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Does Population Size Matter? Analyzing Cleanliness Metrics of ULBs in Madhya Pradesh (2023–2024)

Jaikrit Saraf

Woodstock School, International school, Mussoorie, Uttarakhand

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ABSTRACT

This study investigates the relationship between population size and municipal solid waste management (MSWM) outcomes in Madhya Pradesh, India, using data from the Swachh Survekshan 2023–2024 survey. The analysis compares Urban Local Bodies (ULBs) with populations below 15,000 and above 15,000 to identify whether population size significantly influences cleanliness metrics and overall sanitation performance. Cleanliness indicators examined include residential and market areas, water bodies, public toilets, remediation of dumpsites, door-to-door collection, source segregation, waste processing, and performance rankings (absolute, state, and national). Statistical tests such as independent t-tests, Chi-square tests, and Mann–Whitney U tests were employed to determine significant differences between the two population groups. Findings revealed that larger ULBs consistently outperform smaller ones across most indicators, particularly in source segregation, waste processing, GFC (Garbage Free City) status, ODF (Open Defecation Free) status, and national/state rankings. In contrast, smaller ULBs achieved better performance in remediating dumpsites, likely due to lower waste volumes and fewer legacy waste challenges. These results suggest that population size is a critical determinant of sanitation outcomes, with larger ULBs benefitting from superior infrastructure, financial resources, and citizen engagement. However, the relative strength of smaller ULBs in dumpsite remediation points to the importance of decentralization and capacity building. The findings have significant implications for designing population-sensitive waste management policies and improving equity in Swachh Survekshan assessments.

Keywords: Swachh Bharat Mission, Swachh Survekshan, Madhya Pradesh, Municipal Solid Waste Management, Urban Local Bodies

ISSN: 2455-8834

Volume:10, Issue:10 "October 2025"

1. Introduction

Waste management is the process of collecting, transporting, treating, recycling, and disposing of waste materials to minimize their impact on the environment. The goal is to get rid of waste while efficiently promoting sustainability and hygiene. As human society has grown, waste management has become of greater and greater significance, seeing as there are more people, cities, and countries than ever before, and the output of waste is at an all-time high. As documented by UNEP, global waste generated is approximately 2 billion metric tons as of 2020. It is projected to grow by 70 percent by 2050. Of this, India generated 58 million metric tons of waste in 2020 [1]. Consequently, it has been of utmost priority to categorize, treat, and dispose of trash in the least harmful manner. Waste management is at the forefront of issues regarding well-being as it is a large influencing factor in public health, environmental sustainability, and urban development. Properly disposing of waste is vital to minimizing disease and contamination, and in creating a more pleasant atmosphere for communities. Alternatively, it reduces pollution in the form of landfill leachate or water contamination and, when done right, helps to protect the environment from harmful pollutants. The importance of waste management has only increased with waste production nationwide growing 4% [2]. Waste production in India on all fronts has increased; thus, the extent of waste management also needs to increase. To help combat the growing levels of waste production and improve existing communities and environments, India devised the Swachh Bharat Mission. The Swachh Bharat Mission began in 2014 and comprises 2 phases. Phase 1 spanned from 2014-19 and aimed to create ODF (Open Defecation Free) zones across rural India, and ultimately curb unsanitary defecation practices that were causes of disease in rural areas everywhere. Phase 2 similarly spans 5 years and has been going on from 2019-25. The aim of phase 2 is to progress villages and districts to sustainable waste disposal and management strategies while maintaining their ODF status. Swacch Survekshan was designed alongside the Swachh Bharat Mission. Swacch Survekshan is a ranking system that helps to hold the different states and cities of India accountable for their waste management practices. An additional aim of it is to help infuse "cities with a healthy spirit of competition to improve the status of urban sanitation and ensure best service delivery to their citizens." However, Swachch Survekshan has evolved past simply being a monitoring tool. It has instead been instrumental in pushing states to improve the quality of life and level of waste management in their respective cities and districts.

This paper is a comparative study that aims to explore MSWM (Municipal Solid Waste Management) within Madhya Pradesh, in the context of population, by evaluating and analyzing the different metrics and cleanliness factors provided as per Swachh Survekshan data, and their correlation. Madhya Pradesh consistently ranks amongst the top 3 states regarding cleanliness [3] and has encompassed the cleanest city for the last several years, Indore. By cross-analyzing

ISSN: 2455-8834

Volume:10, Issue:10 "October 2025"

districts and ULBs (Urban Local Bodies) across Madhya Pradesh, it will be clear the role population size plays in the success of SWM that can ultimately be applied to other districts, regions, and states across India that may experience similar roadblocks.

2. Methodology

2.1 Research Aim and Objectives

This study adopts a quantitative and comparative approach to examine the relationship between population size and cleanliness outcomes among Urban Local Bodies (ULBs) in Madhya Pradesh during the 2023–2024 period. The state was selected as the study area because it consistently ranks among the top performers in Swachh Survekshan assessments and houses Indore, India's cleanest city. Madhya Pradesh thus provides a strong case study for identifying systemic patterns in urban waste governance. Mentioned below are the specific objectives of the paper:

- To analyze whether population size (below 15,000 vs. above 15,000) influences cleanliness performance in ULBs.
- To compare the performance of the two population groups across key cleanliness metrics (residential areas, market areas, water bodies, public toilets, remediation of dumpsites, source segregation, processing, and door-to-door collection).
- To evaluate whether population size is significantly associated with GFC status, ODF status, and Swachh Survekshan ranks (absolute, state, national).

2.2 Data and Variables

The study draws exclusively on publicly available Swachh Survekshan 2023–2024 data [4], covering a total of 378 Urban Local Bodies (ULBs) in Madhya Pradesh. These ULBs were categorized into two groups based on population size: smaller ULBs with populations below 15,000 (n = 151) and larger ULBs with populations above 15,000 (n = 227). The primary independent variable is, therefore, population size, which serves as the central basis for comparison across the analysis. For the interpretation of findings, larger ULBs are considered representative of a higher degree of urbanization, reflecting the broader infrastructural, administrative, and social dynamics typically associated with more urban settings [5].

The dependent variables are drawn from Swachh Survekshan's cleanliness metrics, certification statuses, and ranking indicators. The cleanliness metrics include (i) Cleanliness of Residential Areas, which measures the presence or absence of visible waste and overall sanitation in housing neighborhoods; (ii) Cleanliness of Market Areas, which evaluates hygiene and waste

ISSN: 2455-8834

Volume:10, Issue:10 "October 2025"

management practices in commercial zones such as bazaars and marketplaces; (iii) Cleanliness of Water Bodies, which captures levels of sanitation and pollution control in rivers, ponds, or lakes within ULBs; and (iv) Cleanliness of Public Toilets, which assesses accessibility, maintenance, and hygiene standards in public sanitation facilities. Additionally, Remediation of Dumpsites reflects the extent to which legacy dumpsites have been cleared or scientifically treated, while Door-to-Door (D2D) Waste Collection measures the coverage of household-level waste pickup systems. Two further variables, Source Segregation and Processing, capture the efficiency of waste management systems. Source segregation indicates the proportion of households sorting waste into biodegradable and non-biodegradable categories, while processing represents the share of waste treated through composting, recycling, or waste-to-energy methods rather than landfilling. Certification metrics used in the study include Garbage Free City (GFC) status and Open Defecation Free (ODF) status. GFC status is a star-based certification ranging from 0 to 7, awarded based on overall solid waste management performance and adherence to Swachh Survekshan's evaluation criteria. ODF status is classified into four tiers (ODF, ODF+, ODF++, and Water+) and reflects progress in sanitation infrastructure, fecal sludge management, and safe disposal practices. Finally, ranking indicators (absolute rank, state rank, and national rank) serve as performance outcomes that aggregate ULBs' performance across multiple metrics into comparative positions at the city, state, and national levels. These ranks capture the relative standing of each ULB and are key indicators of overall waste management success within the Swachh Survekshan framework.

2.3 Statistical Tools and Techniques

The analysis of the data relied on a combination of parametric and non-parametric statistical methods in order to capture both mean differences and categorical associations across ULBs of varying population sizes. To test whether differences existed in cleanliness performance metrics between smaller and larger ULBs, independent sample t-tests were employed, as these allow for comparison of mean values between two independent groups. To assess the relationship between population size and certification outcomes such as GFC and ODF status, the study used the Chi-square test of independence, which evaluates whether distributions across categorical variables differ significantly. Finally, because ranking indicators such as absolute, state, and national rank are ordinal in nature and not normally distributed, the Mann–Whitney U test was applied to compare ranking outcomes across the two population categories. All statistical tests were conducted using Datatab, an online statistical software, while Google Sheets was utilized for initial data cleaning, organization, and descriptive analysis.

ISSN: 2455-8834

Volume:10, Issue:10 "October 2025"

3. Results

Table 1: Independent T-Test Analysis of Cleanliness Variables (%) based on Population Size (N=378)

Cleanliness Performance Metric	Population	n	M	SD	t	p
Cleanliness of Residential Areas	Less than 15000	151	85.25	16.86	-0.75	0.453
	More than 15000	227	86.57	16.57		
Cleanliness of Market Areas	Less than 15000	151	85.3	16.93	-0.67	0.501
	More than 15000	227	86.49	16.63		
Cleanliness of Water Bodies	Less than 15000	151	86.54	80.79	0.18	0.855
	More than 15000	227	85.48	27.62		
Cleanliness of Public Toilets	Less than 15000	151	86.87	29.9	-1.06	0.29
	More than 15000	227	89.86	24.74		
Remediation of Dumpsites	Less than 15000	151	92.38	26.3	8.66	<0.001***
	More than 15000	227	54.14	49.84		
D2D	Less than 15000	151	90.08	12.29	0.16	0.871
	More than 15000	227	89.85	14.03		
Source Segregation	Less than 15000	151	43.84	35.08	-2.98	0.003***
	More than 15000	227	54.94	35.66		
Processing	Less than 15000	151	44.45	17.76	-2.34	0.02**
	More than 15000	227	49.28	20.76		

***p<0.01, **p<0.05, *p< 0.10

The independent t-tests in Table 1 examined the variation in cleanliness performance between ULBs with populations less than 15000 and more than 15000 (N=378). The findings indicate that population size has a statistically significant impact on certain aspects of cleanliness, particularly those related to waste management processes. While surface-level cleanliness variables such as residential areas, markets, water bodies and public toilets do not exhibit significant differences. Specifically, no statistically significant difference was observed in the cleanliness of residential areas (t=-0.75, p>0.05), market areas (t=-0.6, p>0.05), water bodies (t=0.18, p>0,05), and public toilets (t=-1.06, p>0.05) between towns or differing sizes. This suggests that basic cleanliness conditions in public and residential spaces are relatively consistent, irrespective of population, possibly due to uniform implementation of surface-level cleaning practices mandated by local municipal bodies. On the other hand, there are significant differences between the 2 population

ISSN: 2455-8834

Volume:10, Issue:10 "October 2025"

groups in the context of 3 cleanliness metrics. Those being Remediation of Dumpsites (t=8.66, p<0.01), Source Segregation (t=-2.98, p<0.01), and Processing (t=-2.34, p<0.05).

Table 2: Chi-Square analysis of GFC status based on Population

		No Star	1 Star	3 Star	5 Star	7 Star	Total	Chi Sq	p
Less than 15000	Observed	105	43	3	0	0	151	16.53	0.0002***
	Expected	88.28	52.73	9.19	0.4	0.4	151		
More than 15000	Observed	116	89	20	1	1	227		
	Expected	132.72	79.27	13.81	0.6	0.6	227		
Total		221	132	23	1	1	378		

***p<0.01, **p<0.05, *p< 0.10

A Chi-Square Test of independence was conducted to explore the relationship between population size (less than 15000 vs more than 15000) and GFC status (No star, 1 star, 3-star, 5-star, and 7-star). The analysis revealed a statistically significant association between population size and GFC Status, χ^2 (4, N = 378) =16.53, p=0.002. That is, the distribution of GFC ratings significantly differs as a function of whether the population size is below or above 15000, suggesting a correlation. Hence, due to the less than 15000 population categories having greater 'No star' towns than expected and fewer high-rated ones than towns with greater than 15,000 population, it is concludable that there is a correlation concerning population size and GFC rating, that a smaller population generally leads to a lower GFC status. The findings found that ULBs with populations below 15,000 had a significantly higher number of 'No Star' classifications.

Table 3: Chi-Square analysis of ODF status based on Population

		ODF	ODF+	ODF++	Water+	Total	Chi Sq	p
Less than 15000	Observed	4	2	145	0	151	6.42	0.093*
	Expected	2.8	1.2	144.21	2.8	151		
More than 15000	Observed	3	1	216	7	227		
	Expected	4.2	1.8	216.79	4.2	227		
Total		7	3	361	7	378		

***p<0.01, **p<0.05, *p< 0.10

Another Chi-Square Test was conducted to explore the relationship between population size (less than 15000 vs more than 15000) and ODF status (ODF, ODF+, ODF++, Water+). The test revealed a significant association between population and ODF status, determined by the significant p-value at 0.093. This means that as population size varies, it will affect the GFC rating. Specifically, due to the population category of More than 15000 having a Surplus of districts classified as Water+, which suggests that GFC status is greater when the population is higher. Here, similarly to the GFC status findings, smaller ULBs were less likely to achieve

ISSN: 2455-8834

Volume:10, Issue:10 "October 2025"

higher tier ODF++ and water+ statuses. The finding aligns with national studies that have questioned the sustainability of ODF declarations. For instance, a review in 2023 revealed that self-reported toilet usage often overestimated actual behavior, specifically in rural areas. It found that despite infrastructure being delivered by Swacch Bharat Mission, continued usage was inconsistent due to either poor design, lack of water access, or absence of safe fecal sludge management [6].

Table 4.1: Mann-Whitney U test to determine the relationship between Absolute rank, State rank, National and Population

Group	n	Mean Rank	Sum of Ranks
Absolute Rank			
Less than 15000	151	204.99	30953
More than 15000	227	179.2	40678
U	***z***	***p***	***r***
14800	*-2.25*	*0.025***	*0.12*
State Rank			
Less than 15000	151	209.4	31619.5
More than 15000	227	176.26	40011.5
U	***z***	***p***	***r***
14133.5	*-2.89*	*0.004****	*0.15*
National Rank			
Less than 15000	151	208.4	31468
More than 15000	227	176.93	40163
U	***z***	***p***	***r***
14825	*-2.74*	*0.006****	*14*

***p<0.01, **p<0.05, *p< 0.10

A Mann-Whitney U test was conducted to examine whether there was a significant difference in absolute rank based on population size (less than 150000 versus greater than 15000). The results revealed a statistically significant difference between the groups, U=14800, z=-2.25, p=0.025, and a small effect size (r=0.12). The mean rank for districts with population sizes smaller than 15,000 was 204.99, and for those with a size larger than 15,000, the mean rank was 179.20. This implies that the smaller towns had higher absolute ranks than larger districts. These findings imply that the size of the population relates to variation in absolute rank, and bigger tanks tended to have better rank performances.

Similarly, a Mann-Whitney U test was also conducted to examine whether there was a difference in state rank based on population size (less than 150000 versus greater than 15000). The results showed that there is a significant difference between the 2 groups, U=14133.5, z =-2.89, p=0.004. Since the P value is lower than the significance level of 0.5, this shows that the observed difference was not through random chance and that there's evidence of a correlation.

ISSN: 2455-8834

Volume:10, Issue:10 "October 2025"

The mean rank for districts with a population lower than 15,000 was 209.4, while those with a greater population had a higher average rank of 176.26. Consequently, we conclude that towns with lower populations have a higher state rank (worse) when compared to cities with a population larger than 15,000, meaning that districts with larger populations generally perform better than their counterparts.

The last Mann-Whitney U test conducted compared districts with less than 15,000 people to districts with more than 15,000 to determine if the National rank was affected by population size. It was revealed that the 2 groups differed significantly (U=14,825, z=-2.74, p=0.006). Since the p-value was below 0.5, we can say that this finding is statistically significant and not because of random variation. The less populated districts had a higher average national rank (208.4) and thus lower performance, whereas the larger districts had a lower average rank (176.93) and hence stronger performance. This indicates that more populous districts tend to perform better at the national level.

The Mann-Whitney U tests in this study revealed statistically significant differences in absolute, state, and national ranks based on population sizes. In all three cases, the larger ULBs performed better across the cleanliness and waste management indicators. This reinforces the interpretation that population size plays a big role in shaping sanitation outcomes. These results are supported by SBM itself, with the Ministry of Housing and Urban Affairs [7] stating that "larger cities benefit from better infrastructure, digital engagement, and citizen participation mechanisms," which directly leads to higher scores in the ranking system. Larger cities can also be seen to have better monitoring systems, waste collection methods, and processing infrastructure. The findings here indicate that the observed differences in rank were not due to random variation instead, they reflect systemic disparities in administrative capacity and access to resources as suggested in discussions on the sanitation equity "Swachh Survekshan's structure—while effective at incentivizing progress—can inadvertently favor larger municipalities that have greater capacity to respond to the survey's evaluation criteria." [8]

4. Discussion

Overall, the findings suggested there is a significant difference in cleanliness factors based on population size, with higher populations scoring better for all three apart from remediation. Waste processing having a higher score in ULBs with higher populations could be attributed to better policy awareness and infrastructure, leading to better resource allocation. That is to say that ULBs serving large populations receive more dedicated funding and resources, as there is both a greater need to effectively manage waste and better infrastructure. Also, due to the higher degree of urbanization, resource allocation is more effective in higher population ULBs. This enables them to build and maintain better waste processing infrastructure, such as composting

ISSN: 2455-8834

Volume:10, Issue:10 "October 2025"

plants, biogas facilities, recycling centers, etc. According to a study by the CEEW (Council on Energy, Environment and Water) [9], SBM, the primary reason for the improvement in waste management was due to there being a greater degree of infrastructure in big cities, as well as a better collective attitude towards the importance of waste treatment and processing. Smaller ULBs lack adequate funding, infrastructure, and policy awareness towards waste processing, contributing to their lower scores across the field.

Similarly, source segregation is also more effective in larger, more urban cities due to policy enforcement, incentivization, and greater informational awareness, all underscored by a greater amount of waste output. A report by the CSE (Centre for Science and Environment) [10] states that cities benefitted from dedicated infrastructure, strict compliance systems, bin distributions, and municipal bylaws, which all serve to bolster the local government's segregation efforts. Their model frameworks, as demonstrated in the study, highlight the importance of municipal involvement and robust systems, which larger cities are more equipped to and incentivized to do.

Likewise, both GFC and ODF statuses demonstrated the same pattern in data: UlBs with higher populations have higher GFC and ODF statuses as a direct result of better resource allocation, higher policy awareness and great infrastructure. They also have greater budgets along with better monitoring technology of sanitation facilities. They are, for many of the same reasons mentioned above, consistently higher scoring than their less populous counterparts.

Moreover, ULBs with higher populations also do better when it comes to their Absolute, State and National ranks. This could be attributed to higher municipal revenue, better funding allocation and more robust project implication. Seeing as ranks are in many ways influenced by the cleanliness metrics it could also be concluded that since areas with higher populations scored higher in all the other metrics, then naturally they would score better when it comes to the rank determined by those very metrics.

However, in contrast and being the only exception to these findings are the remediation of dumpsites in these larger cities scores lower than that of their smaller counterparts. This could be effectively attributed to the idea that cities with higher populations deal with a much higher amount of waste as opposed to cities with both lesser waste generation and overall waste management needs. Due to the lower waste volumes and a lesser amount of legacy waste (which refers to aged municipal solid waste in landfills or dumpsites), the dumpsites in smaller cities are easier and quicker to remediate. Due to local authorities in small ULBs having the ability to maintain direct oversight and to act quickly, paired with an exponentially lower amount of waste production, there are fewer procedural delays, which could also be attributed to the fact that there are fewer amounts of relative processes in between waste collection and dumpsite remediation [11].

ISSN: 2455-8834

Volume:10, Issue:10 "October 2025"

5. Conclusion

This comparative study examined the relationship between population size and cleanliness metrics used by the Swachh Survekshan to evaluate ULBs in Madhya Pradesh. The analysis revealed a consistent pattern: ULBs with populations above 15,000, which also tend to be more urban, generally scored higher across key indicators such as source segregation, waste processing, GFC status, and ODF status. The primary exception was the remediation of dumpsites, where smaller ULBs performed better, likely due to their relatively lower volumes of legacy waste. Overall, the findings suggest that larger and more urban ULBs benefit from superior infrastructure, greater financial resources, increased manpower, and higher levels of public awareness, all of which contribute to stronger performance in Swachh Survekshan assessments.

The findings of this study carry several important implications for urban policy and waste management practices. The comparatively weaker performance of smaller ULBs points to the need for targeted policy support, including additional financial assistance, technical expertise, and state-level interventions to overcome structural capacity gaps. At the same time, the relatively poorer outcomes of larger ULBs in dumpsite remediation emphasize the urgency of addressing legacy waste in highly populated cities. Specialized funding, technological innovations, and public–private partnerships could play a crucial role in accelerating such remediation efforts. The results also suggest that infrastructure development and resource allocation should be tailored to the scale of urbanization. Larger ULBs may require advanced and capital-intensive waste processing systems, while smaller ULBs could benefit more from decentralized and cost-effective solutions. Furthermore, since population density appears to be linked with higher awareness and greater manpower for waste management, structured awareness campaigns and capacity-building programs must be extended to smaller ULBs to strengthen participation in segregation and processing practices. Finally, given the consistent advantage observed for more populous ULBs across most cleanliness metrics, it may be worth revisiting the Swachh Survekshan framework to ensure greater equity in evaluation. Adjusting the methodology to account for the structural disadvantages faced by smaller ULBs would make assessments more balanced and inclusive, while also guiding resource allocation more effectively across diverse urban contexts.

While this study provides important insights into if and how population affects cleanliness metrics in ULBs, a few limitations should be considered when interpreting the findings. This study only considers the ULBs of Madhya Pradesh, a consistently high scoring state within Swacch Survekshan, and that which houses the cleanest city in India, Indore. This narrow scope may limit the capability of the results to adequately capture the diversity of urban governance and sanitation outcomes observed across other states. Although the sample size was only one

ISSN: 2455-8834

Volume:10, Issue:10 "October 2025"

state, it was still sufficient to determine consistent patterns in the data seeing as there were upwards of 200 ULBs mentioned. Additionally, the temporal scope is limited to 2023-24. As a result, the observed associations may not reflect longer-term trends, and certain dynamics could be more or less pronounced when examined across multiple years. Despite this constraint, the dataset remains rich and descriptive, offering meaningful insights into patterns of that particular year.

Future research should expand both the spatial and temporal dimensions of the analysis by including ULBs from multiple states with varied performance levels and by extending the analysis across several years. Such work would strengthen generalizability and provide a more detailed understanding of the dynamics between population and cleanliness metrics in the Swachh Survekshan Framework.

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