In-Situ Methane Enrichment System Coupled with Mesophilic Anaerobic Plug Flow Reactor and External Intermittent CO_2 Stripper

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Problem Definition

Biogas Contents

Biogas	Contents(%)
CH_4	55~65%
CO_2	35~45%
Trace Gases -H_2S -H_2 -NH_3 -Water -Siloxane, etc	< 1%

Biomethane Standards

Items	Biomethane Standards	
	Korea	Sweden
Methane Content	> 95.0 Vol %	97±1 Vol %
Water Content	< 32.0 mg/Nm^3	< 32.0 mg/Nm^3
Sulfur	< 10.0 ppm	< 23.0 mg/Nm^3
Inert Gas (CO_2 + N_2)	< 5.0 Vol %	< 4.0 Vol %

Biogas Upgrading

Cleaning of Biogas

- Removal of Water, H_2S, N_2, NH_3, Siloxane, etc

Full Scale Technology

- Pressure Swing Adsorption(PSA)
- Absorption
  - *- Water Scrubbing*
  - *- Organic Physical Scrubbing*[1)]
  - *- Chemical Scrubbing*[2)]
- Membrane
- Cryogenic Upgrading

1) Selexol and Genosorb are examples of trade names for liquids used in organic physical scrubbing.
2) mono ethanol amine(MEA), di-methyl ethanol amine(DMEA)

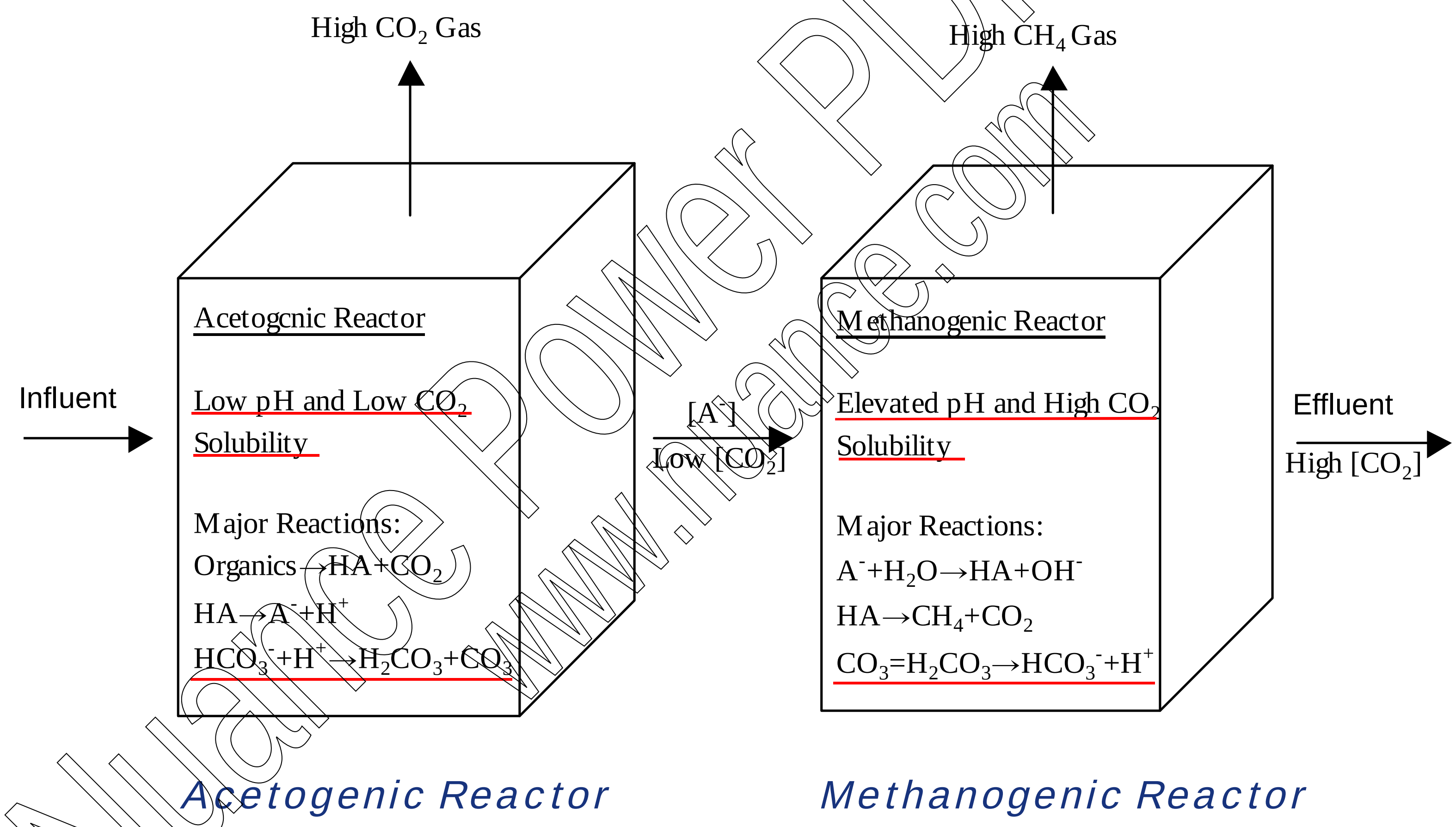
Research Objectives

- **To develop a simple in-situ methane enrichment system coupled with mesophilic anaerobic *plug flow reactor* and *external intermittent CO_2 Stripper***

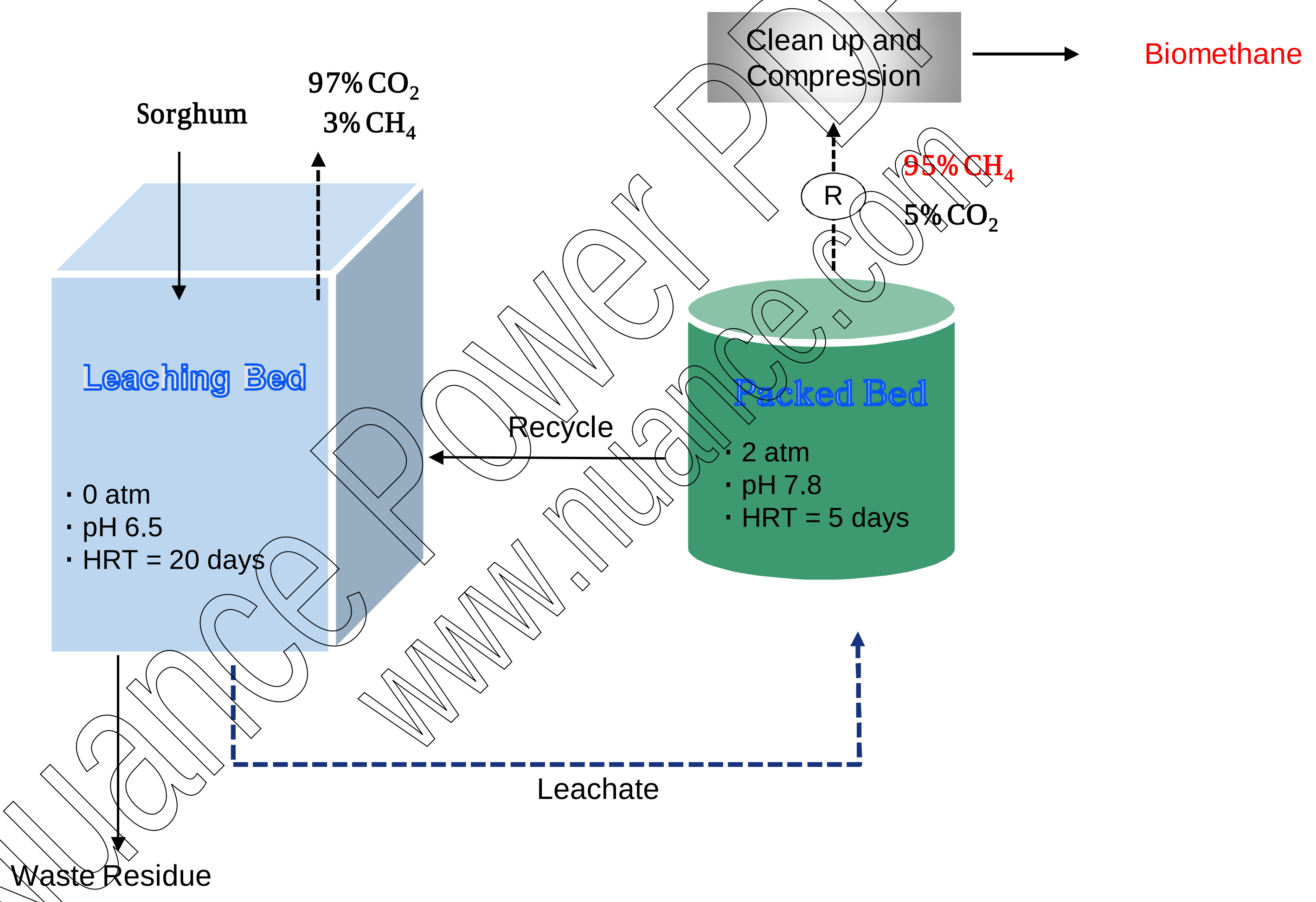
2 Theoretical Background

Dream CNU

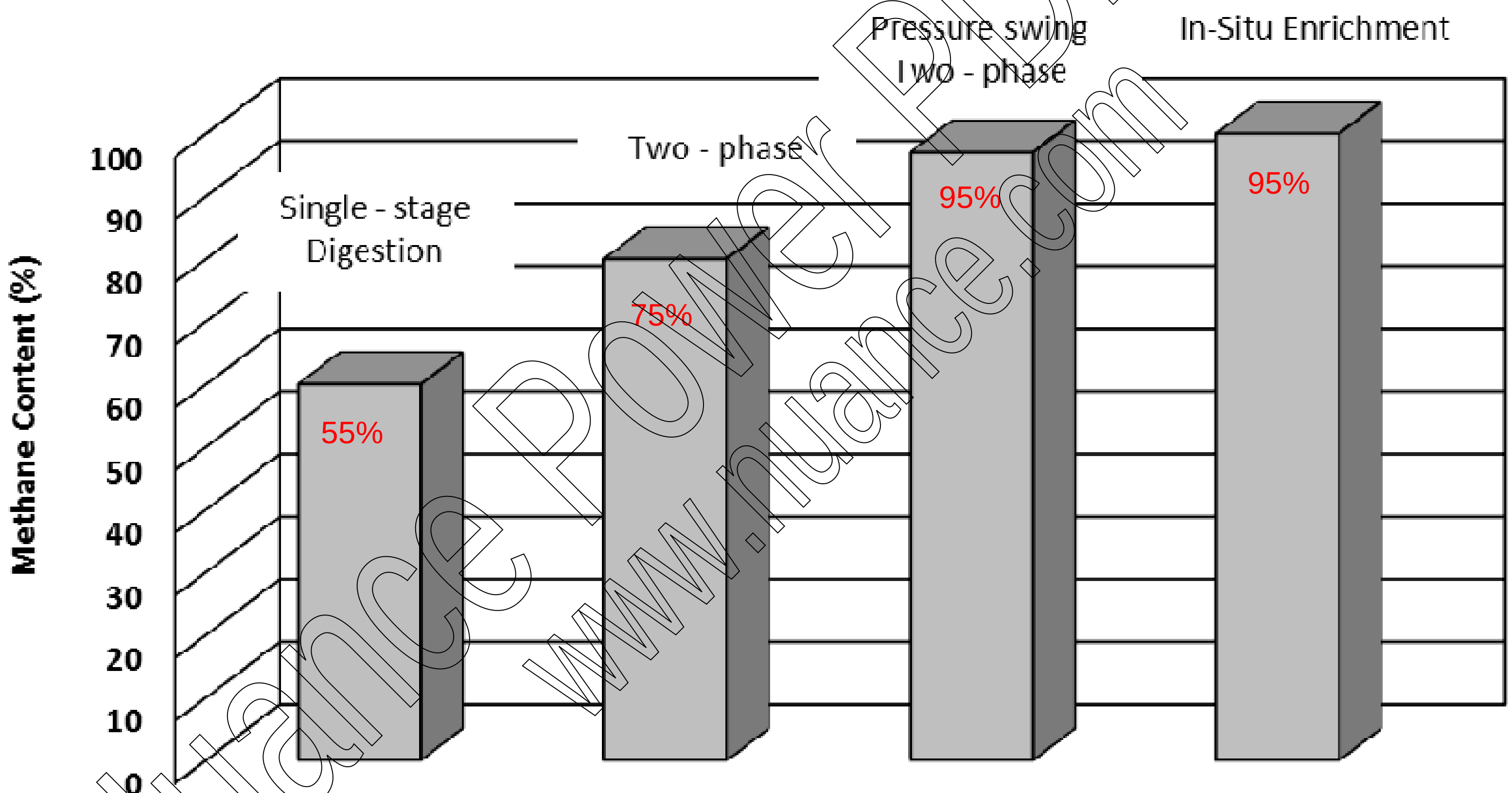
Major Reactions Affecting pH and CO_2 Solubility in Two-phase Anaerobic Digestion



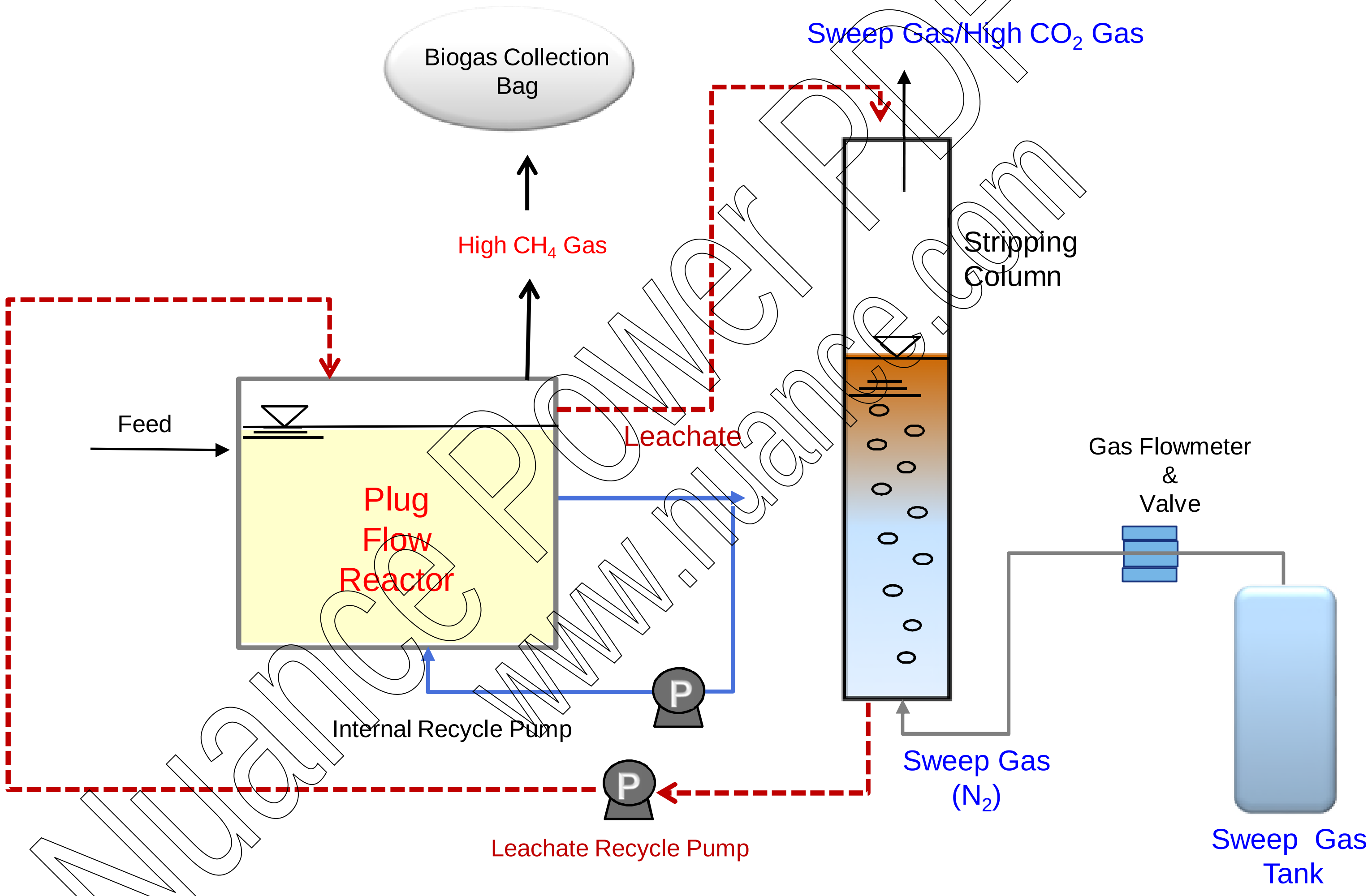
Schematic of Pressure-Swing, Two-Phase Digestion(35℃)



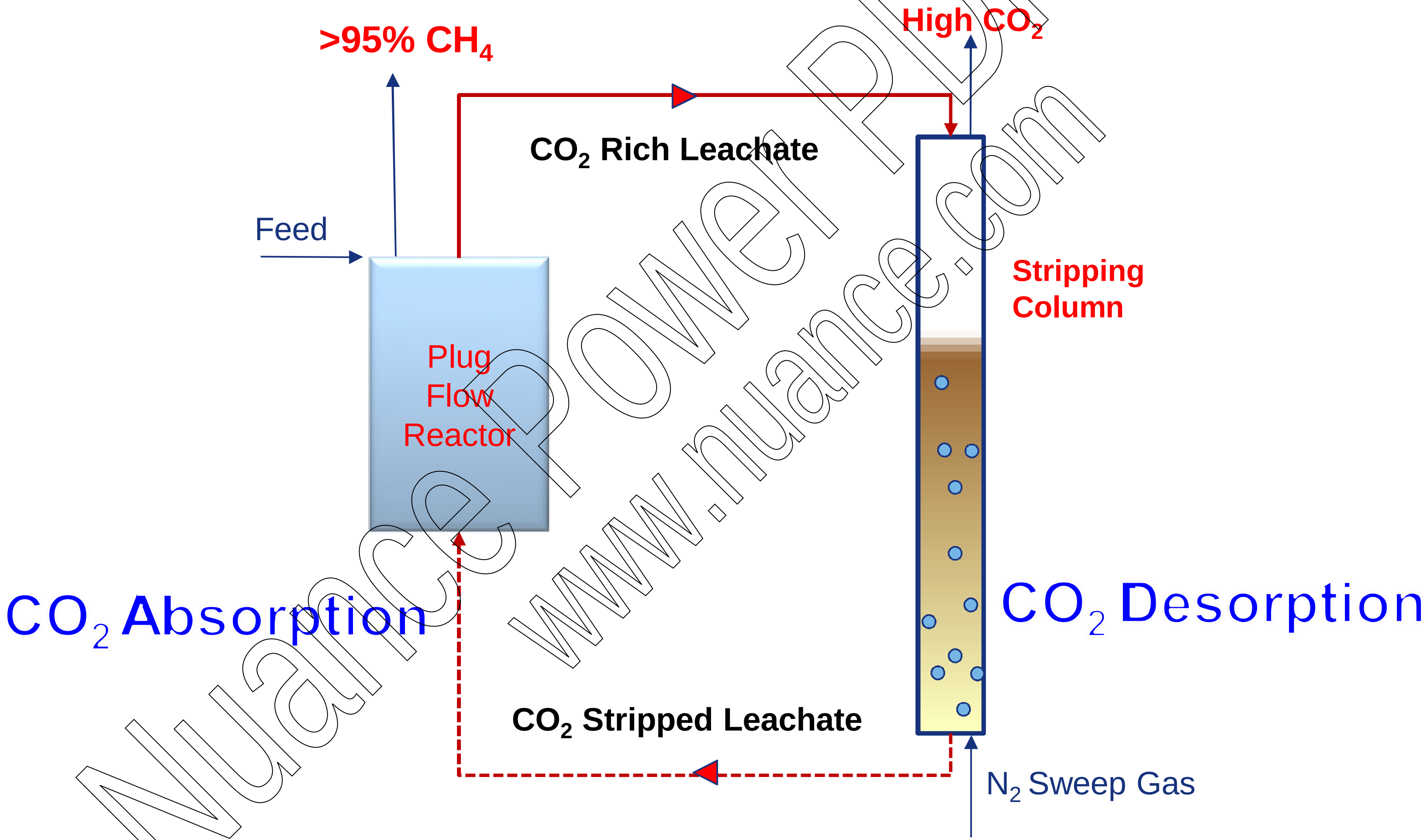
CH_4 Content of Different Anaerobic Reactors



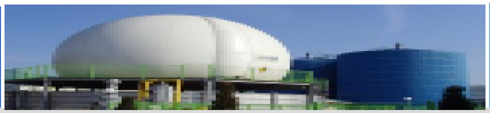
Schematic Diagram of Methane Enrichment System



Mechanism of Methane Enrichment Process



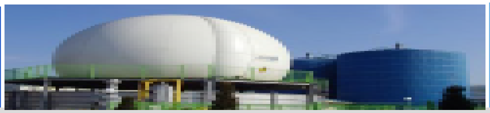
3 Materials and Methods



Operational Conditions for Methane Enrichment System

Parameter	OLR (kgVS/m^3-d)	Temp.	T. Alkalinity (g/L as$CaCO_3$)	Leachate Recycle Rate (v/v-d)	Sweep Gas	Stripper Gas Flow Rate (ml/min)	Stripping Condition
Control Reactor	2.0	35℃	-	-	-	-	
Methane Enrichment System	2.0	35℃	2.0	1.0	N_2	700 & 500	Continuous 4:1 3:1 2:1 1:1
				2.0			
				3.0			
				4.0			
			4.0	1.0			
				2.0			
				3.0			
				4.0			
			6.0	1.0			
				2.0			
				3.0			
				4.0			
			8.0	1.0			
				2.0			
				3.0			
				4.0			

4 Results and Discussions

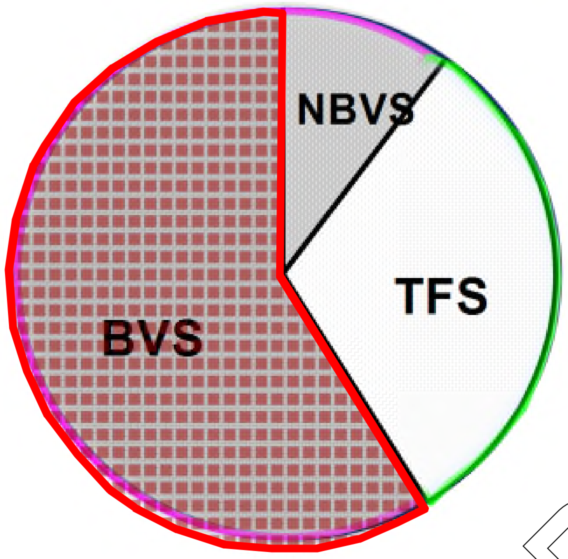


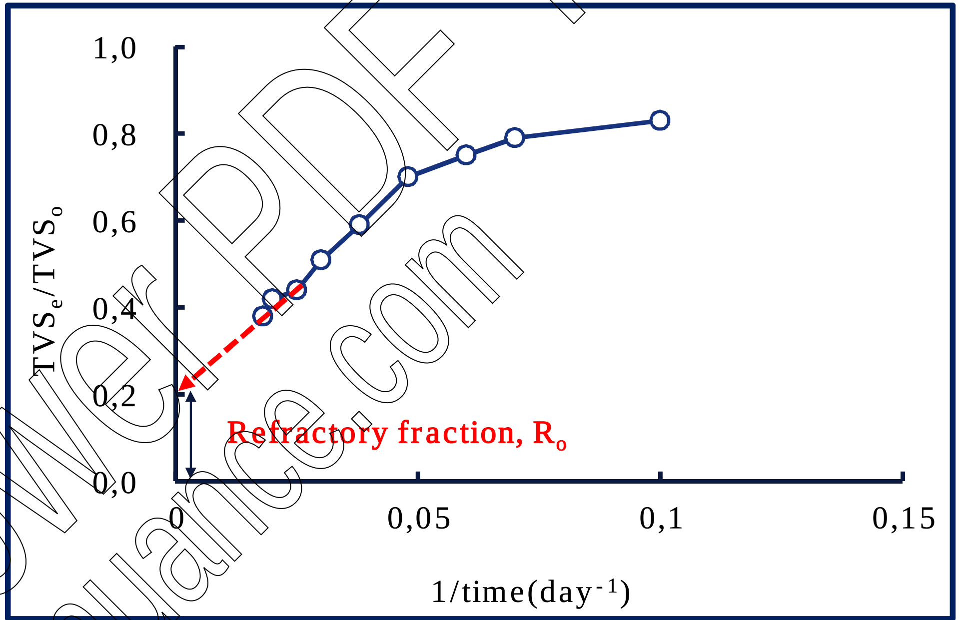
Dream CNU

Physico-chemical Properties of Sorghum used in Experiment

Elements	Unit	Conc.
TS	%	92.8
VS	%	79.9
VS(%)	% of TS	86.1
Ash	% of TS	13.9
COD	g/g	1.25
C : N	-	40.4

Ultimate Biodegradability measured by the Graphical Statistic Analysis(GSA)





(a) BVS(Biodegradable Volatile Solids)

(b) NBVS (Non-Biodegradable Volatile Solids)

(c) TFS(Total Fixed Solids)

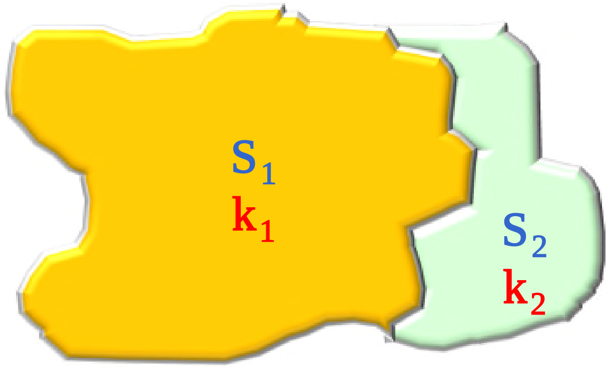
(a)+(b) = TVS(Total Volatile Solids)

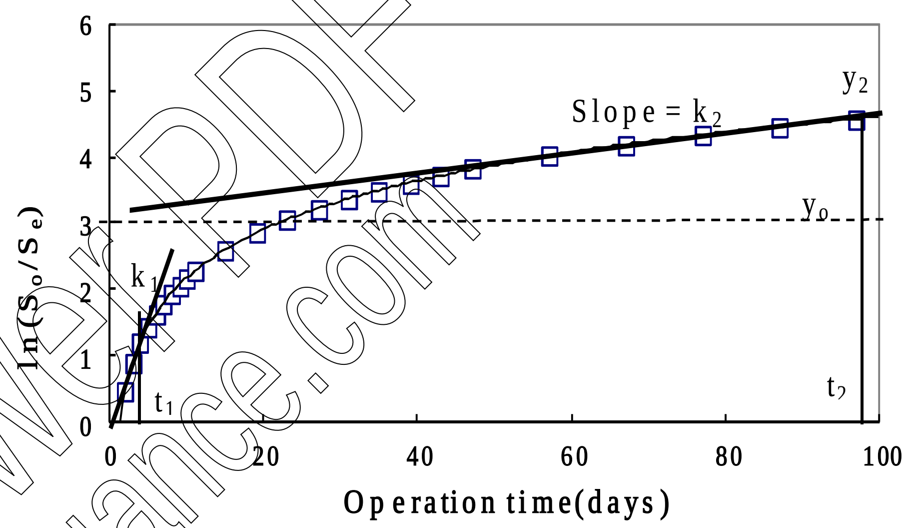
(a)+(b)+(c) = TS(Total Solids)

S/I Ratios	Ultimate biodegradability (%)
0.5	87.4
0.5	85.4
0.5	87.6
Avg.	86.8

(Source : Kang et al, J. of KSEE, Vol.27, No. 5, pp. 555-601, 2005)

Graphical Technique for Isolating Multiple Reaction Rate Coefficient, k_1 and k_2





S_1 : Readily biodegradable fraction(%)

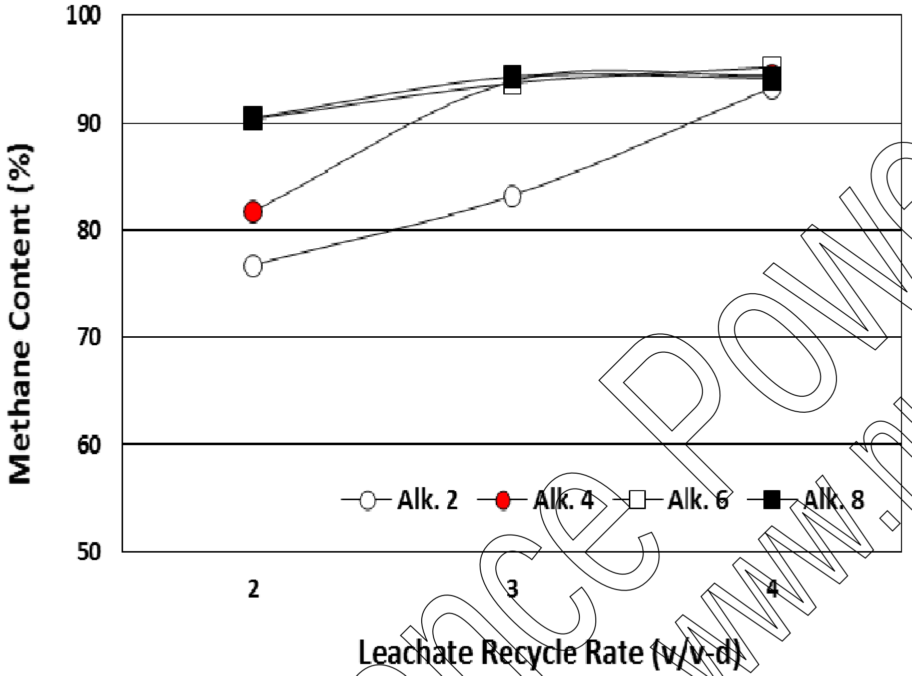
S_2 : Slowly biodegradable fraction(%)

S/I Ratios	Ultimate biodegradability (%)	First-order decay rates					
		k_1 (day^{-1})	Duration (from to days)	S_1/S_0 (%)	k_2 (day^{-2})	Duration (from to days)	S_2/S_0 (%)
0.5	87.4	0.056	1-23	79	0.007	24-70	21
0.5	85.4	0.062	1-23	78	0.008	24-70	22
0.5	87.6	0.061	1-23	76	0.008	24-70	24
Avg.	86.8	0.060	1-23	77	0.008	24-70	23

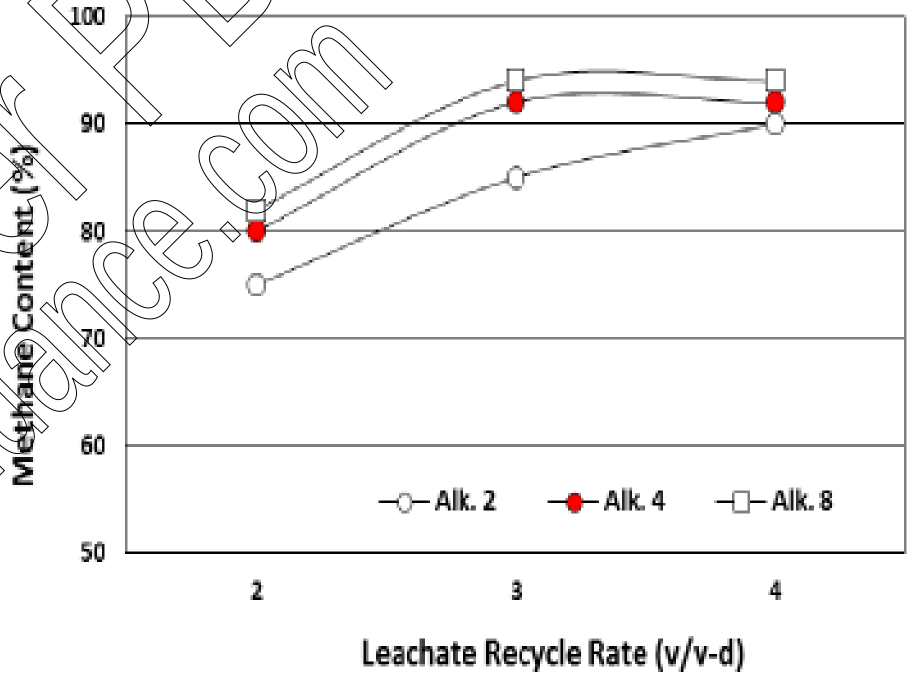
(Source : Kang et al, J. of KSWM, Vol.31, No. 8, pp. 833-842, 2014)

Effect of Leachate Recycle Rate on Average CH_4 Contents

N_2, 700ml/min

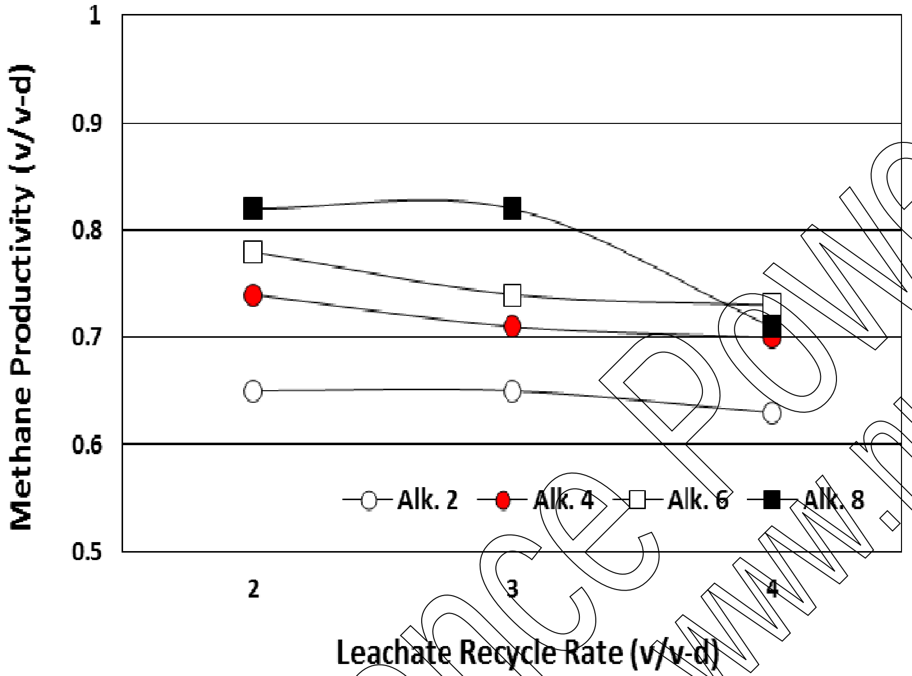


N_2, 500ml/min

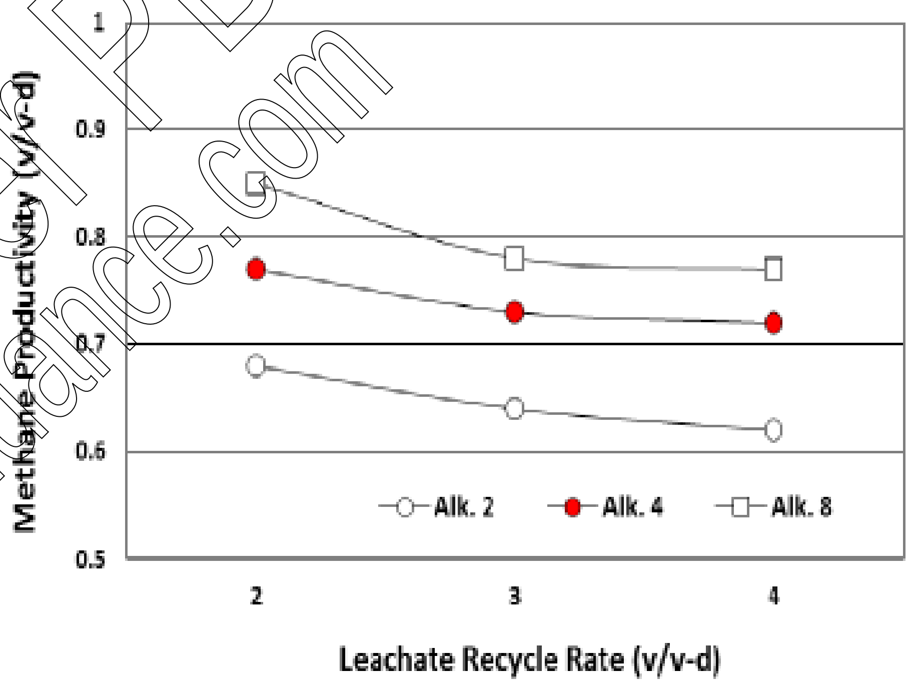


Effect of Leachate Recycle Rate on Average CH_4 Productivity

N_2, 700ml/min

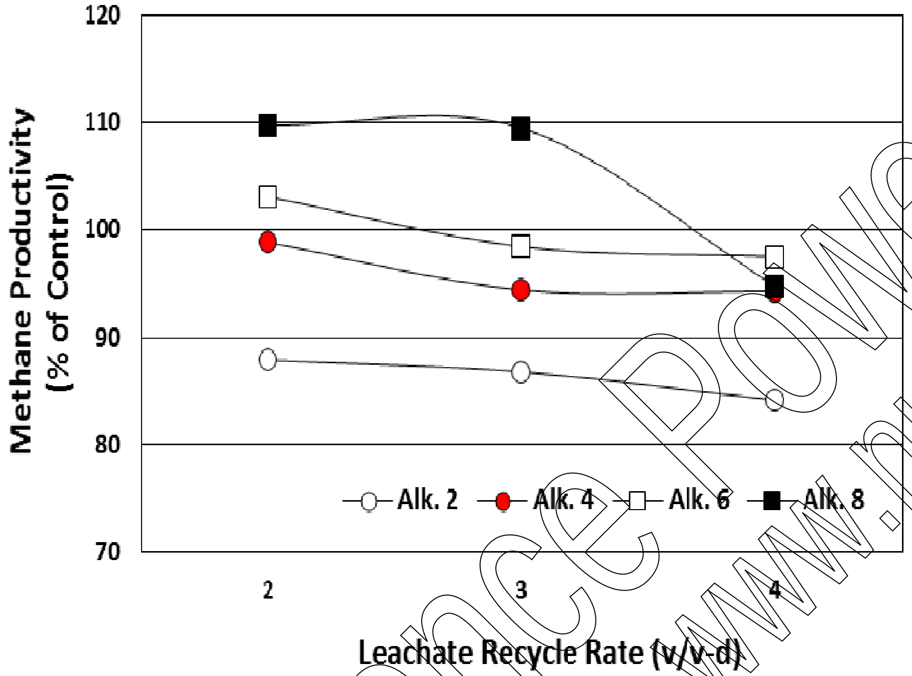


N_2, 500ml/min

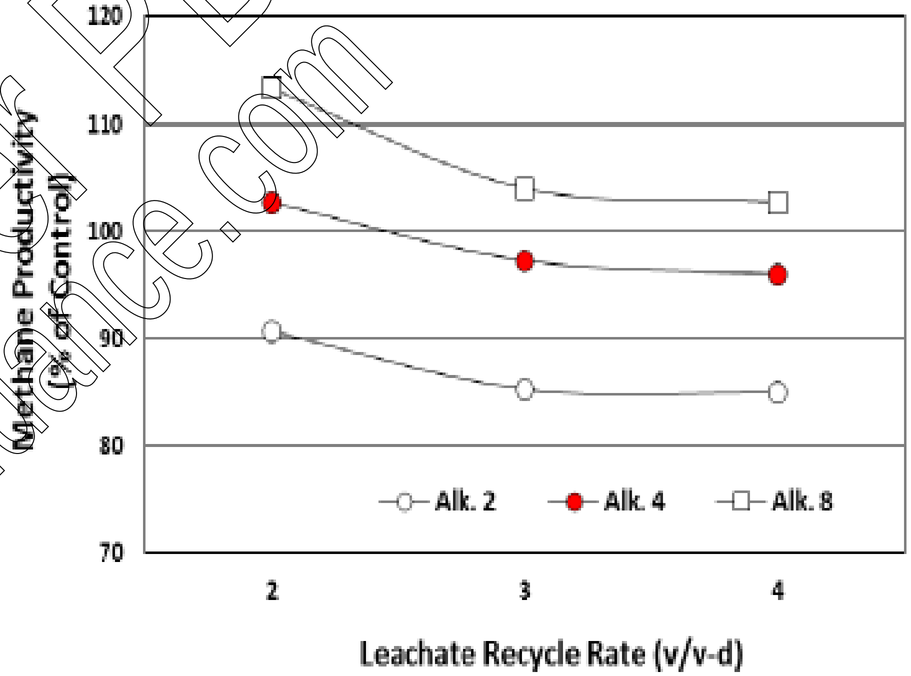


CH_4 Productivity as % of Control

N_2, 700ml/min

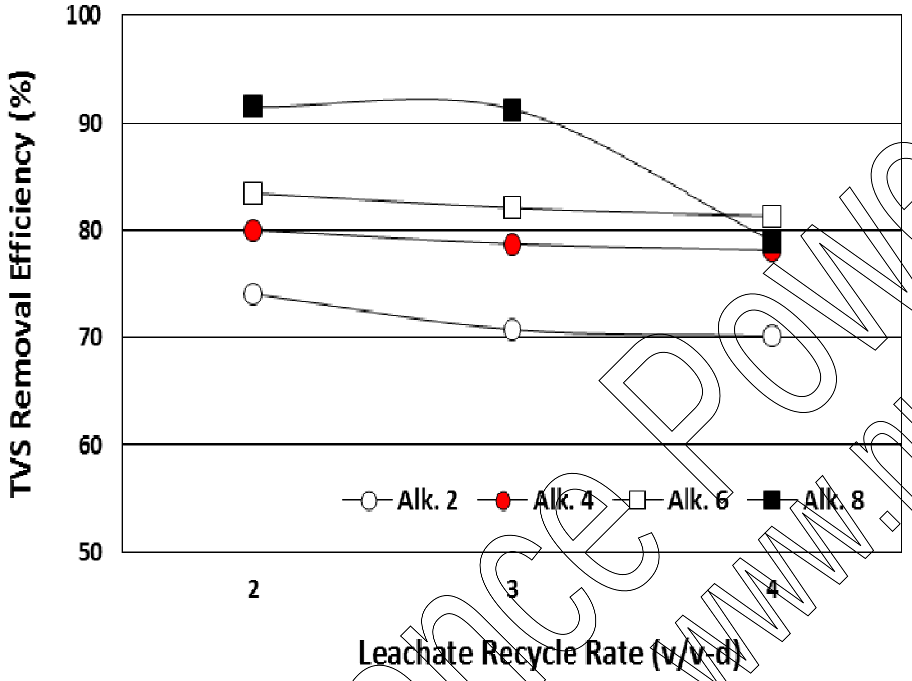


N_2, 500ml/min

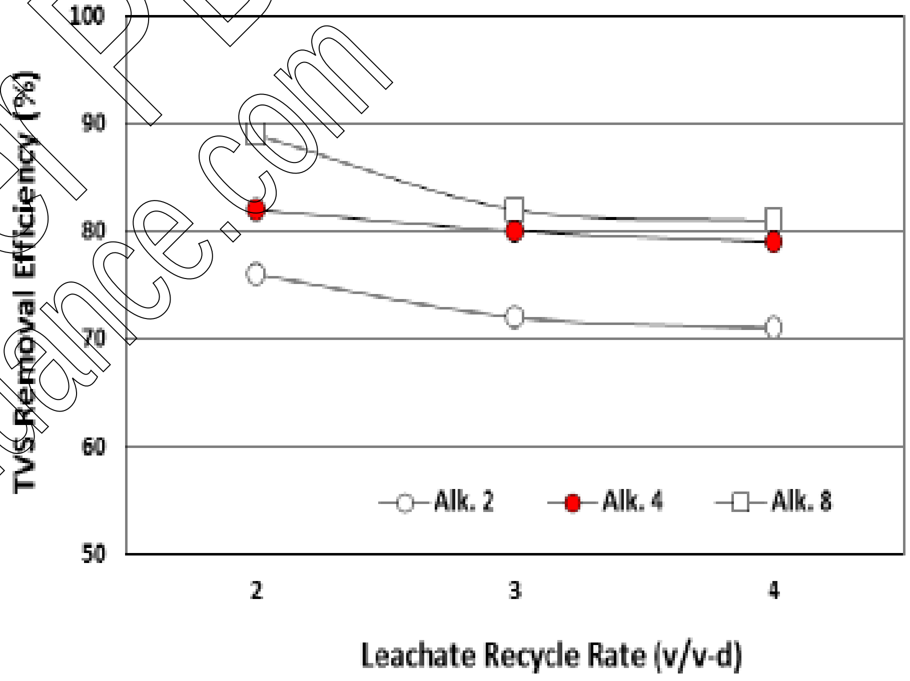


Effect of Leachate Recycle Rate on TVS Removal Efficiency

N$_2$, 700ml/min

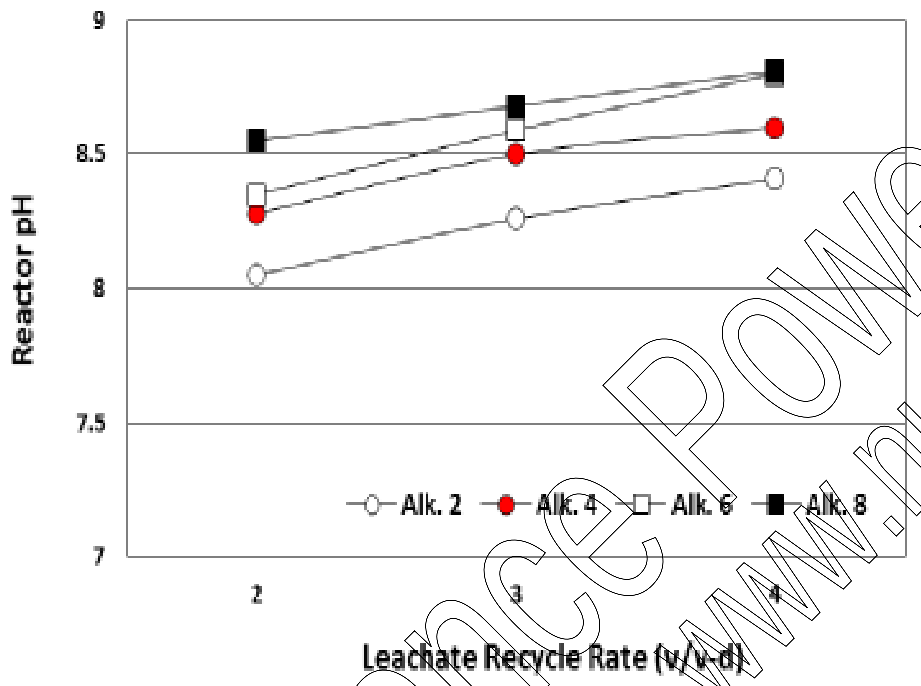


N$_2$, 500ml/min

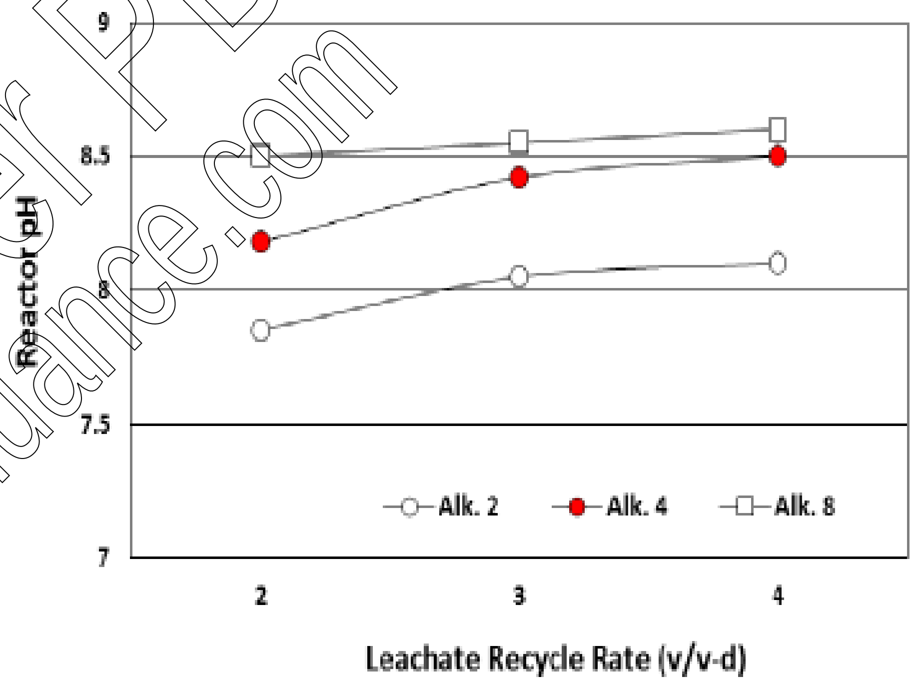


Effect of Leachate Recycle Rate on pH

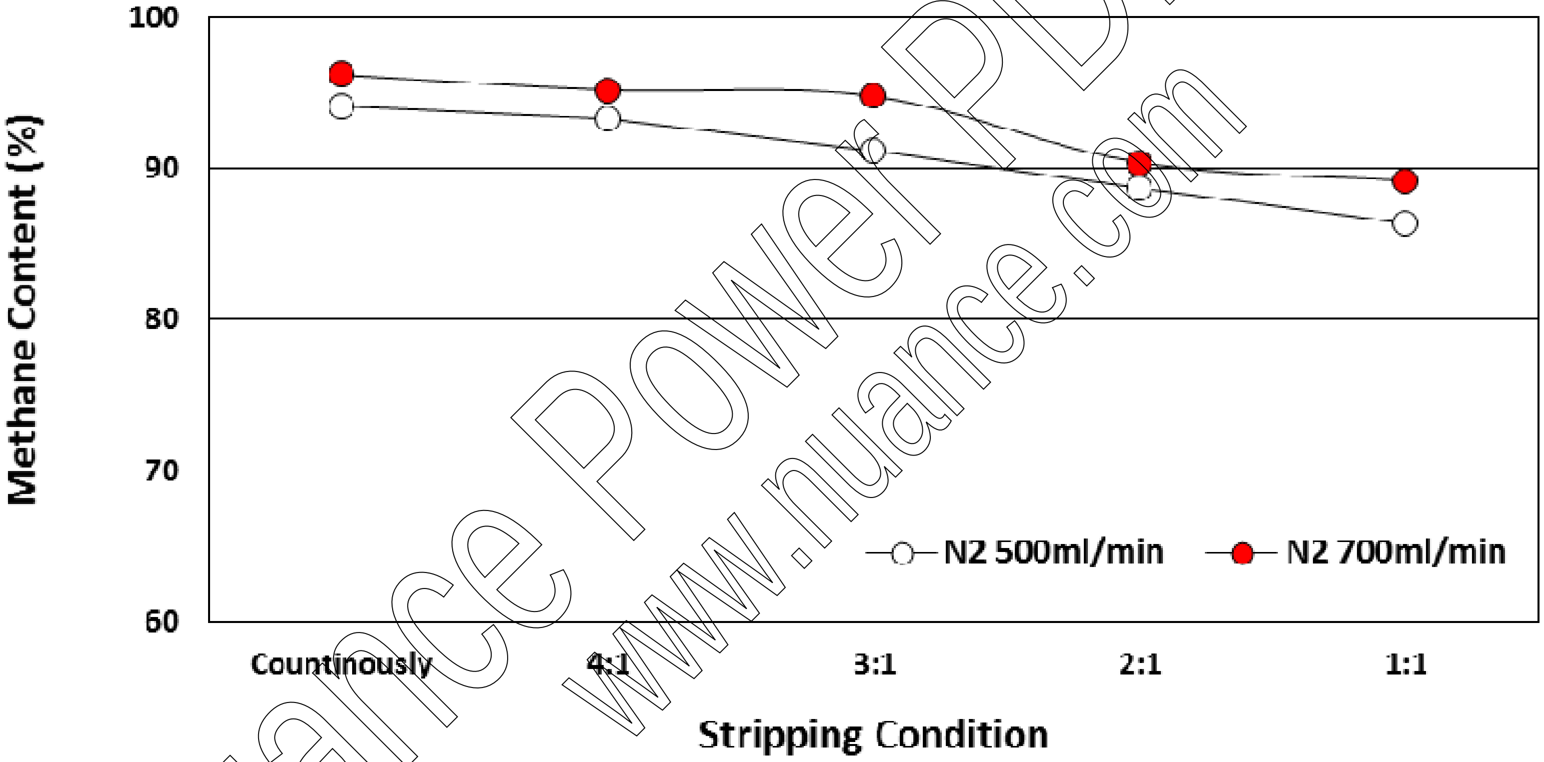
N_2, 700ml/min



N_2, 500ml/min



Effect of Intermittent CO_2 Stripping on CH_4 Content



Conclusions

1) Quantitative evaluation of the system variables defined the effects of leachate recycle rates (LRR), reactor alkalinity and intermittent stripping of CO_2 at different sweep gas flow rates on offgas methane contents, biogas productivity and TVS removal efficiency.

2) Offgas CH_4 contents of over ***95%*** was achieved at 3 volume of leachate recycle per volume of reactor per day(***3v/v-d***) and at the reactor alkalinity of ***4g/L as*** $CaCO_3$, as the optimum operating conditions.

Conclusions

3) **Even at an intermittent stripping ratio up to 3 hours stripping (N_2 sweep gas 700 ml/min) and 1 hour no-stripping, the offgas methane content over 95% was achieved. It thus resulted in a 25% reduction in the total energy and sweep gas consumption.**

4) **The TVS removal efficiency of the methane enrichment system was *86%* which corresponded to *94% of the control reactor* and the methane productivity appeared to be *0.82v/v-d.***

Thank you for your attention

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