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Utilization of Kitchen Waste-to-Energy: A Conceptual Note

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Abstract

India's rapid economic growth and change in lifestyle have increased the level of municipal solid waste (MSW) generation in the country. The metropolitan cities in India are contributing a major portion (in lakhs metric tons per day) of MSW. It is only due to the lack of the availability of poor infrastructure to handle MSW in the country. Also the people's ignorance towards handling this waste is also a big challenge to handle this problem. The implementations of low-cost and user-friendly methods are the primary requirements to handle this kind of situation. It can be easily predicted that kitchen waste (KW) is contributing a major portion in MSW, and its ignorance towards disposing off is increasing the environmental pollution day-by-day. It is the motivation of the present work, and a comprehensive review of KW generation in India is done. A study based on prefeasibility to handle KW is also done, and based on that, a feasible solution is provided to handle KW on waste to energy for sustainable new business investment opportunities in the present work. The proposed plan will not only reduce the level of MSW in the country but will also create a lot of opportunities for employment in the country for a future generation. The present work concludes that installation of this kind of pilot project in the metropolitan cities is the present need for the development of the recycling industry sector using KW as a raw material in India.

Keywords: *Kitchen waste; Municipal solid waste; Waste to energy; Waste management.*

1. Introduction

The continuous rapid growth in population and its shift towards urbanization is increasing the quantity as well as the quality of wastes [1]. In India, the rapid industrialization and changing lifestyle have led to the continuous migration of people from the villages to the cities [2]. From 2001 to 2011, the level of urbanization has increased from 27.81% to 31.16%, and 2,774 number of urban units have been newly established [3]. Urbanization and change in the lifestyle of people are putting more burdens on the energy demand [4-7] and increased fuel costs [8], and this is the time to look for the energy-saving opportunities [9-11]. Besides, coal reserves and fossil fuel sources are depleting day by day [12,13]. Usage of conventional fuels and generating a high amount of greenhouse gases are causing serious harms to the environment and human health [14-21]. Temperature of the earth is growing simultaneously to a hazardous level [22]. Shifting to renewable and recycling technologies will always be an incredible idea [23]. It is also estimated that the world population may dome its curve from 7.7 billion to 8 billion by 2030 [24]. If this scenario comes into existence, the environment would be in a serious trap in keeping the energy demand aside.

Shifting the focus to the land pollution, lack of infrastructure, and serious module in dumping of daily wastes, the earth is contaminating to its bottom level. Many researchers have identified different kinds of wastes generated globally, and the Municipal Solid Waste (MSW) is the present serious problem. This results in the generation of thousands of tons of MSW in the daily life, which causes health hazards in different areas of the nation due to the non-availability of the infrastructure to handle this situation. This negligence in treating the degradable waste leads to the generation of an unpleasant atmosphere with ugly odor. It is also considered to be an important factor responsible for innumerable ailments [25]. If the world produces 1.3–1.9 billion tons of food waste every year, 30% of the waste is remained uncollected by the waste management systems of the respective countries

[26-29]. India alone is contributing 21 million tons of wheat waste due to the lack of storage infrastructure and supply chain [30]. An average waste generation in India was found to be 188,500 tons per day. Approximately 3.49 billion tons of CO_2 is being generated due to the disposable kitchen waste [31]. Also the continuous population growth rate and varying waste characterization in the entire world is going to become a serious issue towards MSW. According to the planning commission report, by 2031, people residing in the urban areas will generate 165 million tons of waste annually, and it will reach 436 million tons by 2050. The various types of MSW have been shown in Figure 1. MSW in India consists of 40-60% compostable, 30-50% inert waste, and 10-30% recyclable [32].

In order to resolve this issue, several initiatives have been started by the private as well as the government organizations in different countries to utilize this waste for its viable use. The recycling and reuse options are playing an important role in this direction. However, pollution-free drinking water and air along with a proper sanitation are the main pillars for the sustainable development of any nation. Still the generation rate of MSW is so higher that it is going to become a difficult task to handle it. It is much necessary to promote the cleanliness and hygienic techniques to stop open defecation in Indian villages. As India is an agriculture-based country, most of the daily solid waste in the village areas is very much suitable to decompose and use it as a useful manure. Organic composition of solid waste in rural India is comparatively found to be higher than any other country [33]. The composition of MSW in India is briefly categorized in Table 1, and similarly depicted in the Figure 1. At the present time, each organization is leading to a corporate social responsibility. Thus they are mainly concentrating on recycling, waste elimination, and implementation of green practices to reduce the level of MSW. There is an important role of the various activities involved in the MSW management, although there is a lack of segregation of MSW in the urban areas in the entire world. In this context, there are two approaches to compensate for the energy demand and environmental crisis: one, to search for sustainable renewable resources; and second, to process the municipal waste into energy.

Table 1. Composition of MSW in India [34].

S.No	Category	Composition
1	Organic bio-degradable (Wet)	Garden waste, plants, agriculture waste, food waste, paper, etc.
2	Dry-incinerable waste	Paper, clothes, wood, sanitary products, cotton pads, etc.
3	Recyclable and non-biodegradable	Glass, plastics, metals, leather, etc.
4	Recyclable and inorganic	Ceramic, debris, etc.

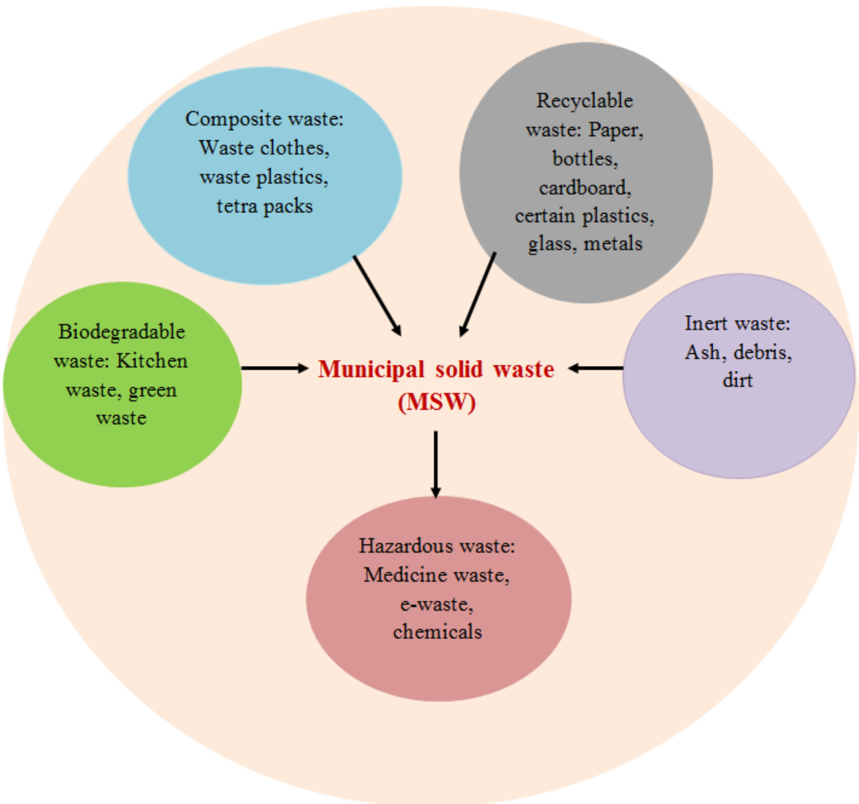

Figure 1. Msw classification

Amongst all of these wastes, the kitchen waste (KW) is termed as the left-over organic matter from various hotels, household, and restaurants, and is incinerated. According to an estimate, the contribution of this waste is to the greenhouse gas (GHG) emissions by accumulating approximately 3.3 billion tons of CO_2 per year [29]. It is a highly energetic biomass, and a higher population density is responsible for tons of KW production daily. Food waste mainly consists of protein and carbohydrates, which are more eligible for fermentation than any other waste [35]. The main problem regarding the processing of KW is a high content of moisture in it. This is the main reason for its higher recycling and disposal process cost. However, the bulking agents can play an important role in biodrying and odor emissions produced by KW [36], although it can be used for the fertilizer and biofuel production after processing. At the present time, each organization is leading to a corporate social responsibility. Thus they are mainly concentrating on the recycling, waste elimination, and implementation of green practices to reduce the level of environmental pollution.

Table 2. Annual KW generated in different countries.

Country	Annual KW	Reference
South Africa	9 million tons	[37]
European countries	89 million tons	[37]
China	30 million tons	[38]
Iran	25 million tons	[39]
Japan	10.14 million tons	[40]
USA	61 million tons	[41,42]

2. KW potential as a source of sustainable energy generation

Due to the rapid growth in population and rising living standard, the set-up of the restaurant and hotel industries are taking place at a faster rate, resulting in the increase in the production of KW, which is a major environmental challenging issue in the country. KW is a highly energetic biomass, and a higher population density is responsible for tons of production daily. At the present time, the role of KW in MSW has an important role, and its ignorance results in an increase in the environmental pollution. The growth of KW is increasing at a rapid rate due to the development of the hotel and restaurant industries in India and various parts of the world. The annual KW generated in some countries is shown in Table 2. A comparative study is demonstrated in Table 3 with kitchen organic waste and other waste materials of available mass in India. However, KW can be utilized in many ways for energy generation.

However, the problems related to waste resources have also provided a window of opportunities to find solutions by involving the multi-shareholder involvement, adoption of innovative technologies, and encouragement of the private sector investments. An estimate made by the Ministry of New and Renewable Energy (MNRE) in 2017 indicated that there was an energy recovery potential of about 5200 MW from MSW but only 24 MSW recovery potential was observed in 2017 in the country. Due to the transition phase, energy requirement in India is the present need due to socio-economic growth. At the present time, 3-4 times more energy is required as compared with the present situation to meet the energy requirement. Thus more focus in the direction of energy enhancement and KW utilization can solve this problem at a certain level. The Indian researchers have proposed a lot of alternates to utilize this waste but the people's awareness to handle the waste is highly required.

A lot of opportunities are going to search out to handle this waste. The various sustainable approaches for food waste to energy and nutrient recycling have been already proposed [29]. William Foster *et al*. derived five incredible processes that support the waste-to-energy concept, namely, pyrolysis, incineration, hydrothermal liquefaction, gasification, and anaerobic digestion [44]. Hydrothermal liquefaction and pyrolysis together help in producing bio-oil, whereas H_2-rich syngas can be obtained by the gasification process at a temperature of 300-800^oC [24,45]. Hydrothermal carbonization is the process that converts the rich wet content feedstock into a valuable product through thermal conversion [46]. A review related to the status and various challenges of MSW has already been discussed [32]. Thus there seems to be a lot of potentials to recover energy from MSW, and KW can play an important role in this direction.

Table 3. Comparative study of organic waste and other materials [33] [43].

S. No	Indian place	Composition (%)				
		Organic	Paper	Glass	Plastic	Metal
1	Dummanpur	71.88	11.16	5.36	0.73	0.15
2	Kongri	65.61	14.4	1.55	0.74	1.21
3	Shyampur	78.46	3.57	0.92	1.21	0.52
4	Mahalung	69	15	-	10	-
5	Bhogpur	76.52	1.54	6.07	0.59	0

Efforts have already been made to check the prefeasibility of biogas production using KW with co-digestion of cow manure due to its high biodegradability [47]. Yukesh Kannah *et al*. have briefly formulated the physical properties of food waste, namely moisture content and bulk density. whereas the chemical properties like pH and electrical conductivity [48]. The study was further extended and water hyacinth was added this time along with KW and cow manure. The results obtained clearly indicated that the reaction could be accelerated, and an increased production was achieved with the addition of water hyacinth [49]. Also an effort was made to use food waste codigested with sewage sludge in high solid anaerobic digesters for biogas production. In this manner, the environment can be protected from the bad effect of methane born due to uncontrollable anaerobic digestion. On the other side, the transportation sector consumes liquid fuel and the problem can be solved at some levels using fruit waste. It can be concluded from the predicted results that the bioethanol production can be achieved through food waste generated from agricultural processes worldwide [50]. KW is also a resource for biodiesel production that can be used as a fuel for vehicles [51]. The influence of thermal hydrolysis was investigated on an organic solution using a fatty acid, and the effect of fatty acid composition on biodiesel was also studied [52]. Zhang *et al*. have stated different ratios of co-digestion of black water with KW to obtain maximum energy [53].

The biological production of volatile fatty acids from food waste using different buffering agents has been proposed [54]. The uses of organic waste-to-energy systems in India have been proposed [55]. The performance of KW as a raw material for biodiesel production has been evaluated from the lipid profile analysis along with its utilization in the pharmaceutical and agricultural industries [56,57]. A bio-refinery using food waste as the input raw material has also been proposed for a sustainable strategy for a circular bio economy [28]. KW can also be utilized for other purposes. The study of a sustainable and convenient solution of KW of a small-scale hydrothermal carbonization plant for co-combustion has been performed for the catering industries [58]. High kitchen waste (HKW) and low kitchen waste (LKW) from MSW hydraulic and mechanical properties have also been evaluated for landfill design [59]. There is not so much work addressed on the integration of all the proposed units for this kind of pilot plant. The studies are not being carried out on solar-assisted electricity generation using KW as the biomass.

3. Bio-fuel generation using KW

An uninterrupted usage of conventional fossil fuels, causing a serious damage to the mankind, generates a huge amount of toxic greenhouse gases. In replacement with these fossil fuels, bio-fuel came into picture as an eco-friendly source of energy, causing minimal harm to the environment. KW that is named as an unwanted material that is generally thrown out as a garbage became an incredible source to produce bio-fuel. Bio-diesel, ethanol, hydrogen, and methane are termed as bio-fuels that can be produced using KW. Ethylene has a huge market of 140 million tons per year that can be produced using ethanol as a chemical feedstock [60]. Performing various processes, it was concluded that KW was the best source to produce hydrogen [61].

Anaerobic digestion of KW is an acceptable method to produce methane at a low cost and with a minimal residue [62]. Moreover, the left-over nutrition-rich material is much effective as a manure in the agricultural sector [63]. Faisal Kader *et al*. was successful in producing 14.4 kg-mol/h of methane using food waste through anaerobic digestion [64]. With an assumption that 165 tons of food waste is processed through anaerobic digestion, 18350 m^3 of biogas is produced, and it is estimated that approximately $21615 can be saved by diverting this amount of waste to landfills every year [65].

4. Materials and methods for integration of proposed pilot plant

There are different forms of KW treatment technologies developed around the world, which are charted in Figure 2. In the present work, we deals with the optimum use of KW for ethanol, biodiesel, biogas, and electricity production in an organized manner integrated with solar energy. In the first phase, data collection on the current status and utilization patterns of KW resources in India have to be collected. The proposed set-up for a pilot plant is shown in Figure 3. KW will be collected from hotels, restaurants, and households, and will be divided into two main categories, i.e. KW and green waste (leaf, vegetable, and fruit wastes, etc.).

Oil is collected from waste food by solvent extraction, and waste cooking oil (WCO) is also collected on the other side. Biodiesel will be prepared using this waste food oil. After oil collection, the residue of KW undergoes fermentation, where ethanol is produced. The left-over residue after ethanol production undergoes the bio-ethanation process, and biogas as well as liquid manure is produced at this step. The next phase is to deal with green waste, where the solar dryer is used to remove the moisture from the waste, and with the help of a cutter machine is divided into small pieces. In the pulverization process, it is converted into a powder form and is used in the form of biomass for the gasifier. In the gasifier, gasification takes place, and these gases are fed into an engine generator for electricity generation.

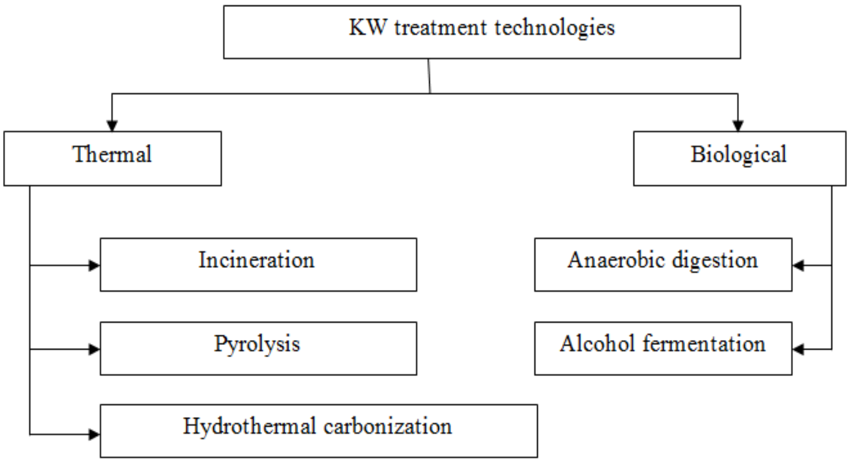

Figure 2. Various KW treatment technologies.

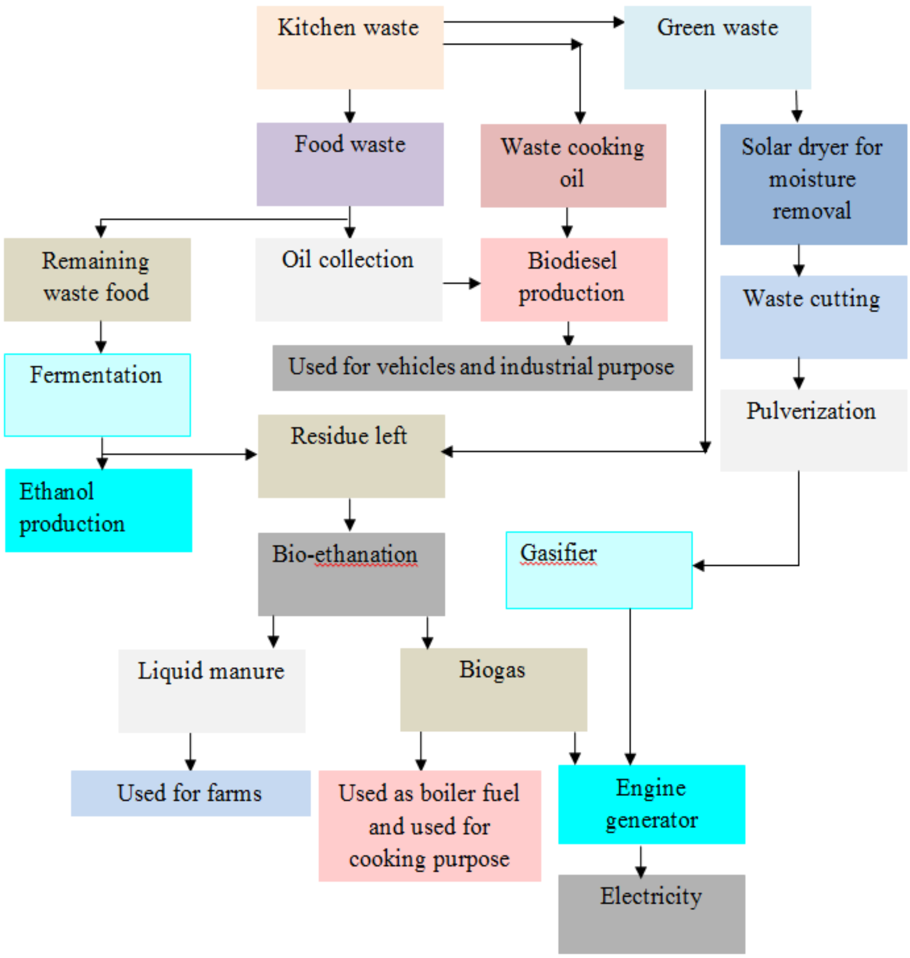

Figure 3. Proposed set-up for pilot plant.

5. Challenges for plant

Now it is mandatory in India that every waste generator shall segregate and store the waste generated by them. However, limited financial resources, technical capacities, and land availability are a big challenge to handle MSW till date. Communal bins are mainly used for the collection of the waste produced in urban areas, though there is a poor and unorganized program for the segregation of MSW in urban areas. The people below the poverty line extract the metals, plastics, and other recyclable wastes from low-lying areas, used to dump MSW to cover up their daily requirements. Several composting and energy recovery plants are working in different states in India using MSW as raw materials. More than 40 mobility schemes run by a public-private partnership in MSW management are working in the country by various companies like the Zen global finance limited, future fuel engineers, Enkem engineers limited, and Thermax limited.

There are various challenges like the lack of awareness and unaccountability; the government policies and inappropriate technical knowledge are the major hurdles to convert KW into energy. However, the main problem regarding the processing of KW is the high content of moisture in it. This is the main reason for its higher recycling and disposal process cost. The role of solar energy may play an important role to reduce moisture from KW. In this work, the feasibility of this activity will be checked, and if is succeeded, it will be beneficial for the society in a direct manner. The integration of the entire proposed unit at a common platform for waste-to-energy utilization is also a big challenge for this kind of project.

6. Recommendations for future work

The aim of this study is to present the status of KW and the various challenges involved to handle it in India. The country is still struggling to make KW to energy a success story. The role of people awareness of KW utilization may play an important role in this direction. The government should take initiative to encourage Universities, technical Institution to take up waste management in its curriculum. In this work, a pilot plant study is planned to integrate a number of units simultaneously, which are running separately for various purposes.

The main advantage of this suggested plant is that the feed raw materials are common, and the waste materials for one unit can be utilized as an input for its adjacent unit. Thus the chance of waste is reducing at its minimum level. After a successful operation in this proposed plant, the waste management problem can be enhanced at a higher level. On the other side, the role of solar energy may play an important role to reduce moisture from KW. In this work, the feasibility of this activity can be checked, and if is succeeded, it will be beneficial for the society in a direct manner. The proposed plan will not only reduce the level of MSW in the country but will also create a lot of opportunities for employment in the country for a future generation.

7. Conclusions

Considering the environmental effects and land pollution due to the unregulated waste management system, municipal solid waste (MSW) is identified as the primary cause. As 30% of the generated food waste is remained uncollected and 70% of the kitchen waste (KW) is not properly recycled, the waste-to-energy system has drawn attention. According to the literature, the researchers have been successful in drawing different products of energy by processing KW using various stated approaches. The proposed pilot plant helps in extracting different forms of energy at every stage of recycling. That too we assure that the plant collectively, as a whole, will run with a complete solar energy, ejecting almost zero toxic gases. The main advantage of this suggested plant is that the feed raw materials are common and the waste materials for one unit can be utilized as an input for its adjacent unit. Limited financial resources, technical capabilities, land availability, lack of infrastructure, and proper government initiatives have been identified as the major challenges that are being responsible for the irregular waste management system. The present work concludes that installation of this kind of pilot project in the metropolitan cities is the present need for the development of the recycling industry sector using KW as a raw material in India.

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