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Conversion of Plastic Waste into Energy and Value-Added Products in Makkah City

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Abstract

Millions of Muslims from all over the world visit the Holy Cities of Saudi Arabia: Makkah and Madinah every year to perform Hajj and Umrah. The rapid growth in urbanisation and local population of Makkah city along with ever increasing number of visitors result in huge municipal solid waste (MSW) generation every year. Most of this waste is currently dumped into landfill sites without any treatment, thus causing environmental and health issues. For example, on average around 2.4 thousand tons of waste is dumped into Makkah city’s landfill sites every day that increases to around 3.1 and 4.6 thousand tons per day during Ramadan and Hajj periods, respectively. Around 23% on average of this waste is plastic waste in the form of plastic bottles, water cups, food plates and shopping bags (Abdul Aziz et al. 2007). A pilot scale catalytic pyrolysis process has been used to convert plastic waste into liquid fuel at Center of Excellence in Environmental Studies (CEES) of King Abdulaziz University, Jeddah. The produced liquid fuel has been found to have high energy value of around 40 MJ/Kg, viscosity of 0.9 mm²/s, density of 0.92 g/cm³, flash point of 30°C, pour point of -18°C and freezing point of -64°C, characteristics similar to conventional diesel. Thus the produced liquid fuel has the potential to be used in several energy related applications such as electricity generation, transportation fuel and heating purposes. It has been estimated that the plastic waste in Makkah city in 2016 could produce around 87.91 MW of electricity with net revenue of 297.52 million SAR. This is projected to increase up to around 172.80 MW of electricity and a total net revenue of 584.83 million SAR by 2040.

Keywords: Pyrolysis technology; Plastic Waste; Liquid Fuel; Makkah; Hajj (Pilgrimage); Umrah; Greenhouse Gas (GHG); Sustainable Environmental Solution (SES)
Conclusions

The potential of pyrolysis technology to treat all the plastic waste produced in Makkah city has been studied. A pilot scale pyrolysis process with a capacity of 20 L has been set up and used to convert plastic waste into liquid fuel and other useful products such as char and gases. The liquid fuel produced from thermal cracking of different types of plastic waste has an average HHV of 40 MJ/Kg. The liquid fuel other characteristics such as viscosity (0.9 mm²/s), density (0.92 g/cm³), flash point (30°C), pour point (-18°C) and freezing point of (-64°C) were found to be similar to conventional diesel. The MSW generated in Makkah city by the local population, pilgrims and during Ramadan has been estimated to be 1.141 million tons in 2016 and projected yearly to reach up to 2.244 million tons in 2040. The plastic waste stream is around 23% of the MSW and if all the plastic waste is treated by pyrolysis process, it has the potential to produce around 87.91 MW of electricity from 210.02 million kg of produced liquid fuel and savings of 150.26, 120.13 and 27.13 (total 297.52) million SAR from landfill diversion, electricity generation from liquid fuel and carbon credit, respectively. The electricity generation and the savings from pyrolysis technology will increase every year as the Makkah population, pilgrims and MSW increases. This is projected to increase up to around 172.80 MW of electricity and a total income of 584.8 million SAR by 2040. The pyrolysis technology seems a promising and sustainable solution to treat the plastic waste stream of Makkah city. However, more in depth studies are required including factors like socio-economics, local conditions, culture and current practices to be carefully considered before taking the final decision on adapting the pyrolysis technology.

Further Research

- The produced liquid fuel can be further treated to clean and improve its quality.
- A detailed feasibility study including economic, environmental and technical aspects of pyrolysis technology is needed for understanding the full potential and benefits of adapting this technology is Makkah to treat all plastic waste.
- A complete material and energy balance of pyrolysis process at industrial scale would help detailed feasibility study.
- A comprehensive study to highlight the detrimental impacts of plastic waste, on environment and human beings, as dumped in landfill sites, would help decision makers in taking the right decision.
- Undertaking Life Cycle Assessment (LCA) on plastic materials and pyrolysis technology for under pinning the benefits and environmental benefits of this technology.
Investigation of socio-economics, local conditions, culture and current practices together with the above recommended research areas is also very important to be carefully considered before taking the final decision on choosing the pyrolysis technology as a sustainable solution for treatment of waste in Makkah city.

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