

Efficacy of cleaner technology in wastewater treatment and Energy conservation using (UASB-R) Anaerobic Digester at Bagasse-Based Pulp and Paper Mill in Tamil Nadu

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ABSTRACT

The present study is conducted in Pulp and Paper industry, karur, Tamil Nadu is taken for the purpose to compare the economic and environmental Benefits of this two fold cleaner technology, Up-flow Anaerobic sludge blanket, Bio-methanation (Cleaner technology) were compared with their older conventional technology, on the factors of environment, economic, water recirculating and energy conservation. Using cleaner technology has more efficiency and environmental sustainability on management perspective cleaner technology in energy conserving and Greenhouse gas Emission reductions shows, 127928 MT CO₂e average per year, on comparing the cost like benefited cost per liter using (secondary clarifier) cleaner technology is 0.00915 percent and return on investment in (up-flow anaerobic sludge blanket reactor) cleaner technology is -0.39691 percent the result shows physico-chemical parameters of conventional and cleaner technology treatment like pH-6.4 and 7.4, TDS -2564.4, and 2019, DO- 0 and 2.4 mg/l, BOD -227.5 and 5.75 mg/l, COD -548.7 and 218.6 mg/l. Within permissible limits of Industrial water standards by Tamil Nadu pollution control board (TNPCB). For more efficiency this two technology are used has an add-on in this Paper industry were Biomethanation is processed using UASB reactor output comes has biogas and they have lots of advantage were water is re-circulated to achieve zero liquid discharge in process has per norms given by Central pollution control board.

1. Introduction

Paper and Pulp process is very complex and needs water and high-energy consumption to run, which leads to environmental issues by using non-renewable energy resources heavy electricity depended industries are Aluminum smelter, copper smelter, iron and steel, cement, paper and pulp, fertilizer industries (Sengupta, 2004). Now industries are self-sufficient to meet their needs on using their own product has a co-processing or co-generation technology like biogas production like Biomethanation, Combined heat and power (CHP) using Bagasse, captive energy building (wind mill) to change into energy. India utilizes various cellulosic-based materials for paper production accounting about 43 percent from forest wood, 28 percent from agro-based product, and 29 percent from re-cycled and reused of waste paper (Balakrishnan, 1999 and Narsi et al., 2004). At present there are 666 pulp and paper mills in India, of which 632 units are eco-friendly agro-residue and recycled by pulping methods (Tewari et al., 2007). The Pulp and paper units today are integrated plants which apart from manufacturing paper generate power, recycle materials and supply to the state electricity grid. There is growing evidence that global greenhouse gas (GHG) emissions must be reduced by a daunting 45 to 80 percent below 1990 levels in the next 50 years (National CDM Authority, Government of India, 2014). With growing industrialization, the industrial residue generation has also been growing; these could also be harnessed for energy generation. Fossil fuel consumption in the world stands around 6Gtc (Giga tons of carbon / year and contributes as largest source of CO₂ leading to net increase of

2.1Gtc/year in atmosphere (Reicher, 1999). The maximum potential among others of the order of 1131 GW per hour followed by distillery with a contribution of 830 GW per hour to a total potential of 2963 GW per hour equivalent electric energy (KusumLata et al., 2002). Biogas potential from agro industrial is 1281 MW per year and Pulp and paper industry produce 58 MW per year (Anil Dhussa, 2004) They use different types of reactors like fully mixed, plug-flow, biofilm (MBBR), UASB, etc. the operational process conditions differs in factors like retention times, loading rates, temperatures in order to maximize the energy output from the waste and also to decrease retention time (RT) and to enhance the process stability. To eliminate this the mandatory laws of pollution control board stimulated to the sugar industry to install ETP with CPCB prepared a guidelines dated in 19-01-2015, on techno-Economic feasibility of implementation of Zero liquid discharged (ZLD) mechanism for reuse and recycle the effluent water conservation and irrigation protocol as alternate to ZLD water (CPCB, 2015). Biomethanation has strong efficacy with economic and environmental advantage for the production of energy (biogas) from organic residues and wastes. It will help to reduce the use of fossil fuels and thus reduce CO₂ emission. Ministry of renewable energy resources has given biogas Potential from Agro-industrial wastes (in MW) in different industry 58 CDM project are taken in account and gives subsidy, funding, demonstration, intuitional background, exemption to operate. (CDM-Registry, 2015). India has set targets to achieve an installed cumulative, grid connected renewable energy capacity of 74 GW by 2022 (15 percent of total energy) which is 4.1 percent at present (MNRE, 2014).

2. Material and methods

Pulp and paper industry profile:

The Paper and pulp mill is located in Karur, was set up with 2, 35,000 TPY in 2003. Its capacity was expanded to 4, 00,000TPY in 2010. This industry uses raw material has bagasse pulp 65 percent and 35 percent of wood pulp combination. The mill has state of the art technology speed machines paper with a capacity of 350 MT per day and

innovative water treatment technology UASB reactor attached for biogas production Lift Irrigation Scheme by bringing in dry lands under cultivation, utilizing the effluent discharge of the neighboring corporate social responsibility (CSR). This has helped to secure benefits like providing a dependable and perennial source of irrigation to farmers in the neighborhood, increase of land value manifold in the region (Table 1).

Table 1 Profile of the Paper and pulp industry

| S. No | Particulars | Details | |
|--|--|----------------------------|-------------|
| 1 | Plant location | Village | Kagthipuram |
| | | Taluk | Karur |
| | | District | Karur |
| | | Nearest town/city | Karur |
| | | State | Tamil Nadu |
| 2 | Plant site co-ordinates | Lat | 11°3'10"N |
| | | Long | 77°49'25"E |
| 3 | Nearest water body | Cauvery within 5km | |
| 4 | Hill Valley | Kolli hills -55 km | |
| 5 | Major Industries within the radius 15 km | Cement industry | |
| 6 | Total investment cost | 2400 Crores | |
| Quantity of Effluent treated and discharged | | | |
| 10 | Quantity of consumed water | 70,000 m ³ /day | |
| 11 | Quantity of Recycled water | 55,000 m ³ /day | |
| 12 | Quantity of discharged water | 15,000 m ³ /day | |
| 13 | ETP area, Up-flow Anaerobic blanket (UASB) | 2.5 acres | |
| 14 | Bio-gas production | 21500m ³ /day | |

Water quality analysis :The water sample was collected before the treatment process of raw effluent and a sample of water is taken from the output of (treated effluent) after activated sludge process and passed for membrane treatment process sample of water is taken from the aeration tank end process of water treatment. Physico-chemical parameters like, pH, TDS, Temperature DO, COD and BOD) characteristics of effluent (APHA, 1995).

Cost variables Benefited cost for a liter: In this cost analysis basic cost parameters like capital expenditures, variable cost, Buy back cost and viability of the mechanism (Life time of the mechanism in years) of the two treatment process are Elicited by the environmental engineer and auditor has a secondary data this are necessary cost to find (Benefited cost for a liter).

Cost variables for Return on investment (R.O.I): In this cost analysis basic cost parameters like capital expenditures, variable cost, Buy back cost and viability of the mechanism (Life time of the mechanism in years) of the two energy technology are Elicited from the environmental engineer and energy auditor has a secondary data this are necessary for cost variables to find Return on investment (R.O.I).

VC= Variable cost, FC= Fixed cost, BB= Buy back cost, Viability of mechanism

Total operational cost = Variable cost + Fixed cost
Profit of Social cost = Profit-Total operational cost.

Steps involved

- Total buyback cost** is equal to capital expenditure in Rupees. Multiply with buy back cost in percent, is divide by is equal to Rupees. (Total buy back cost).
- Actual capital expenditure** equals to capital expenditures in Rupees minus Total buy back cost in Rupees is equal to Rupees,
- Fixed cost** a formula is given fixed cost equals to Actual capital expenditure in rupees divided by viability period of the mechanism in years), it's given Rupees,
- Total operational cost (TOC)** equal to variable cost in Rupees per year plus fixed cost in Rupees, gives Rupees,
- Cost benefited for one liter** of water is equal to Total operational cost per liters of water Total operational cost in rupees divided by total liters of water in rupees per year gives Rupees.

Cost benefited for a liter = $\frac{\text{Total operational cost}}{\text{Litres per year}}$

Sources: (Mahesh et al., 2013)

6. **Return on Investment (R.O.I)** equal to Profit of Social cost in rupees divided by Total operational cost in rupees is equal to Rupees (Sources:Philip Kotler et al., 2004)

$$\text{Return on Investment (R.O.I)} = \frac{\text{Profit of Social cost}}{\text{Total operational cost}}$$

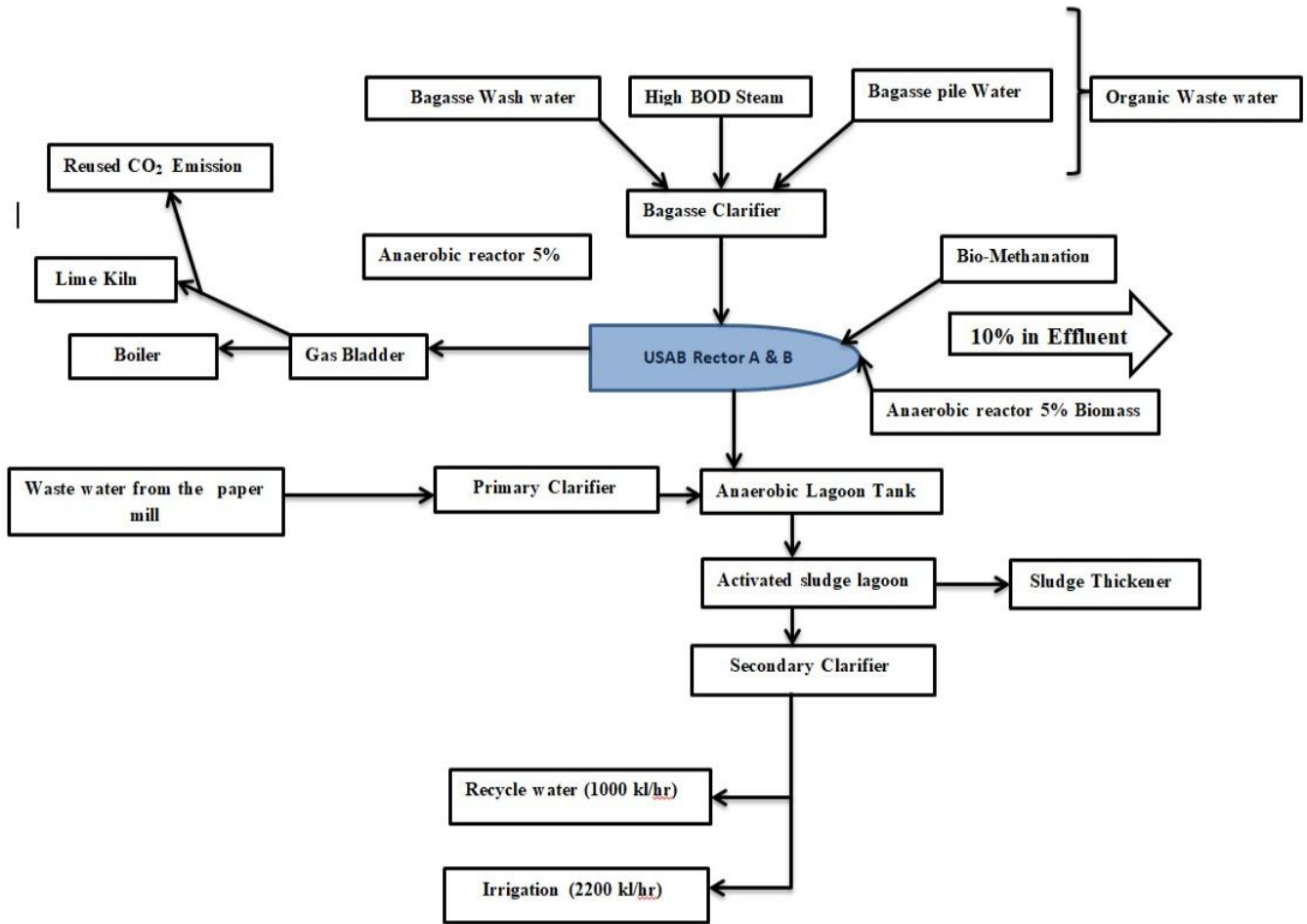


Figure 1 show the Step by step process involved in wastewater treatment and conservation of energy (Biomethanation) using UASB rector process

Effluent treatment plant explanation

High BOD stream, Bagasse pile water, bagasse wash water is passed through a and Bagasse clarifier, (USAB rector) Biomethanation process after that the low BOD stream (water from pulp mill effluent, paper machine, power boiler, pulp effluent is passed to a primary clarifier 1 and treatment is done in secondary clarifier were used, bagasse water is also treated and water is re-circulate for further operation.

High BOD stream is passed through a complex treatment technology (Bar screen fine screen opening ranges from 0.8mm to 1mm) and course screen (25-50mm), Bagasse clarifier (BOD and TSS removed 75 percent).

Low BOD stream (Step by step treatment process)

Primary Clarifier 1: reduce the level of BOD, COD, TS, TSS, DO, color and pH.

Activated Sludge lagoon process (Chinnaraj et al.,2011). Secondary Clarifier: Over flow of ASL reserved by the secondary clarifier. Waste water treatment process: Physical, Chemical, Biological waste water treatment methods (Metcalf and eddy, 1998; Rao, 2008).

Bio-methanation process

An UASB rector requires a long time for start-up example: 2 to 3 weeks in good condition (>20 C) and sometimes the start-up take up to 3 to 4 weeks. (KusumLata et al., 2002). Utilization of 12000m³ to 15000m³ of Biomethanation plant by Paper and pulp makes possible the recovery of biogas and the reduction of uncontrolled release of methane, the second largest designs, such as continuous stirred tank reactors (CSTR), fixed film reactor, fluidized bed rector, up flow anaerobic sludge blanket (UASB) and expanded sludge bed rector (EGSB) currently available . The biogas production per kg COD reduced and per m³ of waste water ranges from maximum 0.66 m³ to minimum 0.26 and maximum 2.0 m³ to minimum 0.83 m³ respectively with the average of .34m³/kg COD reduced and 1.35m³/kg of wastewater (Chinnaraj et al.,2001).

Up-flow anaerobic sludge blanket (UASB)

Up flow anaerobic sludge blanket rector (UASB-R) technology, normally referred to as UASB reactor, is a form of anaerobic digester that is used in the treatment of wastewater. Anaerobic reactors are increasing about 72 percent consist of reactors based on UASB and EGSB technologies. (Rahul, 2016)

Working Process

The waste water is passed upwards through an anaerobic sludge bed (ASB) where the microorganisms in the sludge come into contact with wastewater substrates. The sludge bed composed of natural microorganisms from granules (pellets) 0.5 to 2 mm diameter that have a high sedimentation velocity which is resulting in anaerobic degradation process for production of gas (biogas CH₄ and CO₂) provide reactor mixing for sludge in solid state (three phase separator) and blanket of granular sludge is formed by a settling gravity suspend flocculants is aided. Around 3 months, time small sludge granules begin such as aggregation of bacteria which involves

microorganisms aggregate dense compact biofilms called as "granules" (for methanogens). This is nourished in complex and gas is trapped into biogas referred to high concentration of methane as by-product captured has energy sources. The Phase III targets at treating the acidic bleach filtrate using Physico-chemical/biological pretreatment followed by membrane separation and recovering 90 percent of water. The sludge generated with a stage will enter a process called has lime sludge cycle. Anaerobic lagoon high reduction of BOD 90 percent, COD 60 percent in 10 to 20 days' time. Primary Clarifier: Coagulation process treatment of sludge is done (pH minimization) effectiveness vis-à-vis economy.

Table 2 Physico-chemical characteristics between conventional technology and cleaner technology of waste water.

| S.No | Physico-chemical parameters | Raw water | Conventional technology | Cleaner technology | TNPCB permissible limits |
|------|-----------------------------|-------------|-------------------------|--------------------|--------------------------|
| 1 | pH | 4.8 | 6.4 | 7.4 | 5.5-9.9 |
| 2 | Color | Brown color | Colorless | Colorless | Colorless |
| 3 | TDS | 4046.8 | 2564.4 | 1200 | 2100 |
| 4 | DO | 0 | 0 | 2.4 | 4 |
| 5 | COD | 6750.7 | 548.75 | 218.6 | 250 |
| 6 | BOD | 3758 | 227.5 | 5.75 | 100 |

The wastewater for analysis is collected from the inlet, which is more polluted and from the outlet, that after treatment from the ETP. The results of monthly analysis of pH, colour, COD, BOD, TDS, DO are analyzed after treatment and compared with the standard values (table.2).

pH

The hydrogen-ion concentration is an important parameter in wastewater treatment process. Fig.1 shows that the pH of the influent (raw wastewater) was measured to be 6.8 compared to 7.1 with treated effluent. Low value of pH is due to the metabolism of fungus and also metabolic production of acids by indigenous micro flora. (Shivnarayan, 2015; Khan et al., 2011; Greenberg et al., 1998).

Colour

The colour of the wastewater typically depends upon the different industrial processes. The measurement and removal of colour is essential part as it is unfit for recycling without proper treatment. After the treatment of cleaner and conventional technology water was seen colorless Figure 2 shows the variation of colour at the inlet and at the outlet of the ETP (Deepali et al., 2009).

Total dissolved solids

The total dissolved solids concentration varied from inlet 4046.8 mg/l whereas from treated effluent using conventional technology 2564.4 mg/l and cleaner technology treatment 1200 mg/l respectively. Figure 2 shows the variation of total dissolved solids from the inlet and outlet of ETP (Reddy and Subba Rao, 2001). The values show cleaner technology has very low TDS level in permissible limit as compared with TNPCB standards.

BOD and COD

The BOD and COD levels of influent wastewater varied from 268-387 mg/l and 1110 -1272 mg/l respectively. Whereas the BOD and COD levels of effluent varied from 176 - 282 mg/l and 799-1002 mg/l respectively. Fig.5&6 shows the levels of

BOD and COD is reduced to certain extent due to, biological treatment process for which the effluent is treated which consists of equalization, primary clariflocculator, aeration tank and the secondary clariflocculator, secondary clarifier Biological treatment process results in oxidation of organic matter, which provides energy for microbial metabolic process activated sludge lagoon treatment (Conventional technology) (BOD) 227.5 mg/l and (COD) 548.75 mg/l after adding secondary clarifier for the treatment process (cleaner technology) (BOD) 5.75 mg/l and (COD) 218.6 mg/l (Sawyer and McArty, 1978 ; Maheshwari et al., 2012) treatment output from the cleaner technology is within the TNPCB standards. The slight reduction in BOD and COD values shows that the removal percentage is 40-50% and 30-40% in conventional technology and now using cleaner technology 80 to 95 percent is done and reutilized in biogas production. The pH and TDS of the wastewater from effluent is within the Indian standard limits. And also within the permissible limit set by Minimum National Standard (MINAS) set by Central Pollution Control Board (CPCB) India to discharge for irrigation (Devi et al., 2011; MINAS, 1985; CPCB, 1993).

Cost Analysis between the conventional and cleaner technologies

Cost variables for calculation of Cost benefited for a liter

Conventional technology

Capital expenditure- Rs.3,50,00,000, Variable cost – Rs. 12,00,000 per year, viability period of the mechanism- 12 years, liter of water -465,000,000 per year, Buy back cost – 12.5 percent.

Cleaner technology

Capital expenditure- Rs.6, 00, 00,000, Variable cost – Rs. 25, 00,000 per year, viability period of the mechanism- 8 years, liter of water - 604,800,000 per year, Buy back cost – 16 percent.

Table 3: shows the cost benefited for a liter between the conventional and cleaner technology on treating one liter of water

| S. No | Variable | Conventional Technology (ASL*) | Cleaner Technology (SC*) |
|-------|----------------------------|--------------------------------|--------------------------|
| 1 | Cost benefited for a liter | 0.08020 % | 0.00915 % |

*ASP-Activated sludge process, S.C- Secondary clarifier

Inference for Cost benefited for a liter

- Cleaner technology cost benefited for liter is 0.00915 percent cheaper than conventional technology.
- This two technology are used has an add-on technology in this industry.
- Maintenance cost is cheaper than comparing with other advance technology like reverse osmosis, Nano-technology and membrane technology.
- Environment benefits waste water is recycled and recirculates in a cheaper cost to nearby farming community.

Cost variables for calculation of Return on investment (R.O.I)

Conventional technology

Capital expenditure- Rs. 4,00,00,000, Variable cost – Rs. 50,00,000 per year, viability period of the mechanism- 5 years, Benefited cost - Rs. 33,00,000 per year, Buy back cost – 10 percent.

Cleaner technology (UASB-R*)

Capital expenditure- Rs. 13,00,00,000, Variable cost – Rs. 2,76,00,000 per year, viability period of the mechanism- 25 years, Benefited cost - Rs. 75,00,000 per year, Buy back cost –7 percent.

Table 4: Return on investment Cost-analysis between the conventional and cleaner technology

| S. No | Variable | Conventional Technology (TNEB*) | Cleaner Technology (UASBR*) |
|-------|----------------------|---------------------------------|-----------------------------|
| 1 | Return on Investment | -0.72950% | -0.39691% |

* Tamil Nadu Electricity board and Bio-methanation (Up-flow anaerobic sludge blanket rector)

Inference for return on investment

- Cleaner technology return on investment -0.39691 percent cheaper than conventional technology.
- UASB-R produces bio-methanation energy conservation technology used in manufacturing of Pulp and paper process.
- For Bio-methanation bagasse is used has a raw material in a concept of resource efficient and cleaner production (ReCP) UNEP (Hammer et al.,1994) which is used has an effective utilization of recycled products.

- Effective utilization of waste generated from Clarifier underflow Bio-plant emission reduction in disposal of effluent sludge 427 lit of diesel is saved.
- The secondary clarifier recirculatesthe water (1000 kl/hr), 55,000 m³/day and Irrigation (2200 kl/hr).
- In this industry water is recycled and reusedefficiently using closed loop system on water saving.

Environment Advantage of Bio-methanation plant for per year in Pulp and paper industry

- About 85 percent of COD is converted to biogas and overall average COD reduction is 18917 MT/year and average treated COD is 21577 MT/year.
- The overall performance of USAB reactor in terms of average per year biogas production 21500m³/day and 9663897 M³/year.
- Furnace oil saving is 579888 KL/year.
- Greenhouse gas reduction from CH₄ avoidance 108888MT CO₂e.
- Greenhouse gas reduction from furnace oil saving 19039 MT CO₂e . Furnace oil saving: 6308 t certified emission reduction (CER t d 85 000)
- Total GHG reduction 127928 MT CO₂e.
- Revenue from furnace Oil saving 265.8 MT CO₂e.
- Bagasse clarifier, Up-flow anaerobic sludge blanket for Biomethanation (bio-gas production) Primary and secondary are used has an add-on technology conventional technology and cleaner technology is used for the water treatment technology.
- Reuse of lime sludge for brunt lime production 182810 MT of lime sludge is reused.

3. Result and discussion

Physico-chemical parameter

The pH, color, TDS,DO,COD and BOD are the important parameter to analysis the water such has comparing the two technology conventional (Activated lagoon system) in 1990 and (cleaner technology secondary clarifier) are used in the treatment since from 2003, Activated lagoon were the system used by the industries has an end of pipe technology there were no advanced technology From 2003 this industry installed a state of art technology UASB-R technology biomass (Bagasse is converted into biogas by using Biomethanation and recirculating was has explanation is given above. Comparing the two technologies, Physico-chemical parameter between conventional and cleaner technology, Colorless, pH- 6.4 and 7.4, TDS -2564.4, and 2019, DO- 0 and 2.4 mg/l, BOD -227.5 and 5.75 mg/l, After using moving bed biofilm reactor the reductions of COD, BOD, TSS and TDS concentrations of final effluent are 36 mg/L, 27.5 mg/L, 33 mg/L and 1077.5 mg/L, respectively (Badr El-Din et al.,2013). Comparing COD after treatment process of two technology USAB - 218.6 mg/l and membrane technology 10 mg/L COD content was down to and COD removal rate was up to 75 present in RO (Suqinli and XueZun,2011). within the permissible limits of Industrial water standards by Tamil Nadu pollution control board, this shows cleaner technology is more efficient than conventional technology, For more efficiency and cheaper in cost this two technology are used has an add-onto have techno-economic

viability in this Pulp and paper industry were Biomethanation is processed using UASB reactor output comes as biogas and they have lots of advantage where water is re-circulated to achieve zero liquid discharge (ZLD) in process as per norms given by Central pollution control board as shown in the table : 2.

Technology

Comparing the 3 different factors with five different technologies like effluent recycle, gas separation and chemical oxygen demand (COD) Anaerobic filter, UASB is very low in processing but on other side aerobic treatment and tertiary flocculation was found to be successful. This had resulted in an average COD reduction of 82 percent (Medhat and Usama, 2004). UASB anaerobic treatment requires more time for processing and if the ratio of COD to SO_4 is too low then the process comparing with moving bed biofilm reactor (MBBR) reduction of COD and BOD from the effluent is high without the loss of biomass (Vaidhegi, 2013).

Cost analysis

On comparing cost factors between USABR, MBBR and membrane technology. USAB reactor is very cheaper and used has a twofold technological solution aspect the cost parameter like maintenance, Annual savings, saving of oil has a positive factors and Ministry of New and Renewable energy (MNRE) subsidies given to Biomethanation projects has Clean development mechanism (CDM) benefits, State Government investment like subsidy are also available, in projects for further improvement and the investment in equipment average payback period is 1 year and 6 months is a positive factor in financial indicators (Jain et al., 2014).

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4. Conclusion

It is evident in this paper on the waste water treatment technology and energy conservation system in Pulp and paper industry is recirculation of treated water as per norms and permissible standards. Pulp and paper industry is highly (water polluting industry (ultra-red category) given by the TNPCB. To achieve Zero liquid discharge (ZLD) and Physico-chemical parameter analysis gave good result in pH, TDS, TSS, BOD and COD to recycle the water to farmer, who were the real beneficiaries. This treated water served for irrigation of farmlands like sugar cane, rice fields and other crops. Households were also benefited by using this water for their domestic purpose in and around the industrial area.

Contrary to expectation, the cost of treatment under cleaner technology proved costlier. However the cost of reduced environmental damages over the use of cleaner technology is very high. Therefore, it makes environmental sense to use cleaner technology, although as add-on technology water treatment technology and energy conservation (Biomethanation). The paper too clearly showed the same as cost of the Cleaner technology (USAB) reactor was higher than conventional technology (Primary and secondary clarifier) on capital investment, maintenance and less viability year of the mechanism. But in terms of environmental benefits, long term advantages environmental sustainability such as better soil quality, better human health, paved way towards sustainable development.

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