Rimika Madan Kapoor

Email id: rimikakapoor@gmail.com, rimika@rdat.iitd.ac.in
LinkedIn: https://www.linkedin.com/in/rimika-kapoor-3aa31755/
Address: 191-B, New Colony, Gurugram, Haryana, India 122001.

Career Summary

- A versatile mechanical engineer with 10+ years' experience in research, design and development of gas separation (CO_2, CH_4 and H_2S and moisture) technologies.
- Forefront experience in development of absorption based Biogas upgradation and CO_2 recovery plants (patent applied).
- Expertise in CH_4 loss minimisation from biogas upgrading plants utilisation of bioCH_4 and bioCO_2 in various applications.
- Senior researcher (Indian) in European Union project "Valorisation of Food Waste to biogas (March 2010 - Oct 2013).
- Published 6 international journal papers, 5 project deliverable reports such as performance evaluation and summary reports, 4 newspaper articles.
- Experience in liasoning and providing consultancy to project developers willing in settling up biomethanation plants.
- Off-board technology specialist to Ministry of New & Renewable Energy Sources, Ministry of Drinking Water and Sanitation and Ministry of Petroleum & Natural Gas, GoI in launching Schemes and policies related to biogas
- Extensive experience in managing research projects.
- Strong analytical, problem-solving and decision making capabilities
- Skilled in building cross-functional teams, demonstrating exceptional communication skills, and making critical decisions during challenges.

Core Competences

- Data Analysis and Impressive Presentation Skills
- Multi-tasking in a fast-paced environment
- Ability to work with all levels of internal staff, as well as outside clients and vendors
- Superior interpersonal skills including courtesy, professionalism, and a cooperative attitude
- Core process development
- Ability to be flexible to handle multiple priorities
- Ability to lead and mentor a team of analysts

Educational Qualification

- **Doctorate of Philosophy (PhD), (2017); Thesis title: "*Development of Methane Loss Minimization & Carbon Dioxide Recovery Systems in Water Scrubbing based Biogas Upgradation;*** Indian Institute of Technology Delhi (CRDT, IITD), India

- **Masters in Technology (M-Tech) (2009); Energy and Environmental Management,** Centre for Energy Studies, Indian Institute of Technology Delhi (CES, IITD), India

- **Master of Business Administration (MBA)** (2010) Operation management (major), Human Resource Management (minor): Institute of Management and Technology (CDL), Ghaziabad, UP (IMT, Ghaziabad)

- **Bachelor of Technology (B.Tech),(2004) Mechanical and Automation Engineering**: GGSIP University, New Delhi, India

Professional Experience

❖ Senior Post Doctorate Fellow — June 2017 - present

Centre for Rural Development and Technology, Indian Institute of Technology Delhi, India

- Senior research and technical support of project and research teams working in biogas upgrading laboratory at IIT Delhi
- Link (testing, validating, improving) & integrate bench level R&D to the application stream
- Design and development of water scrubbing technology for BioCH4 & BioCO_2 production from biogas
- Environmental impact assessment of different biogas upgrading technologies
- Performance and emission characteristics of a biomethane fuelled vehicle
- Framing of project proposals related to biogas upgradation and bioCO_2 production from biogas.
- Responsible for project networking, deliverables, outcomes and summary reports.
- Coordinate with visitors, emails regarding queries on biogas technology
- Deliver lectures in workshop, user trainings and conferences on biogas upgrading technology
- Perform site visits and member of joint inspection and monitoring committee of a number of biogas upgrading plants in India
- Off-board technology expert to Ministry of New & Renewable Energy Sources for biogas scheme.
- Off-board technology expert to Ministry of Drinking Water and Sanitation, Govt. of India for Gobar Dhan scheme.
- Prepared "Compressed Biogas (CBG) Roadmap of India" document for Ministry of Petroleum & Natural Gas, Govt. of India for SATAT scheme.
- Spearheaded International and national conference, workshops and trainings on biogas production and purification.
- Writing journal papers, articles and reports
- Help develop and assist on improving internal administrative processes, preparation of Centres' brochure and website.
- Recognized by Professor & Head of Centre for ability to take up complex technical issues, make critical decisions and resolve challenges

❖ Research Associate — March 2010 – June 2017

Centre for Rural Development and Technology, Indian Institute of Technology Delhi, India

1. Biogas Development and Training Centre, BDTC, IIT Delhi (March 2017 – June 2017), Funding Agency: MNRE, India.
2. FIIT, IIT Delhi. "Valorisation of Food Waste to biogas" (March 2010 - Oct 2013). Funding Agency: European Union, Brussels.

- Development of small-scale water scrubbing systems for biogas upgradation and CO_2 recovery system.
- Visits to anaerobic digestion facilities in London, New Forest, Dorset, Cambridge and Ludlow, United Kingdom, July – August 2012
- Participated in research training in Germany: Visit to 5(Sichersreuth, Kemnather Land, Frueth and Donauworth (Hamler), Germany) biogas production and upgradation plants in different parts of Germany during May 2013 - June 2013.
- Participated in various national training course on biogas production, purification and bottling technology and power IIT Delhi, 10-12 Feb, 2011.
- International Training course on Biogas Production, Purification and power commercial technology packages. IIT Delhi, 25th – 29th Oct, 2010.
- Research training at University of Southampton, U.K. on biogas production and life cycle assessment analysis during July 2012 – August 2012.
- Lead the research team in developing reports and project correspondence and meet the deadlines
- Coordinate with international partners in virtual and real meetings
- Preparation of yearly project activity report, progress presentations and time sheets.
- Organize workshops and dissemination events related to biogas technology

❖ Academic

- **Sr. Lecturer**: Mechanical & Automation Deptt, GPM college of Engg (GPMCE), New Delhi (GGSIP University, Delhi): 2006 – 2009.
- **Lecturer**: Dronacharya College of Engg (DCE). (MD University), Gurugram: 2005 – 2006.

❖ Industrial

HVAC Design Consultant, Aurora Consulting Engineers, Gurgaon (HR), India: 2004 – 5.

Presented in Conferences, Seminars, Workshops & Meetings

International: 5
National: 18

Invited Speaker: 4 (National seminars/ workshops)

Radio Talks: 2

Newspaper / Magazine Articles: 4

Trainings Attended:
International: 2 (Germany, United Kingdom)
National: 5

Workshops/Trainings/Events Organized:
International biogas workshop: 1
National: 4

Awards

7th ENERTIA Award for 'Idea Innovation by Student in the Academic Institutions' (IITs, NITs & Top Engineering Institutions of India)" for the project "Bio-Gas Upgradation and Bottling Technology" developed at Centre for Rural Development & Technology, November 2013.

Reviewer

- Journal of Sustainable Energy Technologies and Assessments (Elsevier)
- Energy Conservation and Management (Elsevier)

References

1) **Prof. V.K Vijay**
   Prof.& Head, CRDT, IIT Delhi
   vkvijay@rdat.iitd.ac.in
2) **Prof. PMV Subbarao**
   Professor, Mechanical Engg Deptt, IIT Delhi
   pmvs@mech.iitd.ac.in
3) **Prof. Vivek Kumar**
   Professor, CRDT, IIT Delhi
   vivekk@rdat.iitd.ac.in

I certify that the information stated above are true and correct to the best of my knowledge.

RIMIKA MADAN KAPOOR

Achievements

Patent (Indian)

- **Kapoor R**, V.K. Vijay, P.M.V.Subbarao, "A System for Biomethane and Bio Carbon Dioxide Production from Biogas and a Method Thereof". (Indian) – Patent Application No.: 201811018965, Dated: May 21, 2018.

Journal Publications

- **Kapoor R,** Subbarao PMV, Vijay V.K. Integration of Flash Vessel in Water Scrubbing Biogas Upgrading System for Maximum Methane Recovery. Manuscript Accepted in Bioresource Technology Reports on 30th May 2019. MS# BITEB-D-19-00139R1.
- **Kapoor R,** Ghosh P, Madan K, Vijay V. Evaluation of biogas upgrading technologies and future perspectives: A review. Journal of Environmental Science and Pollution Research. Springer, 2019; 12: 11631-11661. DOI 10.1007/s11356-019-04767-1.
- **Kapoor R,** Subbarao P.M.V, Vijay V.K, Shah G, Sahota S, Singh D, Verma M**.** Factors affecting methane loss from a water scrubbing based biogas upgrading system. Applied Energy 2017; 208: 1379–1388.
- Sahota S**,** Shah G, Ghosh P, **Kapoor R,** Subhanjan S, Singh P, Vijay V, Sahay A, Vijay VK, Thakur IS. "Review of trends in biogas upgradation technologies and future perspectives". Bioresource Technology Reports, 2018; 1:79-88.
- Sahota S**,** Vijay V.K., Subbarao P.M.V., Chandra R., Ghosh P., Goldy G., **Kapoor R.,** Vijay V., Koutu V., Thakur I.S. Characterization of leaf waste based biochar for cost effective hydrogen sulphide removal from biogas. Bioresource Technology 2018; 250: 635 – 641.
- Nock W.J, Walker M**, Kapoor R** and Heaven S. Modelling the Water Scrubbing Process and Energy Requirements for CO2 Capture to Upgrade Biogas to Biomethane. Industrial & Engineering Chemistry Research 2014; 53:12783–12792.
- Bhaskar J, **Kapoor R,** Vijay V, Vijay V.K, Chandra R, Biogas: A Sustainable and Potential Fuel for Transport Application, Journal of Biofuels and Bioenergy 2015; 1: 28-33.
- Yadav S, **Kapoor R,** Vijay V.K. Vidyut Utpadan Hetu Biogas Sudhikaran Ki bhotik Rasaynik Vidhiya-Ek Sameeksha, Jigyasa Journal by IIT Delhi. 2014; 27&28: 116-118.

Book Chapters

- Vijay, V.K.; **Kapoor, R,** Trivedi A and Vandit Vijay. Biogas as Clean Fuel for Cooking and Transportation Needs in India. Chapter 14. Pogaku Ravindra (Ed). Advances in Bioprocess Technology, Springer International Publishing, Switzerland, 2015:257-.276.
- Vijay, V.K.; **Kapoor, R**, Trivedi A, Narele P. Biogas Upgrading and Bottling Technology for Vehicular and Cooking Applications. Raju NJ, Gossel W, Sudhakar M. (Ed). Management of Natural Resources in a Changing Environment Springer International Publishing, Switzerland, 2014: 135-153.
- Vijay, V. K., **Kapoor, R.**, Trivedi, A., Narale, P., (2015) Biogas production, up-gradation and bottling for power generation and vehicular applications. Eds. Govil, J. N., et al., Energy Science & Technology (Volume 11. Hydrogen and Other Technologies), Stadium Press LLC, USA.

International Reports

- **Kapoor R,** Vijay V.K. D 5.2 Evaluation of Existing Low-Cost Gas Bottling Systems for Vehicles Use Adaption in Developing Economies; Public deliverable EU FP7 Valorgas project (grant agreement no. 241334) 2013. http://www.valorgas.soton.ac.uk/Deliverables/120825_VALORGAS_241334_D5-_rev[0].pdf
- **Vijay** V.K. **Kapoor R**, Kaparaju, P. D 5.6. Evaluation of the role of small-scale low-cost biogas upgrading and bottling systems as a means of contributing to local transportation needs in India and EU; Public deliverable EU FP7VALORGAS project (grant agreement no. 241334). 2013.
- Läntelä J, Luostarinen J, Vijay V.K, **Kapoor R**. D5.4 Results of design, construction and testing of low-cost modular biogas upgrading systems. Private Deliverable. EU FP7 Valorgas project (grant agreement no. 241334) 2013.
- Climenhaga M.A., **Kapoor R.** D 2.5 – Institutional and community food waste generation rates and appropriateness of scale for on-site utilisation for second generation biofuel production by AD.; Public deliverable EU FP7 Valorgas project (grant agreement no. 241334) 2012. http://www.valorgas.soton.ac.uk/Deliverables/VALORGAS_241334_D2-5%20rev[1]_130316. pdf.

Personal Details

- Date of Birth : 09/06/1982
- Languages Known : Hindi, English and Punjabi

Hobbies

- Sketching
- Reading
- Dancing

Applied Energy 208 (2017) 1379–1388

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Factors affecting methane loss from a water scrubbing based biogas upgrading system

Rimika Kapoor[a,*], P.M.V. Subbarao[b], Virendra Kumar Vijay[a,*], Goldy Shah[a], Shivali Sahota[a], Dhruv Singh[a], Mahesh Verma[a]

[a] Centre for Rural Development and Technology, Indian Institute of Technology Delhi, New Delhi 110016, India
[b] Mechanical Engineering Department, Indian Institute of Technology Delhi, New Delhi 110016, India

HIGHLIGHTS

- CH_4 loss in water scrubbing based biogas upgradation method was studied.
- CH_4 loss was maximum at 10 bar pressure and 2 m^3/h water flow rate.
- A pressure vessel was used to study effect of pressure difference on CH_4 loss.
- Drop in pressure difference across scrubber and pressure vessel reduced CH_4 loss.
- Pressure difference contributed significantly to CH_4 loss.

ARTICLE INFO

Keywords:
Biogas upgrading
Water scrubbing
CH_4 loss

ABSTRACT

Biogas upgrading is a vital step to produce high quality fuel called biomethane with above 90% methane (CH_4). Among the various technologies available for biomethane production, water scrubbing is the most extensively implemented technology around the world. However, during the process of biogas upgrading, a some amount of CH_4 is separated as CH_4 loss through the water flowing out of the water scrubbing column. In this paper, various factors affecting CH_4 loss from water scrubbing method are analysed. Some factors such as pressure, water flow rate and CH_4 concentration in input gas are dependent upon the solubility and partial pressures of the gases are generally known. Apart from these factors CH_4 losses due to bubble entrainment due to high pressure difference between water scrubbing column and desorption tank and gas short circuiting of the gas through the bottom section of the column due to no water sealing and water level maintencence also contribute to CH_4 losses. Therefore, CH_4 losses during the water scrubbing process due to these factors have been experimentally studied in this paper. A pilot scale water scrubbing system for biogas upgradation was used for the study. It was observed that CH_4 % (v/v) in the upgraded biogas and CH_4 loss % from the desorbed gas increased with the increase in pressure and increase in the concentration of CH_4 in the input gas. Increase in water flow rates caused removal of larger quantities of water containing more absorbed CH_4 and CO_2 from the scrubbing column, thereby increasing CH_4 loss of the system. Highest CH_4 loss % of 9.9% (± 0.1%), was obtained with raw biogas sample when water was desorbed at atmospheric pressures in the desorption tank, i.e. when pressure difference between the water scrubbing column and desorption tank was highest. A pressure vessel was installed in between scrubbing column and desorption tank to reduce the pressure difference for water leaving the column by varying the pressure in the pressure vessel from 1 to 9 bar. With the increase in pressure in the pressure vessel, the pressure difference for water decreased which led to a saving in overall CH_4 loss of the system. Water sealing and water level maintenance in the bottom section of the column also affected CH_4 losses of the system. All the factors discussed in the article contribute to the CH_4 losses from the scrubbing column and cannot be solely credited to a single factor.

* Corresponding authors.
E-mail addresses: rimikakapoor@gmail.com (R. Kapoor), vkvijay@rdat.iitd.ac.in (V.K. Vijay).

http://dx.doi.org/10.1016/j.apenergy.2017.09.017
Received 13 April 2017; Received in revised form 16 August 2017; Accepted 8 September 2017
Available online 14 September 2017

Environmental Science and Pollution Research (2019) 26:11631–11661
https://doi.org/10.1007/s11356-019-04767-1

REVIEW ARTICLE

Evaluation of biogas upgrading technologies and future perspectives: a review

Rimika Kapoor[1] · Pooja Ghosh[1] · Madan Kumar[1] · Virendra Kumar Vijay[1]

Received: 3 December 2018 / Accepted: 4 March 2019 / Published online: 15 March 2019

Abstract

Biogas is acknowledged as one of the foremost bioenergy to address the current environmental and energy challenges being faced by the world. Commonly, biogas is used for applications like cooking, lighting, heat and power production. To widen the scope of biogas application, like transportation, natural gas grid injection and substrate for the production of chemicals and fuel cells, mainly CO_2, H_2S and other impurities need to be removed by various upgrading technologies. It is an important process to produce biomethane with above 90% methane. There are various physico-chemical (adsorption, absorption, cryogenic and membrane separations) and biological (in situ and ex situ) processes for biogas upgradation, and each process is site and case specific. The aim of the present paper is to thoroughly evaluate the existing and emerging biogas upgrading technologies. Analysis of each technology with respect to basis of operations, energy requirement, methane purity and recovery and cost economics has been carried out. A thorough analysis has been done on the major hurdles and the research gaps in this sector. For a wider and successful implementation of the biogas upgradation technology, the trends in research and development (R&D) such as development of efficient biogas upgrading technologies, adsorbents, reduction in cost and methane loss have been thoroughly evaluated.

Keywords Biogas upgrading · Biomethane · CO_2 removal · Future perspectives

Introduction

Fossil fuels are the dominant source of energy providing 80% of the global energy needs. In the current trend of fuel consumption, carbon dioxide emissions are estimated to increase to 37 Gt by 2035 (IPCC 2013). Considering the limited fuel reserves, increasing greenhouse gas emissions and climate change, a transition from fossil-based (coal, petroleum and natural gas) to zero-carbon renewable fuels has been experienced worldwide. For sustainable economic growth, there is a need for accelerated and synergistic deployment of renewable and efficient energy measures by the second half of this century (IRENA 2017a).

Responsible editor: Philippe Garrigues

✉ Rimika Kapoor
rimikakapoor@gmail.com

✉ Virendra Kumar Vijay
vkvijay@rdat.iitd.ac.in

[1] Centre for Rural Development and Technology, Indian Institute of Technology Delhi, New Delhi 110016, India

Renewable resources form the nucleus of energy transition to make it less carbon intensive and compatible to the international climate goals (REN21 2017). To adequately limit the rise in global temperatures, energy use would have to be totally decarbonized in less than 50 years (IRENA 2017b). To meet this goal, International Renewable Energy Agency (IRENA) analysed that renewables must grow to 65% of global energy supply by 2050 (IRENA 2018). World Bioenergy Association estimated that renewable energy contributed approximately 18.6% of the total global energy consumption, in which bioenergy accounted for nearly 14% (Fig. 1) (Kummamuru 2017). Bioenergy is projected to sustainably supply between a quarter and a third of future global primary energy mix in 2050 (Devi P, Devi 2012). There is an increasing inclination towards using modern technologies and efficient bio-energy conversion routes for biofuels production to fulfil the global energy demand.

Biogas is a potential alternative to the world's unquenchable demand for energy and concurrently reduces waste and greenhouse gas (GHG) emissions. Wastes like sewage sludge, agricultural and crop residues, animal dung and industrial organic wastes and wastewaters can be converted into biogas through anaerobic digestion. Biogas production is predicted to

I&EC research
Industrial & Engineering Chemistry Research

Article

pubs.acs.org/IECR

Modeling the Water Scrubbing Process and Energy Requirements for CO_2 Capture to Upgrade Biogas to Biomethane

William J. Nock,*[,†] Mark Walker,[‡] Rimika Kapoor,[§] and Sonia Heaven[†]

[†]Faculty of Engineering and the Environment, University of Southampton, Highfield, Southampton, SO17 1BJ United Kingdom

[‡]Energy Technology Innovation Initiative, University of Leeds, Woodhouse Lane, Leeds, LS2 9JT United Kingdom

[§]Centre for Rural Development and Technology, Foundation for Innovation and Technology Transfer, Indian Institute of Technology Delhi, Haus Khaz, New Delhi, 110 016 India

ABSTRACT: Water scrubbing is the most widely used technology for removing CO_2 from biogas and landfill gas. This work developed a rate-based mass transfer model of the CO_2−water system for upgrading biogas in a packed bed absorption column. The simulated results showed good agreement with both a pilot-scale plant operating at 10 bar, and a large-scale biogas upgrading plant operating at atmospheric pressure. The calculated energy requirement for the absorption column to upgrade biogas to 98% CH_4 (0.23 kWh Nm^{-3}, or 4.2% of the input biogas) is a significantly closer approximation to the measured value (0.26 kWh Nm^{-3}, or 4.8% of the input biogas) than has previously been reported in the literature. The model allows for improved design of CO_2 capture and biogas upgrading operations and can also be a useful tool for more detailed cost−benefit analysis of the technology.

INTRODUCTION

Removal of CO_2 from gas streams is an important process both as a potential step in greenhouse gas sequestration and for upgrading biogas. Biogas is produced from the anaerobic digestion of organic waste material and is mainly composed of CO_2 (typically 35−45%) and CH_4 (typically 55−65%) with smaller proportions of H_2S, water vapor, and other trace compounds. This biogas can be combusted directly on site in a boiler or a combined heat and power (CHP) unit. If the electricity and/or heat produced exceeds on-site requirements, however, an alternative option is to upgrade and export the biogas for use where needed. The upgrading process produces biomethane, with comparable properties to natural gas and involves removal of the noncombustible fractions to increase the calorific value of the gas. This can enable the upgraded biogas to meet the standards for injection into a natural gas grid or for use as a vehicle fuel replacing compressed natural gas (CNG). This is a particularly attractive option in situations where there is insufficient local demand for the heat produced from a CHP plant, making upgrading the most efficient option in terms of overall energy balance.[1]

Several countries have set their own biomethane standards for use in the gas grid or as a vehicle fuel. Switzerland and Sweden require a 96% and 97% CH_4 content, respectively.[2] The European Committee for Standardisation is currently working to produce a European standard on biomethane. Typically a CH_4 concentration of over 95% is required for vehicle or gas grid use. To achieve this a signficant portion of CO_2 from biogas needs to be removed. Different methods are currently employed to achieve this, including pressure swing adsorption, cryogenic, chemical absorption, and membrane techniques.[3] Currently the most widely used method in the biogas industry is the water absorption process.[4] This procedure mixes water and biogas, counter-currently, usually under pressure in a packed column to maximize the gas−liquid contact area. CO_2 is more readily absorbed in water than CH_4, so in the absorption column more of the CO_2 is removed from the gas stream, increasing the CH_4 concentration in the biogas. At 273 K CO_2 has a molar concentration approximately 29 times greater than CH_4, although this ratio reduces with temperature to approximately 23:1 at 303 K. The solubilities of both CO_2 and CH_4 increase with a reduction in temperature.

Depending on the substrate and operating conditions used in the anaerobic digestion process, other compounds such as H_2S and N_2 may be present in the biogas, and some of these may need to be removed before or during CO_2 removal. An advantage of the water absorption process is that it can also be used to remove low concentrations of H_2S.[4] Difficulties can arise, however, if a desorption step is employed to regenerate the water for recirculation back into the absorption column. The desorption step requires mixing with air, and high concentrations of H_2S will oxidize into H_2SO_4, which can lead to corrosion problems. In this case a pretreatment step can remove H_2S prior to upgrading. For the purposes of this model only CH_4 and CO_2 have been considered and the presence of H_2S has been assumed to be negligible.

There is a lack of published work investigating the energy requirements of the CO_2 water scrubbing process. A life cycle assessment from Berglund and Börjesson[5] on the anaerobic digestion of different feedstocks included an energy analysis of biogas upgrading. It was estimated that 11% of the energy content of the produced biogas is used to meet the energy demands of the upgrading process, although no reference is made to the type of process used. Smyth et al.[6] investigated the energy balance of biomethane from anaerobic digestion of

Received: March 26, 2014
Revised: July 3, 2014
Accepted: July 10, 2014
Published: July 10, 2014

Bioresource Technology 250 (2018) 635–641

Contents lists available at ScienceDirect

Bioresource Technology

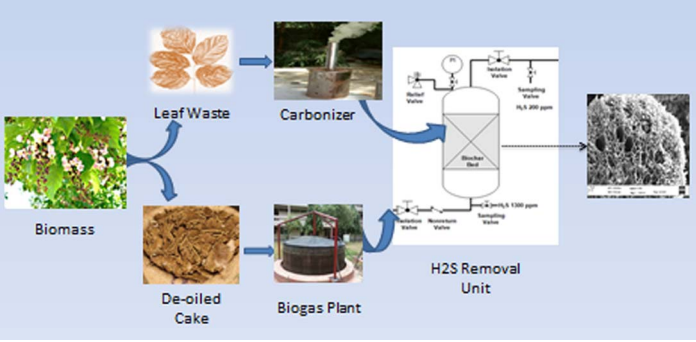
journal homepage: www.elsevier.com/locate/biortech

Characterization of leaf waste based biochar for cost effective hydrogen sulphide removal from biogas

Shivali Sahota[a], Virendra Kumar Vijay[a], P.M.V. Subbarao[b], Ram Chandra[a], Pooja Ghosh[a], Goldy Shah[a], Rimika Kapoor[a], Vandit Vijay[a], Vaibhav Koutu[c], Indu Shekhar Thakur[d,*]

[a] Centre for Rural Development and Technology, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India
[b] Department of Mechanical Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India
[c] Department of Physics and Nanoscience and Engineering, MANIT, Bhopal, Madhya Pradesh, India
[d] School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067, India

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Leaf waste
Biochar
Biogas
Adsorption
H_2S removal

ABSTRACT

Installation of decentralized units for biogas production along with indigenous upgradation systems can be an effective approach to meet growing energy demands of the rural population. Therefore, readily available leaf waste was used to prepare biochar at different temperatures and employed for H_2S removal from biogas produced via anaerobic digestion plant. It is found that biochar prepared via carbonization of leaf waste at 400 °C effectively removes 84.2% H_2S (from 1254 ppm to 201 ppm) from raw biogas for 25 min in a continuous adsorption tower. Subsequently, leaf waste biochar compositional, textural and morphological properties before and after H_2S adsorption have been analyzed using proximate analysis, CHNS, BET surface area, FTIR, XRD, and SEM-EDX. It is found that BET surface area, pore size, and textural properties of leaf waste biochar plays a crucial role in H_2S removal from the biogas.

1. Introduction

Growing environmental concern and forthcoming energy crisis have escalated the quest for alternate sources of renewable and sustainable energy. Biogas is one such clean and renewable energy source which is produced from a wide range of bio-renewable biomass. In general, biogas is produced through anaerobic digestion of lignocellulosic biomass and used as a fuel for heat and power generation (Yadvika et al., 2004). Fuel application of biogas is attributed to its 50–70% of CH_4 along with 30–45% of CO_2 < 1% of nitrogen, 4–5% moisture and

* Corresponding author.
E-mail address: isthakur@hotmail.com (I.S. Thakur).

https://doi.org/10.1016/j.biortech.2017.11.093
Received 14 October 2017; Received in revised form 23 November 2017; Accepted 27 November 2017
Available online 29 November 2017
0960-8524/

Bioresource Technology Reports 1 (2018) 79–88

Contents lists available at ScienceDirect

Bioresource Technology Reports

journal homepage: https://www.journals.elsevier.com/bioresource-technology-reports

Review of trends in biogas upgradation technologies and future perspectives

Shivali Sahota [a,1], Goldy Shah [a,1], Pooja Ghosh [a,*], Rimika Kapoor [a], Subhanjan Sengupta [b], Priyanka Singh [a], Vandit Vijay [a], Arunaditya Sahay [b], Virendra Kumar Vijay [a], Indu Shekhar Thakur [c]

[a] Centre for Rural Development and Technology, Indian Institute of Technology, New Delhi 110016, India
[b] Birla Institute of Management Technology, Greater Noida 201306, India
[c] School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067, India

ARTICLE INFO

Article history:
Received 4 December 2017
Received in revised form 5 January 2018
Accepted 6 January 2018
Available online 17 January 2018

Keywords:
Sustainable development
Biogas upgradation
Bioenergy
Biomethane

ABSTRACT

Biogas is a futuristic renewable energy with high market potential due to wide scale availability of organic biomass, and for facilitating countries in meeting sustainable development goals related with creating and providing access to renewable energy. It has potential of being developed as a vehicular fuel or for generating electricity that can be injected into power grids. Despite its prospect, it faces criticism, such as limited contributions in reducing carbon emissions as compared to solar and wind. Consequentially, for higher efficiency and for better commercialization, it is impending not only to upgrade raw biogas but also utilize the energy value of off-gas. Currently available methods have high operating costs and are energy intensive, limiting the commercial applications of biogas. This review is aimed at presenting the state-of-art upgradation technologies currently available and the ones which are promising. It also discusses the future perspectives for overcoming the challenges associated with upgradation.

Contents

* Corresponding author.
E-mail address: poojaghosh@iitd.ac.in (P. Ghosh).
[1] Shivali Sahota and Goldy Shah have equal contribution.

https://doi.org/10.1016/j.biteb.2018.01.002
2589-014X/

Journal of Biofuels and Bioenergy (June 2015) 1(1): 28-33
DOI: 10.5958/2454-8618.2015.00004.8

Review Article

Biogas: A Sustainable and Potential Fuel for Transport Application

Bhaskar Jha, Rimika M Kapoor, Vandit Vijay, Virendra Kumar Vijay*, Ram Chandra

Biogas Production and Enrichment Laboratory, Centre for Rural Development and Technology, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India

Keywords: Energy scenario, Biogas production potential, Compressed biogas, Biogas

ABSTRACT

Energy is an essential ingredient for economic growth, social development, human welfare and improving the standards of living. This growing consumption of energy has resulted in increased dependence on fossil fuels, which is causing environmental problems. Depletion of fossil fuels, energy security and large emission of greenhouse gases in our atmosphere is a matter of great concern today. Diesel and petrol are the major transport fuels in India and each year billions of money are being expended for their import. Biogas can play a key role in transformation and dependency with a large potential in India (approximately 48,383 million m^3 biogas annually), having possibilities to replace and therefore reduce our dependence on fossil fuels for transportation sector. Based on the Indian Petroleum and Natural Gas Statistics 2011–2012 data, the contribution of upgraded biogas in the transportation sector as a percentage of total petroleum fuels consumption for the year 2011–2012 is approximately 86.8% if used to replace transport fuel which is quite encouraging. A 10 Nm^3/h capacity fully automated biogas purification and bottling plant with improved design parameters has been designed, fabricated and implemented at Indian Institute of Technology Delhi (IIT Delhi) campus. The enriched and bottled biogas has been regularly fuelled to a Wagon R car (from last three years), and to analyse the performance of it, mass emissions testing has been performed at ICAT (International Centre for Automotive Testing). Results of mass emissions, i.e., nitrogen oxides (NOx), carbon monoxide (CO),hydrocarbon (HC) and particulate matter(PM) were complying with Bharat Stage – IV (BS – IV) norms. In principal, biomethane can be used for exactly the same applications as natural gas, if the final composition is in line with the different natural gas qualities on the market.upgradation, Biogas for vehicular application

*Corresponding author Email id: vkvijay@rdat.iitd.ac.in

Advances in Bioprocess Technology pp 257-275 | Cite as

Biogas as Clean Fuel for Cooking and Transportation Needs in India

Authors | Authors and affiliations

Virendra Kumar Vijay, Rimika Kapoor, Abhinav Trivedi, Vandit Vijay

Abstract

In principal, biomethane can be used for exactly the same applications as natural gas, if the final composition is in line with the different natural gas qualities on the market. Therefore, it can be used as a substitute for transport fuels, to produce combined heat and power (CHP), heat alone or serve as feedstock for the chemical sector. It can be transported and stored in the facilities and infrastructure available for natural gas. Biomethane can be produced by upgrading biogas. Biogas upgrading includes increasing the energy density by separating carbon dioxide from methane. Furthermore, water, hydrogen sulphide and other contaminants are removed, sometimes before the upgrading process to avoid corrosion or other problems in downstream applications. Today, a range of technologies for CO_2-separation are on the market. It is difficult to specify the exact characteristics for an upgrading technology, since the design and operating conditions vary between the different manufacturers, sizes and applications. The key quality criteria for the upgrading technologies are the energy demand and the methane loss during upgrading.

Keywords

Biogas Production | Biogas Plant | Vehicle Fuel | Transport Fuel | Housing Society

Management of Natural Resources in a Changing Environment pp 135-153 | Cite as

Biogas Upgrading and Bottling Technology for Vehicular and Cooking Applications

Authors | Authors and affiliations

Virendra Kumar Vijay, Rimika Kapoor, Abhinav Trivedi, Pradip Narale

Chapter
First Online: 29 October 2014

Abstract

Enhanced energy security and climate change mitigation are the main drivers for the transformation of the energy system from fossil to renewable sources. Biomass has to play a key role in this transformation to a low carbon economy. Worldwide, biomass accounts for more than two thirds of all renewable energy supplies. Among biomass sources, biogas is an interesting option with a large potential, offering many exciting possibilities to supplement and therefore reduce our dependence on fossil fuels.

Keywords

Anaerobic Digestion | Biogas Plant | Pressure Swing Adsorption | Vehicle Fuel | Cattle Dung

FORM 5

THE PATENTS ACT, 1970
(39 of 1970)
&
THE PATENTS RULES, 2003

DECLARATION AS TO INVENTORSHIP
[See Section 10(6) and Rule 13(6)]

We, INDIAN INSTITUTE OF TECHNOLOGY, DELHI whose address is Hauz Khas, New Delhi, Pincode -110016, India, do hereby declare that the true and first inventor of the invention disclosed in the complete specification filed in pursuance of our application numbered **2018……** dated **May 21, 2018** are :

Name	Nationality	Address
Virendra Kumar Vijay	Indian	Professor, Centre for Rural Development and Technology, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India
Rimika Madan Kapoor	Indian	Post Doctoral Fellow (Institute - PDF), Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016
P M V Subbarao	Indian	Professor, Department of Mechanical Engineering Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India

Dated this 21st day of May, 2018

FOR INDIAN INSTITUTE OF TECHNOLOGY, DELHI
By their Agent

(RICHA PANDEY) (IN/PA 826)
KRISHNA & SAURASTRI ASSOCIATES LLP

To,
The Controller of Patents
The Patent Office
Delhi