RESOURCE RECOVERY FROM SEWAGE TREATMENT PLANTS (STPs)

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

CONSERVATION OF RIVERS AND LAKES

By

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CANDIDATE'S DECLARATION

I hereby declare that the work which has been presented in the dissertation entitled **"RESOURCE RECOVERY FROM SEWAGE TREATMENT PLANTS"** in partial fulfillment of the requirements for the award of the degree of **Master of Technology in Conservation of Rivers and Lakes**, submitted in Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee, is an authentic record of my own work carried out during the period from July 2006 to June 2007 under the supervision of Sh. Arun Kumar, Head and Chief Scientific Officer, Alternate Hydro Energy Centre and Dr. H. Sinvhal, Professor, Department of Earth Science, Indian Institute of Technology Roorkee.

The matter embodied in the dissertation has not been submitted by me for the award of any other degree or diploma.

Place: Roorkee
Date: 29th JUNE, 2007

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CERTIFICATE

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ABSTRACT

Resources are diminishing due to the vast utilization of Energy for meeting day to day demand in the 'competition and threats' environment. Exponential growth of population further puts pressure on energy heavily.

Biologically produced energy has been identified as an attractive alternative to the increasingly scarce fossil fuel supplies. Resource recovery from waste fetches revenue and makes the environment safe and healthy. Since the Energy Recovery from Sewage Treatment Plants is of the nature of 'non conventional' i.e. 'renewable energy source', it is eco friendly and increases sustainability.

The use of renewable energy makes the environment 'clean and green'. The recoverable items in solid, liquid and gaseous forms from STP's and their values are explained in this dissertation.

We have an opportunity to take a more holistic approach to pollution by dealing with liquid and solid waste streams, and reducing their combined environmental impacts on water, land, and air.

We can recover from sewage treatment plants:

- Biodiesel from fat, oil and grease
- Biogas from other organic material
- Biodiesel from residual sludge
- Fertilizers and metals from inorganic materials
- District heating through sewage-source (water-source) heat pumps
- Water for reuse from water discharged

The Municipalities of Indian towns are utilising the sewage sludge for biogas generation and producing electricity. They utilise the treated effluent for irrigation and reuse for industrial purposes. They also sell the sludge cake as manure. Aquaculture is also being practiced.

The case studies are made in Chennai, Haridwar, Lucknow, Pimpri Chinchwad-Pune, Saharanpur, Sonepat, Rishikesh and Periyakulam town sewage treatment plants. Chennai and Haridwar have ASP based STP's. , Lucknow and Pune have UASB based

STP's. Saharanpur and Sonepat have FAB based STP's. Rishikesh and Periyakulam have WSP based STP's.

The ASP and UASB based sewage treatment plant are biogas producing plants. The FAB and WSP based plants are not capable of producing biogas. But the produced gases are not fully utilised. Most of the gases are flared up. So, it should be monitored to utilise the full strength of biogas and reduce the electricity charges to be paid to the electricity board.

The WSP based sewage treatment plants are well maintained leading to prevention of pollution of the river and at the same time drawing the full opportunity to recover the cost by way of resource recovery.

From the net present worth analysis of resource recovery, it is found that, the most economical option is WSP in the areas having availability of land with low cost (upto Rs. 60.00 lakhs/hectare). In the areas of high land cost (over Rs. 60.00 lakhs/hectare), then the UASB based technology is the economic option. If O& M Charges are properly monitored, ASP technology will also be economical. FAB technology is costlier than the other technologies. With acute shortage of land and higher degrees of treatment, FAB technology may be adopted. With the increase in land demand, Batch Reactor based treatment technology may be a good option.

RESOURCE RECOVERY FROM SEWAGE TREATMENT PLANTS

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LIST OF ABBREVIATIONS/NOTATIONS

SL. NO	ABBREVIATIONS/ NOTATIONS	DESCRIPTION
1	FOG	Fat, oil, and grease
2	CND$	Canadian Dollar
3	STORS	Sludge-To-Oil Reactor System
4	CRD	Central Regional District
5	BRCM	Bamboo reinforced cement mortar
6	BGP	Biogas Plant
7	PFCCB	Pre-fabricated cement concrete blocks
8	HDP	high density plastic
9	ACC	Asbestos Cement Concrete
10	CMWSS Board	Chennai Metropolitan Water Supply and Sewerage Board
11	STP	Sewage Treatment Plant
12	BOD	Bio-chemical Oxygen Demand
13	COD	Chemical Oxygen Demand
14	TSS	Total suspended solids
15	TS	Total solids
16	VSS	Volatile suspended solids
17	CH_4	Methane
18	CO_2	Carbon dioxide
19	H_2S	Hydrogen sulfide
20	m.c	Moisture content
21	vol %	Volume percentage
22	MLD	Million litre per day
23	CPCL	Chennai Petrochemical Corporation Limited
24	MFL	Madras Fertilisers Limited
25	MPL	Madras Pesticides Limited
26	mg/l	Milligram per litre
27	kg	Kilogram
28	cu.m.	Cubic metre
29	m3	Cubic metre

30	m2	Square metre
31	C.V	Calorific Value
32	kWh	Kilo watt hour
33	MWh	Mega watt hour
34	kJ	Kilo joule
35	MJ	Mega joule
36	kl / hr	Kilo litre per hour
37	TTP	Tertiary Treatment Plant
38	RO Bank	Reverse Osmosis Bank
39	HRT	Hydraulic Retention Time
40	IPSs	Intermediate Pumping Stations
41	MPS	Main Pumping Station
42	ASP	Activated Sludge Process
43	FAB	Fluidised Aerobic Bed Bioreactor
44	UASB	Upflow Anaerobic Sludge Blanket
45	WSP	Waste Stabilisation Pond
46	SWD	Sewage Water Depth
47	MPN	Most Probable Number
48	MLSS	Mixed Liquid Suspended Solid
49	MLVSS	Mixed Liquid Volatile Suspended Solid
50	SVI	sludge volume index
51	F/M ratio	Food / Micro-organism Ratio
52	E-coli	Escherichia coliform
53	YAP	Yamuna Action Plan
54	sq. km	Square Kilometer
55	MSL	Mean Sea Level
56	$MgNH_4PO_4$	Ammonium Magnesium Phosphate
57	SETAC	The Society of Environmental Toxicology and Chemistry

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Resources are diminishing due to the vast utilization of Energy for meeting day to day demand in the 'competition and threats' environment. Exponential growth of population further puts pressure on energy heavily.

Biologically produced energy has been identified as an attractive alternative to the increasingly scarce fossil fuel supplies. Resource recovery from waste fetches revenue and makes the environment safe and healthy. Since the Energy Recovery from Sewage Treatment Plants is of the nature of 'non conventional' i.e. 'renewable energy source', it is eco friendly and increases sustainability.

Anaerobic fermentation of organic waste leading to biogas generation is one such process which has considerable potential to supplement energy supplies. Apart from the economic advantages, biogas recycling has great environmental benefits because primary material can be saved and pollution loads from conventionally produced energy can be minimized.

The use of renewable energy makes the environment 'clean and green'. The recoverable items in solid, liquid and gaseous forms from STP and their values are explained in this dissertation.

1.2 THE RESOURCE RECOVERY OPTIONS FROM STPs

When issues of sewage, municipal solid waste, air pollution and climate change are considered in isolation, we limit the scope and creativity of our solutions. European municipalities are showing how green energy can be derived from several waste streams at the same time, and how waste-to-energy infrastructure can effectively treat sewage and also reduce inner-city air pollution and greenhouse gases. Countries like Sweden are dealing with sewage and municipal solid waste in concert, so that energy recovery plants convert organic materials from garbage, offal from abattoirs, and sludge from sewage plants in single processes.

For example: [1]

- There are 3,000 biogas plants in Europe, producing methane from sewage treatment plants and from organic municipal waste.
- Sweden runs 5,300 vehicles and much of its transit system on biogas. Replacing diesel with biodiesel or biogas (natural gas) in buses and cars which will reduce particulate emissions and will also reduce greenhouse gases by 30,000 tonnes/year
- Sweden is enacting environmental legislation which will require that 60% of phosphates be recovered from municipal sewage.

The public has been given very little information about the benefits of treating sewage through processes designed to recover resources, despite the fact that resource recovery is well established elsewhere: searching Google with the keywords "sewage" + "biogas" yields 400,000 pages.

We have an opportunity to take a more holistic approach to pollution by dealing with liquid and solid waste streams, and reducing their combined environmental impacts on water, land, and air.

We can recover from sewage treatment plants:

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- Water for reuse from water discharged

1.3 DIRECT BENEFITS OF TREATMENT PLANTS DESIGNED FOR RESOURCE RECOVERY

Sewage treatment plants designed for resource recovery are less expensive to operate than traditional aerobic plants. We need the right kind of sewage treatment. Traditional treatment relies on aerobic micro organisms to convert the organic energy in wastewater to carbon dioxide and biomass (sludge). The process consumes significant amounts of chemicals and electricity, but consuming electrical energy to get rid of organic energy is senseless;

Producing the electricity and chemicals used in traditional treatment causes upstream pollution. Current practices of land farming sludge from aerobic plants or sending the sludge to landfills is wasteful and unsustainable.

Dr. David Bagley, a scientist at the University of Wisconsin, has calculated that sewage contains almost 10 times the energy required to treat it. Dr. Bagley has published his paper on the energy content of sewage to the SETAC Review Panel website[1].

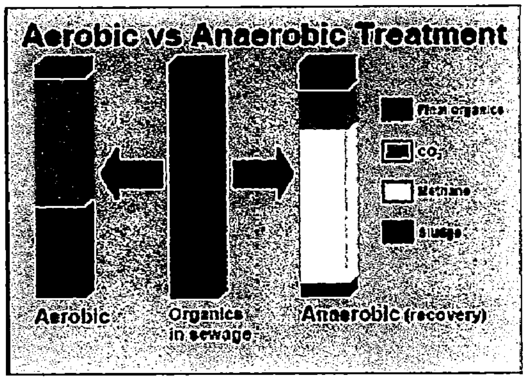


Figure 1.3.1: Aerobic vs. Anaerobic Treatment [1]

In anaerobic treatment plants on the other hand, methanogenic bacteria digest organic materials and produce raw biogas - a mixture of roughly 1/3 CO_2 and 2/3 methane. When the raw gas is stripped of CO_2 and trace sulphur compounds (using treated wastewater) the resulting natural gas can be distributed for use in homes or cars. Anaerobic treatment plants cost less to build since they do not require aeration equipment, and they require less space since they use closed vessels rather than open settling tanks. They also cost less to operate since they do not consume electricity for aeration and use fewer chemicals; aerobic plants require settling agents such as alum and commonly use chlorine to disinfect sludge and effluent. Finally, anaerobic plants produce one fifth to one twentieth of the sludge produced by aerobic plants, since a significant proportion of the energy in the wastewater is converted to methane. Since anaerobic treatment takes place in closed vessels, odours are contained and it becomes practical to co-locate treatment with other land uses.

For example, Victoria's planned Dockside Development will convert sewage and other organic waste from 2,000 tenants into biofuels, electricity, and compost through an anaerobic plant in the basement.

The treated effluent will flow in a creek within the development, providing aesthetic value. CRD reports show that Core Area sewage contains enough energy to provide pure biodiesel for 200 buses and 5,000 cars; the greenhouse gas reductions would equal 30,000 tonnes/year. Applying the right kind of treatment to sewage will not only remove up to 95% of contaminants from the effluent, but can also help counter inner-city air pollution and climate change: biodiesel and biogas burn more cleanly than fossil fuels. Resource recovery plants can be designed to accept and process solid municipal organic waste as well as sewage, further reducing pollution of air, soil, groundwater, and the ocean.

1.4 WHAT CAN WE DO NOW

Pollution is often a misplaced resource, and that's certainly the case with the oils, bio-energy, and metals we are currently flushing out to sea. We are also fortunate that innovative technologies have put these resources within reach. Given the rising cost of energy and the pressing need to reduce greenhouse gas emissions and air pollution, it makes environmental and economic sense to take the resource recovery route to sewage treatment. We have no reason to believe treatment through resource recovery will cost more than residents pay for treatment through existing plants. The government can display the responses in an open forum to help the public learn the pros, cons, and costs of each option. This kind of open process is needed to give the public a clearer picture of the many possible solutions. Buses, cars and boats can be run on biofuels. Resource recovery is an idea that's just too good to waste. The only way to know the costs and resource benefits of secondary treatment with resource recovery will be to open the process to a wide range of sources through a design competition or a Request for Expression of Interest.

CHAPTER 2

LITERATURE REVIEW

2.1 EXAMPLES OF RESOURCE RECOVERY FROM SEWAGE

An independent Scientific and Technical Review Panel reviewed the CRD's Core Area Liquid Waste Management Plan (LWMP). The final report was presented to the CRD Board on July 12; 2006.The panel reviewed over 200 scientific and technical reports and received 82 written submissions received from the public through a seven week call for technical information. One of the technical report is 'The Treatment through Resource Recovery: Options for Core Area Sewage', Prepared for: SETAC Review Panel Capital Regional District Liquid Waste Review, Prepared by: Stephen Salter P Eng, Victoria Sewage Alliance, Victoria, BC. The examples mentioned below are referred from this report.[1]

2.1.1 BIODIESEL FROM FAT, OIL & GREASE IN SEWAGE

Biodiesel is also being used to power the tourist boats operated by a number of Quebec firms. Biodiesel is being used in municipal vehicles (for example in Hennepin County Minnesota) and in transit buses (for example in Cedar Rapids, Iowa).

Biomass to biodiesel conversion technology is developing rapidly in Canada. Fat, oil, and grease (FOG) from sewage can be collected from sewage treatment and commercial grease traps, and converted to biodiesel through esterification and hydrogenation.

CRD reports for 2003 show untreated sewage from the Macaulay Pt. and Clover Pt. outfalls contains 5 million kgs/year of oil & grease per year, which could provide enough pure biodiesel to run all of Victoria's 200 buses. When grease from commercial grease traps is also converted the figure will significantly higher. They are also selling biodiesel from sewage to whale-watching companies, showing tourists from the world over how they have turned pollution into a resource.

2.1.2 BIOGAS FROM SEWAGE

In 1999 the executive committee of Kristianstad Municipality (pop. 75,000) declared themselves a Fossil Fuel Free Municipality, to help the district meet fifteen environmental goals set by the Swedish Parliament. Biogas from the sewage treatment plant is used to fuel buses and other vehicles; 22 buses ran on biogas as of December 2002. In 2002 the biogas cost CND$0.32 per litre, and the Kristianstad Municipality further encourages the public to buy cars that run on biogas by:

- providing free parking places for biogas-powered cars
- subsidizing 50% of the cost of converting cars to run on biogas

CRD reports show sewage contains 16,000,000 kgs/year of organic materials, which could produce enough biogas to run about 5,000 cars, or heat 3,500 homes, or generate electricity for 2,500 homes.

2.1.3 BIOGAS FROM SLUDGE

Anaerobic digestion is commonly used in Canadian sewage treatment plants to "stabilize" sludge resulting from the traditional aerobic treatment processes. A modern method used in Hamar, Norway is to "cook" the sludge at 180 °C before a final digestion stage. This approach ruptures cell walls, killing pathogens and making the conversion to biogas more efficient. Thermophilic anaerobic digestion at 70 °C then converts the sludge to biogas. The biogas (methane or natural gas) can then be used to run vehicles, or to produce electricity and heat from cogeneration plants or Direct Fuel Cells. Treatment plants in the Core Area could also accept and convert other organic waste, including as much as possible of the 46,000,000 kgs/year of organic waste currently sent to the Hartland Landfill. This solid organic waste stream includes sludge produced by existing CRD secondary sewage treatment plants such as the Saanich Peninsula Wastewater Treatment Plant, as well as the Sooke Treatment Plant. Small, local resource recovery/treatment plants could digest their own sludge on site, producing biofuels.

2.1.4 BIODIESEL, METALS, AND MINERALS FROM SLUDGE

Sludge can be converted to biodiesel and minerals through plasma gasification or pyrolysis processes which heat and decompose the waste in the absence of air.

The Dockside Development project will use pyrolysis as a final treatment stage to reduce the residual sludge to biofuels and mineral ingots. Pyrolysis is being used extensively in the USA; the Sludge-To-Oil Reactor System (STORS) in Colton, California also converts ammonia in the sludge to fertilizer. The Tembec high-yield pulp mill in Chetwynd, BC uses resource recovery strategies to achieve zero effluent operation. Sludge from the treatment plant is processed into fuel and ash consisting of metals and minerals. The ash is sent to a mine and blended with ore for refining. Interestingly, the trace metals present in sludge act as catalysts in pyrolysis. A biodiesel conversion plant at the Hartland Landfill could also provide fuel for commercial and municipal vehicles such as recycling trucks.

Anaerobic treatment processes produce 1/5 to 1/20 of the sludge produced by aerobic processes, but pyrolysis can be used to convert the remaining sludge to fuel and minerals. A pyrolysis plant could also accept sludge produced by the region's existing traditional sewage treatment plants in North Saanich, Sooke, and so on. This sludge has been applied to farmland, but is currently going to the CRD's Hartland landfill.

CRD reports show that sewage includes 2,000,000kgs/year of metals and minerals; these could be recovered as ash or solid ingots through the sludge-to-oil process, and included with ore from mines for refining.

TABLE 2.1.4.1: Metals and Minerals in Sewage[1]

Metals and Minerals in Sewage

It is expected that resource recovery technologies will only recover a portion of this material. The summary is included to show the size of the opportunity	Macaulay (2003) kg/year	Clover (2003) kg/year	Total kg/year	2005 Prices ($/kg)	Value ($/year)
Aluminum	22,307	23,873	46,179	$1.87	$86,494
Chromium	43	48	91	$8.54	$776
Copper	1,769	2,538	4,307	$3.83	$16,474
Iron	21,059	21,430	42,489	$0.15	$6,480
Lead	186	219	406	$0.88	$357
Magnesium	98,265	128,342	226,607	$1.95	$442,336
Manganese	1,564	1,054	2,617	$0.73	$1,916
Nickel	96	72	168	$14.52	$2,438
Total kjeldahl nitrogen	616,845	670,442	1,287,287	$0.49	$631,337
Phosphorous	98,982	112,539	211,521	$0.24	$51,611
Potassium	200,833	239,444	440,277	$0.18	$80,571
Silver	38	66	104	$228.60	$23,808
Tin	25	36	61	$7.30	$443
Zinc	1,488	1,750	3,238	$1.28	$4,132
		Totals:	2,265,351		$1,349,171

2.1.5 ELECTRICITY & HEAT FROM CO-GENERATION

In Kristianstad, Sweden biogas cogeneration plants are located close enough to housing developments to provide heat - district heating. The GVRD's Annais Island secondary treatment plant uses biogas cogeneration from their sludge treatment process to produce 4 megawatts of electricity from 5,000 m3 of biogas per day.

The Lethbridge sewage treatment plant generates 1.5 megawatts of electrical power and recovers 1.7 megawatts of thermal energy from their cogen process.

2.1.6 ELECTRICITY FROM BIOGAS-POWERED FUEL CELLS

The US Department of Energy is testing Direct Fuel Cells which convert methane to hydrogen internally, and then convert hydrogen to electricity. Two 500 kilowatt Direct Fuel Cell power plants have been installed at the El Estero Wastewater Treatment Facility in California. These cells generate electricity directly from methane gas (biogas) recovered from sewage treatment. A New York wastewater treatment plant has installed a 200 kilowatt Direct Fuel Cell. Portland, Oregon has also installed a 200 kilowatt Direct Fuel Cell to produce power using anaerobic digester gas from a waste water facility. The South Treatment Plant in Renton, Washington has installed a 1 megawatt Direct Fuel Cell which produces enough electricity for 1,000 homes. Other King County sewage treatment plants use internal combustion engines and micro turbines to produce electricity and heat. This technology could be considered as an alternative to the more traditional internal combustion engine/generator approach.

2.1.7 WATER-SOURCE HEAT PUMPS

Sewage-source (water-source) heat pumps are being used by the Osaka Municipal Government and by the Tokyo sewage treatment plant to extract residual heat energy from sewage after treatment and before it is discharged. The 2010 Olympics Athlete's Village in Vancouver will be heated by sewage-source heat pumps.

Sewage temperatures average 16 °C in winter months, and the tremendous volume of sewage (38 cubic kilometres per year) means it contains significant energy. If a resource recovery plant is co-located with new housing or even social housing, a sewage-source (water-source) heat pump could recover enough energy to heat several thousand homes.

2.1.8 ELECTRICITY FROM SEWAGE-POWERED FUEL CELLS

Researchers at Pennsylvania State University are developing a fuel cell which produces electricity directly from sewage: "The microbial fuel cell could provide a modern solution to two worrying problems - how to reduce the energy costs involved in treating raw sewage and how to produce power without relying on non-sustainable resources."

2.1.9 WATER FROM SEWAGE

The sewage treatment system for the planned Dockside Development LEED Silver project will recover water from treated sewage. The water will be purified by passing through ultrafiltration membranes which remove bacteria, and recovered water will be used for gray water applications such as flushing toilets. The World Health Organization has published standards for water recovered for reuse from wastewater. The Tembec high-yield pulp mill in Chetwynd, BC incorporates a zero-effluent wastewater treatment system, which uses vapour recompression technology to recover process water for reuse in the pulping process. Vapour recompression produces distilled water by recycling the latent heat of evaporation in the compression process. The King County, Washington treatment plant is installing ultrafiltration membranes to recover water from sewage. Water can be recovered through membrane ultrafiltration, vapour recompression, or multiple effect evaporators. Recovered water could be diverted for use in irrigation or gray water systems.

2.2 RECYCLING OF WASTEWATER AND SLUDGE IN SALIX PLANTATIONS[2]

The idea of growing willows (Salix spp.) for production of biofuels was introduced in Sweden 25 years ago. Today, willows are commercially cultivated on a reasonable scale and the Swedish concept is now being introduced in other European countries. Willows, as all green plants, require nutrients and water to grow. Various municipal waste products that are rich in nutrients and/or water, such as wastewater, sewage sludge, organic residuals, ashes and leachate from sanitary landfills could partly or to a full extent replace the need of conventional fertilisation and enhance growth.

2.2.1 WILLOW BIOMASS PLANTATIONS IN SWEDEN

Since the oil crisis in the 1970's, willow has been tested as an energy crop in many European countries. Although growing willows is a rather new phenomenon in agriculture, the acreage in Sweden has increased rapidly and today, willow is grown on 15000 hectares (~0.5% of the farmland). An extensive breeding programme towards frost and disease resistance and high biomass production has resulted in varieties with higher yield and less damages. The average annual production of wood chips from a well-established willow plantation is in the range of 8–12 tonnes of dry matter per hectare, which is equivalent to 3.5–5.5 tonnes of oil per hectare.

The trends now are towards minimising the use of finite resources (chemicals, energy) in wastewater treatment by implementing new biological purification methods. The utilisation and treatment of municipal wastewater and sludge in willow plantations have been introduced on a commercial scale in Sweden.

Several facilities with wastewater irrigation of willow plantations in sizes from 10 to 75 hectares have been established since 1997 with combined recycling and tertiary treatment of wastewater.

A wider development of willow plantations for bio-fuel production in Europe could help many sparsely populated areas to increase employment rates. In this respect also the benefits of application of municipal waste products in willow plantations should be considered. The potential that waste products also could be treated at reasonable costs might encourage the municipal sector as well as the energy and agricultural industry in Europe to participate in the further development of the concept, resulting in an enhanced production of environmentally friendly biofuels as a consequence.

CHAPTER 3

DIFFERENT RESOURCE RECOVERIES

3.1 BIOGAS

3.1.1 BIOGAS

Biogas is a valuable fuel which is in many countries produced in purpose built digesters filled with the feedstock like dung or sewage. Digesters range in size from one cubic metre for a small 'household' unit to more than thousand cubic meters used in large commercial installation or farm plants. The input may be continuous or in batches, and digestion is allowed to continue for a period of from ten days to a few weeks. The bacterial action itself generates heat, but in cold climates additional heat is normally required to maintain the ideal process temperature of at least 35 degrees Celsius, and this must be provided from the biogas. In extreme cases all the gas may be used for this purpose, but although the net energy output is then zero, the plant may still pay for itself through the saving in fossil fuel which would have been needed to process the wastes. A well-run digester will produce 200-400 m3 of biogas with a methane content of 55% to 75% for each dry tonne of input.

3.1.2 COMPOSITION OF BIOGAS

Biogas is a colorless, odorless, inflammable gas, produced by organic waste and biomass decomposition (fermentation). Biogas can be produced from animal, human and plant (crop) wastes, weeds, grasses, vines, leaves, aquatic plants and crop residues etc. The composition of different gases in biogas is as below: [3]

- Methane (CH_4): 55-75%
- Carbon Dioxide (CO_2): 25-45%
- Hydrogen Sulphide (H_2S): 0.1-0.5%
- Nitrogen (N_2): 1-5%
- Hydrogen (H_2): 0-3%
- Carbon Mono Oxide (CO): 0-0.3%
- Oxygen (O_2): Traces

3.1.3 BIOGAS PLANT

Biogas Plant (BGP) is an airtight container that facilitates fermentation of material under anaerobic condition. The other names given to this device are 'Biogas Digester', 'Biogas Reactor', 'Methane Generator' and 'Methane Reactor'. The recycling and treatment of organic wastes (biodegradable material) through Anaerobic Digestion (Fermentation) Technology not only provides biogas as a clean and convenient fuel but also an excellent and enriched bio-manure. Thus the BGP also acts as a miniature Bio-fertilizer Factory hence some people prefer to refer it as 'Biogas Fertilizer Plant' or 'Bio-manure Plant'. The fresh organic material (generally in a homogenous slurry form) is fed into the digester of the plant from one end, known as Inlet Pipe or Inlet Tank. The decomposition (fermentation) takes place inside the digester due to bacterial (microbial) action, which produces biogas and organic fertilizer (manure) rich in humus & other nutrients. There is a provision for storing biogas on the upper portion of the BGP. On the other end of the digester Outlet Pipe or Outlet Tank is provided for the automatic discharge of the liquid digested manure.

3.1.4.1 BIOGAS AND ENERGY

When biogas is captured, it can be used to generate heat, hot water, or electricity-significantly reducing the cost of electricity and other farm fuels such as natural gas, propane, and fuel oil. Biogas can also be flared to control odor if energy recovery is not feasible. Both the flaring and use of biogas reduce greenhouse gas emissions. Biogas is a renewable source of energy with much lower environmental impacts than conventional fossil fuel. The methane generated from anaerobic digestion provides rural electric cooperatives and utilities with a source of "green power" to sell to customers who wish to purchase power from renewable sources. Biogas recovery also provides rural energy benefits such as distributed generation and voltage support.

3.1.5 ENVIRONMENTAL BENEFITS OF ANAEROBIC DIGESTION SYSTEMS[4]

Livestock confinement facilities generate large amounts of animal waste that can create serious environmental concerns. The concentrated waste product from decomposing livestock manure can be environmentally detrimental if it enters rivers, streams, or groundwater supplies. Decomposing manure also causes air quality concerns associated with odor, ammonia emissions, and the contribution of methane emissions to global climate change. Anaerobic digestion offers a number of air and water quality benefits, including:

Odor Control: The effluent odor from anaerobic digesters is significantly less than odors from conventional manure management systems. Odor reduction using anaerobic digestion can be very cost-effective when compared to other alternatives such as aeration.

Greenhouse Gas Reduction: Conventional liquid and slurry manure management practices emit large amounts of methane, a greenhouse gas that contributes to global warming. Biogas recovery systems capture and combust methane, thus reducing greenhouse gas emissions. In addition, by off-setting energy that would otherwise be derived from fossil fuels, biogas recovery and use can help reduce overall quantities of carbon dioxide, another critical greenhouse gas.

Ammonia Control: Ammonia emissions from livestock manures - especially emissions from anaerobic lagoons used in the treatment and storage of these manures - are a growing environmental concern. To control ammonia emissions, producers can cover manure storage tanks. Because gas handling is not required, the storage structures of anaerobic digester systems, which separate treatment and storage, are smaller and easier to cover than the larger structures of traditional systems.

Water Quality Protection: Anaerobic digestion provides several water quality benefits. When an anaerobic digester system, especially a covered lagoon, is properly managed, phosphorous and metals, such as copper and zinc, will settle out in the process cells, thus reducing phosphorous and metals loadings to surface waters when manure is land-applied. Digester systems, especially heated digesters, isolate and destroy disease causing organisms that might otherwise enter surface waters and pose a risk to human and animal health. Anaerobic digestion also helps protect ground water. Synthetic liners provide a high level of groundwater protection for manure management systems. These protective liners are a more affordable option with anaerobic digester systems than with conventional lagoons, because the multiple-cell design of anaerobic digesters requires less volume and, therefore, less lining material is needed. The concrete or steel tanks used in plug flow and complete mix digesters also effectively prevent untreated manure from reaching ground water.

3.2 BIOMASS

3.2.1 BIOMASS

Biomass as the solar energy stored in chemical form in plant and animal materials is among the most precious and versatile resources on earth. It provides not only food but also energy, building materials, paper, fabrics, medicines and chemicals. Biomass has been used for energy purposes ever since man discovered fire. Today, biomass fuels can be utilised for tasks ranging from heating the house to fuelling a car and running a computer.

3.2.2 THE CHEMICAL COMPOSITION OF BIOMASS

The chemical composition of biomass varies among species, but plants consist of about 25% lignin and 75% carbohydrates or sugars. The carbohydrate fraction consists of many sugar molecules linked together in long chains or polymers. Two larger carbohydrate categories that have significant value are cellulose and hemi-cellulose. The lignin fraction consists of non-sugar type molecules. Nature uses the long cellulose polymers to build the fibers that give a plant its strength. The lignin fraction acts like a "glue" that holds the cellulose fibers together.

3.2.3 WHERE DOES BIOMASS COME FROM?

Carbon dioxide from the atmosphere and water from the earth are combined in the photosynthetic process to produce carbohydrates (sugars) that form the building blocks of biomass. The solar energy that drives photosynthesis is stored in the chemical bonds of the structural components of biomass. If we burn biomass efficiently (extract the energy stored in the chemical bonds) oxygen from the atmosphere combines with the carbon in plants to produce carbon dioxide and water. The process is cyclic because the carbon dioxide is then available to produce new biomass.

In addition to the aesthetic value of the planet's flora, biomass represents a useful and valuable resource to man. For millennia humans have exploited the solar energy stored in the chemical bonds by burning biomass as fuel and eating plants for the nutritional energy of their sugar and starch content. More recently, in the last few hundred years, humans have exploited fossilized biomass in the form of coal. This fossil fuel is the result of very slow chemical transformations that convert the sugar polymer fraction into a chemical composition that resembles the lignin fraction. Thus, the additional chemical bonds in coal represent a more concentrated source of energy as fuel. All of the fossil fuels we consume - coal, oil and natural gas - are simply ancient biomass. Over millions of years, the earth has buried ages-old plant material and converted it into these valuable fuels. But while fossil fuels contain the same constituents - hydrogen and carbon - as those found in fresh biomass, they are not considered renewable because they take such a long time to create.

Environmental impacts pose another significant distinction between biomass and fossil fuels. When a plant decays, it releases most of its chemical matter back into the atmosphere. In contrast, fossil fuels are locked away deep in the ground and do not affect the earth's atmosphere unless they are burned.

Wood may be the best-known example of biomass. When burned, the wood releases the energy the tree captured from the sun's rays. But wood is just one example of biomass. Various biomass resources such as agricultural residues (e.g. bagasse from sugarcane, corn fiber, rice straw and hulls, and nutshells), wood waste (e.g. sawdust, timber slash, and mill scrap), the paper trash and urban yard clippings in municipal waste, energy crops (fast growing trees like poplars, willows, and grasses like switch grass or elephant grass), and the methane captured from landfills, municipal waste water treatment, and manure from cattle or poultry, can also be used.

3.2.4 ENVIRONMENTAL BENEFITS

The use of biomass energy has many unique qualities that provide environmental benefits. It can help mitigate climate change, reduce acid rain, soil erosion, water pollution and pressure on landfills, provide wildlife habitat, and help maintain forest health through better management.

Climate Change: Climate change is a growing concern world-wide. Human activity, primarily through the combustion of fossil fuels, has released hundreds of millions of tons of so-called 'greenhouse gases' (GHGs) into the atmosphere. GHGs include such gases as carbon dioxide (CO_2) and methane (CH_4). The concern is that all of the greenhouse gases in the atmosphere will change the Earth's climate, disrupting the entire biosphere which currently supports life as we know it. Biomass energy technologies can help minimize this concern. Although both methane and carbon dioxide pose significant threats, CH_4 is 20 times more potent (though shorter-lived in the atmosphere) than CO_2. Capturing methane from landfills, wastewater treatment, and manure lagoons prevents the methane from being vented to the atmosphere and allows the energy to be used to generate electricity or power motor vehicles. All crops, including biomass energy crops, sequester carbon in the plant and roots while they grow, providing a carbon sink. In other words, the carbon dioxide released while burning biomass is absorbed by the next crop growing. This is called a closed carbon cycle. In fact, the amount of carbon sequestered may be greater than that released by combustion because most energy crops are perennials; they are harvested by cutting rather than uprooting. Thus the roots remain to stabilize the soil, sequester carbon and to regenerate the following year.

Acid Rain: Acid rain is caused primarily by the release of sulphur and nitrogen oxides from the combustion of fuels. Acid rain has been implicated in the killing of lakes, as well as impacting humans and wildlife in other ways. Since biomass has no sulphur content, and easily mixes with coal, "co-firing" is a very simple way of reducing sulphur emissions and thus, reduce acid rain. "Co-firing" refers to burning biomass jointly with coal in a traditionally coal-fired power plant or heating plant.

3.2.5 METHODS OF GENERATING ENERGY FROM BIOMASS

Nearly all types of raw biomass decompose rather quickly, so few are very good long-term energy stores; and because of their relatively low energy densities, they are likely to be rather expensive to transport over appreciable distances. Recent years have therefore seen considerable effort devoted to the search for the best ways to use these potentially valuable sources of energy. In considering the methods for extracting the energy, it is possible to order them by the complexity of the processes involved:

Thermo chemical processing to upgrade the biofuel: Processes in this category include pyrolysis, gasification and liquefaction.

Biological processing: Natural processes such as anaerobic digestion and fermentation which lead to a useful gaseous or liquid fuel.

3.3 COGENERATION

3.3.1 COGENERATION - ELECTRICITY AND HOT WATER[5]

Cogeneration refers to the simultaneous production of electricity from the generator and the production of heat from the engine or micro turbine exhaust or cooling system. Electricity is generally the primary output but the main byproduct, heat, can also be captured and used for food processing, water heating, steam production and many other uses.

3.3.2 INTERCONNECTION

This portion of the system controls the flow of electricity either from "the Grid" to the farm or from the farm to "the Grid." The electricity generator is connected to "the Grid" through a series of redundant electronic and manual interconnection relays, called switchgear, that is designed to prevent damage to "the Grid", the generator and to protect the safety of utility workers, farm workers and the general public.

Much effort goes into designing a safe and reliable switchgear and interconnection system. It could be maintained a backup connection to the utility to provide electrical power to the farm for periods of system maintenance and to provide additional power during the peak usage typically during the summer.

3.4 SEWAGE SLUDGE AND MANURE

As the amount of sewage sludge and manure increases, governments, corporations and the general public are developing methods through which to process and reuse this excess waste[6].

3.4.1 TREATMENT OF BIOSOLIDS

The use and disposal of biosolids is always preceded with treatments designed to ensure regulatory requirements are met, public health and the environment are being protected, to facilitate handling and to reduce costs. The treatment processes prepare biosolids specifically for intended methods of use or disposal.

Stabilization and dewatering are the two common methods of treatment. In the dewatering process, excess water is removed from biosolids so they can be composted, used in landfills, dried or incinerated. Methods include: air drying, vacuum filters, plate and frame filters and centrifuges belt filter process.

In the stabilization treatment, the processes are designed to reduce pathogen levels, odour and volatile solids content. Table provides a list of the different stabilization treatment processes, a brief description of the treatment and the associated end disposal method.

3.4.2 SEWAGE SLUDGE USE AND DISPOSAL

There are three common practices for the disposal of sewage sludge:

- Land Application
- Sludge Incineration
- Surface Disposal

3.4.2.1 LAND APPLICATION

Land application is defined as the spreading, spraying, injection, or incorporation of sewage sludge, including a material derived from sewage sludge (e.g., compost and pelletized sewage sludge), onto or below the surface of the land to take advantage of the soil enhancing qualities of the sewage sludge.

Land application is considered to be the most common method for using biosolids. Some land application practices include crops, revitalization of mines, forests and fertilizer for parks and landscaping.

Advantages

- Ideally, the use of sewage sludge for land applications turns a waste into a resource.
- Biosolids condition the soil and plants while reducing the impacts of high levels of excess nutrients entering the environment.
- Improves conditions of several types of land and has the potential to improve others with future research and testing

Disadvantages

There are several disadvantages to using sewage sludge for land application. Most deal with the environmental and health problems that could occur:

- The general public may negatively view the use of sewage on or near their food source or living spaces - no matter how government tries to convince them otherwise.
- Proper treatment and testing of the sludge must be performed regularly and regulatory standards must be updated. Failure to do so may cause health and environmental problems especially if pathogens are not found or identified.
- The odour associated with the application of sludge is often disliked by many people residing in the area where land application occurred.
- Animals and people who wander into recently treated areas could be harmed
- Food companies may not buy food which is grown from sludge

3.4.2.2 SLUDGE INCINERATION

Incineration is a sludge disposal process that involves the firing of sewage sludge (biosolids) at high temperatures in an enclosed area. The incineration process permanently destroys toxic organic materials by breaking their chemical bonds and reverting them to their constituent elements, therefore reducing or removing their toxicity. This combustion process reduces the volume of hazardous waste to be disposed on land by converting solids and liquids to ash. The collection of ash is less than 20% of its original volume. Many urban sewage treatment facilities produce large volumes of sludge and have limited available space for sludge management. Hence, they are likely to see incineration as their most feasible option.

Types of Incineration Systems

Incineration systems generally consist of a furnace and one or more air pollution control devices. The two most commonly used incineration systems are multiple hearth furnaces and fluidized-bed reactors.

Advantages and Disadvantages

In addition to the problems associated with detrimental emissions in air, soil and water, there are economical disadvantages to incineration.

Cost and Technical Feasibility

Cost is a major consideration with incineration technology. Incinerators are very mechanized and capital-intensive investment that must be managed with a high level of expertise and attention to maintenance. The incineration option is a long-term commitment that is most cost-effective for large volume biosolid treatment systems. To evaluate this option, communities must consider factors like ash disposal, economies of scale, and air pollution. Generally, most incinerators should handle a sludge input rate between 0.25 and 3 dry tons per hour. Anything less than 0.25 dry tons would most likely be too expensive for this technology. In contrast, over 3 dry tons per hour may exceed the limit of the technology and may require multiple incinerators.

Beneficial Use/Production of Energy

Energy recovered from the incineration of sludge may be used to support some of the energy needs of the Wastewater Treatment Plant. Heat from the incinerator may be used to pre-dry the sludge. Incinerators may also be utilized to assist in odour control at a facility. Ash by-products may be used as a substitute raw matter in the manufacturing of cement and brick and as a landfill cover.

3.4.2.3 SURFACE DISPOSALS

Surface disposals (biosolids) are placed on an area of land for final disposal. If biosolids remain on land for longer than two years, this land is considered an active biosolids unit. A surface disposal site is an area of land that contains one ore more active sludge units. Some surface disposal sites may be used for beneficial purposes as well as for final disposal. Surface disposal site include:

- Monofills
- Surface impoundments
- Lagoons
- Waste piles
- Dedicated disposal sites
- Dedicated beneficial use sites.

Advantages

- Surface disposal methods are the cost-effective and generally safe process to recycle, fertilize and condition agricultural, forest and reclamation soils.

Disadvantages

- Generation of emissions into the air, mainly greenhouse gases like methane and carbon dioxide.
- Generation of emissions into the soil and water at dumpsites, including various compounds such as ions, heavy metals, organic compounds and micro organisms in leachate
- Noise and dust from the delivery vehicles
- Odours
- Disturbance of vegetation and the landscape.

3.4.2.4 CONCLUSION: SEWAGE SLUDGE DISPOSAL AND USE

In conclusion, after reviewing the efficiency of the land application, incineration and surface disposal methods of sewage sludge use and disposal, it appears that land application has the potential to be the most ideal and efficient method. If the treatment of sewage and guidelines are followed, sewage sludge could be a resource instead of a waste. Instead of disposition, as with incineration and surface disposal, land application can help to fertilize crops and revitalize land. Also, the above findings indicate that incineration is not a cost effective technique.. It is important to note, however, that all methods need to be used to some extent, depending on the specific needs and interests of users and location.

Finally, no matter the method used, government bodies need to ensure that they are consistently enforcing proper treatment and application guidelines as well as educating the public as to the processes being used.

3.5 AQUACULTURE AND SEWAGE WATER TREATMENT[7]

Growing population and the lack of a corresponding infrastructure for waste water treatment are growing concerns. In every country, the generation of domestic sewage escalates, often beyond the capabilities of conventional sewage treatment plants, which include oxidation/waste stabilization pond, activated sludge, trickling filter, aerated lagoons, Upflow anaerobic sludge blanket process, etc. At the same time, it is increasingly being recognized that sewage is not just a pollutant, but rather a nutrient resource.

3.5.1 SEWAGE-FED CULTURE

Several variations from overhung latrines over the ponds to the application of primary treated sewage into fish ponds exist. The sewage-fed fish culture in Munich, Germany and sewage-fed bheries of West Bengal, an Eastern State of India, are the good examples. The practices in over 5,700 ha area in Bengal produce over 7,000 tons of fish annually.

3.5.2 NORMAL MANAGEMENT PRACTICES

- Fry stocking: 30-50 mm
- Fish density: 40,000 – 50,000/ha
- Sewage application: weekly or bimonthly intervals
- Field indices for pond's sewage intake: algal blooms, fish surfacing, dark color of water
- Production rate: 3-7 tons/ha/year

3.5.3 CARP POLYCULTURE IS PRACTICED IN MOST OF THESE WATERS

- Silver carp (Hypophthalmichthys molitrix)
- Common carp (Cyprinus carpio var. communis)
- Indian major carps – Catla (Catla catla), Rohu (Labeo rohita) and Mrigal (Cirrhinus mrigala)

3.5.4 PROBLEMS RELATED TO SEWAGE-FED CULTURE SYSTEMS

- Accumulation of silt and high organic matter at pond bottom
- Incidence of parasites and fish diseases
- Possibilities of pathogens being transferred to humans

3.5.5 SOLUTIONS

- Regulate sewage intake into the ponds
- Provide freshwater for dilution
- Use of prophylactics
- Depuration of fish in freshwater before marketing

3.5.6 AQUACULTURE-BASED SEWAGE TREATMENT PLANT (ASTP)

An aquaculture-based sewage treatment plant designed in India has incorporated cultivation of duckweeds prior to application of fish ponds and post-fish culture depuration, with the objectives of refinement of sewage-fed fish culture and sewage treatment through aquaculture practices.

The ASTP consists of a set of duckweed ponds, fish ponds and depuration ponds, located at a place 250 m away from the residential area and bore wells. Gravitational flow of sewage wherever feasible for sewage intake into the treatment complex will be advantageous.

3.5.7 DESIGN AND CONSTRUCTION OF A MODEL TO TREAT 1 MLD SEWAGE

A model for treating one million liters per day (MLD) of sewage, from a population of about 20,000 is described below:

Source: A receiving chamber for sewage feeds the effluent to the ASTP.

Duckweed culture complex: It comprises 18 ponds with brick lining (25 m x 8 m x 1 m), with three series of six ponds in a row. The sewage is retained here for a period of two days, with free passage between the series.

Fish ponds: Two fish ponds (50 m x 20 m x 2 m) receive the treated sewage from the duckweed ponds and retain it for three days.

Depuration ponds: Two depuration ponds (40 m x 20 m x 2 m) with freshwater, also used as marketing ponds, provide for depuration of fish for a week before marketing. As the fish harvest is occasional, these ponds are also used for the culture of grass carp, fed with duckweeds from the system.

Outlet: Sewage outlet drains are provided from the fish and depuration ponds for drainage into natural waters.

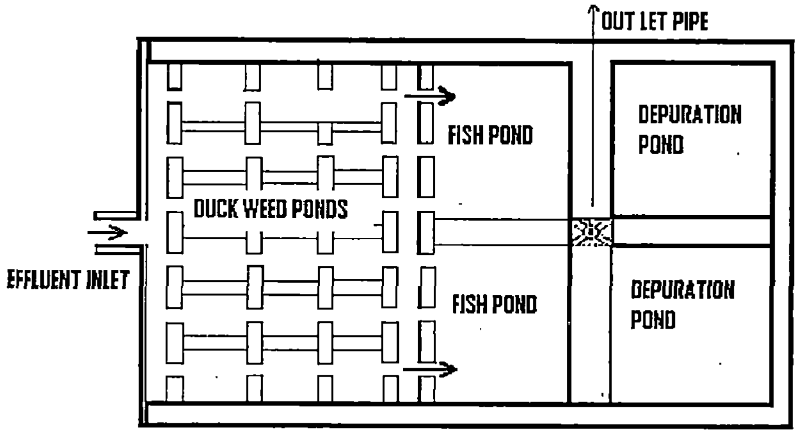


Figure 3.5.7.1: Plan for Aquaculture Treatment system for domestic sewage [7]

3.5.8 DUCKWEED CULTURE

Duckweeds serve as nutrient pumps, reducing eutrophication effects and providing oxygen through the photosynthesis activity. The ponds are inoculated with duckweeds to cover roughly one-third of the surface area (400 g/sq m). The approximate growth rates of individual weeds in the sewage-fed culture system are Spirodela 350 g/sq m/day, Wolffia 280 g/sq m/day, Lemna 275 g/sq m/day and Azolla 160 g/sq m/day. The harvested weeds could be used to feed grass carp in the marketing ponds or composted for application in fish ponds and horticulture fields.

3.5.9 FISH CULTURE

The ponds are stocked with Indian and Chinese carps at a density of 10 000 fingerlings/ha (Catla 40%, Rohu 40% and Silver carp 20%). Grass carp, Ctenopharyngodon idella, is stocked in the marketing pond and fed with duckweeds harvested from duckweed ponds. The fish stocks are checked at monthly intervals for their health and growth through sample nettings. By monitoring of dissolved oxygen levels to maintain 3-5 mg/l, the sewage flow is regulated. Fish harvest is carried out 8-12 months after stocking, with mean individual sizes in the range of 600–800 g. About 600-700 kg of fish are harvested from the two fish ponds, working out to a production level of 3-3.5 tons/ha/year and about 400 kg of fish are harvested from the marketing ponds, representing considerable economic returns from the sewage.

The ASTP provides for retention of sewage for two days in duckweed ponds and three days in fish ponds. This achieves the desired reduction in nutrient concentrations, BOD, COD and the bacterial populations to meet the standards for discharge into natural waters. The fish produced from the system enables recovery of about 40% of the working costs.

TABLE 3.5.1: Total Area Required [7]

Sl.No	Units	Measurements
1	**Duckweed culture complex**	
	Individual Ponds	25m X 8m X 1m
	Total no. of Ponds	18 nos.
	Area	3600 sq.m
2	**Fish Ponds**	
	Individual Ponds	50m X 20m X 2m
	Total no. of Ponds	2 nos.
	Area	2000 sq.m
3	**Depuration/Marketing Ponds**	
	Individual Ponds	40m X 20m X 2m
	Total no. of Ponds	2 nos.
	Area	1600 sq.m
	Total water Area	7200 sq.m

This model has been used in several Indian villages for community sanitation and aquaculture, with modifications. Typically, a third of the pond of the size of 0.2–0.4 ha at the inlet end serves as the receptor of sewage from solid wastes from community latrines. This portion is stocked with duckweeds that multiply in the presence of organic matter and effluents that then pass into the adjacent portion of the pond stocked with fish. With a continuous flow, the organic loading is regulated in different seasons.

3.6 METAL REMOVAL AND PHOSPHORUS RECOVERY[8]

Wastewater sludge may be regarded both as a resource which should be recycled in a proper way and a threat to the environment. Sustainable sludge handling may therefore be defined as a method that meets requirements of efficient recycling of resources without supply of harmful substances to humans or the environment. The sludge handling should be performed in an energy and resource efficient way. The sludge handling scheme should consider most of the sludge components as resources suitable for manufacturing of products, while the pollutants should be separated into a small stream or be destructed.

3.6.1 SOURCE CONTROL

An important resource in the sludge is nutrients which can be utilised through using sludge as fertiliser in the agriculture. Agricultural use is regarded as the best alternative if the pollutants in the sludge is below limiting and guidance values. The policy of Stockholm Water is to regard sludge as a resource that should be recirculated in an eco-cycle. The use in agriculture has therefore been considered as the main alternative. The use of sludge in agriculture has, however, not been accepted from the food industry, certain interest organisations and part of the public even if the sludge quality is better than the stringent requirements from the authorities. Many metals accumulate to high concentrations in the surface layer of soil treated with sewage sludge. The depth of the contaminated soil depends on the depth to which sludge is physically incorporated by ploughing or other cultivation. After addition there is little evidence of significant downward movement of the metals in the soil.

Source control of pollutants to the sewer net has a key role for the sludge quality. Stockholm Water (http://www.siwi.org/) has produced routines for the control of the sludge quality to be able to determine final disposal method for the sludge so that no sludge that is not approved will be supplied to agricultural land.

3.6.2 METAL REMOVAL

3.6.2.1 LEACHING WITH ACID

If the metal content of the sludge is too high, the metal can be removed from the sludge by leaching with acid. After the acid metal solution has been separated from the sludge, the acid is neutralised and the metals is precipitated as a metal hydroxide sludge. The three alternatives there:

- Chemical leaching with sulphuric acid at pH-level 1.5.
- Microbial leaching with addition of sulphur, which by the action of sulphide oxidising bacteria is transformed to sulphuric acid.

$$S + 1.5\ O_2 + H_2O \rightarrow SO_4^{2-} + 2H^+$$

- Microbial leaching with addition ferrous sulphate. The ferrous ions are by iron bacteria oxidised to ferric ions, which oxidises the metal sulphide to soluble sulphate.

An acid solution is obtained by addition of sulphuric acid and precipitation of ferric hydroxide. The largest solubilization was obtained with microbial leaching through addition of sulphur. Biological leaching reduces the costs for chemicals, but the sludge has to be aerated, which increases the capital cost. However, the aeration oxidises the metal sulphides to soluble sulphate, which increases the metal solubilization.

If an ion exchanger is used the metal ions can be transferred from the sludge to the ion exchanger, and a high degree of solubilization can be reached at a higher pH-level. However, the ion exchanger has to be separated from the sludge, which can be achieved if a magnetic ion exchanger is used, which is separated from the sludge with use of a magnetic drum.

3.6.2.2 PHOSPHORUS RECOVERY

Instead of removing the impurities as metals from the sludge the nutrient in the sludge can be recovered and used as fertiliser in the agriculture. The nutrients in the sludge are potassium, calcium, phosphate and nitrogen. Of these nutrients phosphate is most important to recover. Phosphate fertiliser is produced by mining of phosphate ores. More than 300 different phosphate minerals are available, but only apatite (calcium phosphate, $Ca_3 (PO_4)_2$) is used for production of fertiliser. In 1995 the world phosphate rock production was 160 000 ton per year (as P_2O_5), having tripled over the last 40 years. About 90% of this is used as fertiliser. At this rate of consumption the known apatite reserves have been estimated to last for a period up to 1000 years. However, if the present increase in world population and the increasing need for fertiliser for food production is taken into account, the supply of phosphate may well be crucial within a century.

Since nitrogen is the main part of the atmosphere the supply for nitrate is unlimited. Recovery of nitrogen shall be done if the energy required for recovery is less than the energy consumed by producing from nitrogen gas.

In the studies to find solutions for a sustainable sludge handling at centralised municipal wastewater treatment plants phosphorus recovery has been the main issue. In the wastewater treatment process phosphorus is precipitated and transferred to the sludge phase. This process can be both chemical with addition of iron or aluminium salts and biological. In the chemical process is phosphorus precipitated as ferrous or aluminium phosphate. In the biological process is phosphorus at aerobic conditions taken up by the micro-organisms. Also without salt addition some chemical precipitation will occur with metal ions in the wastewater. The phosphate in the sludge will therefore be present as both metal phosphate precipitations and incorporated in the biomass. During anaerobic digestion the biomass will be converted to methane gas and the phosphate will be released to the supernatant. The degree of phosphate release during digestion will thus depend on the degree of biological phosphorus removal in the treatment process. The phosphate released during digestion can be recovered from the supernatant by precipitation.

3.6.3 UTILISATION FOR BUILDING MATERIAL[9]

One resource in sludge is the inorganic materials that can be used for production of building materials. Any environmental hazardous contaminants are bound as mineral to the material and utilisation of sludge reduces mining of raw material for production of building material. If the nutrients are recovered the sludge must otherwise be deposited for instance on a waste disposal site.

The content of sludge from water treatment plants depends mainly on the chemicals used for coagulation of suspended particles in the raw water. The high aluminium content of a sludge produced at water treatment with aluminium salts makes it useful for production of aluminous cement.

There are a number of useful by-products that can be derived from municipal sewage sludge, including:

- Concrete products made from sludge ash, such as reinforced-concrete pipes
- Lightweight aggregate made from sludge ash to replace natural aggregate used in water-permeable bricks and building construction materials
- Compressed baked blocks, based on press and burn technology whereby the pressed molded sludge ash is burned at a temperature of about 1050 degrees

Celsius to manufacture durable interlocking bricks that it can be used as for pavement and park landscaping.

- Sludge melted slag where the sludge is heated up to 1500 °C, the organic matter is decomposed and burnt, and the remaining inorganic matter is melted to a liquid state. When cooled and solidified, this melted inorganic matter, referred to as sludge melted slag, has half the volume of sludge ash and is highly stable with no dissolution of heavy metals contained in the slag. Several uses for sludge melted slag have been investigated, including its use in road bed or construction materials.

All of these applications make use of a valuable resource that would otherwise be wasted.

3.7 RESOURCE RECOVERY FROM FAECAL SLUDGE USING WETLANDS

A large part of the urban population in low-income countries is not served with proper sanitation. Although the public health aspects are of great importance, the options for the recovery of the resources in faecal sludge should not be overlooked. From the perspective that waste is a mixture of valuable resources, faecal sludge should not only be treated and disposed of in a safe and environmental manner, but its components (i.e. water, nutrients, organic matter) should be applied for other purposes e.g., for fertilisation or the production of biomass[10].

Although not much is reported about faecal sludge treatment and reuse, there are some possibilities for treatment and reuse on a small scale. The treatment of faecal sludge on a neighbourhood scale has certain benefits and drawbacks compared with centralised treatment. Neighbourhood scale treatment can result in lower transportation cost of the sludge. After treatment the sludge has a higher solids content which makes it cheaper to transport the sludge to more remote areas.

Faecal sludges are sludges of variable consistency collected from so-called on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua-privies. To some extent, it can be compared with sewage sludge, which is a co-product of conventional wastewater treatment processes. This means that processes for the treatment and disposal of sewage sludge might be applicable for faecal sludge treatment.

For the treatment of sewage sludge, different technologies have been developed and are applied in most of the industrialised countries. Not all of these treatment processes aim at resource recovery. Sludge treatment processes as mechanical sludge dewatering and incineration require high-tech installations and consume a lot of energy. For example, sludge dewatering by sedimentation and composting of the sludge can be done with much lower energy input.

Constructed wetlands for the treatment of faecal sludge might be a powerful tool to raise the quality of life of local communities in developing countries. The waste can be treated as a valuable resource, since the yields of wetlands are valuable products. Resource recovery from faecal sludge can take place in different ways:

- A direct reuse of the faecal sludge in agriculture or aquaculture (e.g. fertilisation, soil conditioning).
- The reuse of the effluent of treatment systems, such as ponds and wetlands (e.g. irrigation, fertilisation).
- The reuse and further treatment of the biomass produced in wetlands or ponds (e.g. composting, energy production, production of building materials, animal feed and fibres).

The integration of faecal sludge treatment and the production with wetlands leads to promising systems in which waste is a valuable resource.

CHAPTER 4

RESOURCE RECOVERY FROM SOME EXISTING STPs

4.1 SEWAGETREATMENT PLANTS AT CHENNAI

4.1.1 FEATURES OF SEWAGE TREATMENT PLANT AT KOYAMBEDU

Chennai Metropolitan Water Supply and Sewerage Board (CMWHSS Board) is having 9 sewage treatment plants with a total treatment capacity of 481 MLD. These treatment plants consist of conventional primary and secondary treatment with disinfections of coliform. The Koyambedu sewage treatment plant (Koyambedu STP) is one of the recently commissioned treatment plants with 60MLD capacity. The Koyambedu STP consists of pre treatment for removal of floating matters and grit and the primary treatment for removal of settleable solids. In addition, the secondary treatment for biological degradation of organic matter and followed by disinfections for coliform removal. The treatment Plant gets an inflow of 60 MLD of untreated sewage[11].

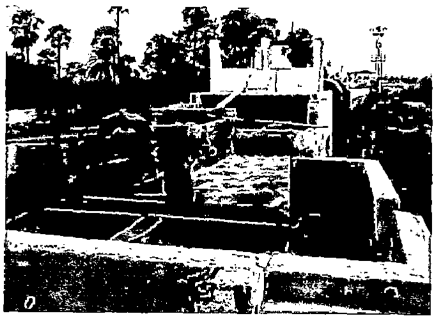


Figure 4.1.1: Inlet of Water

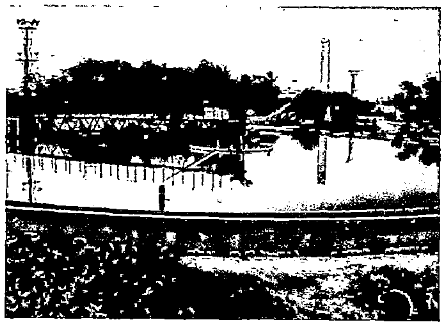


Figure 4.1.2: Primary Clarifier

Figure 4.1.3: Primary Settling Tank

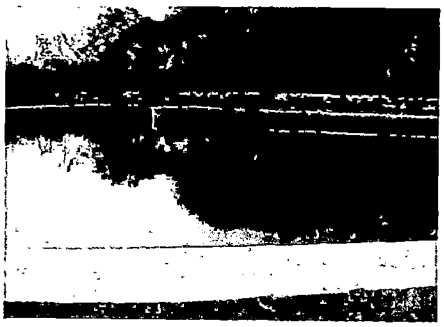


Figure 4.1.4: Secondary Settling Tank

TABLE 4.1.1.1: Characteristics of Untreated Sewage at Koyambedu STP[11]

Sl. No	Parameters	Unit	Quantity
1	BODs, at 20^0e	mg/L	380-410
2	COD	mg/L	910-960
3	Total suspended solids	mg/L	450-550
4	pH	mg/L	6.5-6.9
5	Total solids	mg/L	1800-1950
6	Oil and Grease	mg/L	5-10

At Koyambedu STP, single stage anaerobic digestion process is adopted to treat the primary and secondary sludge. The average sludge inflow to the digester is 480m3/d. The specific gravity of sludge is 1.01-1.02. The biogas production from the sludge is 0.5-0.9 m3/kg of volatile suspended solids (VSS) destroyed.

The bioconversion of organic matter takes place in the digesters with biogas recovery. The digested sludge from the digester is conditioned by polyelectrolyte dosing and fed into the centrifuge for dewatering. The digester sludge is disposed as manure and the supernatant liquid is returned back to the primary clarifier.

A gas engine of 625 kW capacity produces electric power using biogas as a fuel. The exhaust gas from the gas engine is dispersed into the atmosphere through the stack of 15m height.

4.1.2 PRESENT STSTUS

At present 2500 m3/day of biogas is generated and the generated biogas is purified using water scrubber column and moisture trap for the removal of H_2S and moisture content respectively. The purified biogas is stored in the gas holding tank and is used as a fuel for gas engine to generate electric power. Characterization of biogas after purification at Koyambedu STP is shown in Table: 4.1.2.1.

TABLE 4.1.2.1: Characteristics of Biogas at Koyambedu STP

Sl. No	Constituents	Unit	Desirable * composition	Available Composition
1	Methane (CH_4)	vol %	70-90	65 – 67
2	Carbon dioxide CO_2)	vol %	<20	30 – 32
3	Hydrogen sulfide (H_2S)	vol %	<0.001	0.04 - 0.06
4	Moisture content	vol %	Preferably absent	1.0 - 1.5
5	Trace gases	vol %	Preferably absent	1-3.45

Desirable composition given as per the operation & maintenance manual issued by the gas engine manufacturer[12]

From the Table, it can be seen that CO_2, H_2S and moisture content in the biogas exceeds the desirable limits and hence it is required to enhance the quality of biogas. At present the biogas engine produces 471 kW of electric power at Koyambedu STP against the design capacity of 625 kW (25% short fall). It was found that this reduction in power generation of gas engine is due to the presence of high concentration of CO_2 and moisture content in the biogas. Hence there is a need for further purification of biogas to reduce CO_2 and moisture content in the biogas.[16]

4.1.3 TOTAL EXPENDITURE FOR THE YEAR 2005-2006

The details of sewage treatment plants in Chennai city, their capacity and the total expenditure incurred for the year 2005-2007 is furnished in the tables 4.1.3.1 and 4.1.3.2.

TABLE 4.1.3.1: Sewage Treatment Plants at Chennai

ZONE NO	NAME OF THE ZONE	CAPACITY OF THE PLANT(MLD)			ACTUAL INFLOW	EFFLUENT DISCHARED INTO
		OLD	NEW	TOTAL		
1	Kodunkaiyur	80	110	270	150	Buckingham canal
2	Kodunkaiyur	80				
3A	Koyumbedu	34	60	94	85	Koovam River
3B	Nesappakkam	23	40	63	45	Adaiyar River
4	Perungudi	45*	54	54	75	Buckingham canal

*Perungudi old plant was condemned in 1985 due to inundation of Buckingham canal. So it is proposed to construct a new plant of 54 MLD at Perungudi.

TABLE 4.1.3.2: Expenditure for All the Plants[11]

Sl.No	O & M COSTS for the year 2005-2006 (For 4 old plants)	Rs. in lakhs	Rs. in lakhs
1	Repairs and Machineries		121.25
2	E.B.Power charges		477.80
3	Administration charges		5.79
	Electricity	2.63	
	Telephone	2.16	
	Entertainment, Printing, Conveyance, Miscellaneous	1.00	
4	Staffs Salary		44.20
5	Security Service Charges		31.56
	Total		**680.60**
	Cost for 1 MLD = 680.60/ 217 = Rs.3.136 lakhs. Power production = nil		
	Expenditure for the New Plants		
6	**Annual Maintenance Charges for the 4 new plants(Annual Tender)** Rs. 10.00 lakhs per month each including E.B.Charges		480.00
	Total Electricity consumption per year(4745MWHX4.20X1000 = Rs. 199.29 lakhs)		199.30
	Total		**679.30**
	Cost for 1 MLD = 679.30/ 264 = Rs.2.573 lakhs.		
	Total Expenditure		**1359.90**
	Expenditure for 1MLD = Rs.1359.9 lakhs /481MLD =		**Rs.2.827 lakhs**

TABLE 4.1.3.3: Revenue Yield from Resource Recovery 2005-2006[15]

Sl.No	RESOURCES	Rs. in lakhs
1	Sale of Sewage treated water to CPCL, MFL, and MPL @ a rate of Rs. 8.25 per kl.	639.25
2	Sale of Gross per Year	6.00
3	Sewage received from residences thro' lorries	48.00
	Total	693.25
	Recovery from 1MLD Rs. 693.25 lakhs/481 MLD	1.441

4.1.4 PROJECTED GAS PRODUCTION

The gas produced per million litre of sewage is 172 m3 (Appendix 1). The projected gas production vs. the actual gas production is given in Table 4.1.4.1.

TABLE 4.1.4.1: Projected vs. Actual gas production[17]

Sl.No	Location of STP	Gas produced per million litre of sewage in m3	Capacity in MLD	Projected gas production in m3	Actual gas production in m3
1	Kodunkaiyur	172	110	18920	4500
2	Koyambedu	172	60	10320	2500
3	Nesappakkam	172	40	6880	1700
4	Perungudi	172	54	9288	2300
	Total		264	45408	11000

4.1.5 POWER GENERATION AS PER THE PRODUCTION OF BIOGAS

C.V.of Biogas is 21.24 MJ/kg (Appendix 1). Energy production for 1 m3 biogas@21.24 mJ/m3 =2.04 kWh/day. **At Kodunkaiyur,** Energy production / day = 4500 X2.04 = 9180 kWh/day=9.18 MWh/day.

TABLE 4.1.5.1: Energy Production from Biogas[17]

Sl.No	Location of STPs	Biogas production in m3	C.V.of Biogas MJ/m3	Energy production for 1 m3 biogas @21.24 MJ/m3	Energy production /day	
					kWh/day	MWh/day
1	Kodunkaiyur	4500	21.24	2.04 kWh	9180	9.18
2	Koyambedu	2500	21.24	2.04 kWh	5100	5.10
3	Nesappakkam	1700	21.24	2.04 kWh	3468	3.47
4	Perungudi	2300	21.24	2.04 kWh	4692	4.69
Total Energy production per day MWh/day						22.44 MWh
Annual Gas Production: 22.44 MWh X 365 days					8191 MWh	
Total Electricity savings per year@ Rs4.20 per unit					Rs. 344.00 lakhs	

4.1.6 POWER GENERATION THRO' GAS ENGINE

As per the Operation and maintenance register of the Enviro Control Associates (I) Pvt Ltd., Chennai Metropolitan Water Supply and Sewerage Board 60MLD Sewage Treatment Plant – Koyambedu[11], the generation and consumption of gas through gas engine is prepared and shown in Table 4.1.6.1.

TABLE 4.1.6.1: Generation / Consumption Report

Month	Engine Hrs	Cumulative Operating Hrs	Power Generation (KWH)	Gas Consumption (m3)
September'05	22:00	22	9600	3699
October'05	181:08	202	63900	26514
November'05	297:52	500	94500	38571
December'05	283:00	783	86900	35761
January'06	444:58	1228	138900	56926
February'06	369:45	1596	120800	49711
March'06	578:58	2175	198600	81280
April'06	387:41	2562	143200	58688
May'06	256:00	2818	108200	44344
1-6-06 to 5-6-06	44:00	2862	19500	7959
Average 9 Hrs. per day			**984100**	

Total Power Generated as per log book = 984100 kWh for 2862 hours. The Power Generated per hour is 343.9 kWh. The Power Generated per day (9 hrs.) is 3095 kWh (3 MWh). Total power production is13 MWh per day). The Annual Power Production is4745 MWH @ Rs. 4.20per unit, Total Electricity savings per year is Rs. 199.29 lakhs. The Actual Electricity savings per 1 MLD is Rs. 0.755 lakhs/year. The Cost of theoretical Power savings is Rs.344.00 lakhs/year. The Cost of E.B. Power savings per 1MLD is Rs. 1.30 lakhs/year (Appendix 1).

TABLE 4.1.6.2: Annual Expenditure, R. R. and Power Generation

Sl.No	STP	Annual Expenditure	Annual Resource Recovery	Power generation as per the volume of gas produced		Actual Power generation	
		Rs. In lakhs	Rs. In lakhs	MWH	Cost Rs. in lakhs	MWH	Cost Rs. in lakhs
1	All 8 STPs	1160.60	693.25	8191	344.00	4745	199.29

4.1.7 ZERO DISCHARGE PLANT AT CPCL, MANALI, CHENNAI[14]

India's leading Refinery owned by Indian Oil Corporation Ltd., have set up sewage Recycling Plant for Treating Sewage from Chennai Metro and reusing the same for various utility application in refinery. The Chennai Petroleum Corporation Limited is situated in Manali in Tiruvallur District, Tamil Nadu, about 12 KM from Chennai City. The Zero Discharge Project is located at TTP Plant at a distance of 2-3 kms from the Refinery plant area. In order to utilize the latest state-of-art of technology, CPCL concentrated on eco-friendly process, viz., Ultrafiltration for RO pretreatment in Zero Discharge Project. The Zero Discharge Project is a 150 KL / hr capacity Ultra filtration plant with associated units.

4.1.7.1 PROCESS

The treated effluent from guard pond of refinery effluent treatment plant and treated sewage from intermediate storage pond of TTP is pumped to the equalization pond at the zero discharge plant site. The equalized water is dosed with ferric chloride for coagulation and allowed to settle. The clear water overflow is collected in the filter feed tank. Hypo is dosed in this tank. The clear water from the filter feed tank is pumped to the up flow filters (3 Working +1 Standby) to remove the suspended solids. The filtered water from the up flow filter is collected in the Ultrafiltration feed tank for further pumping to Ultra filtration Unit.

4.1.7.2 ULTRAFILTRATION

The ultra filtration feed pump pumps the water at a velocity of 2 m/sec from the fibre side to the shell side of the membrane. It is the dead end filtration mode, where the membrane traps all the turbidity, suspended solids, colloids, bacteria, etc. and pure water comes out of the Ultrafilter hollow fibre. Typically, the process is run with a constant permeate flow. Consequently the Trans Membrane Pressure TMP (Differential Pressure between feed and permeate side) will increase during filtration. A periodical back flush using permeate is required to control the increase of TMP thru the backwash system.

During backwash all accumulated particles are removed. Along with this, membrane inside surface is cleaned from the adherent of scales and microorganism. This is done thru backwash system involving forward flushing, backwash including chemical cleaning with Hypo 200 ppm or HCl 150 ppm and final forward flushing[18].

4.1.7.3 COST CONCERN[15]

The plant cannot run without water even for a single day as it would result in a loss of over Rs 60 crore a day in turnover. In Tamil Nadu, water is a costly commodity. And sometimes, one cannot get it whatever the cost as happened a few years ago when the plant had to be shutdown for want of water resulting in losses of crores of rupees. During the first year of operation, the cost of water will be Rs. 61 per 1,000 litres, about the same amount was paid by CPCL to Metro water for purchasing water. Even sewage water, which CPCL buys from the Chennai Metropolitan Water Supply and Sewerage Board (Metro water), costs Rs 8.25 a kilolitre. So, it has embarked on a major exercise to become self-sufficient in water. The refinery needs about 30 MLD water a day. The sources are water supply by Metro water about 20 MLD and recycling Chennai's sewage and the refinery's discharge. CPCL also has a sewage-recycling unit that gives it about 8.5 MLD water after treating 11 MLD of sewage. Treated sewage water cost works out to about Rs 30-35 a kilolitre, about half that of the freshwater bought from Metro water[15].

4.2 SEWAGE TREATMENT PLANT AT HARIDWAR

4.2.1 PREVIOUS HISTORY

The 72 km long sewerage system with five pumping stations at Haridwar was built in the year 1938. When Ganga Action Plan was started in 1986, the pumping plants and accessories were not functioning properly, the sewer lines were almost choked and, as a consequence, about 34 million liters per day (MLD) effluent was polluting the river Ganga due to over flowing of sewage through 10 drains. There was no sewage treatment plant and untreated sewage was utilized for agricultural purpose infrequently in an area of 40 hectares owned by the Haridwar Municipality.

4.2.2 SEWAGE TREATMENT PLANT

The STP was commissioned in the year 1993 on Activated Sludge Process (ASP) with a capacity of 18 MLD. An additional 80 hectares of agricultural land was developed for sewage farming by laying about 4 kms of sewage farming channels.

TABLE 4.2.2.1: Salient Features of STP

Sl.No	Units	Values
1	Screen chamber	1 no
2	Grit chamber	3 no
3	Primary settling tank	3 nos.-16 m dia 7 m depth-6MLD capacity, 2 to 3 hrs. Retention time
4	Aeration tank	3 units – 16 m x 16 m- continuous flow
5	Secondary settling tank	HRT-2 to 3 hrs
6	Thickener:	To reduce the moisture content- before bio digester
7	Bio digester	7 days
8	Gas Engine	368 kV x 1.2 = 441.6 kW Started with diesel and then with gas
9	Sludge Drying Bed	7 days

4.2.3 INFLUENT AND EFFLUENT CHARACTERISTICS

In the STP, the domestic sewage with BOD and SS characteristics of about 180 mg per liter and 255 mg per liter respectively is treated and these parameters are brought down to less than 20 mg per liter, respectively, which is better than the norms laid down for Ganga Action Plan.

Now the excess sewage is bypassed into the river. There is a proposal for the construction of 26 MLD sewage treatment plant in the same campus is under the consideration of the government under Ganga Action Plan Phase -II.

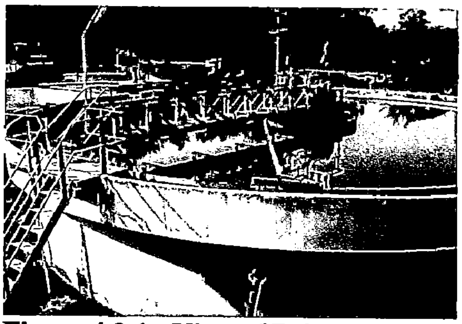


Figure 4.2.1: View of Primary Clarifier

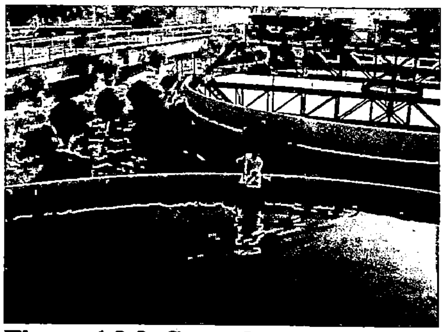


Figure 4.2.2: Secondary Settling Tank

4.2.4 TOTAL EXPENDITURE FOR THE YEAR 2005-2006

The total expenditure of the sewage treatment plant for the year 2005-2006 is obtained from the office of the Ganga Pollution Control Unit, Uttaranchal Peyjal Nigam, Haridwar, and is tabulated in Table 4.2.4.1.

TABLE 4.2.4.1: Total Expenditure for the Year 2005-2006

<table>
<tr><th>Sl.No</th><th colspan="3">Description</th><th>Quantity</th><th>Rate</th><th>Unit</th><th>Amount in Rs</th></tr>
<tr><td colspan="8">SUPERVISORY & OTHER STAFF</td></tr>
<tr><td>1</td><td colspan="3">Assistant Engineer(E&M)</td><td>1 no</td><td>28190</td><td>each</td><td>28190</td></tr>
<tr><td>2</td><td colspan="3">Junior Engineer(Civil)</td><td>1 no</td><td>21530</td><td>each</td><td>21530</td></tr>
<tr><td>3</td><td colspan="3">Junior Accountant</td><td>1 no</td><td>9230</td><td>each</td><td>9230</td></tr>
<tr><td>4</td><td colspan="3">UDC Senior Assistant</td><td>1 no</td><td>9230</td><td>each</td><td>9230</td></tr>
<tr><td>5</td><td colspan="3">LDC Typist</td><td>1 no</td><td>8200</td><td>each</td><td>8200</td></tr>
<tr><td>6</td><td colspan="3">Peon</td><td>1 no</td><td>6180</td><td>each</td><td>6180</td></tr>
<tr><td>7</td><td colspan="3">Lab Assistant</td><td>1 no</td><td>7100</td><td>each</td><td>7100</td></tr>
<tr><td>8</td><td colspan="3">Lab Attendant</td><td>2 no</td><td>6180</td><td>each</td><td>12360</td></tr>
<tr><td colspan="8">OPERATING & RUNNING STAFF</td></tr>
<tr><td>9</td><td colspan="3">Fitter I Class</td><td>1 no</td><td>7100</td><td>each</td><td>7100</td></tr>
<tr><td>10</td><td colspan="3">Electrician I Class</td><td>1 no</td><td>7100</td><td>each</td><td>7100</td></tr>
<tr><td>11</td><td colspan="3">Electrician II Class</td><td>1 no</td><td>6300</td><td>each</td><td>6300</td></tr>
<tr><td>12</td><td colspan="3">Sweeper & Gardener</td><td>2 no</td><td>6300</td><td>each</td><td>12600</td></tr>
<tr><td>13</td><td colspan="3">Operator</td><td>16 Nos</td><td>7100</td><td>each</td><td>113600</td></tr>
<tr><td>14</td><td colspan="3">Labour</td><td>44 Nos</td><td>3542</td><td>each</td><td>155848</td></tr>
<tr><td></td><td colspan="3">Total/month</td><td></td><td></td><td></td><td>404568</td></tr>
<tr><td></td><td colspan="3">Total per year</td><td></td><td></td><td></td><td>48,54,816</td></tr>
<tr><td colspan="8">ELECTRICITY CHARGES</td></tr>
<tr><td>Load KW</td><td>App. Running hours</td><td>Unit rate</td><td colspan="2">Energy Consumed KW</td><td>Energy Charges</td><td>Meter Rent</td><td>Total Elect. Charges</td></tr>
<tr><td>245</td><td>3400</td><td>2.90</td><td colspan="2">833000</td><td>2415700</td><td>9000</td><td>24,24,700</td></tr>
<tr><td colspan="8">MAINTENANCE</td></tr>
<tr><td colspan="7">Repairs, Oil, Diesel, Chemicals etc.</td><td>6,00,000</td></tr>
<tr><td colspan="7" align="right">Grant total</td><td>78,79,516</td></tr>
<tr><td colspan="7">Rate per 1 MLD</td><td>4,37,800</td></tr>
</table>

4.2.5 RESOURCE RECOVERY

Resource recovery from the sewage has been a prominent facet of GAP works at Haridwar[16].

1. Approximately, 120 hectares of land is being irrigated with treated sewage having dissolved Nitrogen and Phosphorous.
2. The treated effluent is being sold at the rate of Rs 800 /hectare/year giving revenue of Rs 0.96 lakh/year.

3. About 2500 cum. of nutrient rich digested sludge cakes, which is an excellent bio-fertilizer and soil conditioner, are sold to the farmers at the rate of Rs 80/cum to yield a revenue of Rs 2 lakh per year.
4. Eucalyptus trees have been planted in the campus, giving a revenue of Rs 5 lakhs per year by way of sales from fuel wood trees.
5. Sales to safety-match box factories, mature poplar trees will fetch Rs 40 lakhs in the year 2003.
6. Also, available free land around the STP unit is being utilized by local farmers to grow vegetables by paying an annual lease of Rs 0.18 lakh per year.

TABLE 4.2.5.1: Resource Recovery

Sl.No	Resource Recovery	Rs in lakh /year
1	Treated effluent at the rate of Rs 800 /hectare/year	0.96
2	Digested sludge cakes, of Rs 80/cum	2.00
3	Eucalyptus trees	5.00
4	Mature poplar trees, Rs 40 lakhs/ 5 years	8.00
5	Growing vegetables by paying an annual lease	0.18
	Total	**16.14**

4.2.6 PROJECTED GAS PRODUCTION[13]

The gas produced per million litre of sewage = 96 m3 (Appendix 2). The projected Biogas production is 1728 m3. The Actual Biogas production is 430 m3. C.V.of Biogas is 21.24 MJ/kg (Appendix 2)

TABLE 4.2.6.1: Energy Production from Biogas

Sl. No	Location of STPs	Biogas production in m3/day	C.V.of Biogas MJ/m3	Energy production for 1 m3 biogas@21.24 MJ/m3	Energy production/day kWh/day	Energy production/day MWh/day
1	Kankhal	430	21.24	2.04 kWh	877.2	0.88
				Total Energy production per day		0.88
Cost of E.B. Power savings = 0.88 MWh/day X365 days X 3.00 X1000 =Rs.963600/year.						
Cost of E.B. Power savings per 1MLD = Rs.963600 / 18 MLD = Rs. 0.54 lakhs/year.						

Power Generation Thro' Gas Engine

At present, the gas is being utilized for running of DFG during power breakdown only and the rest is being flared.

4.3 SEWAGE TREATMENT PLANT AT LUCKNOW

4.3.1 EXISTING STATUS OF SEWAGE DISPOSAL[21]

The sewerage system in Lucknow town was first provided in 1918. Subsequently more and more sewers were laid as the town grew in size. Prior to its development as Gomti Nagar, the site used to be the sewage farm. In the absence of a disposal facility, at present all sewage is discharged directly into the River Gomti. Assuming the present water supply to be 475 MLD and waste water as 75% of it, the total waste water generated is approximately 356 MLD of which only 42 MLD is treated at the Daulatganj Sewage Treatment Plant with the balance 314 MLD being directly discharged into the river without treatment.

At present there is only one treatment plant at Daulatganj with a capacity of 42 MLD. The rest of the sewage discharges directly into the river. Under the National River Conservation Programme, the construction of a sewage treatment plant at Kakraha with a capacity 345 MLD based on UASB technology with application of effluent on land for irrigation has been sanctioned as part of the Gomti pollution prevention works.

4.3.2 TECHNOLOGY ADOPTED

This Sewage Treatment Plant is based on the Fluidized Aerobic Bed (FAB) technology. Since the process is aerobic hence air is supplied to sewage in which micro organism metabolize the soluble and suspended organic matter. Part of the organic matter is synthesis in to new cells and part is oxidized to carbon dioxide and water, so this procedure does not exit any foul gases. Hence no odor problem occurs by this STP.

4.3.3 DESCRIPTION OF EACH UNIT

42 MLD treatment plant has been divided into three equal parallel component of 14MLD each.

4.3.4 EFFLUENT OF STP

Effluent of 42 MLD STP goes through the outlet chamber of 1200 mm dia RCC gravity pipe and ultimately meets the Sarkata Nala at the downstream of Sarkata Nala SPS which ultimately meets the river Gomti.

4.3.5 SALIENT FEATURES

The salient features and the influent and effluent characteristics of the Sewage Treatment Plant are shown in Table 4.3.5.1., and 4.3.5.2.

TABLE 4.3.5.1: Salient Features

Sl.No	Unit	Nos.	Dimensions
1	Settling chamber	1 No.	4.6mx6.4mx2.5m SWD
2	Screens (3 mechanical +1 manual)	4 Nos.	1.0mX6.8mX0.566m
3	Grit Chamber (Mechanical)	3 Nos.	6.0m x 6.0 m x 1.0 SWD
4	Distribution Chamber	1 No.	3.4m x 3.4m x 1.0 SWD
5	Inlet chamber for FAB reactor	3 Nos.	1.0m x 0.50m SWD
6	FAB Reactors	6 Nos.	10.6m dia & 5.50 SWD
7	Feed Chambers	3 Nos.	2.0m x 2.0m x 4.85m SWD
8	Secondary clarisettler	3 Nos.	17.5m dia x 3.75m SWD
9	Chlorine contact tank	3 Nos.	21.50m dia x 2.75n SWD
10	Sludge sump	1 No.	8.30m dia x 3.0 SWD
11	Sludge Thickener	1 No.	14.40m dia x 3.0 SWD
12	Sludge Drying Beds	11 Nos. 3 Nos.	15m x 16m 12.5m x 16m 7.5m x7.5m
13	Filtrate sump	1 No.	2.0m x 2.0m x 2.0 SWD
14	Outer chamber	1 No.	3.00m dia x3.5m ht.
15	Blower Room MCC Room	1 No. 1 No.	11.25mx 7.5m x3.5 ht. 7.50m x 5.00m x 3.5 ht.
17	Filtrate/overflow transfer sump	1 No.	3.0m x 3.0m x 3.0m SWD
18	Sludge pump	2 Nos.	45m /hr 15 m head
19	Filtrate pump	2 Nos.	8 m /hr. 12m head

TABLE 4.3.5.2: Influent & Effluent Characteristics

Sl.No	Parameters	Influent characteristics	Effluent characteristics
1	SS	300 mg/l	< 50 mg/l
2	BOD	250 mg/l.	< 30 mg/l
3	COD	400 mg/l	< 100 mg/l
4	pH	7 - 7.5	7-8
5	Coliform Count	$<10^6 - 10^7$ (Assumed)	$<10^3$ at the CCT outlet

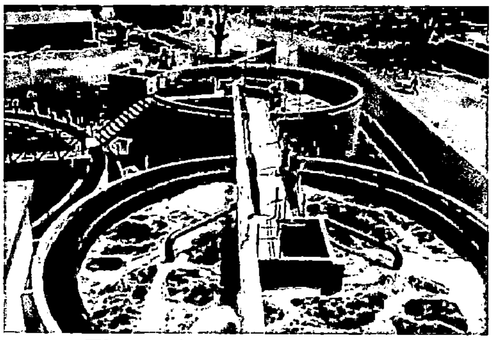


Figure 4.3.1: FAB Reactor

4.3.6 ADVANTAGES OF THE SEWAGE TREATEMNT PLANT

The sewage treatment has following advantages over conventional activated sludge processes.

Small Space Requirement: The concept of compact FAB based sewage treatment plants is used so that expensive land requirement is reduced. A conventional treatment requires large space, and large operating force. The FAB based plants individually occupy much less space, making the plants more manageable.

Lower Operating Power Requirements: The system utilizes aeration tanks of much smaller size, thereby reducing the overall power required in aeration the raw sewage. Since the bio-reactor depth is more, efficient transfer of oxygen takes place, thereby reducing the overall power consumed in treatment.

Low Temperature Sustaining Capability: One of the very important parameters in selecting a particular process is that the system must operate in low temperatures, which are experienced for the least 2-3 months in a year. The temperature can drop to sub-zero levels. The conventional activated sludge system, with large aeration tanks are most susceptible to freezing at the surface layer, thereby totally inhibiting the biological treatment. The systems adopted with latest and proven technology have much smaller bio-reactor area. Additionally, hot air is bubbled for the purpose of aeration. This helps to keep the sewage from freezing. Because of continuous aeration with diffused air, great turbulence is created at the surface level as well, which prevents freezing / icing of top surface of the bio-rector.

Simplicity: The system adopted has much less moving part (only pumps blowers). Further there is no moving part inside the bio-reactor. This gives the advantage of continuously running the bio-reactor system, under widely fluctuating conditions. All the pumps / blowers are manufactures in India only, and hence there is no problem of availability of spaces.

E-Coli: The bio-reactor system adopted in STPs is provided with removal of disease causing E-coli bacteria.

Coliform Removal: The outlet BOD of the bio-reactor system being very low (in other words, hardly any food is available to the E-coli), most of the coliform are killed in the reactor itself. Remaining coliforms are killed by nominal chlorine dosing (of the order of 2-3 mg/l).

Sludge Handling: The sludge generated in the bio-reactors is totally digested. Since the F/M ratio in the bio-reactors is very low, the excess sludge generation is lower than compared to the conventional ASP system. The present system does not envisage any sludge digestion (since the sludge is aerobically stabilised in the bio-reactors itself), making the system more suitable to be installed under such climatic conditions. The excess sludge separated in the secondary clarifier is collected in a sludge sump and then thickened in the gravity thickeners. It is then directly pumped to the sludge drying beds for Sun Drying.

Sludge Production: One more attraction of this technology is that it produced much small quantity of sludge and what is more, this sludge requires no further treatment such as digestion, due to the fact that it produces digested sludge which does not smell like that in conventional plant. Because of this reason, biogas can not be produced by this technology.

4.4 SEWAGE TREATMENT PLANT AT PIMPRI CHINCHWAD- PUNE[22]

The Sewage Treatment Plant at Pimpri Chinchwad- Pune is located at Sangvi, Pune. The Capacity of the treatment plant is 15 MLD and the technology adopted is FAB.

4.4.1 SALIENT FEATURES OF STP

The salient features of the Sewage Treatment Plant are shown in Table 4.4.1.1.

TABLE 4.4.1.1: Salient Features of STP

Location of STP:	Sangvi, Pune
Design Capacity (MLD-million litres per day):	15 MLD
Current utilization level of Capacity	11 MLD
Population of area served by STP:	1.50 lakhs
Characteristics of sludge, if available:	TOC in % of TS: 39.15%
	Moisture content: 66.7%
Sludge drying, mechanical or sun drying:	Mechanical Centrifuge
Arrangement of disinfect ion/chlorination	Gas Chlorination.Dosage:3mg/l
Actual land area occupied by STP	3250 m^2
Details of operating cost/month:	Rs.2.00 Lakhs/month (exclusive of electricity charges)
Electricity consumed in KWH/month:	33330 KWH
Expenditure on electricity consumption/month:	Rs. 150000/month
Mode of disposal of sludge:	Transportation by Corporation Lorries
Agency, which provides funds for operation and repairs and maintenance of STP:	Pimply Chinchwad Municipal Corporation
Capacity	15,000 M^3 / day
Peak factor	2.0

4.4.2 FEATURES & BENEFITS OF FAB

The features and benefit of FAB based treatment technology is tabulated in Table 4.4.2.1.

TABLE 4.4.2.1: Features & Benefits of FAB

Features	Benefits
Attached Growth Process	• No sludge recycle • No monitoring Of M.L.S.S. • Low sludge production
High Bio - Film Surface Area	• High loading rates • Compact plants • Small foot print
Fluidized Bed	• Non clogging design • Better oxygen transfer efficiency • Reduced power consumption. • Low maintenance • Tank of any shape can be utilized

4.4.3 SLUDGE PRODUCTION

This technology produced much small quantity of sludge and what is more, this sludge requires no further treatment such as digestion, due to the fact that it produces digested sludge which does not smell like that in conventional plant. Because of this reason, biogas can not be produced by this technology.

4.4.4 INFLUENT & EFFLUENT CHARACTERISTICS

The influent and effluent characteristics of the sewage treatment plant are furnished in Table 4.4.4.1.

TABLE 4.4.4.1: Influent & Effluent Characteristics

Sl.No	Parameters	Influent characteristics	Effluent characteristics
1	SS	300 mg/l	< 50 mg/l
2	BOD	200 - 250 mg / l	< 30 mg/l
3	COD	400 - 500 mg /	< 100 mg/l
4	pH	7 - 7.5	7-8
5	Coliform Count	$<10^6 - 10^7$ (Assumed)	$<10^3$ at the CCT outlet

Figure 4.4.1: Bar screen and grit chamber

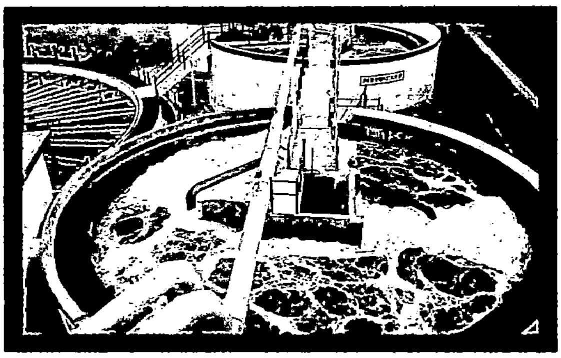


Figure 4.4.2: FAB reactors - 1 & 2

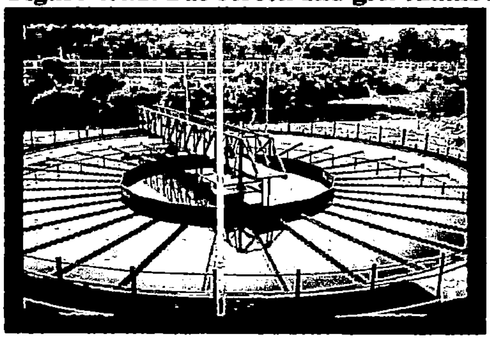


Figure 4.4.3: Final Clari-settler

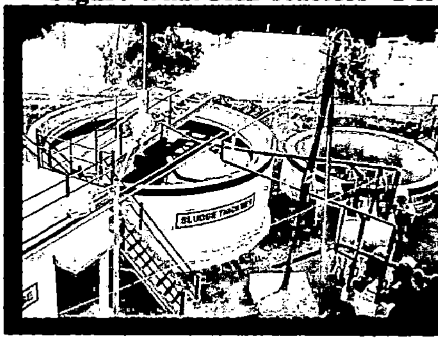


Figure 4.4.4: Sludge sump and Thickener

4.5 SEWAGE TREATMENT PLANT AT SAHARANPUR[20]

4.5.1 LOCATION AND TOPOGRAPHY

Saharanpur, an industrial town of western UP is located between co-ordinate 77°-30' to 77°-15' East Longitude and 29°- 55' to 30° -00' North Latitude. It is an important junction of Northern railways and is a district headquarters. Saharanpur connects UP to Haryana, Punjab and Jammu both by railways and road. The river Yamuna which is the geographical boundary of UP and Haryana forms its western boundary. Two perennial rivers (now drains) Dhamola and Paondhoi passes through the town traveling north to south. The river Dhamola travels from East to West and meets the river Paondhoi near Assura Bridge. Beyond their confluence the river is called Dhamola, which ultimately joins Yamuna through Hindon. The town slopes towards these rivers and most of the drains discharge into them. The population of the town as per 1991 census was 3, 73,904.

4.5.2 PERFORMANCE OF SEWAGE TREATMENT PLANT

One STP of 38 MLD with UASB technology and polishing pond was constructed. The average flow from March 2001 to Feb. 2002 was 23.1 MLD as against 38 MLD designed. The Peak Factor is 2.25 and the Peak Flow is 290m3/hr.

4.5.3 INFLUENT & EFFLUENT CHARACTERISTICS

The influent and effluent characteristics of the sewage treatment plant are furnished in Table 4.5.3.1.

TABLE 4.5.3.1: Influent & Effluent Characteristics

Sl.No	Parameters	Influent characteristics	Effluent characteristics
1	SS	400 mg/l	< 50 mg/l
2	BOD	200 mg /l	< 30 mg/l
3	COD	320 mg /l	< 100 mg/l
4	pH	7 - 7.5	7-8

4.5.4 DETAILS OF UNITS OF STP

The details of units of the sewage treatment plant are furnished in Table 4.5.4.1.

TABLE 4.5.4.1: Details of Units of STP

Screen chambers (mechanical)	2 Nos.	5 x 2 x 1m
Grit channel (manual)	3 Nos.	20 x 21.6 m
Diversion box	One	5.25 x (dia) x 1.5m
Distribution box UASB	8 Nos.	
reactor (9.5 MLD each)	4 Nos.	24x 6.05 m
Sludge sump	One	3.95 (dia) x 7.55 m deep
Filtrate sump	One	4.0 (dia) x 7.0 m deep 24
Sludge drying beds Polishing pond	20Nos.	14 m x 14 m
Filtrate sump	2 Nos.	12670 sq m -1.5 m deep -1.0 day detention
Gas Holder	1 No	152 m3

The Gas produced /day is 900m3 and the Power production /day is 1836 kWh.

4.5.5 TOTAL COLIFORM AND FECAL COLIFORM

The coliform and fecal coliform level in the effluent, UASB and polishing pond is shown in the Table 4.5.5.1.

TABLE 4.5.5.1: Total Coliform and Fecal Coliform

Coliform level	Influent coliform MPN/100ml	faecal coliform MPN/100ml
Effluent	$26x\ 10^5$	13×10^5
UASB	17×10^4	13×10^3
Polishing pond	13×10^3	7×10^3

The removal of coliform and faecal coliform is of 2 log order

4.5.6 TOTAL EXPENDITURE FOR THE YEAR 2005-2006

The expenditure for the sewage treatment plant for the year 2005-2006 is furnished in Table 4.5.6.1. These particulars are obtained from the Nagarpalika office, Saharanpur.

TABLE 4.5.6.1: Total Expenditure for the Year 2005-2006

Sl.No	Description	Quantity	Rate	Unit	Amount (Rs)
SUPERVISORY & OTHER STAFF					
1	Project Engineer	1 no	28190	each	28190
2	Assistant Project Engineer	3 no	21530	each	64590
4	UDC Senior Assistant	1 no	9230	each	9230
5	LDC Typist	1 no	8200	each	8200
6	Peon	1 no	6180	each	6180
7	Lab Assistant	1 no	7100	each	7100
8	Lab Attendant	2 no	6150	each	12300
OPERATING & RUNNING STAFF					
9	Fitter I Class	1 no	6150	each	6150
10	Electrician I Class	1 no	6150	each	6150
11	Electrician II Class	1 no	5130	each	5130
12	Gardener	1 no	4100	each	4100
13	Sweeper	1 no	3080	each	3080
14	Operator	12 nos	6150	each	73800
15	Labour	20 nos	3080	each	61600
	Total				**295800**
	Total per year				**35,49,600**

ELECTRICITY CHARGES

Load KW	App. Running hours	Unit rate	Energy Consumed KW	Energy Charges	Fixed Charges	Meter Rent	Elec. Duty	Tot. Elec. Charges
382.5	1760	3.25	642414.6	2087847	344250	12000	19272	**2463370**

MAINTENANCE

	Repairs, Oil, Diesel, Chemicals etc.	**6,00,000**
	Grant total	**6612970**
	Rate per 1 MLD	**174025**

4.5.7 RESOURCE RECOVERY

Effluent after polishing pond is being discharged in river Dhamola and is not being utilized for irrigation. The dried sludge is regularly being sold to farmers. The unit earns around Rs. 1.52 Lakhs per year from the sale. The unit also claims to have earned Rs. 25000/- from the sale of fish. The biogas being produced is being utilized in DFG & power generation. The total resource generation is tabulated below.

TABLE 4.5.7.1: Total Resource Generation

Resource generation	Value
From power generation	Rs. 16.04 Lakhs
From the sale of sludge	Rs. 01.88 Lakhs
Sale of fish	Rs. 00.25 Lakh
Total	Rs. 18.17 Lakhs

4.5.8 GAS PRODUCTION

The gas produced per MLD of sewage = 143 m3. (Appendix 3)

Projected gas production = 3310.45 m3.

Actual gas production = 900 m3

Projected Energy Production from Biogas

Energy production per day is1.84 MWh/day and the Cost of E.B. Power savings = Rs.26.20 lakhs/year. The Cost of E.B. Power savings per 1MLD is Rs. 0.69 lakhs/year (Appendix 3).

Utilisation of Gas for the Production of Electricity

Energy production per day is 1.126 MWh/day and the Cost of E.B. Power savings @ Rs. 3.90 per unit is Rs.16.04 lakhs/year. The Cost of E.B. Power savings per 1MLD is 0.422 lakhs/year (Appendix 3).

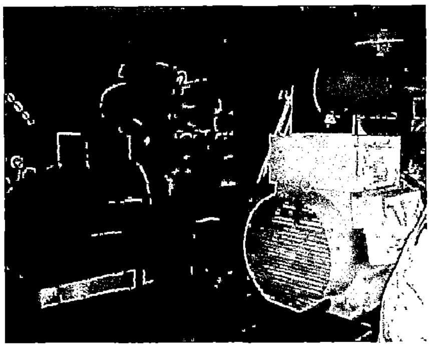


Figure 4.5.1: Gas Engine

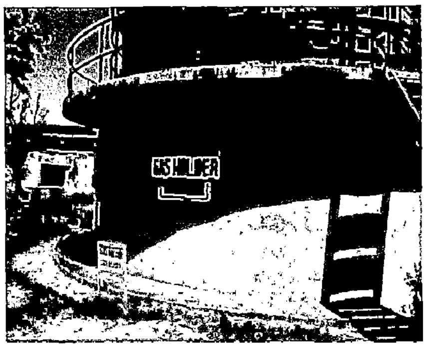


Figure 4.5.2: Gas Holder

4.6 SEWAGE TREATMENT PLANT AT SONEPAT[20]

4.6.1 LOCATION AND TOPOGRAPHY

Sonepat town is situated at 7km away from NH-1 about 50 Km. from Delhi on Delhi Amritsar Road .The town is located at 29 on latitude and 77°E longitude. The topography is almost flat with an average ground level of 225.15 m above MSL. The area under Municipal boundary is 21.37sq.km.

4.6.2 PERFORMANCE OF SEWAGE TREATMENT PLANTS

30 MLD capacity STP, based on UASB technology has been constructed in the town for the requirement of the year 1998.

4.6.3 INFLUENT & EFFLUENT CHARACTERISTICS

The influent and effluent characteristics of the sewage treatment plant are furnished in Table 4.6.3.1.

TABLE 4.6.3.1 Influent & Effluent Characteristics

Sl. No	Parameters	Influent characteristics	Effluent characteristics
1	SS	300 mg/l	< 50 mg/l
2	BOD	200 mg / l	< 30 mg/l
3	COD	500 mg /	< 100 mg/l
4	pH	7 - 7.5	7-8

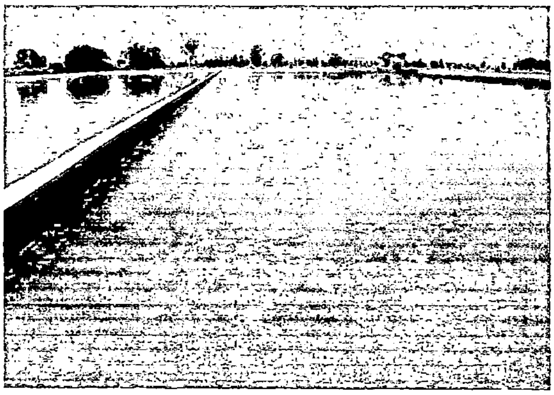


Figure 4.6.1: Polishing Pond

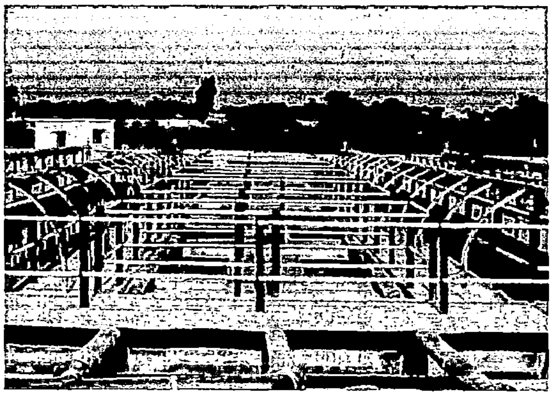


Figure 4.6.2: UASB Reactor

4.6.4 SALIENT FEATURES OF THE STP

The salient features of the sewage treatment plant are furnished in Table 4.6.4.1. These particulars are obtained from the Nagarpalika office, Sonepat.

TABLE 4.6.4.1: Salient Features of the STP

Sl.No.	Item		Description
1	Capacity		30 MLD
2	Average flow		30 MLD (1250 m3/h)
3	Peak factor		2.25
4	Peak flow		2812.5 m3/hr
	Details of units of STP		
5	Primary treatment units		
	1	Inlet chamber	1no.
	2	Screen	
	3	Mechanical	1 No
	4	Manual	1 No.
	5	Grit chambers	4nos (2 Nos. standby)
	6	Outlet chambers	2 Nos.
	7	Division box	3 Nos.
	8	Distribution box	6 Nos.
6	Reactors		3nos
7	1.	Sludge sump	1 no
	2.	Sludge pump	2 no
	3.	Sludge drying beds	18 Nos
8	Polishing ponds		Provided
9	Gas holder		1nos
10	Duel fuel gas engine		2nos Capacity 50 KVA
11	Electricity production capacity of gas		77kw
12	Electricity production diesel		33 kW
13	Total electricity production gas + diesel		110 kW
14	Maximum load of STP		37.36 kW
15	Minimum load of STP		24kW
16	Gas flaring system		1no
17	Disposal of effluent		To drain no.6

The capacity of the STP is 30 MLD, whereas the average flow is about 25.5 MLD. It was reported that the plant was commissioned in Jan.1999. Since then, efforts have been made to clean and connect internal sewer lines with the outfall sewer, resulting in availability of average 25.5 MLD of sewage at present.

4.6.5 TOTAL EXPENDITURE FOR THE YEAR 2005-2006

The expenditure for the sewage treatment plant for the year 2005-2006 is furnished in Table 4.5.6.1. These particulars are obtained from the Nagarpalika office, Sonepat.

TABLE 4.6.5.1: Total Expenditure for the Year 2005-2006

Sl.No	Description	Quantity	Rate	Unit	Amount
SUPERVISORY & OTHER STAFF					
1	Project Engineer	1 no	28190	each	28190
2	Assistant Project Engineer	3 no	21530	each	64590
4	UDC Senior Assistant	1 no	9230	each	9230
5	LDC Typist	1 no	8200	each	8200
6	Peon	1 no	6180	each	6180
7	Lab Assistant	1 no	7100	each	7100
8	Lab Attendant	2 no	6150	each	12300
OPERATING & RUNNING STAFF					
9	Fitter I Class	1 no	6150	each	6150
10	Electrician I Class	1 no	6150	each	6150
11	Electrician II Class	1 no	5130	each	5130
12	Gardener	1 no	4100	each	4100
13	Sweeper	1 no	3080	each	3080
14	Operator	9 nos	6150	each	55350
15	Labour	15 nos	3080	each	46200
	Total				**261950**
	Total per year				**31,43,400**
ELECTRICITY CHARGES					
	Rs.2.00 lakhs per month				**24,00,000**
MAINTENANCE					
	Repairs, Oil, Diesel, Chemicals etc.				**6,00,000**
	Grant total				**61,43,400**
	Rate per 1 MLD				**204780**

4.6.6 RESOURCE RECOVERY

Effluent after Polishing Pond

The treated effluent is being discharged in to drain no. 6 and is being used for irrigating agricultural fields by the cultivators, although no revenue is being realised.

Utilisation of Gas: The average gas production per day is furnished in Table 4.6.6.1.

TABLE 4.6.6.1: The Average Gas Production / Day

Oct.2001	586 cum/day
Nov.2001	594 cum/day
Dec.2001	491 cum/day
Jan.2002	488 cum/day
Feb.2002	505 cum/day
March.2002	455 cum/day
Average	**519 cum/day**

Thus the average of the 6 months is 519 cum /day against 864 cum/day i.e. 60% of production is utilised. Gas is being utilized for running of DFGs during power breakdown only and the rest is being flared.

Sludge

At present about 70 cum of wet sludge / day is being produced and quantity of dry sludge is about 10m3/day. There is not much acceptability on the part of farmers to utilise the sludge cost. There is, therefore, no significant revenue on this account. However a revenue of Rs.0.60 lakh is being received in a year.

4.6.7 GAS PRODUCTION

The gas produced per million litre of sewage is 102 m3 (Appendix 4). The projected gas production is 3060 m3 and the actual gas production is 864 m3.

Energy Production from Biogas: The Energy production for 1 m3 biogas@21.24mJ/m3 is 2.04 kWh /day. The Energy production per day is 1.77 MWh/day. The Cost of Power savings @ Rs. 3.90 per unit is Rs.25.20 lakhs/year. The Cost of E.B. Power savings per 1MLD is Rs. 0.84 lakhs/year.

Utilisation of Gas for the Production of Electricity: At present, gas is being utilized for running of DFGs during power breakdown only and the rest is being flared.

4.7 SEWAGE TREATMENT PLANT AT RISHIKESH[17]

4.7.1 SALIENT FEATURES OF STP

The salient features of the sewage treatment plant are obtained from the office of the Ganga Pollution Control Unit, Uttaranchal Peyjal Nigam, Haridwar, and is tabulated in Table 4.7.1.1.

TABLE 4.7.1.1: Salient Features of STP

Location:	Lakhat Ghat – 6.5 km from Rishikesh
No. of ponds:	5 ponds same retention period
Capacity of pond:	6MLD -Size=167m x 84m x 1.5m
Retention period:	15 days
Flow of sewage:	Zigzag for no short circuiting
Effluent discharge:	Effluent is discharged into Nallah to Saung River near Raiwalla- 15 Km from Rishikesh-by gravity
Effluent quality:	BOD=25 to 30 Mg/l
Aquaculture:	At Pond 1 to 4 -Fish type – silver, catfish
Silt removal:	After 2 years interval

4.7.2 PREVIOUS CONDITION

Rishikesh, surrounded by virgin forests at the toe of the Himalayas, is the first town on river Ganga taken up under the Ganga Action Plan Phase-I for pollution abatement of the river. Hundreds of ashrams, temples, residences, hotels and other commercial establishments dot the banks. This immense human activity, in a narrow band along the length of the town on both the banks, generates nearly 6 million litres of sewage per day into the pristine Ganga before it emerges into the plains.

4.7.3 GANGA ACTION PLAN PHASE-I

The Ganga Action Plan works in Rishikesh comprise, inter alia, sewerage works to tap the sewage outfalls and through appropriate pumping station, diversion of the sewage to a pond type STP at Lakkarghat between Haridwar and Rishikesh. Under the

GAP, existing ponds were renovated and expanded by additional pondage to treat a flow of 6 MLD sewage per day from the town of Rishikesh.

4.7.4 INFLUENT AND EFFLUENT CHARACTERISTICS

The series of five ponds, occupying 6.5 hectares in the STP campus area of 13 hectares, is fully utilized after reducing BOD from 210 to 24 mg per litre, SS from 255 to 55 mg per litre, and coli form levels from 350,000 MPN to 110,000 MPN per 100 ml, although less stringent quality is acceptable for irrigation use.

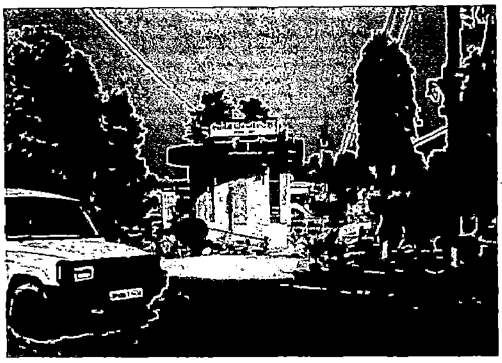


Figure 4.7.1: View of STP

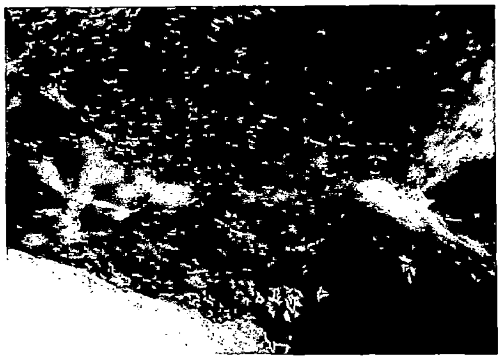


Figure 4.7.2: Inlet Water

Figure 4.7.3: View of Pond

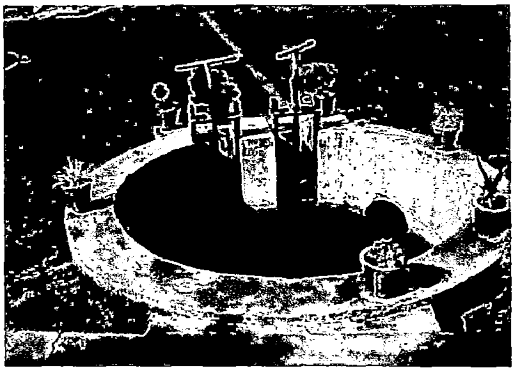


Figure 4.7.4: Outlet Chamber

4.7.5 RESOURCE RECOVERY[17]

55 acres of fodder farm is getting the benefit of 6 MLD of pond effluent, raising fodder crops of Rs.10 lakh per year.

Pisciculture is practiced in the algae rich ponds and fruit and vegetable are grown in 3 hectares of the STP campus site, yielding a revenue of Rs 55,000 per annum.

This STP is a shining example of utilizing a piece of land for sewage treatment, leading to prevention of pollution of the river and at the same time drawing the full opportunity to recover the cost of this land by way of resource recovery from fodder, vegetable and fruit crops as well as pisciculture.

TABLE 4.7.5.1: Resource Recovery

Sl.No	Resource Recovery	Rs. in lakh per year.
1	Fodder crops	10.00
2	By lease rent of oxidation pond for fishery	00.85
3	Total	Rs 10.85lakh/year.

4.7.6 TOTAL EXPENDITURE FOR THE YEAR 2005-2006

The total expenditure of the sewage treatment plant for the year 2005-2006 is obtained from the office of the Ganga Pollution Control Unit, Uttaranchal Peyjal Nigam, Haridwar, and is tabulated in Table 4.7.6.1.

TABLE 4.7.6.1: Total Expenditure for the Year 2005-2006

Sl.No	Description	Amount
1	Cleaning the oxidation pond once in a year-167m X 84.m X 1.50m, assuming 50% filling- 10521 m3 @ Rs. 67.50/m3	710167.50
2	Electricity Charges for 7500 unit including Energy Charges and Meter Rent	22350.00
	Total	732517.5
	Total per 1 MLD	**1,22,86.00**

4.8 SEWAGE TREATMENT PLANT AT PERIYAKULAM

4.8.1 GENERAL

Periyakulam is a 2nd grade municipality in Theni District in Tamil Nadu having a population of 42012 covers an area of approximately 2.10 sq.km. Varaga nathi, a tributary of Vaigai River flowing west to east, divides the town into two halves, the northern half is known as Vadakarai and the southern portion is known as Thenkarai. The general slope of the town is from west to east. There are hower ridges in both portion of the town midway from the extremities to the river. As such, the area to the north of ridge in Thenkarai drains into Varaga nathi and area to the south drains into channel. In

Vadakarai, the area to the south of the ridge drains into Varaga nathi and the area to the north drains into Vari channel. The ground level in the town varies between 935.00 and 908.00. The average bed level of the river in the town reach is 901.00.

Periyakulam town does not have any sewerage arrangements since 1960.The town was served only by dry earth latrines and the night soil was composted. Domestic wastes and storm water flow through the open drains in the streets, to the Varaga nathi. The flow in the open drains frequently became stagnant, causing unsightly appearance and these constituted a potential danger to public health. The river which had a meager flow in dry periods, got also polluted thus was created health hazards, as the river water was used for washing and bathing. So it was considered imperative that a sewerage system should be provided for this town.

4.8.2 HISTORY OF THE SCHEME

The question of a sewerage scheme for this town was considered as early as 1890. The scheme was investigated in 1912-13 and supplemental details were gathered in 1928-29. But the scheme was not put through due to mainly financial reasons.

In 1960, the Municipality came forward with certain proposals viz., construction of intercepting sewers, with the main idea of preventing pollution of Varaga nathi. It was however, recommended by the Sanitary Engineer that a field investigation would be necessary to examine details and frame proposals for a comprehensive sewerage scheme. Government in G.O. MS.No. 2416, Health, dated 23.09.1960 sanctioned the investigation of a comprehensive drainage scheme, the cost of investigation being Rs. 2,800/-.

The field work was done during February- July, 1961. L.S. of streets in the town, population details, levels for river crossings, L.S. of pumping main and site details for pumping station and disposal works gathered.

4.8.3 SCHEME IN BRIEF

The town is divided into two zones-Vadakarai consisting of wards 1 to 8 and Thenkarai consisting of wards 9 to19. The sewage from Vadakarai will be gravitated to the common pumping station north of river at the eastern end of the town. The sewage from Thenkarai will be gravitated to the eastern end and siphoned across the river to the common pumping station. The sewage will be pumped through a 15" pumping main to the disposal works consisting of a stabilization pond and an effluent farm located about 1 mile from the town, called Endapuli Pudukkottai, by the side of Kumbakkarai Road.

The water supply system in operation provided for a per capita rate of 15 gallons per day (66.75 lit. per day). Hence sewerage scheme was designed sewage contribution of 15 gallons per day. The stabilization pond was designed as 4 MLD to meet an ultimate population of 60,000.The scheme was estimated at Rs. 14.15 lakhs.

Figure 4.8.1: Sewage Farm

Figure 4.8.2: Silk Cotton trees, 421Nos

Figure 4.8.3: Palm trees, 419 Nos

Figure 4.8.4: Coconut trees, 295 Nos

4.8.4 RESOURCE RECOVERY FROM STP

The resource recovery from the sewage treatment plant for the year 2005-2006 is obtained from the Municipal Office, Periyakulam, and is tabulated in Table 4.8.4.1.

TABLE 4.8.4.1: Resource Recovery from STP

Sl. No	Description	Amount in Rs
1	Annual lease of Palm trees,419 Nos. in side the campus of STP	27,500/-
2	Annual lease of Coconut trees,295 Nos. in side the campus of STP	35,501/-
3	Annual lease of Silk Cotton trees,421Nos.in side the campus	1,01,000/-
4	Annual lease for cutting guinea gross in 16 acres in side campus	3, 75,501/-
	Total:	5, 39,502/-

4.8.5 EXPENDITURE

The expenditure for the sewage treatment plant for the year 2005-2006 is obtained from the Municipal Office, Periyakulam, and is tabulated in Table 4.8.5.1.

TABLE 4.8.5.1 Annual Maintenance Charges

Sl. No.	Designation	No. of posts	Rate	Unit	No. of days	Amount in Rs
1	Sewage Farm Superintendent	1	175.00	Each per day	365	63875.00
2	Sewage Farm Coolies	3	95.00	Each per day	365	104025.00
3	Sewage Farm Watchman	1	90.00	Each per day	365	32850.00
					Total Rs.	200750.00

4.9 SUMMARY OF STPs

The summary of all the eight STPs for the capacity of the plants, type of technology adopted, the annual maintenance charges and the resource recovery from the STPs are furnished in Table 4.9.1.

TABLE 4.9.1 Summary of STPs

Sl. No	STPs	Capacity in MLD	Type of Technology	O&M Charges (Rs. in lakhs)	Resource Recovery (Rs. in lakhs)	O&M Charges per 1 MLD Plant (Rs. in lakhs)	Resource Recovery per 1 MLD Plant (Rs. in lakhs)
1	Chennai	481	ASP	1359.90	892.54	2 .827	2.196
2	Haridwar	18	ASP	78.80	16.14	4.378	0.90
3	Lucknow	42	FAB	164.00	-	3.905	nil
4	Pune	15	FAB	42.00	-	2.800	nil
5	Saharanpu	38	UASB	66.13	18.17	1.740	0.482
6	Sonepat	30	UASB	61.43	0.02	2.048	0.02
7	Rishikesh	6	WSP	7.33	1.808	1.221	1.808
8	Periyakula	4	WSP	2.01	5.40	0.503	1.35

CHAPTER 5

ANALYSIS OF RESOURCE RECOVERY

From the study of several existing STPs in different parts of the country (Chapter-4), it has been observed that different resources are recovered from these STPs in varied quantity and sustainability. Each recovered resources has been analysed subsequently.

5.1 POWER GENERATION

There are plenty of differences between the power production as per the sludge generation and as per actual. The quantity of power generated (MWh) and its economical values (Rs. in lakhs) for the sewage treatment plants at Chennai, Haridwar, Saharanpur and Sonepat are tabulated below. The values for 1MLD plant are also tabulated. The existence of higher volume percentage of carbon-di-oxide and the short loading of the STP are some of the reasons of low power generation.

TABLE 5.1.1: Comparison of Power Generation

Sl. No	STPs	Capacity in MLD	Energy generation				Energy generation for 1 MLD	
			Projected generation of the sludge per year		Actual generation acquired		Projected generation of the sludge (Rs. in lakhs)	Actual generation acquired (Rs. in lakhs)
			MWh	Rs. in lakhs	MWh	Rs. in lakhs		
1	Chennai	264	8191	344.00	4745	199.29	1.30	0.755*
2	Haridwar	18	321	9.64	0	0	0.54	0**
3	Saharanpur	38	672	26.19	411	16.04	0.69	0.422***
4	Sonepat	30	646	25.20	0	0	0.84	0****

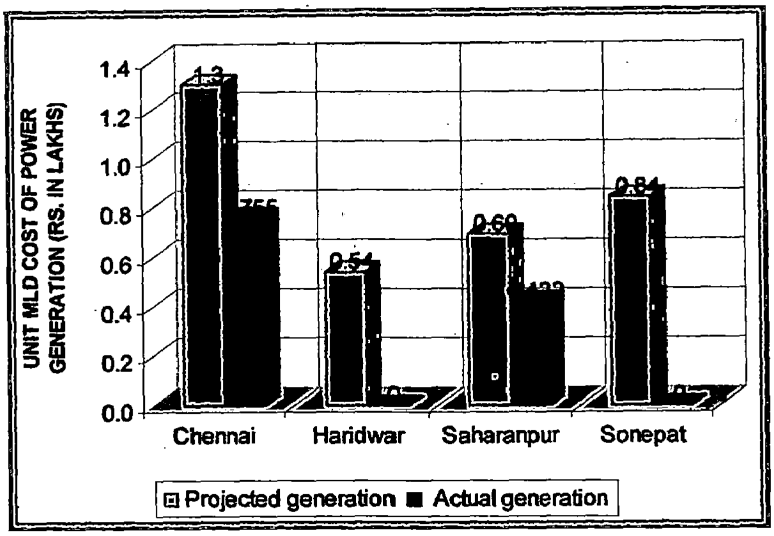
* The reduction of energy generation is due to the presence of higher percentage of CO_2 in the biogas.

** At present, the gas is being utilized for running of DFG during power breakdown only and the rest is being flared.

** *The reduction of energy generation is due to short loading of the STP.

**** At present, the gas is being utilized for running of DFG during power breakdown only and the rest is being flared.

CHART 5.1.1: Comparison of Power Generation for 1 MLD Plant



5.2 COST COMPARISION OF TECHNOLOGIES

Chennai and Haridwar have ASP based STPs. Lucknow and Pune have UASB based STPs. Saharanpur and Sonepat have FAB based STPs. Rishikesh and Periyakulam have WSP based STPs. So, we have to compare the cost of the STPs based on the technology adopted. Table 5.2.1 shows the Unit area of STP required, the unit cost of construction of STP and the unit cost of annual O&M of STP for 1 MLD capacity[23].

TABLE 5.2.1: Cost Comparison

SL. NO	DESCRIPTION	UNIT	WSP	UASB+ PP	FAB	ASP
1	Flow	MLD	1	1	1	1
2	Unit area of STP required[23]	ha	1.00	0.17	0.02	0.20
3	Unit cost of construction of STP[23]	Rs. in Lakhs	17.00	40.00	50.00	45.00
4	Unit cost of annual O&M of STP[23]	Rs. in Lakhs	1.40	2.76	4.50	3.50

5.3 EXPENDITURE AND RECOVERY

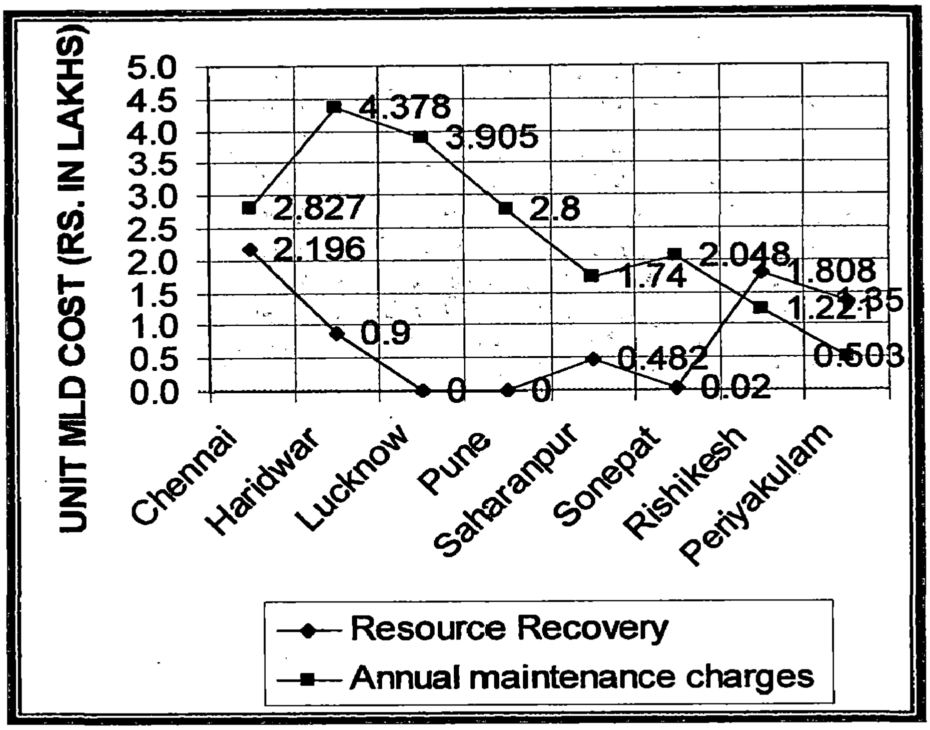
The actual expenditures of each STPs and resource recoveries like sale of treated effluent, sale of digested sludge cake, revenue from growing vegetables, gross and trees, revenue from fish culture etc. are furnished in Table 5.3.1.The expenditure and resource recovery for 1 MLD plants are also tabulated.

TABLE 5.3.1: Comparison of Resource Recovery for All STPs

(Values: Rs. In lakhs)

Sl.No	Parameters	Chennai	Haridwar	Lucknow	Pune	Saharanpur	Sonepat	Rishikesh	Periyakulam
1	Annual maintenance charges	1359.9	78.80	164.00	42.00	66.13	61.43	7.33	2.01
2	R.R. from treated effluent	639.25	0.96	nil	nil	nil	nil	nil	nil
3	R.R. from digested sludge cakes	nil	2.00	nil	nil	1.88	0.60	nil	nil
4	R.R. from growing vegetables, gross and trees	6.00	13.18	nil	nil	nil	nil	10.00	5.40
5	Sewage received from residences thro' lorries	48.00	nil	nil	nil	nil	nil	nil	nil
6	Aquaculture	nil	nil	nil	nil	0.25	nil	0.85	nil
7	Total of 2,3,4,5 and 6	693.25	16.14	nil	nil	2.13	0.60	10.85	5.40
8	Total per 1 MLD	1.441	0.90	nil	nil	0.06	0.02	1.808	1.35
9	Savings in expenditure due to power generation from methane	199.29	nil	nil	nil	16.04	nil	nil	nil
10	Savings in expenditure due to power generation from methane per 1 MLD	0.755	nil	nil	nil	0.422	nil	nil	nil
11	Total Resource Recovery per 1 MLD	2.196	0.90	nil	nil	0.482	0.02	1.808	1.35
12	Annual maintenance charges per 1 MLD	2 .827	4.378	3.905	2.800	1.740	2.048	1.221	0.503

CHART 5.3.1: Comparison of Revenue Generated from Resource Recovery with Expenditure for 1 MLD Plant



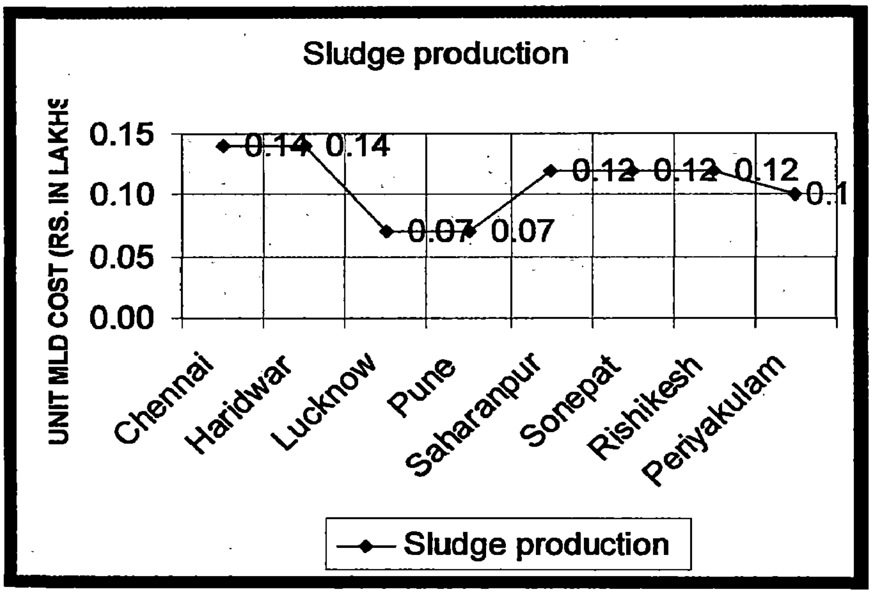
5.4 PROJECTED SLUDGE PRODUCTION

The quantity of sludge produced as per theoretical is calculated in Appendix 5& Appendix 6. The values are tabulated below.

TABLE 5.4.1: Projected Sludge Production (Rs. in lakhs)

Sl.No	Name of the town	Capacity of STP in MLD	Sludge production/ year in m3	Cost of sludge @ Rs. 80.00/ m3 (Rs. in lakhs)	Cost of sludge/ 1 MLD (Rs. in lakhs)
1	Chennai	481	83483	66.79	0.14
2	Haridwar	18	3124	2.50	0.14
3	Lucknow	42	3610	2.89	0.07
4	Pune	15	1288	1.03	0.07
5	Saharanpur	38	5866	4.69	0.12
6	Sonepat	30	4632	3.71	0.12
7	Rishikesh	6	900	0.72	0.12
8	Periyakulam	4	480	0.38	0.10

CHART 5.4.1: Projected Sludge Production per 1 MLD Plant



5.5 FULL UTILISATION OF RESOURCE RECOVERY

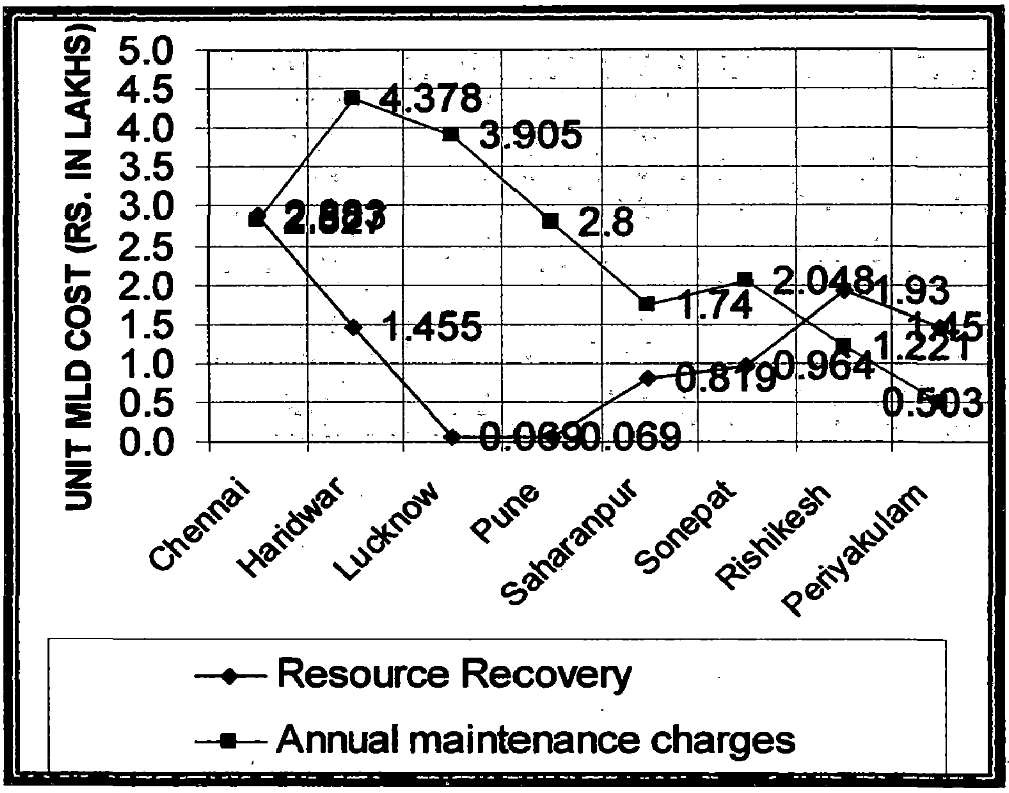
The Resources are not fully utilised in all the STPs. Most of the biogas is flared-up instead of utilising it for power production. The quantity of power production is reduced due to the existence of higher volume percentage of carbon-di-oxide in the biogas. The quantity of biogas will always be reduced due to short loading of the STP. The bio manure sale is also not satisfactory in many cases due to unawareness of the farmers. To find out the best technological option, it is necessary to calculate the resource recovery from the treatment plants on full utilisation of all resources. If all the resources are fully utilised, the remuneration from resource recovery for all the eight STPs will be vary with actual. The values thus calculated are tabulated in Table: 5.5.1.

TABLE 5.5.1: Comparison of All STPs of Full Utilisation of Resource Recovery

(Values: Rs. In lakhs)

Sl. No	Parameters	Chennai	Haridwar	Lucknow	Pune	Saharanpur	Sonepat	Rishikesh	Periyakulam
1	Annual maintenance charges	1359.9	78.80	164.00	42.00	66.13	61.43	7.33	2.01
2	R.R. from treated effluent	639.25	0.96	nil	nil	nil	nil	nil	nil
3	R.R. from digested sludge cakes	66.79	2.50	2.89	1.03	4.69	3.71	0.72	0.38
4	R.R. from growing vegetables, gross and trees	6.00	13.18	nil	nil	nil	nil	10.00	5.40
5	Sewage received from residences thro' lorries	48.00	nil	nil	nil	nil	nil	nil	nil
6	Aquaculture	nil	nil	nil	nil	0.25	nil	0.85	nil
7	Total of 2,3,4,5 and 6	760.04	16.64	2.89	1.03	4.94	3.71	11.57	5.78
8	Total per 1 MLD	1.58	0.92	0.069	0.069	0.13	0.124	1.93	1.45
9	Savings in expenditure due to power generation from methane	344.02	9.63	nil	nil	26.20	25.20	nil	nil
10	Savings in expenditure due to power generation from methane per 1 MLD	1.303	0.535	nil	nil	0.689	0.84	nil	nil
11	Total Resource Recovery per 1 MLD	2.883	1.455	0.069	0.069	0.819	0.964	1.93	1.45
12	Annual maintenance charges per 1 MLD	2 .827	4.378	3.905	2.800	1.740	2.048	1.221	0.503

CHART 5.5.1: Comparison of Revenue Generated from Resource Recovery of Full Utilisation with Expenditure for 1 MLD Plant



5.6 COST ANALYSIS[23]

According to the Table 5.2.1, the construction cost for the STPs including cost of land by technology wise is prepared. The cost of land is taken as Rs. 24.00 lakhs, Rs. 36.00 lakhs, Rs. 42.00 lakhs, Rs. 54.00 lakhs, Rs. 63.00 lakhs and Rs. 84.00 lakhs per hectare. The values are furnished in Table 5.6.1.

TABLE 5.6.1: Cost Analysis for 1 MLD Plant

SL. NO	DESCRIPTION	WSP	UASB+ PP	FAB	ASP
1	Present Flow in 2007 in MLD	1	1	1	1
2	Unit cost of construction of STP/ MLD (Rs. in Lakhs)	17.00	40.00	50.00	45.00
3	Unit area of STP required (ha)	1.00	0.17	0.02	0.20
4	Rate of land /ha (Rs. in Lakhs)	**24.00**	**24.00**	**24.00**	**24.00**
5	Cost of land for 1 MLD(Rs. in Lakhs)	24.00	4.08	0.48	4.80
6	Cost -including cost of land (Rs. in Lakhs)	41.00	44.08	50.48	49.80
7	Rate of land /ha (Rs. in Lakhs)	**36.00**	**36.00**	**36.00**	**36.00**
8	Cost of land for 1 MLD(Rs. in Lakhs)	36.00	6.12	0.72	7.20
9	Cost -including cost of land (Rs. in Lakhs)	53.00	46.12	50.72	52.20
	Rate of land /ha (Rs. in Lakhs)	**42.00**	**42.00**	**42.00**	**42.00**
	Cost of land for 1 MLD(Rs. in Lakhs)	42.00	7.14	0.84	8.40
	Cost -including cost of land (Rs. in Lakhs)	59.00	47.14	50.84	53.40
10	Rate of land /ha (Rs. in Lakhs)	**54.00**	**54.00**	**54.00**	**54.00**
11	Cost of land for 1 MLD(Rs. in Lakhs)	54.00	9.18	1.08	10.80
12	Cost -including cost of land (Rs. in Lakhs)	71.00	49.18	51.08	55.80
13	Rate of land /ha (Rs. in Lakhs)	**63.00**	**63.00**	**63.00**	**63.00**
14	Cost of land for 1 MLD(Rs. in Lakhs)	63.00	10.71	1.26	12.60
15	Cost -including cost of land (Rs. in Lakhs)	80.00	50.71	51.26	57.60
16	Rate of land /ha (Rs. in Lakhs)	**84.00**	**84.00**	**84.00**	**84.00**
17	Cost of land for 1 MLD(Rs. in Lakhs)	84.00	14.28	1.68	16.80
18	Cost -including cost of land (Rs. in Lakhs)	101.00	54.28	51.68	61.80

5.7 COST-BENEFIT ANALYSIS FOR 1 MLD PLANT

As per the guideline laid down by the National River Conservation Directorate, Govt. of India, 'technical option should be based on the cost benefit analysis of various options to achieve the desired standards and the most economic one should be selected'.

The Cost Benefit analysis for the eight sewage treatment plants has been worked out with the following considerations.

1. The rate of land is considered as Rs. 24.00 lakhs, Rs. 36.00 lakhs, Rs. 42.00 lakhs, Rs. 54.00 lakhs, Rs. 63.00 lakhs and Rs. 84.00 lakhs per hectare.
2. The present worth of O&M cost is at interest rate of 6 % for a period of 30 years, as per the following formula:

$$\mathbf{P = A\ [(1+ i)^{n} - 1]/ [i\ (1+i)^{n}]}$$

In functional form, the equation is: P= A [P/A, i, n]

Where P= present worth in Rs.

A= uniform end- of period payment or receipt continuing for a duration of 'n'period.

i = the rate of interest per interest period (usually one year)

n = the number of period of time (usually year).

The above relationship is known as Uniform Series Present Worth Factor, (USPWF).

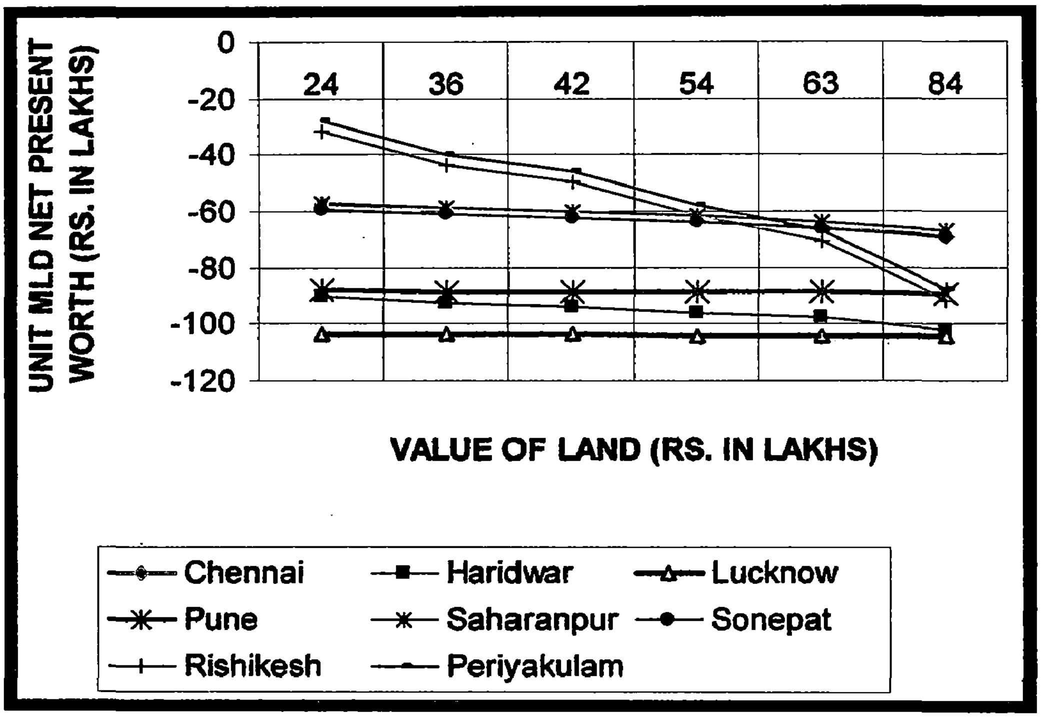
$[(1+ i)^{n} - 1/i\ (1+i)^{n}] = [(1+0.06)^{30}-1/0.06(1=0.06)^{30}] = [(1.06)^{30}-1/0.06(1.06)^{30}] = 13.765.$

Net Present Worth = - [cost of construction] – O&M. [USPWF] + R.R. [USPWF]

TABLE 5.7.1: Cost-Benefit Analysis

Sl. No	**Name of town**	**NET PRESENT WORTH OF UNIT MLD TREATMENT (Rs. in Lakhs)**					
	Cost of land /ha (Rs. in lakhs)	**24.00**	**36.00**	**42.00**	**54.00**	**63.00**	**84.00**
1	Chennai	-57.12	-59.52	-60.72	-63.12	-64.92	-69.12
2	Haridwar	-89.98	-92.38	-93.58	-95.98	-97.78	-101.98
3	Lucknow	-103.29	-103.53	-103.65	-103.89	-104.07	-104.49
4	Pune	-88.06	-88.32	-88.44	-88.68	-88.86	-89.28
5	Saharanpur	-56.76	-58.80	-59.82	-61.86	-63.39	-66.96
6	Sonepat	-59.00	-61.04	-62.06	-64.10	-65.63	-69.20
7	Rishikesh	-31.24	-43.24	-49.24	-61.24	-70.24	-91.24
8	Periyakulam	-27.96	-39.96	-45.96	-57.96	-66.96	-87.96

CHART 5.7.1: Cost-Benefit Analysis for 1 MLD Plant



From the net present worth analysis, it is found that, the most economical option worked is WSP in the areas having availability of land with low cost (upto Rs. 60.00 lakhs/hectare). In the areas of high land cost (over Rs. 60.00 lakhs/hectare), then the UASB based technology is the economic option. If O& M Charges are properly monitored, ASP technology will also be economical. FAB technology is costlier than the other technologies. With the acute shortage of land and require higher degrees of treatment, FAB technology may be adopted.

5.8 GENERAL FINDINGS

The case studies are made in Chennai, Haridwar, Lucknow, Pimpri Chinchwad-Pune, Saharanpur, Sonepat, Rishikesh and Periyakulam town sewage treatment plants. The resources recovered from the above sewage treatment plant are briefed below:

5.8.1 CHENNAI

Chennai is the good example for selling the secondary treated effluent to factories for their industrial purposes. The total installed capacity of all sewage treatment plants in Chennai is 481 MLD. 90 percent of this water has been discharged as the secondary treated effluent. This is about 433 MLD. Out of this water about 212 MLD is sold to the factories like CPCL, MFL and MPL. The balance is of 221 MLD. But, there are no other such factories ready to buy the water, because they have their own sources of water.

There is no possibility to utilize the water for irrigation, because the city is not near by connected with agricultural fields. At present about 1524.77 cum of wet sludge /day is being produced and quantity of dry sludge is about 228.72m3/day. Sludge production per year is 83483 m3 and the cost of sludge @ Rs. 80.00 per m3 is Rs. 66.79 lakhs. There is not much acceptability on the part of farmers to utilise the sludge.

As per gas production is concern, the projected gas production is 45408 m3/day, but, actual gas production is 11000 m^3/day. As per the volume of gas produced, 22.44MWh electricity can be generated. But, only 13 MWh is now being generated. Now, the daily average gas-engine running hours is only 9 hours. The electricity charge is Rs. 477.80lakhs/year.The total electricity savings per year is Rs. 199.29 lakhs through the running of gas engine. The total electricity cost is Rs. 677.09 lakhs /year. If all the produced gas are utilised for the power production, power savings is Rs. 344.00 lakhs/year i.e. 51 % of the total electricity consumption will be met from it.

The annual maintenance charge is Rs. 1359.9lakhs per year. The annual maintenance charges per 1 MLD capacity is Rs. 2 .827 lakhs. This amount is less than that of the average amount fixed for ASP based sewage treatment technology of Rs. 3.50 lakhs. The total resource recovery including power generation is Rs. 892.54 lakhs. The resource recovery for 1 MLD plant is Rs. 1.856 lakhs. But the resources are fully utilised, it is expected to get revenue of Rs. 749.43 lakhs per year including power generation.

5.8.2 HARIDWAR

Approximately, 120 hectares of land is being irrigated with treated sewage having dissolved Nitrogen and Phosphorous. The treated effluent is being sold at the rate of Rs 800 /hectare/year giving revenue of Rs 0.96 lakh/year. At present about 57.06 cum of wet sludge /day is being produced and quantity of dry sludge is about 8.56m^3/day. Sludge production per year is 3124 m^3 and the cost of sludge @ Rs. 80.00 per m^3 is Rs. 2.50 lakhs. About 2500 m^3 of nutrient rich digested sludge cakes, which is an excellent bio-fertilizer and soil conditioner, are sold to the farmers at the rate of Rs 80/ m^3 to yield a revenue of Rs 2 lakh per year. Eucalyptus trees have been planted in the campus, giving revenue of Rs 5 lakhs per year by way of sales from fuel wood trees. Sales to safety-match box factories, mature poplar trees will fetch Rs 40 lakhs in the year 2003. . Also, available free land around the STP unit is being utilized by local farmers to grow vegetables by paying an annual lease of Rs 0.18 lakh per year.

As per gas production is concern, the projected gas production is 1728 m3/day, but, actual gas production is 480 m^3/day. As per the volume of gas produced, 0.88MWh electricity can be generated. But, at present, the gas is being utilized for running of DFG during power breakdown only and the rest is being flared. The electricity charge is Rs. 24.25 lakhs/year. If all the produced gas are utilised for the power production, power savings is Rs. 9.636 lakhs/year i.e. 40 % of the total electricity consumption will be met from it.

The annual maintenance charge is Rs. 78.80 lakhs per year. The annual maintenance charge per 1 MLD capacity is Rs. 4.378 lakhs. This amount is higher than that of the average amount fixed for ASP based sewage treatment technology of Rs. 3.50 lakhs. The total resource recovery is Rs. 16.14 lakhs. The resource recovery for 1 MLD plant is Rs. 0.897 lakhs. But the resources are fully utilised, it is expected to get a revenue of Rs. 16.24 lakhs per year, including power generation.

5.8.3 LUCKNOW

This Sewage Treatment Plant is based on the Fluidized Aerobic Bed (FAB) technology. Since the process is aerobic hence air is supplied to sewage in which micro organism metabolize the soluble and suspended organic matter. Part of the organic matter is synthesis in to new cells and part is oxidized to carbon dioxide and water, so this procedure does not exit any foul gases. Hence no odor problem occurs by this STP.

It produced much small quantity of sludge and what is more, this sludge requires no further treatment such as digestion, due to the fact that it produces digested sludge which does not smell like that in conventional plant. Because of this reason, biogas can not be produced by this technology.

The digested sludge is pumped to sludge drying beds where the water is drained out to filter sump and natural drying occurs. The dried cakes are manually removed and it can be used as fertilizer or for land filling. The sludge generated in the bio-reactors is totally digested. Since the F/M ratio in the bio-reactors is very low, the excess sludge generation is lower than compared to the conventional ASP system. This sludge is an excellent manure, but no good responsibilities from the formers.

The annual maintenance charge is Rs. 164.00 lakhs per year. The annual maintenance charge per 1 MLD capacity is Rs. 3.905 lakhs. This amount is less than that of the average amount fixed for FAB based sewage treatment technology of Rs 4.50 lakhs. Now the resource recovery from the plant is nil. But the resources are fully utilised, it is expected to get revenue of Rs. 2.89 lakhs per year, towards the sale of sludge.

5.8.4 PIMPRI CHINCHWAD-PUNE

This Sewage Treatment Plant is based on the Fluidized Aerobic Bed (FAB) technology. There is no odor problem occurs by this STP.

It produced much small quantity of sludge. Biogas can not be produced by this technology. The digested sludge is pumped to sludge drying beds where the water is drained out to filter sump and natural drying occurs. The dried cakes are manually removed and it can be used as fertilizer or for land filling. This sludge is excellent manure, but no good responsibilities from the formers.

The annual maintenance charge is Rs. 42.00 lakhs per year. The annual maintenance charge per 1 MLD capacity is Rs. 2.80 lakhs. This amount is lesser than that of the average amount fixed for FAB based sewage treatment technology of Rs 4.50lakhs. Now the resource recovery from the plant is nil. But the resources are fully utilised, it is expected to get revenue of Rs. 1.03 lakhs per year, towards the sale of sludge.

5.8.5 SAHARANPUR

Effluent after polishing pond is being discharged in river Dhamola and is not being utilized for irrigation. At present about 107.16 m^3 of wet sludge /day is being produced and quantity of dry sludge is about 16.07m^3/day. Sludge production per year is 3124 m^3 and the cost of sludge @ Rs. 80.00 per m3 is Rs. 4.69 lakhs. The dried sludge is regularly being sold to farmers. The unit earns around Rs. 1.88 Lakhs per year from the sale. The unit claims to have earned Rs. 25000/- from the sale of fish.

As per gas production is concern, the projected gas production is 5434 m3/day, but, actual gas production is 900 m^3/day. As per the volume of gas produced, 1.84MWh electricity can be generated. The electricity charge is Rs. 24.63 lakhs/year. If all the produced gas are utilised for the power production, power savings is Rs.26.20 lakhs/year i.e. 100 % of the total electricity consumption will be met from it.

There are large factories like Indian Tobacco Company, Star Paper and Pulp mill etc. are available in Saharanpur. It is not possible to sell water as like Chennai, because they are using their own sources of water for their industrial purposes.

The annual maintenance charge is Rs. 66.13 lakhs per year. The annual maintenance charge per 1 MLD capacity is Rs. 1.74 lakhs. This amount is less than that of the average amount fixed for UASB based sewage treatment technology of Rs 2.76 lakhs. The resource recovery from the plant is Rs. 18.17 lakhs. The resource recovery for 1 MLD plant is Rs. 0.478 lakhs. But the resources are fully utilised, it is expected to get revenue of Rs. 4.69 lakhs per year, including power generation.

5.8.6 SONEPAT

The treated effluent is being discharged in to drain and is being used for irrigating agricultural fields by the cultivators, although no revenue is being realised. At present about 84.60 cum of wet sludge /day is being produced and quantity of dry sludge is about 12.69m3/day. Sludge production per year is 3124m3 and the cost of sludge @ Rs. 80.00 per m^3 is Rs. 3.71 lakhs. There is not much acceptability on the part of farmers to utilise the sludge. There is, therefore, no significant revenue on this account is expected. At present Rs.0.60 lakh from the sale of sludge is being received in a year.

As per gas production is concern, the projected gas production is 3060 m^3/day, but, actual gas production is 864m3/day. The average of the 6 months is 519 m^3 /day against 864 m^3/day i.e. 60% of production is utilised. Gas is being utilized for running of DFG during power breakdown only and the rest is being flared. The electricity charge is Rs. 24.00 lakhs/year. If all the produced gas are utilised for the power production, power savings is Rs. 25.20 lakhs/year i.e.100 % of the total electricity consumption will be met from it.

The annual maintenance charge is Rs. 61.43 lakhs per year. The annual maintenance charge per 1 MLD capacity is Rs. 2.048 lakhs. This amount is less than that of the average amount fixed for UASB based sewage treatment technology of Rs 2.76 lakhs. The resource recovery from the plant is Rs. 0.60 lakhs. The resource recovery for 1 MLD plant is Rs. 0.02 lakhs. But the resources are fully utilised, it is expected to get revenue of Rs. 3.50 lakhs per year, including power generation.

5.8.7 RISHIKESH

55 acres of fodder farm is getting the benefit of 6 MLD of pond effluent, raising fodder crops of Rs.10 lakhs per year. Pisciculture is practiced in the algae rich ponds and fruit and vegetable are grown in 3 hectares of the STP campus site, yielding revenue of Rs 85,000 per annum. This STP is a shining example of utilizing a piece of land for sewage treatment, leading to prevention of pollution of the river and at the same time drawing the full opportunity to recover the cost by way of resource recovery from fodder, vegetable and fruit crops as well as aquaculture. At present about 900 cum of dry sludge per year is produced and the cost of sludge @ Rs. 80.00 per m^3 is Rs. 0.72 lakhs. There is not much acceptability on the part of farmers to utilise the sludge. There is, therefore, no significant revenue on this account.

The annual maintenance charge is Rs.7.33 lakhs per year. The annual maintenance charge per 1 MLD capacity is Rs. 1.221 lakhs. This amount is less than that of the average amount fixed for WSP based sewage treatment technology of Rs 1.40 lakhs. The resource recovery from the plant is Rs. 10.85 lakhs. The resource recovery for 1 MLD plant is Rs. 1.808 lakhs. But the resources are fully utilised, it is expected to get revenue of Rs. 11.57 lakhs per year, including sale of sludge.

5.8.8 PERIYAKULAM

16 acres of guinea gross farm is getting the benefit of 4 MLD of pond effluent, raising guinea gross and earning a revenue from annual lease of Rs. 3, 75,501/- per year. Also it yields a revenue from the annual lease of Palm trees, 419 Nos. inside the campus of STP: Rs. 27,500/-, annual lease of Coconut trees, 295 Nos. in side the campus of STP:

Rs. 35,501/- and annual lease of Cotton trees, 421Nos.in side the campus of STP: Rs. 1, 01,000/- The overall income from the sewage treatment plant is Rs, 5.40 lakhs. Aquaculture could be practiced in the algae rich ponds will yield a good revenue. At present about 480cum of dry sludge /year is produced and the cost of sludge @ Rs. 80.00 per m^3 is Rs. 0.38 lakhs. There is not much acceptability on the part of farmers to utilise the sludge. There is, therefore, no significant revenue on this account.

The annual maintenance charge is Rs. 2.01 lakhs per year. The annual maintenance charge per 1 MLD capacity is Rs. 0.503 lakhs. This amount is very much less than that of the average amount fixed for WSP based sewage treatment technology of Rs 1.40 lakhs. The resource recovery from the plant is Rs. 5.40 lakhs. The resource recovery for 1 MLD plant is Rs. 1.35 lakhs. But the resources are fully utilised, it is expected to get revenue of Rs. 5.78 lakhs per year, including sale of sludge.

CHAPTER 6

CONCLUSIONS

1) We can recover from the sewage treatment plants the following:
   - Biodiesel from fat, oil and grease
   - Biogas from other organic material
   - Biodiesel from residual sludge
   - Fertilizers and metals from inorganic materials
   - District heating through sewage-source (water-source) heat pumps
   - Water for reuse from water discharged
2) In India, the total waste water generation in class I cities are 16,662.5 MLD. Only 74 percent of the total waste water generated is collected. Out of 299 class I cities, 160 cities have covered sewerage system having more than 75 percent of the population, 92 cities have between 50 and 75 percent of the population enjoying covered sewerage facilities. On the whole, 70 percent of the population of class I cities are provided with the sewerage facilities.
3) Out of 16662.5 MLD of the waste water generated, only 4037.2 MLD (24 percent) is treated before letting out and the rest i.e. 12,625.30 MLD is being disposed off untreated. Only 27 cities have primary treatment facilities and 49 cities have primary and secondary treatment facilities.
4) The treatment available in the cities with existing treatment plants can process 2.5 to 89 percent of the sewage generated.
5) The waste waters, treated, partly treated or untreated, are disposed by the municipalities into natural systems such as drains, rivers, lakes and sea or used for irrigation. The mode of disposal in 188 cities is indirectly into rivers/lakes/ponds/creeks, in 63 cities to the agricultural lands, in 41 cities directly in to rivers and in 44 cities it is discharged both into rivers and on agricultural lands.
6) The Municipalities are utilising the sewage sludge for biogas generation and producing electricity. They utilise the treated effluent for irrigation and reuse for industrial purposes. They also sell the sludge cake as manure. Aquaculture is also being practiced.

7) Chennai and Haridwar have ASP based STPs. Lucknow and Pune have UASB based STPs. Saharanpur and Sonepat have FAB based STPs. Rishikesh and Periyakulam have WSP based STPs.

8) The ASP and UASB based sewage treatment plant are biogas producing plants. The FAB and WSP based plants are not capable of producing biogas. But the produced gases are not fully utilised. Most of the gases are flared up. So, it should be monitored to utilise the full strength of biogas and reduce the electricity charges to be paid to the electricity board.

9) The WSP based sewage treatment plants are well maintained and shining examples of utilizing a piece of land for sewage treatment, leading to prevention of pollution of the river and at the same time drawing the full opportunity to recover the cost by way of resource recovery.

10) From the net present worth analysis, it is found that, the most economical option worked is WSP in the areas having availability of land with low cost (upto Rs.60.00 lakhs/hectare).

11) In the areas of high land cost (over 60.00 lakhs/hectare), then the UASB based technology is the economic option.

12) If O& M Charges are properly monitored, ASP technology will also be economical.

13) FAB technology is costlier than the other technologies. With the acute shortage of land and require higher degrees of treatment, FAB technology may be adopted.

14) The total waste water generation in class I cities is 16,662.5 MLD. The annual Power Production: 401500 MWh @ Rs. 4.00 per unit (average), the total electricity savings per year is Rs. 160.60 crores. If all waste waters are properly managed only in class I cities in India, we will get Rs. 160.60 crores/year in future through the power production from biogas (Appendix 7).

APPENDIX 1

A.1 GAS PRODUCTION IN CHENNAI

A.1.1 GAS PRODUCTION[17]

Total suspended solids in the influent = 450 mg/l

Total suspended solids in the effluent = 30 mg/l.

Total suspended solids removed = 420 mg/l

Assuming volatile solids to be equal to 70 % of suspended solids, we have

Volatile solids removed = 70 % X 420 mg/l. = 294 mg/l

Now assuming that the volatile solids (matter) is reduced by 65% in the sludge by digestion, we have

Volatile solids reduced = 65% X 294= 191.1 mg/l

There fore Volatile matter reduced per million litre of sewage

$= 191.1 \text{ X}10^6/10^6 = 191.1$ kg

Now assuming that 0.9 m3 of gas is produced per kg of volatile matter reduced, we have,

the gas produced/ million litre of sewage = 0.9 X 191.1=171.99 m^3 (or) =172 m^3

A.1.2 CALORIFIC VALUE OF BIOGAS

CH4=65vol%; CO2=32vol%

Calorific value of pure CH4 =50,000kJ/kg

Calorific value of biogas(0.65 X16 X 50,000)/(0.65 X 16 +0.32X44)

=21241.8kJ/kg = 21.24 MJ/kg

Avg. mole wt. = 0.65 X 16 + 0.35 X 44 = 25.8 kg/k.mole

Volume per unit weight = 22.414/mol wt. (m3/kg) = 22.414/ 25.8

= 0.8688 m3/kg

C.V. of biogas = 21241.8 kJ/kg

= 21241.8/0.8688 [(kJ/kg)/ (m3/kg)]

= 24450 kJ/ m^3

Projected Electricity = 24450/3600 [1J=1watt sec]

= 6.792 kWh/ m^3

Efficiency of Gas engine, η = 30%,

Actual Electricity	= 6.792 X 0.30 = 2.04 kWh/ m^3

A.1.3 POWER GENERATION AS PER THE PRODUCTION OF BIOGAS

At Kodunkaiyur

Biogas production	=4500 m^3
C.V.of Biogas	= 21.24 MJ/kg
Energy production for 1 m3 biogas@21.24 mJ/m3	=2.04 kWh/day
Energy production per day (4500 X2.04)	= 9180 kWh/day=9.18 MWh/day
Total Energy production per day	= 22.44 MWh/day
Annual Gas Production: (22.44 MWh X 365 days)	=8191 MWH @ Rs4.20 per unit
Total Electricity savings/year (8191X4.20X1000)	= Rs. 344.00 lakhs
KOYAMBEDU:	
(5.1MWh X 365 = 1861.5 MWh X 4.20.X 1000)	= Rs. 78.18 lakhs
Total Power Generated as per log book	= 984100 kWh for 2862 hours.
Power Generated per hour	= 343.9 kWh
Power Generated per day (9 hrs.)	= 3095 kWh (3 MWh)
Kodunkaiyur	= 5 MWh
Koyambedu	= 3 MWh
Nesappakkam	= 2 MWh
Perungudi	= 3 MWh
Total	= 13 MWh per day
Annual Power Production: 13 MWh X 365 days	=4745 MWh @ Rs. 4.20per unit
Total Electricity savings/year (4745X4.20X1000)	= Rs. 199.29 lakhs
Cost of Power savings	
(22.44 MWh/day X365 days X 4.20 X1000)	= Rs.344.00 lakhs/year
Cost of Electricity savings per 1MLD	= Rs. 344.00 lakhs / 264 MLD
	= Rs. 1.30 lakhs/year
Actual Electricity savings per 1 MLD	= 4745X4.20X1000
	= Rs. 199.29 lakhs/264 MLD
	= Rs. 0.755 lakhs/year

A.2 GAS PRODUCTION IN HARIDWAR

A.2.1 GAS PRODUCTION[13]

Total suspended solids in the influent =255 mg/l.

Total suspended solids in the effluent = 20 mg/l.

Total suspended solids removed =235 mg/l.

Assuming volatile solids to be equal to 70 % of suspended solids, we have

Volatile solids removed = 70 % X 235 mg/l. = 164.5 mg/l.

Now assuming that the volatile solids (matter) are reduced by 65% in the sludge by digestion, we have Volatile solids reduced = 65% X 164.5= 106.93 mg/l.

Volatile matter reduced per million litre of sewage = 106.93 $X10^6/10^6$ = 106.93 kg

Now assuming that 0.9 m3 of gas is produced per kg of volatile matter reduced, we have, the gas produced per million litre of sewage = 0.9X106.93=96.23 m^3(Say)=96 m^3

For Haridwar STP (18 MLD) = 18 X 96 = 1728 m^3

Actual Biogas production = 430 m^3

Calorific Value of Biogas

CH_4=65vol%; CO_2=32vol%

Calorific value of pure CH_4 =50,000kJ/kg

Calorific value of biogas

(0.65 X16 X 50,000)/ (0.65 X 16 +0.32X44) =21241.8kJ/m3= 21.24 MJ/kg

A.2.2 PROJECTED ENERGY PRODUCTION FROM BIOGAS

Biogas production from STP = 430 m^3

Energy production per day =430 X2.04 = 877.2 kWh/day

=0.88 MWh/day

Cost of Electricity r savings (0.88 MWh/day X365 days X 3.00 X1000)

= Rs.9.64 lakhs/year

Cost of Electricity savings per 1MLD = Rs. 9.64 lakhs / 18 MLD

= 0.54 lakhs/year

A.3 GAS PRODUCTION IN SAHARANPUR

A.3.1 GAS PRODUCTION[13]

Total suspended solids in the influent = 400 mg/l.

Total suspended solids in the effluent = 50 mg/l.

Total suspended solids removed = 350 mg/l.

Assuming volatile solids to be equal to 70 % of suspended solids,

We have, Volatile solids removed = 70 % X 350 mg/l. = 245 mg/l.

Now assuming that the volatile solids (matter) is reduced by 65% in the sludge by digestion, we have, Volatile solids reduced = 65% X 245= 159.25 mg/l.

There fore Volatile matter reduced per million litre of sewage

($159.25\ X10^6/10^6$) = 159.25 kg

Now assuming that 0.9 m3 of gas is produced per kg of volatile matter reduced, we have, the gas produced/MLD of sewage (0.9 X 159.25) = 143.33 m^3 (or) = 143 m^3

Projected gas production = 38 X 143 = 5434 m^3.

Actual flow23.15 MLD / day

Gas production for flow23.15 MLD = 23.15 X 143 = 3310.45 m^3

Actual gas production from STP = 900 m^3

C.V.of Biogas = 21.24 MJ/kg

A.3.2 PROJECTED ENERGY PRODUCTION FROM BIOGAS

Biogas production from STP = 900 m^3

Energy production per day (900 X2.04) = 1836 kWh/day =1.84 MWh/day

Cost of Electricity savings (1.84 MWh/day X365 days X 3.90 X1000)

= Rs.26.20 lakhs/year

Cost of Electricity savings per 1MLD (Rs. 26.19 lakhs / 38 MLD) = 0.69 lakhs/year

A.3.3 UTILISATION OF GAS FOR THE PRODUCTION OF ELECTRICITY

Energy production per day =1126 kWh/day=1.126 MWh/day

Cost of Electricity savings

(1.126 MWh/day X365 days X 3.90 X1000) = Rs.16.04 lakhs/year

Cost of Electricity savings per 1MLD (Rs. 16.04 lakhs / 38 MLD)= 0.422 lakhs/year

APPENDIX 4

A.4 GAS PRODUCTION IN SONEPAT

A.4.1GAS PRODUCTION[13]

Total suspended solids in the influent =300 mg/l.

Total suspended solids in the effluent = 50 mg/l.

Total suspended solids removed = 250 mg/l.

Assuming volatile solids to be equal to 70 % of suspended solids,

We have, Volatile solids removed = 70 % X 250 mg/l. = 175 mg/l.

Now assuming that the volatile solids (matter) is reduced by 65% in the sludge by digestion, we have, Volatile solids reduced = 65% X 175= 113.75 mg/l.

Volatile matter reduced / million litre of sewage = 113.75 $X10^6/10^6$ = 113.75 kg

Now assuming that 0.9 m3 of gas is produced per kg of volatile matter reduced, we have the gas produced per million litre of sewage = 0.9X113.75=102.38m^3(Say)

= 102 m^3.

Theoretical gas production = 30 X 102 = 3060 m^3.

Actual gas production for Sonepat STP (30 MLD) = 864 m^3

Calorific Value of Biogas

CH4=65vol%; CO2=32vol%

Calorific value of pure CH4 =50,000kJ/kg

Calorific value of biogas (0.65 X16 X 50,000)/ (0.65 X 16+0.32 X44)

=21241.8kJ/m3= 21.24 MJ/kg

A.4.2 ENERGY PRODUCTION FROM BIOGAS

Biogas production = 864 m^3

Energy from 1 m3 biogas@21.24 MJ/ m^3 =2.04 kWh/day

Energy production per day =864 X2.04 = 1763 kWh/day=1.77 MWh/day

Electricity savings (1.77 MWh/day X365 days X 3.90 X1000)

= Rs.25.20 lakhs/year

Cost of Electricity savings per 1MLD = Rs. 25.20 lakhs / 30 MLD

= Rs. 0.84 lakhs/year

APPENDIX 5

A.5 SLUDGE PRODUCTION

PARAMETERS	VALUES	REACTOR VOL.	PST VOL	SST VOL	TOTAL (V)	SRT	Sludge (KG/D)	Primary Sludge (KG/D)	Total Sludge (KG/D)
CONVENTIONAL ACTIVATED SLUDGE PROCESS									
F/M (day-1)	0.3								
Q (m3/d)	10000								
S0 (kg/m3)	0.25	3125	1250	1250	5625	5	468.75	1750	2218.75
V (m3)								Include Inert	
X (kg/m3)	2								
Inf. SS kg/m3	0.25								
Inorganic SS	0.075								
EXTENDED AERATION ACTIVATED SLUDGE PROCESS									
F/M (day-1)	0.1								
Q (m3/d)	10000							Inert Sludge	
S0 (kg/m3)	0.25	6250	0	1250	7500	20	325	750	1075
V (m3)									
X (kg/m3)	4								
Inf. SS	0.25								
Inorganic SS	0.075								
MEMBRANE BIOREACTOR									
F/M (day-1)	0.1								
Q (m3/d)	10000							Inert Sludge	
S0 (kg/m3)	0.25	2500	0	0	2500	30	200	750	950
V (m3)									
X (kg/m3)	10								
Inf. SS	0.25								
Inorganic SS	0.075								
LINPOR PROCESS									
F/M (day-1)	0.3								
Q (m3/d)	10000							PST	
S0 (kg/m3)	0.25	1953.125	1250	1250	4453.1	5	468.75	1750	2218.75
V (m3)									
X (kg/m3)	3.2								
15%	CARRIER								
X (kg/m3)	3.2								
Inf. SS	0.25								
Inorganic SS	0.075								
UASB PROCESS									
COD Loading	1								
Q (m3/d)	10000								
S0 (kg/m3)	0.25	4000			4000		1225	750	1975
X (kg/m3)	65								
X (kg/m3)	3.2								
Inf. SS	0.25								
Inorganic SS	0.075								
VSS	0.175								

Source: Class notes made by Dr.A.A.Kazmi, Asst. Proff. of Civil Engineering Dept, IIT, Roorkee.

A.6 SLUDGE PRODUCTION

A.6.1 CHENNAI

Mass of sludge in ASP based STP	= 221.88 kg/MLD (Appendix 5)
Sludge concentration	=65 to 75 kg/ m^3 (say) 70 kg/ m^3
Volume of sludge	= 221.88 /70 kg/ m^3 = 3.17 m3/MLD
Sludge production per day	= 481 MLD X 3.17m3/MLD =1524.77 m^3
Quantity of dry sludge=15% of wet sludge	=1524.77 X 0.15 = 228.72 m^3
Sludge production per year	= 228.72 m3 X 365 days = 83483 m^3
Cost of sludge @ Rs. 80.00 per m^3	= Rs. 66.79 lakhs.

A.6.2 HARIDWAR

Mass of sludge in ASP based STP	= 221.88 kg/MLD
Sludge concentration	=65 to 75 kg/ m^3 (say) 70 kg/m3
Volume of sludge	= 221.88 /70 kg/ m^3 = 3.17 m3/MLD
Sludge production per day	= 18 MLD X 3.17m3/MLD =57.06 m^3
Quantity of dry sludge=15% of wet sludge	=57.06 X 0.15 = 8.56 m^3
Sludge production per year	= 8.56 m^3 X 365 days = 3124 m^3
Cost of sludge @ Rs. 80.00 per m^3	= Rs. 2.50 lakhs.

A.6.3 LUCKNOW (Assuming the quantity of sludge produced by FAB based STP is 50% as in ASP based STP)

Mass of sludge in FAB based STP	= 110 kg/MLD
Sludge concentration	=65 to 75 kg/ m^3 (say) 70 kg/ m^3
Volume of sludge	= 110 /70 kg/ m^3 = 1.57 m3/MLD
Sludge production per day	= 42 MLD X 1.57m3/MLD =65.94 m^3
Quantity of dry sludge	=15% of wet sludge=65.95 X 0.15 = 9.89 m^3
Sludge production per year	= 9.89 m^3 X 365 days = 3610 m^3
Cost of sludge @ Rs. 80.00 per m^3	= Rs. 2.89 lakhs.

A.6.4 PIMPRI CHINCHWAD-PUNE

Mass of sludge in FAB based STP	= 110 kg/MLD
Sludge concentration	=65 to 75 kg/ m^3 (say) 70 kg/ m^3

Volume of sludge	= 110 /70 kg/ m^3 = 1.57 m3/MLD
Sludge production per day	= 15 MLD X 1.57m3/MLD =23.55 m^3
Quantity of dry sludge	=15% of wet sludge=23.55 X 0.15 = 3.53 m^3
Sludge production per year	= 3.53 m^3 X 365 days = 1288 m^3
Cost of sludge @ Rs. 80.00 per m^3	= Rs. 1.03 lakhs.

A.6.5 SAHARANPUR

Mass of sludge in UASB based STP	= 197.5 kg/MLD (Appendix 5)
Sludge concentration	=65 to 75 kg/ m^3 (say) 70 kg/ m^3
Volume of sludge	= 197.5 /70 kg/ m^3= 2.82 m3/MLD
Sludge production per day	= 38 MLD X 2.82 m^3/MLD =107.16 m^3
Quantity of dry sludge	=15% of wet sludge=107.16X0.15=16.07m3
Sludge production per year	= 16.07 m^3 X 365 days = 5866 m^3
Cost of sludge @ Rs. 80.00 per m^3	= Rs. 4.69 lakhs.

A.6.6 SONEPAT

Mass of sludge in UASB based STP	= 197.5 kg/MLD
Sludge concentration	=65 to 75 kg/ m^3 (say) 70 kg/ m^3
Volume of sludge	= 197.5 /70 kg/ m^3= 2.82 m3/MLD
Sludge production per day	= 30 MLD X 2.82m3/MLD =84.60 m^3
Quantity of dry sludge	=15% of wet sludge=84.60X0.15= 12.69 m3
Sludge production per year	= 12.69 m^3X 365 days = 4632 m^3
Cost of sludge @ Rs. 80.00 per m^3	= Rs. 3.71 lakhs.

A.6.7 RISHIKESH

Sludge production per day = 0.08 m^3/person/year (Population of the town = 75000)

Wet sludge production per year	= 0.08X 75000 = 6000 m^3
Quantity of dry sludge=15% of wet sludge	=6000 X 0.15 = 900 m3
Cost of sludge @ Rs. 80.00 per m^3	= Rs. 0.72 lakhs.

A.6.8 PERIYAKULAM

Sludge production per day = 0.08 m^3/person/year (Population of the town = 40000)

Sludge production per year	= 0.08 X 40000 = 3200 m^3
Quantity of dry sludge (15% of wet sludge)	=3200 X 0.15 = 480 m3
Cost of sludge @ Rs. 80.00 per m^3	= Rs. 0.38 lakhs.

APPENDIX 7

A.7 BIOGAS PRODUCTION IN FUTURE

The total waste water generation in class I cities is 16,662.5 MLD[19].

As per Indian conditions, the minimum total suspended solids in the influent are 200mg/l. and the maximum total suspended solids in the influent are 500 mg/l. So, taking average total suspended solids in the influent as 350 mg/l; Total suspended solids in the influent is 350 mg/l; Total suspended solids in the effluent is 30 mg/l. & Total suspended solids removed is 320 mg/l.

Assuming volatile solids to be equal to 70 % of suspended solids,

We have Volatile solids removed = 70 % X 320 mg/l. = 224 mg/l.

Now assuming that the volatile solids (matter) is reduced by 65% in the sludge by digestion, we have Volatile solids reduced = 65% X 224= 145.6 mg/l.

Therefore Volatile matter reduced / million litre of sewage

$= 145.6 \times 10^6/10^6 = 145.6$ kg

Now assuming that 0.9 m3 of gas is produced / kg of volatile matter reduced, we have

The gas produced per million litre of sewage = 0.9 X 145.6= 131.04 m3 (or)

= 131 m3

The total waste water generation in class I cities is 16,662.5 MLD.

Biogas production =16,662.5 X 131 = 2182787.5 m^3

Considering one-forth of the volume, we have, 545697 m^3 of biogas production.

POWER GENERATION THRO' GAS ENGINE

Biogas production =545697 m^3

C.V.of Biogas = 21.24 MJ/kg

Energy production for 1 m3 biogas @21.24 MJ/ m^3 = 2.04 kWh/day

Energy production per day =545697 X2.04 = 1113221.88 kWh/day

= 1113.22 MWh/day. (Say)

= 1100 MWh/day

Annual Power Production: 1100MWh X 365days = 401500 MWh @ Rs. 4.00per unit (average), total Electricity savings per year = 401500X4.00X1000

= Rs. 160.60 crores.

APPENDIX 8

A.8 COST-BENEFIT ANALYSIS

As per the guideline laid down by the National River Conservation Directorate, Govt. of India, 'technical option should be based on the cost benefit analysis of various options to achieve the desired standards and the most economic one should be selected'. The Cost Benefit analysis for the eight sewage treatment plants has been worked out with the following considerations.

1) The rate of land is considered as Rs. 24.00 lakhs, Rs. 36.00 lakhs, Rs. 42.00 lakhs, Rs. 54.00 lakhs, Rs. 63.00 lakhs and Rs. 84.00 lakhs per hectare.
2) The present worth of O&M cost is at interest rate of 6 % for a period of 30 years, as per the following formula:

$$\mathbf{P = A\,[(1+i)^{n} - 1]/\,[i\,(1+i)^{n}]}$$

In functional form, the equation is: P= A [P/A, i, n]

Where P = present worth in Rs.

A = uniform end- of period payment or receipt continuing for a duration of 'n'period.(Let it be Rs. 1.00)

i = the rate of interest per interest period (usually one year)

n = the number of period of time (usually year).

The above relationship is known as Uniform Series Present Worth Factor, (USPWF).

$$= [(1+ i)\, n - 1/i\,(1+i)^{n}] = [(1+0.06)^{30}-1/0.06(1=0.06)^{30}]$$

$$= [(1.06)^{30}-1/0.06(1.06)^{30}] = 13.765.$$

Net Present Worth = - [cost of construction] – O&M. [USPWF] + R.R. [USPWF]

A.8.1 NET PRESENT WORTH-I

(The rate of land is considered as Rs. 42.00 lakhs per hectare)

Chennai	= -53.40 - 38.91 + 31.59	= -60.72
Haridwar	= -53.40 - 60.26 + 20.08	= -93.58
Lucknow	= -50.84 -53.75 + 0.945	= -103.65
Pune	= -50.84 - 38.54 +0.945	= -88.44
Saharanpur	= -47.14 -23.95 +11.274	= -59.82

Sonepat	= -47.14-28.19+13.269	=-62.06
Rishikesh	= -59.00-16.81+26.57	= -49.24
Periyakulam	= -59.00-6.92+19.96	=-45.96

A.8.2 NET PRESENT WORTH-II

(The rate of land is considered as Rs. 24.00 lakhs per hectare)

Chennai	= -49.80 - 38.91 + 31.59	= -57.12
Haridwar	= -49.80 - 60.26 + 20.08	= -89.98
Lucknow	= -50.48 -53.75 + 0.945	= -103.29
Pune	= -50.48 - 38.54 +0.945	= -88.06
Saharanpur	= -44.08-23.95+11.274	= -56.76
Sonepat	= -44.08-28.19+13.269	=-59.00
Rishikesh	= -41.00-16.81+26.57	= -31.24
Periyakulam	= -41.00-6.92+19.96	=-27.96

A.8.3 NET PRESENT WORTH-III

(The rate of land is considered as Rs. 36.00 lakhs per hectare)

Chennai	= -52.20 - 38.91 + 31.59	= -59.52
Haridwar	= -52.20 - 60.26 + 20.08	= -92.38
Lucknow	= -50.72 -53.75 + 0.945	= -103.53
Pune	= -50.72- 38.54 +0.945	= -88.32
Saharanpur	= -46.12-23.95+11.274	= -58.80
Sonepat	= -46.12-28.19+13.269	=-61.04
Rishikesh	= -53.00-16.81+26.57	= -43.24
Periyakulam	= -53.00-6.92+19.96	=-39.96

A.8.4 NET PRESENT WORTH-IV

(The rate of land is considered as Rs. 54.00 lakhs per hectare)

Chennai	= -55.80 - 38.91 + 31.59	= -63.12
Haridwar	= -55.80 - 60.26 + 20.08	= -95.98
Lucknow	= -51.08 -53.75 + 0.945	= -103.89
Pune	= -51.08- 38.54 +0.945	= -88.68

Saharanpur	= -49.18-23.95+11.274	= -61.86
Sonepat	= -49.18-28.19+13.269	=-64.10
Rishikesh	= -71.00-16.81+26.57	= -61.24
Periyakulam:	= -71.00-6.92+19.96	=-57.96

A.8.5 NET PRESENT WORTH-V

(The rate of land is considered as Rs. 63.00 lakhs per hectare)

Chennai	= -57.60 - 38.91 + 31.59	= -64.92
Haridwar	= -57.60 - 60.26 + 20.08	= -97.78
Lucknow	= -51.26 -53.75 + 0.945	= -104.07
Pune	= -51.26- 38.54 +0.945	= -88.86
Saharanpur	= -50.71-23.95+11.274	= -63.39
Sonepat	= -50.71-28.19+13.269	=-65.63
Rishikesh	= -80.00-16.81+26.57	= -70.24
Periyakulam	= -80.00-6.92+19.96	=-66.96

A.8.6 NET PRESENT WORTH-VI

(The rate of land is considered as Rs. 84.00 lakhs per hectare)

Chennai	= -61.80 - 38.91 + 31.59	= -69.12
Haridwar	= -61.80 - 60.26 + 20.08	= -101.98
Lucknow	= -51.68 -53.75 + 0.945	= -104.49
Pune	= -51.68- 38.54 +0.945	= -89.28
Saharanpur	= -54.28-23.95+11.274	= -66.96
Sonepat	= -54.28-28.19+13.269	=-69.20
Rishikesh	= -101.00-16.81+26.57	= -91.24
Periyakulam	= -101.00-6.92+19.96	=-87.96

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