Waste to Energy through Co-fermentation of Organic Waste and Septage in Nashik: A Close the Loop Cycle Approach

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Abstract

With the current economic development and the steep growth of urban population in India, the quantity of solid waste, wastewater generation and per capita energy consumption is increasing. Improper solid waste management and inadequate sanitation imposes a major environmental and health threat in Indian cities. Hence there is a need for integrated and sustainable solutions. In this regard waste to energy is a very suitable option for processing black water with organic solid waste and thus recover sufficient energy to create a sustainable business model.

Within the framework of the "International Climate Initiative" of the Federal Ministry of Environment, Nature Conservation and Nuclear Safety of Germany, GIZ is supporting Nashik Municipal Corporation in implementation of a "Waste to Energy" project through production of biogas. In this paper, we give an overview of the innovative concept developed by HAMBURG WATER Cycle®, which involves co-fermentation of the organic degradable parts of municipal solid waste and black water from community toilets and co-generation of heat and power. The Public Private Partnership (PPP) approach is built on a comprehensive finance and operational model. The transparent project development in Nashik opens the possibilities to develop and replicate sustainable Waste to Energy technology with the potential of reducing investment costs for the public sector and to achieve sustainability in operation. Close the loop cycles are creating additional benefits if it comes to carbon footprint reduction and resource efficiency, which for India is of rising economic and environmental importance.

Keywords: *Waste to Energy, Co-generation, Co-fermentation, Public Private Partnership (PPP) and Carbon Footprint Reduction.*

1.0 Introduction:

Urbanization in India is increasing rapidly during the last decades and has put an immense pressure on cities in India, its overall infrastructure and environment. This transformation process is of great concern for the threats caused by global warming, as it results in huge emissions of greenhouse gases (GHGs), especially carbon dioxide (CO_2) and methane (CH_4). The greenhouse gas emissions from urban areas are mainly from transportation, electricity consumption in various sectors, industrial processes, land use change and improper handling of liquid and solid wastes generated in cities. With the current steep growth of the urban population in the country, the quantity of solid waste, wastewater generation and per capita energy consumption is increasing day by day. Therefore there is an urgent need for an integrated approach with respect to solid waste and wastewater management on the one hand and control of GHG emissions on the other hand.

Waste to Energy through anaerobic digestion processes is a well-established option for processing organic waste and wastewater worldwide. However conventional biogas plants are based on anaerobic digestion of either organic solid waste or wastewater. The usage of co-fermentation processes in urban waste management is rather innovative and as of now has not been tested in India. A number of projects have come up during the last years treating organic waste with the objective to generate biogas based on conventional digestion processes such as in Vijayawada, Koyambedu, Chennai and Lucknow. The operation and financial models of these plants have been carefully analyzed. All of the mentioned plants did not meet the expectations and many are closed in the meantime or have stopped operation. In particular the inadequate supply with raw waste caused technical failures in the digester due to the lack of essential nutrients, leading to inadequate production of biogas. Moreover badly designed operation procedures and contracts resulted in malfunction of the plants in a long run. Many of the Biomethanation plant's failures described are due to lack of proper input materials and knowledge of waste characteristics, improper waste segregation and unviable business models and not related to technology.

The objective of the "Waste to Energy" project in Nashik is the demonstration of a technically feasible pilot plant and the illustration of boundary conditions leading to a financially viable operation of the plant. HAMBURG WATER Cycle® provides an innovative concept which involves co-fermentation of the organic degradable parts of municipal solid waste and black water from community toilet complexes (CTCs) and incorporates co-generation of heat and electricity as well. Heat can be used for pasteurization and for increasing the temperature of the digester for an enhanced digestion process. Black water helps in increasing gas production in the digester, which results into higher power generation through providing essential micro nutrients required for enhanced bacterial growth in the digester. The output of gas in this innovative technology is expected to be higher as compared to conventional biomethanation processes used in the country. Close the loop approaches are creating additional benefits if it comes to carbon footprint reduction and resource efficiency with nutrient recovery. The project is in the implementation phase in Nashik through a Public Private Partnership (PPP) approach and built on a comprehensive financial and operational model for achieving sustainability in operation.

This paper is an attempt to provide detailed perspectives of the concept developed by HAMBURG WATER Cycle® and to showcase the results of a feasibility study conducted to assess the possibilities for innovative waste management in urban scenarios for emphasizing on material and energy recovery and closed the loop approaches.

2.0 Approach and Methodology:

Within the framework of the "International Climate Initiative" of the Federal Ministry of Environment, Nature Conservation and Nuclear Safety of Germany, GIZ is supporting Nashik Municipal Corporation in implementation of a "Waste to Energy" project. The project involves construction of a waste-to-energy plant which will consume food and vegetable waste from upto 1300 restaurants and hotels, as well as black water collected from about 200 community toilets in Nashik. In total it would consume between 10 to 15 tons of organic waste and 10 to 20 tons of black water each day. The plant will be installed at a site adjacent to the existing Municipal Solid Waste Management (MSW) plant in Nashik. One of the main characteristics of the process is the co-fermentation of black water and organic solid waste to produce energy using a high-rate bio-digester. The biogas generated will be utilized for the production of electricity in a combined heat and power plant. Uncontrolled methane emission from improperly treated waste streams can be therefore avoided as well as any energy intensive treatment as it would be the case in conventional disposal systems. Additionally the innovative concept will recover nutrients through agricultural use of residues as manure or use in the adjacent composting plant of NMC.

2.1 Site selection

The Waste to Energy project in Nashik is being implemented in cooperation with Nashik Municipal Corporation. The project area has been shortlisted among various other cities such as Delhi, Raipur and Nashik, as Nashik offered the best conditions for project implementation due to the availability of secured input material (organic waste from hotels and black water from toilet complexes) and their utilization as well as the existing infrastructure. NMC will also make provisions for utilization of the produced energy into the state power grid.

2.2 Steps for implementation:

2.2.1 Feasibility study

A feasibility study was conducted to assess the possibilities for combining liquid and solid organic waste flows in Nashik, their potential for material and energy recovery and ensuring that secured input of substrate is available. The study also focused on suitable operational and business models for sustainable operation of the plant.

2.2.2 Availability of input material flows:

The overall performance of the Biomethanation Plant is greatly influenced by the input feed specification and the plant requires segregated biodegradable MSW (e.g., hotel and restaurant waste, market waste) for optimal plant performance rather than un-segregated MSW. The homogeneity of the feed stock is an important parameter from the efficiency point of view. Therefore special care has been taken through detailed study and analysis for ensuring continuous supply of input material flows. Based on the feasibility study, a survey of commercial establishments and community toilets in the city and a study on balance of inputs and outputs from admixtures of organic waste and black water from community toilets were carried out.

2.2.2.1 Detailed survey for characterization and quantification of organic solid waste generated in commercial establishments (hotels and restaurants:

A detailed survey for characterization and quantification of solid waste generated in hotels in Nashik was conducted through a questionnaire. It was designed to assess detailed information on:

- quantity of organic and inorganic waste generated (by actual on site weighing of different fractions of waste),

- access and frequency of solid waste collection vehicles,
- facilities for segregation and storage of waste,
- current charges for services and
- willingness to pay for dedicated services for collection of solid waste from hotels etc.
- efforts were also made for mapping all hotels and restaurants in Nashik on a GIS platform with attributes such as quantity of organic waste generation in each establishment.

The study on characterization and quantification of solid waste generated in hotels in Nashik revels that there are around 1300 establishment present in the city from where organic waste for the project can be made available through a dedicated collection and transportation system.

	Administrative Division	**Commercial establishment**
1	CIDCO	225
2	Nashik East	274
3	Nashik West	219
4	Nashik Road	309
5	Panchavati	273
6	Satpur	84
	Total	**1384**

Table 1. Total No. of Commercial establishments in Nashik

CIDCO, Nashik East and Nashik West divisions are close to the site selected for the waste to energy plant and having maximum number of hotels with high potential of organic waste generation. The total amount of organic waste generated in these establishments in approx. 25 to 30 tons per day. Apart from these hotels large amount of raw organic waste from six vegetable markets in the city will be made available for the plant through dedicated vehicles for each market.

2.2.2.2 Study on wastewater streams from selected Community Toilet Complexes (CTC) in Nashik for black water

The flow patterns of selected septic tanks from CTCs were assessed bi-hourly for four consecutive days in order to simulate the hydraulic load of the septic tanks inflow. This was to ensure that sufficient quantity of black water is available throughout the year for sustainable operation of the plant.

Nashik Municipal Corporation owns around 400 community toilet complexes within the city and which ensures the source for black water as second input substrate.

Division	**Public Toilets seats**		
	Female	**Male**	**Total**

Nashik East	567	575	1144
Nashik west	275	262	537
Satpur	302	348	650
CIDCO	236	259	495
Nashik Road	577	531	1108
Panchvati	789	839	1634
Total	**2746**	**2814**	**5568**

Table 2. Total No. of Community Toilet seats in Nashik

Considering the size of the septic tanks of CTC's and usage pattern in Nashik availability of black water will not be an issue for the plant. An effective and highly mechanized system for collection and transportation of black water from CTC's to the plant is planned to ensure the reliable and regular flow of input materials.

2.2.2.3 Balance of input and output study at different admixtures

The detailed analysis of the physico-chemical and biological characterization for organic waste from hotels and black water from septic tanks of community and public toilets was carried out by Birla Institute of Technology, Pilani, Goa (BITS Pilani Goa) for assessing the methane generation potential. Following parameters were used for characterization: PH, Total Dissolved Solids (TDS), Total Suspended Solids, Volatile Suspended Solids (VSS), Total Ammonia Nitrogen (NH_3-N), Total Nitrogen (N) and Total Phosphorous (TP), BOD and COD. The anaerobic co-digestion of organic waste and black water was carried out for different samples as well as admixture from 1:1, 1.5:1, 2:1, 1:1.5 and 1:2. The various proportions of organic wastes, black water and admixture were examined for energy yielding characteristics through their Biomethanation Potential (BMP). Samples from six divisions from community toilet complexes and selected hotels were collected in four months interval to accommodate the seasonal variations. The methodology and results of the study are shown below:

Ratio	Organic Waste (TPD)	Black water (TPD)	Total input (TPD)	Sample 1		Sample 2	
				Biogas yield (m^3/day)	Specific gas yield (Methane – m^3/day)	Biogas yield (m^3/day)	Specific gas yield (Methane – m^3/day)
1:1	15	15	30	2272	1363	1372	823
1.5:1	18	12	30	2128	1277	1423	854
2:1	20	10	30	1555	933	1415	849
1:1.5	12	18	30	2269	1361	1326	795
1:2	10	20	30	2248	1348	1643	986

Table 3. Biomethanation Potential (BMP) for different admixture

Admixture of organic waste to black water at 1:1.5 ratios gives better biogas production in sample 1 whereas in sample 2 ratio 1:2 gives highest yield. The biogas yield of these samples is in a range of 1600 to 2300 cum/day. If more food waste is added to the samples the production of biogas decreases. Therefore it has been suggested to use the mixture of organic waste and black water in the proportion of 1:1.5 (12 TPD food waste and 18TPD black water). However it has been left to the operator to select the best suitable ratio based on requirements and studies conducted in the city.

Addition of wastewater from septic tanks of CTCs ensures regular supply of sulphur and other trace elements (Ni, Co, Mo, Fe, Zn, Cu, Mn etc.) for bacterial growth in the digester. In domestic wastewater, there is usually no lack of such substances as they originate from urine and faeces in sufficient concentrations. Digesters are prone to failure in absence of supply of these trace elements.

3.0 Project design

The analysis of the operation of existing plants in India and identification of the shortfalls following framework conditions were ensured through detailed surveys and feasibility study and consultation with stakeholders involved in the implementation process.

- Reliable source of input material flows with consistent quality
- Robust technical design,
- Sound operational and financial model for sustainable operation
- Capacity building strategy for operators of the plant

3.1 Brief description of the projected plant:

The plant is designed for an input of 10 to 20 TPD black water and 10 to 15 TPD organic wastes. The daily amount of digested slurry is about 30 tons. The ideal ratio for mixture as per the balance input and output study conducted by Birla Institute of Pilani, Goa is 12 TPD black water and 18 TPD organic wastes for maximum biogas production. The digest can be safely post-treated in the existing aerobic composting facility. The required addition of water to the composting process could then be made redundant. Alternatively, the direct application on nearby agricultural areas is feasible. The methane produced in the plant is converted to electricity in the combined heat and power plant. The daily production of biogas is expected to be 1600 m^3 to 2,100 m^3, which can generate about 3000 kWh electricity per day with the power for internal use already deducted. In return the plant operator will supply a "guaranteed energy" daily subject to a minimum of 1150 kWh electricity to NMC free of cost. This electricity will be fed to the MSEB grid which can be utilized by NMC to avail rebate on monthly electricity bills. Any additional power generated by operator will be source of additional revenue for the operator. Excess heat would also be used to pre-heat and conditioning of the incoming waste water, thus accelerating the digestion process of the waste mixture.

The key technical component of the projected plant is a stirred anaerobic reactor with following components.

- Receiving station for organic waste
- Pretreatment
- Pasteurization (optional)
- Gas storage with flare (in case of excess gas)
- CHP with gas pretreatment

- Heat distribution system
- Transfer of digestate

The plant should be designed in such a way that it should be robust and construction should be based on local conditions. With respect to keep the maintenance cost low the introduced technical design uses mainly machinery made in India. The process flow chart is shown below:

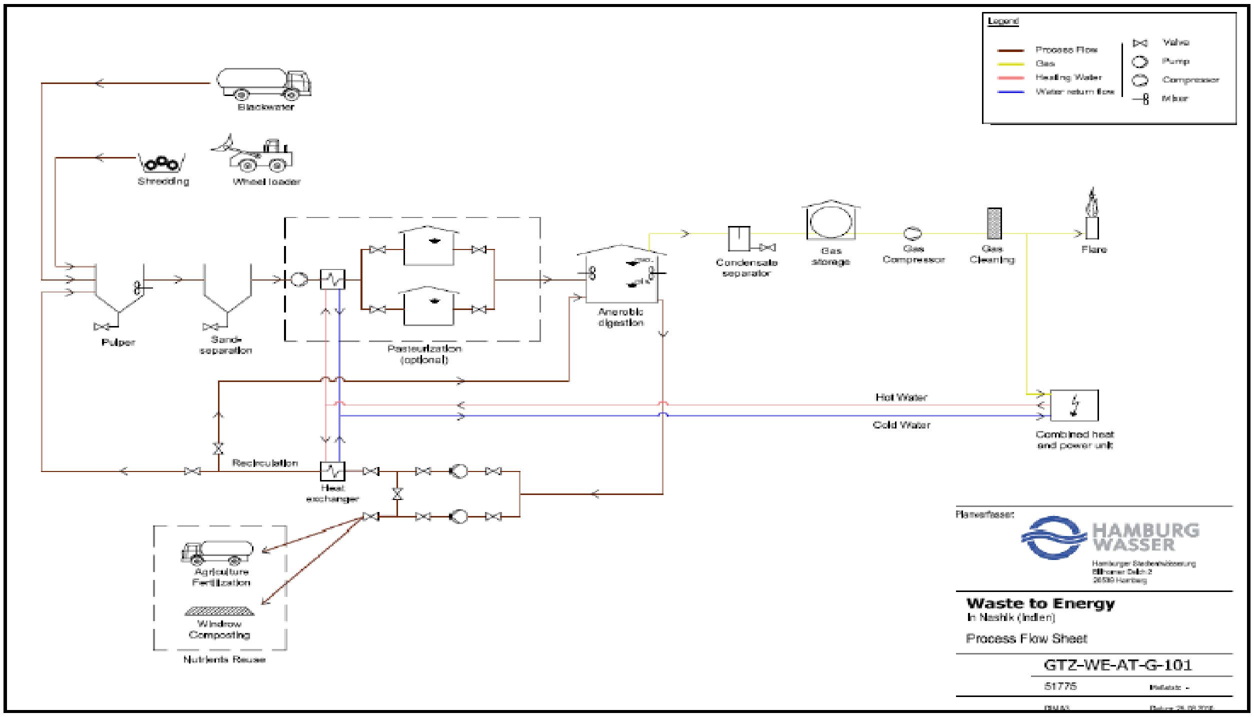

Figure1. Process flowchart for proposed waste to energy plant in Nashik

The feasibility study revealed that though there is a reliable quantity of input materials available in Nashik the access to these flows requires a well operated logistic system in order to ensure undisturbed supply to the plant. A very close coordination between collection-transportation, plant operation and disposal of the products is required. The system for collection and transportation of solid waste from hotels is already established and enforced through municipal bylaws in Nashik. It will be the responsibility of the operator to collect and transport the required quantity of waste flows to the project site from Nashik

3.4 Operation model

In addition to the availability of input material the reliable marketing for the final product is one of the main prerequisites for a long term financially viable operation of the plant. Till date plants are failing as a result of involvement of multiple stakeholders in operation and maintenance of the plant from collection to final disposal of products. Therefore it has been ensured through the tendering process that provision of services should be “one – stop – solutions”.

The project will be implemented through on Design, Finance, Built, Operate and Transfer (DFBOOT) mode through the involvement of a private player for ensuring additional investment required. Involvement of private players will also ensure sustainable operation and maintenance of the plant. The planning & implementation concept will be documented. The PPP approach opens possibilities to develop and replicate sustainable Waste to Energy plants through "fair" contract arrangements and proper contract management. The operation of the plant will be with the contractor for a period of 10 years and NMC will pay monthly tipping fees for collection and transportation of 30 TPD of waste flows from city to the site and the operation of the plant. In return the plant operator will guarantee the supply of daily minimum of 1150 KWh electricity to NMC free of cost through supply to the grid and in return NMC will get rebate on monthly electricity bills. Any additional power generated by operator will be source of additional revenue for the operator.

3.5 Capacity Building Strategy

A capacity building strategy is designed for NMC staff and the future operator in the fields of human resource development and organizational development. It includes onsite trainings, setting up of an onsite laboratory and lab protocols for various tests and analysis, financial management etc.

4.0 Way forward

It is expected that the project will not only reduce the GHG emissions of NMC but also contribute to the improvement of current practices in solid waste management and waste water management by demonstrating financially viable and technically feasible solutions in line with climate change goals of Government of India. Learning's from this project may help in up-scaling this or adjusted approaches within the framework conditions of Indian cities.

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