Resource Recovery and Sustainability Assessment of Residential University Waste Systems

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by

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Abstract

The present research aims to assess the sustainability performance of integrated waste systems development in residential university campus (RUC) based on a techno-socio-economic approach, taking the Indian Institute of Technology Kharagpur (IIT Kgp) India as the study site. First objective, based on the physico-chemical characterization, the estimated average daily solid waste generated in the study site was 7.53 tons. The physical composition of waste was found to be, food waste 59% (4434 kg/day), yard waste 17% (1280 kg/day), plastic 5% (352 kg/day), cardboard 4% (292 kg/day), polythene bags 4% (278 kg/day), paper 2.6 (198 kg/day), glass 2.5% (177 kg/day), inert 1.8% (137 kg/day), leather 0.85% (64 kg/day), other 0.80% (60 kg/day), metal 0.60% (45 kg/day), and e-waste 0.43% (32 kg/day), with an average generation rate 0.32 kg/capita/day. Moisture content of MSW was between 7-52%, volatile solids 38-85%, ash content 6- 19%, fixed carbon content 0.69- 5%. The ultimate analysis results showed that the carbon range of the components analyzed was 33-47%, carbon to nitrogen ratio was 35.3±4.9. The calorific value was 4300- 4730 kcal/kg (on a dry basis). Overall, developing an integrated waste treatment plant with anaerobic digestion was suggested for the RUC. The second objective estimated that the percentage of recoverable components of the total waste generated. It was 27–73% across different zones with a recycling potential of about 89%. The total net recycled waste of 448.3 tons (annually) was generated by the RUC. Total approximate revenue from the sale of dry recycled waste was ₹ 0.43 crore annually and for yard waste, a possible profit of ₹ 0.68 crores annually from 685.6 tons of yard waste was estimated. A comparative CBA was performed to assess S1 (the existing practices of collection, transportation, open dumping/burning) and S2 (the scenario with segregation at source executed by the installation of different bins). For S1 total cost was ₹46.98 crore for 5 years. For S2, the total cost was ₹28.85 crores for 5 years. The cost of S1 is higher given the higher cost of willingness to pay component capturing the compensating to be provided to the stakeholders to tolerate the current waste management practices that are generating disutility and environmental and aesthetic losses. On the benefit side, for S1, i.e., in the existing situation, negligible benefits were reaped. On the other hand, for S2, benefits were reaped in the form of economic revenue generation by the sale of waste and through material resource recovery and imputed benefits from aesthetics and cleanliness, measured using the willingness to pay/accept the

approach, summing up to for 5 years, ₹ 29.63 crores. Moreover, for S2, different alternative technologies were compared, such as anaerobic digestion plant, windrow composting and leaf mould composting. The net present value (NPV) for S1 was ₹ -60.72 crores and for S2 ₹ 1.01 crores. The NPV for S2 is greater than S1 and was accompanied by environmental and social benefits, and hence it is the feasible option. The investigations recommended setting up an IWM system with 50% source segregation that includes an anaerobic digestion plant, windrow composting, and material recycling facility to develop a self-sustaining waste management unit in the study area. Further, the present study proposed to incorporate the informal sector workers (working as waste pickers) by including them in the proposed IWM system. This objective was achieved by using the primary survey. The survey cumulatively highlighted the vulnerability of these workers and displayed the necessity of bringing them to be a part of the formal setup. As included in the third objective, the salary of informal sector labour employed contractually for dry waste sorting will be ₹ 9,500 per month, accompanying perks for the worker (total up to ₹ 76,500 annually) such as access to RUC's infirmary, free bank account facilities. Finally, environmental impacts were evaluated using EASETECH™ software and ReCiPE Midpoint (Heuristic) World environmental impact assessment method. "The functional unit is management of as 1 tonne of MSW generated". For MSW, waste treatment scenarios include open dumping of MSW (S1), Scenarios with assumed source segregation efficiency of 50% in Scenario S2 and 90% in Scenario S3. The existing MSW disposal practice in IIT Kgp (baseline scenario, S1) has the highest global warming potential (GWP) 1388 kg CO_2 equivalent, which can be potentially reduced by 50.9% and 86.5% on implementing waste management scenarios S2 and S3 respectively. The collection and transportation of MSW contribute to 9.5 kg CO_2 eq. and the capital goods contribute to 2.6 kg CO_2 eq. The development of IWM systems with 50% sorting (S2) contributes to 681.8 kg CO_2 eq. of GWP emissions. The outcomes of this research were used to develop recommendations for accelerating the transition towards the development of IWM systems in the RUC, which will be a useful tool for other similar campuses, small towns, etc.

Keywords: Physico-chemical characterization, Recycling potential, Cost-Benefit, Life Cycle Assessment, Resource recovery.

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