

# AN INVESTIGATION OF IMPACT OF IRON AND ALUMINIUM ADDITION ON THE ANAEROBIC DIGESTION PROCESS

*Svetlana Ofverstrom*

*Ieva Sapkaite*

*Regimantas Dauknys*

*Vilnius Gediminas Technical University, Lithuania*

## ABSTRACT

In this study, the impact of iron and aluminium salts addition on anaerobic digestion process was investigated. Mixture of primary and activated sludge collected at Vilnius wastewater treatment plant in Lithuania was digested under laboratory conditions by using anaerobic digester (W8, Amfield, UK). To compare the relative digestibility of iron-dosed (Fe-dosed) and aluminium-iron-dosed (Al-Fe-dosed) sludge with un-dosed sludge three continuous experiments were made. Results showed that iron and aluminium negatively impacted anaerobic digestion process by reducing the volume of biogas produced. Fe-dosed sludge produced 20-50% less biogas and Al-Fe-dosed sludge produced 30-40% less biogas in comparison to the same un-dosed sludge. VS destruction decreased during dosing of Fe or/and Al salt. Biogas composition was not measured during the experiments.

## KEYWORDS

Wastewater sludge (primary and activated sludge), lab-scale anaerobic digestion, aluminium salt, iron salt, biogas production.

## 1 INTRODUCTION

Nitrogen and phosphorus removal from wastewater is a way to avoid eutrophication of water bodies [1]. Usually there are two possible schemes to remove phosphorus – biological and chemical. The most often used method for phosphorus removal from wastewater is biological treatment. Chemical phosphorus removal involves the addition of a chemical coagulant, either aluminium (Al), iron (Fe), or lime. As a consequence of chemical phosphorus removal, the volume of sludge increases, between approximately 37% and 97% [2].

The effect of both Al and Fe on anaerobic digestion efficiency has been studied by a number of investigators with conflicting results. Gossett et al. found reduction of gas production from addition of both iron and aluminium [3, 7]. Johnson et al. found the iron rich primary sludge from chemically enhanced treatment reduced gas production by 32% while Lee found that addition of iron increased gas production [4, 5, 7]. Jackson– Moss and Duncan found that addition of up to 5,650 mg/L had no effect on an upflow anaerobic sludge blanket reactor. [6, 7] There is no general consensus of chemical phosphorus removal impact on anaerobic digestion because it is difficult to isolate impact of chemical phosphorus removal from other site-specific variables, such as sludge age and wastewater composition [8, 9].

<https://doi.org/10.15626/Eco-Tech.2010.059>

The objective of this study was to investigate any possible negative effect of aluminium (Al) or/and iron (Fe) salt addition on biogas production and organic matter destruction during anaerobic digestion of mixture of primary and activated sludge.

## 2 METHODOLOGY

Experiment was held under laboratory conditions at Vilnius Gediminas technical university, Lithuania during April - June month, 2010. Laboratory-scale anaerobic digester model (W8, Armfield, UK) was used for experiments. The model was of two independently operating units of 4,8 L each. The gas off-take from each reactor was taken into a volumetrically calibrated collector vessel (300 ml) operating by water displacement [10, 11].

Primary and activated sludge was taken from wastewater treatment plant in Vilnius, Lithuania every 5<sup>th</sup> day and stored in a refrigerator under +4°C conditions. Laboratory digesters were started by seeding with digested sludge from previous experiments of anaerobic digestion of un-dosed primary and activated sludge mixture [12]. Laboratory digesters were fed with primary and activated sludge (1:2) mixture, 0.24 L/day. The digesters were operated at mesophilic conditions (35°C) with 20-days solids retention time.

The experiments were three – anaerobic digestion of un-dosed, Fe-dosed and Al-Fe-dosed sludge mixtures. Doses of Fe and Al were selected according to Gothenborg (Sweden) WWTP average amounts of Fe and Al in digested sludge during 2008 year. It was obtained that the amount of Fe was 52-81 mgFe/gTS and Al was 13-29 mgAl/gTS. Minimum selected dose of Fe was 50 mgFe/gTS and maximum – 100mgFe/gTS, minimum dose of Al selected was 15mgAl/gTS and maximum - 30mgAl/gTS (see *Table 1*).

The concentration of total solids (TS) in sludge mixture after the digestion of primary and activated sludge mixture using W8 model was 16.8gTS/L [12].

The experimental doses of FeCl<sub>3</sub>·6H<sub>2</sub>O and Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>·18H<sub>2</sub>O added are shown in *Table 1*.

*Table 1. Selected experimental doses of Al and Fe salts*

Reactor	Fe (III), mg/gTS	FeCl <sub>3</sub> ·6H <sub>2</sub> O, g/L	FeCl <sub>3</sub> ·6H <sub>2</sub> O, g/day	Al (III), mg/gTS	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·18H <sub>2</sub> O, g/L	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·18H <sub>2</sub> O, g/day
I	50	4,17	1,0	15	0,77	0,19
II	100	8,34	2,0	30	1,54	0,37

Selected maximum and minimum doses of FeCl<sub>3</sub>·6H<sub>2</sub>O were used after the control period of 20 days without any chemical addition. The duration of the dosing period was 20 days. The chemicals were continuously dosed into the sludge mixture from a stock solution containing an appropriate quantity of Fe and Al-Fe salt together with distilled water. After 20 days of dosing of Fe salt selected Fe salt dosing was continued with addition of maximum and minimum amounts of Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>·18H<sub>2</sub>O.

During experiments pH, alkalinity (ALK), volatile fatty acids (VFA), total solids (TS), volatile solids (VS) were measured regularly and biogas production was monitored. The relative digestibility was assessed by measuring two parameters: (1) biogas volume, (2) organic matter destruction. The gas off-take from each reactor was taken to a volumetrically calibrated collector vessel (300 ml) operating by water displacement. Values were calculated

from 4-days average biogas production. The organic matter destruction was calculated from measuring the VS concentration before and after digestion according to Standard Methods [13].

### 3 RESULTS AND DISCUSSION

An examination of pH, alkalinity and volatile fatty acid data (see *Table 2*) showed that there was a significant reduction of alkalinity in digesters receiving chemically derived sludge with maximum dose of Fe or/and Al salt. Associated with this lower alkalinity was a lower pH than in the control unit. In the digester receiving maximum dose of Fe or/and Al salts, the alkalinity decreased to a value of only 300-400 mg/L as CaCO<sub>3</sub>, at which time the pH dropped to 6.06.

The pH was too low for the methane-producing bacteria, with the result that failure occurred.

*Table 2. Experimental parameters of un-dosed, Fe-dosed and Al-Fe dosed sludge mixture digestion*

Parameter	Control digester	Fe-dosed sludge (min)	Fe-dosed sludge (max)	Al-Fe-dosed sludge (min)	Al-Fe-dosed sludge (max)
Load, g BSM/L/d	0.67-1.01	0.70-0.75	0.70-0.75	0.85-0.88	0.85-0.88
FS TS, g/L	15.8-23.8	18.2-25.5	18.2-25.2	18.2-25.5	18.2-25.2
DS TS, g/L	17.8-23.8	17.6-23.2	24.4-32.2	22.2-22.5	24.0
VS destruction, %	21-32	14-18	13-14	12-17	13-14
pH	6.80-7.07	6.52-6.72	6.25-6.32	6.52-6.80	6.06-6.26
T, °C	34.6-35.4	34.8-35.5	34.9-35.5	34.6-37.0	35.0-35.5
VFA, mg/L	120-300	180-240	120-180	180-300	180-250
ALK, mg/L	1250-1750	900-1350	500-650	700-1000	300-400

Biogas, ml/d 100-150 80-125 50-80 100-130 80-95  
 FS TS – fed sludge TS, g/L, , g/L, DS TS – digested sludge TS, g/L, VFA- volatile fatty acids as Acetic, mg/L, ALK – alkalinity as CaCO<sub>3</sub>, mg/L

During digestion of un-dosed sludge mixture VS destruction was 21-32%. VS destruction of Fe-dosed sludge was from 14-18% and 13-14% for minimum and maximum doses. VS destruction of Al-Fe-dosed sludge mixture was 12-17% and 13-14% for minimum and maximum doses accordingly. Gosset *et. al.* investigated the effect of the addition of iron and aluminium salts to sludge on the digestability and found that both iron and aluminium reduced VS destruction by about 10%. Novak and Park found that iron addition had little impact on the volatile solids destruction by anaerobic digestion. [3, 14].

Daily biogas productions from un-dosed Fe-dosed and Al-Fe-dosed sludge mixture are shown in *Figure 1* and *Figure 2* as 4-day running averages. In all cases, deviations from the control un-dosed sludge were evident from the beginning. Biogas production from un-dosed primary and activated sludge mixture was from 100 ml/day to 150 mL/d, depending on VS load of fed sludge mixture. Within first days of addition of Fe salt to sludge mixture biogas production decreased to about 20-25% for Fe-dosed sludge (minimum dose) and 50% of normal level for Fe-dosed sludge mixture with maximum dose of Fe salt (see *Figure 1*).

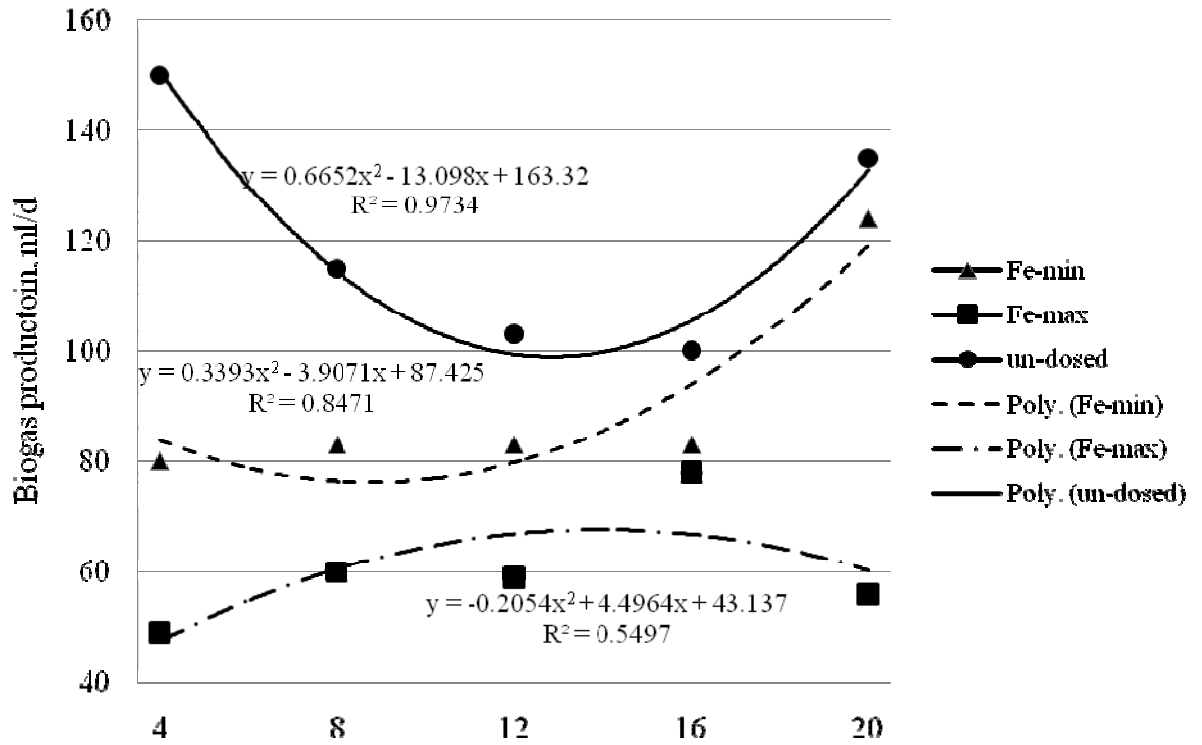


Figure 1. Biogas formation from un-dosed and Fe-dosed sludge mixture

Biogas production remained depressed during most of time for Fe-dosed sludge (maximum dose) but biogas production from Fe-dosed sludge with minimum dose of Fe salt increased from approx. 12-15 days of experiment and until the end of experiment biogas production from Fe-dosed (minimum dose) was close to biogas production from un-dosed sludge.

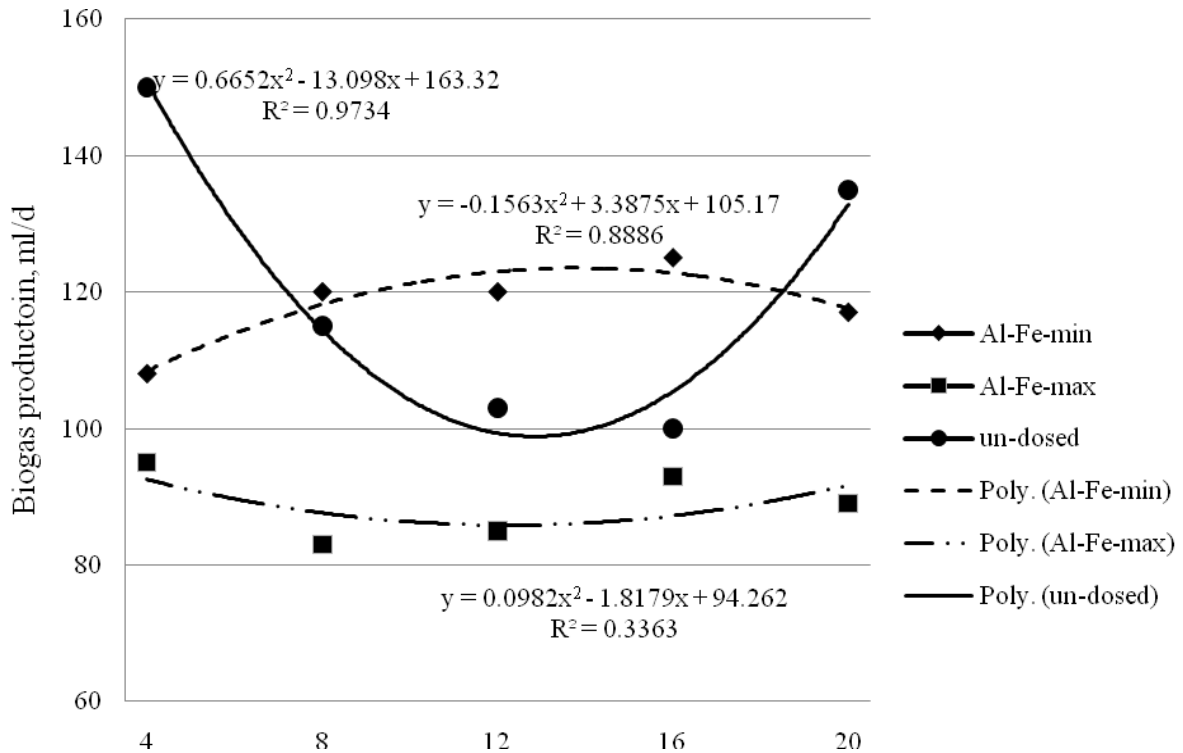


Figure 2. Biogas production from Al-Fe-dosed sludge mixture

During addition of both Al and Fe salt to sludge mixture biogas production from Al-Fe-dosed sludge increased approx. 10-20 % compare to biogas production from Fe-dosed sludge (see Figure 2). Biogas composition was not measured during experiment. Biogas production from Al-Fe-dosed sludge (minimum dose) was more stable during experiment than biogas production from un-dosed sludge.

#### 4 CONCLUSIONS

The results obtained from the lab-scale experiments demonstrated the negative effect of aluminium or iron salt on anaerobic digestion of primary and activated sludge mixture.

During dosing of minimum and maximum doses of  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  into sludge mixture VS destruction in digested sludge was decreasing compare to un-dosed sludge mixture up to 30%.

Addition of  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  salt had negative effect on biogas production. Biogas production from Fe-dosed sludge mixture decreased to about 20-25% for Fe-dosed sludge with minimum dose of Fe salt added and 50% of normal level for Fe-dosed sludge mixture with maximum dose of Fe salt added.

Addition of  $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$  salt into Fe-dosed sludge mixture raised biogas production up to 10-20 % compare to biogas production from Fe-dosed sludge.

In order to have the comprehensive understanding of Al and Fe affect on anaerobic digestion of primary and activated sludge mixture it is useful to measure composition of biogas produced during anaerobic digestion.

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