

Green Manufacturing Practices : TNPL Case Study On Value Addition To Waste



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ABSTRACT

The paper discusses about various green manufacturing practices adopted in TNPL with respect to value addition to bagasse, sugarcane residue generated during sugar manufacturing, during paper manufacturing and various measures taken for both solid and liquid management in the bagasse based pulp industry and its economic and environmental benefits. The inorganic solid wastes, such as, lime sludge, lime grits and fly ash are utilized as raw material to manufacture cement on a commercial scale for first time in pulp and paper industry. Total 62,631 MT of lime sludge and 20,839 MT of fly ash were used in the cement plant during 2013-14. The organic solid wastes are utilized as fuel for power generation and to reduce the GHG emission and to conserve the fossil fuel resources. The combined anaerobic/aerobic biological treatment process reduces treatment cost by reduced power consumption and less sludge disposal problem. The biomethanation plant produced 34.46 million cubic meter of biogas and saved 20,679 KL of furnace oil in the last four years. In addition to that 4,53,907 MT of CO₂ equivalent greenhouse gas emission was also reduced in the last four years.

Introduction

The population increase and economic growth around the world especially in the developing countries, has strong link with quantity of wastes that are generated due to higher production and consumption. It has detrimental impact on our natural capitals, environment, ecosystem and climate (1). But, availability of many raw materials is decreasing around the globe and it is a biggest challenge faced by world over the time. The availability and quality of "Natural Capitals," such as, air, water, land, minerals, oil, coal and forest vary enormously between regions to regions and country to country. Apart from supplying raw materials for industrial manufacturing and human need "Natural Capitals" are essential for fertile soil, productive land, & seas, fresh water and clean air, biodiversity, pollination of plants, natural

protection against flooding, and regulation of our climate (2,3). Generation of more wastes is leading to lower efficiency, higher cost and environmental impact. Management of both solid and liquid waste is essential for sustainable growth and manufacturing. Ensuring the waste elimination gives environmental and economic benefits to industry and society. Deviation from linear model of take, make, dispose to circular economy that takes insights from living systems. Circular economy is similar to natural systems that work like ecosystem, processing nutrients that can be fed back into the cycle to closed loop to reach zero waste in manufacturing process (3). Therefore, waste management through energy recovery, recycling and conversion of useful products would improve economical and environmental performance. The efforts taken by Tamil Nadu Newsprint and Papers Limited (TNPL) on the above areas are presented and discussed in this paper.

Value Addition To Bagasse As Paper Making Raw Material

TNPL manufacture printing and writing paper using bagasse as main raw material. The mill currently produces 4,00,000 TPA printing and writing paper. TNPL is building a new green field board mill with a capacity of 2,00,000 TPA and it will be commissioned by the end of 2015.

Bagasse is an alternate sustainable annual fibre source to manufacture pulp and paper (4) and contribute to preserve the wood fibre. The leftover residue after crushing and processing of sugarcane to remove the sugar juice is bagasse and having fibre with 0.5-1.5 mm length and 20 -25 micron diameters similar to other non wood fibres. The bagasse received from sugar mill having 3-4% residual

Figure-1: Value addition to bagasse in TNPL through Paper Making

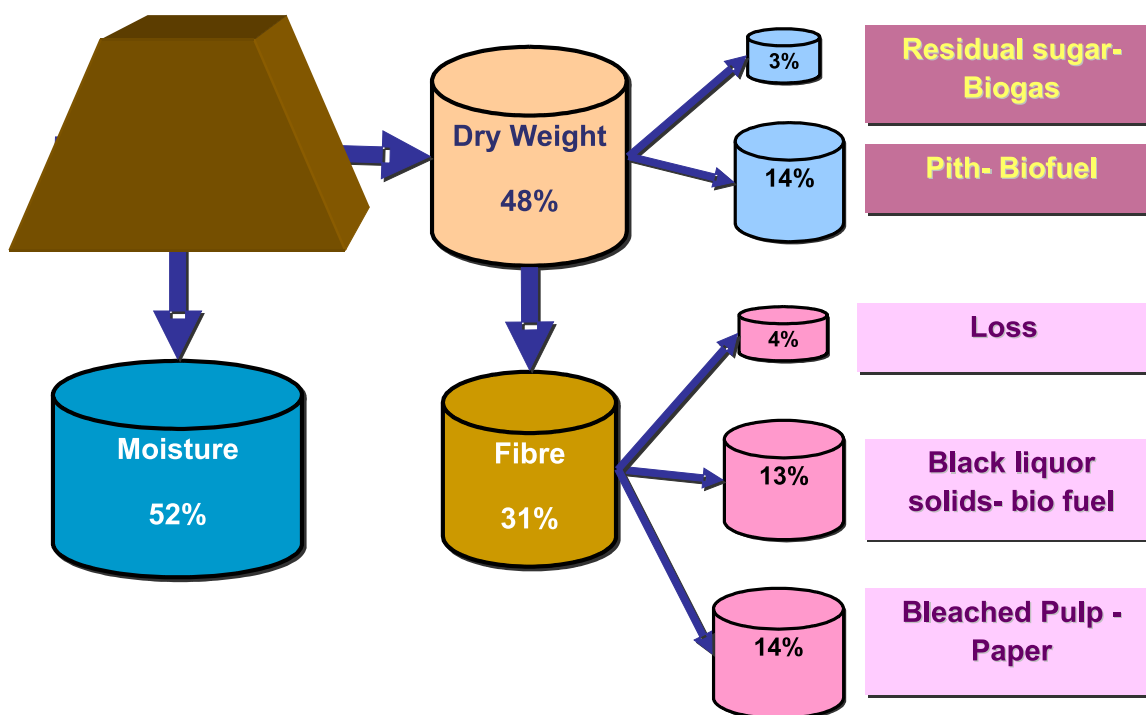


Table 1: Wood saved in the last 3 years due to the use of bagasse.

Year	Bagasse pulp produced in MT	Equivalent wood conserved in MT
2011-12	165914	730056
2012-13	170632	709786
2013-14	157898	678909

Table 2: Quantity of various solid wastes generation.

S. No	Parameter	Unit	2011-12	2012-13	2013-14
I	Inorganic Solid waste				
1	Fly ash	MT	45806	36618	43205
2	Wet ash	MT	19824	11522	14356
3	Lime sludge	MT	291645	294587	302644
4	Lime grits	MT	4204	3973	3834
II	Organic Solid Waste				
1	Bagasse pith from Pulp Mill	MT	98036	82816	87053
2	Dust from Chipper House	MT	2257	9129	9078
3	ETP Primary Sludge	MT	70686	68241	53362
4	ETP Secondary sludge	MT	3755	4817	5501

sugars is stored in open yard by wet bulk storage method for a period of 3 to 9 months depending on availability and use. During storage, the bagasse is kept under wet condition by spraying water over bagasse pile to preserve bagasse quality and avoid fire hazard. After storage, the bagasse is reclaimed and washed before feeding to the continuous digester for production of pulp to manufacture paper. Value addition to sugarcane waste (bagasse) through pulp & paper production and effective utilization of biomass waste viz. residual sugars, bagasse pith and Black liquor, for bio-energy generation is presented in Figure-1.

The data on production of pulp from bagasse for 2011-12, 2012-13 & 2013-14 and conservation of wood is presented in Table - 1.

Value Addition To Solid And Liquid Waste

In traditional wood/agro based paper mill complex operating based kraft pulping, bleaching, papermaking, chemical recovery process, captive thermal power plants, water and wastewater treatment process generate various inorganic solid wastes that include wet ash, fly ashes, dregs grits and

Table - 3: Properties of solid wastes

S. No	Description	Major constituents (on OD basis)
1	Fly Ash	Ash: 88 - 92%, LOI : 8 to 12%
2	Wet Ash	Ash : 90-95 % , LOI : 3 to 5%
3	Lime Sludge (Moisture:45 to 50%)	Acid insolubles: 6-7%, Silica as SiO ₂ : 6% Mixed Oxides (R ₂ O ₃): 1% Calcium as CaCO ₃ : 88 - 90% Magnesium as MgCO ₃ : 1 – 1.5% Free CaO: 0.8 , Sodium as Na ₂ O: 18%
4	Lime grits (Moisture: 25 to 30%)	Acid insolubles: 6- 7% , Silica as SiO ₂ : 6-7% Mixed Oxides (R ₂ O ₃): 3.1% Calcium as CaCO ₃ : 85 - 88% Magnesium as MgCO ₃ : 3% Free CaO: 1.% , Sodium as Na ₂ O: 1.8%
5	Bagasse Pith (Moisture:45-50%)	GCV: 4000 -4200 Kcal/kg , Ash: 9% Volatile matter: 72% , Fixed carbon:13%
6	Dust from Chipper house (Moisture: 25-30%)	GCV: 4000-4600 Kcal/kg, Ash: 2.4% Volatile matter: 72% , Fixed carbon:19%
7	ETP primary sludge (Moisture:75-80%)	GCV: 2300-2700 Kcal/kg Organics: 60-70% , Inorganics:30-40%
8	ETP Secondary sludge (Moisture: 83-85%)	GCV: 2500-3000 Kcal/kg Organics: 60-70% , Inorganics:30-40%

Table- 4: Quantity of solid wastes recycled or utilized in the mill

S. No	Parameter	Unit	2011-12	2012-13	2013-14
1	Lime sludge: re-burnt in lime kiln	MT	180173	182571	182810
2	Chipper dust used as fuel in boiler	MT	2257	9129	9078
3	Bagasse pith used as fuel in boiler	MT	98036	82816	87053

organic wastes, such as, primary sludge, secondary sludge, bagasse pith and pulp mill brown stock screening rejects (5,6,7). The quantity and type of waste generated in TNPL and its major composition are presented in Table - 2 & 3. Conventionally solid wastes are used as land-filling, burning or incineration or land application as soil amendment (8,9,10). However, it is suggested that based on the market potential, location of mill and type of wastes (organic or inorganic) many value added products can be produced from the wastes generated from the paper mill such as cement, paper board, particle board and even fuel-alcohol (9 10) and they can also be used internally (Table 4).

Agro based raw-material contain high silica when compared to wood. Hence, two stage caustizing proces is necessary to purge silica entering to chemical recovery cycle from agro based raw materials like bagasse to avoid silica build-up in

system. In the two stage caustisizing process about 30% of lime is used in first stage and produced lime sludge is purged. Remaining 70% lime is used in the second stage and produced lime sludge is recycled back to system through lime kiln (11). However, in the wood based mills, there is no purging required and only single stage caustisizing is followed and entire lime sludge is reused. The lime sludge generated from the first stage caustisizing and fly ash generated from power boilers are issues of concern in inorganic solid waste management and disposal. Conversion of these wastes into useful products to replace natural resources wherever possible will reduce waste disposal problem and depletion of natural resources.

Utilization and management of 1st stage lime sludge, dregs, and grits is necessary for sustainable operation of the mill. Mixing of these wastes along with fly ash to produce cement

Table -5: Environmental benefits of LSMF

S. No	Parameter	Unit	Value
1	Cement production in 2013-14	MT	113904
2	Solid waste elimination due to reuse of Lime sludge	MT	62631
3	Solid waste elimination due to reuse of Fly ash	MT	20839
4	Conserved Lime Stone	MT	73487
5	GHG emission reduction due to lime stone conservation	t CO ₂ e	32334
6	GHG emission reduction due to logistic reduction of lime sludge	t CO ₂ e	470
7	GHG emission reduction due to logistic reduction of fly ash	t CO ₂ e	156
8	Total GHG emission reduction due to LSMF	t CO ₂ e	32960

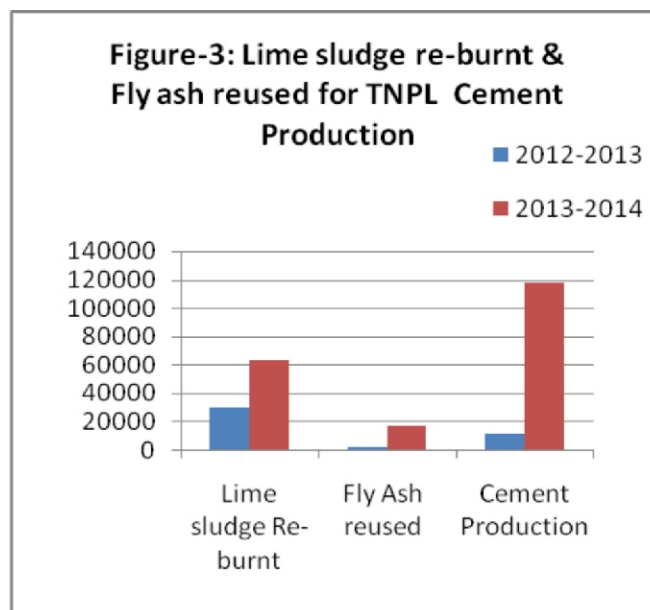
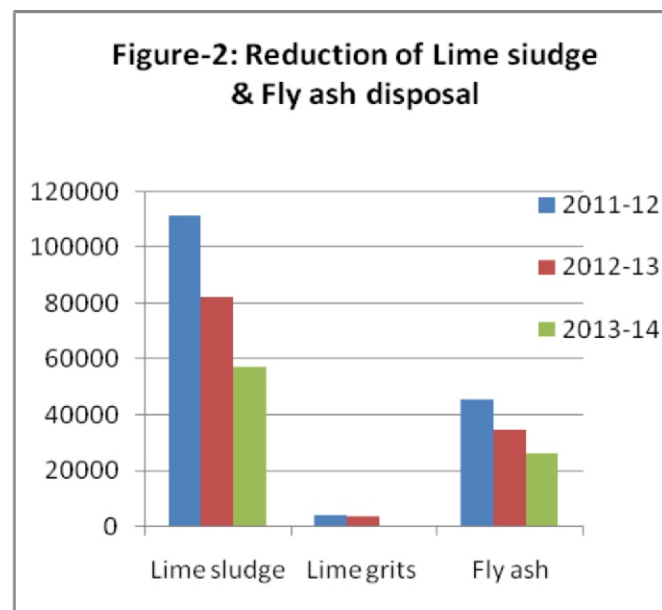


Table 6: GHG emission reduction due to CO₂ sequestration through PCC.

S. No	Parameter	Unit	Value
1	Precipitated Calcium Carbonate per annum	MT	50000
3	GHG emission reduction per annum	t CO ₂ e	22000

is an alternative to current land-filling or disposal to other vendors (10). TNPL conceived the idea of converting the first stage lime sludge and fly ash into high grade cement and installed 600 tonnes per day (TPD) mini cement manufacturing unit called Lime Sludge and Fly ash Management system (LSFM). The project was commissioned during 2012 and first of its kind in the pulp and paper industry. This project is a beacon for other mills, in the direction of converting wastes into wealth besides addressing the concerns being faced in the disposal of solid

wastes. The benefits with respect to conservation of natural resources and GHG emission reduction achieved in 2013-14 by implementation of this project is presented in Table -5. This has also reduced inorganic solid waste disposal quantity and it is presented in the Figure - 2 and inorganic solid waste, such as, lime sludge, lime grits and fly ash used for production of Cement is presented in Figure-3.

TNPL had set up a Precipitated Calcium Carbonate (PCC) plant through OMYA, Switzerland on Built Operate and Own (BOO) basis next to cement plant. Besides cost saving and

Table 7: Energy generation and GHG emission reduction by utilization organic waste as fuel.

S. No	Parameter	Unit	2011-12	2012-13	2013-14
1	Chipper dust	MT	2257	9129	9078
2	Bagasse Pith	MT	98036	82816	87053
3	Thermal energy generated	GJ	753910	686727	718284
4	GHG emission reduction	t CO ₂ e	73849	67248	70359

Table 8: GHG emission reduction due lime sludge re-burning in 2013-14

S. No	Parameter	Unit	Value
1	Burnt Lime production	MT	101351
2	Reuse of Lime sludge	MT	182810
3	Conserved of Lime Stone	MT	169340
4	GHG emission reduction due to logistic reduction of lime sludge	t CO ₂ e	1371
5	GHG emission reduction due to burning of Lime Sludge in kilns	t CO ₂ e	80436
6	Total GHG emission reduction	t CO ₂ e	81807

Table 9: Quantity of wastes disposed to other industries and use.

S. No	Parameter	Unit	2011-12	2012-13	2013-14
1	Lime sludge	MT	111472	82180	57203
2	Lime grits	MT	4204	3973	0
3	Fly ash	MT	45806	35028	26195
4	Wet ash	MT	19824	11522	14356
5	ETP Primary sludge	MT	70686	68241	53362

Table 10: Economical and environmental benefits of kitchen waste biogas plant.

S. No	Parameter	Unit	Value
1	Organic solid waste utilized from canteen per day	Kg	160
2	Organic solid waste utilized from guest house per day	kg	60
3	Total organic solid waste utilized from tnpl per day	kg	220
4	Emission reduction per annum by avoidance of CH ₄	t CO ₂ e	7.6
5	Volume of biogas used in the heating equipment per day	m ³	20
6	Emissions reduction by fossil fuel displaced per annum	t CO ₂ e	10.4
7	Emission reduction per annum	t CO ₂ e	18.0
8	Savings per annum Rs in lakh		2.0

effective utilization and reduction of solid wastes, PCC plant utilizes CO₂ emitted through cement kiln flue gas for the production of PCC. The CO₂ sequestered via PCC are used as fillers during paper manufacturing and fixed in the paper and reduce greenhouse gas emission and climate change. The addition of wet slurry instead of dry powder reduces the fugitive emissions in the Chemical Additive Plant. The greenhouse gas emission reduction from cement and PCC plant complex is presented Table - 6.

Utilization organic solid wastes, such as bagasse pith and wood dust as carbon neutral bio fuel to generate thermal energy reduced the dependence on the fossil fuel like coal in the power boiler. The thermal energy generated from the carbon neutral green fuel and avoidance of GHG emission for the year 2011-12, 2012-13 & 2013-14 is presented in Table 7. Similarly, re-burning of lime sludge in the lime kiln avoids fresh mining of lime stone and GHG emission from lime kiln (Table 8).

Management and reduction of solid wastes are ongoing process. The entire lime grits are now utilized in the cement plant (Table 9). However, the present capacity of the cement plant is inadequate to utilize the entire 1st stage lime sludge generated from the chemical recovery process and fly ash

from power boiler. Cement plant capacity is being increased from 600 TPA to 900 TPA to utilize these wastes. Wet ash is still an issue. Disposal of ETP primary and secondary sludge is not an issue because, the primary sludge contain mostly fibre and filler is utilized as raw material for board manufacturing by the local small scale industries. The ETP secondary sludge is good organic manure and it is used by plantation department or by the local farmers (Table 9).

As good corporate citizen, TNPL is also focusing its attention to others apart from its process problem. One such example is installation of biogas plant to manage solid waste generated from industrial canteen and guesthouse. The benefit of kitchen waste biogas plant is presented in the Table 10.

Value Addition To Liquid Waste

Water shortage is a serious sustainability challenges facing the planet today due to impacts of climate change (12,13,14). Only less than 1% of world's water is accessible fresh water. Growing population, industrialization, urbanization, increasing per capita consumption put water supplies in greater pressure. Proper management, reduction and reuse

Table 11: Properties of wastewater generated

S. No	Parameter	Unit	High BOD Stream	Low BOD Stream
1.	pH		4.5	7.0
2.	BOD ₅	ppm	4000(max)	600(max)
3.	COD	ppm	6000(max)	1200(max)
4.	Total Suspended Solids	ppm	7000(max)	1000(max)
5.	Total Dissolved Solids	ppm	3500(max)	1800(max)
6.	Color, Pt. Co units	ppm	300	350

Table 12: Economic and environmental benefits of biogas plant

S. No	Particulars	Units	2010-11	2011-12	2012-13	2013-14
1	COD Treated	MT	16624	22127	24443	23595
2	COD Reduced	MT	14013	18847	21008	18917
3	Biogas generation	1000 M ³	5933	8735	10133	9664
4	Furnace oil saving	KL	3560	5241	6080	5798
5	GHG reduction due to CH ₄ avoidance	t CO ₂ e	66589	98023	113710	108447
6	GHG reduction due to Furnace Oil saving	t CO ₂ e	11558	17016	19740	18824
7	Total GHG Emission reduction	t CO ₂ e	78147	115039	133450	127271

Table 13: Properties of treated wastewater

S. No	Parameter	Unit	TNPCB Norms	TNPL Results
1.	PH	No.	5.5 – 9.0	7.5 – 8.0
2.	BOD ₅	ppm	30	10-13
3.	COD	ppm	250	150 - 200
4.	Total Suspended Solids	ppm	100	45 - 50
5.	Total Dissolved Solids (in organics)	ppm	2,100	1,400-1,600
6.	Color, Pt.co units	ppm	-	230-260
7.	AOX	Kg/T	1.0	<0.1

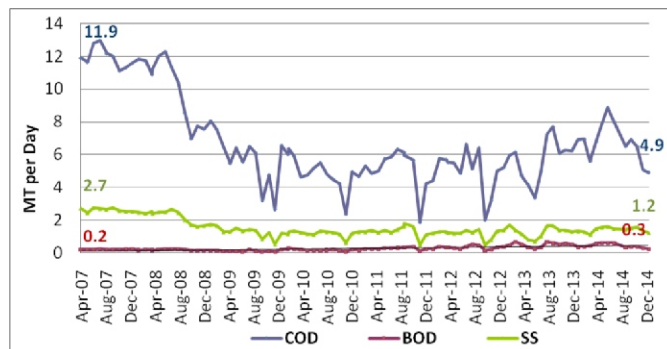


Figure 4: Reduction in total pollution load

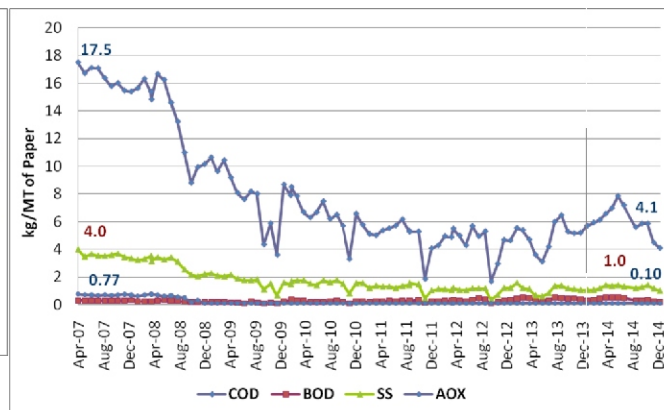


Figure -5: Reduction in specific pollution load

of water and wastewater are essential for sustainable operation of industry including pulp and paper which consume large quantity of water and discharge large quantity of wastewater (15,16). This would also help to ease the conflict for water between the civil society and industry. Minimizing the use of fresh water usage to conserve water and increase recycling would increase the COD load in the wastewater and it is hard to treat in traditional one stage aerobic process and require multiple stage to improve cost economics and quality (16,17).

In two stage biological treatment processes, first stage anaerobic treatment is adapted to effluents with high organic pollutant to reduce high organic load and to generate energy (17, 18). However, organic removal efficiency of anaerobic system is between 75% and 85%. Hence, with anaerobic treatment alone it is not possible to comply with required pollution norms. Treated wastewater from anaerobic treatment is post-treated by an aerobic biological stage. With an anaerobic-aerobic wastewater treatment, very efficient pollution load reduction (95–97% for COD; 99–99.8% for BOD) is obtained along with in-house renewable energy generation and the treated water can be recycled back into process. When compared to aerobic wastewater treatment

very less biomass i.e. secondary sludge is produced during anaerobic degradation process. Therefore, about 80% reduction is achieved in excess sludge production from combined anaerobic/aerobic treatment plant (16,17).

As indicated earlier, the sugarcane bagasse received from the sugar mill will be at 50% moisture (Figure 1). The bagasse is made into slurry by mixing with water and stored in open yard. This helps in washing residual sugars present in the bagasse and to achieve high compaction without any air entrapped into it. During formation of the pile, the excess water is drained out as wastewater which has high COD/BOD due to presence of dissolved organic compounds like sugar and sugar acids. In the fibre preparation plant, bagasse is thoroughly washed with water by making it slurry of about 1.5% consistency. After washing, the bagasse slurry is passed through inclined screw conveyors with perforated troughs, to drain out as wastewater with high COD/BOD. The wastewater is passed through screens to separate pith. The pith from the screen is thickened in belt press and then in screw press and consumed as biofuel in boiler. The high COD/BOD wastewater generated (Table 11) from the bagasse storage and fibre preparation is treated by combined anaerobic/aerobic treatment process.

The High BOD Stream consisting of about 12,000 to 15,000 m³ of wastewater from Bagasse storage yards and Bagasse preparation plant was treated in open anaerobic lagoon and it is replaced with a closed biomethanation reactor to generate biogas and to avoid greenhouse gas emission. The biogas generated from the biomethanation plant is utilized at Lime Kiln as fuel to replace furnace oil. Around 85-90% of reduction in COD and around 95% reduction of BOD are achieved across the bio-methanation plant. The outlet of bio-methanation plant is further treated by Activated Sludge process along with other effluents. The plant was further expanded by putting additional reactors in 2008. Economic and environmental benefits of biomethanation plant are presented in the Table - 12.

Effluent, with low BOD and suspended solids, generated from other sections of the plant viz. Paper machine, Pulp mill and Soda recovery plant treated in aerobic system based on "Activated Sludge Process" along with wastewater from the biomethanation plant outlet to achieve the required BOD/COD reduction as per the pollution control norms (Table -13). The long term performance of treated effluent quality in terms of absolute and specific pollution load are presented in the Figure - 4 and 5. The specific pollution load reduced from COD; 17.5 to 4.1 kg/MT of paper, AOX 0.77 to 0.1 kg/MT of paper and suspended solids from 4.0 to 1.0 kg/MT of paper.

The treated effluent water conforming to the Pollution Control Board norms is utilized for irrigating the dry barren lands around the mill. 1700 acres of arid land are irrigated with the treated effluent water under TNPL Effluent Water Lift Irrigation System (TEWLIS) scheme. The main crops cultivated in TEWLIS area are coconut, sugarcane, paddy and tapioca. The lands which were dry and parched earlier are now lush green and are a source of perennial revenue to the local farmers.

Conclusion

Utilization of bagasse, sugarcane residue generated during sugar manufacturing for pulp and papermaking can add more value when compared to use as fuel in the power boilers. Because, it is fractioned into various components and used effectively. For example, cellulosic fibre for pulp and paper, lignin and extractives as renewable fuel in chemical recovery

boiler, pith as renewable fuel in power boiler. High COD/BOD (residual sugars) generated from bagasse washing and storage is converted into biogas through anaerobic process and used as fuel to replace fuel oil and reduce greenhouse gas emission and climate change. The inorganic solid wastes, such as, lime sludge, lime grits and fly ash are utilized as raw material for Cement manufacturing in a commercial scale for first time in pulp and paper industry. The organic solid wastes are utilized as fuel for power generation and to reduce the GHG emission and to conserve the fossil fuel resources. All these efforts made the TNPL manufacturing process greener, economically viable and environmentally sustainable.

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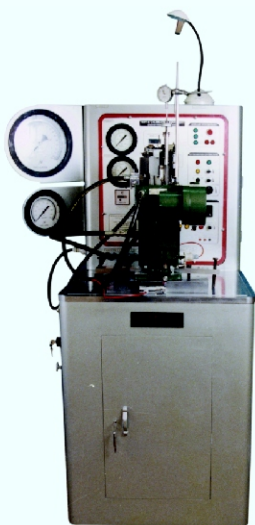
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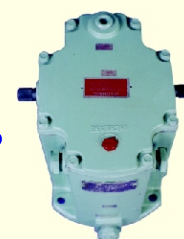
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