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Feasibility Study of Sewage Sludge for Thermochemical Conversion

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Abstract

Our current global population is 7.2 billion and growing. Earth's total resources are only good for 2 billion people at the current demand level. The way we are living, we are already using 2 to 3 times more of the Earth's natural resources than what is sustainable. Due to increasing population and all round development in the country, the per capita average annual freshwater availability has been reducing since 1951 from 5177 m3 to 1869 m^3, in 2001 and 1588 m^3, in 2010. Forecast revealed that the further reduce to 1341 m^3 in 2025 and 1140 m^3 in 2050. Currently, India has the capacity to treat approximately 37% of its wastewater, or 22,963 million liters per day (MLD), against a daily sewage generation of approximately 61,754 MLD according to the 2015 report of the Central Pollution Control Board. According to MNRE estimates, the Potential of Energy Recovery in India is about 1460 MW from MSW and 226 MW from sewage. The large volume of sewage offers tremendous potential for Water Authorities to recycle that sludge into energy within their cities and reduce their reliance on bulk conventional energy sources for their day today activities. The preset paper investigates the feasibility of using the sewage sludge as a potential bio residue.

Keywords: Sewage sludge, Energy recovery, proximate analysis, gasification

INTRODUCTION

According to geography and topology, India has enough water resources and yet due to phenomenal growth in population of the country necessitates ever-increasing water demand for irrigation, domestic and industrial needs. The increase in population has also resulted in increased domestic, agricultural and industrial activities, which have become the major cause for water pollution. The untreated sewage and scarcity of fresh potable water have resulted in health issues of both rural urban population of the nation.

Resource depletion is another crisis the mankind has to foresee for existence of lives in earth. When humans use any natural resource at a faster rate than the rate at which it replaced, then that resource is depleted. In this view, resources like coal, oil, and gas are depleting faster and become not sustainable and non-renewable. The above rule is also have no exemption for renewable resources like soil, fish, water, plastics, etc.

OIL

Oil, the primary fuel is the source of all 33% of world's energy use. About 66% of the world's oil use is for transportation. According to the theory of peak Oil supply, the oil demand will drop by 3% every year after the world's peak oil supply of 105 million barrels per day in 2025 and the oil supply will last for about 35 years maximum. Most of the countries planned to ban petrol and diesel vehicles by 2030. Hence, efforts made to develop cheaper and more sustainable energy to replace oil and fossil fuel.

WATER

Our earth's 70% surface is of water and yet only less than 1% of it is fresh which caters the entire world's demand for water. The depletion of natural resource water seems to be more serious than the oil depletion. Since the fresh water, demand could not be fulfilled by any other alternatives as in the case of fossil fuels, nation's water management is to be given top priority. The India's economic growth in parallel with growth of industrial sector accounts for 20% fresh water usage. In addition, the population growth demands 70% fresh water for agricultural activities and 10% to satisfy the domestic needs. The situation of water scarcity will become worse by the year 2025 that the per capita fresh water availability is likely to drop to below 1,000 cubic meters.

The wastewater generated by ever-increasing population and industrialization has been rising to a very alarming state. In addition, the situation is becoming worse due to continuous decrease of freshwater resources like rivers, wells, lakes and groundwater. The rising levels of wastewater as the consequence of all the above leads to adverse effects on river and marine life, drinking water scarcity and increased land pollution. The sewage sludge is the residue obtained from the waste water treatment system with high concentration of solid particles

Hence, a proper technological solution is the need of the hour to dispose the sewage sludge. If not, the liquid waste and the solid waste disposal become more cumbersome. The Fig.1 represents various technological routes available to dispose the sewage sludge and produce useful form of energy.

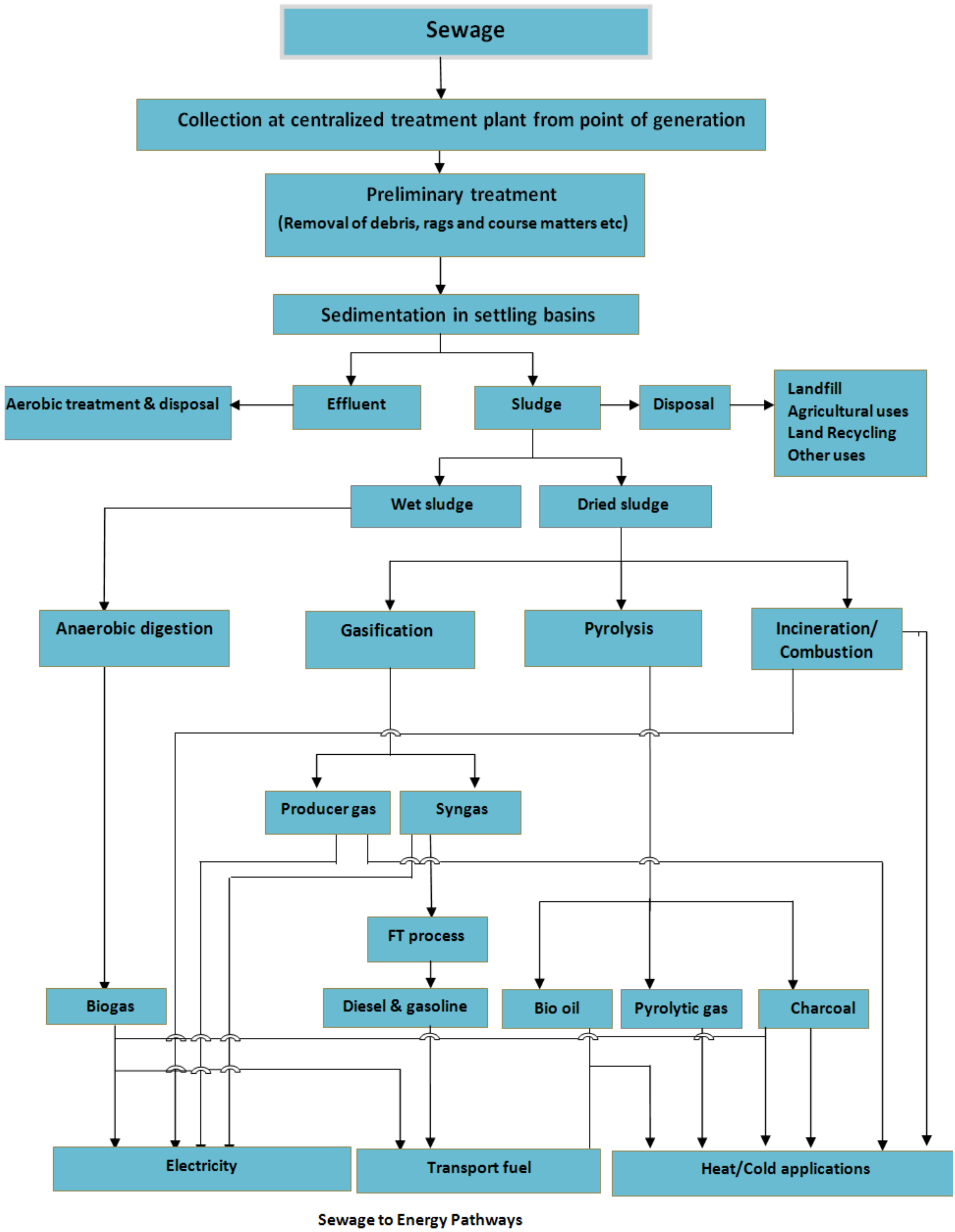

Figure 1. Technological Routes of Energy Generation from Sewage [Source: EIA]

A great deal of concern framed to proper disposal of these solids to protect the environment. Failure to do this may result in a mere shifting of the original pollutants in the waste stream to the final disposal site where they may again become free to contaminate the environment. A more reasonable approach to ultimate solids disposal is to view the sludge as a resource that can be recycled or reused.

There is more energy in wastewater than is needed for treatment – about five times more. The wastes generated find their way into land and water bodies without proper treatment, causing severe water and air pollution. Waste to energy generates clean, reliable energy from a renewable fuel source, thus reducing dependence on fossil fuels, the combustion of which is a major contributor to GHG emissions.

LITRATURE REVIEW

Raveendran et. Al., (1995) have reported the compositions of various biomasses that are commonly available. A complete analysis of ash has also become as an important catalyze the decomposition.

Williams and Besler (1993) have reported that the combustible matter consists of hemicellulose, cellulose and lignin. During their decomposition, product is char, known as fixed carbon.

BIOMASS – A RENEWABLE ENERGY SOURCE:

Biomass is something simple as wood has been a renewable energy source more than a millennium ranks fourth and is providing 14% of the world's and 35% of the developing nation's energy needs. Biomass is a co2 neutral fuel emits co2 equal to an amount that it absorbs during its growth. Biomass in waste to energy plants not only provides heat and electricity but also cut down transportation, pollution and amount of trash placed in landfills.

Biomass can used in the production of methane, ethanol and biodiesel. Most of the biomass fuels have low nitrogen and Sulphur, which it leads to low NOX and SOX emission problems. The problems of using biomass as a fuel are to handle its ash content.

The general components found in biomass are carbon, hydrogen, oxygen, nitrogen, Sulphur, chlorine, water and oxides of silicon, sodium, potassium, aluminum, iron that are grouped as moisture, combustible matter and ash. These are available in varied quantities depending upon the type of biomass.

The proximate analysis provides percentage composition of moisture, volatile matter, fixed carbon and ash. The estimated quantities of these constituents from weight loss obtained at various temperature levels when the biomass is heated. The weight loss obtained, between room temperature and 120ºC refers to moisture content, between 200 to 450ºC as volatile matter, between 450 to 650ºC as fixed carbon and the rest as ash.

Their chemical compositions are necessary for arriving at a mechanism of gasification. An insight into the mechanism would provide operating conditions required for maximizing the specific calorific value of the product. Hence, the chemical analysis of each of these groups becomes important. Ultimate analysis of biomass would yield the compositions of various constituents in the combustible matter.

IMPORTANCE OF EACH COMPONENT OF BIOMASS

Moisture: The biomass with low moisture is preferred since it burns readily and provides much useful heat. On the other hand, extremely low moisture can cause fouling problems in the combustion equipment and even explosion hazard.

Ash: The ash is the non-combustible content that contributes to low combustion efficiency and slagging and fouling problems. Silica, potassium and chlorine can cause problems of fouling even at low temperature.

Volatiles: The percent volatiles refers to fraction of fuel that readily vaporize when heated to a high temperature. Biomass with high percent volatiles tend to vaporize before combustion and with low percent volatiles burn as glowing char.

Carbon and Hydrogen: The percentage of carbon and hydrogen in any biomass would be around 45% and 6% respectively. A higher percentage contributes to higher the heating value of biomass.

Nitrogen: The percentage of nitrogen varies around 0.2% and certain biomass it exceeds 1%, which is responsible for NOX emissions.

Sulphur: Sulphur percentage in biomass varies 0.2% to 0.7% and contributes to NOX emissions.

The expressions for finding the HHV of biomass with respect to its composition are,

HHV = 0.196(FC) + 14.119, where HHV is higher heating value in MJ/kg of fuel.

HHV = 33.5(CC) + 142.3(HC) – 15.4(OC) – 14.5(NC) (0.01), where (CC) was carbon content (weight %), (HC), hydrogen content (weight %), (OC) oxygen content (weight %) and (NC), nitrogen content (weight %)

Table 1. Proximate Analysis of sewage sludge

S.N	Reference Source	Proximate Analysis			
		Moisture	Volatile matter	Ash	Fixed carbon
1	Inguanzo M et.al	5.2	60.7	30	9.8
2	Shen L et.al	5	72.5	16	11.5
3	Dogru M et.al	11.8	60.6	27	12.8
4	Otero M et.al	4.3	59.3	31	9.7
5	Otero M et.al	3.9	58.5	31	10.7
6	Otero M et.al	8.5	50.8	43	5.9
7	Mene´ndez JA et.al	78.1	60.7	37	2.4
8	Folgueras MB et.al		55.9	40	3.8
9	Folgueras MB et.al		49.6	44	6.4
10	Folgueras MB et.al		71	21	7.8
11	Presenet Investigation	3.7	44.2	49.2	2.9

Table 2. Ultimate Analysis of sewage sludge

S.N	Reference source	Ultimate analysis (weight %)							
		Carbon (C)	Hydrogen(H)	Nitrogen	Sulphur	Oxygen (O)	C/H	C/O	Heating value MJ/kg
1	1	35.7	5.2	3.5	0.7	25.4	6.8	1.4	16.6
2	2	45..9	6.3	5.1	0.6	26.9	7.3	1.7	20.9
3	3	39.5	6. 2	3.9	1.5	25.5	6.4	1.6	17.1
4	4	38.1	5.2	4.5	0.9	20.3	7.3	1.9	16.8
5	4	38.3	5.1	3.7	0.7	21.4	7.5	1.8	16.6
6	4	30.1	4.1	3.8	0.9	17.8	7.3	1.7	13.3
7	5	37.3	5.8	5.5	0.8	13.7	6.4	2.7	16.6
8	6	29	4.4	3.2	0.5	22.6	6.6	1.3	12.8
9	6	25.5	3.7	2.4	0.6	23.8	6.9	1.1	12.6
10	6	40	6	7	0.7	25.1	6.7	1.6	18.4
11		34.2	5.8	3.9	0.5	24.2	5.9	1.4	15.8

CHARACTERIZATION OF SEWAGE SLUDGE

The physico-chemical characterization of sewage sludge varies widely depending upon the region, method and type of spreading material used and collection. However, by judicial analysis of the results, several investigators have reported the analytical results.

The sewage sludge normally contains moisture, volatile matter, fixed carbon and ash. Thermal degradation of sludge results in removal of moisture between room temperature to 120ºC, decomposition of volatile matter between 200 to 420ºC and gasification of fixed carbon beyond 420ºC. Fixed carbon generated from volatile matter during its decomposition.

Table 2.1 compares the proximate composition of Sewage sludge reported in the literature as well as that of present investigations, while Table 2.2 those of ultimate analysis.

SAMPLE PREPARATION

Around 200 kg of sewage sludge from a nearby wastewater treatment plant collected and dried in the shadow to achieve a constant weight. The dried sludge was stored in double polythene bag and sealed to prevent the moisture entering the system. Several samples analyzed to get an average composition of the sludge. A table 2.4 gives the results.

Empirical formula

Based on the presence of most significant elements, (C, H, O and N) it is common to propose empirical formula for combustible matter. Thus, Davalos, et.al, (2002) have arrived as $CH_{2.04}O_{0.52}N_{0.09}$

As is evident from the compositions reported by several investigators, the composition varies from region to region. However, it is customary to arrive at an empirical formula based on analysis obtained for the sample taken for investigation. Similarly, the following empirical formula comprising C, H and O arrived at for the present study, on moisture and ash free basis: $\mathbf{C_{2.85}H_{5.8}O_{1.51}}$**.**

CONCLUSIONS

From the literature and the present investigation, it found that Sewage sludge appears to have combustible matters in quality and quantity favoring its choice as sustainable bio residual energy source. Among the various disposal methods, gasification is user friendly and economically viable. $\mathbf{C_{2.85}H_{5.8}O_{1.51}}$ is empirical chemical formula for combustible matter. The major components of the combustible matters are hemicellulose, cellulose and lignin.

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