www.sphinxsai.com

ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN : 0974-4290
Vol.6, No.4, pp 2484-2492, July-Aug 2014

Bioenergy from Sanitary landfill gas – A Resource with Economic and Environmental benefits.

V.Nehru Kumar[1], M.Sasi Kumar[2]*

[1]Centre for Environment, Health and Safety,
Department of civil engineering, Annamalai University, Chidambaram, India.

***Corres.author: sasionmove@yahoo.com,**
***Phone No: +91 8220509877**

Abstract: Management of Municipal Solid Waste (MSW) has become a major challenge in India. The green house gases primarily methane (50-55%) and carbon dioxide (40-45%), which are emitted from the MSW dumpsites are major concerns in the national emission budget. The MSW, if managed properly, can be used as a resource for energy recovery. The Sanitary landfill gas mainly constitutes of methane (50-55%) and carbon dioxide (40-45%). Both these green house gases which are also termed as bio energy are released from municipal solid waste landfill by the process of biodegradation of the organic matter present in the municipal solid waste that is dumped in sanitary landfill. It basically involves the conversion of the complex carbohydrates which are present in organic matter to energy. Bio-energy is also known as biofuel which could be effectively utilized as an alternative for conventional fossil fuel. This helps in the reduction in ozone depleting green house gases emitted into the atmosphere and thus solves the problem of the global warming. This review paper deals with the characteristics, economic and environmental benefits of the bioenergy gases emitted from sanitary landfill.
Keywords: Municipal solid waste, Biodegradation, Sanitary Landfill gas, Bioenergy, Biofuel.

Introduction:

The Urbanization lead to the population explosion in major cities in developing countries especially inIndia. India has a population of over 1.21 billion account for 17.5% of the world population. In the year 2011 in India, 377 million people live in the urban areas of the country. This is 31.16 % of the Country's total population[1].

The projected MSW quantities are expected to increase from 83.8 million tonnes in 2015 to 221 million tonnes in 2030.It is also reported that per capita per day production of MSW will increase to 1.032 kg, and urban population as 586 million in 2030.Current global MSW generation levels are approximately 1.3 billion tonnes per year, and are expected to increase to approximately 2.2 billion tonnes per year by 2025. This represents a significant increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years[2].

The main constituents of landfill gas, the Methane represents 12% of total global methane emissions[3]. Methane makes up around 29% of the total Indian Green House Gas emissions, while the global average is only 15%[4]. Landfills are responsible for almost half of the methane emissions attributed to the municipal waste sector[5]. There is need to utilize the methane emissions for the power and also to minimize its affect to the climate change. The Municipal solid waste generation in the world is expected to be 2.4 Billion tonnes per year[6].

The municipal solid waste generated in India (Table 1) in the year 2011-12 is 127486 TPD, out of which 89334 TPD is collected and 15881 TPD is processed or treated which indicates 70% of the MSW is collected while only 12.45% is sent for treatment or for processing units.

Table 1: State wise Municipal Solid Waste Generation Data as on 31-07-2012:

Sl.no	State	Quantity Generated (TPD)	Collected(TPD)	Treated (TPD)
1	Andaman and Nicobar	50	43	Nil
2	Andhra Pradesh	11500	10655	3656
3	Arunachal Pradesh	94	NA	Nil
4	Assam	1146	807	72.65
5	Bihar	1670	1670	Nil
6	Chandigarh	380	370	300
7	Chhattisgarh	1167	1069	250
8	Daman Diu & Dadra	41	NA	Nil
9	Delhi	7384	6796	1927
10	Goa	193	NA	NA
11	Gujarat	7379	6744	873
12	Haryana	537	NA	Nil
13	Himachal Pradesh	304	275	153
14	Jammu & Kashmir	1792	1322	320
15	Jharkhand	1710	869	50
16	Karnataka	6500	2100	2100
17	Kerala	8338	1739	1739
18	Lakshadweep	21	21	4.2
19	Madhya Pradesh	4500	2700	975
20	Maharashtra	19204	19204	2080
21	Manipur	113	93	2.5
22	Meghalaya	285	238	100
23	Mizoram	4742	3122	Nil
24	Nagaland	188	140	Nil
25	Orissa	2239	1837	33
26	Puducherry	380	NA	Nil
27	Punjab	2794	NA	Nil
28	Rajasthan	5037	NA	Nil
29	Sikkim	40	32	32
30	Tamil Nadu	12504	11626	603
31	Tripura	360	246	40
32	Uttar Pradesh	11585	10563	Nil
33	Uttrakhand	752	NA	Nil
34	West Bengal	12557	5054	606.5
	34 states	**127486**	**89334**	**15881**

Source: CPCB, 2012.

Four phases in the decomposition of landfill waste:

Phase – I:

Aerobic bacteria in presence of oxygen decompose the organic waste. Aerobic bacteria consume oxygen and breaks down the long molecular chains of complex carbohydrates, proteins and lipids. Carbon dioxide is the primary byproduct. Nitrogen content is very high in the beginning and declines over the time. Phase – I continuous until all available oxygen is consumed.

Phase –II:

Without oxygen availability the anaerobic bacteria converts compounds created by aerobic bacteria converts compounds created by aerobic bacteria into acetic, lactic acids, formic acids and alcohols such as methanol and ethanol. Landfill becomes highly acidic and it mix with moisture in Landfill and dissolves the nutrients and thus Nitrogen and Phosphorous available for different bacteria's. The carbon dioxide and hydrogen is the byproduct. If the oxygen is entered in the landfill, then the Phase –II is reversed to Phase – I.

Phase – III:

Anaerobic bacteria consume acids and forms acetate. This causes landfill to become neutral, thus methane producing bacteria establishes themselves. At this stage both methane as well as the acid producing bacteria goes mutually beneficial. The acid producing bacteria produces compounds that would be useful to the methogenic bacteria, while methogenic bacteria consume carbon dioxide and acetate. Too much of consumption by methogenic bacteria would prevail a harmful situation to the acid producing bacteria. Hence a symbiotic condition has to be sustained for the continuation of phase- III.

Phase – IV:

This phase- IV begins when the biogas production and the composition are relatively constant. i.e., Methane = 45 – 60 % by volume and Carbon di oxide = 40 – 60% by volume, other trace gases = 2 – 9 % by volume basis.

The Landfill gas would be generated for almost 50 years, which depends on the organic content of the waste that is dumped in the landfill.

The typical constituents of the Municipal Solid Waste landfill gas (Table 2) are methane and carbon dioxide with other traces of Non-Methogenic Organic Compounds (NMOC's) viz., Nitrogen, Oxygen, Hydrogen sulphide, Carbon Monoxide, Hydrogen, Ammonia, Acetone, Vinyl chloride, Toluene, Chloroform, Dichloro methane, Diethylene chloride, Vinyl acetate, Trichloroethane, Perchloroethane etc,.

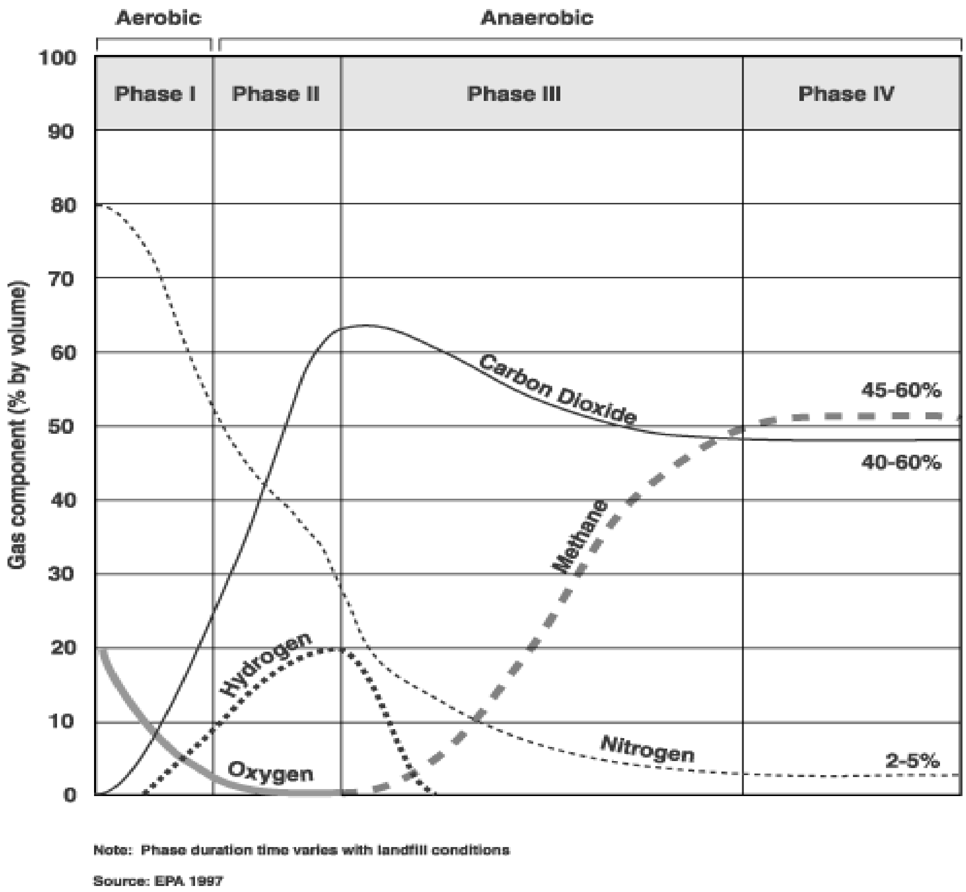
The Figure 1 indicates the different gas composition in four different phases. The nitrogen initially has maximum concentration is declined due to consumption by the microbes. The carbon dioxide and methane are found in higher concentration in the phase-IV due to complete degradation of the organics in MSW.

Table 2: Typical constituents of Municipal landfill gas:

Constituent	Range (Percentage / Concentration)
Methane	30 – 60 %
Carbon dioxide	34 – 60 %
Nitrogen	1 – 21 %
Oxygen	0.1 – 2 %
Hydrogen Sulphide	0 – 1 %
Carbon Monoxide	0 – 0.2 %
Hydrogen	0 – 0.2 %
Ammonia	0.1 – 1 %
Acetone	0 – 240 ppm
Benzene	0 – 39 ppm
Vinyl Chloride	0 – 44 ppm
Toluene	8 – 280 ppm
Chloroform	0 – 12 ppm
Dichloromethane	1 – 620 ppm
Diethylene Chloride	0 – 20 ppm
Vinyl Acetate	0 – 240 ppm
Trichloroethane	0 – 13 ppm
Perchloroethane	0 – 19 ppm
Others	Variable

Source: Technical EIA guidance for common solid waste management facility, MOEF, India.

Figure 1:



Criteria's for landfill gas production:

The important criteria's for landfill gas productions are waste composition, age of refuse, presence of oxygen in landfill, moisture content, temperature.

Landfill Gas:

The landfill gas is produced by anaerobic degradation of organic material present in the municipal solid waste. The major constituents of the landfill gas are methane and carbon dioxide. Some of the minor constituents are Hydrogen sulphide, Carbon monoxide, Ammonia, Hydrogen gas, Acetone, Benzene, Vinyl Chloride, Toluene, Chloroform, Dichloromethane, Diethylene chloride, Vinyl Acetate, Trichloroethane, Perchloroethane. Management of landfill gas is very important because of its explosive risk and green house gas potential. Hydrogen sulphide with concentration above 1000 ppm is lethal within few minutes. Therefore landfill gas management is essential to prevent the release of green house gas and also the trace constituents into the atmosphere.

In addition to mitigating the environmental as well as health aspects of the landfill gas, collection of the landfill gas is very much useful in generating heat or electricity. In the tropical climate the moisture content and the ambient temperature are higher which enhances the microbial activity and the generation of landfill gas.

Influencing Parameters and Constraints of MSW Landfill Technology with regard to landfill gas:

Landfill Technology:

a). Influencing Parameters:

1. Potential for methane gas.

b). Limitations:

1. Utilization of methane may not be feasible for remote sites.

2. Cost of pretreatment to upgrade the gas may be high.

c). Benefits:

1. The gas produced can be utilized for power generation or as domestic fuel for direct thermal application.

2. Reduced Green House Gas emissions.

d). Environmental concerns:

1. Spontaneous ignition due to possible methane concentrations.

2. Incase of inefficient gas recovery process yielding from total amount of gas actually generated, the green house gases may escape to the atmosphere.

Gas control system:

HDPE pipes are generally used for collecting the biogas from the landfill for sustaining safe venting system.

The gas control system involves the following features:

- ✓ A containment system is provided which encloses the gas within the site and prevents migration outside the landfill
- ✓ A system in either passive or active mode is provided for the collecting and removing landfill gas from within the landfill and in particular from the perimeter of the landfill
- ✓ A system for flaring or utilizing the collected gas with adequate back up facilities
- ✓ Gas vents will be placed 30 to 75 m on the landfill cover and level of methane will be monitored regularly.

Methods involved in the effective prevention of the landfill gas emissions:

1. Capture and utilize the gas as fuel in gas engine and generate electricity or pipe the landfill gas to the nearby industrial facility and utilize its energy content.
2. Flaring the landfill gas i.e., converting methane into carbon dioxide without energy recovery.
3. Installation of methane oxidation layer i.e., converting methane to carbon dioxide by using methanogenic bacteria.

Monitoring of landfill gas:

The landfill gas is characterized by unpleasant odor which would be the main reason for the public residing nearby to complain.

When the methane concentrations are above 5% by volume but less than 15% in atmospheric air the landfill gas can cause explosive hazard. The landfill area and near by area should be periodically monitored for at least once in 3 months interval. If the methane concentration is above 5% then the ventilation or evacuation must be carried out as per the norms of the governing authority.

The gas well samplings can be taken at various positions of the landfill sites to measure the presence of volatile organic compounds.

Utilization options available with the landfill gas:

- ❖ Flaring - Loss of available energy.

- Boiler - Produces Heat.
- Internal combustion heat – Generates motive power.
- Gas Turbine - Makes electricity.
- Fuel cell - Makes electricity.
- Convert methane to methyl alcohol.

Environmental Benefit:

The Landfill gas is a renewable energy helps in reducing the carbon foot print and it can be utilized as an alternative energy to the conventional fossil fuel, which is emitting the green house gases that is responsible for causing smog and acid rains. Further Landfill gas energy projects helps in mitigating the global climate change, because it reduces the emissions of methane, which is 21 times more potent Green House Gas (GHG) than Carbon dioxide. The direct and indirect CO_2 equivalent (CO_2e) emission reductions from a direct–use project utilizing 1,000 scfm (standard cubic feet per minute) of LFG are approximately 105,900 and 12,470 metric tons per year, respectively[7].India is one of the world's largest emitters of methane from solid waste disposal, currently producing around 16 Mt CO_2 eq per year, and predicted to increase to almost 20 Mt CO_2 eq per year by 2020[8]. The landfill gas to energy project is also eligible to apply as clean development mechanism (CDM) project[9]. The energy recovery from various treatment and disposal methods can also contribute indirectly to the reduction of greenhouse effect by replacing fossil fuels in electricity production[10].

Economic Benefit:

The landfill gas project provides economic benefits for the communities by providing jobs and also enhances local sales. On setting up the project, the captured gas can be utilized as a fuel or heat or it can be sold as renewable green energy in the energy market.

The Municipal solid waste generated in major Indian cities is rich in organic matter and has the potential to generate about 15 – 25 lit/kg of gas per year over its operative period (0.015 – 0.025 m^3/kg).The yearly gas production rates observed in full size sanitary Landfill in other countries range from 5 – 40 lit/kg. (0.005 – 0.04 m^3/kg). The Landfill gas has calorific value = 4500 – 5000 Kilo Calories /cubic meter[11].

The Landfill gas can be tapped at an average of 6m^3 per every Tonne of MSW placed in engineered LF up to 15-20 years. One hundred tonnes of raw MSW with 50-60% organic matter can generate about 1- 1.5 Mega Watt power, depending upon the waste characteristics [12]. A Landfill with 1 Million Tonne of MSW will sustain a power generation at 1MW for almost 15 years. The use of LFG for generating electricity is a promising approach both in terms of conserving energy and also for reducing air pollution[13].

The CO_2 emission per capita (tonnes of CO_2/ person) in India is 1.6, with total CO_2 emission in the year 2011 is 1970 million tonnes of CO_2. The data for different countries in time period is shown in Table 3.The projected baseline CH_4 Emission from MSW landfill for India (Table 4) is estimated to be 18.1 and 19.1 MtCO_2Eq for the year 2015 and 2020 respectively.

A cost-benefit analysis of a landfill system with gas recovery (LFSGR) has been carried out for Mumbai city's solid waste, which had concluded that a savings of Rs. 6.366 billion (approx. $0.140 billion) per annum with reference to the existing system of waste disposal would be attained [14]. In Thailand, the total electricity production of 1.07 to 1.1 MW could be achieved from the solid disposal site capacity of 800 tonnes per day[15].

The state wise Based Distributed/ Grid Power Generation Projects installed since inception till 31-03-2011 in India has been tabulated in Table 5, From 348 projects all over India, 65287 m^3 Biogas is utilized to produce 6617.25 KW of electricity. The Tamilnadu state tops among the Indian states and is expected to produce 3088 KW of electricity under full installation capacity of the project.

Table 3: CO_2 Emissions in 2011 (million tonnes CO_2) and CO_2/ capita emissions, 1990-2011(tonne of CO_2/ Person :

Country	Emissions 2011	Per capita emissions				Change	Change	Change in CO2	Change in population
		1990	2000	2010	2011	1990-2011	1990-2011 in %	1990-2011 in%	1990-2011 in%
Annex 1 *									
US	5420	19.7	20.8	17.8	17.3	-2.4	-12%	9%	19%
EU 27	3790	9.2	8.4	7.8	7.5	-1.7	-18%	-12%	6%
Germany	810	12.9	10.5	10.2	9.9	-3	-23%	-21%	4%
UK	470	10.3	9.3	8.1	7.5	-2.8	-27%	-20%	8%
Italy	410	7.5	8.1	6.9	6.7	-0.8	-11%	-4%	7%
France	360	6.9	6.9	6.1	5.7	-1.2	-17%	-9%	10%
Poland	350	8.2	7.5	8.8	9.1	0.9	11%	11%	1%
Spain	300	5.9	7.6	6.3	6.4	0.5	8%	29%	16%
Netherland	160	10.8	10.9	10.5	9.8	-1	-9%	2%	11%
Russia	1830	16.5	11.3	12.4	12.8	-3.7	-22%	-25%	-4%
Japan	1240	9.5	10.1	10	9.8	0.3	3%	7%	3%
Canada	560	16.2	17.9	16	16.2	0	0%	24%	19%
Australia	430	16	18.6	17.9	19	3	19%	57%	24%
Ukraine	320	14.9	7.2	6.7	7.1	-7.8	-52%	-58%	-14%
Non-Annex 1									
China	9700	2.2	2.8	6.6	7.2	5	227%	287%	15%
India	1970	0.8	1	1.5	1.6	0.8	100%	198%	30%
South Korea	610	5.9	9.7	12.2	12.4	6.5	110%	141%	11%
Indonesia	490	0.9	1.4	2	2	1.1	122%	210%	24%
Saudi Arabia	460	10.2	13	15.8	16.5	6.3	62%	181%	43%
Brazil	450	1.5	2	2.2	2.3	0.8	53%	106%	24%
Mexico	450	3.7	3.8	3.9	3.9	0.2	5%	45%	27%
Iran	410	3.7	5.2	5.4	5.5	1.8	49%	100%	27%
South Africa	360	7.3	6.9	7.1	7.2	-0.1	-1%	35%	27%
Taiwan	270	6.2	10.5	11.7	11.8	5.6	90%	119%	13%
Thailand	230	1.6	2.7	3.3	3.3	1.7	106%	155%	18%

Source of population data: UNDP, 2010 (WPP Rev, 2010)
Annex 1 Countries: Industrialised countries with annual reporting obligations under the UN Framework Convention on Climate Change (UNFCC) and emission targets under the Kyoto protocol. The United States has signed but not ratified the protocol, and thus the US emission target in the protocol has no legal status.

Table 4: Projected Baseline CH_4 Emissions from Municipal Solid Waste by Country: 2005–2020 ($MtCO_2eq$)

Country	**2005**	**2010**	**2015**	**2020**
United states	130.6	125.4	124.1	123.5
China	46	47.5	48.8	49.7
Mexico	33.3	35.5	37.4	39.2
Canada	25.3	27.7	30.7	33.6
Russia	34.2	33.2	32.2	31.1
Saudi Arabia	19.4	22.1	24.8	27.5
India	15.9	17.1	18.1	19.1
Brazil	16.6	17.5	18.3	19
Ukraine	13.4	14.7	16.4	18
Poland	17	17	17	17
South Africa	16.8	16.6	16.4	16.2
Turkey	10.4	11	11.6	12.1
Israel	9.7	10.6	11.3	11.9
Australia	8.7	9.4	10.6	11.9
Congo	7.4	8.6	9.8	11.2
Rest of the world	342.7	346.7	360.5	375.9
Total	**747.4**	**760.6**	**788.1**	**816.9**

Source: USEPA, 2006

Table 5: State-wise Biogas Based Distributed/ Grid Power Generation Projects installed since inception till 31-03-2011

Sl. No.	**Name of the State**	**Installed**			**Under installation**			**Grand Total**		
		Nos.	**M^3**	**KW**	**Nos.**	**M^3**	**KW**	**Nos.**	**M^3**	**KW**
1.	Andhra Pradesh	15	1540	149	49	5595	647	64	7135	796
2.	Bihar	--	--	--	2	50	6	2	50	6
3.	Goa	--	--	--	15	1500	180	15	1500	180
4.	Gujarat	1	200	12.75	30	2550	300	31	2750	312.75
5.	Haryana	--	--	--	1	2200	115	1	2200	115
6.	Himachal Pradesh	--	--	--	1	180	15	1	180	15
7.	Karnataka	5	590	66.00	36	6575	695	41	7165	761
8.	Maharashtra	16	720	74.5	35	5420	563	51	6140	637.5
9.	Punjab	5	625	72.5	19	1645	181.5	24	2270	254
10.	Rajasthan	--	--	--	7	455	50.5	7	455	50.5
11.	Tamil Nadu	10	1305	154	42	30755	2934	52	32060	3088
12.	Tripura	--	--	--	1	32	3	1	32	3
13.	Uttrakhand	3	205	21	3	180	22	6	385	43
14.	Uttar Pradesh	--	--	--	8	960	109	8	960	109
15.	Madhya Pradesh	1	350	25.00	1	35	3	2	385	28
16.	Chhattisgarh	1	170	45.00	--	--	--	1	170	45
17.	Kerala	40	1110	113.50	--	--	--	40	1110	113.5
18.	West Bengal	1	340	60.00	--	--	--	1	340	60
Total		**98**	**7155**	**793.25**	**250**	**58132**	**5824**	**348**	**65287**	**6617.25**

Source: Ministry of New and Renewable Energy

Conclusion:

With the Indian population is projected to be 135,33,05,000 by the year 2020 and 162,00,51,000 by the year 2050, the per capita MSW generation expected to increase tremendously over the years due to urbanization. Source segregation, recover, recycle and reuse play the major part in reducing green house gas emission. A systematic solid waste management program has to be adopted with the consent of Indian government authorities and there is urgent need to set up the engineered landfill with gas recovery facility in India to sustain the growth of the nation. The bioenergy recovery from landfill has to be enhanced from local to national bodies by framing national policy that would help in mitigating the environmental concerns and reaching the energy demand in future of India.

References:

1. Chandramouli C., Rural Urban distribution of Population , Census of India, 2011.
2. Status report on Municipal Solid Waste Management ,Central Pollution Control Board India, 2012.
3. Global mitigation of Non-CO_2 GHG, A report from US Environmental Protection Agency, 2006b.
4. Tom K., Turning a Liability into an Asset: Landfill Methane Utilisation Potential in India., IEA, 2008,1-25.
5. A report from Inter Panel Climate Change (IPCC) Assessment, Climate change, 2007.
6. UN Habitat report, Solid waste management in the world cities, 2010.
7. Landfill Methane Outreach Program, United States Environmental Protection Agency.
8. Faisal Z. S., and Emran M. K., Landfill gas recovery and its utilization in India: Current status, potential prospects and policy implications., J. Chem. Pharm. Res., 2011, 3(5),174-183
9. Wiwattanadate D., European Linking Directive: Opportunity to Enhance CDM in Thailand PSU-UNS: ICEE., 2007.
10. Vikash T., Dahiya R. P., Anand S., and SreeKrishnan T. R., Quantification of methane emission from municipal solid waste disposal in Delhi., Elsevier., 2006.
11. A report by International Energy Agency, 2008.
12. Energy recovery from Municipal Solid Waste, Ministry of Urban Development, India.
13. Dinesh S., and Romeela M., Power generation from landfill gas., IPCBEE., 2011, 17, 237-241.
14. Sudhakar Y., and Jyoti K. P., Economic evaluation of a landfill system with gas recovery for municipal solid waste management: a case study., Int. J. Environment and Pollution., 2001,15(4), 433 - 447.
15. Chart C., kiatkrai A., and Pimolrat P., Feasibility of Landfill Gas Utilization for Power Generation: A Case Study in Thailand., Proceedings of the International Conference on Sustainable Solid Waste Management., 2007, 370 -376.

*****

Journals's Page

International Journal of ChemTech Research

(Oldest & Original)

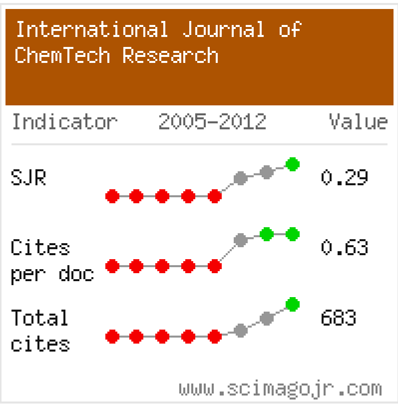
CODEN (USA): IJCRGG, ISSN: 0974-4290 [www.sphinxsai.com]

Journal's url= http://sphinxsai.com/frameijchemtech.html

Subject area:

This Journal publishes the Research/Review papers from all branches of Chemistry, Chemical Engineering and applied sub - disciplines like Synthetic Chemistry, Analytical Chemistry, Environmental Chemistry, Biochemistry, Polymer Chemistry, Chemical Engineering, Chemical Technology, Petroleum Chemistry, and Agricultural Chemistry, Biotechnology, Nanotechnology Pharmaceutical, Biological activities of Synthetic Drugs, *etc*.

http://www.scimagojr.com/journalrank.php?area=1500&category=1501&country=IN&year=2011&order=cd&min=0&min_type=cd



Link =

http://www.scimagojr.com/journalsearch.php?q=19700175055&tip=sid&clean=0

Journal's url= http://sphinxsai.com/framesphinxsaichemtech.htm

Please log on to - www.sphinxsai.com

*****