MODIDICATION OF LEACHET CHARACTERISTCS IN LANDFILL USING MIXXTURE OF LIME AND SAWDUST WASTE

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ABSTRACT

Landfill bioreactor is a modified technique comparing with the conventional landfill processes due to its ability to reduce time for decomposition and enhancing the biogas generation. The basic goal of this paper is to investigate the performance of a three lab-scale bioreactors under anaerobic conditions. Three types of reactors differ in its internal composition were experimented ,bentonite clay was used as a cover material. First reactor was filled with organic solid waste only; second reactor was filled with a mixture of organic solid waste, Lime and sawdust, while the third reactor was filled with mixture of solid waste and lime. Leachate characteristics traced includes pH, EC, TDS, TSS, Heavy metals (Cr, Fe, Mn, Zn, and Mo), Sulfate SO^{-2}_4 and Phosphate PO^{-3}_4.

Experiments were conducted from October 2014 to march 2015, Results shows a significant variation in removal efficiency for each reactor, heavy metals removal for the first reactor was (Mn 58.6%, Cr 13.4%, Mo 0%, Zn 27.2%, Fe 58.6%),and the second reactor removal efficiency was (Mn 77.2%, Cr 67.5%, Mo 69.19%, Zn 67.9%, Fe 56.7%), while for the third reactor was (Mn 30.1%, Cr 13.8%, Mo 18.48%, Zn 29.8%, Fe 70%). The results show that the solid waste, Lime and sawdust enhanced the removal of heavy metals in the 2nd reactor which gave best removal efficiency for heavy metals. While the lime addition in the 3rd reactor increase the removal efficiency of iron to 70%. It can be conclude that this modified landfill bioreactor enhance leachate characteristics and so enhancing the solid waste stabilization.

KEYWORDS: Leachate, Landfill, Bioreactor, Lime, Sawdust, Anaerobic.

تعديل خواص عصارة مكب النفايات باستخدام خليط من الجير و نفايات نشارة الخشب

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الخلاصة .

المفاعل الحيوي هو أسلوب معدل لعملية الطمر الصحي مقارنة مع عمليات طمر النفايات التقليدية نظرا لقدرته على تقليل الوقت المطلوب لعمليات التحلل وكذلك تعزيز توليد الغاز الحيوي. الهدف الأساسي من هذه الورقة هو للتحقيق في أداء ثلاثة مفاعلات حيوية مختلفة تحت الظروف اللاهوائية، تختلف هذه المفاعلات الحيوية الثلاثة في تكوينها الداخلي و لجميعها فقد تم استخدام طين البنتونيت كمادة غطاء. شغل المفاعل الأول مع النفايات الصلبة العضوية فقط، المفاعل الثاني تم تشغيله مع خليط من النفايات الصلبة العضوية والجير ونشارة الخشب، في حين تم تشغيل المفاعل الثالث مع خليط من النفايات الصلبة والجير. خصائص العصارة التي تم تتبعها شملت درجة الحموضة، التوصيلية الكهربائية، المواد الذائبة الكلية، المواد العالقة الكلية، المعادن الثقيلة (Cr, Fe, Mn, Zn, Mo)، الكبريتات (SO^{-2}_4)، و الفوسفات (PO^{-3}_4).

أجريت التجارب للفترة من أكتوبر 2014 إلى مارس 2015، اطهرت النتائج تفاوت كبير في كفاءة الإزالة لكل مفاعل من المفاعلات الثلاث، كانت كفاءة إزالة المعادن الثقيلة للمفاعل الأول (Mn 58.6%, Cr 13.4%, Mo 0%, Zn 27.2%, Fe 58.6%), اما المفاعل الثاني (Mn 77.2%, Cr 67.5%, Mo 69.19%, Zn 67.9%, Fe 56.7%)، في حين أن كفاءة الازالة في المفاعل الثالث كان (Mn 30.1%, Cr 13.8%, Mo 18.48%, Zn 29.8%, Fe 70%). أظهرت النتائج أن مزيج النفايات الصلبة، والجير ونشارة الخشب في المفاعل الثاني عززت إزالة المعادن الثقيلة. في حين أن إضافة الجير فقط في المفاعل الثالث ادى الى زيادة كفاءة إزالة الحديد إلى 70٪. يمكن من خلال نتائج البحث التوصل الى استنتاج الى ان التعديلات المقترحة للتركيبة الداخلية للمفاعلات قيد البحث حسنت فعاليتها في تعزيز خصائص العصارة و بالتلي تعزيز تثبيت النفايات الصلبة.

Nomenclature.

EC: Electrical Conductivity.

pH: Potential Hydrogen.

TDS: Total Dissolved Solids.

TSS: Total Suspended Solids.

1. INTRODUCTION.

The landfill is the most common method for solid waste disposal and it is like other methods of treatment have advantages and disadvantages. Uncontrolled leachate and gas production are the major disadvantages as well as the public and aesthetic problems resulted from open dump solid waste disposal (Chart, 2004). Many researches were done in order to minimize the problems associated with landfill practices (Yuen, 2001). In order to improve knowledge of landfill behavior and decomposition processes of MSW, there has been a strong interest in upgrade existing landfill technology from a storage/containment concept to a process-based approach, in other words as a bioreactor landfill **(**Mostafa, 2002**)**. Bioreactor is any system boosts the biological activity in a specific environment, and so bioreactor landfill is the technique that employs modification on the process of the conventional landfill either by leachate recirculation into MSW fills with or without oxygen supply or with chemicals to enhance the biological processes and reduce stabilization time needed for organic waste. The waste is considered stabilized when leachate is no longer pollution hazard, gas production and settlement is negligible **(**Borglin, 2004). The use of bioreactor landfill will significantly increase the organic solid waste decomposition over the ordinary organic solid waste landfill (Swati, 2007).

The anaerobic digestion process takes place in an airtight container, known as a digester. The first stage of anaerobic digestion is a chemical reaction called hydrolysis (Shefali, 2002), where complex organics particles are separated into basic sugars, amino acids, and fatty acids with the addition of hydroxyl groups. This is followed by three biological processes:

- Acidogenesis - further broken down by acidogenic bacteria into simpler molecules, volatile fatty acids (VFAs) occurs, producing ammonia, CO_2 and hydrogen sulfide as byproducts.
- Acetogenesis - the molecules particles from acidogenesis are further processed by microscopic organisms called acetogens to create CO_2, Hydrogen and acetic acid (Ljupka, 2010).
- Methanogenesis - methane, CO_2 and water are produced by bacteria called methanogens. in order to maximize digestion, pH level should be kept within (5.5-8.5) and the temperature between 30-60°C, in order to maximize digestion rates (Amin, 2012).

In this paper a lab-scale solid waste bioreactor landfill will be used. Modification of the landfill bioreactor will be done by mixing waste with specific materials to improve the performance of solid waste stabilization and enhancing the leachate characteristics.

2. MATERIAL AND METHODOLOGY.

Three lab-scales of bioreactors (**Fig 1**) have been designed and constructed in Al-Mustansiriya University, College of Engineering.

2.1. Structure and filling of reactors.

2.1.1. First reactor.

First reactor made of ductile iron pipe of (1.3m) height and (0.4m) diameter, the effective height of solid waste was (1m). The reactor was underlying by (15cm) gravel layer for drainage purposes and PVC pipe for leachate collection as in **fig (2)**. The solid waste in reactor was separated by a strainer from the gravel layer. the reactor was sealed by (15cm) bentonite clay as cover material, Bentonite are excellent sealants and absorbents, so it acts as an excellent barriers for landfills and toxic waste repositories (Haydn, 2002). **Table (1)** and **(2)** shows the chemical and physical characteristics of bentonite. The reactor was well lidded from top to ensure that the anaerobic conditions will occur. The reactor filled with (84kg) of dry and well compacted organic solid waste (corrupted fruits and vegetables), The waste density was 668.45kg/m^3, The compaction was applied in order to increase the dry density which significantly speed up the degradation processes **(**Chart, 2004**)**.

2.1.2. Second and third reactor.

The frame structure of the second and third reactors is identical, it made of ductile iron pipe, height and diameter are (1.1m) and (0.3m) respectively, The reactors were underlying by (15cm) of gravel layer and sealed from top by (15cm) bentonite. The solid waste effective height was (80cm) with drainage pipe for leachate collection as in **figure (3)**. Second reactor was filled with (50kg) organic solid waste, 3kg of sawdust and 2.211 kg of Lime. The purpose of adding the saw dust is to reduce the volume of organic compound in the reactor as well as to investigate its behavior as adsorbent media. Lime was added in the 2nd and 3rd reactor to minimize the acidic affect on microorganisms activities, Lime proven a good capability in pH adjusting (Abdullahi, 2012), As well as the Lime will reduce the emission of Co_2 and mitigate the greenhouse gases according to equation (1) (Guang, 2000). The third reactor was filled with (50kg) organic solid waste and (4.422 kg) of lime to find out the effect of sawdust absence. **Table (3)** describes the specification and filling mixture of the three reactors.

$$\mathbf{Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O} \qquad (1)$$

2.2. Monitoring of bioreactor landfill.

The produced leachate was analyzed for parameters of pH, Sulphate SO^{-2}_4, Phosphate PO^{-3}_4, EC, Fe^{+2}, Zn^{+2}, Cr^{+3}, Mn^{+2}, Mo^{+2}, Total Dissolved Solids TDS and Total Suspended Solid TSS. Standard Methods for wastewater examination (Eaton, 2005) and Spectrophotometers (HACH) were used.

3. RESULTS AND DISCUSSION.

3.1. The effect of lime on pH.

The initial pH values differ in each reactor due to the Lime addition and its effects on pH value during the study period. **Table (4, 5 and 6)** describes the physiochemical characteristics of leachate generated through the study period from the 1st, 2nd and 3rd reactors, respectively. The first reactor has initial pH of 4.9 and then increase slightly to 6.3 after 6 months of operation due to acid formation phase. pH value in 1st reactor kept under pH value 6.4 which is the minimum optimum value for the anaerobic digestion (Fabien, 2003). While the pH initial value in 2nd reactor was 6.07 and increased to 7.02 in two months due to the addition of 2.211 kg of Lime. In 3rd reactor the initial pH was 7.1 due to the addition of 4.422 kg lime. Lime is considered as a pH regulator due to its effect in breaking down the organic matters and neutralizes acidity (Edson, 2011).

3.2. Removal of heavy metals.

Initial leachate characteristics clearly showing that the leachate exhibited significant value of heavy metals such as Mo^{+2}, Fe^{+2} and Mn^{+2}. and the higher values of that three elements was in the 2nd reactor which are 600mg/l, 277.7mg/l and 237.7mg/l for Mo^{+2},Fe^{+2} and Mn^{+2} respectively.

In this study, Fe^{+2} values have been significantly reduced throughout the study period as shown in **figure (4)**. The final effluent concentration of Fe^{+2} was varies among the three reactors, with 85mg/l, 120mg/l and 70 mg/l for the 1st, 2nd and 3rd reactor, respectively. The optimum removal of Fe^{+2} was in 3rd reactor with 70%. The highest removal was 70% for 3rd and lowest removal for the 2nd reactor which is very close to the removal of 1st reactor which are 56.7% and 58.8%, respectively. The 4.422kg of Lime addition in the 3rd reactor makes pH in range of (7.1-9.2) which increase the removal of iron as shown in **figure (4)**, it's observed that the increase in metals removal is related to the increase in pH (Hamidi, 2004), such result is due to the fact that most metallic elements are soluble in an acidic environment.

2nd reactor leachate have the highest initial value for Mn^{+2} and Mo^{+2}, with 258.9mg/l and 600.3mg/l respectively, The final effluent was significantly reduced to 65mg/l and 185 mg/l for $Mn^{+2}$and Mo^{+2}, respectively with pH was in range of (6.07-8.8) as shown in **figure (5)**. 2nd reactor was more efficient in removal of $Mn^{+2}$and $Mo^{+2}$from leachate. The removal efficiency of $Mn^{+2}$and Mo^{+2}in 2nd reactor was 77.2% and 69.19 %, respectively, While the removal efficiency in 1st and 3rd reactor was 23% Mn^{+2}, 0% $Mo^{+2}$and 30.1% Mn^{+2}, 18.48% Mo^{+2}, respectively.

Sawdust is a more suitable adsorbent compared to rice husk in the removal of heavy metals from the simulated landfill leachate (Agbugui, 2015). Sawdust was capable of adsorbing $Mn^{+2}$and Mo^{+2}, Normally Mo^{+2} is anion forming metalloid and therefore like chromate, arsenic, uranium and vanadium, should be adsorbed best with pH value between (5-7) (Chistensen, 2010).

The polymeric material in sawdust is lignin, tannins or other phenolic compounds. From the nature of the material that are efficient in capturing heavy metal ions especially Cr^{+3} (Agbugui, 2015). In this study the initial values of Cr^{+3} and Zn^{+2} in 2nd reactor was 9.4mg/l and 19.3 mg/l, respectively, which is higher than other reactors. The removal efficiency of both metals in the 2nd reactor was 67.5% and 67.9%, respectively, as shown in the **figure (6)** which is the best removal among the other reactors throughout the study period.

3.3. Removal of SO^{-2}_4 and PO^{-3}_4.

The initial value of SO_4 in 2nd reactor was 1206.7 mg/l which is the highest while the initial value of SO^{-2}_4 for the 1st and 2nd was 262.4mg/l and 343.3 mg/l, respectively. The SO^{-2}_4 reduced significantly to 253.2 mg/l in 2nd reactor as shown in **figure (7)**, While the effluent value from 1st and 3rd reactors was 200 mg/l and 130 mg/l. The removal efficiency of SO^{-2}_4 in the 2nd reactor was 79%. The initial value of PO^{-3}_4 in 3rd reactor was 24.9 mg/l and the effluent was 15.2 mg/l. the 3rd reactor removed the PO^{-3}_4 efficiently with a removal efficiency of 64.3% as shown in **figure (8)**. The decline in phosphate concentration may due to the phosphate assimilation by microorganisms.

3.4. Removal of TSS.

The TSS initial value in the 2nd was higher than other reactors with 365 mg/l which decreased to 231mg/l in the first three weeks, then tend to increase to 470 mg/l, The final effluent throughout this study was 58 mg/l. the removal efficiency in the 2nd and 3rd reactors was 84.11% and 84.5% which indicates that both reactor have same behavior in removing TSS. **Figures (9), (10)** and **(11)** shows TSS concentration variation with time in 1st,2nd and 3rd reactors respectively, the fluctuation in TSS values appear in the previous figures may related to the variation of microorganism activity in breaking down organic matters, which effected by many factors such as pH and temperature.

4. CONCLUSION.

Based on the previous results in the present study, it can be concluded the following:

1- Removal of heavy metals, phosphate and sulphate can be influenced significantly by mixture composition of solid waste in bioreactor landfill.
2- 1st reactor which was containing solid waste only like an ordinary landfill was suffering from insignificance leachate enhancement.
3- Designed solid waste mixture in 2nd reactor provided adsorbent media (sawdust) and pH adjustment material (lime), and such designed mixture enhanced the removal efficiency of heavy metals and sulphate.
4- 3rd reactor although it was less efficient in pollutant removal than 2nd reactor, however this reactor was more efficient in pollutant removal than 1st reactor and such result prove the positive effect of lime addition as a pH regulator for microorganism activity.
5- The results showed that the 2nd reactor have optimum removal for heavy metals and Sulphate, which makes the 2nd reactor best choice among the other two reactors. Fe^{+2} was removed more efficiently by 3rd reactor. Both 2nd and 3rd reactors were efficiently removed TSS from leachate.

A recommendation for future studies is the investigation the influence of leachate recirculation percent and ratios of sawdust and lime on the performance of reactors.

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Table (1): Chemical Composition of Bentonite

Comp.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O
Percentage	56.77	15.67	5.12	4.48	3.42	1.11
Comp.	K_2O	P_2O	SO_2	CL	LiO_3	
Percentage	0.6	0.65	0.59	0.57	9.49	

Table (2): Physical Properties Bentonite.

Clay Type	**Surface area (m^2/g)**	**Density (Kg/m^3)**	**Oil Retention (%)**	**pH**	**Adsorption of water vapor %**
Bentonite	220	750	35	10.1	11.8

Table (3): specification and filling waste mixture of the three reactors.

Reactor No. **Components**	**1**	**2**	**3**
Organic waste weight(kg)	84	50	50
Lime	-	2.211	4.422
Sawdust (kg)	-	3	-
Density of mixture (kg/m^3)	668	770	820
Cover material	bentonite	bentonite	bentonite

Table (4): characteristic of leachate from 1st reactor.

Item	**Time, Weeks**							
	1	**4**	**9**	**10**	**27**	**29**	**30**	**34**
pH	4.94	5.22	6.06	6.26	6.3	7.46	6.05	6.22
Mn^{+2} mg/l	56.93	49.23	97.2	95.33	115.2	51.7	62.56	43.68
Zn^{+2} mg/l	4.715	3.67	7.98	9.44	9.27	4.29	4.78	3.43
SO^{-2}_4 mg/l	262.44	195.9	456	346.6	486	209	220.8	200
PO^{-3}_4 mg/l	22.7	38.4	35.4	33	23.04	11.33	15.08	9.36
TSS mg/l	279	400	350	621	314	241.9	309.5	600
Mo^{+2} mg/l	112.5	95.031	192	173.3	350	310	224.48	145.6
Cr^{+3} mg/l	2.11	1.61	3.27	4.33	3.335	2.3343	2.8	1.83
Fe^{+2} mg/l	205.4	306.9	249.6	330	191.7	90.68	110.77	85
Ec µS/cm	2006	3665	16004	17505	29983	31075	32678	18660
TDS ppm	1059	1920	8241	9014	15532	16115	17112	9325

Table (5): characteristic of leachate from 2nd reactor.

Item	**Time, Weeks**							
	1	**4**	**9**	**10**	**27**	**29**	**30**	**34**
pH	6.07	6.4	6.72	7.02	7.5	8	8.3	8.8
Mn^{+2} mg/l	285.09	119.7	62.8	80.6	55.3	82.5	82.8	65
Zn^{+2} mg/l	19.3	7.29	5.36	7.06	4.69	6.38	7.56	6.2
SO^{-2}_4 mg/l	1206	423	290.18	346.6	224	341	306	253.2
PO^{-3}_4 mg/l	25.1	19.4	8.4	29.6	12.11	16.28	19.98	15.2
TSS mg/l	365	231	360	470	347.9	388	86.7	58
Mo^{+2} mg/l	600.3	451	401	321	250	310.2	257.4	185
Cr^{+3} mg/l	9.457	3.798	2.083	2.903	3.55	3.784	3.834	3.07
Fe^{+2} mg/l	277.7	181.2	238.2	280.8	90.1	140.75	140.94	120
Ec µS/cm	3249	3860	27859.5	28862.5	44010	37235	46890	19335
TDS ppm	1691	2009	14500	15022	22512	19173	23400	9660

Table (6): characteristics of leachate from 3rd reactor.

Item	Time, Weeks							
	1	**4**	**9**	**10**	**27**	**29**	**30**	**34**
pH	7.1	7.5	7.8	8	8.2	8.31	8.8	9.2
Mn^{+2} mg/l	70.09	114.24	79.4	95.33	70	72.75	53.2	49
Zn^{+2} mg/l	5.41	8.26	6.41	7.8	3.99	4.8	3.5	3.8
SO^{-2}_4 mg/l	343.37	443.64	322.42	346.6	308	292.5	196	130
PO^{-3}_4 mg/l	24.9	31.6	10.6	33	11.2	12.3	9.94	8.9
T.S.S mg/l	292	394	416	472	200	147.27	75.94	45.04
Mo^{+2} mg/l	330	205.2	160	200	301	270	277.2	269
Cr^{+3} mg/l	2.76	4.87	2.87	4.33	3.225	3.187	2.506	2.38
Fe^{+2} mg/l	237.7	301.8	282.7	330	110.9	122.25	90.94	70
Ec µS/cm	2628	4750	18933	23791.8	42254	34497	36540	24434.8
TDS ppm	1371	2500	9965	12522	21613	17955	18214	12213.8

Figure (1): 1st, 2nd and 3rd reactors.

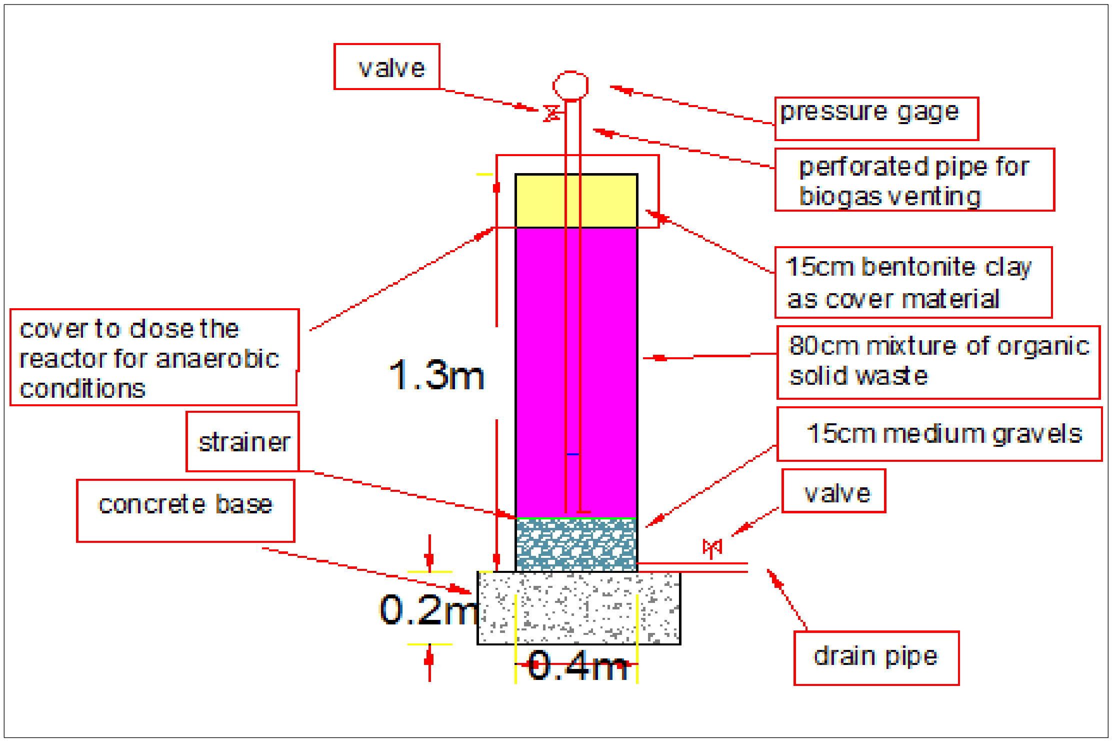

Figure (2): Scheme of 1st bioreactor.

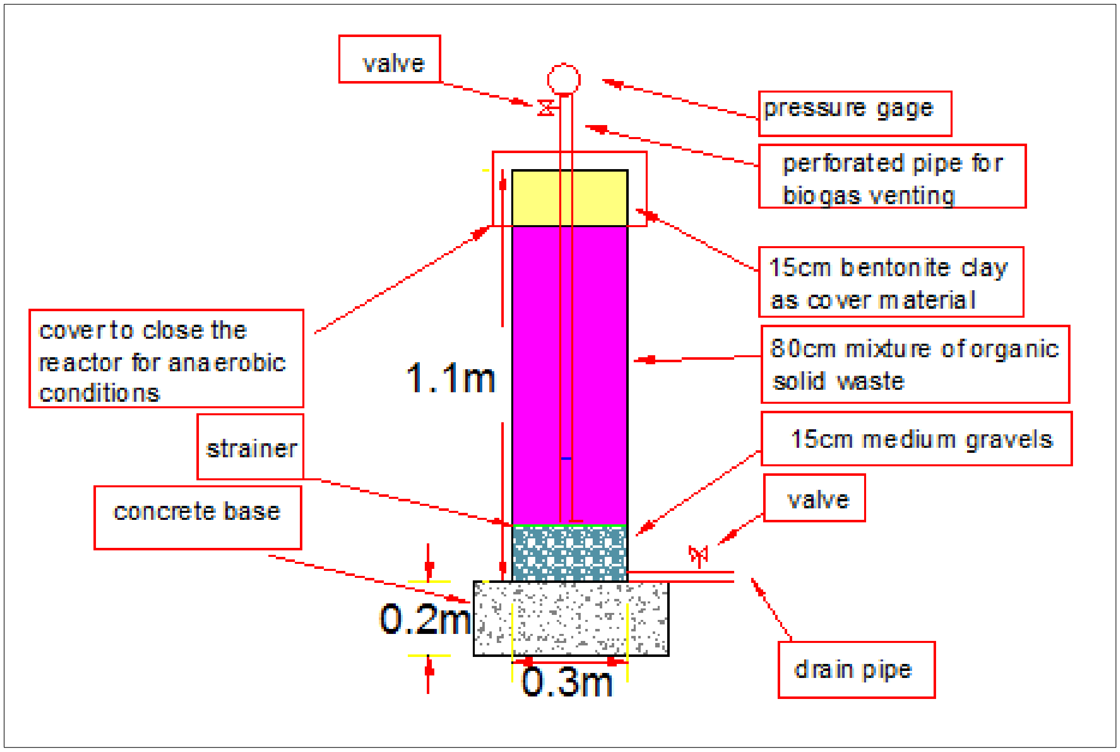

Figure (3): Scheme of 2nd and 3rd reactors.

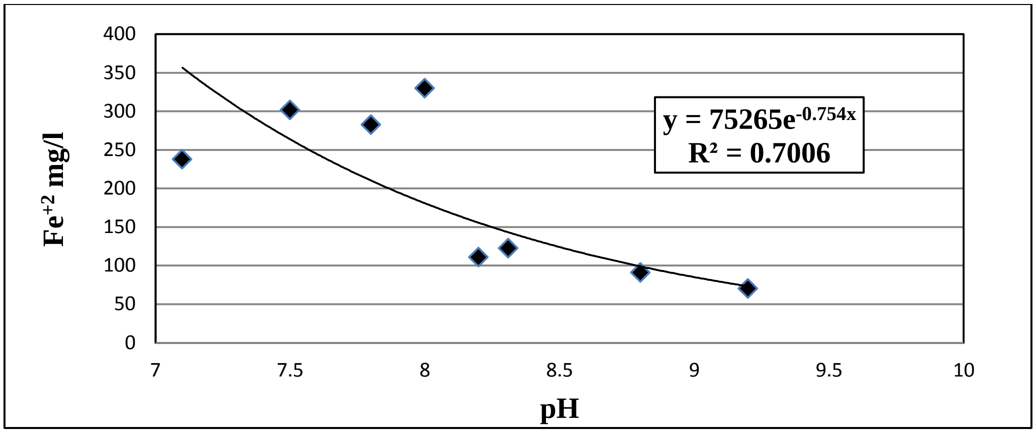

Figure (4): Variation of Fe^{+2} with pH increasing, 3rd reactor.

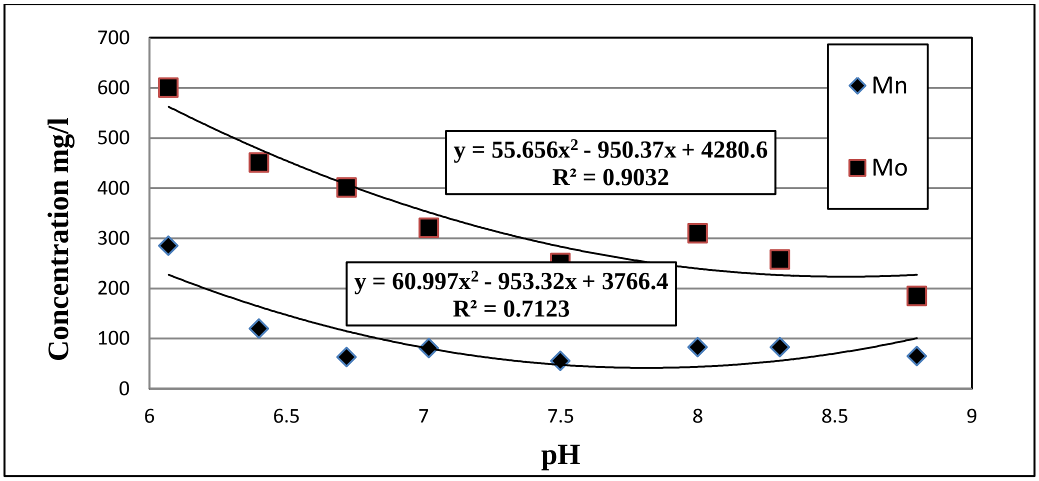

Figure (5): Variation of Mo^{+2} and Mn^{+2} with pH, 2nd reactor

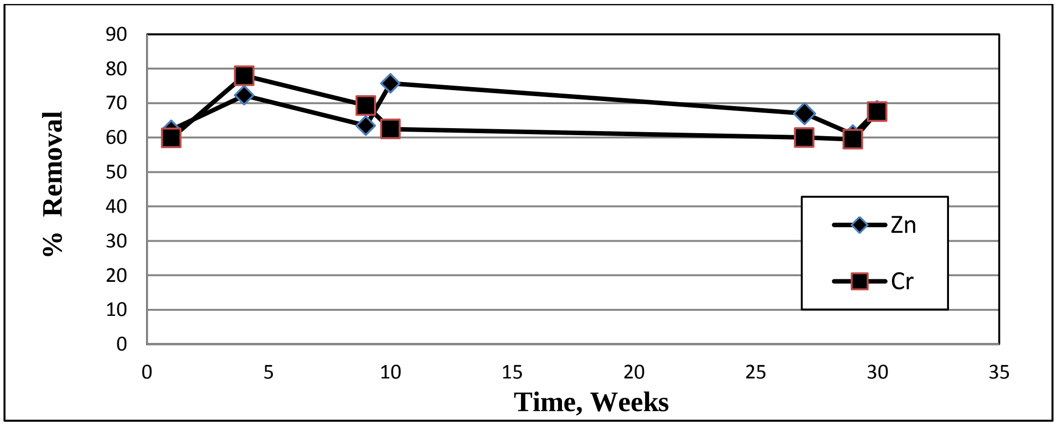

Figure (6): Zn^{+2} and Cr^{+3} removal efficiency, 2nd reactor

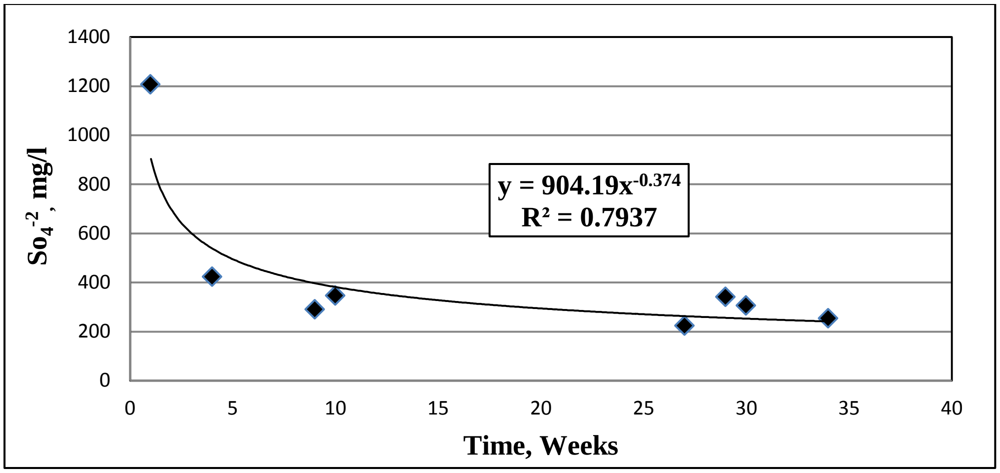

Figure (7): So_4^{-2}variation with time, 3rd reactor

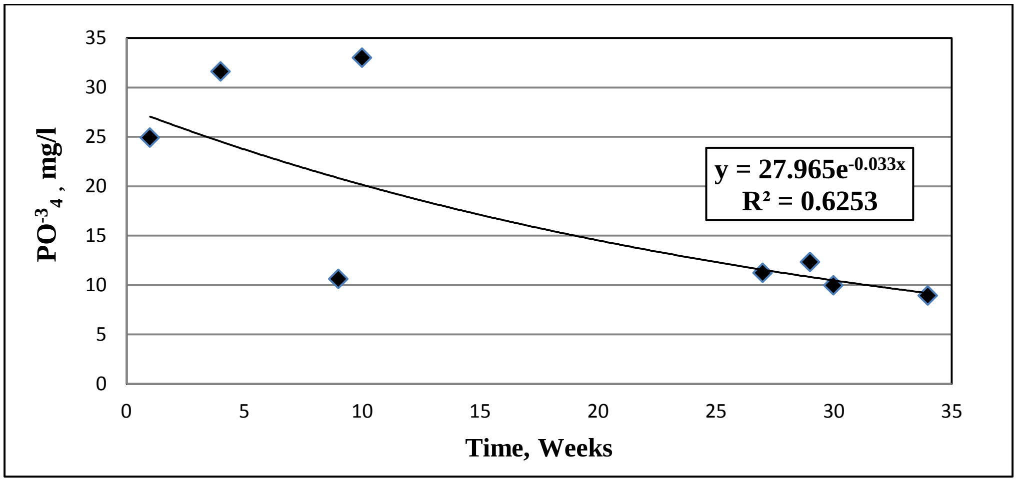

Figure (8): $PO^{-3}{}_4$ variation with time, 2nd reactor.

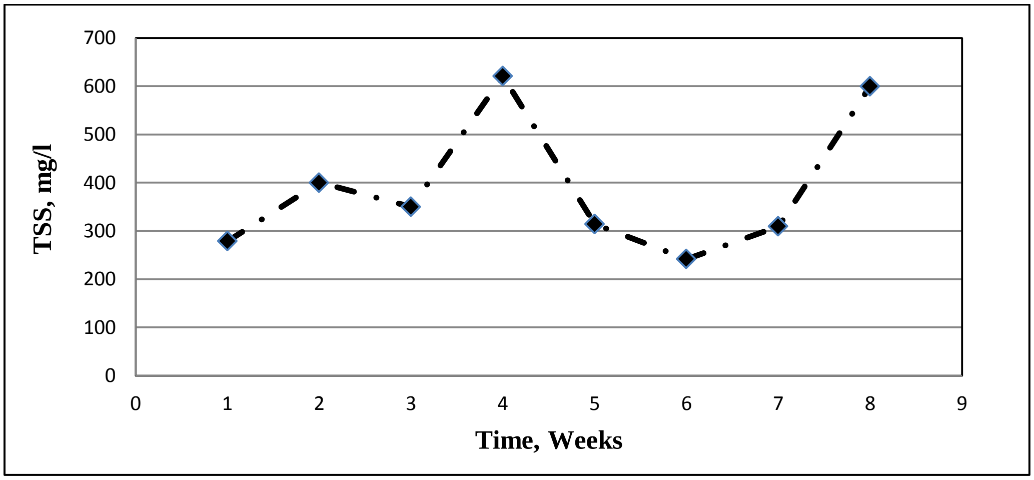

Figure (9): TSS variation throughout time, 1st reactor.

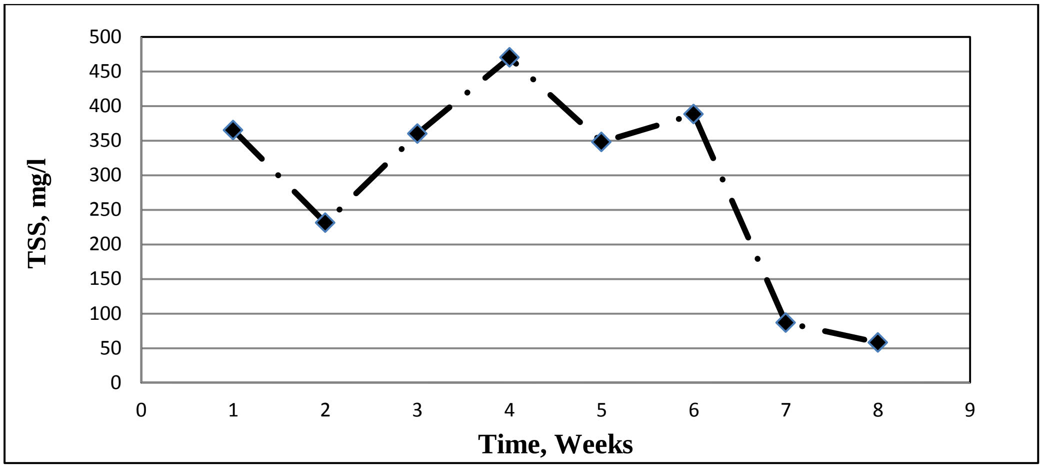

Figure (10): TSS variation with time, 2nd reactor.

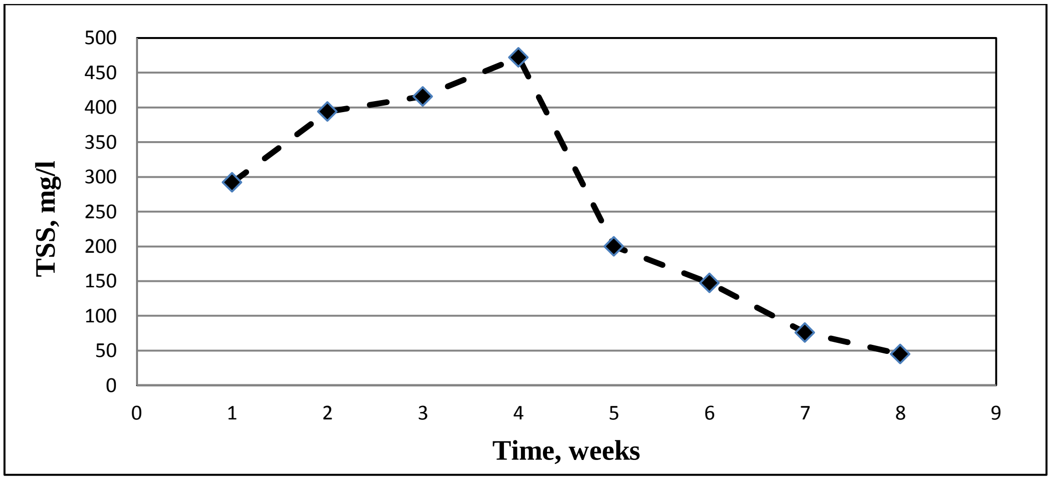

Figure (11): TSS variation throughout time in the, 3rd reactor