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Tracing Carbon Footprint in the Wastewater Treatment Plant

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Abstract

The greenhouse gases, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) can all be produced in wastewater treatment operations. Major progress has been encountered for estimating (N_2O) and (CH_4) emissions from wastewater treatment plants, yet, limited number of studies considered CO_2. One problem with the mass balance technique in the Activated Sludge lies in satisfactorily measuring waste activated sludge volumes and in obtaining representative samples for analysis. A traditional mass balance approach for analyzing the performance of the activated sludge secondary clarifier does not account for variations in sludge depth and suspended solids concentrations within different layers. In turn, a gap in knowledge is present in closing the Carbon mass balance within the Activated Sludge system. In this essence, the main focus of this research is to quantify the carbon dioxide emissions from the Aeration Tank in the biological treatment. This will be achieved by generating a full-scale of accurate measures to precisely simulate the SC behavior aiming at determining the fate of the CO_2 through the Activated Sludge system. Results from this research attained a reasonable carbon balance closure of 95%.

Keywords: Activated sludge, carbon dioxide, mass balance, wastewater treatment plant.

Introduction

Global warming, caused by the atmospheric build-up of Green House Gas (GHG) emissions, influences many aspects of daily life including human health, agriculture, water resources and energy use. Alongside construction, transportation and power generation, Wastewater Treatment Plants (WWTP) plays a significant role in GHG production; including CO_2, N_2O and CH_4. With diverse challenges facing the surrounding environment, air pollution management is a matter of grave concern. Therefore, the generation of GHGs emissions from wastewater treatment plants must be estimated before any mitigation and reduction strategy can be implemented.

A typical Wastewater Treatment Plant (WWTP) consists of a set of unit processes including primary, secondary and territory treatment. Although, a significant portion of these emissions come from electricity consumption, Carbon Dioxide (CO_2) emissions are also associated with the Aerobic Digestion in the biological treatment. However, this amount of CO_2 is always neglected from the WWTP's GHG account.

Activated Sludge (AS) is the most popular biological systems used in wastewater treatment plants.Conducting mass balances across the interconnected components of such system allow tracking key operating parameters from one unit of operation to a downstream one ensuring overall stability. Despite this fact, the absence of accurate measurements makes it difficult to achieve a complete mass balance closure across the system.

A review of literature made in this area indicates that mass balance showed reasonable closure for most of the elements such as N and P, but not for the Carbon Dioxide (CO_2). Thus, previous studies were developed under the assumption of Secondary Clarifier (SC) operating at steady state; neglecting for the variation in sludge depth and suspended solids within different layers. In practice, the determination of sludge depth is not accurate as it is predicted based on the visible depth measurements rather than exact sludge depth measurements. To that end, the main aim of this study is related to a more reliable predication of the carbon fate in Wastewater treatment plant; to accurately formulate carbon mass balance and to better understand the real contribution of CO_2 to GHG emissions.

In this essence, this research allows in-depth studyof the activated sludge treatment process through the development of a Bench scale plant. In which, the process will be adjusted continuously in order to establish sound measures under broad scale of conditions and settings. Particular attention will be given to both, the fate of carbon in the activated sludge process as well as the performance of the secondary clarifier under dynamic conditions; a full scale dynamic data including the exact sludge depth and concentration measurements within different layers in the SC.

Literature Review: Recently, global warming and climate change have become looming issues due to their effects on the environment. During wastewater treatment, the greenhouse gases; carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), can be transmitted to the atmosphere[1]. The aim of wastewater treatment is to enable effluents to be safely disposed of without causing danger to human health and the surrounding environment. Treatment of wastewater involves a sequence of physical, chemical and biological processes[2]. In which, the performance of the wastewater treatment plant can be controlled based on the characteristics of the sewage and the degree of treatment provided in each operation.

Mass balance is widely used approach for detecting the performance of wastewater treatment plant[3,4]. Conducting solids mass balances across the interconnected components of the wastewater treatment plant allow tracking key operating parameters from one unit of operation to a downstream one ensuring overall stability. Despite this fact, the absence of reliable measurements makes it difficult to achieve a perfect mass balance closure across the system. In particular, Secondary treatment biological treatment process releases carbon dioxide (CO_2), which has always been neglected in the mass balance.

Reviewing literature showed a reasonable mass balance closure for most of the elements in the wastewater treatment plant; such as N and P, but not for the Carbon Dioxide (CO_2)[5,6]. From one side, the SC was assumed to be operated under steady state condition ignoring the hydrodynamic state, i.e. the exact sludge level was not encountered in the mass balance, and hence the sludge accumulation term was omitted[7]. From the other side, the Aeration Tank contribution of carbon was not considered when performing carbon mass balance closure.

Therefore, quantifying the accumulation is a necessity to close the carbon balance across the AS system and thus determining the exact amount of produced CO_2.

Methodology

To accurately estimate the Carbon balance in the Wastewater Treatment Plant, a bench scale unit was set up to simulate a number of conditions of the biological treatment Process. The methodology of the study in hand was broken down into the following sequential steps as shown in figure-1.

Bench Plant Design: The utilized bench-scale plant is a small model of the activated sludge process; as shown in figure-2. Such model had the advantage of developing, at less costly, data on day-to-day- base of the wastewater characteristics as well as the overall efficiency of the system, thereby providing a full representation of a full-scale plant. It mainly consisted of: i. a bioreactor, in which the microorganisms are kept in suspension; ii. a secondary settling tank and iii. a sludge recycling system for returning activated sludge back to the Bioreactor. The bench-scale system was designed for a flow range of 75 l/d.

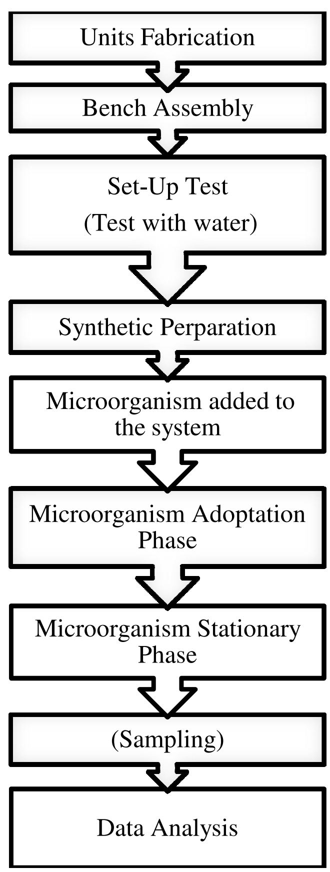


Figure-1
Methodology Framework

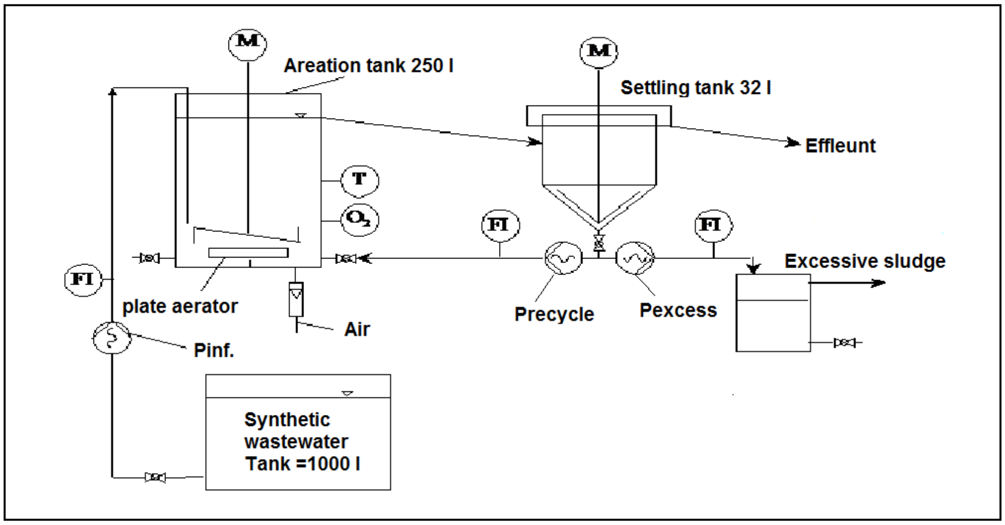


Figure-2
Bench-Scale Structure

Composition of the Synthetic Wastewater: Synthetic wastewater has been prepared in the laboratory as feed, keeping the chemical parameters within range of values presented in table-1. The use of synthetic waste in the study was mainly to apply better control on feed chemical concentrations of N, P. Meanwhile, a mixture of various carbon drinks will be used as a main source of required carbon.

Table-1
Composition of the Synthetic Wastewater

Nutrient	**Molecular Formula**	**Concentration (mg/l)**
Urea	$CO(NH_2)_2$	277
Magnesium Sulfate	$MgSO_4\ 7H_2O$	100
Calcium Chloride	$CaCl_2$	7.5
Potassium Dehydrogenate Phosphate	KH_2PO_4	53
Di-Potassium Dehydrogenate Phosphate	K_2HPO_4	107

This Bioreactor was fed by a synthetic sewage stored in a feeding tank for no longer than a week time. Then, it has been aerated by a disc diffuser, to promote air distribution among the wastewater, and further mixed by a mixer with variable rotation speed (n= 100 rpm). One small tubing inlet and one small tubing outlet with threaded valves will be installed to control the flow of fluid through the bioreactor. The Bioreactor provided a location where biological degradation of the wastewater constituents takes place. Initially, microorganisms oxidize the carbon compounds in the wastewater to produce carbon dioxide, new cells and biomass. Likewise in the Nitrification, the ammonia (NH_4) is also oxidized to nitrate (NO_3) for which pumped oxygen is required. Then, under anoxic conditions, nitrate (NO_3) is further converted into nitrogen (N_2) and oxygen (O_2) through Denitrification. From the Bioreactor, the treated flows will be passed to the settling tank where a fraction of the settled biomass is recycled to the Bioreactor while, the reminder biomass (excessive sludge) will be pumped out of the tank to keep a constant concentration of Total Solids in Bioreactor.

Operating the Bench Plant: Upon bench setting-up and the synthetic preparation phases, the plant was inoculated with an activated sludge from a municipal wastewater treatment plant. After an adaptation period of 8 weeks, the TS concentration was adjusted, in the activated sludge reactor, to TS 3.5g/l at a sludge load of (0.05 kg BOD_5/kg TS.d). The excess sludge was discharged from the plant once a week, in this case; the TS-increase was substantially represented by an increase in the sludge level in the secondary clarifier. Thus, the setting of a TS content of 3.5 g/l in the system was possible.

By volume and measurements of TS in the return sludge (TS_R), the excess sludge (TS_{Excess}) and drain ($TS_{Eff.}$) were detected. As the dry matter concentration in the plant effluent ($TS_{Eff.}$) was very low accompanied by high Effluent rate flow, samples were filtered to control the TS-measurement error (due to low dry mass low). In addition, the bench scale plant tests were operated at a temperature of 20°C, a constant pH of 7.0 and a dissolved oxygen concentration of 5 mg/l. These parameters were daily checked and adjusted as necessary.

Sampling and Measurements: As, wastewater sampling at various points in the treatment process is useful in evaluating operation efficiency, samples has been collected from the storage tank, reactors, aeration tank, settling tank and excessive sludge a period of six months; as shown in figure-3 and table-2. In addition, the exact measurement of the sludge blanket level with respect to location, time of day has been exercised to establish the exact sludge volume and eventually performing the carbon mass balance.

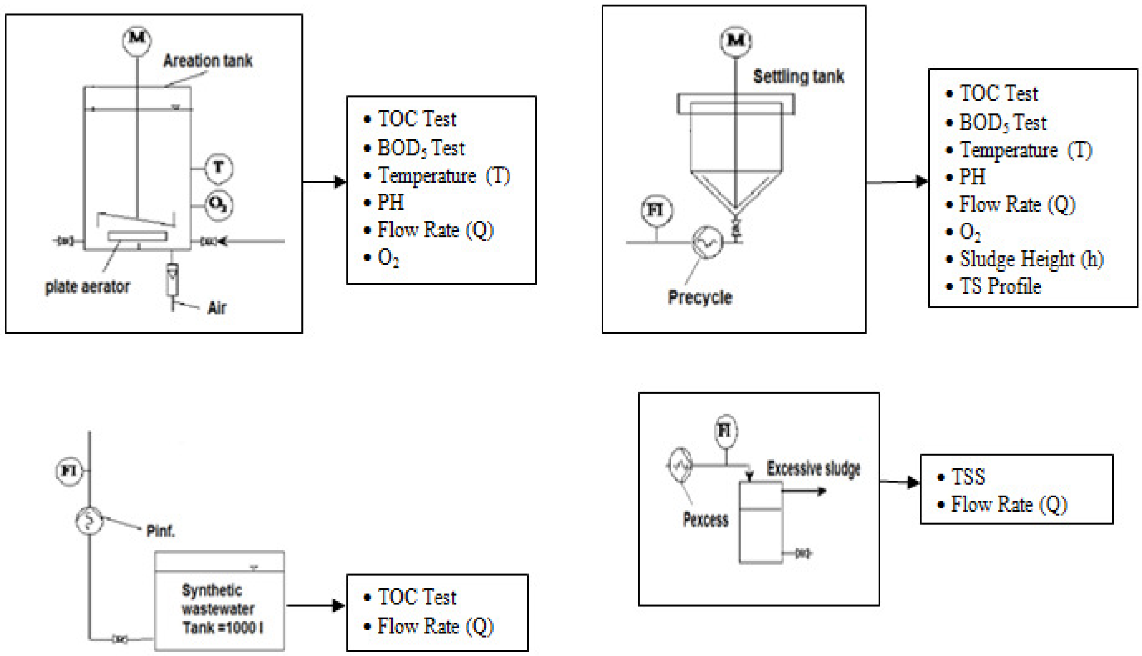
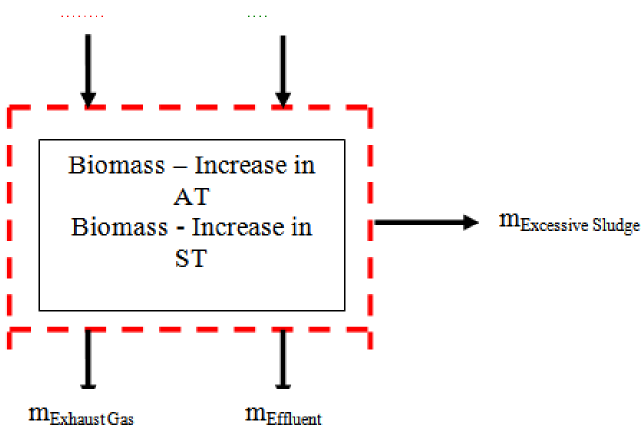


Figure-3
Sampling and Measurements Points

Procedure for Establishing the Carbon Balance: From Activated Sludge System mass balance; the solids entering the system will equal the solids leaving the system.

$$m_{Influent} + m_{Air} = m_{Effluent} + m_{ExhaustGas}$$

$$+ m_{Biomass increase,AT} + m_{Biomass increase,ST} + m_{ExcessSludge}$$



Where: $m_{Influent} = Q_{Influent} \cdot C_{TOC}$,

$m_{air} = Q_{Rotameter} \cdot C_{TOC} \approx 0$,

$m_{ExhaustGas} = Q_{Air} \cdot \rho_{Air} \cdot C_{Co2} \cdot C_{Ratio}$

For complete balancing of the carbon analysis of the sludge is necessary. The empirical formula for bacteria as indicated with C5H7O2N /HAR89/. The proportion of carbon in the biomass amounts to 53% thereafter. This corresponds to Schlegel /SCH85/, indicating 50% for single-celled organisms

$$C_{Ratio} = \frac{12}{44} = 0.271$$

The CO_2 will be quantified from the Q_{Air}

Mass balances can be used to mathematically define the accumulation in the Aeration Tank/ Bioreactor as follows:

$$m_{Biomass-increase,AT} = \Delta C_{TS,AT} \cdot V_{AT}$$

$$\Delta C_{TS,AT} = (c_{TS_{AT,End}} - c_{TS_{AT,Begin}})$$

By monitoring the depth of the sludge blanket in the Settling Tank and the concentration within different layers, the accumulation in the settling tank is calculated as follows:

$$m_{Biomass-increase,ST} = A_{ST} \cdot \Delta h \cdot \Delta C_{TS,ST}$$

$$\Delta h = (h_{ST,End} - h_{ST,begin})$$

$$\Delta C_{TS,AT} = (c_{TS_{ST,End}} - c_{TS_{ST,Begin}})$$

And finally, the daily wasted excessive sludge mass:

$$m_{Excess} = Q_{Excess} \cdot C_{TS,Excess}$$

Table-2
Parameter Measurements

Parameter Measurements	**Standard/ Equipment**	**Description/Significance**	**Frequency**
TOC	TOCOR 5000	TOC measures the organic carbon concentration in the wastewater. Sample is introduced in the combustion tube, which is filled with an oxidation catalyst and heated to 680°C. In the samples, carbon is first converted to CO_2 by the combustion furnace for TOC and TC analysis. (TOC = TC – TIC)	Daily
BOD_5	DIN38409-H51	Biochemical Oxygen Demand (BOD) is a test to measure the dissolved oxygen (DO) content , while being incubated under controlled conditions (20°C) for 5 days (hence BOD_5) and then the DO is measured again. The drop in DO is the measure of the BOD_5.	Weekly
Temperature	OXI 91	In general, in warm temperatures, biological treatment activity accelerates and slows in cool temperatures. Meanwhile, the process can totally stop in extreme hot or cold atmosphere.	Daily
pH	pH 91	The “pH” approximates the concentration of the hydrogen ion in the solution. pH is measured on a scale of 0 to 14, as lower values indicating high H+ (more acidic) and higher values indicating low H+ ion activity (less acidic). While, a pH of 7 is counted as neutral.	Daily
Flow Rate	Flow meter	Wastewater flow rates will be monitored and recorded for purposes of evaluating the Bench plant performance.	Daily
TSS concentration	DIN38414-S2	A well- mixed sample is filtered using a weighed standard glass-fiber filter. Under 105°C, the residue retained on the filter is dried to a constant weight. The increase in weight of the filter represents the total suspended solids. In case the suspended material clogs the filter and prolongs filtration. An estimate of the total suspended solids may be induced from the difference between the total solids and the total dissolved solids.	Daily
O_2	OXI 91	Sufficient D.O. is required for the operation of many wastewater treatment processes. In essence, the D.O. is continuously monitored in the activated sludge tanks. A dissolved oxygen meter is an electronic device that converts signals from a probe that is placed in the water into units of DO in milligrams per liter. The probe is filled with a salt solution and has a selectively permeable membrane that allows DO to pass from the stream water into the salt solution. The DO that has diffused into the salt solution changes the electric potential of the salt solution and this change is sent by electric cable to the meter, which converts the signal to milligrams per liter on a scale that can be read.	Daily

Results and Discussion

Samples were collected from the bench scale plant over two different periods of 75 days each: summer (29.07.2014 to 15.10.2014) and (01.11.2014 to 15.01.2015), as shown in tables-3 and 4 respectively.

Table-3
Collected Data for the First period

Sample	$TOC_{Inf.}$ [g/l]	$TOC_{Eff.}$ [g/l]	$MLSS_{BR}$[g/l]	$MLSS_{Excess}$[g/l]	$MLSS_{Eff.}$[g/l]	C_{CO2}[%]
29-Jul.	346	25	3.42	3.68	23	0.5
2-Aug.	340	18	3.39	3.63	25	0.4
5-Aug.	351	24	3.45	3.71	19	0.5
12-Aug.	347	26	3.53	3.58	17	0.5
17-Aug.	344	19	3.65	3.54	20	0.5
19-Aug.	352	18	3.4	3.6	22	0.5
22-Aug.	346	20	3.46	3.57	20	0.6
27-Aug.	343	16	3.56	3.7	24	0.4
1-Sept.	349	17	3.5	3.8	20	0.5
6-Sept.	351	14	3.6	3.75	25	0.6
12-Sept.	349	18	3.56	3.69	21	0.5
15-Sept.	343	15	3.5	3.5	23	0.4
18 Sept.	332	14	3.5	3.61	20	0.5
21 Sept.	345	9	3.59	3.62	21	0.5
24 Sept.	323	7	3.64	3.7	20	0.4
28-Sept.	375	17	3.7	3.9	18	0.5
1-Oct.	368	17.5	3.41	3.4	19	0.4
5-Oct.	350	10	3.38	3.38	21	0.5
10-Oct.	345	13	3.45	3.35	20	0.5
15-Oct.	340	13	3.4	3.4	19	0.5

Table-4
Collected Data for the Second Period

Sample	$TOC_{Inf.}$ [g/l]	$TOC_{Eff.}$ [g/l]	$MLSS_{BR}$[g/l]	$MLSS_{Excess}$[g/l]	$MLSS_{Eff.}$[g/l]	C_{CO2}[%]
1-Nov.	348	13	3.61	3.8	20	0.4
5-Nov.	340	12	3.66	3.77	19	0.4
10-Nov.	325	13	3.71	3.9	20	0.4
11-Nov.	320	12	3.39	3.6	20	0.4
15-Nov.	324	13	3.43	3.7	20	0.5
18-Nov.	350	20	3.39	3.5	25	0.5
21-Nov.	343	23	3.4	3.52	23	0.5
25-Nov.	338	19	3.38	3.5	22	0.6
28-Nov.	330	25	3.41	3.56	24	0.4
2-Dec.	350	27	3.43	3.6	22	0.5
6-Dec.	342	29	3.5	3.66	23	0.5
10-Dec.	340	22	3.53	3.7	21	0.4
14-Dec.	335	25	3.55	3.7	25	0.5
18-Dec.	310	20	3.45	3.8	20	0.4
21-Dec.	350	25	3.38	3.7	23	0.5
25-Dec.	342	17	3.4	3.8	21	0.5
28-Dec.	340	19	3.4	3.9	20	0.4
3-Jan.	360	22	3.5	4	22	0.5
6-Jan.	350	18	3.65	4.2	20	0.5
9-Jan.	365	20	3.5	4.3	23	0.5
12-Jan.	360	24	3.6	4.2	22	0.6
15-Jan.	365	21	3.6	4.3	25	0.5

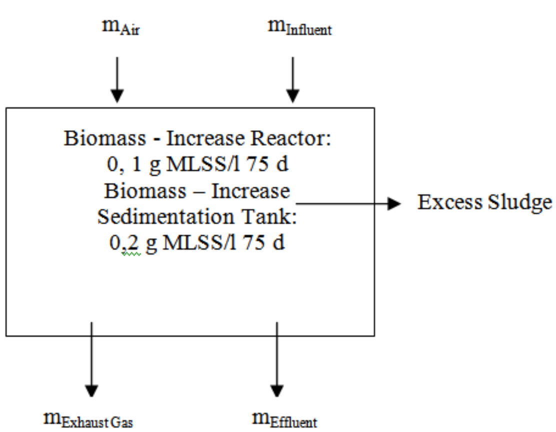
Carbon Balance for the First Period of Study: Carbon Mass Balance: Bench-Scale Plant 29.07.2014 - 15.10.2014 (75 Days)

$m_{Influent}$ = 40 l/d
$TOC_{Influent}$ = 0,35 g/l
$IC_{Influent}$ = 0 g/l
$V_{Excess\ Sludge}$ = 10 l/75 d
$MLSS_{Excess\ Sludge}$ = 3,5 - 3,7 g/l
MLSS-Increase $_{Sedimentation\ Tank}$ =0,2 g/l in 75 d
$V_{Sludge,\ Sedimentation\ Tank}$ = 15 l

$m_{Effluent}$ = 40 l/d
$TOC_{Effluent}$ = 0,015 g/l
$IC_{Effluent}$ = 0,005 g/l

m_{Air} = 0,2 m^3/h
r_{CO2} = 1,739 g/l
27,3 % C per Mol CO_2
Exhaust Gas, CO_2 = 0,5 Vol.%

Carbon Content in Biomass:
0,5 g C/g MLSS
$MLSS_{Reactor}$ = 3,5 - 3,6 g/l
MLSS-Increase $_{Reactor}$ = 0,1 g/l in 75 d
$V_{Reactor}$ = 70 l
$TOC_{Reaktor,\ 29.07.2014}$= 0,03 g/l
$IC_{Reaktor,\ 29.07.2014}$ = 0,02 g/l
$TOC_{Reaktor,\ 15.10.2014}$ = 0,045 g/l
$IC_{Reaktor,\ 15.10.2014}$ = 0,02 g/l
(TOC- and IC-increase in the reactor neglected)



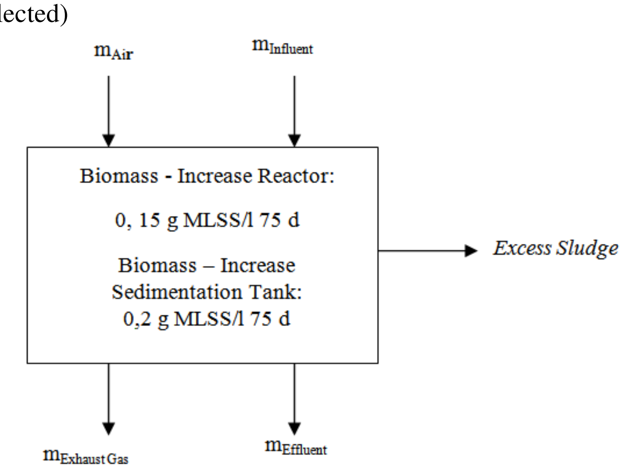
Mass Balance:
$m_{Influent}+m_{Air}=m_{Effluent}+ m_{Exhaust\ Gas}+m_{Biomass\text{-}Increase\ Reactor}+ m_{Biomass\text{-}Increase\ Sedimentation\ Tank}+ m_{Excess\ Sludge}$
Influent: $m_{Influent}$ = 0,33 g TOC/l X 40 l/d = 13,2 g C/d
Effluent:$m_{Effluent}$ = 0.02 g (TOC+IC)/l X 40 l/d = 0,8 g C/d
Air: m_{Air} = 0 g TC/$m^3$where,0 g C/d (assumption)
Exhaust Gas: mExhaust Gas = 0,5 Vol.% CO_2 at 0,2 m³/h = 4,8 m³/d0,5/100 X 4,8 m^3/d = 0,024 m^3/d = 24 l CO_2 /d
mExhaust Gas=24 l CO_2/d X 1,739 g/l = 43,03 g CO_2/d X 27,3/100 g C/g CO_2 = 11,4 g C/d
Biomass - increase Reactor:
$m_{Biomass\ Increase\ Reactor}$ = 70l X 0,5 g C/g MLSS X 0,1 gMLSS/l 75d = 0,046 g C/d
Biomass - increase Sedimentation Tank:
$m_{Sedimentation\ Tank}$ =15 l X 0,5 g C/g MLSS X 0,2 g MLSS/l 75d = 0,02 g C/d
Excess Sludge: $m_{Excess\ Sludge}$ = 10l X 0,5 g C/g MLSS X 3,7 g/l / 75d = 0,246 g C/d
Total: $m_{Effluent}+m_{Exhaust\ Gas}+m_{Biomass\text{-}Increase,\ Reactor}+m_{Biomass\text{-}Increase,\ Sedimentation\ Tank}+m_{Excess\ Sludge}$=
(0,8+11,4+0,046+0,02+0,246) g C/d = 12,512 g C/d
Closure of the Carbon Mass Balance:
100 % X 12,512 g C/d / 13,2 g C/d =94,7 %

Carbon Balance for the Second Period of Study: Carbon Mass Balance: Bench-Scale Plant 01.11.2014 - 15.01.2015 (75 Days)
$m_{Influent}$ = 40 l/d
$TOC_{Influent}$ = 0,35 g/l
$IC_{Influent}$ = 0 g/l
$V_{Excess\ Sludge}$ = 10 l/75 d
$MLSS_{Excess\ Sludge}$ = 3,81 g/l
MLSS-Increase $_{Sedimentation\ Tank}$ =0,2 g/l in 75 d
$V_{Sludge,\ Sedimentation\ Tank}$ = 15 l

$m_{Effluent}$ = 40 l/d
$TOC_{Effluent}$ = 0,015 g/l
$IC_{Effluent}$ = 0,005 g/l

m_{Air} = 0,2 m^3/h
r_{CO2} = 1,739 g/l
27,3 % C per Mol CO_2
Exhaust Gas, CO_2 = 0,5 Vol.%

Carbon Content in Biomass:
0,5 g C/g MLSS
$MLSS_{Reactor}$ = 3,5 - 3,6 g/l
MLSS-Increase $_{Reactor}$ = 0,1 g/l in 75 d
$V_{Reactor}$ = 70 l
$TOC_{Reaktor,\ 01.11.2014}$= 0,03 g/l
$IC_{Reaktor,\ 01.11.2014}$ = 0,02 g/l
$TOC_{Reaktor,\ 15.01.2015}$ = 0,045 g/l
$IC_{Reaktor,\ 15.01.2015}$= 0,02 g/l
(TOC- and IC-increase in the reactor neglected)



Mass Balance:

$m_{Influent} + m_{Air} = m_{Effluent} + m_{Exhaust\ Gas} + m_{Biomass\text{-}Increase\ Reactor} + m_{Biomass\text{-}Increase\ Sedimentation\ Tank} + m_{Excess\ Sludge}$

Influent: $m_{Influent}$ = 0,33 g TOC/l X 40 l/d = 13,2 g C/d
Effluent: $m_{Effluent}$ = 0.02 g (TOC+IC)/l X 40 l/d = 0,8 g C/d
Air: m_{Air} = 0 g TC/$m^3$where,0 g C/d (assumption)
Exhaust Gas: $m_{Exhaust\ Gas}$ = 0,5 Vol.% CO_2 at 0,2 m^3/h = 4,8 m^3/d 0,5/100 X 4,8 m^3/d = 0,024 m^3/d = 24 l CO_2 /d

$m_{Exhaust\ Gas}$=24 l CO_2/d X 1,739 g/l = 43,03 g CO_2/d X 27,3/100 g C/g CO_2 = 11,4 g C/d
Biomass - increase Reactor:
$m_{Biomass\ Increase\ Reactor}$ = 70l X 0,5 g C/g MLSS X 0,15 gMLSS/l 75d = 0,07 g C/d
Biomass - increase Sedimentation Tank:
$m_{Sedimentation\ Tank}$ =15 l X 0,5 g C/g MLSS X 0,2 g MLSS/l 75d = 0,02 g C/d
Excess Sludge: $m_{Excess\ Sludge}$ = 10l X 0,5 g C/g MLSS X 3,81 g/l / 75d = 0,254 g C/d
Total: $m_{Effluent}+m_{Exhaust\ Gas}+m_{Biomass\text{-}Increase,\ Reactor}+m_{Biomass\text{-}Increase,\ Sedimentation\ Tank}+m_{Excess\ Sludge}$=
(0,8+11,4+0,046+0,02+0,254) g C/d = 12,544g C/d
Closure of the Carbon Mass Balance:
100 % X 12,544 g C/d / 13,2 g C/d =95,03 %

In order to close the carbon mass balance in the activated sludge system, adding the bioaccumulation term for the AT and the Sedimentation Tank is a necessity. Analysis of data collected for both periods under consideration revealed that, on average, a 95% carbon balance closure can be achieved.

More specifically, a realistic result of 85% of the encountered carbon was found in the form of CO_2; which is caused by the oxidation reaction. Meanwhile, the missing 5% of carbon can be mainly attributed to activated sludge carbon adsorption and to errors in measurements of TS (pressure filtration) in AT and Sedimentation Tank.

Although the accumulation term can be of noticeable effect when performing carbon mass balance over the two periods, it is of minor influence when considering long periods of study.

Furthermore, the work reported in this research improves upon the existing carbon mass balance; as by comparing the data of Geissen[8], found there was 85% of carbon balance closure in bio-systems.

Finally, the results from the bench-scale show that the suggested method can obtain the exact amounts of produced CO_2 from the activated sludge process which, in turn, forms an addition to GHG.

Conclusion

The bench-scale bioreactor established in this study allowed in-depth research to be executed on the activated sludge process with a special focus on the fate of carbon across the system. In which, the fate and the mass balance of the carbon during the activated sludge process was investigated taken into account the accumulation in both the Aeration and Sedimentation Tanks. Results from this research achieved a 95% closure of carbon balance in the activated sludge. Moreover, in the light of the findings set out in this study based on the development of a bench scale unit, the amounts of CO_2 generated from real life wastewater treatment plant can be estimated.

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