

SI-1: Projected twelve-fold growth in Municipal Solid Waste generation calls for urgent techno-policy interventions across urban India

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1 Additional Info: Methodology

1.1 Historical data harmonization

Even though accurate historical MSW data are difficult to obtain, there are primarily two approaches for which data of varied quality exists for Indian MSW. First, some estimates are available for per capita waste generation per day for some cities. Such data points based on individual waste generation rate has been referred to as bottom-up estimates in this study. Second data comes from waste collection estimates specific for cities and/or states within India which has been referred to as top-down estimates within this study. Bottom-up estimates based on kg per capita per day amount of MSW generation lead to inherent uncertainties due to consumption variations among cities and socioeconomic drivers of waste generation [Zhou et al., 2022]. Top-down estimates primarily come from government reports which rely on city and state-level reporting of waste collection [Powell et al., 2016]. Such top-down estimates for years prior to 2000 are few and often do not reconcile with the bottom-up approach of kg per capita per day estimates. Reliance of Top-down estimates on reporting from the city-level waste collection stakeholders leads to several challenges in the robustness of this data. Nationally, this leads to incomplete coverage of cities and often the averages of a few cities are often used across a state which then inform the national estimates. One of the earliest comprehensive study on MSW estimates for India was carried out by the National Environmental Engineering Research Institute in 1996 that estimated the total MSW generation in selected cities [NEERI, 1995]. This was followed by a report from the Ministry of Urban Development in 2000. On account of at least one data point being available for each decade, we chose bottom-up (kg per capita per person) data to compile a historical MSW trajectory from 1947 until 2000 and rely on top-down estimates available from government agencies to further extend this analysis from 2000 to 2020. We further compare top-down estimates to highlight uncertainties and data challenges.

1.2 Moderate Consumption Lifestyle

Three types of approaches exist within academic and grey literature. First, the top-down approach looks at the combined annual growth rates of waste streams. One of the nationally agreed growth rate has been published by the India's CPCB. CPCB estimates a 5% annual growth rate in MSW, considering previous trends, demographic changes in the cities, and lifestyle consumption patterns. The second and most common approach for estimating MSW generation, as previously discussed, remains the bottom-up approach with kg/day values per capita for the urban population. There have been several proposals for kg/day quantities, but most range between 0.5 to 0.64 kg/day. To consider an upper bound for a moderate consumption lifestyle, we take 0.64 kg/day estimates calculated by a recent study using household waste generation survey [Chaudhary et al., 2021]. A third and preferred approach focuses on household waste generation pattern data that considers varied economic realities of the urban world. Under this methodological approach, the urban economic divide is reflected by the differences in income, and hence, consumption patterns of households should lead to varied composition and quantities of MSW. However, such granular data requires additional research efforts and remains unavailable. Instead, the World Bank methodology takes a simplified approach. Based on the scale of the urban population in cities, it assumes that the per capita waste generation increases. So, a mega city of a ten million+ population would have a much higher kg/day MSW generation than a city of 0.5 million residents. In reality, such differences are being blurred in the era of e-commerce, youth aspirations, and urban sprawl. However, taking such an approach of cascaded kg/day estimates of cities of varied sizes within India, the World Bank report estimates national MSW generation in India. We provide three MSW projected estimates based on the above three methodological approaches for a moderate consumption lifestyle scenarios in Indian cities.

1.3 Critical analysis and Synthesis

Based on the historical data and projected scenarios, we take a critical analysis approach to examine the technology policy and infrastructural progress. We synthesize our insights into consolidated results and propose practical interventions to deliver a net zero-aligned circular material future. Expert judgments have been made to propose interventions which are evidence-based and greatly rely on the lived experiences of the authors across different parts of the country.

1.4 Projection of MSW Composition

We leverage historical data and estimates developed by [Chen et al. \[2020\]](#) to provide MSW composition projection for 2050. Even though their MSW generation scale differ across scenarios, no changes were observed in MSW composition for India across all five SSPs. We assume that the MSW composition would likely remain similar in the medium term given the established material value chains that drive national consumption.

2 Differing estimates of MSW generation

From a top-down approach, the Union Ministry of Housing and Urban Affairs (MoHUA) estimated that the total MSW generation rate in 2000 was 100,000 tonnes per day (TPD) [[CPCB, 2007](#)]. The annual MSW generation rate was reported to be 152,076 TPD in 2018-19 [[CPCB, 2019](#)]. According to MoHUA, as of January 2020, 147,613 TPD of MSW was generated across India.

The 2014 Task Force on Waste-to-Energy report under the Planning Commission estimates that urban India will generate 276,342 TPD of MSW by 2021; 450,132 TPD by 2031; and 1,195,000 TPD by 2050. [Singh \[2020\]](#) estimated per capita MSW generation is 0.45 kg per day with a growth rate of 1.3 percent per annum in the future.

In one of its seminal reports, the World Bank estimated the MSW generation rate for Urban India at 0.34 kg/capita/day in 2005 (109,589 tons/day (TPD)) with a forecast of its increase to 0.7 kg/capita/day in 2025 (376,639 TPD) due to population and economic growth [[Hoornweg and Bhada-Tata, 2012](#)]. An updated recent analysis by the World Bank group estimated an average of 0.57 kg/capita/day MSW generation in India in 2018, lower than the global average of 0.74 kg/capita/day [[Kaza et al., 2018](#)]. The CPCB report indicated that the MSW generation rate lies between 0.2 and 0.3 kg/capita/day in small towns/cities with less than 0.2 million population. It is usually 0.30–0.35, 0.35–0.40, and 0.4–0.6 kg/capita/day in cities with population ranges of 200,000–500,000, 500,000–1 million, and above 1 million, respectively [[CPCB, 2016](#), [CPHEEO, 2016](#), [MNRE, 2017](#)].

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