Waste management, carbon economy and white biotechnology: prospects and challenges

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Waste management through implementation of 'white biotechnology' and 'carbon economy' has significantly contributed to the reduction of greenhouse gas emissions and growth of waste biomass-based economy. The global impacts of adaptation of these concepts have actually caused increased awareness for safer disposal of waste without landfilling. Although India is among the leading countries that promote white biotechnology and carbon economy, waste management has not been well addressed in terms of bioconversion of waste into products. It is important to delve deep into the basics of these concepts and analyse the scope of applications.

Waste management in terms of recycling and bioconversion of waste into valuable products is an underexplored area in India. Although awareness programmes have been initiated across the country for popularizing waste management, the real scenario is not satisfactory. The concept of waste management should not be confused with the clean-up programmes. Waste generated at the domestic and industrial scale needs different management strategies. Identification, collection and proper segregation of different types of wastes are the most important steps in the waste management chain. Basically, waste management is a socio-economic challenge. Every citizen is equally responsible for generating waste and should contribute to the management domain. Waste generated at the domestic level needs to be processed using proper disposal methods. However, the overall scenario of waste management system in Indian urban and rural areas is still under-developed. This can be attributed to the shortage of technical knowledge, financial investment and skilled persons against the large volume of waste generated. In recent times, there have been some initiatives for bioconversion of biodegradable domestic waste into vermicompost and organic manure. Moreover, awareness programmes are being organized for proper segregation of domestic waste before disposal. In a strict sense, waste management should not contaminate the environment during any step of the adopted strategies.

Value addition is a new domain to the core meaning of a waste management system. In particular, waste generated by many industries (such as sugarcane, apple juice, pulp and paper, beer, etc.) is much rich in carbon, nitrogen and other vital micro- and macronutrients required by microorganisms (e.g. bacteria and fungi). These industries generate large amounts of nutrient-rich waste (million tonnes) annually that is mostly dumped into the environment. Emission of greenhouse gases (GHGs) (CH_4, CO_2, etc.), microbial putrefaction and groundwater contamination, habitat for disease vectors, etc., can have direct adverse effects on the environment and human health[1]. New trends in regulations for a ban on landfilling of solid/liquid waste have been imposed in different continents[2–4]. India also needs to implement such stringent regulations.

One of the most successful strategies of value addition of waste is application of the concepts of carbon economy and white biotechnology. These concepts originated to utilize sustainable, low-cost carbon sources for the cost-effective production of high-value chemicals utilizing microbial natural ability to degrade carbon-rich lignocellulosic biomass such as sugarcane bagasse, paper waste, etc. This approach reduces emission of GHGs (concept of carbon economy) into the biosphere and also adds value to waste by live microorganisms (white biotechnology). In fact, white biotechnology has been declared as an integral part of the solution to climate change. Moreover, waste biomass-based economy has been projected to have a high probability of reaching the market by 2030 (ref. 5). In the last few decades, application of carbon economy and white biotechnology has shown promising results in terms of reduction of GHG emissions and cost-effective production of many high-value chemicals such as bioethanol, biobutanol, fumaric acid, citric acid, hydrogen gas and several industrially important enzymes such as lipase. Some of these products have been successfully scaled-up to commercial production. The global scenario of value-addition approach of waste management is highly encouraging. Study on mechanistic details of the microbial ability for bioconversion of lignocellulosic biomass into high-value products has actually paved the way for further research on the enhancement of product yields.

India is among the leading countries that promote carbon economy and white biotechnology in academic and industrial research. However, compared to the number of studies carried out at lab-scale, converting them into large-scale production is scarce, and this warrants further research. It is high time to delve into the environmental fate of different types of waste and make people aware of the inevitable consequences of improper waste management.

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2. www.epa.gov/solidwaste/nonhaz/municipal/landfill/msw_regs.htm (accessed on 17 September 2018).
3. Monte, M. C., Fuente, E., Blanco, A. and Negro, C., *Waste Manage.*, 2009, **29**(1), 293–308.
4. Testa, F., Daddi, T., Giacomoa, M. R. D., Iraldoa, F. and Frey, M., *J. Clean. Prod.*, 2014, **64**, 91–97.
5. www.oecd.org (accessed on 17 September 2018).

ACKNOWLEDGEMENT. We thank the Department of Biotechnology, Government of India for providing funds (sanction no. BT/22/NE/2011 dated November 30th).

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