Chapter X

General Conclusion and Discussion

Waste includes all items that people no longer have any use for or which they either intend to get rid of or have already discarded. Additionally, wastes are such items which people are required to discard, probably because of their hazardous properties. Many items can be considered as waste e.g., household rubbish, sewage sludge, wastes from manufacturing activities, packaging items, garden waste, etc. which collectively is called as municipal solid waste (MSW). The management of MSW is a serious issue being faced by municipal authorities worked area as they are responsible for its disposal. The MSW is usually disposed off in landfills which emit landfill gases containing greenhouse gases like CH$_4$, CO$_2$ and N$_2$O besides other species like volatile organic compounds (VOCs). Because of increasing quantities of generated MSW due to increased urbanization, landfills have become important anthropogenic source of GHG emission which needs to be assessed for emission of GHGs as per the requirement of United Nation Framework Convention on Climate Change (UNFCCC). There are prescribed methodologies for assessing the GHG emissions from landfills but a number of factor influence the GHG emission in landfills for which very little information is available in developing countries like India. The present study is aimed to generate reliable estimation of GHG emissions from landfills and developed understanding about the processes which influence the GHG emissions which is the thesis under different chapters.

The study was conducted in Delhi (28° 35’ N 77° 12’ E), which is a landlocked city and has just river Yamuna as a major water body flowing through it. It has an area of 1484.5 km$^2$ and is 213 to 305 m above mean sea level. Delhi has three landfills which are older than 20 years, namely, Ghazipur (GL), Bhalswa (BL) and Okhla (OL) which receive every day almost 4500 to 5500 tons of MSW of the total 11000 tons of generated solid waste in the city. When MSW is disposed in landfill, the biodegradable fractions decompose via a complex series of microbial and abiotic reactions resulting in production of landfill gases (LFG) consisting of about 50-60% (v/v) CH$_4$ and 40-50% (v/v) CO$_2$ together with small quantities (<1%, v/v) of N$_2$O, non-methane hydrocarbon (NMHC) and other trace gases. The climate of Delhi is
mainly monsoon-influenced humid subtropical edging semi-arid, with huge variation between summer (average 35°C including day and night temperature variation) and winter (average 15°C including day and night temperature variation) temperatures and precipitation (797.3 mm in a year). Delhi's version of a humid subtropical climate is markedly different from many other humid subtropical cities.

“Landfill gas emission from municipal solid waste in Delhi showed wide variability”

In order to generate accurate CH$_4$ emission estimates with reduced uncertainties from landfills of Delhi, CH$_4$ flux measurements have been carried in all the three landfills of Delhi, during 2008-2011 period covering the winter, summer and monsoon seasons to develop landfill specific CH$_4$ EFs. The static box technique has been used which is a well established technique to collect the LFGs emissions from the landfills. Field sampling was carried out in different seasons, viz. winter, summer and monsoon seasons. It has been found that the CH$_4$ emission fluxes in one season were significantly different ($p<0.03$; 95%) with the other. The seasonal fluxes have been estimated as 1027±286, 1485±591 and 1132±351 mg m$^{-2}$ h$^{-1}$ from GL, BL and OL respectively in the winter season. In summer, it has been found to be 2856±975, 2331±771 and 1312±537 mg m$^{-2}$ h$^{-1}$ from GL, BL and OL respectively while for monsoon season, the CH$_4$ emission fluxes have been found to be 856±227, 755±221 and 660±169 mg m$^{-2}$ h$^{-1}$ from GL, BL and OL respectively. The average CH$_4$ emission fluxes have been estimated as 1494±893, 1576±746 and 961±322 mg m$^{-2}$ h$^{-1}$ from GL, BL and OL respectively. The CO$_2$ emission fluxes have been found to be 6595±1418, 7754±2309 and 4016±1314 mg m$^{-2}$ h$^{-1}$ from GL, BL and OL respectively in winter, whereas, in the summer it was found to be 10518±3223, 9956±4168 and 5824±2033 mg m$^{-2}$ h$^{-1}$ from GL, BL and OL respectively. In the monsoon season the emissions were found to be 4468±1309, 4912±2703 and 4152±1602 mg m$^{-2}$ h$^{-1}$ from GL, BL and OL respectively. The lowest CO$_2$ emission fluxes have been found during the monsoon season compared to other two seasons except for OL which shows slight higher emissions during monsoon season compared to winter season. The average CO$_2$ emission fluxes have been found for three landfills as 7520± 3401, 8005±3907 and 5066±1985 mg m$^{-2}$ h$^{-1}$ from GL, BL and OL respectively. The N$_2$O
emission fluxes have shown the maximum value for GL with $1210\pm329 \, \mu g \, m^{-2} \, h^{-1}$ followed by BL and OL where the $N_2O$ fluxes have been found to be with $998\pm298$ and $944\pm339 \, \mu g \, m^{-2} \, h^{-1}$. However no significant differences in the seasonal $N_2O$ emission fluxes have been found in each of the landfills.

The total annual the $CH_4$ emission has been found to be $10.2\pm2.9$, $6.8\pm3.3$ and $7.2\pm3.5 \, Gg$ in the year 2008-09, 2009-10 and 2010-11 respectively from the three landfills in Delhi. Whereas, the total $CO_2$ emissions have been estimated as $41.5\pm10.5$, $39\pm17$ and $38\pm14 \, Gg$ in the year 2008-09, 2009-10 and 2010-11 respectively. The total $N_2O$ emissions have been estimated as $5.8\pm0.7$, $6.0\pm0.5$ and $5.8\pm0.6 \, Mg$ in the year 2008-09, 2009-10 and 2010-11 respectively.

The $CH_4$ EFs have been found to be $5.6\pm3.5$, $4.4\pm1.9$ and $4.2\pm1.4 \, g \, kg^{-1}$ for GL, BL and OL respectively based on the estimated $CH_4$ emissions. The $CO_2$ EFs were found to be $20\pm7$, $23.3\pm9$ and $16.3\pm4.7 \, g \, kg^{-1}$ for GL, BL and OL respectively while the $N_2O$ EFs have been found to be $3.8\pm0.1$, $2.5\pm0.2$, and $3.1\pm0.3 \, mg \, kg^{-1}$ for GL, BL and OL respectively.

Although no direct correlation between the $CH_4$ flux from landfills and MSW temperature could be found, yet the impact of ambient temperature is evident by the occurrences of higher $CH_4$ fluxes during afternoon when ambient temperatures were higher compared to forenoon. The difference in average $CH_4$ flux values of $326\pm245$, $370\pm448$ and $208\pm187 \, mg \, m^{-2} \, h^{-1}$ respectively for GL, BL and OL have been observed in forenoon and afternoon. The hourly variations of $CH_4$ fluxes have also been measured from 8 AM to 4 PM in different seasons. It has been found that the $CH_4$ emissions are highest during the period of 1 PM to 3 PM in all the three landfills.

Moisture contents of the MSW showed slightly weak correlation with $CH_4$ emission in GL, BL and OL ($r = 0.5, 0.48$ and $0.47$ for GL, BL and OL respectively) in the winter season. In summer season, the strong coefficients of correlation ($r$) between $CH_4$ and $CO_2$ fluxes and moisture content of MSW have been found (i.e. $0.75, 0.7$ and $0.69$ for GL, BL and OL respectively) but no correlation was found in any of the three landfills during monsoon season.

The pH has been found below the neutral level in the landfills which may be indicative of fermentation stage. The average moisture contents were found in the three landfills in the range of 25 to 75% during the three years of the measurement.
The moisture content facilitates the degradation of the MSW and CH\textsubscript{4} generation in all the seasons. The moisture content have been found in dumped MSW as 30-42\%, 25-35\%, 50-75\% in winter, summer and monsoon respectively. The subsurface temperature had been found as 2-6°C higher than the ambient temperature. The OC/VC ratio has been found as 0.39±0.3 which is lower than the IPCC (2006) default value of 0.5. This has been also found that the most of the N exists in inorganic forms of nitrogen. A weak correlation has been found between N\textsubscript{2}O emissions with NH\textsubscript{4}\textsuperscript{+}, which could be indicative of nitrification process responsible for N\textsubscript{2}O emissions. This has been seen that landfills in Delhi possess as a significant contributor in anthropogenic GHG emission in India as well as in world. CH\textsubscript{4} and CO\textsubscript{2} emissions were much influenced by the seasons except in N\textsubscript{2}O emission, where highest emissions were found during April to July and lowest emissions were found during August to October. Perhaps, higher organic carbon content, moisture content and relatively poor landfill management practice pushed to higher emission to GL than BL and OL.

“The result of methane emission estimations by different methodologies despite being comparable were marked with variability”

The estimation of CH\textsubscript{4} emission have been generated using three methodologies (i) IPCC default method (DM, 1996), (ii) first order method (FOD) and (iii) modified triangular method (MTM) for three landfills. DM is based on mass balance approach, was recommended by the IPCC (1996) for estimating CH\textsubscript{4} emissions from landfills. A number of empirical constants like methane correction factor (MCF) and dissimilated organic fraction converted into LFG have been used as provided by IPCC (2006). FOD based on first order kinetics constrain with empirical constants like decay constant, degradable organic carbon, MCF, activity data like periodical MSW composition data etc. MTM is also based on first order decay which has mainly two phases; first phase is fast degradation phase with 3-6 years and slow degradation phase with 4 to 16 years.

The IPCC-DM (1996) resulted in the estimated CH\textsubscript{4} emission for GL, BL and OL as 23.0, 22.8 and 18.7 Gg respectively for the year 2013. The IPCC FOD method yielded the CH\textsubscript{4} emission values from GL, BL and OL as 14.2, 12.3 and 10.2 Gg
respectively in the year 2013. The MTM resulted in the \( \text{CH}_4 \) emission from GL, BL and OL as 21.0, 15.9 and 16.8 Gg y\(^{-1}\) respectively for the year 2013. Therefore, in total DM, FOD and MTM showed the \( \text{CH}_4 \) emission as 64.5, 36.7 and 53.7 Gg respectively from Delhi’s landfills in 2013. The average \( \text{CH}_4 \) EF opted for Delhi by deriving the EFs estimated from the commencement of three landfills in 2013 for three landfills have been estimated as 15±7, 19±11 and 31±5 g kg\(^{-1}\) from FOD, MTM and DM methods respectively for the year 2013.

It is clearly evident from the above estimation that the DM yielded the highest emission values followed by MTM and FOD methods. The model based estimations did not show the comparable \( \text{CH}_4 \) emission with the field estimations. This has been found that the \( \text{CH}_4 \) emission about 6.3, 3.6 and 5.6 times higher than field estimation. The default factors used in respective models are most of them are not fit to Indian climatic regimes, landfill types, landfill management practice and MSW characteristics. Therefore, \( \text{CH}_4 \) emission estimations for a particular year, these models give the over estimations, as because these models are incapable to cope the all landfill gas generation driving factors. It is, therefore, important to use \( \text{CH}_4 \) EFs developed through in-situ measurements which captures the site specific circumstances for reduction of uncertainties in \( \text{CH}_4 \) emission estimation.

“**Region/climatic specific decay constant (k) and oxidation potential of MSW are important factors in FOD model**”

There are large uncertainties in the \( \text{CH}_4 \) emission estimation by FOD method from the landfills in Indian condition due to the limited research have been carried out so far to derive decay rate constant (\( k \)) and oxidation factor/potential which are important factor in FOD model. The inventory compilers are encouraged to use country specific \( k \) values and oxidation potential in the model. National values are, however, not available. In view of it study has been tried to carry out to assess the most realistic \( k \) value and oxidation factor (OX) value representative of Indian MSW conditions. The \( \text{CO}_2 \) emissions in the LFG have been found to be higher by about as 20-23% from in the field measurements carried out in Delhi’s landfills from the earlier reported value, the oxidation potential in GL and BL have been found to be 20%, where 23% in OL. Using these OX values, and \( k \) values as 0.09, 0.07 and 0.07 for the GL, BL and OL
respectively CH$_4$ emission have been estimated as 8.2, 4.4 and 3.3 Gg for GL, BL and OL respectively which are close to the CH$_4$ emission values obtained through field measurements, indicating the representativeness of these OX and $k$ values for Indian landfill conditions.

The IPCC methodologies are mostly dependent on the potential emission from the MSW. Where, IPCC good practice guidelines recommended the use of high $k$ values ($k= 0.15$ to $0.7$) where higher temperature and moisture content exist because influence of these lead to fast degradation of organic matter of MSW. In respect to those, the derived values (i.e. $k=0.09$, $0.07$) are comparatively low in spite of the fact that these landfills are situated in tropical belt. However, these derived values are expected to reduce the uncertainties in the emission estimation by IPCC FOD model. These values could be acceptable because firstly, where good quality of MSW composition data is not available as stated in previous Chapter. Secondly, as per our field experiments this has been found that CO$_2$ emissions 20-23% greater than CH$_4$ emission, this has been indicating of aerobic degradation of MSW is more dominating then anaerobic. Thirdly, the generated LFG below the surface are not all comes out to atmosphere instantly, mainly due to vertical and lateral pressure, moreover top layer covering, if there any crack or fissure appears, gases come out suddenly, which is quite difficult to estimate. Due to low diffusion rate we found lower emissions in field measurement than IPCC-FOD method. This is very important aspect if the CH$_4$ emission is estimated by FOD method for a particular year by using of IPCC recommended $k$ values, that would be the over estimations for the particular year, as because of all generated CH$_4$ is not emitted, which was supported by the field measurement data. Therefore use of our obtained $k$ values in IPCC- FOD model for the CH$_4$ emission estimation which would be much comparable with the field measurement data.

“City/towns wise methane emission estimation following IPCC-FOD method reduces uncertainty in national methane emission scenario”

So far the national CH$_4$ emission estimation in India from the landfill sites has been made by using the *top down* approach taking into account the total urban population, average compostable fraction, and average carbon content of the MSW etc. However,
the uncertainty involved in this estimation has not been properly assessed. Quantification of MSW is the prime factor for the notational CH$_4$ emission inventory from MSW. But most of the cases national per capita generation rate has been used, though state wise per capita is given. The per capita waste generation increasing rate, compostable fraction in MSW according to class of cities, recyclable amount in the waste, MSW collection efficiencies, MSW treatment facilities etc. none of them consider in their inventory of national CH$_4$ emission estimation from MSW. Moreover while using IPCC-FOD, decay constant ($k$) is the most crucial parameter, they used arbitrary value (though it was in IPCC given range) without confirming the appropriateness of this value with field measurement. These all factors propagate the uncertainty in the estimation.

In the present study, an attempt has been made to estimate national CH$_4$ emissions for the year 2011 from the landfills of India using IPCC-FOD method in a bottom-up approach that include development of city/town wise CH$_4$ emission estimation incorporating available information on various input parameters like state wise per capita MSW generation rate, increasing rate in per capita MSW generation, MSW collection efficiencies, fraction of recyclable materials, waste composition, MSW treatment facilities etc. In addition, IPCC-FOD method has also been employed to estimate national CH$_4$ emissions from MSW in India for the year 2011 using top down approach. Monte Carlo analysis was conducted with different input parameters to the IPCC-FOD method to estimate the total input uncertainty in the CH$_4$ emission estimates developed using top down approach and also to assess the relative strength of different parameters in influencing the uncertainties in CH$_4$ emission estimation. Total estimated MSW generation in different Indian megacities followed the order: Kolkata (3255 Gg) > Mumbai (3103 Gg) > Delhi (2555 Gg) > Chennai (1714 Gg) > Bangalore (1278 Gg) > Hyderabad (1147 Gg) > Ahmadabad (840 Gg) during 2011. MSW generation in eleven Class-I cities was found to be in the range of >300 to < 840 Gg; in fifteen Class-I cities, MSW generation has been estimated to be in the range of >200 to <300 Gg; and in thirty four Class-I cities, it has been estimated in the range of >100 to <200 Gg during 2011. The total MSW generation for the year 2011 was estimated as 61031 Gg in India by summing up the values of all city-wise MSW generation. This estimation indicates that the average PCD MSW generation in seven
megacities of India was 0.49 kg during 2011. Average PCD MSW generation in class I and other cities of India was estimated as 0.42 and 0.44 kg for the year 2011 respectively.

City-wise CH$_4$ emission estimations from landfills of 7863 cities of India have been generated using the IPCC FOD method incorporating the city level values of input parameters in a bottom-up approach. The estimation shows that the CH$_4$ emission from the landfills of seven megacities followed the order: Mumbai (36.2 Gg) > Delhi (28.1 Gg) > Kolkata (24.7 Gg) > Chennai (17.0 Gg) > Bangalore (11.9 Gg) > Hyderabad (11.2 Gg) > Ahmadabad (10.2 Gg). Among the Class I cities, CH$_4$ emission of 24 cities have been found in the range of 2 to <8 Gg, 44 cities in the range of 1 to <2 Gg, 52 cities in the range of 0.5 to <1 Gg and about 355 cities in the range of 0.1 to <0.5 Gg during the year 2011. CH$_4$ emissions from the landfills of the rest of 7381 towns (i.e. Class II-VI cities and new towns) have been found in the range of 0.001 to <0.1 Gg during 2011. The summing up the city wise emission estimation yielded the total CH$_4$ emission from MSW in India as 572 Gg for the year 2011. The CH$_4$ emission has also been estimated using the top down approach based on total national values of input parameters which yielded the emission estimate as 531 Gg from MSW in India in the year 2011.

Monte Carlo analysis of all the input parameters to the IPCC-FOD method in the top down approach indicates that uncertainties in the parameters like $W_{pt}$, F, $k$, MCF, DOC and $M_f$ account to about 42%, 43%, 46%, 25%, 23% and 19%, respectively other parameters like $W_i$, $R_f$, $C_f$, and $DOC_f$ account to 4%, 2%, 5% and 5% respectively in the estimation of CH$_4$ emission from the Indian landfills using the IPCC-FOD. For the uncertainty estimation in the bottom up approach of CH$_4$ emission estimation from landfills, uncertainty associated with city specific values of parameters like $W_{pt}$, F, $k$, DOC and $C_f$ along with the uncertainties associated with other input parameters derived from simulation performed for top down approach have been used under error propagation method. The potential uncertainty in the national CH$_4$ emission estimations using bottom up approach has been found as 36% (~ 206 Gg of CH$_4$) whereas the top down approach revealed high uncertainty of 56% (~ 297 Gg). This suggests the importance of bottom-up approach in reducing the
uncertainties in the estimation of CH$_4$ emission from the landfills using the IPCC-FOD method compared to top down approach.

“Incubation studies help assessing GHG emissions potential and degradability of MSW”

To assess the degradability the MSW samples were subjected to incubation experiment has been carried out for 635 days. The 35°C temperature was found to be the optimum temperature for CH$_4$ generation as the CH$_4$ emission was significantly higher by 14 to 25% at 35°C compared to 15, 25 and 30°C. The CH$_4$ emission at moisture contents of 10, 20 and 30% was found to be significantly lower compared to that of 40 and 50%. However no differences in CH$_4$ emissions were found at 40% and 50% moisture contents.

During a first year of experiment, it has been noticed that the emission rate of GHG was faster than the second year. The degradations of different elements were found to be higher in first year compared to second year. During these experiments the initial elemental concentrations of OC, N, S, O and H have been found as 19.1, 1.39, 0.34, 23.0, and 4.8% respectively. The IC concentration has been found as < 1% in the total carbon concentration. After 635 days the elemental concentrations have been found as 9.7, 0.54, 0.11, 11.3 and 1.0% for OC, N, S, O, and H respectively. The correlation analysis of CH$_4$ and other elements showed negative correlation with CO$_2$, N$_2$O, OC, N, O, S and positive correlation with H. The elements like C, N, O, S and H were found to be very much correlated with each other except for N with H, CO$_2$ and H with N$_2$O. Based on the molar composition of MSW, the chemical formula of MSW has been found as C$_{12.5}$H$_{29.7}$O$_{9.8}$N and the whole reaction can be expressed as

C$_{12.5}$H$_{29.7}$O$_{9.8}$N + 0.4 H$_2$O $\rightarrow$ 7.6 CH$_4$ + 10.3 CO$_2$ + NH$_3$. This equation suggests that potential CH$_4$ and CO$_2$ would evolve as 2.23 and 3.03 g respectively. At the end of this study, the total generation of CH$_4$ and CO$_2$ have been found to attain maximum value and it has been found that ~1.6 g and ~1 g C are used for the CH$_4$ and CO$_2$ emission respectively. The total C loss has been found to be < 1 g C which was used for microbial respirations and the generation of volatile organic compound. The total CH$_4$, CO$_2$ and N$_2$O emission have been estimated as 54%, 43% and ~2% respectively.
Loss of substrate in the early days of experiment showed rapid decay (exponential loss) followed by a long period of time with minimum loss. The decay rate \( k \) has been calculated as 0.27 y\(^{-1} \) which is representative the fast degradability of the range of 0.17 to 0.7 of organic waste. Depending upon the \( k \), the half life \( (t_{1/2}) \) of the MSW has been calculated as 2.6 years. The half-life value of MSW depends upon a large number of factors associated with the composition of the waste and the conditions at the site.

This chapter gives a clear concept of degradation of MSW in regulated ambient temperate along with time by the anaerobic process. The degradation processes are divided in all the five phases. The decaying of each element is reflected in the mineralization process in certain condition with the GHG emissions scenario. The decay rate constant as well as half life of MSW was also derived by this experiment while no inoculum process has been done to accelerate the degradation process to get the result in earliest. This decay rate is in the range of fast degradable range but it is in lower end in IPCC recommended range, therefore this \( k \) value might be the appropriate decay constant representing the in Indian conditions like presence of high moisture content in MSW, rejuvenation of moisture from the top layer in landfill, types of waste (mainly households, vegetable market, kitchen waste from restaurant, etc.) and high temperature which can degrade MSW very rapidly, although further experiments are required for ascertaining the India specific values.

“Indian landfills need to be assessed for energy generation potentials and for appropriateness of different technologies”

The MSW to energy market in India was estimated to grow at a compound annual growth rate (CAGR) of 9.7% by 2013. Hence there is a need to assess the appropriateness of different technologies for their use in Indian MSW. In this study, the energy generation potential of MSW reaching to Delhi’s three landfills, under different technological options available for WTE generation has been assessed.

The MSW is the important source of \( \text{CH}_4 \) which could be harnessed as a potential energy source that would also contribute to the climate change mitigation efforts. Delhi has three landfills which have been estimated using LandGEM model to emit 14, 12 and 8 Gg \( \text{CH}_4 \) from GL, BL and OL respectively from the dumping of
segregated MSW, which could have been 33, 27, 23 Gg CH\textsubscript{4} from GL, BL and OL respectively for the deposition of bulk waste in these landfills. The calorific values have been found to be 0.058-0.078 kW kg\textsuperscript{-1} for segregated MSW and 0.092-0.126 kW kg\textsuperscript{-1} for the bulk waste (MSW) being deposited in Delhi’s landfills.

The MSW deposited in Delhi’s landfills have been subjected to composition analysis which revealed that its major constituent is readily decomposable material, followed by recyclable material and moderately decomposable material. It has also been found that almost 50% of the recyclables were being removed prior to the MSW reached to the landfills. To assess the energy generation potential from the MSW reaching to Delhi’s three landfills, two situations have been hypothesised; (i) bulk MSW waste is subjected to five available technologies namely biomethanation, incineration, gasification/pyrolysis, refused derived fuel (RDF) and plasma arc gasification and (ii) the segregated waste reaching to the landfill sites is subjected to above mentioned five technologies for waste to energy recovery.

The result shows that different technologies for harnessing the energy from the MSW have different potentials. It has also been found that the segregation process reduces the energy production potential by 40-60% compared to bulk MSW. The plasma arc gasification technology shows the highest potential for energy generation in the ranges of 17-35, 16-32 & 11-28 MW d\textsuperscript{-1} from GL, BL and OL respectively as compared to the other technologies like gasification/pyrolysis technology (17-32, 16-29 & 11-25 MW d\textsuperscript{-1} from GL, BL and OL respectively), incineration process (17-32, 16-29 & 11-25 MW d\textsuperscript{-1} from GL, BL and OL respectively), RDF process (9-19, 8-18 & 6-15 MW d\textsuperscript{-1} from GL, BL and OL respectively), biomethanation process (3-10, 3-8, 2-8 MW d\textsuperscript{-1} from GL, BL and OL respectively ). Thus, the plasma arc gasification seems to have highest energy generation potential, but a number of other factors like installation cost, handling of by-products, environmental regulations etc. are required to be considered for identifying the most viable technology for WTE.

The management of solid waste is a serious problem factual in an emerging economy like India because of two important reasons: (a) Unavailability of land for disposal of MSW due to rapid growing population; and (b) Disorganized way of MSW disposal which results into generation of greenhouse gases (mainly methane). Since energy is the key for any sustainable economic development, India is losing
prospective organic resource by way of improper MSW disposal. It is therefore necessary to harness the locked energy resource from the organic fraction of MSW. Adoption of environment-friendly waste-to-energy could solve the two major global critical problems; solid waste management and power crisis problems to some extent.