सत्यमेव जयते

UNDP India

GREEN ENERGY FROM WASTES

Biomethanation Projects for Urban and Industrial Wastes set up under UNDP/GEF assisted Project on Development of High Rate Biomethanation Processes as means of Reducing Greenhouse Gases Emission

MARCH 2006

MINISTRY OF NON - CONVENTIONAL ENERGY SOURCES
GOVERNMENT OF INDIA

CONTENTS

MESSAGE

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भारत सरकार
Minister of State (Independent Charge)
Ministry of Non-Conventional Energy Sources
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I am happy that the Ministry is bringing out this publication for disseminating the information about the work done as part of the Project on Development of High Rate Biomethanation Processes, implemented with partial financial assistance from United Nations Development Programme (UNDP) and Global Environment Facility (GEF).

I do hope that the details of projects based on state-of-the art systems for biomethanation of various waste substrates in urban areas and industries in our country will be helpful in propagation of this technology, which provides twin benefits of waste treatment and generation of decentralized energy.

(VILAS MUTTEMWAR)

MESSAGE

MAXINE OLSON
UN Resident Coordinator and
UNDP Resident Representative

The United Nations Development Programme (UNDP) has been supporting the Government of India in promoting sustainable environmental management. The thrust is on building national capacity for environmentally sustainable development, promoting best practices and supporting strategically selected interventions. Climate Change is one of the important focus areas of UNDP for supporting adoption of clean and environment friendly technologies.

I am pleased that the Ministry of Non - Conventional Energy Sources (MNES) is bringing out a booklet "Green Energy from Wastes" to disseminate experiences and learning emerging from the UNDP / Global Environment Facility supported Project "Development of High Rate Biomethanation Processes as means of Reducing Greenhouse Gases Emission".

The booklet provides details on the demonstration plants installed under the Project. These plants are successful examples of commercially viable and replicable state-of-art biomethanation technologies for treatment of different types of urban, industrial and agricultural wastes. This experience is currently being mainstreamed into the Waste-to-Energy programme of MNES and has influenced the formulation of policies by the Government of India in this sector.

Presently, a major portion of wastes generated in urban as well as industrial sectors in the country is disposed of untreated, resulting in air and water pollution as well as emission of greenhouse gases. As a first step, creating awareness for adoption of waste-to-energy technologies for treatment and processing of wastes before its disposal will go a long way in ensuring reduced dependence on fossil fuels and also in controlling the GHG emissions into the atmosphere. The publication of this booklet, in fact, is very timely.

I extend my best wishes to all those associated with the publication of this booklet and hope that it would benefit all concerned in this field.

MAXINE OLSON

FOREWORD

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V. Subramanian

सचिव
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The increasing industrialization, and urbanization, the changes in the pattern of human life, that accompany the process of economic growth, give rise to generation of larger quantities of wastes leading to increased threats to the environment. It is estimated that about 42 million tonnes of solid wastes and 6000 million cubic metres of liquid wastes are being generated (in India) every year by urban population, besides generation of huge quantities of liquid and solid wastes by the industries. A major portion of the wastes remains untreated whereas some of it is stabilized by using energy-intensive conventional methods. The disposal of untreated wastes into land and water bodies results in air and water pollution as well as emission of green house gases like methane and carbon dioxide. This problem can be significantly mitigated through adoption of eco-friendly waste-to-energy technologies for treatment and processing of wastes before their disposal. One such technology is known as anaerobic digestion or biomethanation technology, which is environmentally one of the most benign technologies as it leads to generation of energy from wastes besides rendering wastes suitable for application as a rich source of organic manure. This not only reduces the quantity of wastes, but also improves its quality to meet the required pollution control standards.

Ministry of Non-Conventional Energy Sources (MNES) undertook a Project entitled, “Development of High Rate Biomethanation Processes as means of reducing Greenhouse Gases Emission”. The Project was partly funded by UNDP / GEF. 16 demonstration sub-projects based on biomethanation of wastes generated by seven waste substrates, namely, leather / tannery industry, slaughterhouse, pulp & paper, vegetable markets, sewage and animal wastes, were taken up under this project. While 14 demonstration projects have been installed for different waste substrates, evaluation of two projects already installed in the country was taken up as a part of this project. The demonstration plants are based on various state-of-the-art technologies developed within the country and abroad. The demonstration projects have been completed with full involvement of various stakeholders, namely, Industry, Government Organizations, Research/Educational Institutions and State Nodal Agencies. Implementation of demonstration sub-projects has helped in indigenization and absorption of know-how in the area of biomethanation technology for various waste sectors, both in terms of hardware and development of human resource capabilities.

The project has greatly helped in creating awareness among decision makers in various sectors, technology providers, research and development organizations, industries, urban local bodies, etc., about the potential of biomethanation technology for the treatment of wastes alongwith energy recovery. This is evident from a number of biomethanation projects getting developed in hitherto unexplored waste sectors in the country.

The publication of details about the demonstration projects for biomethanation of various waste substrates is being brought out with a view to share information for giving necessary impetus to the development of a larger number of similar projects.

(V. Subramanian)

Introduction to Project on Development of High Rate Biomethanation Processes as means of Reducing Greenhouse Gases Emission

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Background

Methane (CH_4) and carbon dioxide (CO_2) are prominent greenhouse gases (GHG). Methane emissions are caused by energy related activities; agricultural activities and uncontrolled anaerobic degradation of organic materials such as organic constituents of municipal and industrial wastes. Although the volume of methane (CH_4) contribution to the world's greenhouse gas (GHG) emissions is one third of that of carbon dioxide, its global warming potential is 21 times that of carbon dioxide CO_2. Methane emissions from waste are reported to be about 31% of the total methane emissions in India. India generates large quantities of wastes from the agricultural, municipal, industrial and food processing sectors. Much of these wastes find their way into the environment with little or no treatment, which results in their biodegradation leading to release of methane into the atmosphere. In addition, untreated waste disposal creates serious health and sanitation problems. Waste treatment technologies such as aeration, are highly energy intensive, directly and indirectly contributing to GHG emissions.

This problem can be mitigated by adoption of eco-friendly technologies for treatment and processing of wastes before their disposal. One such technology is known as anaerobic digestion or biomethanation technology for production of biogas under controlled conditions. Biomethanation is known to be applicable for treating wastes from a number of sectors including municipal wastes, sewage and wastes from industries such as distilleries, pulp and paper, slaughterhouses, sugar, and food processing etc.

The Project

Ministry of Non-conventional Energy Sources (MNES) implemented a Project entitled, "**Development of High Rate Biomethanation Processes as means of Reducing Greenhouse Gases Emission"** with partial assistance from United Nations Development Programme (UNDP) and Global Environmental Facility (GEF). The main objective of the project was to enable India to make its contributions in protecting the global and local environment by developing aggressive plans for gainful utilization of the wastes generated in municipal, industrial and agricultural sectors for energy recovery. The key objectives of the Project were as follows:

i) To develop institutional framework at the national level to generate necessary awareness and capabilities to provide impetus to the Bio-energy Development Programme utilizing high rate biomethanation processes.

ii) To develop requisite expertise and capabilities in the national and state level institutes, R&D organizations and universities to assimilate and adapt technology, improve applied R&D skills in the field of high rate biomethanation processes, and to provide technical know-how and assistance in setting up plants using the biomethanation processes.

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iii) To promote the use of biomethanation technology and biogas utilization as cost effective means of energy generation through the establishment of demonstration sub-projects and national and local level seminars and workshops, promotional campaigns, training and demonstration, and,

iv) To develop a national master plan and a shelf of investment proposals to utilize this important renewable energy resource through commercialization of processes.

Financial Arrangements

The UNDP / GEF funds were mainly for acquisition of technologies, consultancy services, engagement of experts, organization of training programmes & study tours, workshops & seminars, awareness generation and part of the cost of demonstration sub-projects. MNES share was for meeting the part expenditure on hardware cost for demonstration sub-projects besides expenditure on personnel, training, etc.

Institutional Arrangement

The Project was implemented under the supervision / guidance of National Bio-energy Board (NBB) established in the Ministry under the Chairmanship of Secretary, MNES. NBB is an apex body, which provides policy guidelines for the development of a national strategy for bio-energy and oversees implementation of this Project. The NBB consists of representatives of related Government Ministries and Departments namely, the Planning Commission, Departments of Bio-Technology, Economic Affairs, Scientific and Industrial Research, Science and Technology, Ministries of Urban Affairs and Employment, Environment and Forests and UNDP. A Project Management Cell (PMC) was also created for assisting NBB in the implementation of this Project.

A few eminent National Laboratories and Institutions have also been associated with NBB for providing assistance in various technology related matters like design, analysis of critical aspects of construction, supervision, commissioning, trouble shooting, monitoring and evaluation of sub-projects at the demonstration stage. In the case of technology imports for demonstration sub-projects, these technology institutions also assisted the NBB in technology assessment, technology absorption and adaptation of designs to Indian conditions. The names of the Technology Institutions / Implementing Agencies involved are as follows:

- National Environmental Engineering Research Institute (NEERI), Nagpur, for Sewage
- Central Leather Research Institute (CLRI), Chennai, for Leather & Abattoir Industry Wastes and Vegetable Market Wastes
- Central Pulp & Paper Research Institute (CPPRI), Saharanpur, for Pulp & Paper Industry Effluent
- Indian Institute of Science (IISc), Bangalore, for Biogas Utilisation for Generation of Power
- Indian Institute of Technology, Roorkee, for Animal & Agro Residue Sector

In addition to the above laboratories and institutions, State Nodal Agencies, viz. Punjab Energy Development Agency, Chandigarh, and Tamil Nadu Energy Development Agency, Chennai, were also associated as Implementing Agencies for a few sub-projects. National and International Consultants and Consultancy Organisations were also involved for specific tasks / assignments under the Projects.

Achievements

Major achievements under this Project are as follows:

- Completion of 16 sub-projects (one of these is under installation) including two evaluation studies and setting up of 14 technology demonstration projects for biomethanation of a wide range of substrates such as waste from paper and pulp, leather, abattoir and agro-processing industries, vegetable markets and municipal sewage. These projects have been set up for different target groups (municipalities, small industry and large industry) and are based on state-of-the-art technologies developed indigenously as well as those obtained from abroad.
- A total of 46 Business Meets and Workshops were organized with stakeholders from the different waste generating sectors. Besides organizing nine national training programs, over 110 professionals were deputed for specially organized training programmes and study tours abroad for gaining first hand exposure to latest developments in the area of biomethanation.
- The project has facilitated interaction between project developers (municipalities, industry), technology institutions, national laboratories and state nodal energy agencies. A quarterly newsletter, “Bio-Energy News”, is brought out as part of this project.
- A National Master Plan (NMP) for Waste-to-Energy has been prepared.

Programmes for Energy Recovery from Urban and Industrial Wastes

ANIL DHUSSA*
Director, MNES

Background

The rapid industrialization and urbanization have not only increased the problems caused by ever increasing quantities of wastes, but have also led to creation of awareness about the need for appropriate solutions for overcoming this problem. In recent years, technologies have been developed that not only help in generating substantial quantity of decentralized energy but also in reducing the quantity of waste for its safe disposal. In developed countries, environmental concerns rather than energy recovery are the prime motivator for waste-to-energy facilities, which help in treating and disposing of wastes whereas the energy in the form of biogas, heat or power is seen as a bonus, which improves the viability of such projects. In India and several other developing countries, energy is seen as a major output as presently hardly any costs are imputed to the treatment of wastes. While combustion, incineration and biomethanation are the most common technologies, pyrolysis and gasification are also emerging as probable options.

Ministry of Non-Conventional Energy Sources has been implementing a programme for promotion of Energy Recovery from Urban and Industrial Wastes since 1995. Presently, Ministry is implementing two separate Accelerated Programmes for Energy Recovery from Urban Wastes and from Industrial & Commercial Wastes.

Achievements

Three projects for energy recovery from Municipal Solid Wastes with an aggregate capacity of 17.6 MW have been set up at Hyderabad, Vijayawada and Lucknow. Other urban waste projects include a 1 MW project based on cattle manure at Haebowal, Ludhiana; a 0.5 MW project for generation of power from biogas at sewage treatment plant at Surat; and, a 150 kW plant for vegetable market and slaughterhouse wastes at Vijayawada. Another 300 kW project based on vegetable market waste is under commissioning at Chennai. Besides, about 25 waste-to-energy projects with an aggregate capacity of about 30 MW from a variety of industrial wastes have also been set up.

Energy Recovery from Urban Wastes

According to a recent estimate in the year 2002, about 42 million tonnes of solid waste (1.15 lakh tonnes per day) and 6000 million cubic meters of liquid waste are generated every year by our urban population. This translates into a potential for generation of over 1700 MW of power from urban wastes in the country. The potential of Municipal Solid Waste (MSW) estimated for conversion to energy for next fifteen years is given below:

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Year	Projected MSW Generation (in TPD)	Corresponding Power Generation (in MW)
2007	148000	2550
2012	215000	3650
2017	304000	5200

Some recent developments regarding municipal solid waste management and energy recovery from urban wastes, are given below:

- Notification of Municipal Solid Wastes (management and handling) Rules of 2000 necessitates all Class I cities to provide proper treatment and disposal facilities for MSW;
- Twelfth Finance Commission has recommended that at least 50% of the grants provided to States for the ULBs should be utilized to support the cost of collection, segregation and transportation. Segregated wastes require relatively simpler and less expensive equipment and devices for conversion into energy;
- Initiatives being taken under National Urban Renewal Mission are expected to give a major boost to the efforts for improving waste management in 60 large cities; and,
- Hon'ble President of India has given a call for setting up waste-to-energy projects, like the one in Hyderabad, in all the cities of the country.
- Parliamentary Standing Committee on Energy, while appreciating the installation of 6 MW power plant based on MSW at Hyderabad, desired that similar projects should be taken up for all the major cities where huge quantity of solid waste is generated.

Programme Objectives

The main objectives of the Programme on Energy Recovery from Urban Wastes are as follows:

- To harness the available potential of MSW-to-energy;
- To promote the setting up of projects for recovery of energy from urban wastes; and,
- To create a conducive environment for the development and implementation of waste-to-energy projects.

Technology Options

The most widely used waste-to-energy technologies are based on biological or thermal processes. Biological process involves biomethanation of biodegradable fraction of waste for producing methane-rich biogas, which can be used as fuel for generating electricity. Thermal process involves combustion of organic waste as fuel with evolution of heat energy for generation of power. Advances in thermal conversion involve destructive heating of organic materials with a limited supply of oxygen (gasification)

or without any oxygen (pyrolysis) to produce a combustible gaseous product consisting of simple hydrocarbons and hydrogen.

Programme Contents

The Ministry has prepared an Accelerated Programme for promotion of projects for Energy Recovery from Urban Wastes. Following the success of the projects at Hyderabad and Vijayawada, the projects for power generation from MSW through a two-stage process involving production of RDF by processing of MSW and combustion of RDF for generation of power are being promoted in a fast track mode. The strategy includes development of projects through public private partnership for specific cities. Another feature of the new programme is to provide Project Development Assistance of a maximum of Rs. 10 lakh per project for the fast track projects. Project development will include assessment of quality and quantity of wastes, identification of project site, preparation of waste collection and transportation plan, finalisation of power purchase agreement, development of a bankable project with Feasibility Report and the Detailed Project Report; preparation of bid document for inviting bids; firming up of means of project finance; obtaining all statutory clearances for the project; and, providing assistance and supervision during execution and commissioning.

The scheme provides for attractive incentives in the form of capital subsidy through FIs / banks for making MSW based projects financially viable and remunerative. Capital subsidy upto Rs. 1.5 crore per MW for fast track projects based on combustion of RDF and upto Rs. 2 crore per MW for projects based on biomethanation, are being provided. With a view to promote the adoption of state-of-the-art technologies in the country, higher financial assistance upto Rs. 3 crore per MW is being offered for setting up of demonstration projects based on such technologies. The Scheme is being implemented by Municipal Corporations, other Urban Local Bodies, Govt. institutions and private developers having technical and managerial capabilities for implementing such projects.

Energy Recovery from Industrial and Commercial Wastes

Rapid industrialization has resulted in the generation of huge quantity of wastes, both solid and liquid, in industrial sectors such as sugar, pulp and paper, fruit and food processing, sago / starch, distilleries, dairies, tanneries, slaughterhouses, poultries, etc. It has been estimated that there is a potential for recovery of about 1000 MW of energy from industrial wastes. Despite requirements for pollution control measures, these wastes are generally dumped on land or discharged into water bodies, without adequate treatment, and thus become a large source of environmental pollution and health hazard. This problem can be mitigated through the adoption of effective waste management systems and waste-to-energy conversion technologies.

The estimated potential for recovery of energy / generation of power from solid and liquid wastes being generated in various industrial sectors is expected to increase to about 1300 MW by 2007, 1600 MW by 2012 and 2000 MW by the year 2017. The sector-wise potential for the recovery of energy from industrial wastes is given below:

Sectors	Potential for Recovery of Energy (in MW)			
	2001	2007	2012	2017
Sugar	290	363	453	567
Pulp and paper	46	58	72	90
Sago Starch	19	24	30	37
Maize / Starch	84	105	132	164
Distillery	402	503	628	785
Dairies	49	69	77	96
Tanneries	5	6	8	10
Slaughterhouse	75	94	117	146
Poultries	52	65	81	102
Total	**1022**	**1287**	**1598**	**1997**

Projects with an aggregate capacity of about 27 MW have been installed in the country so far in distilleries, pulp and paper mills, slaughterhouses, tanneries and starch industries.

Programme Objectives

The main objectives of the Programme on Energy Recovery from Industrial Wastes are given below:

i) To assess and upgrade various conversion technologies;

ii) To create a conducive environment for the development of the sector in the country; and

iii) To accelerate the installation of energy recovery projects for industrial wastes with a view to harness the available potential by 2017.

Programme Contents

A modified scheme has been evolved to provide capital subsidy ranging from Rs. 50 to 150 lakh/ MW, depending upon the technology adopted and the end use applications. Subsidy is to be released to the Financial Institutions / banks upon successful commissioning of the projects. The type of projects covered under this programme are as follows:

i) Biomethanation of industrial solid and liquid wastes / effluents.

ii) Power generation from biogas through boiler + steam turbine configuration or biogas engine / turbine configuration.

iii) Power generation from industrial solid wastes through boiler + steam turbine configuration.

Details of Demonstration Plants based on High Rate Biomethanation

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As part of the Project on Development of High Rate Biomethanation Processes as means of Reducing Greenhouse Gases Emission, a total of 14 full-scale demonstration plants based on state-of-the-art *Biomethanation Technologies* have been set up for treatment of wastes from urban and various industry sectors. The seven waste sectors covered under the Project, besides a sub-project on utilization of biogas for power generation, are as follows:

- Leather Industry Wastes
- Abattoir Industry Wastes
- Pulp & Paper Industry Effluent
- Food Processing Industry Effluent
- Vegetable Market Yard Wastes
- Sewage / Municipal Wastewater
- Animal Manure

The aim of setting up of these demonstration plants was to establish and demonstrate techno-economic viability of the biomethanation processes for recovery of energy and also to demonstrate the effective utilisation of methane for electricity generation and heat production instead of being a contributor to global warming. The installation of these sub-projects was also meant to facilitate the creation of awareness among different target groups. Another objective was the development of requisite expertise and capabilities at national and state levels in installation of such plants for replication and expansion of the bio-energy sector in the country. The other benefits from adoption of such treatment processes include improved quality of environment (air and water) both at the local and global levels, better health and sanitation, improved quality of life in urban and rural areas, and an alternative clean fuel source.

The booklet is a compilation of information containing a brief on the technology deployed, process layout, performance parameters, benefits, location of the demonstration sub-project, type of waste and predicted emission reduction of GHGs (tonnes CO_2 per annum) for each demonstration sub-project. A summary of information for these demonstration sub-projects is given in Table 1 whereas the addresses of the Technology Suppliers, Technology Institutions and Beneficiary Organisations are given in the Appendix.

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Table-1: Project Information Summary

Particulars	RRL Bhubaneswar	AKEL, Medak	HAIL, Aligarh	VISHTEC, Melvisharam	TIL, Dewas	Ugar Sugar, Belgaum	SMC, Surat
Location (State)	Orissa	Andhra Pradesh	Uttar Pradesh	Tamil Nadu	Madhya Pradesh	Karnataka	Gujarat
Beneficiary Organisation Business	Research	Slaughterhouse	Slaughterhous	Company formed by Local Tanners for Treatment of Wastes	Tannery	Sugar Industry	Municipal Authority
Waste Stream (Solid / Liquid)	Liquid (Municipal Wastewater)	Solid	Solid	Solid	Solid	Biogas Utilisation (available from spent wash)	Biogas Utilisation (available from digestion of sewage sludge)
Process / Technology	Anaerobic Fixed Film Technology	BIMA (Biogas Induced Mixing Arrangement)	CSTR (Continusously Stirred Tank Reactor)	CSTR (Continuously Stirred Tank Reactor) and Indigenous Dual Fuel Engine	Modified UASB (Upflow Anaerobic Sludge Blanket)	Indigenous Biogas Engine	Imported Biogas Engine
Technology Supplier	NEERI, Nagpur	M/s Enkem Engineers Pvt. Ltd., Chennai, Licensee of Entec, Austria	M/s RSB, Japan	CTC, France	M/s Mailhem Engineers Pvt. Ltd., Pune	M/s Greaves Ltd., Pune	M/s Chemtrols Ltd., Mumbai and M/s. Guascor, SA, Spain
Date of Project Commissioning	October, 1997	November, 2001	Under Installation	December, 1999	March, 20000	December, 2000	March, 2004
Size (Biogas m^3/day	25	1600 - 1800	4,500	200	125	11,000	4,500
Fuel Displaced	NA	Furnace Oil	Grid Power	Grid Power	Coal	Grid Power	Grid Power

Particulars	RRL Bhubaneswar	AKEL, Medak	HAIL, Aligarh	VISHTEC, Melvisharam	TIL, Dewas	Ugar Sugar, Belgaum	SMC, Surat
Biogas Use (electricity, heat etc.)	Flared/ Heat in Canteen	Steam	Electricity	Electricity	Heat in Canteen	Electricity	Electricity
Net Emissions Reductions tCO2e Per Annum	113	4800	-	5800	450	15700	1300
Potential CDM Value, Per Annum, @ $ 4/ CER	$452	$19200	-	$23200	$1800	$62800	$5200
Baseline Treatment Regime	Project based and actual emission avoided	Project based and actual emission avoided	-	Project based and actual emission avoided	Project based and actual emission avoided	Project based and actual emission avoided	Prior to the project the methane was being flared hence only grid based baseline adopted

Source : Values for Emission Reductions taken from the Report on “Three Countries viz. Jordan, China and India Studies” by M/s. Eco Securities, U.K. and M/s. Price Waterhouse Coopers, Mumbai.

Table-1: Project Information Summary

Particulars	VSIL Salem	TNPL, Karur	Satia Paper, Muktsar	CMDA, Chemai	VMC, Vijayawada	BARC, Mumbai	Haebowal Ludhiana
Location (State)	Tamil Nadu	Tamil Nadu	Punjab	Tamil Nadu	Andhra Pradesh	Maharashtra	Punjab
Beneficiary Organisation Business	Starch Industry	Pulp & Paper Industry	Pulp & Paper Industry	Municipal Authority	Municipal Authority	Research Institution	Owned by PEDA
Waste Stream (Solid / Liquid)	Liquid	Liquid	Liquid (Black Liquor	Solid	Solid and Liquid	Kitchen Wastes/ Vegetable Waste	Animal Manure
Process / Technology	HUSMAR (Hybrid Upflow Sludge Media Anaerobic Reactor with dual fuel engine	UASB (Upflow Anaerobic Sludge Blanket	UASB (Upflow Anaerobic Sludge Blanket)	BIMA (Biogas Induced Mixing Arrangement) with imported biogas engine	Modified UASB (Upflow Anaerobic Sludge Blanket) with imported biogas engine	Bi-phasic	BIMA (Biogas Induced Mixing Arrangement with imported biogas engine
Technology Supplier	New Jersey Institute of Technology (NJIT), USA	M/s. GENL, Pune Licensee of Paques, The Netherlands	M/s Western Paques, Pune Licensee of Paques, The Netherlands	M/s. Enkem Engineers Pvt. Ltd., Chennai Licensee of Entec, Austria, and Gas engine from M/s. Deutz Asia Pacific (Pvt.) Ltd., Singapore	M/s. Mailhem Engineers Pvt. Ltd., Pune and Gas engine from M/s. Cogen India, Pune Licensee M/s. Jenbacher, Austria	BARC, Mumbai	M/s. Enkem Engineers Pvt. Ltd., Chennai Licensee of Entec, Austria and Gas engine from M/s. Cogen India, Pune Licensee of M/s Jenbacher, Austria
Date of Project Commissioning	Sept., 2002	Mar., 2003	May, 1997	June, 2005	June., 2004	Oct., 2005	Dec., 2004

Particulars	VSIL Salem	TNPL, Karur	Satia Paper, Muktsar	CMDA, Chemai	VMC, Vijayawada	BARC, Mumbai	Haebowal Ludhiana
Size (Biogas m^3/day	5,000	15,000	10,000	2,500	1400	500	10,000
Fuel Displaced	Furnace Oil	Furnace Oil	Rice Husk	Grid Power	Grid Power	Electricity/ Liquefied Petroleum Gas	Grid Power
Biogas Use (electricity, heat etc.)	Electricity	Heat in Lime Kiln	Boiler Fuel	Electricity	Electricity	Electricity / Heat	Electricity
Net Emissions Reductions TCO2e Per Annum,	58000	51000	...	5800	...	...	...
Potential CDM Value, Per Annum, @ $ 4 / CER	$2,32,000	$2,04,000	...	$23,200	...	...	...
Baseline Treatment Regime	Project based and actual emission avoided	Project based and actual emission avoided	...	Project based and actual emission avoided	...	...	Prior to the project the methane was released to atomsphere hence only grid based baseline adopted.

Source : Values for Emission Reductions taken from the Report on “Three Countries viz. Jordan, China and India Studies” by M/s. Eco Securities, U.K. and M/s. Price Waterhouse Coopers, Mumbai.

LEATHER INDUSTRY WASTES

BIOMETHANATION PLANT BASED ON TANNERY FLESHING AND CETP SLUDGE AT MELVISHARAM, TAMIL NADU

- **Place of Installation** : *Melvisharam, Tamil Nadu*
- **Date of Commissioning** : *January 2000*
- **Status of Functioning** : *Visharam Tanners Enviro Control Systems Pvt Ltd (VISHTEC) is operating and maintaining the plant*
- **Implementing Agency** : *Central Leather Research Institute, Chennai, India*
- **Technology Supplier** : *M/s Centre Technique Cuir Chaussure Maroquinerie (CTC), France*
- **Technology Institution for Supervision** : *Central Leather Research Institute, Chennai, India*

BACKGROUND

In India, there are about 3000 tanneries processing around 600 million kg of raw skin and hide per annum generating around 50 MLD of liquid waste and 305 million kg of solid waste. The pollution load in wastewater from tanneries is of the order of 30 – 120 kg of BOD_5 and 75 – 320 kg of COD per tonne of raw hide or skin processed. The environmental problems in the tanning industry have become more challenging after the Supreme Court verdict leading to the closure of polluting tanneries during 1995.

Although the liquid waste could be managed satisfactorily through the Common Effluent Treatment Plants / Effluent Treatment Plants (CETPs/ETPs), the solid waste from tanneries causes a major environmental problem through contamination of the soil, and groundwater apart from emission of huge quantities of green house gases to the atmosphere. Fleshing and sludge are the two major solid wastes emanating from tanning and treatment of tannery wastewater. It is reported that about 140-200 kg of fleshing, which are putrescible by nature, are generated for every tonne of leather processed. It contains about 80-90% moisture, 6-12% dry volatile matter and 4-8% ash and minerals. Large-scale leather processing activity in the country employing mechanical removal of fleshing has led to the generation of large quantity of fleshing which poses serious disposal problem. Similarly large quantity of sludge is produced when wastewater from tanneries is treated. In Tamil Nadu alone, the ETPs generate about 100 tonnes of sludge per day (dry basis). As the sludge contains chromium, it is classified as hazardous material. In view of non-availability of secured landfill sites, solid waste and sludge are dumped in low-lying areas in an inappropriate and uncontrolled manner or are just piled up within the tannery / CETP premises. Therefore the disposal of solid wastes including chrome-containing wastes poses serious problem due to stringent environmental regulations.

These solid wastes were managed through open dumping, land filling, thermal incineration, etc, triggering to secondary and tertiary environmental impacts. In view of this, demonstration project on high rate biomethanation technology have been installed for recovery of bioenergy from the biodegradable solid wastes of tanneries. This has not only helped in solving a major environmental problem of the tannery industry but also at the same time, led to production of green energy in the form of methane gas and improvement in viability of the treatment process.

Central Leather Research Institute (CLRI), Chennai, an apex R&D Institution for leather sector, have been associated as Technology Institution for implementation of the demonstration projects. United Nations Industrial Development Organisation, Regional Programme Office, Chennai and Leather Technology Mission of Govt. of India, also participated in terms of identifying the appropriate technology and in sharing of cost of the project. The technology has been sourced from Centre Technique Cuir Chaussure Maroquinerie (CTC) of France where the process for biomethanation of fleshing has been successfully developed and demonstrated.

In order to identify a suitable site for implementation of the demonstration project, three major tannery clusters in Tamilnadu namely Ranipet, Melvisharam and Vaniyambadi were short listed and a detailed analysis to assess quantity and characteristics of the Wastes-Fleshing and Primary Sludge was done by CLRI. Based on the quantity and characteristics of the wastes produced, location of cluster of tanneries and performance of the existing CETP facility, Melvisharam cluster was selected as a suitable site for setting up a 5 tonnes per day capacity demonstration plant adjacent to CETP which is managed by Visharam Tanners Enviro Control Systems Pvt. Ltd. (VISHTEC), a co-operative company formed by the Tanners of Melvisharam.

DESCRIPTION OF THE PLANT

The plant has been designed to handle about three tonnes of tannery fleshing and two tonnes of primary sludge from the CETP. General View of the plant and a process flow diagram are given in Figure-1 and Figure-2 respectively. The fleshing from the tanneries is stored

on a concrete platform for aeration for about 24 hrs. to oxidise the residual sulphide. The fleshing is then passed through a grinder to reduce the particle size to about 6 – 10 mm, which is mixed with thickened primary sludge in a feed preparation tank fitted with an agitator to completely mix the waste slurry and prevent any deposition in the tank.

The slurry is then fed to the digester for degradation of the organics. There are two completely mixed digesters designed for degradation of about 60-80% of the volatile solids with biogas yield of 0.9 m^3 for every kg of volatile solids destroyed after stabilization of the biological process. Both the digesters are operated in series in order to obtain an acid phase in digester 1 and the methane production phase of the biomethanation process in digester 2.

The digester is provided with a suitable arrangement to prevent any scum formation. At the upper part of the digester, the floating crust, if any, is sucked into a funnel connected with the high flow-mixing pump and sent back at the bottom of the digester, through a distributor.

The biogas, which has H_2S concentration in the range of 0.6 to 1 per cent, is stored in a gasholder. The biogas is then passed through a hydrogen sulphide scrubbing unit (process developed by IISc, Bangalore) to reduce the hydrogen sulphide levels to less than 0.01 per cent level to prevent corrosion of engine and also to minimize air pollution due to sulphur oxides. The biogas is then used for generation of electricity in a dual fuel engine.

The digested slurry / residue from the digesters is stored in a tank and then transferred to sludge drying beds for dewatering and drying. The stabilised dried cake is used as organic manure.

The trial run and commissioning of the anaerobic digesters and other units of the plant were completed by Feb. 2000. For start up, the cow dung containing total solids of 13 – 15% and volatile solids of 70-80% was fed into the digester to start the digestion process. After feeding about 12 tonnes of the seed material, the fleshing and primary sludge were fed into the digester. The performance of the plant has been closely monitored and evaluated by CLRI.

The maximum gas production during the entire study period was observed as 77 m^3/day for an average feed rate of 2.8 tonnes /day. The material fed during the study period comprised of around 8 –10% TS and 55-65% VS as against the designed TS and VS levels of 14% and 82%, respectively. The average VS destruction was 50% against the designed VS destruction of 60%. The average specific gas production was 0.7 m^3/kg of VS destruction for the entire study period against the designed specific gas production of 0.9 m^3/kg of VS destruction. The diesel consumption in the dual fuel engine when operated on full diesel is 0.3 litre/kWh of diesel. However, the electricity generation was 49 kW per hour with hourly gas consumption of 14 m^3 and diesel consumption of 4.5 l. The electrical energy generated is being utilised for operating the biomethanation plant and an aerator in the CETP.

TECHNOLOGY INVOLVED

The global experience on recovery of energy from fleshing from tanneries was limited to CTC, France based on the information available with UNIDO, Chennai, one of the stakeholders of this project. CTC, France was therefore identified as the technology provider and the biomethanation plant was implemented based on the detailed project report including detailed engineering drawings prepared by CTC, France.

Fig. -1 Two Digesters and the Gas Holder

WASTE ARRANGEMENT AND BIOGAS UTILIZATION

The fleshing is supplied by the tanneries located at Melvisharam. The primary sludge is provided by VISHTEC, the company managing the common effluent treatment plant of the tanneries located at Melvisharam.

Biogas generated from the biomethanation plant is utilized for generating electricity with a dual fuel engine of 63 KVA capacity. The electricity generated is utilized for operating the biomethanation plant and also the aerator in the aeration tank of the common effluent treatment plant.

MATERIAL BALANCE

Material balance calculation of the plant for a feed of 3 tonnes/day of fleshing and 2 m^3/day of primary sludge is as under:

• Capacity of the plant (Effluent treatment plant sludge 2 m^3/d + Fleshing 3 TPD)	:	5 t/d
• Volume of digester	:	65 m^3 each
• No. of digesters	:	Two
• Retention time	:	24 days
• Volatile solids feed rate	:	578 kg VS/d
• Volatile solids loading rate	:	4.27 kg VS/m^3/d

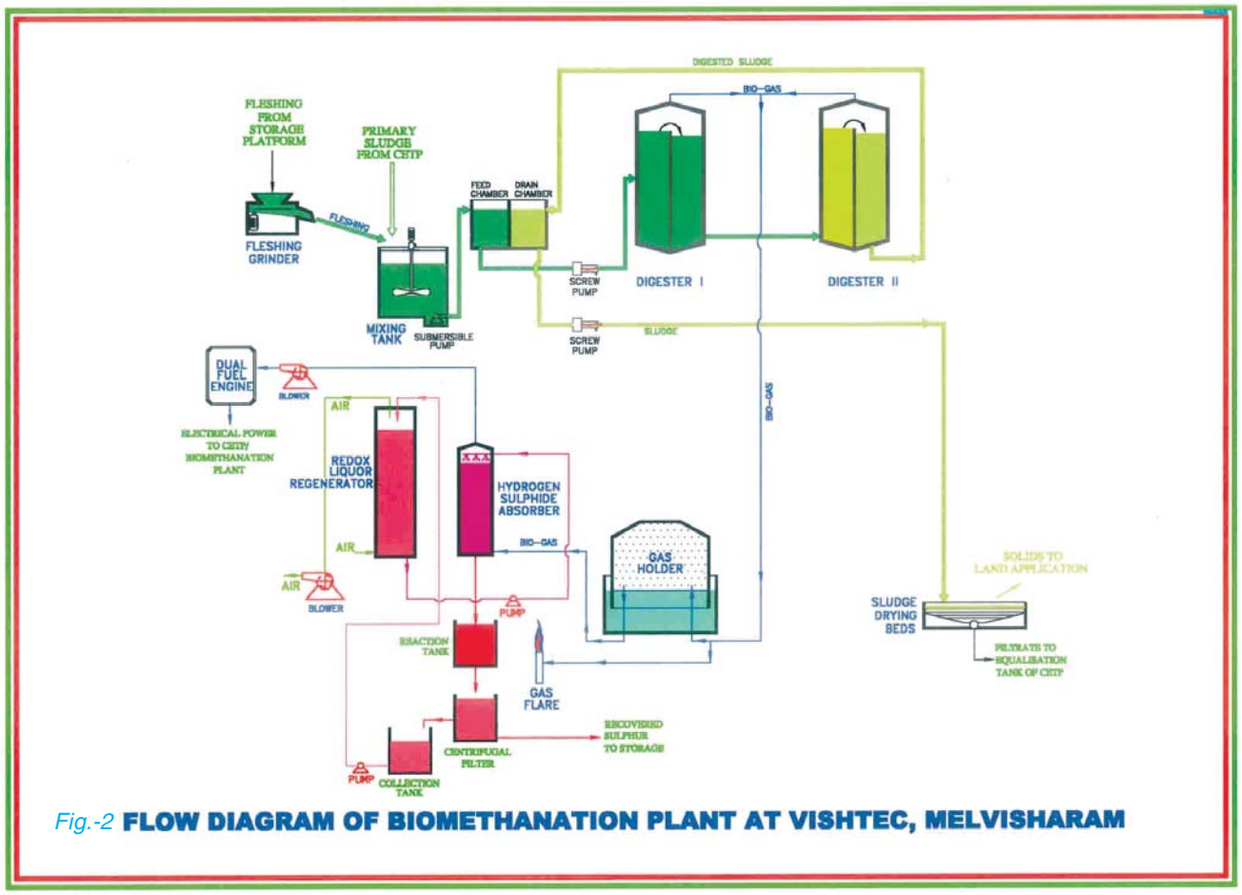


Fig.-2 **FLOW DIAGRAM OF BIOMETHANATION PLANT AT VISHTEC, MELVISHARAM**

- VS destruction : 60%
- Specific gas production : 0.9 m^3/kg VS destroyed
- Expected biogas production : 312 m^3/d
- Expected methane gas production : 228 m^3/d

ENERGY BALANCE

Energy balance calculation of the plant is as under :

- Expected electrical energy generation from biogas : 700 kWh
- Energy required for biomethanation plant : 250 kWh

MANPOWER REQUIREMENT FOR PLANT

- Engineers [Electrical / Mechanical] : 1
- Chemist : 2
- Operators : 6
- Supporting Staff : 1

COST ECONOMICS

The total cost of the project is Rs.1.58 crores. The total cost of the project was shared among NBB, UNIDO, LTM/CLRI and VISHTEC as given below.

- MNES : Rs. 67.47 lakhs
- UNDP/GEF : Rs. 27.30 lakhs
- UNIDO : Rs. 27.64 lakhs
- LTM/CLRI : Rs. 27.64 lakhs
- VISHTEC (Beneficiary) : Rs. 7.90 lakhs

The electricity generated is utilized for the operation of aerator in the common effluent treatment plant, hence, the operating cost of common effluent treatment plant is reduced through the savings of electrical energy consumption from the state electricity board.

BENEFITS ACHIEVED

- **Employment Generation :** Waste to energy conversion plant is providing employment to about 20 persons for the collection of waste and operation and maintenance of the plant.

- **Fuel Savings/ Revenue Earned :** The plant provides a saving of Rs.2.0 lakhs/annum on their electrical bill for their CETP by utilizing the electrical power generated in the biomethanation plant for operating the aerator in the CETP.

- **Waste Management / Cleanliness :** The project has demonstrated an eco-friendly process for the management of fleshing from tannery and primary sludge from tannery wastewater treatment plant and has improved the environment in the entire cluster of tanneries at Melvisharam. The plant has reduced the green house gas emissions and odour nuisance significantly.

OPERATIONAL DIFFICULTIES AND TROUBLE SHOOTING

Frequent downtime of fleshing grinder and breakage of cutter wheels in view of presence of metallic objects in the fleshing was observed. Proper fleshing collection procedure recommended to avoid the downtime of fleshing grinder.

BIOMETHANATION PLANT BASED ON LEATHER INDUSTRY SOLID WASTES AT DEWAS, MADHYA PRADESH

- **Place of Installation** : *Dewas, Madhya Pradesh*
- **Date of Commissioning** : *August 2002*
- **Status of Functioning** : M/s. *Tata International Ltd. (TIL) is operating and maintaining the plant*
- **Implementing Agency** : *Central Leather Research Institute, Chennai*
- **Technology for Chrome Separation** : *M/s. Tata International Ltd. (TIL), Dewas*
- **Technology Institution for Supervision** : *Central Leather Research Institute, Chennai*

BACKGROUND

In leather processing, one of the major waste generation area is the preparation of wet blue for drum processing, which yields hazardous solid wastes like shavings, trimmings & splits, etc. About 60 - 65% of total solid wastes generated in a leather finishing unit is from process for preparation of wet blue. Extrapolating for total finished leather production in India of 4200 million sq.ft./year, the generation of blue waste works out to be 120,000 tonnes per annum. Till now small quantities of such wastes are being used in leather board making and as a low-grade fuel in brick kilns, the rest goes for land filling causing soil pollution.

The R&D wing of M/s Tata International Limited developed a process, where these waste resources can be used in-house. Collagen and Chrome can be gainfully utilized after separation. The Collagen when separated as gelatin cannot be stored for a long time because of its putrefaction property. Hence biomethanation of gelatin was considered to be a good option to generate gaseous fuel. The chrome can be used for resource recycling after converting to Basic Chromium Sulphate.

CLRI was involved as the implementing agency to coordinate the execution of the project and to provide technical advice and assistance.

Chromed Leather Solid Waste

DESCRIPTION OF THE PLANT

The process flow sheet of the plant to treat the leather industry solid waste through biomethanation process is shown in Figure.1. The process has been divided in three distinct stages as follows.

Pretreatment Stage

Chromed tanned leather wastes in the form of shavings are brought in hand trolleys to the loading platform and the same is lifted by an electric hoist. The loading is done in 1 to 1.3 tonnes per batch. The waste is lifted and emptied into the gelatin vessel through the opening on the top. Hot untreated effluent water stored in the hot water tank is added to the vessel. Required amount of Alkali is also added to the vessel.

Steam is used for heating the treated effluent water in the vessel up to 85 - 90°C. The vessel contents are agitated by an anchor type agitator to keep the waste in suspension and for proper heat transfer. This operation takes about 8 hours.

The contents of the tank are pumped into a centrifuge for removal of solids. The filtered gelatin solution passes through a heat exchanger where the gelatin is cooled down to 35°C by untreated effluent water. The temperature of the untreated effluent water is thus raised up to 65°C and the same is stored in hot untreated effluent water tank for using in next batch of gelatin production.

Biomethanation

The gelatin separated from chromium hydroxide in the pretreatment stage is collected in an equalization tank. A small amount of alkali is dozed to adjust pH.

The gelatin is pumped into the primary digester at a constant rate. The primary digester is a modified Upflow Anaerobic Sludge Blanket (UASB) design for handling slurries in biomethanation plants. The solids are trapped in central portion whereas the hydrolysed portion passes through annular portion, which works as UASB digester.

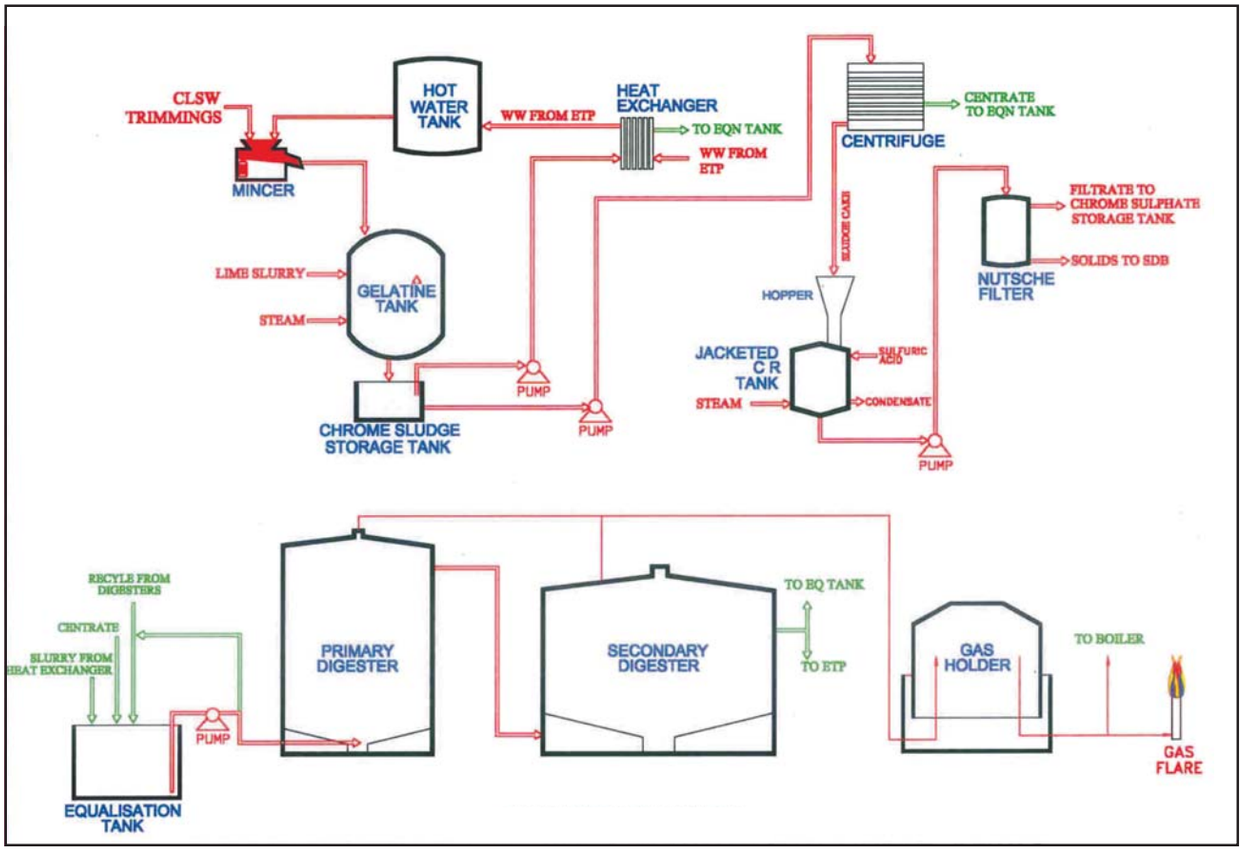


Fig.-2, Flow Diagram of Biomethanation Plant at M/s. Tata International Limited, Dewas.

The second stage (secondary) digester is a conventional UASB design where too methanogenesis takes place. The overall COD reduction obtained in the biomethanation process is 85%.

The biogas from both primary and secondary stages is collected in the gas holder (flexible rubber balloon). The gas is washed, scrubbed and compressed in a twin lobe type of compressor and sent either to a flare or to the canteen for use as a fuel.

Post Treatment Stage

The cake from the centrifuge is emptied into the hopper and is taken to the chrome recovery tank for sulphuric acid treatment. The recovered chrome in chrome sulphate form is filtered through a small filter and the filtrate is neutralised for pH adjustment to 4.0 to 4.5 and filtered again. The pH adjusted and filtered chrome solution is ready for use as a chrome tanning agent in leather processing. The residue is disposed in the sludge drying bed.

Gas and Digested Slurry Utilisation

The gas produced is utilized in the boiler/canteen or is flared. The overflow from UASB is sent to ETP for treatment. The sludge is dried in drying beds. The filtrate from the sludge drying beds is mixed in the equalization tank of existing ETP.

General Vew of the Plant

TECHNOLOGY INVOLVED

The technology developed in the in-house R&D wing of TIL has been scaled-up for this project.

WASTE ARRANGEMENT AND BIOGAS UTILIZATION

Chrome leather shaving wastes generated in the TIL leather finishing unit is being used in the project with a view to manage chrome bearing wastes in an eco-friendly manner.

Biogas is used at present in the canteen for cooking food for the employees of TIL.

MATERIAL BALANCE

Material balance calculation of the plant for a feed of 2 tonnes/day of chrome leather shaving wastes is as under:

- Capacity of the plant : 2 t/d
- Volume of digester
  - Primary : 50 cum
  - Secondary : 170 cum
- Feed rate : 23 m^3/d
- COD loading : 690 kg/d
- COD removal efficiency : 80%
- COD destruction : 552 kg/d
- Specific gas production : 0.3 Nm^3/kg COD red
- Expected biogas production : 165 m3/d

ENERGY BALANCE

Biogas generated is proposed to be used as a fuel in the boiler for generating hot water for tanning process. At present it is being used as fuel in their canteen.

MANPOWER REQUIREMENT FOR PLANT

- Engineers [Electrical/ Mechanical] : 1
- Chemist : 1
- Operators : 6
- Supporting Staff : 1

COST ECONOMICS

Total cost of the project is Rs.86.5 lakhs. 50% has been borne by TIL and the rest by NBB / MNES.

BENEFITS ACHIEVED

- **Employment Generation:** Waste to energy conversion plant is providing employment to about 10 persons for the collection of waste and operation and maintenance of the plant.
- **Fuel Savings/ Revenue Earned:** Revenue generated from biogas through thermal energy recovery is about Rs.14.0 lakhs per annum and through recovery of basic chromium sulphate from the solid wastes about Rs.5.0 lakhs per annum.
- **Waste Management/ Cleanliness :** The project has demonstrated an eco-friendly process for the management of chrome leather shaving wastes from leather finishing unit. The process implemented is a total solution for the management of hazardous wastes in an environment friendly manner. It has improved the environment in and around the TIL complex.

OPERATIONAL DIFFICULTIES AND TROUBLE SHOOTING

The design of centrifuge was modified at the time of commissioning to improve the filtration process for maximum recovery of gelatin. Appropriate filter medium has been chosen for Nutsch filter for effective separation of basic chrome sulphate for reuse in the tanning process.

ABATTOIR INDUSTRY WASTES

BIOMETHANATION PLANT BASED ON ABATTOIR SOLID WASTES AT RUDRARAM, ANDHRA PRADESH

- **Place of Installation** : *Rudraram, Medak Andhra Pradesh*
- **Date of Commissioning** : *February 2002*
- **Status of Functioning** : M/s. *Al-Kabeer Exports Pvt Ltd, Hyderabad is operating and maintaining the plant*
- **Implementing Agency** : *Central Leather Research Institute, Chennai*
- **Technology** : BIMA (Biogas Induced Mixing Arrangement) Technology of *M/s ENTEC, Austria*
- **Technology Institution for Supervision** : *Central Leather Research Institute, Chennai*

BACKGROUND

About 15 million cattle and 1 million sheep and goat are being slaughtered annually in the country. The waste generated in the abattoirs including the liquid and solid wastes is detrimental to the environment. The solid wastes are generally collected and dumped in the pits and then carried away to landfill or dumping sites, thus adversely effecting the environment. In addition, enormous resources having potential for energy generation are wasted. The solid wastes generated from the abattoirs viz. gobar, paunch content, feed wastes, have large potential for biomethanation. A project for demonstration of biomethanation technology for energy recovery from slaughterhouse wastes and their treatment has been installed at M/s Al kabeer, Rudraram, Medak in Andhra Pradesh.

DESCRIPTION OF THE PLANT

A schematic of the biomethanation process employed at this project is shown in Figure-1. The solid wastes are collected in a dissolution tank, which is equipped with a mixer to completely mix the wastes. The homogenised wastes pass through a macerator to reduce the particle size for effective biodegradation.

The homogenised waste is pumped into high-rate biomethanation digesters in which the homogenised wastes are treated under anaerobic conditions and the organic material is degraded into biogas. The produced biogas is stored in a gasholder, from where it is used for thermal energy application in the abattoir.

The digested substrate is collected in a buffer tank from where it is pumped to a filter press to dewater the residue. The dewatered solids are used as bio-manure whereas the press water is collected in a storage tank and pumped to the ETP for further treatment and disposal.

Biogas Digester and the Gas Holder

TECHNOLOGY INVOLVED

Biogas Induced Mixing Arrangement (BIMA) Technology, patented by M/s. Entec, Austria has been used for Anaerobic Digestion of Wastes.

WASTE ARRANGEMENT, BIOGAS AND MANURE UTILIZATION

Solid wastes generated in the abattoir of M/s. AKEL are used as feedstock in the biomethanation plant. Biogas is used as fuel in the boiler to generate steam, while nutrient rich manure is sold to farmers.

MATERIAL BALANCE

Material balance calculation of the plant for a feed of 60 tonnes/day of raw wastes is as under:

- Raw Feed : 60 tonnes/day
- Make up water available from effluent treatment plant : 20 m^3/day

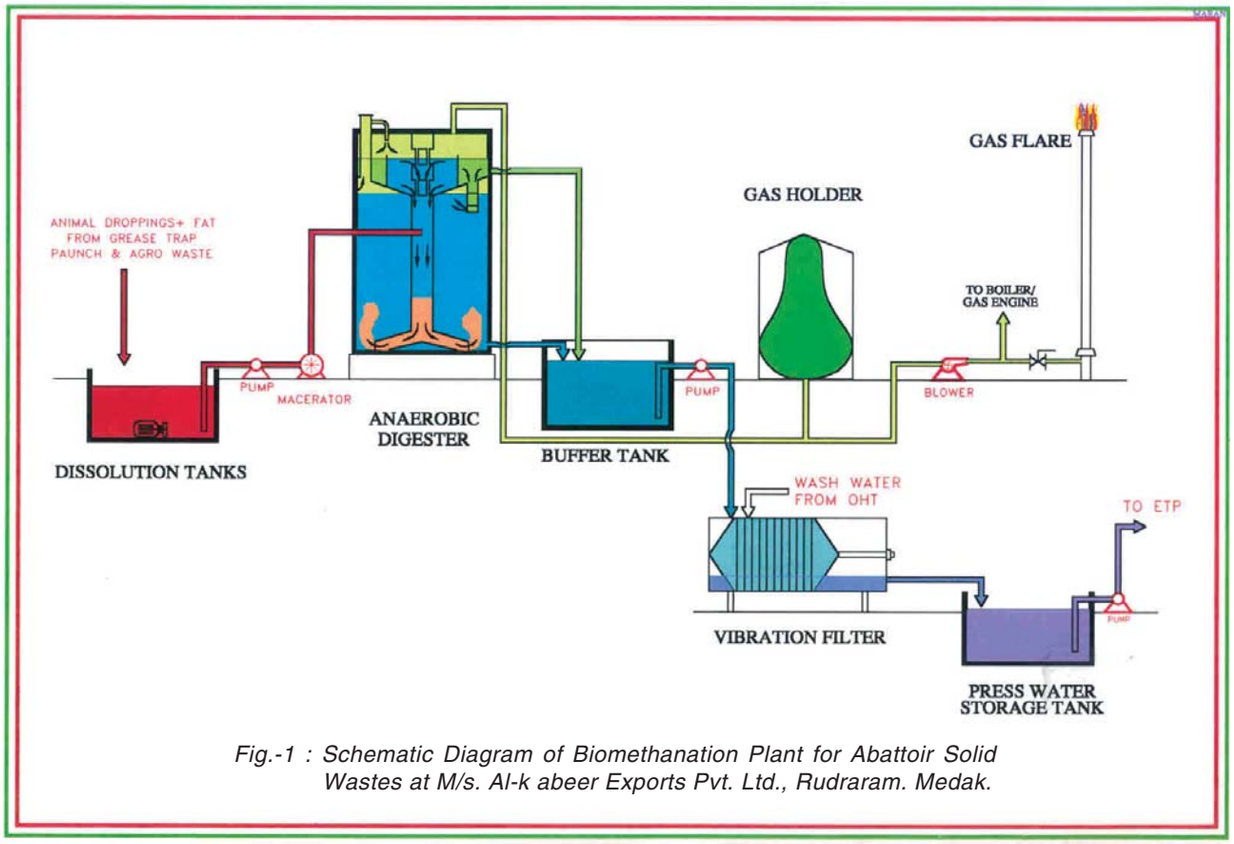


Fig.-1 : Schematic Diagram of Biomethanation Plant for Abattoir Solid Wastes at M/s. Al-k abeer Exports Pvt. Ltd., Rudraram. Medak.

- Volatile Solids Loading Rate : 5.732 tonnes/day
- Digester Retention Time : 26 days
- Efficiency of Digesters : 55%
- Volatile Solids Destroyed : 3.153 tonnes/day
- Biogas Produced : 2600 m^3/day
- Biofertilizer Production (70% solids) : 7 tonnes/day

ENERGY BALANCE

Energy balance calculation of the plant is as under :

- Auxiliary power requirement : 420 kWh/day
- Electrical energy equivalent of biogas generated from plant : 4680 kWh/day

At present, biogas is being utilized as fuel in the boiler to generate steam.

MANPOWER REQUIREMENT FOR PLANT

- Engineers [Civil/ Electrical/ Mechanical] : 2
- Chemist : 1
- Supporting Staff : 1

COST ECONOMICS

Total cost of the project is Rs.3.75 crore, 50% of this has been borne by AKEL and the rest by NBB /MNES.

BENEFITS ACHIEVED

- **Fuel Savings/ Revenue Earned :** The plant is saving about 420 klitres of furnace oil per annum.
- **Waste Management/ Cleanliness :** The project has demonstrated an eco-friendly solid waste management technology for abattoir industry with a view to minimize green house gases emission and odour nuisance significantly.

OPERATIONAL DIFFICULTIES AND TROUBLE SHOOTING

Problem in operating the filter press was experienced during commissioning of the plant, but by selecting appropriate filter cloth, the filtration of the digested sludge was improved.

BIOMETHANATION PLANT BASED ON ABATTOIR SOLID WASTES AT ALIGARH, UTTAR PRADESH

- **Place of Installation** : *Aligarh, Uttar Pradesh*
- **Date of Commissioning** : *Expected to be Commissioned by June 2006*
- **Status of Functioning** : *Under Execution*
- **Implementing Agency** : *M/s Hind Agro Industries, Aligarh, Uttar Pradesh*
- **Technology** : *Low Speed Agitator Tank Reactor (LSATR) Technology*
- **Technology Institution for Supervision** : *Central Leather Research Institute, Chennai*

BACKGROUND

M/s Hind Agro Industries Ltd., (HAIL) is a 100% export oriented modern integrated abattoir-cum-meat processing plant for buffaloes and sheep meat with an installed capacity of 33510 MT of chilled and frozen meat per annum. It has been set up by M/s Hind Agro Industries Ltd. with the cooperation of three agencies of State and Central Governments ie. UP Pashudhan Udyog Nigam Ltd.; a U.P. State Govt. Undertaking; the Pradeshiya Industrial and Investment Corporation of U.P. Ltd. (PICUP), a UP State Financial Institution; and Food Processing Department, Government of India. The plant has been established with the technical know-how and collaboration of Fletcher Projects of Newzeland and Seanet of Australia and commercial production was commenced from June 1997. The present operating capacity of the plant is Buffalo-800 nos. per day and Sheep-1000 nos. per day on single shift basis of 12 hours a day. The estimated waste generation at present is about 50 tonnes per day consisting of (i) Animal Droppings (ii) Rumen (iii) Fat and Grease and (iv) Fodder Residues and Hay.

The Sources, Waste Quantity and the Characteristics of the wastes are as below:

Waste Quantity: About 50 tonnes per day as per composition mentioned below:

Description	Value (tonnes /day)	
	Buffalo	Sheep
• Droppings	2.75	2.0
• Rumen & Other (paunch)	16.50	6.0
• Fat (from grease trap)	1.10	1.0
• Agro wastes	1.65	1.0
• Other wastes	11.00	9.0
Total	**33.00**	**19.0**

Waste Characteristics are:

Description	Characteristics		
	Moisture Content (%)	Dry Solids (%)	Volatile Solids (%)
• Droppings	81.0	19.0	78.6
• Rumen & Others (paunch)	87.0	13.0	87.3
• Fat (from grease trap)	52.2	47.8	98.6
• Agro wastes	60.0	40.0	68.0
• Other wastes	65.0	35.0	91.0

DESCRIPTION OF THE PLANT

A flow sheet of the biomethanation process is shown in Figure I. The solid wastes generated are collected in a homogenous tank. The tank is equipped with a mixer to completely mix the wastes. The homogenised wastes then passes through a macerator to reduce the particle size for effective biodegradation.

The slurry is thereafter pumped into LSATR (Low Speed Agitator Tank Reactor) digester. It is a highrate anaerobic digester in which the homogenised waste is treated under anaerobic conditions where bioconversion of the organic material into biogas takes place. The biogas produced is stored in a gas holder from where it is compressed and sent to a biogas engine for generation of electricity.

The digested residue is collected in a buffer tank from where it is pumped to a dewatering system. The dewatered solids are to be used as bio-manure. The wastewater is discharged to ETP for further treatment and disposal.

The residue from the biogas plant, is rich in nutrients. Hence, it can be used as manure. Thus it is possible to use the solid wastes profitably to generate power and to produce biomanure.

LSATR Digester and the Gas Holder

TECHNOLOGY INVOLVED

Low Speed Agitator Tank Reactor (LSATR) Technology has been used in the Anaerobic Digester and is supplied by M/s RSB Japan Corporation, Japan.

WASTE ARRANGEMENT, BIOGAS AND MANURE UTILIZATION

Solid wastes generated in the abattoir of HAIL are used as feedstock in the biomethanation plant. Biogas is used as fuel in the biogas engine to generate electricity. The nutrient rich manure is proposed to be sold through subcontracting

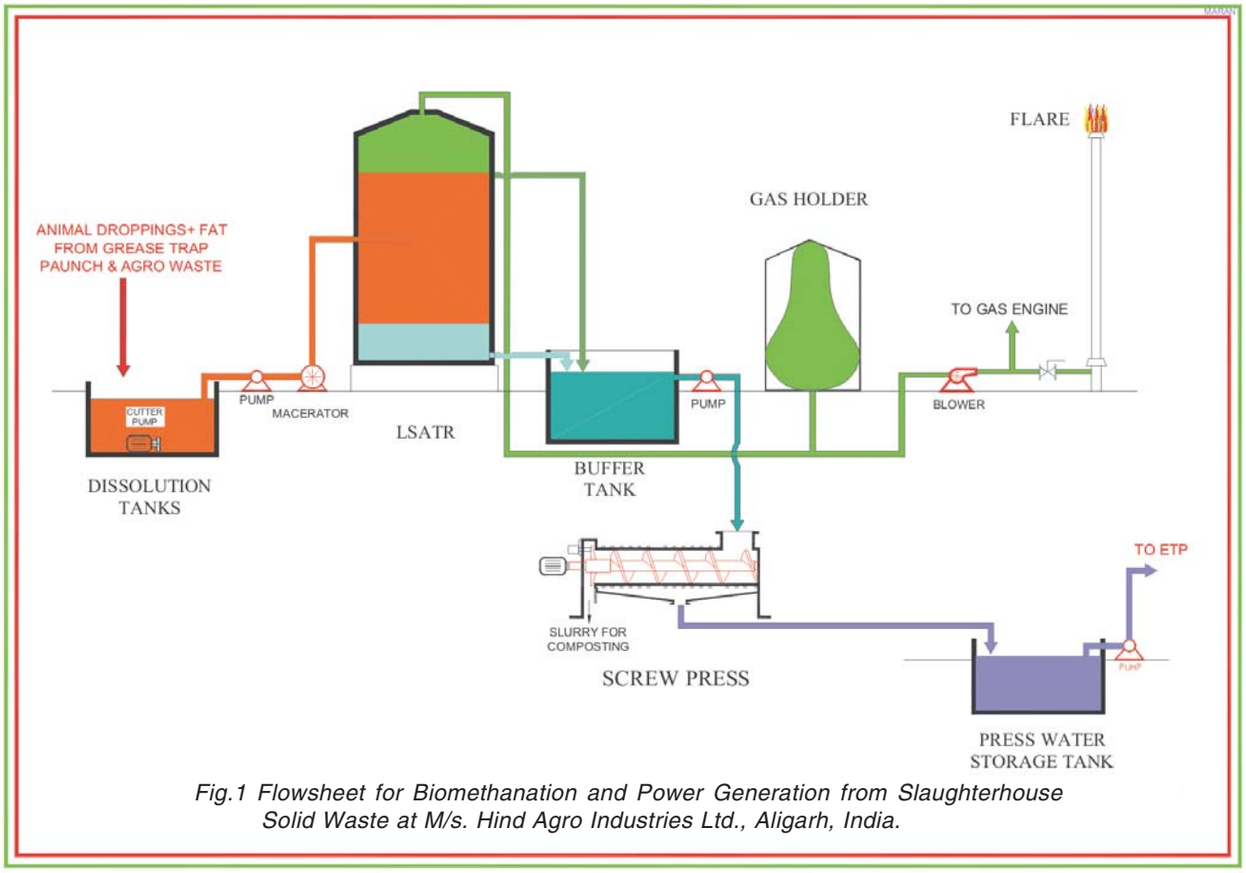


Fig.1 Flowsheet for Biomethanation and Power Generation from Slaughterhouse Solid Waste at M/s. Hind Agro Industries Ltd., Aligarh, India.

MATERIAL BALANCE

Material balance calculation of the plant for a feed of 52 tonnes/day of raw waste is as under:

- Raw Feed : 52 tonnes/day
- Make up water available from effluent treatment plant : 28 m^3/day
- Volatile Solids Loading Rate : 12 tonnes/day
- Digester Retention Time : 36 days
- Efficiency of LSATR Digester : 50%
- Volatile Solids Destroyed : 5.66 tonnes/day
- Biogas Produced : 5200 m^3/day
- Biofertilizer Production (25% solids) : 20 tonnes/day

ENERGY BALANCE

Energy balance calculation of the plant is as under :

- Auxiliary power requirement : 300 kWh/day
- Electrical energy generation : 10500 kWh/ day from the Plant

MANPOWER REQUIREMENT FOR PLANT

- Engineers [Electrical/ Mechanical] : 3
- Chemist : 1
- Supporting Staff : 1

COST ECONOMICS

Total cost of the project is Rs.325.00 lakh + USD 6,56,000. 50% of this cost has been borne by M/s HAIL and the rest by NBB/ MNES.

BENEFITS ACHIEVED

- **Fuel Savings/ Revenue Earned :** The plant is expected to save electrical energy consumption of the factory.
- **Waste Management/ Cleanliness :** The project is expected to demonstrate an eco-friendly solid waste management technology for abattoir industry with a view to minimize green house gas emissions and odour nuisance significantly.

OPERATIONAL DIFFICULTIES AND TROUBLE SHOOTING

The plant is under erection and expected to be commissioned shortly.

FRUIT / FOOD PROCESSING WASTES

BIOMETHANATION PLANT BASED ON TAPIOCA PROCESSING INDUSTRY WASTEWATER AT PAPPIREDDIPATTY, TAMIL NADU

- **Place of Installation** : *Pappireddipatty, Dharamapuri District, Tamilnadu*
- **Date of Commissioning** : *February 2003*
- **Status of Functioning** : *Functioning Satisfactorily*
- **Implementing Agency** : *Tamil Nadu Energy Development Agency , Chennai*
- **Technology** : *Hybrid Upward Flow Sludge Media Anaerobic Reactor (HUSMAR)*

BACKGROUND

Tapioca (Manihot Esculenta Crantz) is a crop of great economic importance, both as human food, animal feed as well as raw material for industrial products. In India, Tapioca is grown over an area of about 3 lakh hectares, with a production of 58 to 60 lakh tonnes of tubers. Tamil Nadu ranks second in terms of cultivation and production of tapioca after Kerala but it stands first in respect of processing of tapioca into sago and starch throughout the country meeting about 80% of country's demand. There are about one thousand sago & starch industries in small-scale sector scattered throughout the State of which 800 units are located in and around Salem district. About 3 cubic metre of wastewater is generated for processing one tonne of tubers, which contains high pollution load, and has to be treated to meet pollution norms set-up by the State Pollution Control Board. At present, there are more than 100 units producing biogas using Tarpaulin cover over the conventional anaerobic lagoons and utilizing the biogas produced for roasting of sago and / or for generation of electrical energy.

The wastewater of about 1200 m^3/day generated in processing of tapioca tubers for production of starch at M/s Varalaxmi Starch Industries Ltd.,(VSIL) was therefore utilized for generation of about 0.5 MW of electricity. The raw wastewater contains biodegradable matter such as (i) immature / partially matured starch; (ii) water from tapioca tubers as 55-60% of its weight is water only; and (iii) mechanically un-extractable starch which is 1-2% of the total starch present in the tubers.

DESCRIPTION OF THE PLANT

The wastewater obtained after washing of tuber is directed through a gravity sewer to a wet well equipped with a screen to remove grit / debris, if any, that might flow into the gravity sewer. Wastewater from the wet well flows into a set of primary settling tanks to remove any solid particles and left over debris. Wastewater is

Overall view of the plant

then flows to an equalization tank to take care of variation in the flow rates and/or the composition. The storage capacity is for 4 days.

Hybrid Upward Flow Sludge Media Anaerobic Reactor (HUSMAR)

The plant consists of two HUSMAR with 16.5 m diameter and 11.5 m height. In the central part of HUSMAR, Cross Flow Media (CFM) is filled to a height of 4.8 m between two concrete beams. The top of HUSMAR tank is covered with a floating inverted tank to collect the biogas. The cross flow media has been made of corrugated PVC sheets of 0.7 to 0.3 mm thickness, 60 mm flute, 60 mm corrugated angle, bonded together in

rectangular modules of size of 1.2 m x 0.6 m x 0.6 m providing with a surface area of 102 sq metre per cubic metre.

View of the Biomethanation Plant

Each HUSMAR is provided with following sensors:

- Flow
- pH
- Pressure
- Gas totalizors
- Temperature

The entire plant is controlled by SCADA system.

Gas Engine

Wastewater from the equalization tank is pumped into two anaerobic digesters operating in parallel. However, before reaching the anaerobic digesters, the wastewater is mixed with chemicals to improve the pH and also C: N ratio. About 85% of influent BOD is removed in these digesters. The cross flow media provides more space for the growth of bacteria and helps in reducing the HRT to two days and to increase the solid retention time. The wastewater is recycled for efficient gas generation.

Biogas Storage

The biogas, which is produced as a result of stabilization of the wastewater, leaves the digesters and is collected under a negative pressure through gas collection header at the top of the reactor. The biogas consists of 60 – 65% methane and 35-40 % carbon dioxide.

Effluent Treatment Plant

Effluent from the two anaerobic digesters flow by gravity into two aerobic sludge tanks which are capable of removing > 90% of influent BOD from the effluent from the digesters.

Anaerobic Digesters (HUSMAR)

Effluent from the sludge tanks is then taken to a secondary clarifier where final clarification of the wastewater occurs and the final BOD concentration in the wastewater is > 35 mg/l.

PROJECT COST

Total cost of the project is Rs. 3.59 crores.

TECHNOLOGY INVOLVED

HUSMAR Technology has been developed at NJIT, New York, USA and the plant was constructed as per the process layout given below.

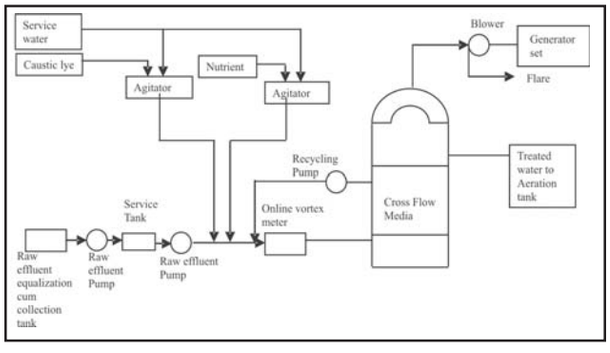


Fig. 1- Process Flow Diagram

MATERIAL BALANCE

Wastewater feed : 1200 m^3 / day

Parameters	Max.	Average	Min.
• Throughput capacity, kg of COD/day	15000	13500	12000
• COD reduction, %age	90	75	60
• BODs reduction % age	90	80	70
• Biogas production cum /day	9400	8400	7300
• Electrical power generation, kWh/day	100% 15000	80% 12000	70% 10500
• Electrical power consumption in the biomethanation plant kWh/day	2000	2000	2000
• Availability of net electrical power for other use, kWh/day	100% 13000	80% 10000	70% 8500
• Consumption of chemicals in the biomethanation plant, kg/day			
Ammonium Phosphate	900	900	900
Sodium Bicarbonate	1125	1125	1125

ENERGY BALANCE

- Energy generation from the plant : 500 kW
- Auxiliary power required : 30 kW
- Power to be used for sago production : 470 kW

MANPOWER REQUIREMENT FOR PLANT

- Operator : 2
- Technical Assistant : 1
- Lab Assistant : 1

BENEFITS ACHIEVED

- Reduction in emission of green house gases
- Employment generation
- Fuel Savings
- Effective waste Management (cleanliness)

PULP & PAPER INDUSTRY WASTEWATER

EVALUATION OF PERFORMANCE OF A PILOT PLANT BASED ON UASB TECHNOLOGY FOR TREATMENT OF PULP AND PAPER INDUSTRY WASTEWATER AT M/s SATIA PAPER MILLS LTD., MUKTSAR, PUNJAB

- **Place of Installation** : *Muktsar, Punjab*
- **Period of Evaluation** : *March – September 1994*
- **Implementing Agency** : *M/s. Satia Paper Mills Ltd. (SPML) , Muktsar, Punjab*
- **Technology Provider** : *UASB from Paques BV , The Netherlands*
- **Technology Institution for Supervision** : *Central Pulp & Paper Research Institute, Saharanpur*
- **Engineering Company and Turnkey Contractor** : *M/s. Western Paques (India) Ltd. (WPIL) / Global Environmental Engineering Ltd. (GENL)., Pune*

BACKGROUND

A Pilot plant based on UASB technology of Paques BV was installed and commissioned at M/s Satia Paper Mills Ltd., Muktsar, Punjab in order to evaluate the treatability of the black liquor rich effluent. The pilot plant was commissioned in March 1994 and was run for a period of more than six months in order to study; (i) the treatability of effluent rich in spent pulping liquor at 100% volumetric loading rate i.e. 10 kg/m^3/day, the designed one and; (ii) to validate the guaranteed performance to be achieved in respect of reduction of COD, BOD and biogas production at steady state conditions viz. COD reduction - 50-60%; BOD reduction - 70-75%; Gas production - 0.3-0.4m^3/kg COD; Methane content -60-65% and fluctuation in the quality of substrate and its impact on performance parameters.

DESCRIPTION OF THE PILOT PLANT

The various units in the pilot plant are shown in Figure-1, which include;

i) **Sump Tank :** The capacity of the sump tank is around 1 m^3 in which the raw black liquor is received and provided with service water line to dilute the black liquor as required.

ii) **Buffer Tank :** The capacity of the buffer tank is around 1m^3 in which the diluted black liquor is received at a regulated rate with the help of pump (capacity 120 LPH). A condensate line is provided in the tank to maintain temperature during winter season.

iii) **Biopaque Reactor :** The reactor capacity is 3.8 m^3. The effluent from buffer tank is provided with recirculation arrangements to control volumetric loading rate in the reactor. The reactor is provided with sample ports at different heights in order to evaluate the amount and quality of sludge in the system. Three-phase separator for effective separation of solids, liquid and gases is located at the top portion of the reactor. The biogas is collected in a gas dome and treated effluent is discharged.

iv) **Water Seal :** The water seal is provided in a gas line for gas scrubbing, which is measured through gas flow meter.

v) **Gas Monitoring System and Gas Burners :** After measuring the gas produced in bioreactor, the gas is flared.

COMMISSIONING OF THE PILOT PLANT

The pilot plant was commissioned at M/s Satia Paper Mills in the month of March 1994 after starting in 3rd week of December 1993. It took almost 3-4 months to achieve desired volumetric loading rate of 100% i.e. 10 kg/m^3/d. According to the mill, the pilot plant was run continuously over a period of more than six months at desired Volumetric Loading Rate and could achieve the results guaranteed by the Technology Provider.

PERFORMANCE OF THE PILOT PLANT

Various parameters concerning plant operation like VLR, COD of the influent and effluent, suspended solids, pH, VFA, gas production were monitored. The results of pilot are summarized below:

Table-1. Performance of UASB Pilot Reactor at M/s Satia Paper Mills Ltd., Muktsar, Punjab

COD Load	COD discharged kg/day	VLR kg. COD/m^3/day	COD/ redn %	Rate of gas prodn m^3/kg COD	Hydraulic loading %
32.78	16.71	8.60	49.0	0.403	13.6
34.82	18.10	9.14	48.0	0.344	91.4
32.05	16.13	8.41	49.6	0.329	84.1
37.05	15.94	9.71	56.9	0.269	97.1

43.57	18.25	11.44	58.1	0.266	114.4
40.19	18.25	10.58	53.6	0.346	105.8
38.50	20.12	10.10	47.7	0.343	101.0
38.96	20.34	10.22	47.8	0.400	102.2
35.96	17.17	9.44	52.2	——	94.4
35.49	3.33	9.15	42.6	0.397	91.5
15.90	10.73	7.17	32.5	0.420	71.7*
35.30	17.35	9.30	50.8	0.382	93.0

OBSERVATIONS

i) Performance of pilot plant appeared to be satisfactory in respect of VLR, % COD reduction and specific biogas production, which were 90%, 45-50% and 0.25 – 0.35 m^3/kg COD reduced respectively.

ii) Higher Recirculation Rates were maintained in order to augment the capacity, which was needed to be reduced in commercial scale installation.

iii) The COD reduction could not be achieved more than 50% primarily due to refractory organic materials like high molar mass lignin.

The pilot plant operation and performance gave confidence in considering the demo plant on full-scale operation

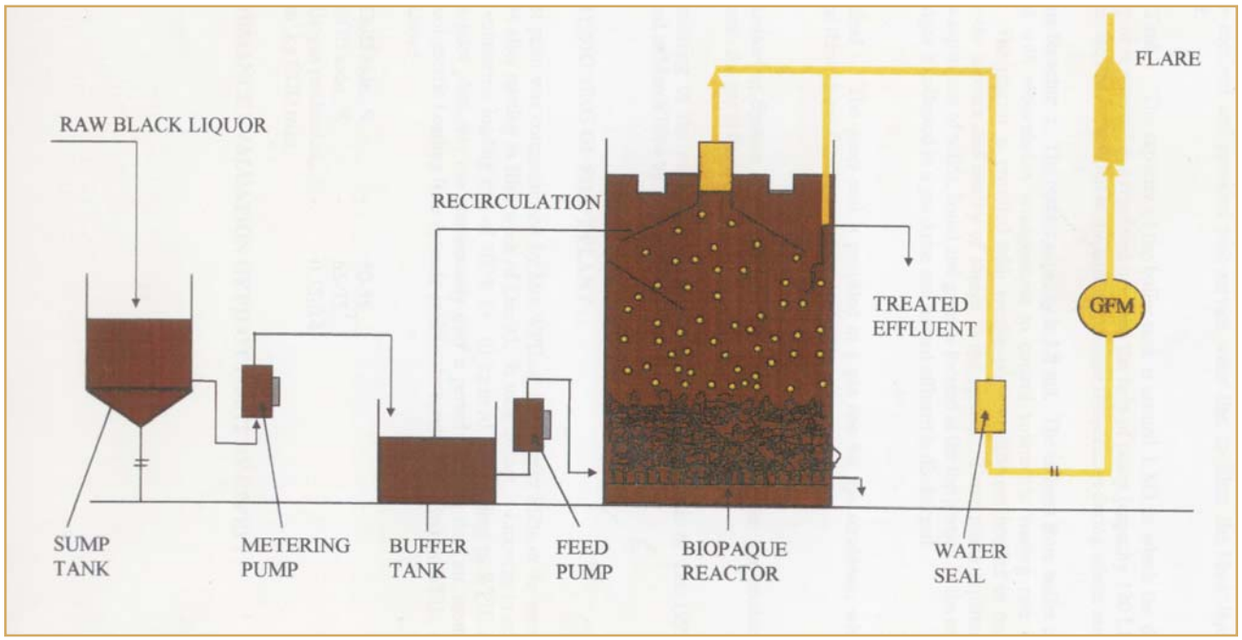


Fig.1 Pilot Plant Schematic based on UASB Process at M/s. Satia Paper Mills, Punjab

BIOMETHANATION PLANT BASED ON PULP AND PAPER INDUSTRY WASTEWATER (BLACK LIQUOR) AT MUKTSAR, PUNJAB

- **Place of Installation** : *Muktsar, Punjab*
- **Date of Commissioning** : *October 1997*
- **Status of Functioning** : *Functioning Satisfactorily*
- **Implementing Agency** : *M/s. Satia Paper Mills Ltd. (SPML) , Muktsar, Punjab*
- **Technology Provider** : *UASB from Paques BV , The Netherlands*
- **Technology Institution for Supervision** : *Central Pulp & Paper Research Institute, Saharanpur*

BACKGROUND

Pulp and Paper industry is one of the core industries with production capacity of nearly 6.30 million tonnes per annum of paper and board and is expected to grow by more than 6-7 per cent per annum. Similarly, per capita paper consumption is projected as 6.0 kg by 2005. However, the industry is considered to be one of the highly polluting industries and consuming large amount of energy and water in unit operations.

The paper industry is reportedly the sixth largest consumer of energy in the country and energy accounts for about 24.5% of the total production cost, which is rising steeply every year. There is a potential for energy conservation to the extent of about 20% to 25%, which can be achieved through efficient energy management practices.

Another area that needs immediate attention is the wastewater discharged by industry, which is highly heterogeneous containing compounds from wood or other raw materials, process chemicals as well as compounds formed during processing. The actual quantities and characteristics of the generated wastewater streams are however highly dependent on raw materials, manufacturing processes and process conditions used in the mill. The economic yardstick will no more accept pulp and paper mills consuming 250 to 300 cum of water per tonne of paper. In fact, to bring down the quantity of effluent discharged to 100 – 125 cum per tonne of paper, efficient water management in the mills is a must. According to the current scenario all over the world, the discharged wastewater volume may vary from near to zero to 30 cum per tonne of pulp or 8-10 cum per tonne of paper in developed countries. In recipient water bodies, the pulp and paper industry wastewaters may cause oxygen deficiency, acute or chronic toxicity, mutagenicity and contamination of sediments. Further high uses of water invariably adds to cost as it entails higher energy consumption and loss of valuable fibre, besides contributing to the environmental stress. Therefore, the main challenge before the industry is to evolve strategies on effective water and energy conservation to become cost competitive and to comply with wastewater discharge standards stipulated by the regulatory authorities. Industry therefore needs to reduce chemical consumption, install adequate pollution and wastewater treatment systems and adopt cleaner processes/ techniques.

Indian pulp and paper industry which has more than 475 plus small and medium scale mills out of a total of over 525 mills, process mainly non-wood materials like agro residues such as bagasse, rice and wheat straw, jute and grasses and waste paper in chemical pulping and have no chemical recovery system. The treatment of wastewaters especially black liquors is difficult and expensive with biological aerobic, chemical and physical methods. On the other hand, anaerobic treatment is an attractive treatment alternative for pulp and paper mills wastewaters as the organic load in the wastewaters could be recovered partially as methane, a valuable energy source and less energy would be then needed for aeration in the subsequent treatment process.

A full-scale demonstration project for biomethanation of black liquor through Upflow Anaerobic Sludge Bed (UASB) Reactor system was installed at M/s Satia Paper Mills, Muktsar, Punjab after carrying out pilot studies on the applicability this reactor configuration.

Central Pulp & Paper Research Institute (CPPRI), Saharanpur was involved as technology institution and supervised execution of the plant and performance monitoring and evaluation upon its commissioning.

DESCRIPTION OF THE PLANT

The layout of the biomethanation plant at M/s. Satia Paper Mills is given in **Figure-1**

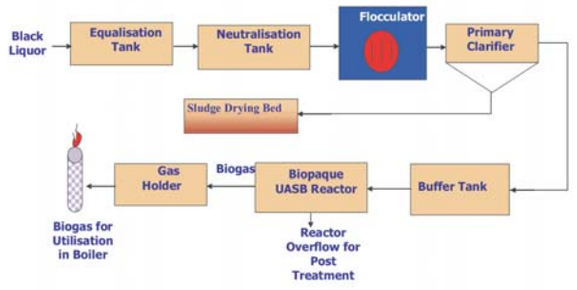


Fig.-1 **PROCESS FLOW DIAGRAM OF DEMO-BIOMETHANATION PLANT AT SATIA PAPER MILLS, (PUNJAB)**

As indicated in the figure, the plant comprises of the following units namely:

Equalisation Tank

It is a rectangular tank of about 210m^3 with dimension 8.4 m x 8.4 m x 3.0 m. Its main function is to receive black liquor and to minimise fluctuation / variation in flow and COD concentration of black liquor. The retention time in equalisation tank is two hours.

Neutralisation Tank

It is a rectangular tank of 35 m^3 and is used for neutralising the black liquor to a pH of around 6.5 by addition of hydrochloric acid through an acid dosing pump. A mechanical stirrer is provided in neutralization tank for uniform mixing of acid with black liquor. The retention time in neutralisation tank is half an hour.

Clariflocculator

It is a circular tank of 98 m^3, the purpose of which is to enhance the mechanism of flocculation. It is fitted with mechanical stirring device of 10 r.p.m. The retention time in clariflocculator is half an hour.

Clarifier

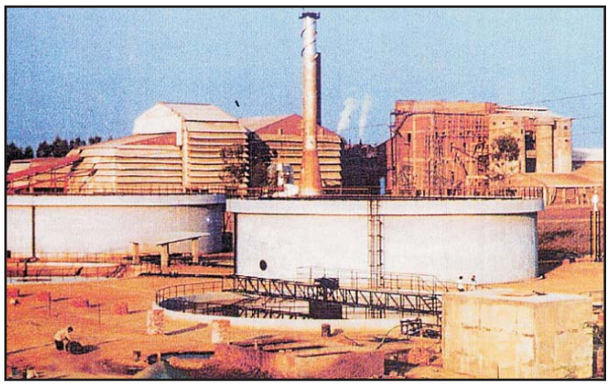
It is a special feature of biomethanation plant to facilitate the arresting of suspended fibers/solids and lignin as well as significant amount of silica which gets precipitated during neutralisation of black liquor. The capacity of the clarifier is around 1100m^3 and retention time is eleven hours. Two pumps are provided for removal of settled matter from the bottom of the clarifier.

Buffer Tank

The main functions of buffer tank are: i) to ensure uniform mixing of influent with nutrients and recycled effluent; ii) to control and stabilise pH of influent; and iii) to act as a hydraulic buffer for continuous and constant supply of influent to the bio reactor. The capacity of buffer tank is 840 m^3 and is an integral part of bio reactor . The retention time in buffer tank is eight hours.

Reactor

Two UASB reactors each of capacity of about 2600 m^3 are provided to handle the organic waste of 53 tonnes COD /day generated by the mill. The reactors are made of concrete to minimise heat loss and the drop in temperature.



Full Scale Biomethanation Plant for Treatment of Black Liquor at M/s. Satia Paper Mills, Muktsar

The influent is fed at the bottom of the reactor through a special distribution system, which ensures proper and uniform contact between influent and active biomass present inside the reactor. As the influent rises through the sludge bed, the anaerobic microbes convert the organic matter present in the wastewater into methane rich biogas, which provide a natural mixing of influent and biomass as it moves upwards. The three phase settler provided at the top of the reactor, separates biogas and sludge from the effluent. The treated effluent overflows via gutters, a part of which is recirculated to buffer tank and rest is discharged to the drain for post treatment along with other waste streams.

Gas Handling System

The biogas generated is collected through a number of stubs which are connected to a common header. The biogas goes to a gas holder after defoaming through foam trap in which water is sprayed continuously through a specially designed nozzle. A preventive measure to remove the sludge particles entering the pipe line is taken by providing a sediment trap before gas flow meter so as to ensure its smooth functioning. The online gas flow meter measures the quantity of biogas generated.

Gas Holder

The floating tank gas holder having a capacity of 70 m^3 serves as buffer and provide some back pressure on the settler. The gas holder is made of mild steel with a water seal at the bottom. A pressure vacuum release valve is provided at the top of gas holder. The valve is opened to let air in if full vacuum is created and

release some gas when the pressure exceeds 150 mm water column.

Gas Blower

A gas blower of capacity of 600m^3/h has been provided for transportation of biogas from the gas holder to the boiler where it is burnt. To enable it to run even at low rate of biogas production, a recirculation line is provided at the pressure side of gas boiler. A low level sensor is also provided which automatically stops the blower if gas holder level is low and will restart automatically when level becomes normal.

Gas Flare System

The gas flare system is provided to flare the biogas when not used in the boiler. The valve in the gas line to the flare can be opened and flare can be ignited by means of auto ignition system or manually.

MASS AND ENERGY BALANCE

The average characteristics of black liquor going to the biomethanation plant are given in Table -1

Table 1 : Characteristics of Black Liquor

Parameters	Value
• Flow, m^3/d	1800-2000
• Total Solids, mg/l	30,000-45,000
• Total Suspended Solids, mg/l	4000-6500
• COD, mg/l	25,000-32,000
• BOD, mg/l	8000-12,000
• Sulphite, mg/l	16-26
• Sulphate, mg/l	400-1000
• Total Sulphuras S, mg/l	225-500
• Silica, mg/l	275- 550
• pH	9.0-11.0
• Lignin, mg/l	8000-12,000
• Sodium, mg/l	3500-4500

As indicated in Table-1 there was a high level of residual sulphite and sulphide in black liquor which subsequently resulted in reduced efficiency of the plant.

PERFORMANCE OF THE PLANT

The bioreactors were started by continuous feeding of black liquor with a loading rate of 0.5 kg COD /m3 /day The Performance was monitored regularly and organic loading was increased gradually to the designed load over a period of more than five months. The bioreactors were also operated up to 120 -125% organic loading without having any operational problem or adverse effect on the efficiency of the plant The results of the performance of the plant evaluated over a period of more than two years are given in Table-2.

Table 2 : Performance of the Plant

Parameters	Designed	Achieved
• Volumetric loading Rate, Kg COD/m^3/day	10.0	12.0
• COD reduction, %	55 - 60	40 - 50
• BOD reduction, %	70 - 75	75 - 82
• Biogas production, m^3/day	85001	11000 - 12000
• Equivalent rice husk, t/d	17 - 18	22 - 24

The decline in biogas production by 15-20% has been observed in winter season when reactor temperature goes down below 25^{0}C. The blow heat recovery has been installed by the mill to provide hot water for washing of pulp in order to increase the temperature of black liquor to 44-45^{0}C, which was available at about 38^{0}C.

UTILISATION OF BIOGAS

The biogas produced is used as fuel and burnt alongwith rice husk in a boiler for production of steam. The saving in rice husk due to flaring of biogas is about 15-20% of total energy requirement of mills.

ECONOMIC VIABILITY OF THE PLANT

The economics of full scale biomethanation plant has been analysed and is given in Table 3.

Table 3 : Economics of Biomethanation Plant

Particulars	With Subsidy (50%)	Without Subsidy
• Capital Cost, Rs. million	11.20	22.40
• Operational Cost, Rs. million / annum	7.00	7.00
• Interest on Capital, Rs. million/annum	2.00	4.03
• Depreciation (@ 10% in 10 years)	1.12	2.24
• Recurring Expenditure (B+ C+D), Rs.million / annum	10.12	13.27
• Equivalent Fuel Saving, Rs.million / annum	14.0	14.0
• Indirect Savings (Energy & Chemical Savings in ETP), Rs. million / annum	3.5	3.5
Payback Period, Years	**1.5-2.0**	**4.0-5.0**

OPERATIONAL DIFFICULTIES AND TROUBLE SHOOTING

Identification of source of seed sludge for UASB reactor : The quality of seed sludge plays an important role in the anaerobic digestion specially for the start up of the reactor. Though the best seed material is adapted granular sludge having good settleability and methanogenic activity from similar anaerobic digesters, but due to their scarce availability the anaerobic seed sludge (flocculent type) from anaerobic lagoons treating distillery spent wash (of methanogenic sludge activity 0.28 kg methane COD reduced /kgVSS/day) was selected and used.

BENEFITS ACHIEVED

- **Employment Generation :** Direct employment to 12 persons
- **Fuel Savings :** The plant leads to a fuel saving in terms of rice husk of about 22-24 tonnes/day.
- **Others :** The indirect savings are in terms of energy and chemicals in ETP and land required for post treatment of the effluent.

BIOMETHANATION PLANT BASED ON BAGASSE WASHWATER AT KARUR, TAMILNADU

- **Place of Installation** : *Kagithapuram, Karur, Tamil Nadu*
- **Date of Commissioning** : *April 2003*
- **Status of Functioning** : *Functioning Satisfactorily*
- **Owners and Implementing Agency** : *M/s. Tamilnadu Newsprint and Papers Limited, (TNPL) Karur, Tamil Nadu*

BACKGROUND

M/s Tamilnadu Newsprint and Papers Limited (TNPL) is the largest bagasse based pulp and paper industry in India with 2,30,000 MT/ year installed paper production capacity. TNPL uses nearly 10,00,000 MT/year sugarcane (wet whole) bagasse to produce chemical and mechanical bagasse pulp. The bagasse received from the sugar mill with 3-4% residual sugars is stored in the bagasse yard by wet bulk storage method for a period of 3 to 9 months. During storage, the bagasse is kept under wet condition by spraying water over bagasse pile to preserve bagasse quality. After storage, the bagasse is reclaimed and washed before cooking/ refining to produce the pulp to manufacture paper. Wastewater generated during bagasse washing and from the bagasse yard having high COD, is treated by anaerobic process followed by activated sludge process. Earlier, anaerobic treatment was carried out in conventional anaerobic lagoon.

Though the desired BOD/COD reduction was achieved in the open anaerobic lagoons, the Green House Gases (GHG) viz., Methane was getting released to the atmosphere due to uncontrolled anaerobic reaction in the lagoon. To avoid release of GHG and also to use methane rich bio-gas as a fuel to replace the fossil fuel, TNPL decided to install a bio-methanation plant, in place of the open anaerobic lagoons, by diverting the high COD stream.

After successful pilot plant study, new anaerobic bio-reactor based on UASB process was commissioned in March 2003 to treat 12,000 m^3/ day of wastewater from the bagasse yard and bagasse washing. The project was completed at a cost of about Rs. 4.00 crore.

DESCRIPTION OF THE PLANT

The process flow diagram is depicted in Figure – 1. The plant is designed to handle 12,000 m^3/day of bagasse wash wastewater having average 6000 mg/ l COD concentration with a hydraulic retention time of 20 hours and maximum organic loading rate of around 5.75 kg COD / m^3/day.

The bagasse wash wastewater is received into an equalization tank from bagasse clarifier and fed to a neutralization tank where the wastewater is neutralized using Milk of Lime to raise the pH from 4.0 - 4.5 to 6.5 –7.0. After neutralization, the wastewater is taken into a clarifier to settle the suspended solids. The settled sludge is taken to a sludge pit and then to a Decanter Centrifuge to thicken solids. The thickened sludge is then sun dried and used as fuel in the boiler.

The clarified wastewater is taken to a buffer tank where nutrients, such as, Urea and DAP are added. From buffer tank, the wastewater is fed to two reactors through reactor feed pumps. The treated effluent from the reactors is sent to activated sludge process for further treatment. Biogas generated in the reactors is passed through foam trap and sediment trap and stored in gas holder. From the gas holder the gas is pumped to lime kiln using gas blowers.

A gas pipe has also been provided to power boilers, so as to utilise the bio-gas whenever there is no consumption in the lime kiln, due to any planned or unplanned shut down.

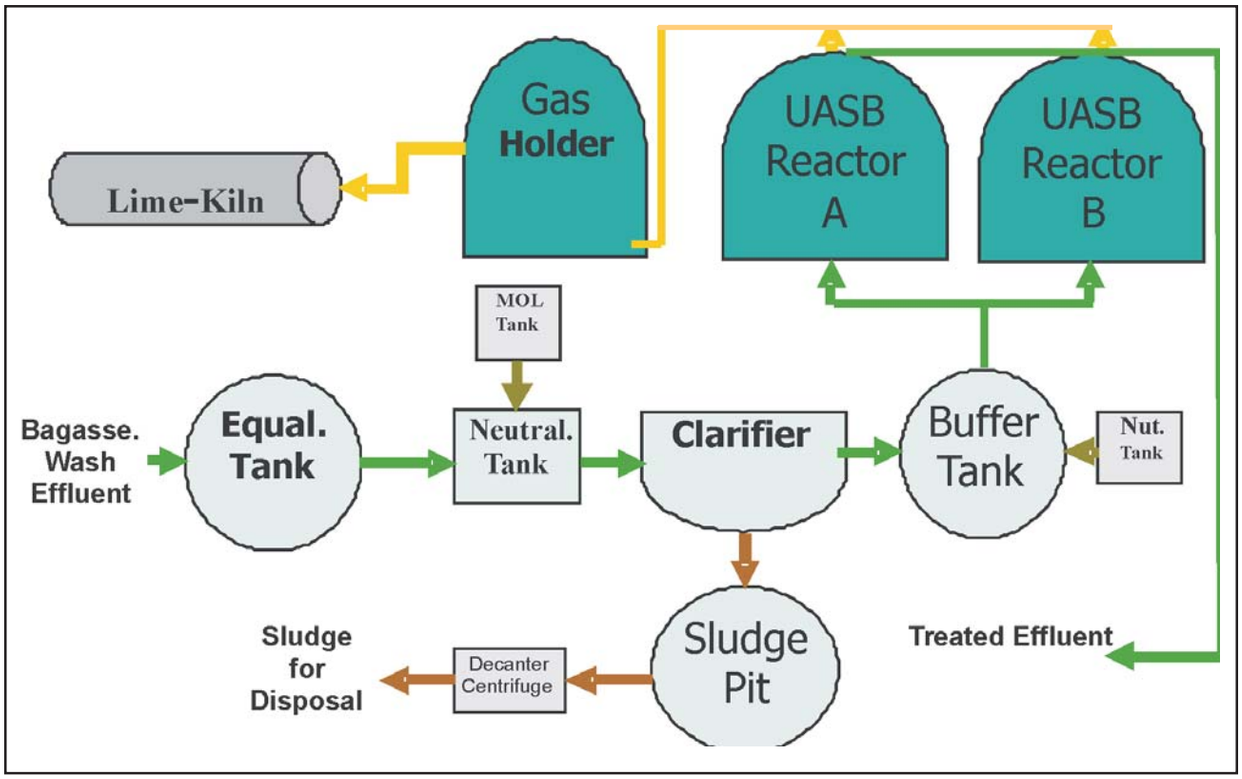


Fig. 1 : Process flow diagram

Overall view of the plant

TECHNOLOGY INVOLVED

View of a UASB Reactor

Anaerobic granular sludge bed technology refers to a special kind of reactor concept for the "high rate" anaerobic treatment of wastewater. The concept was initiated with upward-flow anaerobic sludge blanket (UASB) reactor. A scheme of a UASB is shown in the Figure - 2. From a hardware perspective, a UASB reactor is at first appearance nothing more than an empty tank (thus an extremely simple and inexpensive design). Wastewater is distributed into the tank at appropriately spaced inlets. The wastewater passes upwards through an anaerobic sludge bed where the micro-organisms in the sludge come in contact with wastewater-substrates. The sludge bed is composed of micro-organisms that naturally form granules of 0.5 to 2 mm diameter that have a high sedimentation velocity and thus resist wash-out from the system even at high hydraulic loads. The resulting anaerobic degradation process typically is responsible for the production of gas. The upward motion of released gas bubbles causes hydraulic

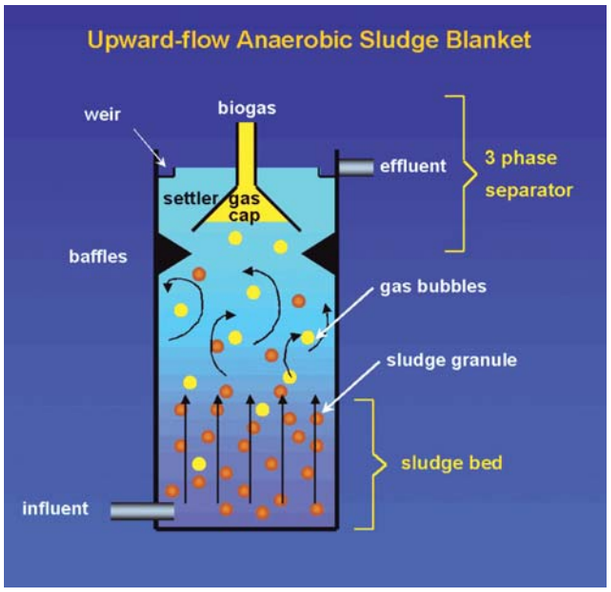


Fig. 2 : UASB Reactor

turbulence that provides reactor mixing without any mechanical parts. At the top of the reactor, the water phase is separated from sludge solids and gas in a three-phase separator (also known the gas-liquid-solids separator). The three-phase-separator is commonly a gas cap with a settler portion above it. Below the opening of the gas cap, baffles are used to deflect gas to the gas-cap opening.

Gas firing in Lime Kiln

WASTE ARRANGEMENT

The effluent having high COD is generated from two of the process areas viz., from bagasse washing/storage yard and from fibre preparation plant.

MATERIAL BALANCE

The material balance for the plant is as follows :

Description	Unit	Values
• Raw effluent inlet	m^3/day	9,000 - 10,0000
• COD	ppm	3,000 -4,000
• COD load	t/day	21.60 – 32.00
• COD reduction	%	80 – 85
• Organic load to the reactors	kg/ m^3/day	2.10 – 3.20
• Gas production factor	m^3/Kg CODred	0.52
• Gas generated	m^3/day	14,000

* *The COD load to the reactors, after considering 20% reduction in the clarifier.*

MANPOWER REQUIREMENT FOR PLANT

The plant is operated on 3 shift basis. The manpower deployed for each shift consists of one each Operator, Chemist and Helper. In addition, a Supervisor and a Process Engineer are available in the General Shift.

COST ECONOMICS

The total cost of the project was Rs.4.00 crores. Out of which Rs. 1.92 crore was provided by NBB and the balance was brone by TNPL. A statement of returns from the plant is as follows:

Description	Unit	Value
• Average bio-gas generation	m^3/day.	14,000
• Savings in the furnace oil consumption in lime kiln	KL/day	8.0
• Price of furnace oil	Rs./KL	11,500
• Savings against reduction in consumption of furnace oil	Rs./day	92,000
• Operational expenditure for bio-methanation plant	Rs./day	35,000
• Net savings	Rs./day	57,000
• Annual Savings	Rs. lakh/ year	188.00

Note : *Fuel value of sludge generated from the Bio-methanation plant is not considered in the above calculation, since the value is less.*

BENEFITS ACHIEVED

- ***Reduction in Emission of GHG (MT of CO_2 per annum)***

• Avoidance of uncontrolled methane emission from anaerobic lagoon	: 47,500
• Reduction of fossil fuel CO_2 emission due to savings of furnace oil	: 8,500
Total	: 56,000

- ***Employment Generation :*** Direct employment to 14 persons.
- ***Fuel Savings :*** The plant facilitates savings of about 8 KL per day of furnace oil.
- ***Others :*** The pre-treatment lagoons are now idle consequent upon commissioning of the Project thus resulting in savings of about 25,000 m^2 of land. COD reduction is done in more environment friendly way.

OPERATIONAL DIFFICULTIES AND TROUBLE SHOOTING

- Higher suspended solids level observed occasionally in the treated effluent (sludge washout).
- The biogas is consumed in the lime kiln along with furnace oil. Gas firing in the lime kiln was disturbed initially due to pressure variation between gas and the furnace oil. After adjusting the inlet pressure, the problem was overcomed.
- Higher moisture carryover to the lime kiln was rectified by installing an additional moisture trap near the consumption point.
- The COD as well as the flow of the incoming effluent are not consistent. However, the gas production factor is found to be higher (>0.5 against 0.47 m^3/kg of COD reduced).

The plant is now running satisfactorily.

MUNICIPAL WASTEWATER/ SEWAGE

BIOMETHANATION PLANT BASED ON DOMESTIC SEWAGE AT REGIONAL RESEARCH LABORATORY, BHUBANESWAR, ORISSA

- **Place of Installation** : *Regional Research Laboratory, Bhubaneswar, Orissa*
- **Date of Commissioning** : *October 1997*
- **Status of Functioning** : *The plant is not in operation at present due to some technical constraints*
- **Implementing Agency** : *Regional Research Laboratory (CSIR), Bhubaneswar*
- **Technology Provider** : *National Environmental Engineering Research Institute (NEERI), Nagpur*

BACKGROUND

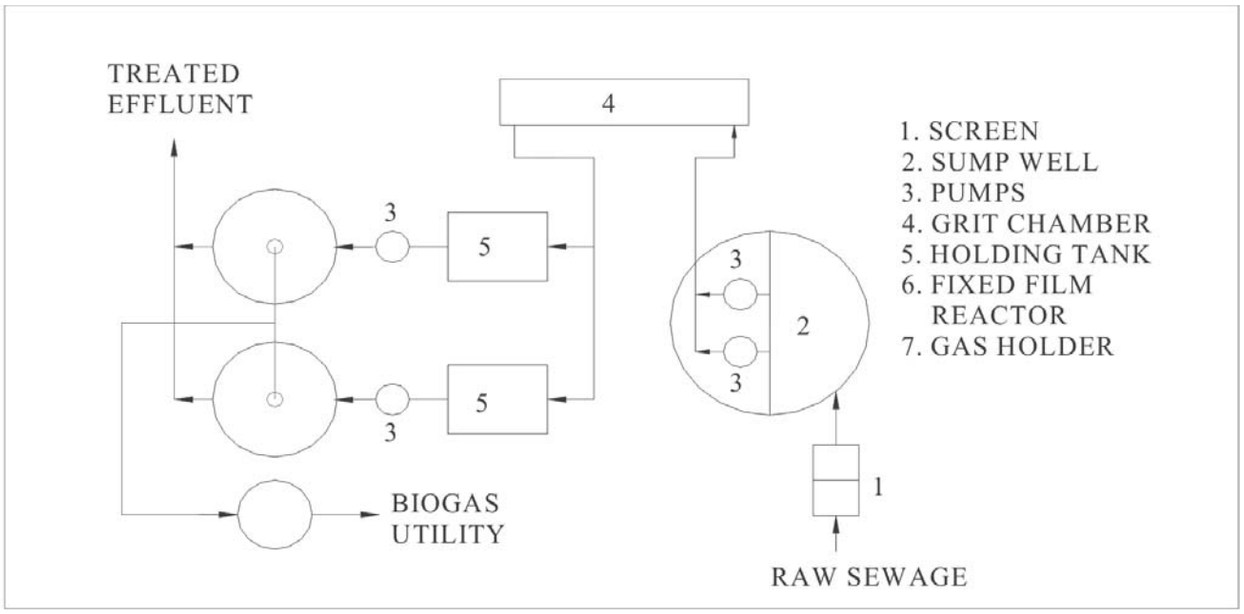
Regional Research Laboratory (RRL), Bhubaneswar has a campus generating substantial amount of domestic wastewater, which is required to be treated in order to maintain a clean environment. In view of this, RRL installed a 0.4 MLD (Million Litres per Day) Sewage Treatment cum Biogas Plant based on anaerobic fixed film technology developed by NEERI, Nagpur. The financial assistance was provided by MNES, Dept. of Housing and Urban Development, Govt. of Orissa and Council of Scientific & Industrial Research (CSIR).

DESCRIPTION OF THE PLANT

The Sewage Treatment Plant at RRL, Bhubaneswar basically consists of a wet well for sewage collection, pumping station, grit chamber, two holding tanks connected in parallel, two mild steel reactors and a biogas holder. The plant is installed on an area of 400 m^2. The sewage from the campus is collected in the well or a sump by means of a sewer line connected to the wet well through a coarse screen to entrap and remove the large size particles and other non-degradable matter. The sewage from the wet well is pumped to the elevated grit chamber provided with a medium screen to remove inorganic particulate matter and medium size particles not entrapped in the coarse screen. The sewage flow rate can be measured by means of a proportional weir provided in the grit chamber. The sewage from the holding tanks is finally fed to two fixed film reactors each with a capacity of 120 m^3

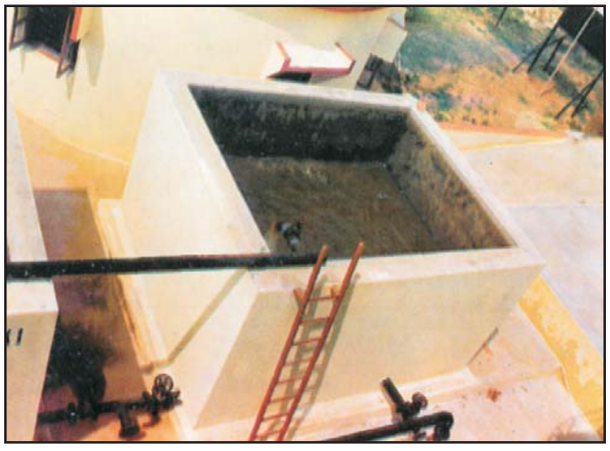
Fixed Film Reactors and Biogas Holder

The sump or the wet well is of 8.0 m diameter, half of which is used as wet well for collecting sewage and the other half is used as dry well for housing the sewage pumps. Both the grit chamber and the holding tanks are made of R.C.C. and are used to distribute wastewater to the fixed film reactor. Each fixed film reactor made of mild steel with diamtere of 5 m and height of 6.6 m incuding top dome and can hold 100 m^3 of sewage. Both the reactors have initially been packed with plastic corrugated pall rings of 38 mm dia and 38 mm length. The bacteria grow and stay over the surface of PVC rings and by this, the cell wash out is almost avoided. The sewage in the reactors is biodegraded through microbial action of bacteria and biogas with 75-80% methane is produced which is collected in the 10 m^3 capacity biogas holder.



Layout Diagram of the Sewage Treatment Plant

Sump & Pump House, Control Room and Grit Chamber



Holding Tanks

TECHNOLOGY INVOLVED

The high rate biomethanation process is based on the fixed film technology utilizing microbial films as a means of achieving high mean cell residence time (MCRT) independent of hydraulic retention time (HRT) thereby achieving higher conversion efficiency. Compared to the conventional anaerobic reactors where the MCRT is rarely greater than twice the HRT, the fixed film process can achieve MCRT of the order of more than 10 times the HRT. Biomass retention in the form of films allows lower HRT without the chances of cell wash out. In addition to the above, high efficiency can be maintained over a wide range of organic loading rates.

WASTE ARRAGEMENT AND BIOGAS UTILIZATION

The wastewater from the houses of the RRL campus is collected through a netweork of sewage lines and is taken to the sump well through the main sewage channel for treatment.

The biogas generated from sewage treatment is used for heating or illumination purposes. The treated effluent is used for irrigation of horticulture energy plantation.

MATERIAL AND ENERGY BALANCE

- Sewage feed rate : 400 m^3/day
- Total dissolved solids in the influent : 200-210 mg/l
- Total suspended solids in the influent : 305 mg/l
- Total suspended solids in the effluent : 72.7 mg/l
- COD of influent : 180-250 ppm
- COD of effluent : 30-50 ppm
- Biogas generation : 20 m^3/day

ENERGY AUDIT

- Total biogas generated with 400 m^3 of sewage : 20 m^3/day
- Total quantity of methane with average of 75% methane in biogas : 15 m^3/day
- Energy gained from methane @ of 37.26 MJ/m^3 : 558.9 MJ/day
- Energy output per m^3 of sewage : 1.40 MJ
- Total Energy consumption for pumping the sewage : 75 kWh/day
- Energy input @ 3.6 MJ/kW for pumping 400 m^3 of sewage : 270MJ/day
- Energy consumption per m^3 of sewage : 0.675 MJ
- Energy Ratio : 1.40/0.675 = 2.07

MANPOWER REQUIREMENT FOR PLANT

- Technical Personnel : 2
- Supervisor : 1

PROJECT COST

The total cost of the project was Rs. 23,41,700 out of which Rs. 11, 70,850 was borne by MNES, Rs. 3, 40,000 was contributed by Dept. of Housing and Urban Development, Govt. of Orissa and the balance Rs. 8, 30,850 was borne by Council of Scientific & Industrial Research (CSIR). The plant was constructed as a model unit without any commercial purpose, hence generation of any revenue was not envisaged.

BENEFIT ACHIEVED

- Energy in terms of biogas generated from the wastewater.
- Clean environment in and around the plant and reduced pollution.
- Better effluent quality available for energy plantation and discharge in the sewer.
- Minimal maintenance cost.
- Indigenous and eco-friendly technology for wastewater treatment demonstrated.

OPERATIONAL DIFFICULTIES AND TROUBLE SHOOTING

Difficulties were encountered in getting continuous and adequate supply of sewage water for operating the plant at full capacity. Problem of chocking of the suction line of the sewage pumps were faced and the same was overcome by suitable modifications.

VEGETABLE MARKET YARD WASTES

BIOMETHANATION PLANT BASED ON MIXED MUNICIPAL WASTES AT VIJAYAWADA, ANDHRA PRADESH

- **Place of Installation** : *Ajit Singh Nagar, Vijayawada, Andhra Pradesh*
- **Date of Commissioning** : *May 2004*
- **Implementing Agency** : *Vijayawada Municipal Corporation, Vijayawada*
- **Technology** : *Modified UASB Technology*
- **Technology Institution for Supervision** : *Central Leather Research Institute, Chennai*

BACKGROUND

In any vegetable / fruit market, large quantities of biodegradable wastes are produced because of damage, bruising, rotting of produce. At present, part of these wastes are disposed of usually only by feeding stray cattle. Otherwise, heaps of the uncollected wastes are allowed to rot in the market places causing unhygienic conditions besides health and pollution problems. This waste being highly biodegradable can be a promising feedstock for biogas generation, which would also solve the problem of waste management for the concerned market authorities.

In view of the above, a demonstration project for biomethanation of 20 tonnes mixed wastes per day for generation of 150 kW of electricity and rich biomanure was installed by Vijayawada Municipal Corporation at Vijayawada. The mixed wastes consist of 16 tonnes of vegetable market waste from the Rythu bazaars (Market Yard) and 4 tonnes of slaughterhouse waste from the Kabela (Slaughterhouse) daily. The sewage sludge from the adjoining Sewage Treatment Plant is used for making the slurry to be fed into the digesters.

DESCRIPTION OF THE PLANT

Among the various configurations of the anaerobic reactors - an important part of the anaerobic treatment plant, Upflow Anaerobic Sludge Blanket (UASB) type reactor has become popular because of its utility for treatment of different types of wastes.

Certain distinct advantages for use of UASB type reactors are as under :-

- It is suitable for the treatment of wastewaters containing more than 75 % of the Biological Oxygen Demand (BOD) in the form of soluble solids i.e. the wastewater containing high ratio of the soluble to suspended solids.
- The loading rates i.e. kg of BOD_5 treated per cubic metre of the digester volume per day are reported to be very high when compared to the alternative designs.
- The digester design does not have any moving parts and/or any packing media. This eliminates the need of frequent replacement of the packing media/ moving parts. Therefore the maintenance cost is reduced considerably.
- The anaerobic process is quite stable.

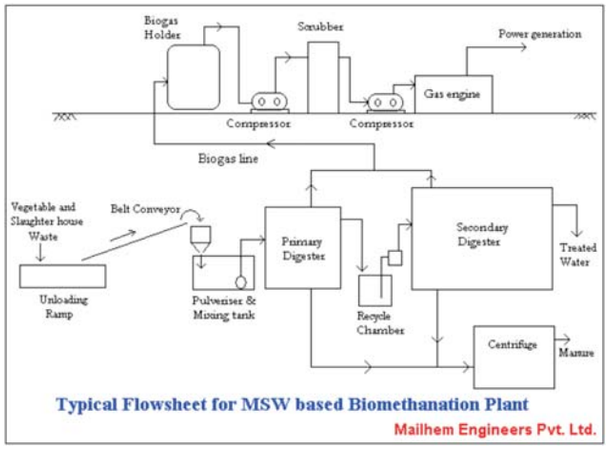
On the other hand, a few disadvantages of this type of reactors are long periods of stabilization and requirement of the specially developed seeding sludge. It is also considered unsuitable to treat the waste having large percentage of suspended solids.

To overcome these disadvantages, a hybrid design for treatment of slurry containing high-suspended solids was considered. This is a two stage process. The sizes of the reactors for the first stage and the second stages are decided on the basis of the suspended organic contents in the slurry to be treated. The first stage is a hydrolysis stage and the second is methanisation and polishing stage. The first stage is designed to give maximum solid retention time for the hydrolysis and the second stage is a UASB digester.

The entire process consists of following five sections:-

- Waste handling and slurry preparation section
- Anaerobic digestion section
- Biogas collection and scrubbing system
- Manure processing section
- Power generation section

Overall View of the Plant



WASTE HANDLING AND SLURRY PREPARATION SECTION

Loading dock with ramp :- The trucks / dumpers carrying the pre-sorted vegetable waste and slaughterhouse waste are brought near the loading dock onto the ramp and the waste is unloaded.

Belt conveyor :- The waste material is then loaded onto a slow moving belt conveyor with a 15 degree angle of inclination. Personnel stationed on either side of the conveyor at the top will further sort the waste manually.

Chaff Cutter :- The machine is used for chopping the big banana and coconut leaves into smaller pieces before loading on the belt conveyor.

Pulverizer :- The waste from the belt conveyor falls into the hopper of pulverizer and it shreds the vegetable and slaughterhouse wastes.

Recycled sewage waste water is used for dilution in the ratio of 1 : 1.

Waste storage tank :- The slurry is collected in the waste storage tank and mixed thoroughly. It is then fed directly to the primary digester. A flow meter is installed to measure the quantum of slurry fed to the digester.

Vegetable Waste Unloading at Site

Vegetable Waste Loading on Belt Conveyor

Loading of Waste

ANAEROBIC DIGESTION

Anaerobic digestion section has one each Primary and Secondary Digesters. Both the digesters are based on modified Upflow Anaerobic Sludge Blanket Technology for treatment of slurry containing high percentage of suspended solids.

Primary and Secondary Digesters are made of RCC and contain proprietary internal modules made from FRP reinforced with Mild Steel. Top cover of both the digesters is made of Mild Steel with FRP lining. A stirrer cum scum breaking mechanism is also installed in each digester. The overflow of primary digester is pumped into the secondary digester. Suitable provision has also been made for removal of sludge from the bottom of the digester and pumping it into the manure pits. The digested slurry from the secondary digester is partly recycled back into the primary digester and the rest is sent to effluent buffer tank.

Anaerobic Digester

BIOGAS COLLECTION AND CLEANING

Biogas Collection: Biogas from both the digesters is stored in a Dry Membrane Type Gas storage system having a storage capacity of 5 hours. Neoprene rubber balloon used for gas storage are housed in an enclosure and are provided with level indication and metering devices, safety valves, moisture removal systems. Blowers are used for blowing the biogas from the gas storage to the gas cleaning section and then to biogas engine.

Dry Membrane Balloon Type Gas Holder

Biogas Flare : Biogas flare is used to flare the biogas when gas is not in use, excess generation of gas or during shut down. It has a pilot flame and control valves, which automatically flare the biogas.

Biological Biogas Scrubber Tower : The biogas generated contains a small percentage of H_2S, which needs to be scrubbed. The system provided is a proprietary scrubbing tower using specially developed microbial culture on a packing media. Nutrients are dosed, which are essential for the growth of microorganisms. The gas and liquid is passed in counter current in the tower and "clean" gas is fed to the engine. Nutrient dosing tank along with agitator, dosing pump (metering type) are used and dose is adjusted according to the H_2S content.

Biological Scrubber for Removal of H_2S

MANURE PROCESSING

The overflow of the secondary digester stored in an effluent buffer tank is passed through a thickener and then pumped into a decanter- centrifuge. The sludge from the bottom of the digesters is periodically pumped to the decanter. The solid cake from the decanter is stored in the manure storage yard and the effluent is taken for further treatment before it is pumped out for irrigation.

POWER GENERATION

100% biogas engine of 150 kW capacity is used for power generation from the biogas. Part of the electricity is used for captive consumption and the rest is exported to the state grid.

MATERIAL BALANCE

Material balance for 20 tonnes per day capacity biomethanation plant is as follows:

Vegetable waste :

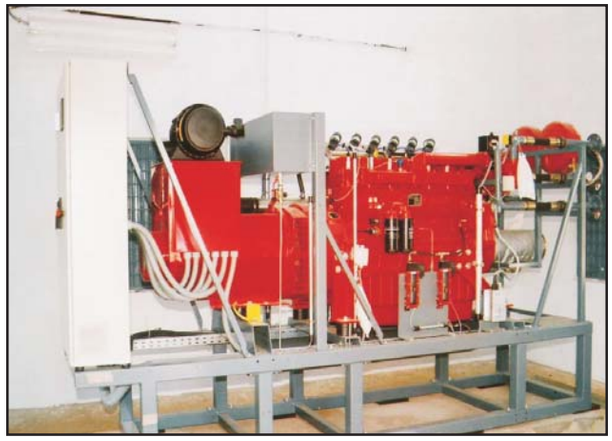
Total quantity	: 16 tonnes per day (pre-sorted)
• Total solids	: 18 %
• Total Volatile Solids	: 80 %

Slaughterhouse waste :-

Total quantity	:	4 tonnes per day
• Total Solids	:	20 %
• Total Volatile Solids	:	90 %
• Dilution water required	:	20 m^3 / day
• Digester retention time	:	28 days
• Volatile solids charged	:	3 tonnes / day
• Volatile solids destroyed	:	2.42 tonnes / day
• Biogas generated	:	1615 m^3/ day
• Biomanure produced	:	0.67 tonnes/ day

ENERGY BALANCE

• Auxiliary power	:	500 kWh/ day
• Energy generated	:	2800 kWh/ day
• Power exported to grid	:	2300 kWh/ day



Imported Biogas Engine

MANPOWER REQUIREMENT FOR PLANT

• Process Engineer	:	2
• Maintenance Engineer	:	1
• Laboratory Technician	:	1
• Operators	:	8

COST ECONOMICS

Total cost of the project is Rs. 283 Lakh.
The project has been set up with the aim to demonstrate biomethanation of mixed wastes. 75 % of the total cost has been provided by NBB and the rest by VMC. VMC owns the plant and is the beneficiary for the revenue generated from the electricity, manure and treated water from the project.

BENEFITS ACHIEVED

- **Employment Generation :** This waste to energy project is providing employment to about 12 employees at the project site.
- **Fuel Saving / Revenue Earned :** Saving is in terms of fuel required for shorter trips of the waste carrying trucks and less manpower requirement. Revenue is generated by sale of electricity, by sale of manure to local farmers; and by use of treated water for irrigation of grass lands to raise cattle fodder.
- **Waste Management / Cleanliness :** " This plant is so clean and environment friendly that I can't believe I am in a Waste Treatment Facility – Good. Keep it up." – a remark signed by one of the visitors to this treatment plant facility.

BIOMETHANATION PLANT BASED ON VEGETABLE MARKET WASTES AT KOYAMBEDU WHOLE SALE MARKET COMPLEX, CHENNAI, TAMIL NADU

- **Place of Installation** : *KOYAMBEDU Wholesale Market Complex (KWMC), Chennai, Tamil Nadu*
- **Date of Commissioning** : *June, 2005*
- **Status of Functioning** : *Under stabilization*
- **Implementing Agency** : *Central Leather Research Institute, Chennai*
- **Technology** : BIMA digester technology of *M/s ENTEC, Austria*

BACKGROUND

The Koyambedu Wholesale Market Complex is one of the projects evolved by the Chennai Metropolitan Development Authority (CMDA) to decongest the central business district of Chennai city and to facilitate trading of perishables items like vegetables, fruits and flowers. It has developed over an area of 60 acres with good infrastructural facilities to attract traders and consumers.

This Market Complex being one of the largest in Asia generates large quantity of organic wastes. About 80 tonnes of wastes is generated per day and at present; this waste is collected by a private agency and transferred to a transfer station within the market complex. From there, it is transported to the Kodungaiyur dumpsite by the Corporation of Chennai. Such organic waste dumps are a potential threat to the environment and the public health. Perishable nature of these wastes coupled with high moisture content promotes natural decomposition. This leads to emission of obnoxious odours and gases like methane, carbon dioxide which are potential greenhouse gases. The organic content of the wastes also provide an ideal medium for vector and pest breeding. As a result of this, there is always a risk of epidemic. Realizing that such wastes cause health hazards, CMDA has set up a waste treatment plant based on high rate biomethanation technology to generate electricity.

Koyambedu Wholesale Market Complex View

Central Leather Research Institute (CLRI), Chennai was involved as technology institution and an implementing agency.

DESCRIPTION OF THE PLANT

The process flow diagram of the plant is shown in Figure-I. Various unit operations of the plant are described below:

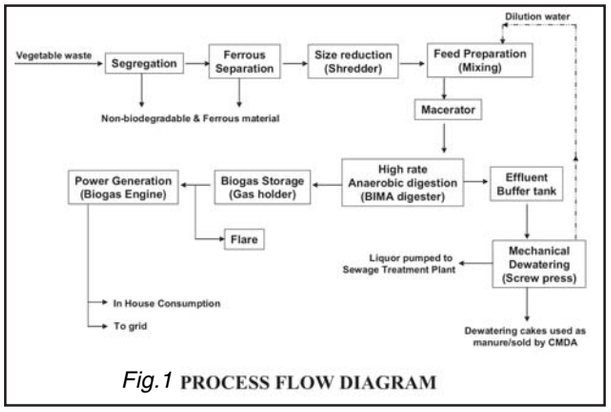


Fig.1 PROCESS FLOW DIAGRAM

Receiving Area

The waste collected from the vegetable market is brought to the existing transfer station where packing material and silts are removed. The waste free from plastics, cloth, stones, slit and other impurities is transferred to the receiving area and collected at the receiving platform.

Waste Handling

On the receiving platform, a mechanical handling system namely "Grab" with traveling electric hoist is provided to handle the received waste and the walkway is provided for the person to handle the Grab. The waste is transferred by the Grab to the feeding hopper of the conveyor and transferred through the conveyor for size reduction

Waste Segregation

The waste being carried through the conveyor is sorted by persons standing on the supporting platforms parallel to the conveyor. The inerts such as plastics, clothes, wood, stones, which are not biodegradable, are removed.

Ferrous Separation

Magnetic separator is provided parallel to the conveyor so that the iron (ferrous) materials, if any, which would get stuck to the magnetic separator and the iron materials are removed manually and stored in the bins for sale/ disposal.

Size Reduction

The waste is delivered into the Shredder to reduce the wastes to uniform size of around 15 - 20 mm. Shredder has knives which cuts the wastes into small particles. The shredder can process about 4 tonnes /h.

Feed Preparation

The fresh vegetable waste is blended in a collection tank to provide a waste of uniform characteristics, and a feed stock with a solid concentration not exceeding 10%.

Anaerobic Digestion (BIMA Digester)

The plant involves the emerging concept of anaerobic digestion. “Biogas Induced Mixing Arrangement”, BIMA Digester, utilizes the vegetable waste, where stabilization takes place with the production of biogas. The main advantages of BIMA digesters are its mixing system (doesn’t have any mechanical moving parts), ability to control scum/sediments and handle high solids concentration.

Overall view of the Plant

Biological H_2S Removal System

Hydrogen Sulphide (H_2S) content of biogas has to be reduced before the gas is used as fuel in gas engine since H_2S will corrode the gas engine parts and reduce the performance and life of the engine. Hence H_2S content has to be reduced to a permissible level of 500 ppm before the gas is used in the gas engines. A biological desulphuration system, in built in BIMA digester, has been installed. A group of facultative bacteria which adhere to the walls of BIMA digester separating the upper and main chamber are utilised for biological desulphuration.

Biogas Collection

The biogas, which is produced by anaerobic digestion of waste, leaves the digester automatically to the gas holder and contains about 60% methane and 40% carbon dioxide. In place of a conventional gas holder which is prone to corrosion, a dry type gas holder, which is made of a synthetic membrane (polyester) and is suspended in a concrete silo, has been installed in the plant.

Power Generation

The produced biogas, after removal of hydrogen sulphide, is used as fuel to produce electricity. The gas is withdrawn from the gasholder by gas blowers and is blown into the gas engine. An alternator is connected to the engine to produce electricity. A 230 kW, 100% biogas engine imported from M/s Deutz Germany is installed for generation of electricity. The net power generated after captive consumption is exported to the State Elecetricety Grid.

Biogas Flare

In case of maintenance of gas engine and when gas exceeds beyond the storage capacity of the gasholder, the biogas is burnt in the flare, which is an automatic device with an auto start arrangement having auto ignition with spark plug.

Dewatering of Digested Substrate

The digested substrate from biogas digester is collected in an effluent buffer tank for dewatering. Dewatering is carried out in a screw press of capacity 6 m^3 / h. The digested substrate is pumped to screw press by screw pumps. One continuous type of screw press 6 m^3 / h capacity, which consists of rotating screw fitted closely inside a curb has been installed. As the screw is rotated, the material is moved forward and consequently the pressure is increased. The centrate is discharged through the openings in the curb and the dewatered cake is discharged at the other end of the press. The liquor from screw press is used as liquid fertiliser in CMDA campus or is pumped to nearby STP for further treatment. The dewatered cakes are disposed by CMDA for use as manure.

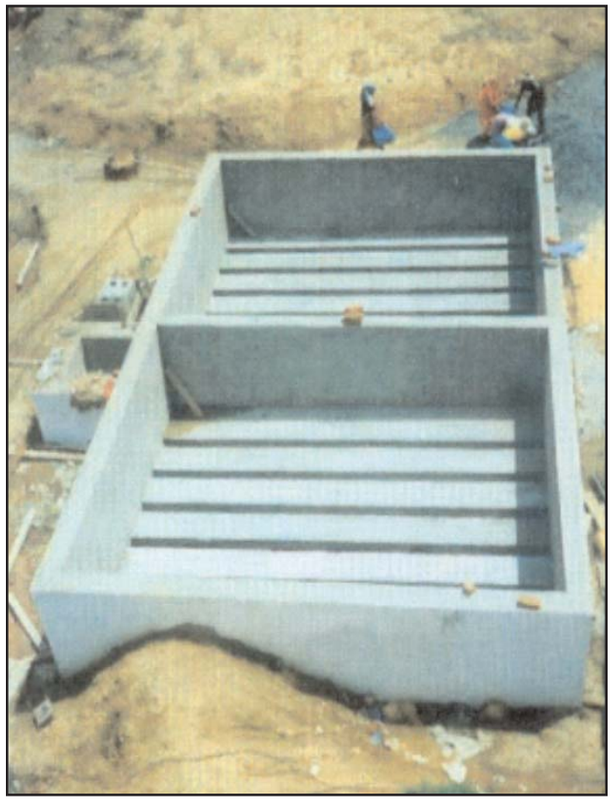
Screw Press

Odour Control System

The following units are connected to the biofilter to reduce the odour at the plant :

- Receiving area
- Conveyor
- Shredder
- Feed preparation tank
- Screw press

PVC pipes are taken out from the above units and connected through a common PVC pipe to the bio-filter where the odour is controlled. Bio-filter is nothing but a concrete tank with two compartments and a common chamber. Inside the tank, channels are constructed through which the odorous air is collected from the units is passed. The media is provided in both the compartments of the bio-filter to remove the odour.



Odour Control System

WASTE ARRANGEMENT, BIOGAS AND MANURE UTILIZATION

The Market Authorities are presently having waste collection arrangement through its sub-contractor and the vegetable waste is delivered at the plant site. The biogas generated is used as fuel in gas engine and the excess power generated is exported to TNEB grid. The dewatered cake is sold / used as manure by CMDA.

MATERIAL BALANCE

- Quantity : 30 tonnes/day
- Water required to reduce the Solid concentration to 12% : 32.5 m^3/day
- Make up water available from effluent treatment plant : Nil
- Efficiency of BIMA digesters : 55%
- Total VS in the waste : 5.70 kg/day
- Loading rate : 3 kgs/m^3/day
- Biodegradable Volatile Solids : 5.70 tonnes/day
- Volatile Solids destroyed : 3.135tonnes/day
- Hydraulic retention time : 36.6 days.
- Biogas production : 2500 m^3/day
- Biosludge production (25% solids) : 10 tonnes/day

ENERGY BALANCE

- Energy generated in the plant : 5250 kWh/day
- Auxiliary power requirement : 433 kWh/day
- Net energy for export : 4817 kWh/day

MANPOWER REQUIREMENT FOR PLANT

- Engineers (Electrical / Mechanical) : 2
- Chemist : 1
- Helper : 6

PROJECT COST

Total cost of the project is about Rs. 5.00 crore.

BENEFITS ACHIEVED

- **Reduction in Emission of Greenhouse Gases :** Waste to Energy conversion plant has resulted into 80% reduction in GHG emissions by this quantity of waste, capturing of methane and its utilization for generation of electricity.
- **Employment Generation and Benefits to Local Community / Industry :** Employment for about 10 persons for operation and maintenance of the Plant.
- **Waste Management/ Cleanliness :** Project is environment friendly and provides a means of keeping the premise clean.

NISARGRUNA BIOMETHANATION PLANT FOR SORTED MUNICIPAL SOLID WASTES DEVELOPED BY BARC, MUMBAI, MAHARASHTRA

- **Place of Installations** : *At and Around Anushaktinagar, Mumbai, Maharashtra*
- **Installations** : *Five Plants since June 2001*
- **Status of Functioning** : *Functioning Satisfactorily*
- **Implementing Agency** : *Bhabha Atomic Research Centre (BARC), Mumbai.*
- **Technology** : *Modified Conventional Gobar Gas Plant*

BACKGROUND

NISARGRUNA technology involves use of biphasic digestion. The aerobic phase involves use of thermophilic bacteria, which digest the waste slurry mainly to organic acids. Thermophilic bacteria are sustained using hot water, which in turn is obtained, by using solar energy. In the anaerobic phase methane generation takes place. The spent slurry is collected in manure pits provided with sand filters. This helps in recycling of water. The biodegradable garbage is reduced by 90% in this process. Two valuable by-products viz. methane and manure make the plant economically self-sustainable. Use of thermophilic bacteria and related modifications have increased the scope of conventional gobar gas plant from gobar to any biodegradable material including stale food, which is otherwise difficult to process. Such decentralized plants can be installed to solve major problems in urban areas where solid waste management has been a persistent problem. In rural areas such plants may turn out to be energy and manure sources.

DESCRIPTION OF THE PLANT

Design of NISARGRUNA plant

The NISARGRUNA plant work on similar principles of traditional gobar gas plants with the exception of type of feed with the above modifications. The biogas plant has following components:

i) A mixer / pulper (5 HP motor) for crushing the solid waste
ii) Premix tanks (3)
iii) Predigester tank
iv) Air Compressor
v) Solar heater for water heating
vi) Main digestion tank (35 m^3)
vii) Gas delivery system
viii) Manure pits (4)
ix) Tank for recycling of water and water pump
x) Gas utilisation system

Processing in NISARGRUNA Plant

The waste generated in kitchen in the form of vegetable refuge, stale cooked and uncooked food, extracted tea powder, waste milk and milk products can all be processed in this plant. There are two important modifications made in the conventional design of the biogas plant in BARC. A 5 HP mixer has been introduced to process the waste before putting it into predigestor tank. The waste is converted in slurry by mixing with water (1:1) in this mixture. Usually this is the failure point as solid waste is difficult to get digested and can easily clog the system. The other modification is use of thermophilic microbes for faster degradation of the waste. The growth of thermophiles in the predigestor tank is assured by mixing the waste with hot water and maintaining the temperature in the range of 55-60^{o}C. The hot water supply is from a solar heater. Even few hours sunlight is sufficient per day to meet the needs of hot water.

After the predigestor tank the slurry enters the main tank where it undergoes mainly anaerobic degradation by a consortium of archaebacteria belonging to *Methanococcus* group. These bacteria are naturally present in the alimentary canal of ruminant animals (cattle). They produce mainly methane from the cellulosic materials in the slurry. The undigested lignocellulosic and hemi-cellulosic materials then are passed on in the settling tank. After about a month high quality manure can be dug out from the settling tanks. There is no odour in the manure. The organic contents are high and this can improve the quality of humus in soil, which in turn is responsible for the fertility.

The gas is generated in the main tank and is a mixture of methane (70-75%), carbondioxide (10-15%) and water vapours (5-10%).

Chemical analysis of organic manure shows, Carbon 35-40%; Nitrogen 2-3.5%; Phosphorous 0.5-0.9%; and Potassium 0.5 - 0.8%. This manure would have maximum benefit when used in slurry form. However, transportation may be a problem, hence it may be air dried and used. An important character of this manure is that it is weed free. The weed seeds present in vegetable matter and other waste materials are killed in predigester due o higher temperature and acidic conditions.

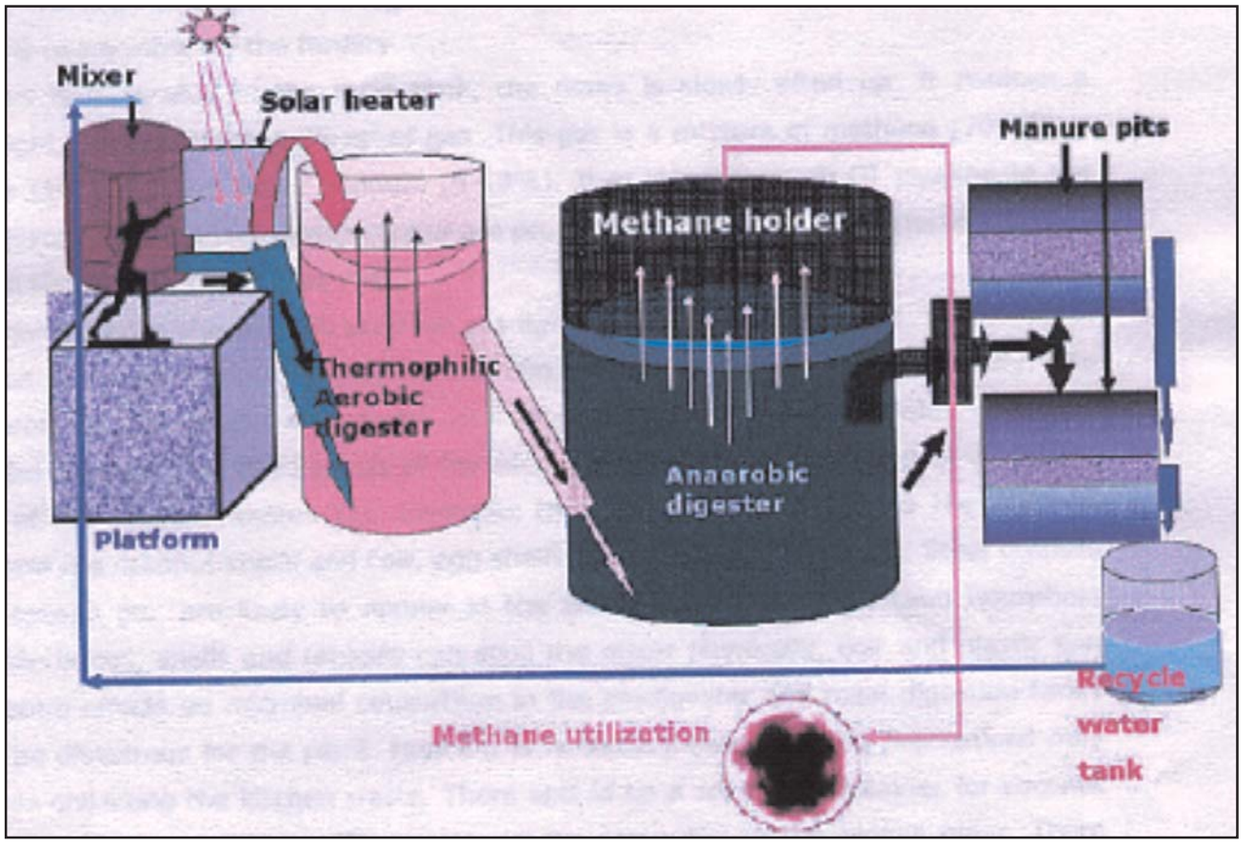


Fig.-1 : BARC model of kitchen waste biogas plant

Types of Biodegradable Waste that could be Treated in the Nisargruna Plant

Vegetable and fruit market waste, fruit and food processing industries waste, kitchen waste from residential colonies / schools / colleges / army / big establishment canteens, hotels, hostels, hospital / religious places, paper, garden waste, animal and abattoir waste etc. Municipal Authorities, therefore, have to ensure of such segregated waste before putting up of the biogas plant.

Waste that cannot be Treated and to be Strictly Avoided for Nisargruna Plant

Coconut shells, egg shells, big bones, plastic/ polythene, glass, metal, sand, slit, debris and building materials, wood, cloth / clothes, ropes.

Suitable Locations for Installation of Plant

Hotel premises, army / big establishment canteens (private / government), residential schools / colleges, housing colonies, religious places / temple trusts, hospitals, hotels, sewage treatment plants, villages etc.

Site Requirements

i) It should be close to sources of waste being produced and to the point of utilization of biogas power.

ii) It should be free from underground cables, drainage pipes etc.

iii) Water table should be below 3 meters

iv) A slightly sloping site would be helpful in enabling an easy flow of slurry.

Five such NISARGRUNA plants have been installed at and around Anushaktinagar area in Mumbai for environmental friendly disposal of about 20 tonnes waste generated in this area. Locations, Capacity and Date of Commencement are as follows :

Existing NISARGRUNA Plants

Location	Capacity,tpd	Date of commencement	Utility of gas
BARC, Mumbai	1	June 2001	Kitchen
Anushaktinagar, Mumbai	5	June 2002	Kitchen
BARC Hospital site	5	June 2003	Kitchen
Govandi, Mumbai	5	June 2003	Electricity since May 2005
Deonar, Mumbai	5	February 2005	Boiler (utility still to start)
INS Kunjali	1	June 2004	Kitchen
Proposed NISARGRUNA Plants			
Matheran, Maharashtra	5	December 2005	Kitchen
Malvan, Maharashtra	5	December 2005	Electricity
Hiranandani, Thane	5	October 2005	Yet to be decided
INS Chilka	2	December 2005	Kitchen

Cost Details, Saving and Payback Period from a Nisargruna Plant

The cost details and the savings envisaged from the plant are given in the Table-1. The life of the plant could be 20 –30 years and payback period is 4-5 years.

Table-1

Treatment Capacity (tones/ day)	Installation Cost* (Rs. in lakhs)	Monthly Operation & Maintenance Charges (Rs.)	Methane Generation (Cu. m.)	Manure Production (tones/ day)	Requirements					Savings
					Area, m^2	Power	Manpower	Fresh Water (Kl/day)	Hot water (l/day of 50-60^{0}C)	Cooking (Equivalent LPG Cyl/day) /Power (kW)
1	5-6	8,000	100-120	0.1	300	5 hp for 2 hrs.	2	2	200	2-3 LPG cyl/day
2	9-10	12,000	200-240	0.2	500	5 hp for 3 hrs.	3	3	400	4-5 LPG cyl/day
4	20-22	22,000	400-480	0.3	700	5 hp for 3 hrs.	4	5	400	8-10 LPG cyl/day
5	28-30	30,000	500-600	0.5	800	10 hp for 4 hrs.	5	7	600	12-14LPG cyl/day /25kW
10	65-70	50,000	1000-1200	2.5	1200	15 hp for 4 hrs.	10	15	1000	22-25 LPGcyl/day /50kW

* This is an approximate cost for biogas generation plant and may increase by 10-20% depending on location, site-specific parameters, cost of materials, labour cost etc. in different states/cities. Cost of additional infrastructure like office space, toilets, security, and power generation will be extra, if required.

ANIMAL/AGRO RESIDUE

BIOMETHANATION PLANT BASED ON CATTLE DUNG AT HAEBOWAL, LUDHIANA, PUNJAB

- **Place of Installation** : *Haebowal, Ludhiana*, Punjab
- **Date of Commissioning** : *October 2004*
- **Status of Functioning** : *Functioning Satisfactorily*
- **Implementing Agency** : *Punjab Energy Development Agency, Chandigarh*
- **Technology Supplier** : *BIMA of M/s ENTEC, Austria*
- **Technology Institution for Supervision** : *Chemical Engg. Deptt., Indian Institute of Technology, Roorkee, U.A.*

BACKGROUND

In Ludhiana until the mid 70's, dairies were spread all over the city and their operations were an indirect cause of health and environmental problems. Subsequently, all such dairies were shifted to two dairy complexes (one at the east end and the other at the west end) at the outskirts of the city. One such location is the Haebowal dairy complex which is spread over an area of 50 acres. It has 1490 dairies with an animal population of about 1,50,000 and generates about 2500 tonnes per day of animal wastes (droppings). Although about 20-30% of the waste is collected for the manufacture of dung cakes, a good portion of it is dumped in the open spaces in the dairy complex. The remaining wastes are flushed into the drains which are discharged to the canal and ultimately to the Sutlej River. These disposal practices lead to the deterioration of the environment(air and water both) and have adverse impact on health and hygiene at the local levels besides emission of green house gases (GHG) to the atmosphere.

In order to reduce GHG emissions and to prevent improper disposal of the wastes, a demonstration facility to treat 235 tonnes of animal waste was set up in this dairy complex for generation of one MW of electricity and 47 tonnes / day of stabilized organic manure.

DESCRIPTION OF THE PLANT

The plant includes the various unit operations as described below :

Dissolution (Homogenization of Raw Manure)

The fresh animal dung is blended in a collection tank to provide a waste of uniform characteristics, and a waste feed with a solid concentration not exceeding 10%.

Anaerobic Digestion

The plant involves the emerging concept of anaerobic digestion. "Biogas Induced Mixing Arrangement", BIMA Digesters installed for this project, utilize the homogenized (diluted) Cattle Dung, where anaerobic digestion takes place with the production of biogas. The main advantages of BIMA digesters are its mixing system (doesn't requires mechanical moving parts), ability to control scum/sediments and handle high solids concentration. A biological desulphurization unit has been installed in the digester to reduce the H_2S content of biogas below 500 ppm before it can be utilised for power generation through a biogas engine.

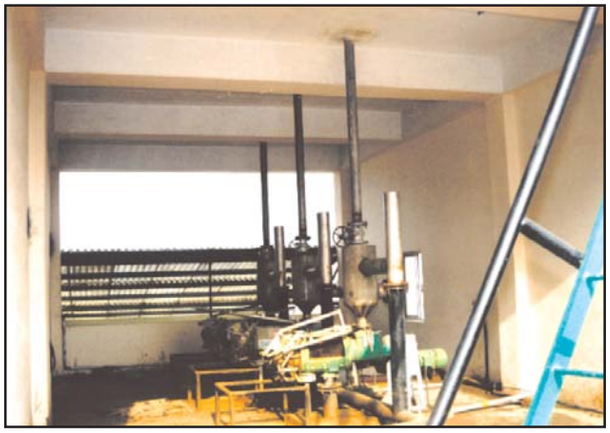
Biogas Collection

The biogas, which is produced as a result of stabilization of the waste, leaves the BIMA digester automatically to the gas holder. The biogas consists of 55 - 65% methane and 35-40% carbon dioxide. In place of a conventional gas holder which is prone to corrosion, a dry type gas holder made of a synthetic membrane (polyester) and suspended in a concrete silo, has been installed in the plant.

Two BIMA Digesters and the Gas Holder

Biofertilizer Production

The digested substrate leaving the digester is dewatered in a screw press. The dried manure shows a much better availability of nutrients for the plants due to its biochemical composition. The manure is almost free of odour and can be precisely applied due to its homogeneity.



Screw Presses

Effluent Treatment Plant

The BOD/COD concentration of the press water is reduced by treatment of the high concentration press water through Activated Sludge Process in the effluent treatment plant to meet the regulatory discharge standards. The effluent is recycled to the homogenization tank and the settled solids are sent to the drying yard. Some of the activated biomass (settled solids) is recycled to the aeration tank to maintain the food to micro-organism ratio.

TECHNOLOGY INVOLVED

Biologically Induced Mixing Arrangement (BIMA) technology has been used for Anaerobic Digestion. Process layout of the plant is shown in Figure-1.

Effluent Treatment Plant

Gas Engine with associated piping network

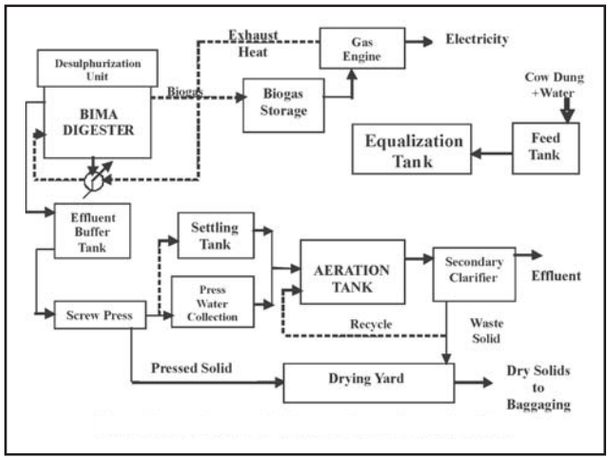


Fig.-1 Layout of the Process Plant

WASTE ARRANGEMENT, BIOGAS AND MANURE UTILIZATION

Cattle waste collection is done through a contractor. Biogas is used to generate power, which is being sold to the state utility. The nutrient rich manure is sold to farmers.

MATERIAL BALANCE

Material balance calculation of the plant for a feed of 235 tonnes/day of raw waste is as under :

- Raw Feed (solid concentration 16%) : 235.0 tonnes/day
- Water required to reduce the solid concentration to 10% : 141.0 m^3/day
- Make up water available from effluent treatment plant : 290 m^3/day
- Volatile Solids Loading Rate : 30 tonnes/day
- Digester Retention Time : 27 days
- Efficiency of BIMA Digesters : 55%
- Lignin Content of the Waste : 35.65 %

- Biodegradable Volatile Solids : 19.5 tonnes/day
- Volatile Solids Destroyed : 10.725 tonnes/ day
- Biogas Produced : 9116.0 m^3/day
- Biofertilizer Production : 47 tonnes/day

ENERGY BALANCE

Energy balance calculation of the plant is as under:

- Auxiliary power requirement : 2600 kWh/day
- Energy generation from plant : 19800kWh/day
- Power to be exported to grid : 17200kWh/day

MANPOWER REQUIREMENT FOR PLANT

- Engineers [Civil/ Electrical/ Mechanical] : 3
- Chemist : 1
- Accountant : 1
- Supporting Staff : 5

COST ECONOMICS

Total cost of the project is Rs. 13.66 crore. 50% has been borne by PEDA and the rest by NBB / MNES, GOI as grant. It is expected to be economically viable at the electricity rate fixed by State Electricity Board and the revenue to be generated from manure disposal.

BENEFITS ACHIEVED

- Reduction in emission of greenhouse gases :
- Emission of GHG before and after setting up the plant is as follows:
- Without Plant : 1002.753 kg CO_2– C equivalent / hr
- With Plant : 201.354 kg CO_2 – C equivalent / hr

Waste – to - Energy conversion plant has resulted into 80 % reduction in emission of GHG.

- **Employment Generation :** Waste to energy conversion plant is providing employment to about 100 persons for the collection of cattle waste.
- **Revenue Earned :** Through sale of electricity and digested manure
- **Waste Management/ Cleanliness :** Provides a sound means of waste recycling and the project is environmental friendly.

OPERATIONAL DIFFICULTIES AND TROUBLE SHOOTING

Problem of wearing out of Screw Presses, and choking of Feed Pump have been experienced, but after modifications, these are now running satisfactorily.

BIOGAS UTILISATION FOR GENERATION OF POWER

EVALUATION OF PERFORMANCE OF BIOGAS ENGINES INSTALLED AT KANPUR AND VARANASI, UTTAR PRADESH

- **Place of Installation** : *Kanpur and Varanasi, Uttar Pradesh*
- **Period of Evaluation** : *March – December 1999*
- **Status of Functioning** : *Generating power for 4–6 hrs daily since commissioning*
- **Implementing Agency** : *U.P. Jal Nigam, Uttar Pradesh*
- **Technology Institution** : *CGPL, Indian Institute of Science, Bangalore*

BACKGROUND

UP Jal Nigam has set up STPs at different cities in Uttar Pradesh under Ganga Action Plan for treating the municipal wastewater to the desired level. Two sewage treatment plants namely 5 mld capacity based on UASB technology at Jajmau, Kanpur and 8 mld capacity based on Activated Sludge Process (ASP) at Bhagawanpur, BHU, Varanasi were selected for performance study where biogas generated was being used in duel fuel engines for generation of power for use in the treatment plants. The engines used were three engines of 70 KVA each, at Varanasi and one engine of 40 KVA at Kanpur, all DFG Kirloskar Cummins make. The important findings of the evaluation study are as under:

i) It was observed that duel fuel engines, which were installed to run on biogas produced from the plants were non-functional and were heavily corroded because of the presence of H_2S gas as H_2S when come in contact with moisture produces sulphuric acid.

ii) The biogas, which is mainly a mixture of methane and carbon dioxide also has hydrogen sulfide in different concentrations depending on the source of effluent generating the gas. This hydrogen sulfide being a highly corrosive and toxic gas required to be scrubbed to avoid the failure of engine parts. Though the requirement for engine application, as per published literature and as mentioned by the suppliers of 100% biogas engines, is less than 0.1 % (i.e. < 1000 ppm) of hydrogen sulfide in the sweet gas, lower the concentration better is the life.

iii) Hydrogen sulfide scrubbing system based on ISET process developed by CGPL, IISc Bangalore, were installed at these plants at a later stage which is an economical and efficient way for removal of hydrogen sulfide in the raw gas to less than 100 ppm. The sweet biogas was then used in the dual fuel engines.

iv) The performance evaluation of biogas engines shows that the diesel replacement upto 70 % in the dual fuel mode is possible.

v) The biogas generation and energy recovery from these sewage treatment plants was as mentioned below.

vi) It was inferred that at Varanasi, the power generation potential from biogas in a day is 816 kWh of electricity against the total power requirement of 2092 kWh. While, the electricity generation at Kanpur was about 288 kWh /day which make the plant self sufficient with respect to the energy requirement for the treatment.

BENEFITS ACHIEVED

- Reduction in Greenhouse Gas Emission
- Employment Generation
- Saving of Fossil Fuel / Revenue Earned

Location	Strength of Sewage	Plant Capacity, MLD	Biogas Yield, m^3/ kg of COD removed	Biogas Generation, m^3/day	Total Installed Load at Plant, kWh /day	Generated Electricity (at 30% engine efficiency) kWh/day
Jajmau, Kanpur	Low	5.0	0.15	150.0	244	288
Bhagwanpur, Varanasi	Low	8.0	0.15	371.0	2092	816

BIOGAS BASED POWER GENERATION PLANT AT ANJANA SEWAGE TREATMENT PLANT, SURAT, GUJARAT

- **Place of Installation** : *Surat,Gujarat*
- **Date of Commissioning** : *October 2003*
- **Status of Functioning** : *Functioning Satisfactorily*
- **Implementing Agency** : *Surat Municipal Corporation, Surat*
- **Technology Provider** : *Biogas Engine Generator of Spanish origin*
- **Technology Institution for Supervision** : *Sardar Vallabhbhai National Institute of Technology, Surat*

BACKGROUND

There are six sewage treatment plants installed in the City of Surat. Out of which four plants have sludge digesters wherein biogas is also being generated. The average biogas generation is about 100-120 m^3/ h from each digester at Anjana STP. The average power consumption is about 2,55,000 kWh / month and the electrical energy bill is about Rs. 10.00 lakhs / month. Municipal Corporation, Surat, therefore, considered it appropriate to utilize the biogas available for generation of power, which would be sufficient to meet the power requirement of the plant besides aiming to reduce the emission of Green House Gases (GHG).

Biogas collecting Blowers and its piping

DESCRIPTION OF THE PLANT

This plant includes various components such as a twin tower H_2S scrubber, on line gas analyzer, inflatable - polymer based gasholder, automated biogas flaring system, 100% biogas engine generator set, etc. The Schematic diagram of biogas based power plant is given at Figure-I. Various units of the plant are as described below.

Biogas Collection System

There are three conventional anaerobic sludge digesters installed at Anjana STP which, currently generate @ 4200 -4320 m^3/day of biogas. Twin lobe type root blowers operated with variable speed drives are provided to collect the biogas from the digesters and to transfer the gas to the scrubber and then to the polymer based gas balloon. Evacuation of biogas from the digesters is controlled by the gas pressure developed in the digesters.

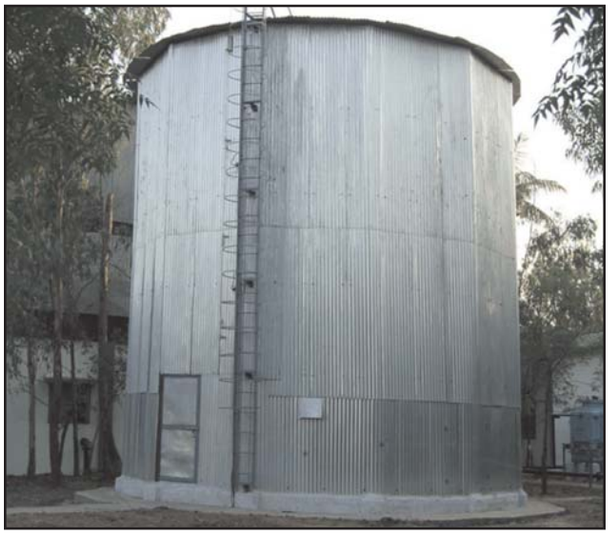
H_2S Scrubber

Biogas collected from the digesters contains hydrogen sulphide (H_2S). To minimize H_2S, the biogas is passed through a twin tower chemical scrubber consisting of a packed bed tower supplemented by a ventury jet column. This scrubber is designed to scrub the biogas to reduce the H_2S level to 100 ppm at the outlet of the scrubber. NaOH is used as a scrubbing solution in this scrubber. On line H_2S analyzers and methane analyzers are provided at the inlet and outlet of the scrubber to monitor the gas composition.

H_2S Scrubbing System

Foil Bag Membrane Type Biogas Holder

A foil bag type Gas Balloon made of synthetic membrane, encased in a MS fabricated, GI sheet lined protection silo serves as a buffer tank to store around 450 m^3 of biogas. This gas storage system helps to even out the fluctuations in the gas generation within the digesters, if at all, during the day.



Biogas holder with MS protection Silo

Automatic Biogas Flaring System

The biogas generated from the digesters contains methane gas as a major constituent which is a green house gas. In order to prevent the excess biogas from escaping to the atmosphere, an automatic biogas flaring system is provided which burns the biogas and reduces the emission of green house gases.

Biogas Flaring System

Biogas Blowers for the Engine Generator Set

For efficient combustion to take place within the imported 100% biogas engine, it is imperative to maintain certain minimum pressure of the biogas at the inlet of biogas engine. Twin lobe type root blowers are provided just before the biogas engine to consistently maintain this parameter during the engine operation. These blowers are connected in such a way that it can suck biogas from biogas holder and/or directly from digester.

Biogas Blowers for Engine, Cooling Tower

Biogas Engine Generator Set

The biogas engine generator set is the main heart and soul of this power generation plant. The Capacity of the installed Biogas engine generator set is 730 kVA and is capable of operating with a wide variety of gases including, natural gas, sewage gas, landfill gas etc. as fuel with minimal adjustments. The electrical efficiency of this engine generator set is 35.4 % at full load.

Biogas Engine Generator & its Auxiliaries

Supervisory Control and Data Acquisition System

Supervisory control and data acquisition system has been installed for the precise and efficient control of the plant process and also to collect and store data generated from various field instruments such as digester pressure transmitter, biogas flow meter, on line CH_4 and H_2S analyzers, pH meter of H_2S scrubber, electrical power analyzer, various engine generator set

parameters, etc. Data so collected are used to generate various customized reports, to continuously monitor the plant condition, efficiency and also to plan for scheduled maintenance etc.

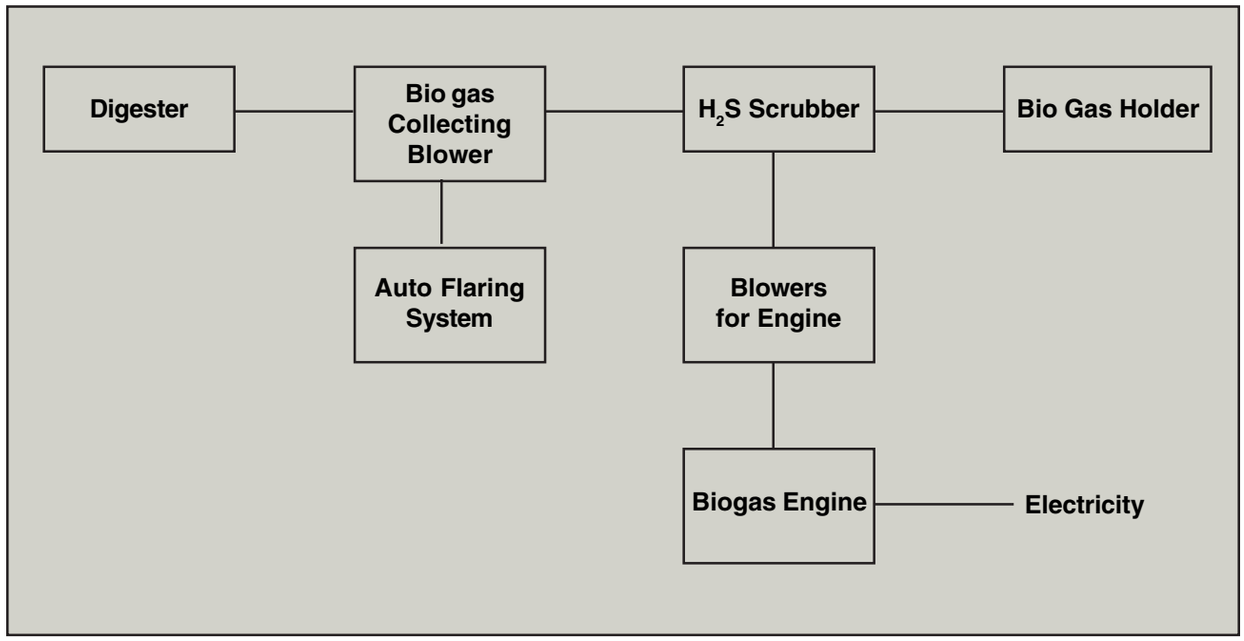


Fig. 1 - The Schematic diagram of biogas-based power plant

WASTE GENERATION AND DISPOSAL

Used scrubbing solution in the H_2S Scrubber is the only waste generated in this power plant. The used scrubbing solution, so negligible in quantity, is diluted and given a treatment along with the inlet sewage into the Sewage Treatment Plant. Practically, the power generation plant along with the sewage treatment plant is working on the principle of Zero Waste System.

MATERIAL BALANCE

Material balance, in terms of biogas generation and its utilization is as under:

Biogas Contains

CH_4	67 %
H_2S	80 ppm
CO_2	32 %
N_2	0.3 %
Moisture	balance
Net Calorific Value	5600 kcal / NM^3

- Biogas generated from digester : 4320 m^3/ day
- Biogas consumed by engine : 3870 m^3/ day
- Biogas stored in gas holder : 450 m^3/ day
- Electricity generated : 6234 kWh /day
- Air consumed by engine : 5249 m^3/ day
- Water used in cooling & process : 22 m^3/ day
- Engine efficiency : 36.5 %

ENERGY BALANCE

• Bio gas consumption	3870
• Electricity generation	6234 kWh/day
• Auxiliary consumption	468 kWh/day
• Net electricity utilized in STP	5762 kWh/day

MANPOWER REQUIREMENT FOR PLANT

• Electrical Engineer	01
• Fitter	01
• Wireman	01
• Beldar/Cleaner	03

COST ECONOMICS

Total Capital Cost of Equipments/Machineries used for this project is Rs. 245.46 lakh, out of which 50 % was borne by Surat Municipal Corporation and the balance 50 % was borne by NBB. Cost of building for the power plant is Rs. 17 lakh, which is entirely borne by Surat Municipal Corporation. The power generated is for captive consumption for operations of Anjana sewage treatment plant, thereby drastically reducing grid power utilization. This process, besides waste minimization, reduction of release of green house gases into atmosphere, works as a cost effective and financially viable model saving immensely on energy bills.

BENEFITS ACHIEVED

- **Employment Generation :** This power plant is providing employment to about 6 persons.
- **Fuel Saving / Revenue Saving/Earned :** The non conventional biogas fuel becomes a source of energy to generate electricity, thereby reducing the utilization of Grid Power. An effective and intelligent means of conservation of conventional fuels coupled with drastic saving on energy bills.
- **Others :** Drastic reduction in emission of green house gases

OPERATIONAL DIFFICULTIES AND TROUBLE SHOOTING

The Power generation plant is working well and satisfactorily without any problems since commissioning.

POWER GENERATION FROM BIOGAS THROUGH INDIGENOUS HYDROGEN SULFIDE REMOVAL SYSTEM AND GAS ENGINES AT BELGAUM, KARNATAKA

- **Place of Installation** : *Ugar Khurd, Belgaum,Karnataka*
- **Date of Commissioning** : *August 2000*
- **Status of Functioning** : *Functioning Satisfactorily*
- **Implementing Agency** : *M/s Ugar Sugar Works, Belgaum*
- **Technology Provider** : *ISET Process developed by ABETS, CGPL, Indian Institute of Science, Bangalore*
- **Technology Institution for Supervision** : *ABETS, CGPL, IISc, Bangalore*

BACKGROUND

M/s Ugar Sugar Works Ltd., (USWL) had set up a biomethanation plant in its factory premises for their distillery effluent treatment to maintain the requisite pollution control. The raw biogas from ETP was earlier used in boilers or simply flared in a burner by USWL without utilizing the fuel potential of the biogas. This project was envisaged to generate power using biogas generated from the ETP installed at USWL.

Biogas mainly a mixture of Methane and Carbon dioxide has hydrogen sulfide in different concentrations depending on the source of effluent generating the gas. Hydrogen sulfide being a highly corrosive and toxic gas needs to be scrubbed to avoid the failure of engine parts. Though the requirement for engine application is less than 0.1 % (i.e < 1000 ppm) of hydrogen sulfide, lower the concentration better is the life. In this project, hydrogen sulfide scrubbing is carried out using ISET (Indian Institute of Science Sulpher Extraction Technology) process developed by Combustion, Gasification and Propulsion Laboratory (CGPL), IISc, which is an economical and efficient system for removal of hydrogen sulfide in the raw gas to less than 100 ppm. The sweet biogas is used in four gas engines of Greaves make, each of 300 kVA capacity.

DESCRIPTION OF THE PLANT

Design and Operating parameters of the plant for H_2S removal are as under :

Particulars	Design Parameters	Operating Conditions
• Raw gas flow rate, m^3/hr	600	600-800
• Hydrogen sulphide concentration, %	7.5	4 - 5
• Hydrogen sulphide in sweet gas	< 100 ppm	< 20 ppm

The System and its major elements are as follows :

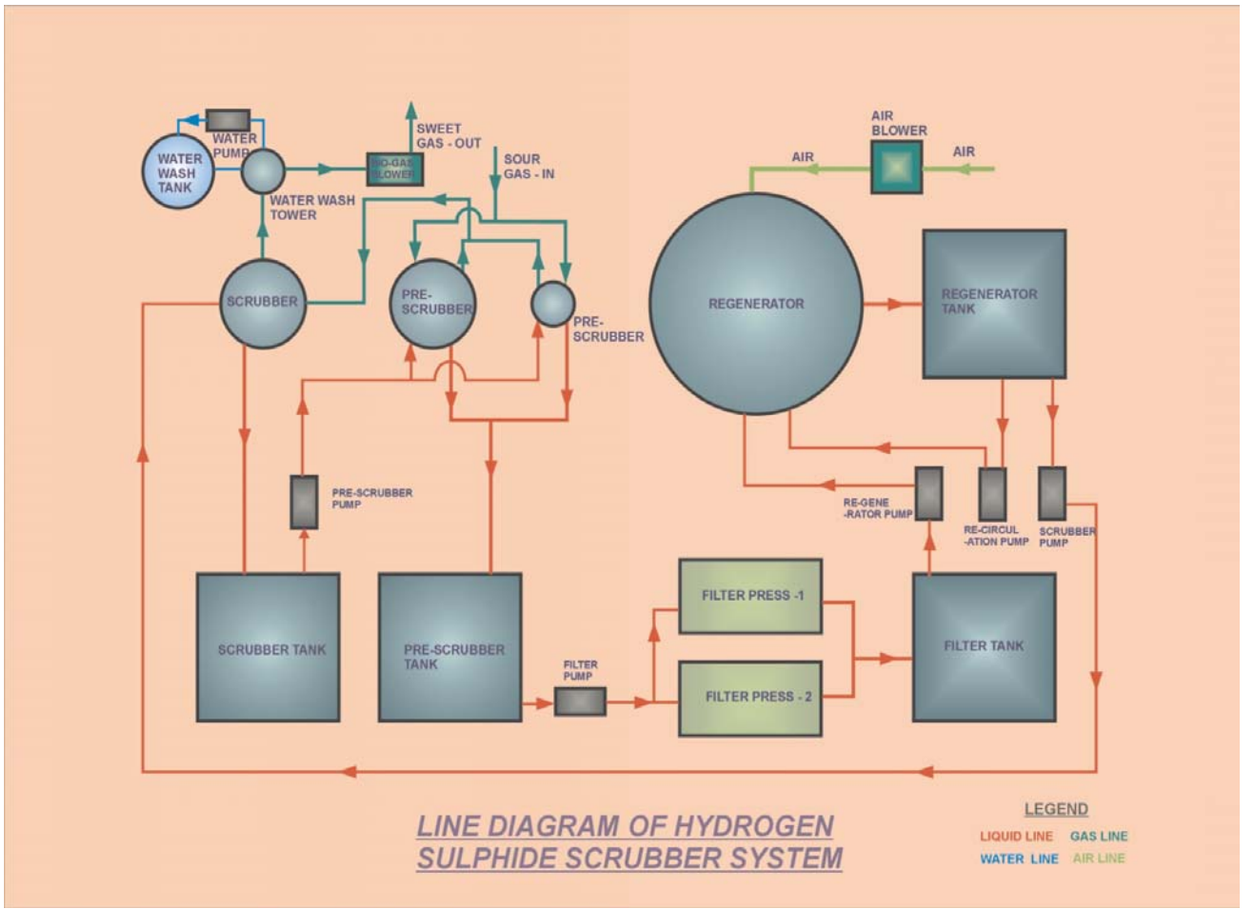
- Pre scrubber
- Scrubber
- Regeneration Tower
- Filter Press
- Wash Tower
- Biogas Blower
- Air Blower
- Pumps

Process Description and Operation : The process uses the counter current gas liquid contact in the designed packed columns for the required reactions. The process consists of three steps which are mentioned below.

a) Sweetening of Sour Gas : The raw gas containing hydrogen sulphide from the gas holder is scrubbed in a two stage counter current operation. The gas is first passed through the pre-scrubber from the bottom and the scrubbing solution is pumped from the top in a packed column containing large size packing material. During this process, most of the hydrogen sulphide gets converted to elemental sulphur. The partially sweet gas is then passed to the scrubber. Scrubber consists of smaller size packing to provide a larger surface area to increase the gas liquid contact area for reducing the hydrogen sulphide concentration to less then 100 ppm in the sweet gas. Scrubbing solution containing ferric ions is pumped at the top of the Scrubber and partially sweet gas from the Pre-Scrubber is passed from the bottom. The sweet gas from the scrubber is scrubbed with water to remove any trace chemical carryover. The scrubbed water is utilized in the system for cake washing or the water loss make up. The scrubbing liquid containing sulphur flows to a tank from where it is taken for sulphur removal.

b) Precipitated Sulphur Removal : The sulphur laden solution is pumped through the filter press for sulphur removal. The sulphur free solution is sent to regenerator for oxidation

The testing was carried out to establish the power level of the engines for biogas, as the engines were natural gas engines adopted for biogas. During the initial trials of engines, modifications mainly with the carburetor and



c) Regeneration : The reduced, sulphur free solution is pumped from the top of the regenerator and the air from the atmosphere is passed from the bottom. The reduced scrubbing solution reacts with air and gets oxidized to ferric ions.

The plant trials were started during third quarter of 1999 with scrubber being run first to establish the gas scrubbing quality and quantity which is vital to the power generation. The scrubber trials were completed in couple of week's time during which it was established that the scrubber was able meet the design specifications in quality of the sweet gas & the quantity of raw gas scrubbed. The peak gas flow rate was around 605 m^3/h and the plant was run at this flow rate for about 2 hrs. The sweet gas was initially used in single engine at a time to test the performance of each engine individually.

compression ratio were carried out to deliver the rated power of around 240 kW. Paralleling and synchronization of the engines were carried out subsequently in order to achieve the rated capacity of the plant. Since then the plant has been in operation for last four and a half years and has operated over 20,000 hrs during this period, scrubbed cumulatively around 3,200,000 m^3 of biogas and has generated around 4.5 million units of energy till date. The plant has been operating at a PLF (Plant Load Factor) of around 0.20 which is low compared to what is an achievable PLF of around 0.8. The energy generated at present is mainly used in the ETP area (where the plant is situated). The reason for such a low usage of the plant has been mainly insufficient gas production and load evacuation from the plant to other requirements in the factory

Scrubber and Pumps

Regenerator

TECHNOLOGY INVOLVED

The ISET process uses the red-ox potential of chelated iron ion for scrubbing hydrogen sulphide from the gas mixture. H_2S when dissolved in aqueous medium is ionized to H^+ and S^{2-}. The sulphur ions are oxidized by chelated iron ions, which can exist in both ferric (Fe^{3+}) and ferrous (Fe^{2+}) state. When the sulphur ion comes

Regenerator

One of the300 kVA Gas Engine from M/s. Greaves

in contact with ferric ion complex, it gets oxidized to elemental sulphur and is precipitated. In the process the ferric ions get reduced to ferrous ions.

$2Fe^{3+} + S^{2-} \quad 2Fe^{2+} + S$

The ferrous ions are later oxidized to ferric ions by reaction with oxygen in the atmospheric air.

$4Fe^{2+}+4H^{+}+O_2\ 4Fe^{3+} + 2H_2O$

SULPHUR UTLIZATION

The sulphur produced is being utilized for agricultural purposes in sugar fields identified by the factory and is priced at Rs. 2.0 per kg of sulphur.

MATERIAL AND ENERGY BALANCE

Material Balance : Period considered: August 2004 to September 2004

Particulars	Quantity
• Total quantity of gas scrubbed, m^3	1,879,974
• Total Quantity of hydrogen 4.5 % sulfide scrubbed at in the inlet (average measured value)	84,598
• Estimated sulfur generation for 84, 598 m^3 of hydrogen sulphide scrubbed, (kg)	108,819
• Actual sulphur generated in kg	113,380

Energy Balance : Period considered: August 2004 to September 2004

Particulars	Quantity
• Total quantity of gas scrubbed, m^3	1,879,974
• Total energy generated, kWh	2,671,450
• In-house energy consumption, kWh	908,205
• Energy exported, kWh	1,848,780
• Energy generated in kWh/m^3 of gas scrubbed	1.45

MANPOWER REQUIREMENT FOR THE PLANT

• Engineers (Electrical/Mechanical)	:	4
• Chemists/Operators	:	4
• Skilled Personnel	:	12

COST ECONOMICS

The total project cost incurred is Rs. 2.25 crore, of which Rs. 70 lakh has been provided by MNES as a part of 50 % cost sharing on the total hardware cost (Hydrogen sulfide scrubbing system and Gas engine cost). The present tariff considered for calculating the plant economics is based on the energy cost USWL gets from the State Electricity Board per unit of power that is being exported to the grid by their Co-generation plant and is Rs. 3.49 per unit of energy generated.

Particulars	Data
• Present Plant Load Factor (PLF)	0.20
• Cumulative gas scrubbed, million m^3	3.13
• Gross energy generated, million units	4.55
• In-house energy consumed, million units	1.50
• Net energy, million units	3.05
• Energy cost per kWh, Rs.	3.49
• Gross revenue generated excluding the in house power consumption*, million Rs.	10.63
• Present O & M cost per kWh gross energy generated (inclusive of chemical cost, manpower, engine maintenance) at present PLF of 0.2#, Rs	1.80
• O & M cost incurred, million Rs.	8.10
• Net Revenue generated, million Rs.	3.73

* Inclusive of revenue from sulfur of around 100 MT @ Rs. 2.0 per kg.

\# The plant load factor was limited due to the load evacuation constrained by the internal transmission lines of the industry.

It is necessary that the plant runs at higher PLF for better revenue generation for the user as suggested by the figures showing the present net revenue generation of around Rs. 75,000/month (after deducting the running cost) to an estimated revenue generation of around Rs. 1.1 million at a PLF of 0.8. The two reasons for such an increase estimate on the revenue generated at PLF of 0.8 are as follows :

i) The in-house power consumption remaining the same, as there is no decrease in any of the liquid and air flow rates in the scrubber at lower PLF. The present in-house power consumption is around 30 % of the gross energy generated and will be around 8–10 % of the gross energy generated at PLF of 0.8

ii) The manpower cost remains the same as it is at present even at higher PLF.

Present Revenue Generation at USWL at PLF of 0.20 and Estimated Monthly Revenue Generation at Achievable PLF of 0.8:

Particulars	PLF : 0.20	PLF : 0.80 (Achievable)
• Cumulative gas scrubbing, m^3	81,109	3,45,600
• Scrubber operation, hrs per month	496	576
• O & M cost per kWh (all inclusive), Rs	1.80	1.24
• Gross power generation kWh	1,15,890	5,18,400
• In-house energy consumption, kWh	39,175	39,175
• Net energy export, kWh	76,714	4,79,225
• Net Revenue generation (inclusive of revenue from sulfur sale), Rs	74,042	10,72,912

BENEFITS ACHIEVED

- **Greenhouse Gas Reduction :** Reduction of CO_2 – C by 3375 tonnes compared to diesel as fuel till date.
- **Employment Generation:** Direct employment is created to around 20 people for plant operation.
- **Fuel Savings/Revenue Earned :** At a selling price of Rs. 3.49 per unit of power the revenue earned at present operation is around Rs. 1.69 per unit and will be around Rs. 2.25 per unit of power when the plant is operated at 80 % capacity.
- **Others:** The precipitated sulphur generated is being used for agricultural purposes in the field as a pesticide.

OPERATIONAL DIFFICULTIES AND TROUBLE SHOOTING

Frequent choking of Scrubber with sulfur was experienced during the initial stages. Modification carried out in the Pre-Scrubber ensured that maximum quantity of sulphur (more than 90 % of total sulphur) was removed in Pre-Scrubber and this stopped the frequent choking of scrubber.

The gas engines procured were basically Natural Gas engines, which had to be modified mainly with respect to carburetor to achieve the required power output.

APPENDIX - LIST OF ADDRESSES

INDICATIVE LIST OF TECHNOLOGY PROVIDERS/ SUPPLIERS IN INDIA

BIOMETHANATION TECHNOLOGY

i) M/s ENKEM Engineers Pvt. Ltd.
824, Poonamalle High Road,
Kilpauk (Near KMC),
Chennai - 600010
Tel. : 044-26411362/26428992
Fax : 044-26411788
E-mail : enkem2000@vsnl.net

ii) M/s Mailhem Engineers Pvt. Ltd.,
14, Vishrambag Society,
Senapati Bapat Road,
Pune - 411 016.
Tel. : 020-24002285
Fax : 020-25659857
E-mail : info@mailhem.com

iii) M/s REVA Enviro Systems Pvt. Ltd.,
3, Suyog Nagar, Ring Road
Nagpur - 440 015
Tel. : 0712-2743123, 2743124
Fax : 0712-2743120

iv) M/s Linde Process Technologies India Ltd.
38, Nutan Bharat Society, Alkapuri
Vadodara-390 007
Tel. : 0265-2336319, 2336196
Fax : 0265-2335213/2313629

v) M/s Hydroair Tectonoics Pvt. Ltd.
401, "Devavrata", Sector-17,
Vashi, Navi Mumbai-400 705
Tel. : 022-27892813/68/95
Fax : 022-27893892

vi) M/s Chemtrols Engineering Ltd.,
Amar Hill, Saki Vihar Road, Powai,
Mumbai-400 072
Tel. : 022 –28575089/ 28570557
Fax : 022-28571913
E-mail : jaypee@chemtrols.org

vii) M/s Degrimont India Ltd.
Water and the Environment
D-43, South Extension - II,
New Delhi - 110 049
Tel. : 011-26481191, 26481192
Fax : 011-26228782

viii) M/s Global Environmental Engg. Ltd
1233/C, K. G. Mansion
Opp. Hotel Kohinoor Executive, Apte. Road,
Pune - 411 004
Tel. : 0212-2327876, 2328007
Fax : 0212-2328441

ix) M/s UEM India Limited
D-19, Kalkaji,
New Delhi-110 019
Tel. : 011-26447825/ 26421634
Fax : 011-26239801
E-mail: uemindia@uemgroup.com

INCINERATION/ COMBUSTION TECHNOLOGY

x) M/s SELCO International
H.NO:1-10-74, R K Apartments
Ashok Nagar
Hyderabad-550 020
Telefax : 040-27650114
E-mail : selco@satyam.net.in

xi) M/s Shriram Energy Systems Ltd.
7-1-29, United Avenue (North End)
G1 B – Block Ameerpet
Hyderabad-500016
Tel.: 040 -23739552
Fax: 040 -237 39551
E-mail: shriramenergy@yahoo.com

ENGINEERING COMPANY / TURNKEY CONTRACTOR

xii) M/s Batliboi Environmental Engineering Ltd.
Batliboi House, Govandi (W)
Mumbai-400 043
Tel. : 022-25587421/ 25583031
Fax: 022-25566677/ 25566949
E-mail: beel@vsnl.com

BIOGAS ENGINE SUPPLIER

xiii) M/s Green Power International (P) Ltd.
B-46, Ist Floor, Kalkaji
New Delhi-110019
Tel. : 011-26447526 / 26447527
Fax : 011-26447525
E-mail gpil@greenpowerintl.com

xiv) M/s Cogen India Engineering Pvt. Ltd.,
5, Saraswati Heights,
759/39, Deccan Gymkhana,
Pune- 411004,
Tel. : 020-25676435 / 6
Fax : 020-25675824
E-mail cogen@bom3.vsnl.net.in

xv) M/s Guascor S.A., (Spain)
M/s APE (India) Ltd,
19 Community Centre, East of Kailash,
New Delhi-110 065
Tel. : 011- 26443889/ 26420938
Fax : 011- 26470867
E-mail ape@vsnl.com

xvi) M/s. Greaves Ltd.
Diesel Engines Unit
Chinchwad, Pune-411019
Tel. : 020-27472101/ 27473569
Fax : 020-27472276
E-mail : sysengg@GRVSMKTG.XEEPNQ.xeemail.com

Note : The above list is as per the information available in the Ministry and should not be taken as recommendation of the Ministry. The implementing agencies / beneficiaries, therefore, need to ascertain about their experience / ability in demonstrating the technologies before finalizing the implementation of projects.

TECHNOLOGY INSTITUTIONS INVOLVED IN INSTALLATION OF DEMONSTRATION PROJECTS UNDER UNDP / GEF PROJECT

i) Director,
Central Leather Research Institute,
Adyar, Chennai – 600 020
Tel. : 044-24911386/ 24910945
Fax : 044-24911589
E-mail : clrim@vsnl.com

ii) Chairman,
GPL, Dept. of Aerospace Engineering,
Indian Institute of Science,
Bangalore – 560 012
Tel. : 080-23600536 / 22932338
Fax : 080-23601692 / 23600085
E-mail : nksr@cgpl.iisc.ernet.in
nksr@aero.iisc.ernet.in

iii) Director
Central Pulp & Paper Research Institute,
P. Box No. 174, Paper Mill Road, Himmat Nagar,
Sharanpur – 247 001
Tel. : 0132 - 2727227 / 2727036 / 2725317
Fax : 0132 - 2727387
E-mail : agk_directorcppri@rediffmail.com

iv) Director,
National Environmental
Engineering Research Institute,
Nehru Marg, Nagpur – 440 020
Tel. : 0712-2249885-90
Fax : 0172-226252 / 2249752

v) Professor Surendra Kumar
Department of Chemical Engineering
Indian Institute of Technology,
Roorkee, Uttaranchal.
Tel. : 01332-285714
Fax : 01332-276535/ 273560
E-mail : skumar@iitr.ernet.in

BENEFICIARY ORGANISATIONS INVOLVED IN INSTALLATION OF DEMONSTRATION PROJECTS UNDER UNDP / GEF PROJECT

PULP & PAPER INDUSTRY WASTES

Executive Director,
M/s Satia Paper Mills Ltd.,
Vil. : Rupana, Muktsar - Malout Road,
Muktsar-152 026, Punjab,
Tel. : 01633 - 262001/ 263585
Fax : 01633-263499

Dy. Manager (Project Coordination)
M/s Tamil Nadu Newsprint and Papers Limited,
Kagithapuram – 639136,
Karur Dist., Tamilnadu
Tel. : 098424-56940 & 56941 (cell) / 04324-277001 (10 lines)
Fax : 04324-277027/ 277025
E-mail : pmd@tnpl.co.in / pmd1@tnpl.co.in

LEATHER & ABATTOIR INDUSTRY WASTES

Company Secretary,
M/s Hind Agro Industries Ltd.,
B- 3, Friends Colony (West),
Main Mathura Road, New Delhi-110065;
Tel. : 011-26918786 26372786
Fax: 011-26817941/ 6817942
E-mail: hindgrp@nde.vsnl.net.in

Managing Director
M/s. Tata International Ltd.,
Industrial Area, Agra Mumbai Road,
Dewas – 455 001, Madhya Pradesh.
Tel. : 07272 - 258900 / 08
Fax : 07272 - 258150 / 258271
E-mail : dchakrab@tatainternational.co.in
dintl@tatainternational.co.in

M/s. Visharam Tanners Enviro Control Systems Pvt. Ltd. (VISHTEC),
C. Abdul Hakeem Road,
Melvisharam - 632 509
Ranipet, Vellore District, Tamil Nadu
Tel. : 04172 - 267344 / 266444
Fax : 04172 - 22653

General Manager
M/s. Al-kabeer Exports Limited.,
Plot No. 1098, Road No. 36,
Jubilee Hills, Hyderabad – 33
Tel. : 040-23544851/52/53/54
Fax : 040-23548126
E-mail: alkabeer@hd1.vsnl.net.in

VEGETABLE MARKET YARD WASTES

Member Secretary,
Chennai Metropolitan Development Authority(CMDA)
Thalamuthu Natarajan Building,
No. 1, Gandhi Irwin Road, Egmore,
Chennai - 600008,
Tel. : 044-28534355
Fax : 044-28548416

Commissioner
Municipal Corporation, Vijayawada
Tel. : 0866-2421058
Fax : 0866-2423022
E-mail: mcvij@ap.nic.in

BIOGAS UTILISATION

Commissioner
Surat Municipal Corporation,
Muglisara, Surat – 395003.
Tel. : 0261-2423751-56 / 2422285
Fax : 0261-2451935 / 2422110

Managing Director,
M/s Ugar Sugar Works Ltd.,
Ugarkhurd, Dist. Belgaum
Tel. : 08339- 272230 (5 lines)
Fax : 08339- 272232
E-mail: ugarsugr@sancharnet.in

FRUIT / FOOD PROCESSING WASTES

Managing Director,
M/s Varalakshmi Starch Industries Ltd.,
No. 8, Gandhi Road, Salem – 636007,
Tel. : 0427- 2316280/ 2316281/ 2312854
Fax : 0427-2318854 / 2316186
E-mail : vsil@vsnl.com

ANIMAL / AGRO RESIDUES

Director
Punjab Energy Development Agency,
SCO 54-56, Sector - 17-A,
Chandigarh.
Tel. : 0172- 2663328/2667005
Fax : 0172-2667005 / 2663352
E-mail : peda@glide.net.in

MUNICIPAL WASTEWATER /SEWAGE

Director
Regional Research Laboratory (RRL)
Bhubaneswar - 75 1013
Tel. : 0674-2581126
Fax : 0674-2581160

Director
National Environmental Engineering Research Institute,
Nehru Marg,
Nagpur - 440 020
Tel. : 0712-2249885-90
Fax : 0172-226252 / 2249752

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