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The Effect of Population Density on the Level of Public Awareness in 3R-Based Domestic Waste Management: A Study in the Densely Populated Settlements

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Abstract

This study examines the effect of population density on public awareness of 3R-based domestic waste management in Sangkrah Village, Surakarta City, Indonesia. A quantitative cross-sectional survey design was employed involving 100 residents selected through accidental sampling. Data were collected using structured questionnaires and analyzed using descriptive statistics, Pearson correlation, and simple linear regression. The findings indicate that most respondents possess a good understanding of the 3R concept, yet the implementation of recycling practices and participation in waste management activities remain at a moderate level. Statistical analysis shows that population density has no significant effect on public awareness of domestic waste management. The correlation between the variables was extremely weak, indicating that density alone does not determine environmental awareness. These findings suggest that public awareness is more strongly influenced by other factors, including infrastructure, social participation, and institutional support. The study provides empirical evidence for designing more effective urban waste management policies and community-based environmental programs.

INTRODUCTION

Rapid urbanization has become one of the most significant drivers of environmental challenges worldwide, particularly in developing countries where population growth and urban expansion often outpace the capacity of environmental infrastructure and public services. The United Nations projects that nearly 68% of the global population will reside in urban areas by 2050, increasing pressure on natural resources, public facilities, and municipal waste management systems. As urban populations expand, household consumption patterns intensify, resulting in a substantial increase in domestic solid waste generation. Recent studies have demonstrated that unmanaged household waste contributes to environmental degradation, greenhouse gas emissions, public health risks, and declining urban sustainability (Kaza et al., 2021; Ferronato & Torretta, 2022; Wilson et al., 2023). Consequently, improving domestic waste management has emerged as a critical policy priority for achieving sustainable urban development and environmental resilience.

Within the broader framework of sustainable waste management, the 3R concept Reduce, Reuse, and Recycle has gained international recognition as a fundamental strategy for minimizing waste generation and promoting resource efficiency. The 3R approach supports the transition from a linear economy toward a circular economy by encouraging waste prevention, material recovery, and responsible consumption behaviors (Kirchherr et al., 2022; Velenturf & Purnell, 2021). Numerous governments and international organizations have incorporated 3R principles into environmental policies to reduce dependence on landfills and enhance waste valorization. Recent evidence suggests that successful implementation of 3R-based waste management not only reduces environmental burdens but also generates economic opportunities and strengthens community participation in environmental stewardship (Awasthi et al., 2021; Nizami et al., 2023; Akramila et al., 2025; Setiad, 2025).

Despite the increasing emphasis on technological and institutional solutions, scholars have consistently argued that public awareness and behavioral engagement remain the most important determinants of effective household waste management. Environmental awareness influences how individuals perceive waste-related problems, evaluate environmental consequences, and participate in sustainable waste practices. Studies conducted across Asia, Africa, and Latin America reveal that communities with higher levels of environmental awareness are more likely to engage in waste segregation, recycling activities, and waste reduction initiatives (Miafodzyeva & Brandt, 2021; Wang et al., 2022; Nanda & Berruti, 2024). However, awareness alone does not automatically translate into behavioral change. The existence of infrastructural limitations, socioeconomic constraints, and weak institutional support often creates a persistent knowledge–action gap in household waste management practices.

One factor frequently associated with environmental awareness and waste management behavior is population density (Henao-Rodríguez et al., 2024; Abushammala & Ghulam, 2022). Urban ecological theories suggest that densely populated settlements generate larger quantities of waste and experience greater environmental pressures, potentially encouraging residents to develop stronger environmental awareness due to their direct exposure to waste-related problems. Conversely, social disorganization theory argues that high-density environments may weaken collective responsibility and reduce community participation in environmental initiatives. Empirical findings regarding this relationship remain inconclusive. Several studies report that population density positively influences environmental concern and recycling participation because residents are more frequently exposed to environmental externalities (Liu et al., 2021; Zhang et al., 2023). In contrast, other studies indicate that densely populated communities often face overcrowding, limited public space, and inadequate infrastructure, which discourage participation in waste management activities despite high environmental awareness (Yukalang et al., 2022; Kwakye et al., 2024).

The inconsistency of previous findings highlights a significant gap in the literature. Existing studies have primarily focused on the influence of socioeconomic status, education level, environmental knowledge, and institutional support on waste management behavior, while the role of population density remains underexplored and theoretically fragmented (Raab, 2024; Chaiya & Pinthong, 2024). Furthermore, most studies examining household waste management have been conducted in metropolitan cities or national-level contexts, leaving limited evidence from densely populated urban settlements in medium-sized cities of developing countries. Previous research has also predominantly measured waste management outcomes through behavioral indicators such as recycling rates or participation levels, with less attention devoted to understanding how population density influences

environmental awareness as a precursor to behavioral change (Wang et al., 2022; Ferronato & Torretta, 2022).

Another limitation concerns the contextual specificity of existing research. Urban settlements in developing countries often exhibit distinct social, cultural, and infrastructural characteristics that differ substantially from those of developed countries. In Indonesia, rapid urbanization has generated numerous high-density settlements where waste management challenges intersect with socioeconomic vulnerability, limited infrastructure, and environmental risks (Roitman & Rukmana, 2022; Dewi et al., 2023). Surakarta City represents one such context. As one of the fastest-growing urban centers in Central Java, Surakarta has experienced continuous population growth accompanied by increasing domestic waste generation. Within this urban landscape, Sangkrah Village constitutes a particularly relevant case due to its high population density, limited spatial capacity, and persistent waste management challenges. Although local authorities have promoted waste reduction initiatives and environmental awareness programs, the effectiveness of these interventions in shaping public awareness remains insufficiently understood (Etim, 2024)s.

From a theoretical perspective, the relationship between population density and environmental awareness remains contested. Urban ecology perspectives predict a positive association because environmental pressures become more visible in densely populated environments. In contrast, behavioral and institutional perspectives suggest that awareness is primarily shaped by education, social norms, infrastructure availability, and community engagement rather than demographic density alone. The absence of empirical consensus indicates the need for further investigation, particularly in urban settlements characterized by high population concentration and limited environmental infrastructure.

Accordingly, this study aims to examine the influence of population density on public awareness regarding 3R-based domestic waste management in Sangkrah Village, Surakarta City, Indonesia. The novelty of this research lies in its focus on environmental awareness rather than solely waste management behavior, its examination of population density as a potential determinant within a densely populated urban settlement, and its contribution to clarifying competing theoretical perspectives regarding environmental behavior in high-density communities. This study contributes theoretically by extending the discussion on the determinants of environmental awareness within the context of urban waste management. Practically, the findings provide evidence-based insights for local governments and environmental stakeholders in designing more effective waste management policies and community engagement programs. By identifying whether population density influences public awareness of 3R practices, this research contributes to the development of more context-sensitive and sustainable urban environmental governance strategies.

METHODS

Research Design

This study employed a quantitative research design using a cross-sectional survey approach to examine the relationship between population density and public awareness of 3R-based (Reduce, Reuse, Recycle) domestic waste management. Quantitative research is appropriate for investigating relationships among variables through systematic measurement and statistical analysis, enabling researchers to test empirical associations and generate objective findings (Creswell & Creswell, 2023; Saunders et al., 2023). The cross-sectional design was selected because data were collected at a single point in time to capture residents' perceptions, awareness

levels, and waste management practices within a densely populated urban settlement.

Research Setting

The research was conducted in Sangkrah Village, Pasar Kliwon District, Surakarta City, Central Java, Indonesia. Sangkrah Village represents one of the most densely populated urban settlements in Surakarta, covering approximately 0.46 km² with a population of 12,756 residents, resulting in a population density of approximately 27,730 inhabitants per square kilometer. The area consists of six neighborhood associations (Rukun Warga/RW) and twenty-two community units (Rukun Tetangga/RT). The selection of Sangkrah Village was based on its high population concentration, limited environmental carrying capacity, and increasing domestic waste generation, making it an appropriate setting for investigating environmental awareness and community-based waste management practices.

Approach

This study used a quantitative approach with a survey method. Quantitative research is a scientific approach that emphasizes the collection of data in numerical form (Zulfikar et al., 2024). Quantitative research is based on and rooted in the positivist paradigm, where human behavior is studied through observation and reasoning (Su, 2018). This study aims to explore the initial picture of the relationships between variables in Sangkrah Village. The minimum required sample size was calculated using the Cochran formula, with a 10% margin of error due to the large population size. The Cochran formula is commonly used in surveys or cross-sectional studies when researchers estimate a large population (Ahmed, 2024).

Cochran's Formula for Large (Infinite) Populations:

Population and Sampling Procedures

The target population comprised all residents of Sangkrah Village. Sample size determination followed Cochran's formula for finite populations, which is widely recommended for survey-based studies involving large populations (Ahmed, 2024). Using a confidence level of 95%, an estimated proportion of 0.50, and a margin of error of 10%, the minimum required sample size was calculated at 95 respondents. To improve statistical adequacy and anticipate incomplete responses, the final sample size was increased to 100 respondents.

Participants were selected using accidental sampling, a non-probability sampling technique in which respondents are recruited based on accessibility and willingness to participate during the data collection period (Etikan & Bala, 2022). Although this approach facilitates efficient data collection in community settings, the findings should be interpreted cautiously because the sample may not fully represent the characteristics of the entire population.

$$n = \frac{z^2 pq}{e^2}$$

Description:

n = Sample size

z = Confidence level (90% = 1.65; 95% = 1.96; 99% = 2.58)

p = Proportion value obtained from previous research (literature). If the proportion is unknown, the estimated proportion is 50% (0.5)

q = 1-p

e = Estimated error rate (10%)

N = Population size

$$n = \frac{1{,}96\ x\ 0{,}5\ x\ (1 - 0{,}5)}{0{,}1^2}$$

$$n = 96{,}4$$

Correction for Finite Population (Finite Population Correction):

$$n = \frac{n_0}{1 + \frac{n^0 - 1}{N}}$$

$$n = \frac{96{,}4}{1 + \frac{96{,}4 - 1}{12.756}} n = \frac{96{,}4}{1 + \frac{95{,}4}{12.756}} n = \frac{96{,}4}{1 + 0{,}00745} = \frac{96{,}4}{1{,}00745} = 95{,}3$$

Based on calculations using the Cochran formula with a finite population correction, a sample size of 95 respondents was obtained. However, in research practice, it is often recommended to round the sample size to a more accessible and safer number, 100 respondents, to anticipate the possibility of non-response. The calculation results indicate that for smaller populations, the number of subjects (sample size) can be smaller to provide researchers with sufficient confidence in their findings (Ionas, 2019). The data collection technique in this study was a questionnaire collected using the accidental sampling method. Accidental sampling is a sampling technique in which subjects are selected based on ease of access, such as people encountered by chance (Subhaktiyasa, 2024). However, the accidental sampling technique has a drawback: the sample obtained may not represent the characteristics of the entire population (Fauzy, 2022). Therefore, the findings of this study need to be interpreted with caution, especially when generalizing to the entire population of Sangkrah Village or other densely populated areas.

Quantitative data calculations and analysis techniques were performed statistically using MiniTab statistical software (Sofwatillah et al., 2024). To examine the relationship between population density and public awareness of 3R-based domestic waste management, we used the Pearson correlation test to measure the strength and direction of the linear relationship, and simple linear regression analysis to identify the effect of one variable on another.

RESULTS AND DISCUSSION

This section presents the empirical findings of the study regarding the relationship between population density and public awareness of 3R-based domestic waste management in Sangkrah Village, Surakarta City. The findings are organized into four main components. First, the characteristics of respondents and perceptions of settlement density are presented to provide contextual understanding of the study area. Second, the level of public understanding of the 3R concept and the implementation of recycling behavior are examined. Third, community participation in waste management activities is analyzed. Finally, statistical analyses, including Pearson correlation and simple linear regression, are reported to assess the relationship between population density and public awareness of domestic waste management. All data presented in this section were obtained from questionnaire responses collected from 100 residents of Sangkrah Village and analyzed using Minitab statistical software.

Condition of Sangkrah Village Settlement

The condition of settlements in Sangkrah Village was determined through community perceptions of the densely populated environment in which they live, using a scale of 1-5, with 1 = strongly disagree and 5 = strongly agree. Densely

populated settlements are residential areas lacking green open spaces, with very high building and population density (Maharani et al., 2022).

The analysis showed that cumulatively, 68% of respondents gave a score of 4 or 5, indicating that the majority of residents felt they lived in a densely populated environment. Nine percent of respondents gave a score below 3, indicating that their neighborhood was not densely populated. Meanwhile, 23% of respondents gave a score of 3, indicating a neutral perception, indicating that community perceptions were still relative or situational.

Respondent Characteristics

This research was conducted by distributing questionnaires directly and online to residents in Sangkrah Village regarding the level of public awareness in managing 3R domestic waste, this study requires 100 respondents with various age ranges (Artham, 2020). This study uses a survey questionnaire with a Google Form application that is distributed in two ways, namely direct interviews on location and distributing through social media for those who live in Sangkrah Village. After collecting the data, I processed it using Excel and MiniTab, which later the respondents will be a sample representing the population of this study, an overview of the respondents who will be used as research samples is taken based on gender characteristics and age range.

Gender

The first characteristic of respondents is their categorization by gender. The sample is categorized by male and female, as shown in the following table.

Table 1. Respondent Characteristics by Gender

Gender	Total	Presentation
Male	32	32%
Female	68	68%

Source: Primary Survey Data, 2025

Based on Table 1 above, it can be seen that the majority of respondents in this study were female. Women made up 68%, or 68 people, of those who completed the questionnaire. Conversely, men made up 32%, or 32 people. This finding suggests that women have a greater understanding and awareness of domestic waste management, particularly among housewives. This difference is also influenced by the use of accidental sampling as a data collection technique, which is also based on ease of access during interviews (Artham, 2020).

Age

This study involved 100 respondents with a diverse age range between 12 to 76 years, based on descriptive analysis, the following statistical values were obtained.

Table 2. Statistical Results of Respondents by Age

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Age (Example: 20)	100	0	36.98	1.62878	16.2878	12	22	35	51.75	76

Source: Primary Survey Data, 2025

Based on Table 2 above, the average age (mean) is 37 years, with a minimum age of 12 years and a maximum age of 76 years. The age distribution of respondents obtained from the interview survey results varies widely, spanning from young people to the elderly. This suggests that perceptions of 3R waste management may be influenced by age. Most respondents aged 22-52 (Q1 and Q3) are in the productive

age group, or descriptively, the most active in social activities and have relatively good access to information (Soetanto, 2017). The data in Table 2 above also shows the standard deviation, indicating age variation, which can provide an opportunity for further analysis to determine whether certain age groups may influence the level of awareness or active participation in 3R practices compared to others.

Respondents in this study were then categorized by age range. Respondents were divided into 12-20 years, 21-30 years, 31-40 years, 41-50 years, and over 51 years. The following table shows respondent characteristics by age range.

Table 3. Respondent Characteristics by Age

Age	Total
>12-20	19
21-30	22
31-40	19
41-50	14
>50	26

Source: Primary Survey Data, 2025

Based on table 3 above, it can be seen the number of each respondent from various age ranges, with the result that the age group >50 years dominates in filling out the survey, while the age group 41-50 years has the least contribution in filling out the survey. Based on the table it can also be seen that the level of awareness and understanding of 3R domestic waste management and the level of participation in implementing waste management cannot be measured only through the level of age maturity, although the table above shows that the majority of respondents are in the age range >50 years, it is certainly the presence of other driving factors, for example knowledge of domestic waste and 3R management, individual level of awareness, individual initiative in managing waste (Wang te al., 2017).

Public Understanding of the 3R Concept

One objective of the study was to assess residents' understanding of the principles of Reduce, Reuse, and Recycle. Respondents evaluated their level of understanding using a five-point scale ranging from very poor understanding (1) to very good understanding (5).

Table 4. Understanding of 3R

Scale (1–5)	Count	Percent (%)	Cumulative Percent (%)
1	14	14.0	14.0
2	18	18.0	32.0
3	14	14.0	46.0
4	39	39.0	85.0
5	15	15.0	100.0
Total (N)	100		

Source: Primary Survey Data, 2025

The results indicate that respondents generally possessed a relatively good understanding of the 3R concept. The largest proportion of respondents (39%) selected scale 4, while an additional 15% selected scale 5. Combined, 54% of respondents reported high levels of understanding regarding waste reduction, reuse, and recycling practices.

However, approximately 32% of respondents selected scales 1 or 2, indicating limited understanding of the 3R framework. This variation suggests that awareness

campaigns and environmental education programs may not yet have reached all segments of the community equally.

Implementation of Recycling Behavior

The study also measured the extent to which residents practiced waste recycling activities in their daily lives. Responses were measured using a five-point frequency scale ranging from never (1) to very often (5).

Table 5. Implementation of Waste Recycling

Scale (1–5)	Count	Percent (%)	Cumulative Percent (%)
1	16	16.0	16.0
2	21	21.0	37.0
3	31	31.0	68.0
4	22	22.0	90.0
5	10	10.0	100.0
Total (N)	100		

Source: Primary Survey Data, 2025

Table 5 shows that the largest proportion of respondents (31%) reported a moderate level of recycling behavior (scale 3). Respondents reporting high or very high recycling practices (scales 4–5) accounted for 32%, while 37% reported low levels of recycling activity (scales 1–2).

The findings indicate that although knowledge of the 3R concept is generally adequate, the practical implementation of recycling behavior remains moderate. Most residents appear to engage in recycling activities occasionally rather than consistently.

Community Participation in Waste Management Activities

Community participation represents an important dimension of household waste management. Participation was measured through involvement in activities such as waste sorting, waste bank programs, recycling initiatives, and environmental awareness campaigns.

Table 6. Waste Management Participation

Participation in waste management activities	Count	Percent	CumPct
1	19	19,00	19,00
2	21	21,00	40,00
3	22	22,00	62,00
4	29	29,00	91,00
5	9	9,00	100,00
N =	100		

Source: Primary Survey Data, 2025

As shown in Table 6, the largest proportion of respondents (29%) reported relatively high participation levels (scale 4). Respondents indicating moderate participation (scale 3) accounted for 22%, while 40% reported low participation levels (scales 1–2). Only 9% of respondents indicated very high participation in waste management activities.

These findings suggest that community involvement in waste management initiatives remains uneven. While a substantial proportion of residents participate actively, a considerable number of households still demonstrate limited engagement in environmental programs.

The relationship between population density and the level of public awareness in managing domestic waste based on 3R

The analysis in this study was conducted using a correlation test using the Pearson correlation method with MiniTab software. The Pearson correlation test is used to measure the strength and direction of the linear relationship between two variables assumed to have a normal distribution (Figures 1 and 2). The results of the correlation test between the variables Population Density and Public Awareness Level in 3R-Based Domestic Waste Management indicate that there is no significant relationship between the two.

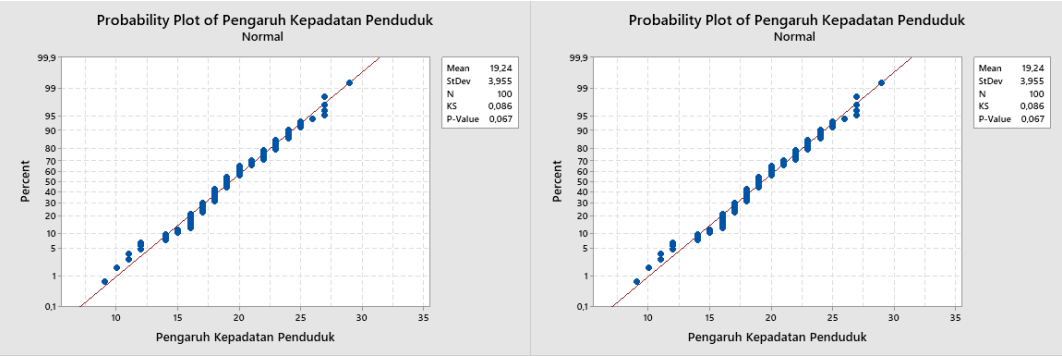

Figure 1. Normalitas

Source: Primary Survey Data, 2025

This is indicated by the P-value of 0.958 (Figure 3), which far exceeds the significance limit of 0.05. Referring to the Statistics book (Septin, 2023), a correlation value of 0.005 (Table 4) falls into the category of very weak correlation, or almost no correlation. Therefore, it can be concluded that population density has no significant relationship with the level of public awareness of 3R-based domestic waste management. Although there is no direct linear relationship between population density and 3R awareness, the interpretation of these results requires further study, possibly taking into account demographic factors.

Tables 2 and 3, considering age, can examine the relationship. When the correlation test data (Figures 1 and 2) are compared by age group, it is found that respondent participation is dominated by the productive age group, particularly those aged 21-30. However, not all age groups show the same level of participation or awareness of 3R. In several groups in the age range as seen in Table 3, respondents from the 41-50 years and >50 years age groups may potentially have different perceptions and habits in managing waste due to several factors, for example, experience factors, habitual values, and understanding of exposure to environmental information (Soetanto, 2017).

Correlation Between Population Density and Public Awareness

Prior to conducting inferential analysis, normality assessments indicated that the variables satisfied the assumptions required for Pearson correlation analysis. The relationship between perceived population density and public awareness regarding 3R-based domestic waste management was subsequently examined.

Table 7. Effect of Population Density

Variable	Correlation Coefficient (r)
Level of Public Awareness	0.005

Source: Primary Survey Data, 2025

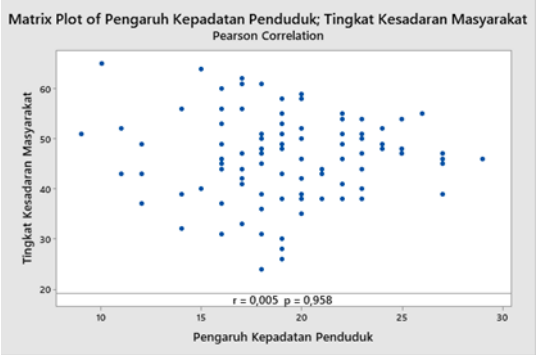

Figure 2. Pearson Correlation

Source: Primary Survey Data, 2025

In this study, we conducted a simple linear regression analysis between population density scores and the level of public awareness of 3R-based domestic waste management. Regression analysis was conducted to detect the relationship between the two variables (Astuti, 2023). In the regression analysis conducted between the two variables, although there was no significant relationship between density and public awareness, it does not immediately mean that population density has no effect at all. A very weak correlation statistically only indicates the context of the analyzed data. However, in direct field research, the two variables can have a variable relationship when viewed from each individual's perspective regarding their level of awareness of their household waste.

Table 8. Regression Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	45,88	4,26	10,76	0,000	
The Effect of Population Density	0,011	0,217	0,05	0,958	1,00

Source: Primary Survey Data, 2025

The results of regression analysis also extend the evidence presented that the population density does not take a central role in determining the public knowledge on 3R-based domestic waste management. The p-value corresponding to the population density variable is p = 0.958, the regression coefficient is 0.011. The effect is not significant since the p value represents more than the standard significance level (q = 0.05). Therefore, population density differences do not make a significant change in predicting differences in the degree of awareness of the citizens in relation to waste managements practices. It suggests that other determinants e.g. ease of access to infrastructure, provision of waste management, or community activities are probably more decisive in determining levels of awareness than density in itself.

Bridging the Knowledge Action Gap in 3R Waste Management

Based on the current research, the population density is not sufficiently connected to the magnitude of community awareness on the subject of a 3R-based domestic waste management in Sangkrah Village in terms of a statistically significant correlation. Such a finding makes the usual assumption that the density of population automatically takes a certain influence over environmental awareness and waste management behaviour among urban communities difficult to withhold. The Pearson correlation coefficient r 0.005, and the non-significant p-value 0.958 were observed, which serves to demonstrate a very weak relationship between these variables and the fact that factors other than the density in isolation influence public attitudes and practices concerning 3R waste management to a large degree.

An interesting inference of the discovery is the disparity between knowing and practicing. Although most of the respondents reveal sufficient conceptual knowledge of the 3R framework, the practical level is middle. Such incongruence is reminiscent of the so-called gap between knowledge and action as addressed at length in environmental behaviour literature (Hutabarat et al., 2015). It can be supported by empirical studies that have found that, even though awareness efforts can lead to improved levels of conceptual understanding, this does not necessarily manifest into a change in behaviour, unless a fully developed infrastructure, incentive programmes, and socially-established norms are also present (Rahman et al., 2020; Fitriansyah et al., 2020). The current statistics thus indicate that population density in Sangkrah Village is not the biggest obstacle; institutional limitations, such as insufficient waste management facilities and governmental and waste-recording mechanisms are more decisive.

A further clue comes with comparative analysis to related studies. Case studies were conducted on Cicadas Village, Bandung, and factors such as low scores of 3R practise with high population density were found to be largely affected by socio-economic statuses and poor infrastructure. Cumulatively, these insights reveal that despite the possible correlation between population density and the level of public awareness in various contexts, other structural factors are bound to become the key determinants in driving the change in waste management behaviour, especially within the urban communities (Fitriansyah et al., 2020). Ompusunggu et al. (2025) argue that the failure to manage household waste depicts a more robust correlation with health conditions and infrastructural deficiencies as compared to population density. Such comparisons are important to explain that urban waste management is multi-dimensional, with awareness, infrastructure, and socio-economic pressures co-shaping the outcomes.

Another essential aspect is the contribution of demographical variables and especially age and sex. The current research observation suggests that the target respondents are mostly women, which is an essential practice of housewives in domestic waste. This gender disparity conforms to the study conducted by Hutabarat et al. (2015) that noted that women have a larger burden when it comes to waste management and through that, women exert an influence on levels of awareness. Age is also an important factor: respondents of the productive age category (21-50 years) have shown a slightly higher awareness and engagement and the respondents who are older respondents have further established existing habits that might inhibit their behavior change. The results indicate that intervention strategies should be demographically-oriented, and the focus of the campaign be aware of intergenerational disparities in knowledge gains, information access, and daily schedules (Soetanto, 2017).

Theoretically, the finding that density and awareness are not strongly related calls the ecological assumption that higher density must worsen the waste behavior by lack of space and larger waste production, under the urban setting. Rather, the findings speak to behaviorism-infrastructure models, which focus on the idea that the mediators of awareness are the enabling conditions and social capital, and not density in and of itself (Damanhuri et al., 2009). Such an orientation promotes combined socio-environmental scaffolding in which institutional provision, cultural norms and what is commonly termed collective efficacy are deployed to explain awareness and practice per 3R waste management.

Despite the useful impact that the current study has on global knowledge in the field of household waste production and disposal preferences within high-density urban environment, several limitations can be mentioned. To begin with, the applications of accidental sampling might have been biased, specifically, by providing excessive representation of the female and elderly population, which might have framed the

supposed generalisability. Second, cross-sectional design elicits perceptions at one point in time, thus it is inimical to knowledge about the dynamics of awareness and change in behaviour over time. Third, the research is conducted based on self-reported questionnaires, which makes it vulnerable to social desirability bias since respondents might overreport awareness and their participation rates in order to fit the socially desirable standard. These shortcomings highlight the need in future research to utilize sampling methods of greater strength, utilize longitudinal designs, and ensure that mixed methods approaches allow a combination of survey and direct observation of the behavior of those generating household waste.

These results imply two things. The first is operational; in policy directions in Surakarta and other striking city conditions, shifting can no longer proceed with a concentration on minimizing density and urban planning; rather urban policy should seek to reinforce rubbish management processes. Direct promotion of the behavioural change is possible through concrete interventions like the adequate availability of waste bins, guarantees constant collection, and the creation of waste banks. In complement, the design of public education campaigns should not only aim at informing, but also at motivating behaviours such as waste sorting based on economic incentives (such as recycling programs). The engagement of local leaders and the community based organisations might even strengthen the participation because it creates collective responsibility. The study contributes theoretically to the body of urban environmental studies research by showing that density as a variable is not enough to be explanatory to waste awareness and behaviour in urban studies. Instead, awareness has to be examined along with socio-economic, cultural, and institutional contexts. This observation is a challenge to reductionist notions and in favor of more holistic environmental policy and planning.

CONCLUSION

Based on the results of research in the densely populated settlement of Sangkrah Village, Surakarta City, it can be concluded that although the community has a good level of understanding regarding the 3R concept (Reduce, Reuse, Recycle), the implementation of waste recycling behavior in the field is still quite adequate. This indicates a gap between knowledge and real actions. Furthermore, analysis using the Pearson correlation test and simple linear regression revealed that population density does not have a significant relationship with the level of community awareness in 3R-based domestic waste management. With a very high P-value (0.958) and a very weak correlation coefficient (0.05), it can be statistically concluded that population density is not the main determining factor for the high or low level of community awareness in domestic waste management.

Therefore, efforts to increase community awareness and participation in 3R-based waste management in densely populated areas such as Sangkrah Village need to focus more on other more influential factors, such as the provision of adequate infrastructure, more intensive and attractive socialization programs, and strong community support.

Suggestion

Improve waste management facilities, such as separate bins (organic and inorganic) in various strategic locations, and increase the number of waste collection vehicles to make the collection process more efficient. Conduct ongoing public awareness campaigns based on the 3Rs (Reduce, Reuse, Recycle). This outreach can be conducted through various media and community activities to increase public awareness and participation in waste reduction.

Establish a waste bank community in each neighborhood unit (RW). This program will encourage people to sort and exchange waste for economically valuable waste,

while simultaneously creating a clean environment. The government needs to ensure a regular and periodic waste collection schedule from house to house. This will help maintain environmental cleanliness and prevent waste accumulation.

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