REVIEW ON ENERGY GENERATION USING WASTE WATER

[1]Ms. Dhanashri Pande, [2]Prof. A. A. Pande, [3]Prof. R. R. Badnakhe

PG Student, M. Arch Landscape, PIADS, Nagpur, Maharashtra, India[1], Assistant Professor, Civil Engineering Department, Sipna College of Engineering and Technology Amravati, Maharashtra, India [2,3]

ABSTRACT

Developments have shown that it is possible to generate sufficient energy from organic material contained in a variety of waste water stream. This is done to reduce the significant portion of the energy used to run the plant.. This waste to energy is environmental friendly solution to the municipal waste water since waste water treatment plants are the largest consumers of energy, however, it is an energy intensive operation. The present work provides an overview of technological measures to increase the self sufficiency of wastewater treatment plants (WWTPs). The operation of WWTPs entails a huge amount of electricity. Thermal energy is also required for pre-heating the sludge and sometimes exsiccation of the digested sludge. On the other hand, the entering organic matter contained in the wastewater is a source of energy. Organic matter is recovered as sludge, which is digested in large stirred tanks (anaerobic digester) to produce biogas. The onsite availability of biogas represents a great opportunity to cover a significant share of WWTP electricity and thermal demands. In foreign countries, widely used WWTP Method is activated sludge process. It is the process that utilizes the mechanical aeration to facilitate oxidation. But, instead of using energy to treat waste water, it is feasible to harness energy from waste as well as treating it using a Microbial Fuel Cell (MFC). MFCs are device that uses microorganisms as biocatalysts to transform chemical energy into electricity.

Keyword: - Waste Water Stream, Wastewater Treatment Plants (WWTPs), Activated Sludge Process, Mechanical Aeration, Microbial Fuel Cell (MFC), etc.

1. INTRODUCTION

The current view of wastewaters is that they generally represent a burden and necessarily, the energy costs in processing the wastewater at Wastewater Treatment Plants (WWTP) before they can safely be released into the environment are quite huge. The opportunity exists to improve the current wastewater treatment processes by applying new solutions and technologies that can also reduce energy inputs and/or generate energy for other processes. The most appropriate technologies and their limitations are partly determined by the value of the required energy product (heat, electricity, combined heat and power or fuel) and the driving market forces that determine how this energy product can be used with our current technology. Furthermore, the ease of separation of the energy product from water can be key to the feasibility of the process (e.g. biogas separates easy from wastewater by natural partitioning whereas bio-ethanol requires energy intensive distillation).

2. MOTIVATION

Energy requirements are increasing exponentially worldwide. Even now, most of global energy requirements are dependent on fossil fuels which will eventually exhaust. The process of attaining fossil fuels i.e. combustion also has a negative impact on the environment resulting from the carbon dioxide emission. Electricity is a big part of our modern life making it one of the most important resources to mankind. Electricity as we know can be generated by both conventional and non-conventional sources of energy. But as these sources not only require huge amount of space and funds for installation but also are harmful for the environment, there is need for alternative technologies that not only is cheap in comparison but also increases the efficiency of energy production

3. WASTEWATER TO ENERGY

Given the variety of inputs, intermediates and outputs, there are several technologies that can potentially be used to generate energy from wastewaters. The characteristics and loads of the different wastewater streams determine the technologies appropriate for energy recovery. The costs and benefits of each technology can then be compared on a life cycle basis. The mind-map presented in Figure 1.

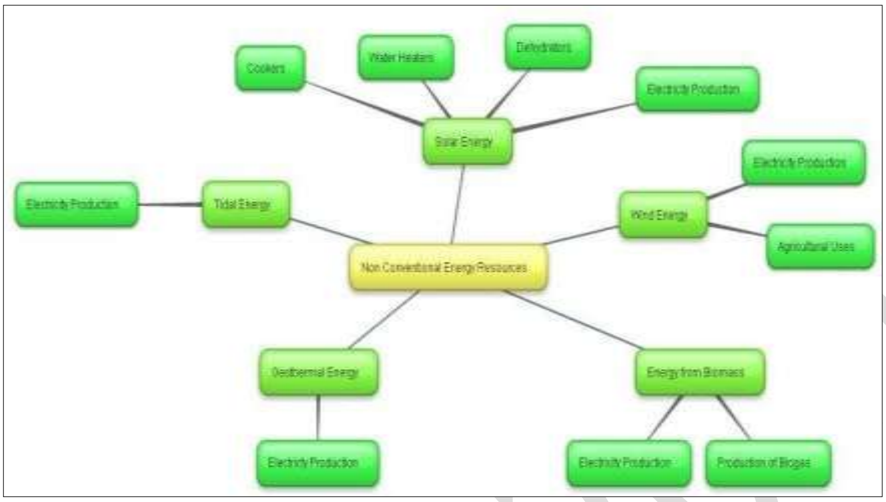

Fig-1: Non-conventional Energy Resources

Wastewater is water contaminated with human, agricultural, or industrial wastes. While typically seen as a nuisance, the organic matter contained in wastewater from our sewage systems (commonly known as "sludge") can become a valuable resource with sludge-to-energy systems. Various water treatment technologies are present that purify wastewater by removing undesirable chemicals or biological contaminants and making it fit for human consumption. Use based classification of surface waters in India has been laid down by the Central Pollution Control Board (CPCB). The details of the permissible and desirable limits of various parameters in drinking water as per Bureau of Indian Standards (BIS) standard specifications for potable water are also detailed in the IS 10500:1991. There are many commonly used technologies used in India for the treatment of wastewater such as, activated sludge process, trickling filters, rotating biological contractors, etc. Some of these methods work best for industrial wastewater while some suits best to municipal wastewater.

Out of all those some of the treatment methods that contribute to the energy generation in India are discussed and studied in this paper. Anaerobic digestion (AD) is the most commonly recognized technology and has been applied to wastewaters of different characteristics at both small and large scales. AD is suitable for use with domestic sewage, as well as in the industrial and agricultural sectors. Bio-ethanol production by Fermentation is suited to concentrated, high carbohydrate wastewaters and has potential in the fruit industry where sugar- rich wastewaters are generated in large volumes. On the other hand Combustion and Gasification are specifically applied to concentrated waste streams (containing <40% water) due to the energy expended in de-watering. They are most appropriate in the treatment of dewatered and solar-dried (or previously stockpiled) wastes. Unlike others, Microbial fuel cells (MFC's) are an emerging technology that can also operate with dilute waste streams while producing electricity directly. MFCs are suited to applications in remote/rural sites with no infrastructure. A single waste stream or technology may not be suitable for achieving efficient energy recovery. And thus, integration of technologies and/or waste streams may be required to release the maximum energy from wastewater. There are also frequently missed opportunities for reducing energy needs by the recovery of waste heat. The greatest potentials are realized when an industrial ecology approach is used to integrate process or waste heat from several industries, with pre-planning and the formation of industrial parks.

3.1 Need of Energy Generation from Waste

The net energy generated, wastewater treatment and water reclamation are the main costs and benefits considered in defining the feasibility of energy from wastewater project. However, additional benefits such as certified emission reductions (CERs), fertilizer production, or the production of other secondary products, could easily tip the balance of economic feasibility. For the implementation of energy from wastewater technologies, essential services like WWTP operation, schools, hospitals and the needs of communities that are not serviced by sewage and electrical infrastructure should preferentially be targeted. Several risks, barriers and drivers to developing an energy from wastewater project were and are identified. But that can be solved by research collaboration and information-sharing between research groups, government agencies and municipal practitioners. The use of wastewater as a renewable energy resource can improve energy security while greatly reducing the burden of wastewater disposal.

There is a growing need for alternative forms of energy as well as Processes that reduce energy use in the global community. The climate of the World has increased in temperature and is continuing to do so with every passing Day. Between 1970 and 2004, global green house gas emissions Increased 70%, with carbon dioxide being the greatest anthropologic greenhouse Gas. This steady increase in greenhouse gas levels, along with the Depletion of the world's fossil fuel resources, requires the research and utilization of technologies that can limit both the use of fossil fuels and the production of greenhouse gases. With that in mind generation of electricity in a cheap and efficient manner became the primary goal of every country. Each power generating company tries to develop the best suitable method to generate electricity and renewable have become the primary source of power generation with the rapid consumption of conventional fuel. Hydropower, large and small, remains by far the most important of the "renewable" for electrical power production worldwide, providing 19% of the planet's electricity. Thus, the adoption of appropriate wastewater treatment Processes can be an essential part of the reduction in greenhouse gases (GHG) by reducing intrinsic Energy needs, reducing the emission of gaseous pollutants and the direct separation of carbon Dioxide (CO2).

Energy use can account for as much as 10 percent of a local government's annual operating budget. A significant amount of this municipal energy use occurs at water and wastewater treatment facilities. With pumps, motors, and other equipment operating 24 hours a day, seven days a week, water and wastewater facilities can be among the largest consumers of energy in a community and thus among the largest contributors to the community's total GHG emissions. These economic and environmental costs can be reduced by improving the energy efficiency of water and wastewater facilities equipment and operations, by promoting the efficient use of water, and by capturing the energy in wastewater to generate electricity and heat. Improvements in energy efficiency allow the same work to be done with less energy. Improvements in water use efficiency reduce demand for water, which in turn reduces the amount of energy required to treat and distribute water.

4. OBJECTIVE

This paper is based on the need to explore the potential for energy from wastewaters that could contribute to the national energy demand. Thus, the adoption of appropriate wastewater treatment processes can be an essential part of the reduction in greenhouse gases (GHG) by reducing intrinsic energy needs, reducing the emission of gaseous pollutants and the direct sequestration of carbon dioxide (CO2).

The objectives of this paper are as follows:

- Present a review of established and emerging technologies for generating energy from wastewater.
- Identify obstacles and areas of concern (including technical, commercial, social, environmental and regulatory aspects). The various options for energy recovery from wastewater can be distinguished according to input streams, process intermediates and energy outputs as follows:

5. LITERATURE REVIEW

Howell Henrian, G. Bayona and B. Tabios, (2008) -This investigatory project entitled "Harvesting Electrical Energy from Cellulose Using Cow Manure Microorganisms as Biocatalysts in a Two-Chamber Microbial Fuel Cell" sought to find out if cow manure can be an alternative source of electricity and determine if cow manure could be an efficient biocatalyst in generating electricity from cellulose in a two-chamber microbial fuel cell constructed from inexpensive and local materials. Specifically, this study aimed to assess electricity generation from cellulose in an MFC with varying concentrations of cow manure; and verify if the concentration of cow manure directly affects the voltage generation in a MFC. Previous reviews looking at wastewater resource recovery provide very valuable insights into particular branches of this broad and complex research field. Outstanding examples include the reviews on biological recovery routes, energy and product recovery from sewage sludge, phosphorous recovery from domestic wastewater, platforms for energy and nutrient recovery from domestic wastewater, bioelectrochemical recovery nutrient recovery with microalgae-based treatment systems. Despite these valuable contributions, as yet there is no review available that provides a holistic overview of the field.

Hydropower Opportunities in the Water Industry" by Theophilus Gaius-obaseki- Discussed about sustainable and cost effective ways of producing energy to reduce its dependence on fossil fuel for energy generation, reduce the carbon emissions, ensure the security of its power supply and energy cost. Addressing the problem of energy sustainability in the water and wastewater industry thus requires a thorough review and research into technologies that are cost effective and sustainable for each location. The industry thus needs to harness renewable and non-polluting resources that are at its doorstep like micro- hydropower. Overview of hydropower application options is available to the water and wastewater treatment industry. With the help of hydropower theory, author explained about classification of hydropower, type of turbine selected for power generation in United Kingdom. From this paper, author concludes that hydropower is proven and generally predictable source of renewable energy and is one of the few that is not intermittent. Noise is one of the disadvantages and is minimized by adequate acoustic installation. Today WWTPs are usually the facilities with the highest energy demand in public ownership. Thus, renewable energy facilities are added in order to reduce the overall demand of energy supply taken from the power grid. Consequently also small hydropower plants are part of this strategy, using new identified site for small hydropower implementations. This paper gives an overview of the approaches so far, suitable technique as well as restrictions which have to be considered for an operation of small hydropower concepts for energy recovery and storage.

Micro Hydro Installation Analysis in a Wastewater Treatment Plant" by H. Beltran and team- Introduced the technical and economic viability of a new micro hydro-installation solution to reduce the power consumption of a medium sized wastewater treatment plant. Their work analyses the hydroelectric potential of the plant and summarizes the turbine generator design procedure performed to optimize the production. Water turbines are classified into two different groups: impulse turbine and reaction turbine. The first group, which mainly includes Pelton, Turgoand Crossflow, works by changing the velocity of water jet. The water is accelerated prior to enter the turbine using its own pressure but, once the water is flowing over the turbine runner blades the pressure is constant and all the work output is due to the change in kinetic energy of water. Conversely, reaction turbine such as Francis or Kaplan types base their functioning on the change of pressure experienced by the water as it moves through the turbine and gives up its energy. Impulse turbines are more frequently used for high head sites, while reaction turbines are usually used for low head sites. The analysis of the results shows that an acceptable power production can be obtained by introducing the proposed installation. Micro hydroelectric power is both an efficient and reliable form of clean source of renewable energy. It can be an excellent method of harvesting renewable energy from small rivers and streams. The choice of turbine depends mainly on the pressure head available and flow rate. Design considerations for micro hydroelectric power plants are flow duration curve, flow rate measurement, trash rack design, head measurement, turbine power, turbine speed and turbine selection. There are two basic modes of operation for hydro power turbines: Impulse and reaction. Impulse turbines are driven by a jet of water and they are suitable for high heads and low flow rates. Reaction turbines are filled with water and use both angular and linear momentum of the flowing water to run the rotor and they are used for medium and low heads and high flow rates. Micro hydropower installations are usually run-of- river systems, which do not require a dam and are installed on the water flow available on a year round basis.

U.S. Geological Survey, Wolff et al., 2004 -While desalination is a fairly insubstantial contribution to water supply nationally, it is a source being considered and, in a few places, used by communities around the country, tapping sources such as brackish water or seawater (Wolff et al., 2004). The extraction (or taking) of water from these different sources can require anywhere from modest to extreme amounts of energy. This section explores and evaluates the literature around the energy use of water extraction. Most papers and reports come from and are focused on California, which has been very engaged in the water- energy nexus and water and energy conservation (Gleick, 1994; CEC, 2005; Cooley et al., 2008; Cooley & Wilkinson, 2012; Bennett et al., 2010), but there have been other studies done in Texas, New York, Wisconsin and parts of the Intermountain West. According to U.S. Geological Survey (USGS) data, 22 billion gallons per day (BGD) of surface freshwater and 13 BGD of surface seawater are withdrawn in the U.S. (USGS, 2005; Smith, 2011). Typically, little to no energy is required to "make" surface freshwater into a supply. Most of the freshwater goes to agriculture and thermoelectric generation. While virtually all the seawater goes to thermoelectric generation. Most studies do not separate surface water extraction from conveyance, a topic we address in a separate section. It is to be noted, however, that the U.S. Environmental Protection Agency (EPA) regulates water intakes for thermoelectric cooling, which might also offer regulatory innovation to garner the multiple benefits of water, energy and wider environmental goals.

Wastewater treatment technologies: A preview Niraj S. Topare - Sewage/Wastewater is essentially the water supply of the community after it has been fouled by a variety of uses. From the standpoint of sources of generation, wastewater may be defined as a combination of the liquid (or water) carrying wastes removed from residences, institutions, commercial and industrial establishments, together with such groundwater, surface water and storm water as may be present. Generally, the wastewater discharged from domestic premises like residences, institutions and commercial establishments is termed as "Sewage/Community wastewater". It comprises of 99.9% water and 0.1% solids and is organic because it consists of carbon compounds like human waste, paper, vegetable matter etc. Besides community wastewater/sewage, there is industrial wastewater in the region. Many industrial wastes are also organic in composition and can be treated physic-chemically and/or by micro-organisms in the same way as sewage. Methods of wastewater treatment were first developed in response to the adverse conditions caused by the discharge of wastewater to the environment and the concern for public health. Further, as cities became larger; limited land was available for wastewater treatment and disposal, principally by irrigation. and intermittent filtration. Also, as populations grew, the quantity of wastewater generated rose rapidly and the deteriorating quality of this huge amount of wastewater exceeded the self-purification capacity of the streams and river bodies5,6. Therefore, other methods of treatment were developed to accelerate the forces of nature under controlled conditions in treatment facilities of comparatively smaller size. In general from about 1900 to the early 1970s, treatment objectives were concerned with:-

- The removal of suspended and floatable material from wastewater,
- The treatment of biodegradable organics (BOD removal) and
- The elimination of disease-causing pathogenic micro-organisms.

From the early 1970 to about 1990s, wastewater treatment objectives were based primarily on aesthetic and environmental concerns. The earlier objectives of reduction and removal of BOD, suspended solids, and pathogenic micro-organism continued, but at higher levels. Removal of nutrients such as nitrogen and phosphorus also began to be addressed, particularly in some of the streams and lakes. Major initiatives were taken around the globe, to achieve more effective and widespread treatment of wastewater to improve the quality of the surface waters.

6. BARRIERS AND RISKS

In order to determine why the above potentials are not being realized, an analysis was conducted on the barriers and risks associated with energy from wastewater in the South African context. The analysis was achieved through a thorough review of academic literature, through site visits to existing small-scale AD installations and through a stakeholder workshop run with industry and local government input. Detailed outputs of the review, as well as the full workshop report and details of the site visits can be found in WRC report 1732/1/09 Appendix. From an institutional perspective, it was observed that wastewater management in the urban context is the domain of civil engineers, and constitutionally, is a function of local government (which sometimes relies on the water boards to execute). Energy technology sits between mechanical, electrical and process engineers, and constitutionally, is a function of national government. It is very challenging to work across these disciplines that have different mandates and objectives. On the one hand, we have to enable various engineering disciplines to jointly design something that both treats wastewater to acceptable standard and generates energy cost effectively. Furthermore, we need to challenge the division of powers between spheres of government. **Technology and wastewater considerations:** The principal consideration which arose when exploring the barriers to energy from wastewater implementation, were the characteristics of the wastewater streams and the appropriate technologies. The wastewater issues were identified as: **Water content:** Depending on the water content, different technologies will be appropriate. For dilute wastewaters, de-watering may be impractical due to the energy cost associated with it. These wastewaters will be amenable to growing biomass. **Effluent composition:** Many industrial wastes may contain components that are inhibitory to microbial growth or recalcitrant to degradation and may therefore require prior separation or pre-treatment. Such extraction may also yield economically valuable by-products. **Volume and seasonality:** These are important factors to consider especially since most of the wastewaters suitable for energy from wastewater are from the agricultural sector. Scalability and reliability of new technologies (such as microbial fuel cells) is not proven Technology designs are not always suited to the local context of a developing country like South Africa, for example in terms of maintenance and operational requirements for distributed systems.

There are perceptions that energy from wastewater technologies are complex to build and implement. In addition, South Africa lacks the human resource capacity for maintenance. **Financial risks and barriers:** Number of financial risks and barriers were identified through the study. These may be grouped into those related to the technologies, and those relating to access to finance. Certain technologies are expensive both in terms of capital outlay and the skills/expertise required for maintenance particularly where both parts and expertise are required to be imported. In addition, newer technologies require significant capital expenditure to get them established. Small companies/ municipalities in particular may not have enough resources to pursue energy from wastewater, especially if long payback periods are encountered. However, with the increase in electricity tariffs as well as the energy shortage in South Africa, this will become more feasible. With respect to access to finance, energy from wastewater is often very low on budget allocations, and there is the perception that funding opportunities are poor. Although public private partnerships were identified to be necessary for the realization of opportunities, legislation surrounding the nature of such partnership contracts limits the interest from private sector parties in pursuing such projects. A further note was made on the expense and difficulty in accessing third party funding sources such as those from DME, Eskom Demand Side Management and the Clean Development Mechanism (CDM). Not having a feed-in and /or peak tariff in South Africa further limits the potential profitability. **Implementations barriers:** Then consideration was in the institutional and human resource constraints on projects. With respect to the former, it was identified that inefficiency in government departments was a significant barrier to realization of projects for example the time it takes to do an Environmental Impact Assessment is quite substantial, as is the time to obtain other licenses during start-up. As mentioned above, the need for going to tender and contractual considerations limit the interest in public private partnerships. A further consideration was that the primary focus of wastewater treatment is on effluent quality and not energy generation. With respect to human resource constraints, it is identified that there is a considerable lack of skills at all levels (from designing and implementation to operation) which limits the ability to build and operate energy from wastewater operations. The need to develop and retain skills in the sector was identified as a high priority throughout the study. **Need for decision support tools**: Harnessing the potential of energy from wastewater requires use of decision support frameworks and tools such as those which are offered in the context of a life cycle approach. Using such approaches, the costs (CAPEX, operations and maintenance) and inputs and outputs (chemicals, solid waste generation, water pollution, and gas pollutants) of the various technologies appropriate to a given wastewater can be assessed and compared. Other benefits such as secondary products can also be taken into consideration. The net benefit of the energy from wastewater process includes the replacement of conventionally derived energy (i.e. coal-powered electricity), the generation of energy or fuel products and useful by-products as well as the reduction of polluting wastes and water usage.

CONCLUSIONS

In developing countries like India, the problems associated with wastewater reuse arise from its lack of treatment. The challenge thus is to find such low-cost, low-tech, user friendly methods, which on one hand avoid threatening our substantial wastewater Dependent livelihoods and on the other hand protect degradation of our valuable natural Resources. The use of constructed wetlands is now being recognized as an efficient Technology for wastewater treatment. Compared to the conventional treatment systems, Constructed wetlands need lesser material and energy, are easily operated, have no Sludge disposal problems and can be maintained by untrained personnel. Further these Systems have lower construction, maintenance and operation costs as these are driven By natural energies of sun, wind, soil, microorganisms, plants and animals. Hence, for planned, strategic, safe and sustainable use of wastewaters there seems to be a need for policy decisions and coherent programs encompassing low-cost decentralized Waste water treatment technologies, bio-filters, efficient microbial strains, and organic / Inorganic amendments, appropriate crops/ cropping systems, cultivation of Remunerative non-edible crops and modern sewage water application methods.

The energy pattern analysis of a small-scale WWTP has been analyzed. The energy consumption is found to be about 1.046 kWh/m3 of wastewater treatment. This is significantly less than the values reported in the literature for large-scale WWTP. Further, previous studies have not included manual energy consumption in their analysis. It is found to be about 32 % of the total energy consumption. There is a lot of variation in the reported values in the literature. The plausible reason is that the energy intensity depends on the capacity of the treatment plant, extent of automation, and choice of treatment technology. This suggests that a number of such investigations are required for various categories of treatment plants so as to have a Holistic view on the wastewater treatment and energy nexus. Based on the evidence of this study, it can be stated that the decentralized treatment systems have less energy Intensity in comparison to a large- scale plant. Wastewater contains certain amount of energy that may be recovered. Extracting energy from wastewater cannot affect the overall energy consumption structure, since it only contributes a very small portion of the total energy consumption in 100% energy recovery efficiency. However, it is possible to make the wastewater treatment plant self-sustainable for energy demand by applying anaerobic wastewater

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