RECENT PROGRESS IN WASTE MANAGEMENT SYSTEM OF LUCKNOW CITY: A MINOR REVIEW

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ABSTRACT

Indian cities are facing a major challenge of solid waste management (SWM) which has led to the increase in the pile of garbage in and around the city. This review is done to understand the current scenario of waste management in Lucknow city and propose a more efficient process that can enhance the existing waste management technique. Based on review we have suggested stabilization by microbial fuel cells (MFCs), biological hydrogen production, decomposition by microbial electrolysis cells (MECs)and stabilization by leachate recirculation inbioreactors for different categories of waste generated in the city.

Keywords:Bioreactor, Garbage,Microbial fuel Cell, Solid Waste Management, Stabilization.

I.INTRODUCTION

India is the second largest country in terms of population with over 1.21 billion people, it is approximately 18% of world's population. Hence the demand of resources is very high which is directly related to the generation of municipal solid waste (MSW). Urbanization has also lead to the significant increase in generation of MSW in the country. As per census of India 2011, urban population of the country is 377 million[1]. As a result of this, resources are being used profusely to meet their demands and standard of living causing increase in waste generation and pollution of environment due to the insufficient technique and knowledge of managing the waste. Thus public health problems are a major threat to society.

Lucknow the capital city of Uttar Pradesh is having a population of 2,902,900 (year 2011). Due to the development of this city people from entire state have migrated here in search of employment. The average increase in population of the city from 1971 to 2011 is 3.22% per year[2]and this has caused the expansion of city from 600 sq. km to 980 sq. km within a span of 10 years since 1999[3].Lucknow has been divided into 6 zones consisting 110 administrative wards[4]. The governing authority for the management of MSW in the city is Lucknow Municipal Cooperation (LMC). The total waste generated was 1365tpd. The average rate of MSW generation is 0.48 kg/capita/day[5]. Sources of solid waste generation are Industrial, Commercial, Residential, hospital (bio-medical waste) & public. The constituents of solid waste consist of paper, leather, synthetic material, glass, metals, rubber, compostable or biodegradable and inert materials. Fig.1 shows the composition of waste produced in Lucknow. The quantity of these constituents varies from place to place depending on the source.

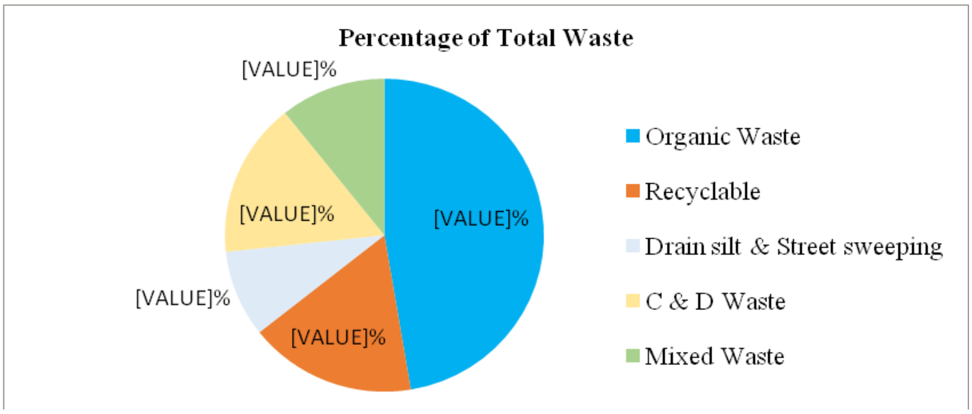

Fig. 1. Distribution of waste composition in Lucknow city (Lucknow Municipal Corporation (LMC), 2016)

1.1. MSW Generation in Lucknow City

With the increase in population & expansion of the city the generation of solid waste has increased at an alarming rate. Fig. 2 shows the rate of waste generation from 2006 to 2014 which is a topic of concern as the waste management system of the city is still not developed.

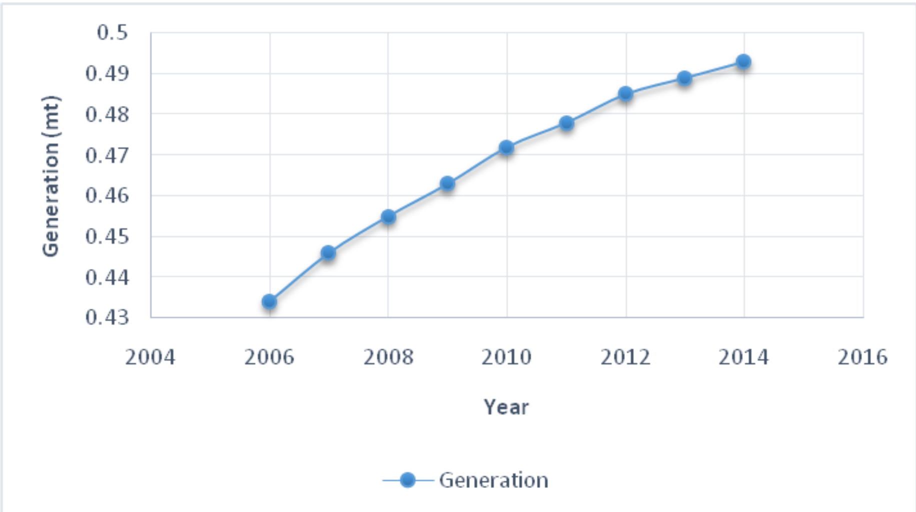

Fig. 2.MSW (in metric tonnes) showing yearly generation for 2006-2014 data(LMC 2016)

II.CURRENT SCENARIO

Primary collection of waste is done through rickshaw trolleys, hand carts & other carrier vehicles. The MSW collection efficiency ofLucknow is 83% as shown in fig. 3.

2.1.Current & Completed Projects

2.1.1.Ecogreen

Leading waste management company in India. In March 2017, LMC handed over city's waste management plant to ecogreen. The project includes transforming dumps into transfer stations/mini transfer stations, manual carts into electric carts, power generation by using Circulating Fluidized Bed Combustion (CFBC).

2.1.2.Biomedical waste treatment plant

LMC has setup a general biomedical waste treatment plant in Mohanlalganj at Raibareli road under PPP (Public Private Partnership) mode. The gross capacity of the incinerator used is 250 kg per hour[4].

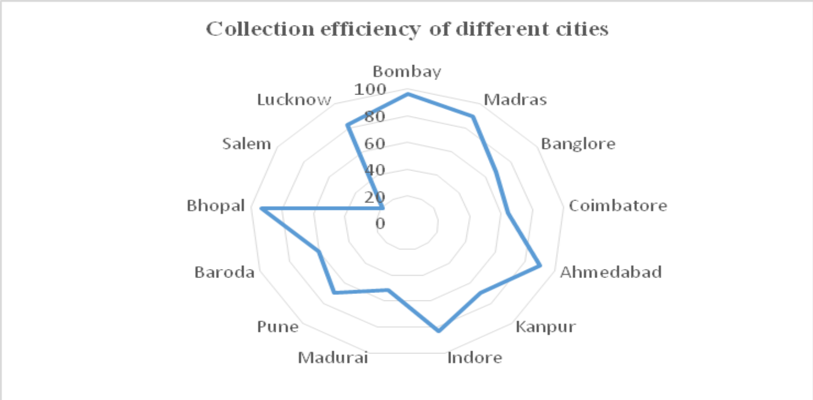

Fig. 3. Collection efficiency of different cities reflecting the efficiency of Lucknow as 83% as well as of other major cities of India (Nandan et al., 2017[4])

III.RECENT WASTE TO ENERGY (WTE) TECHNOLOGIES

3.1.Microbial Fuel Cells (MFCs)

Microbial fuel cells (MFCs) are bio-electrochemical tools generated from organic phenomenon from an extensive domain of substrates by using bio-electrogenic microorganisms, to come up with energy. The MFC devices use electrochemically active microorganisms (EAMs) to generate electricity. It has application of both aerobic and anaerobic treatments using bacteria as a catalyst which is an encouraging technique for generation of bio-hydrogen fabrication. A range of organic substrates like domestic waste, animal waste and wasted sludge will be utilized as a rawstock. Represented in fig.4.

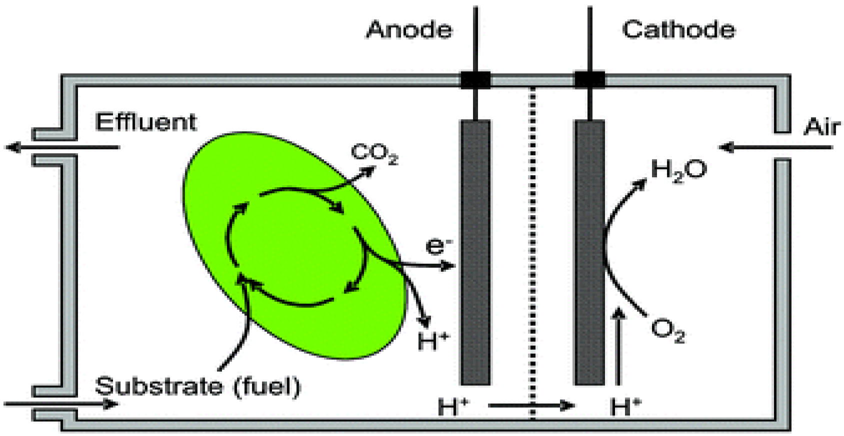

Fig.4. Schematic representation of MFC showing transfer of electrons from bacteria to anode, then transferred to cathode via electric system (Royal Society of Chemistry)

3.1.1.Two types of MFCs

Mediated

Most microbial cells are electrochemically inactive. Electron transfer from microbial cells to the electrode is carried out by mediators such as methyl viologen, humic acid, thionine, ethyl blue and neutral red. Most of the available mediators are expensive and toxic.

Mediator-free

It uses electrochemically active bacteria to transfer electron to the electrode. Examples of these bacteria are *Aeromonashydrophilao*, *Shewanellaputrefaciens*.Johnson Ebou, 2015[6]reported maximum power density of 588.229mW/m^2 using a single chambered MFC from organic waste. M.A. Moqsud2014[7]uses compost for bioelectricity generation by using rice plants. The peak voltage generated was 700 mV. MFCs has widespread applications such as wastewater treatment, biochemical oxygen demand (BOD) sensors, bioremediation, hydrogen production and electricity generationare shown in fig 5.

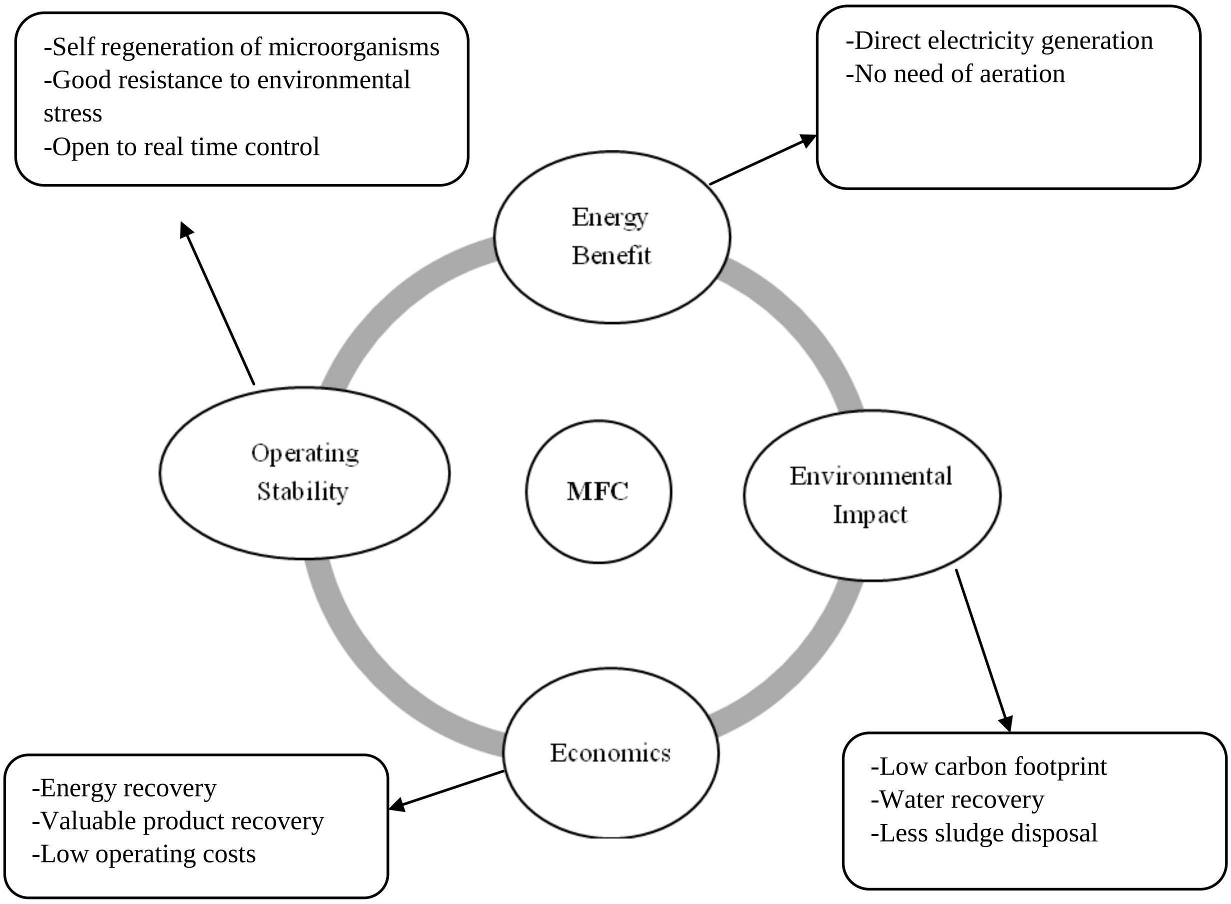

Fig. 5.MFC cycle showing inter-relation of energy associated with the electricity generation system (Beyene, 2017)

3.2.Biological Hydrogen (H_2)Production

Hydrogen is readily available on earth and exists innon-elemental form. Majorsources for the industrial production of H_2 molecule are fossil fuels through steam reforming of natural gas, water electrolysis process, and as a by-product from some industrial processes. The total hydrogen production is more than one billion m^3/day from different sources such as natural gas (48%), oil (30%), coal (18%), and water electrolysis (4%)[8]. H_2might be ‘‘fuel of the future’’ and it can replace non-renewable fuels by renewable bio-hydrogen energy. Production of hydrogen from waste via biological method has prominent demand due to its sustainability and renewable nature. Biologically synthesized H_2 is worthwhile due to low energy requirements and expenditure, high energy generation of 142 kJ/g (2.75 times a hydrocarbon fuel)[9], less greenhouse gas(GHG) and high calorific value. The two basic H_2 production methods are named as physio-chemical and biological methods. Physio-chemical methods are energy exhaustive and generate greenhouse gasesinfluencing global warming while the latter one is environmentally sustainable reduces energy depletionand have a low-cost substrate.

3.3.Microbial ElectrolysisCells(MECs)

MEC is a smart green technology to overcome the global warming and energy demand, which is characterised by electrochemically energetic bacteria to convert MSW into H_2 and chemicals likemethane (CH_4),hydrogen peroxide, ethanol,acetate, and formic acid[10] This method similar to MFCs except the cathode of MECs are not open to air. Currently MEC has gained acute attentions a capable source for obtaining clean and legitimate energy from wastes. Furthermore, MEC has higher hydrogen recovery andsubstrate assortmentthan to dark photo fermentation and MFC[11].MECs could change any biodegradable waste into hydrogen, biofuels and other valuable products. Electrons are transferred to the cathode to reduce the protons for hydrogen production. This approach brings a way for comprehending hydrogen production to pass through the endothermic barrier forced by the microbial fermentation products and the potential required is comparatively low related to the theoretically posed voltage. MEC gains above 90% of hydrogen revival against 33% with the fermentation process. MEC showed an ability to change a variability of soluble organic matter to H_2 or CH_4 with immediate wastewater treatment.According[12],the MEC stage holds excessive potentials for future waste biorefinery. MECs mutate biodegradable waste into valuable energy and bioproducts, making the system energy-positive and carbon-less. The yield and rate of MECs are increased when integrated with the fermentation process. Exploitation of reactor configurationsincorporating new materialscosts are often reduced and system efficiency getenhanced.

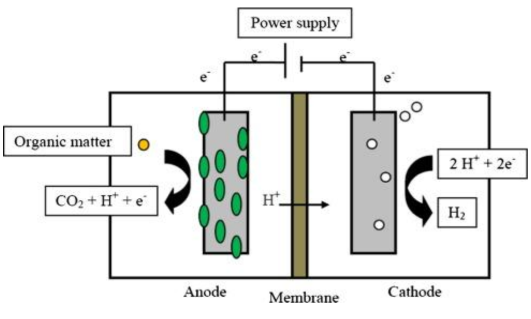

Fig. 6. Microbial Electrolysis Cell representing the mechanism of charge to energy transfer

(A Kadier, 2015)

3.4.Leachate Recirculation in Bioreactor

Landfill is the most common practice adopted in almost every country of the world for decomposition of waste. In Lucknow city, there are three active landfill sites that are loaded regularly by MSW. It has occupied vast area of land and formed a pile of garbage which is left over without any effective treatment. Problems associated with these landfills are:

- Formation of CH_4 which is a GHG having global warming potential(GWP) of 28 to 36 over 100 years is released into atmosphere increasing the GHGs concentration.[13]
- Leachate percolates into the land contaminating the groundwater.
- Decomposition of waste is slow hence more land is required for dumping waste.

Bioreactor landfill is a solution for the above mentioned problems. They speed up the rate of decomposition thus resulting in the decrease in volume of biodegradable waste components. It can be a very effective tool in dealing problems of increasing solid waste generation that would require extra land to be disposed. Bioreactors can be aerobic, anaerobic or hybrid depending upon the conditions provided. Fig 7 and 8 shows a flow chart of the process involved in aerobic and anaerobic decomposition of the waste respectively[14]. Leachate recirculation is done in both the cases to optimize the treatment process, it helps in improving the quality of leachate, increasing the rate of waste stabilization & better production of gasses[15]. Methane is generated during anaerobic decomposition of the waste which is captured and utilized as a source of energy.

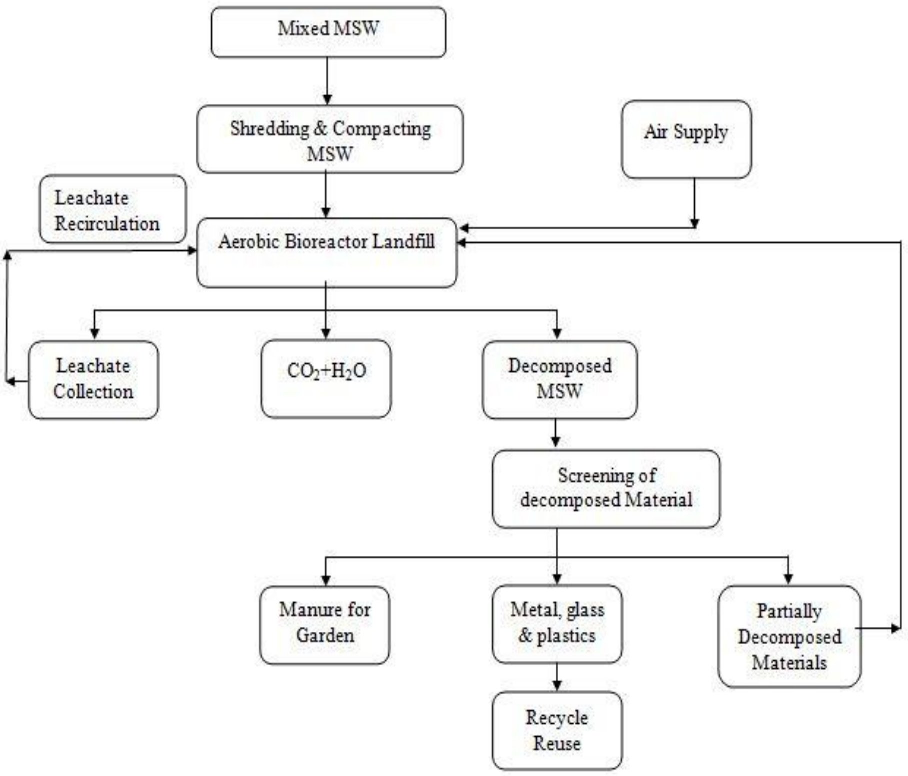

Fig.7. Various processes associated inaerobic decomposition of MSW (A. Anto, 2016 [14])

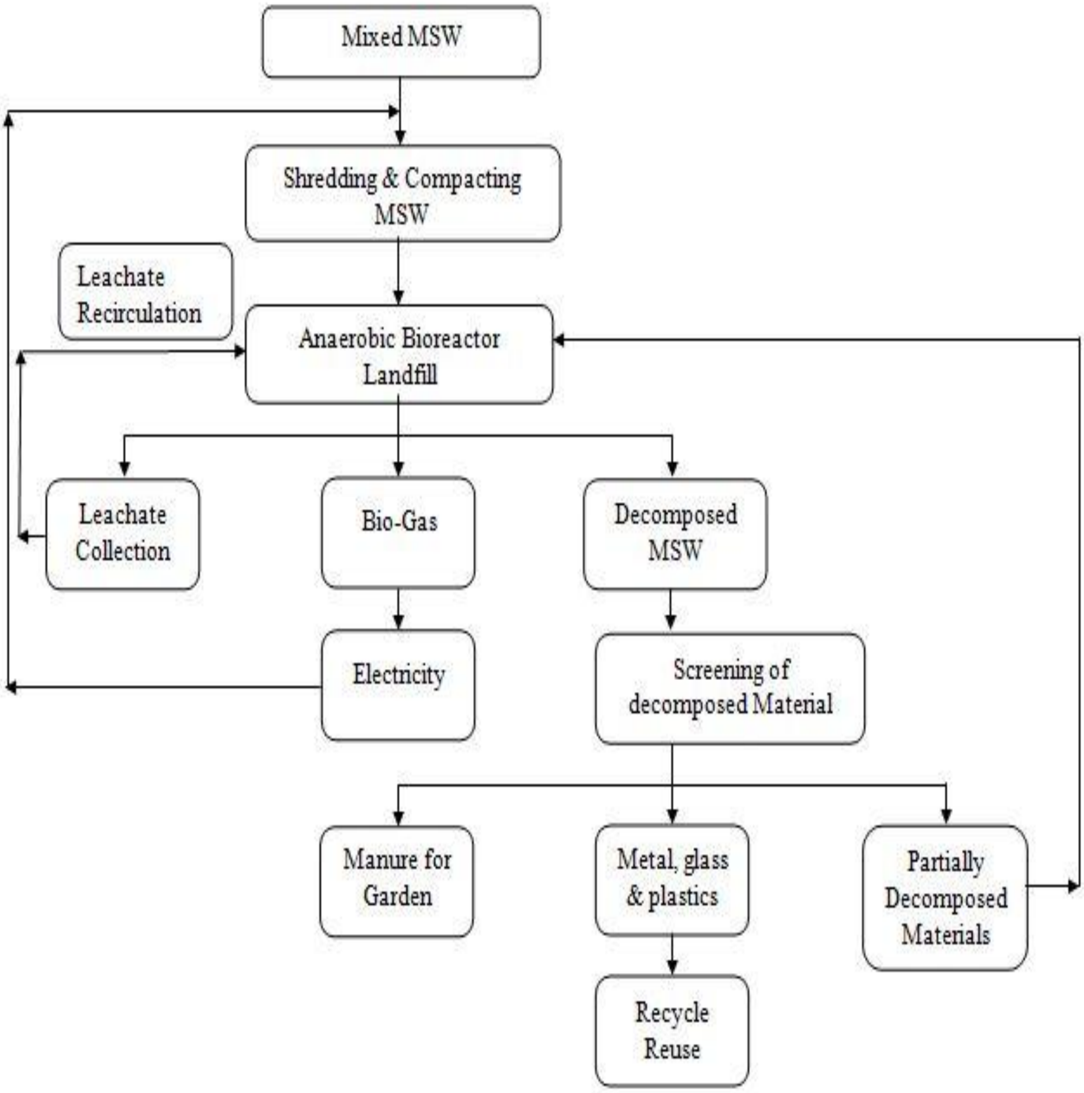

Fig. 8. Various processes associated inanaerobic decomposition of MSW (A. Ando, 2016 [14])

A study [16] conducted found that in an anaerobic bioreactor, degradation at optimum pH range 6.5-7.5 have resulted in the increase of methane gas and reduction in carbon dioxide, volatile fatty acid (VFA) and hydrogen. 92% of Chemical Oxygen Demand (COD)reduction was observed due to the formation of methane gas and rapid rate of decomposition. VFA is a major &importantcompound formed in anaerobic decomposition and it was observed that initial concentration of VFA in leachate was 4246 mg/l and it was reduced to 686mg/l as a result of simple organic compounds breakdown[16]. Leachate recirculation has proved to be an effective process in decreasing the heavy metalconcentration due to settlement & absorption of metals on the waste[17]. Heavy metals that reduced are Cd-99%, Fe-92% & Cr-89% [16]. Bioreactor is capable of providing early and acceptable results as compared to traditional landfill technique.

2. Comparison of various WtE Technologies

Based on the study we have compared above discussed technologies, its primary products and its applications to obtain energy from waste.

TABLE 1. Comparison of WtE Technologies **(**[6]**,** [8]**,** [10]**,** [11]**,** [14])

S.No.	WtE technologies	Primary products	Application
1	Microbial Fuel Cell	H_2	Bioelectricity, Bio-hydrogen production, Waste-water treatment
2	Biological hydrogen production	H_2	Bioelectricity
3	Microbial electrolysis cell	H_2, CH_4, acetate, hydrogen peroxide, and formic acid	Used for generation of electricity and immediate wastewater treatment
4	Aerobic Bioreactor	CO_2, H_2O	Energy source for micro-organisms (speeds up decomposition)
5	Anaerobic Bioreactor	CH_4	Bio gas (generation of electricity)

V.RECOMMENDATIONS

After studying about the current SWM of the city following recommendations are given to enhance the process:

- The first step for the effective municipal solid waste management (MSWM) is segregation of waste which is to be done at the point of generation irrespective of the waste collection method adopted i.e. door-to-door collection or community bins. Adopting it will decrease the load on treatment units and increase its efficiency.
- Urbanization has caused an increase in the generation of waste in the city but the collection system is still not developed. Piles of garbage beside the roads& barren lands can be easily seen, due to the lack of dustbins available for disposing waste by the public. Need for dustbins and their frequent cleaning is required so that the waste of the city can reach the treatment sites.
- At present the waste collected from the city is disposed off recklessly at the dumping sites which is growing in size day by day and also polluting the ground water due to leaching. Use of modern technologies like bioreactor will not only aid in rapid decomposition of the waste but also the byproducts formed can be used as an energy source.
- Spreading awareness and making people understand the importance of 3R's i.e Reduce, Reuse and Recycle will surely help in proper management of waste.

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VI.CONCLUSION

Municipal solid waste is collected from households, commerce, and organizationsincluding packaging, foodwaste, paper waste, and both sturdy and nonsturdymaterials.Its constituents vary substantially based on their sources. Waste to energy conversion is an ecological and economical phenomenon which is rapidly growing with waste disposal,energy demandand environmental monitoring. The commonly used thermal technologies are incineration, gasification and pyrolysis, Biochemical conversion (fermentation and anaerobic digestion) and bioreactor in landfills are usually opted technologies.These methods emit gaseous pollutants to the atmosphere like oxides of carbon (CO_x), sulfur (SO_x) and nitrogen (NO_x), hydrogen chloride (HCl), hydrogen sulfide (H_2S),polyaromatic hydrocarbons (PAH), heavy metals and ammonia (NH_3) and reduces toxicity. Biochemical conversion methods use bacteria, enzymes and microorganisms to breakdown biomass whichhas advantages such as simplicity, environmentfriendly and low cost. Anaerobic digestion through bioreactors and ethanol fermentation are biochemical conversions that generate biogas and bioethanol respectively. However, they have disadvantages of a long treatment time and organic and trace gas emission to the atmosphere. Recently microbial fuel cells (MFCs), microbial electrolysis cells (MECs) and bioreactors are thepromising ecologicalWtEconversion technologies which change MSW into electricity, hydrogen, and chemicals. Since biologically synthesized Hydrogen has no GHGand has superior energy yield than carbon source fuel.

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