
9	5000	0.53	1733	0.347	0.231	1156	1.529	0.41	1341	0.268	0.179	894	1.529
10	5000	0.53	1768	0.354	0.236	1179	1.499	0.41	1368	0.274	0.182	912	1.499
11	5000	0.53	1799	0.360	0.240	1199	1.473	0.41	1392	0.278	0.186	928	1.473
12	5000	0.53	1826	0.365	0.243	1217	1.451	0.41	1413	0.283	0.188	942	1.451
13	5000	0.53	1851	0.370	0.247	1234	1.432	0.41	1432	0.286	0.191	954	1.432
14	5000	0.53	1873	0.375	0.250	1249	1.415	0.41	1449	0.290	0.193	966	1.415
15	5000	0.53	1893	0.379	0.252	1262	1.400	0.41	1465	0.293	0.195	976	1.400
16	5000	0.53	1912	0.382	0.255	1274	1.386	0.41	1479	0.296	0.197	986	1.386
17	5000	0.53	1929	0.386	0.257	1286	1.374	0.41	1492	0.298	0.199	995	1.374
18	5000	0.53	1944	0.389	0.259	1296	1.363	0.41	1504	0.301	0.201	1003	1.363
19	5000	0.53	1958	0.392	0.261	1305	1.353	0.41	1515	0.303	0.202	1010	1.353
20	5000	0.53	1972	0.394	0.263	1314	1.344	0.41	1525	0.305	0.203	1017	1.344
21	5000	0.53	1984	0.397	0.264	1322	1.336	0.41	1535	0.307	0.205	1023	1.336
22	5000	0.53	1995	0.399	0.266	1330	1.328	0.41	1544	0.309	0.206	1029	1.328
23	5000	0.53	2006	0.401	0.267	1337	1.321	0.41	1552	0.310	0.207	1034	1.321

According to Table 5, it could be noted that biodegradable COD fractions in each m^3 wastewater is increased in the absence of PS. Thus, oxygen requirement and necessary power requirements also increased for each m^3 wastewater treated. Note that, in both situation, oxygen and power requirement for each kg COD is constant since this situation has no any relationship with each other.

4. CONCLUSIONS

Presence of PS affects activates sludge operational. In the absence of PS, biodegradable particulate COD enters the activated sludge system and come up with an increased oxygen demand, excess sludge as well as total mass. In the presence of PS, total excess sludge 33% less than that of the absence of PS (1175 – 788 kg/day). Total aeration volume also decreased from 3006 to 1986 m^3 when PS applied. Oxygen requirement also important due to its consistent power requirement. Absence of PS increased total oxygen requirement by 29%. These increases come up with an increased power requirement. Each m^3 wastewater requires 0.24 and 0.18 kWh electricity in the absence and presence of PS respectively. In other words, absence of PS caused 0.011 kWh/capita.day more power consumption.

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