SUSTAINABILITY ASSESSMENT OF WASTE TREATMENT TECHNOLOGIES: AN INDIAN CASE STUDY

ABSTRACT

The present research focuses on assessing the sustainability performance of waste treatment technologies to help accelerate the transition towards integrated waste systems development in Indian Smart Cities. The research involve five stages. First field surveys were performed in six Indian Smart cities to identify bottlenecks and waste handling and treatment systems challenges. Second, detailed waste characterization studies were performed in Visakhapatnam, India, to develop a waste characterization dataset for municipal solid waste (MSW) (based on source, socio-economic and seasonal variation) and legacy waste (age of waste). Based on the outcomes of this study, treatment technologies were identified. Third, the environmental impacts of the developed treatment scenarios for both MSW and legacy waste were evaluated using life cycle assessment (ISO 14040:2006 and ISO 14044: 2006) by incorporating the waste characterization database developed in the first phase. Fourth, an economic evaluation of the treatment systems was performed by implementing a life cycle costing approach (IS-13174:1994) using the present worth method. Finally, evidence-based policy interpretation was made to develop recommendations for accelerating the transition towards integrated waste management systems development in Smart Cities.

The outcome of the waste characterization study indicates that the amount of MSW generated in Visakhapatnam city is 1250±100 tons/day, with a generation rate of 0.65 kg/capita/day. Based on source stratification, organic matter (45.5 ± 6.5%) was a major component, followed by inert waste. The paper, plastic, and textile components amount to 25% of the overall waste. From seasonal studies, it was found that organic matter was higher in pre-monsoon (42%) compared to winter (39%). The moisture content of MSW was between 26–38% across the seasons. Volatile solids were between 39 – 43%. Calorific values ranged between 1360-1700 kcal/kg. In the case of legacy waste, based on physical composition, soil-like material and plastic (waste plastic bags and foils) were the major components of the recovered landfilled waste. The calorific value of the refuse-derived fuel sample prepared from recovered landfill waste ranged from 2473kcal/kg to 5214 kcal/kg.

Environmental impacts were evaluated using EASETECH™ software and ReCiPE Midpoint (Heuristic) World environmental impact assessment method. For MSW, waste treatment scenarios include open dumping of MSW (S1), landfill without gas recovery [LFWGR] (S2), landfill with gas recovery (S3), anaerobic digestion + LFWGR (S4), and incineration + LFWGR (S5). The existing MSW disposal practice in Visakhapatnam city (baseline scenario, S1) has the highest global warming potential (1107 kg CO_2 eq), which can potentially be reduced by 68.2%, 81.5%, 98.2%, and 94.5% by the implementation of waste management scenarios S2, S3, S4, and S5, respectively. Scenario S4 involving anaerobic digestion and engineered landfill without energy recovery was the option with higher mitigation potential in most of the impact categories and contributed to significant environmental benefits in terms of ecological footprints. In the case of legacy waste, environmental impacts of landfill mining of soil-like material with on-site sorting for land application were compared with no-landfill mining (base scenario) and futuristic scenario (including material recycling and incineration). Overall, the results showed that excavation of landfilled waste with on-site recovery of soil and land application of soil resulted in higher environmental benefits than no mining condition. Application of recovered metals in the manufacturing process, incineration of plastic and textile components improved the environmental performance.

The outcomes of economic analysis for MSW systems indicated that the combination of engineered landfill and anaerobic digestion has the highest benefit-cost ratio compared to incineration and anaerobic digestion. Although the benefit of incineration and anaerobic digestion is high, the overall benefit-cost ratio decreased due to the high capital cost of incineration compared to engineered landfills. Based on the sensitivity analysis, operation cost is the most sensitive parameter, followed by the discount rate. Based on evidence-based policy intervention, decentralization of power, bottom-to-top approach in governance scientific waste characterization, public-private partnerships, systems engineering applications for decision-making, and the development of an indicator-based performance index indicate pathways for accelerating the transition towards the development of integrated waste systems in the studied Smart Cities.

Key words: *Municipal Solid waste; Legacy Waste; Life Cycle Assessment; Life Cycle costing; Evidence-based policy intervention; Anaerobic digestion; Incineration*