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Perspectives and Socioeconomic Influences of Personal Protective Equipment Waste Management on Post-COVID-19

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Abstract

The COVID-19 pandemic brought an upsurge in Personal Protective Equipment (PPE) usage, leading to emergent challenges in its post-use management, especially in urban centers like Jakarta. This study conducted a quantitative exploration, employing simple random sampling techniques, to investigate Jakarta citizens; perceptions of PPE waste management. Two significant factors, "Safe Management and Regulation" and "PPE Waste Handling," were identified as paramount in addressing the issue. Through cluster analysis, the population was segmented into three distinct clusters: "Regulatory-Driven Safety Respondents," "Operational PPE Focus Respondents," and "Minimal Management Respondents." The study also unveiled a notable influence of socioeconomic variables on PPE waste management attitudes, particularly occupancy and income. These findings give policymakers, urban planners, and researchers invaluable insights, emphasizing the need for a dual-focused approach encompassing regulatory and operational strategies tailored to specific demographic segments for optimal impact.

INTRODUCTION

In the face of unprecedented global challenges, the importance of understanding and implementing sustainable practices has never been more pronounced. The world, propelled by the stark realities of climate change, diminishing natural resources, and rampant urbanization, is swiftly transitioning towards sustainable frameworks (Khan, 2022; Suryawan & Lee, 2023). One such pressing issue is the management of Personal Protective Equipment (PPE) waste, which has surged significantly due to the global pandemic of COVID-19 (Ardusso et al., 2021; De-la-Torre et al., 2021; Sari, Inoue, et al., 2022). With millions using single-use PPE daily, the ramifications on waste management and environmental health have been profound (Haque et al., 2021).

Jakarta, Indonesia's bustling capital, exemplifies the challenges and complexities of managing such waste, especially in dense urban settings (Husen & Samadi, 2021; Suryawan & Lee, 2023). As a metropolis known for its cultural diversity, economic significance, and rapid development, Jakarta grapples with waste management and environmental sustainability

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challenges. The recent influx of PPE waste adds to the existing problem, posing severe threats to its environment, public health, and urban infrastructure. The management of PPE waste, if not addressed strategically, can exacerbate existing challenges such as land scarcity for landfills, environmental degradation, and public health concerns (Kulkarni & Anantharama, 2020; Sari, Yosafaat, et al., 2022). Furthermore, the narrative of waste management transcends mere logistics and taps into deeper societal dimensions. Public perceptions, knowledge, and attitudes towards sustainability play a pivotal role in the success or failure of any waste management strategy (Debrah et al., 2021; Soares et al., 2021). Historically, sustainability issues, including waste management, have been approached with a top-down strategy, predominantly driven by regulations and directives. However, for long-lasting and holistic solutions, the involvement and perspectives of the community are paramount.

While the importance of PPE in combating the spread of COVID-19 has been well-documented in the literature (Ammendolia et al., 2021; Patrício Silva et al., 2021; Rhee, 2020), there needs to be more studies focusing on the post-use management of these essential tools, especially in densely populated urban areas like Jakarta. Current research primarily emphasizes the medical and preventive aspects of PPE (Atthar et al., 2022; Haji et al., 2020), with little attention given to the environmental and logistical challenges posed by their disposal. Moreover, as urban centers continue to grapple with the challenges posed by waste management, the sudden influx of PPE-related waste further complicates these issues. The specific challenges PPE waste poses, environmental implications, and potential health risks if not adequately managed remain underexplored in (Septiariva et al., 2022). The influence of socioeconomic factors on PPE waste management practices and perspectives remains an area ripe for exploration. Understanding these influences can help craft more effective, targeted interventions and policies for improved waste management in the future. The primary aim of this study is to delve into the perspectives and practices related to PPE waste management post the Covid-19 pandemic in Jakarta. As the capital city of Indonesia and a major urban center, Jakarta has witnessed a surge in PPE usage due to the pandemic, making PPE waste management a significant concern for public health and environmental sustainability. Specifically, the study seeks to identify the factors influencing these practices, evaluate their relative importance, and segment the population based on their attitudes and practices towards PPE waste management using cluster analysis.

METHOD

This study illuminates the pertinent PPE domestic waste management issue within Jakarta, Indonesia's bustling capital city. Drawing from a robust quantitative methodology, the research endeavors to harness insights from the student population, a segment pivotal in shaping the future trajectories of sustainability practices. This study followed a systematic and robust quantitative approach, beginning with a thorough literature review. The aim was to identify previous methodologies, interventions, and practices related to PPE waste management, especially in similar urban contexts. The gathered insights from the literature laid the foundation for framing the research methodology and tailoring the questionnaire to the unique context of Jakarta. Jakarta is a testament to the confluence of traditions, cultures, and rapid urbanization, as captured in Figure 1.

This sprawling metropolis on Java's northwest coast offers a canvas rich in diversity and perspectives, making it a strategic choice for this research. Given the city's sheer scale and demographic intricacies, the methodology adopted ensured inclusivity and representation. It led to the adoption of a two-pronged approach for data collection, entailing a combination of digital platforms like Google Forms and traditional face-to-face interviews. This hybrid methodology catered to the diverse preferences of Jakarta's residents. It ensures that the study captured a comprehensive cross-section of the population. Simple random sampling was employed to emphasize the elimination of biases, especially during participant selection. In research, biases can significantly alter outcomes, often leading to skewed conclusions.

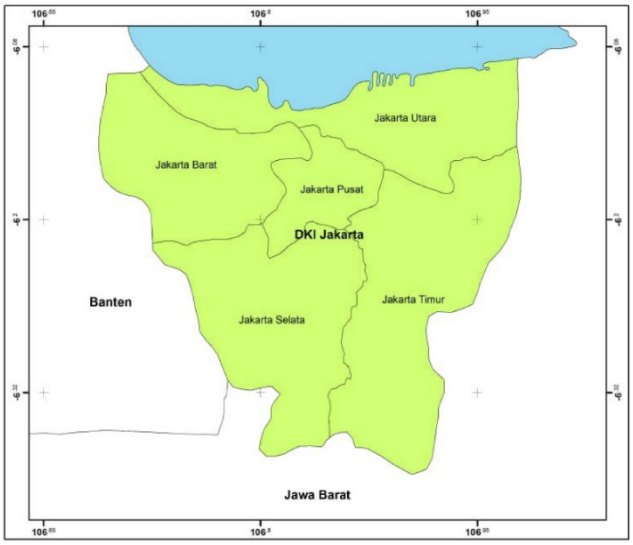

FIGURE 1. Study Location (Suryawan *et al*., 2023)

The beauty of simple random sampling lies in its egalitarian approach, wherein every individual within the population has an equal probability of being chosen. This approach is especially crucial for a city as demographically intricate as Jakarta. To ensure that the sample size was statistically valid and representative, Slovin's equation was put into play. Therefore, this study encapsulated the views and insights of 529 respondents, making them symbolic of Jakarta's broader student cohort.

The structured questionnaire played a pivotal role in the data collection process (Table 1). Divided into distinct sections, the questionnaire captured vital demographic details of the respondents and delved deep into their perspectives, understanding, and practices related to PPE waste management. The choice of a 5 Likert scale facilitated the nuanced capture of respondents' sentiments, allowing them to express their agreement or disagreement with specific statements (Suryawan et al., 2023; Sutrisno et al., 2023). The scale's versatility and widespread acceptance in social research made it apt for this study. Drawing inspiration from global paradigms and comparing with literature such as (Rahmalia et al., 2022; Ranjbari et al., 2021), the study aimed to not only understand the technicalities of PPE waste management but also to dive deep into the socio-cultural and emotional facets of the issue. Engaging with these dimensions, especially in an educational context, cannot be overstated. As educational institutions are hubs for future change-makers, ensuring that the ethos of sustainable waste management is ingrained early on is of paramount importance.

Data was processed and analyzed using SPSS, a statistical software in social research. Initial steps included cleaning the data and removing any incomplete or incongruent responses. Subsequent steps included descriptive statistics, such as frequency distributions and measures of central tendency, to gauge the initial patterns and trends in the data. Factor analysis was then employed to identify latent variables that underpin student perspectives on sustainability. Factors were extracted using the principal component method, and the rotation method chosen was Varimax with Kaiser normalization. Eigenvalues higher than one were considered significant. The suitability of the data for factor analysis was verified through the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity. A KMO value greater than 0.6 and a significant Bartlett's test are typically deemed acceptable for factor analysis. Once the underlying factors were discerned, a reliability test, specifically Cronbach's alpha, was conducted to gauge the consistency of the items within each factor (Suryawan et al., 2023).

Subsequent to factor analysis, a cluster analysis was employed to group the respondents based on their perspectives on PPE waste

TABLE 1. Indicators and Questions in Questionnaire

No	Keywords	Question
1	Containment of PPE waste	In my opinion, the containment of PPE waste at home should be separated from other garbage because PPE waste is infectious.
2	Treatment with disinfectants	I believe that PPE waste at home should be treated with disinfectants to protect it from viruses.
3	Destruction of PPE waste	I believe PPE waste at home should be destroyed to prevent reuse.
4	Collection by officials	I think officials should collect PPE waste and manage it in places separate from other domestic waste (food waste, paper, garden, etc.).
5	Provision of waste management facilities	I believe the government should provide domestic PPE waste management facilities, such as PPE waste banks, PPE 3R temporary disposal sites, and waste collection companies.
6	Treatment following regulations	I think treating PPE waste should follow the applicable regulations, such as disinfection, incineration, pyrolysis, or autoclaving.
7	Public awareness campaigns	I believe the government needs to conduct socialization regarding safe PPE waste management.
8	Government regulations	I think the government needs to create regulations/policies on the limitation and safe management of disposable PPE use.
9	Provision of PPE waste bins in public places	In my opinion, the government needs to provide specific PPE waste bins in public places/facilities.
10	Action against illegal disposal	I believe the community/government needs to take quick action regarding the illegal disposal of PPE waste, such as dumping in open land, rivers, or the sea.

management. The hierarchical method was chosen for the clustering process, which began with each case being a single cluster and ended when all cases were combined into one overarching cluster. A dendrogram, a tree-like diagram, was employed to showcase the clustering process and determine the optimal number of clusters. Once the clusters were finalized, each cluster's characteristics were analyzed and interpreted based on the factors derived from the factor analysis.

RESULTS AND DISCUSSION

Table 2 provides a factor analysis of PPE management strategies implemented after the Covid-19 pandemic. Two principal components emerged, highlighting the primary focus areas in managing PPE waste. From a statistical perspective, the Eigenvalues for both factors are above the typical threshold of 1, indicating their significance in explaining the variance in the data. Factor 1 has an Eigenvalue of 2.180, which denotes its higher variance than Factor 2, with an Eigenvalue of 1.194. In terms of the percentage of variance explained, Factor 1 accounts for 20.533%, whereas Factor 2's contribution is slightly less. While Cronbach's Alpha for both factors is around 0.5, suggesting moderate reliability, it is essential to consider that values acceptable reliability coefficients of 0.4 to 0.8 are generally more desirable for greater internal consistency (Ekolu & Quainoo, 2019).

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy stands at 0.703. Typically, a KMO value above 0.6 is considered adequate, suggesting that the sample is suitable for factor analysis. Bartlett's Test of Sphericity further confirms the appropriateness of the factor analysis, with a significant value (Sig. = 0.000). The test's significance implies some relationships between the variables, and it is appropriate to proceed with the factor analysis. The first factor, termed 'Safe Management and Regulation,' underscores the importance of regulation and structured mechanisms to ensure the safe disposal and handling of PPE waste. This factor encompasses the

TABLE 2. Factor Analysis Results for PPE Management Post-Covid-19

Indicators	Components		Eigenvalue	% of variance	Cronbach's Alpha
	1 = Safe Management and Regulation	2 = PPE Waste Handling			
Destruction of PPE waste	0.791		2.180	21.647	0.5
Provision of waste management facilities	0.608				
Government regulations	0.554				
Treatment in accordance with regulations	0.538				
Containment of PPE waste		0.660	1.194	20.533	0.5
Collection by officials		0.616			
Public awareness campaigns		0.542			
Treatment with disinfectants		0.537			
KMO and Bartlett's Test					
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.703				
Bartlett's Test of Sphericity	361.658				

"Destruction of PPE waste," which is crucial to prevent any secondary contamination and the virus's possible spread. It also comprises the "Provision of waste management facilities," ensuring that adequate and specialized facilities are available for PPE waste disposal.

Furthermore, this factor emphasizes the importance of "Government regulations" in guiding and setting standards for PPE waste management. Lastly, the "Treatment following regulations" points to the adherence and execution of set guidelines in treating PPE waste. The second factor, 'PPE Waste Handling,' leans more towards the processes and measures involved in treating and handling PPE waste. It begins with the "Containment of PPE waste," which is the first step in ensuring that PPEs don't pose a risk to the environment or public health. The "Collection by officials" denotes a structured collection mechanism, likely with trained personnel to minimize the risk of contamination. "Public awareness campaigns" within this factor emphasize the role of information dissemination and ensuring that the general public is aware of proper PPE disposal methods. Finally, "Treatment with disinfectants" highlights the importance of treating PPE waste to eradicate pathogens.

Regarding "Safe Management and Regulation," previous research by (Salim et al., 2019; Ulhasanah & Goto, 2018) emphasized the integral role of stringent government regulations in maintaining the integrity of waste management systems. They underscored that safety protocols can often be overlooked without clear rules and consistent enforcement, leading to environmental and public health risks. (Nwedu, 2022) essence suggested that managing hazardous waste, including PPE, is only as robust as the regulatory framework supporting it. Our findings concur with this perspective, as the factor demonstrates respondents' weight on

TABLE 3. Cluster Analysis and Classification of Respondent Perspectives

Factor	Clusters			Mean Square	df	F	Sig.
	1	2	3				
Safe Management and Regulation	2.24	-4.598	-4.126	162.357	526	420.096	0.000
PPE Waste Handling	-1.494	2.185	-3.442	109.839	526	187.385	0.000
	Regulatory-Driven Safety	Operational PPE Focus	Minimal Management Approach				

regulations and their proper implementation, especially in the aftermath of a health crisis like COVID-19. On the other hand, "PPE Waste Handling" encapsulates the operational aspect of PPE management. In a study by (Sari, Inoue, et al., 2022; Sari, Yosafaat, et al., 2022), the significance of proper PPE waste containment, collection, and treatment was brought to the forefront. (Fam et al., 2018; Leuders et al., 2022) highlighted that irrespective of the strength of the overarching regulatory framework, if the actual waste handling practices are subpar, it can lead to severe ramifications. They stressed community engagement, public awareness campaigns, and the importance of using disinfectants and other treatments to ensure that PPE waste does not become a source of secondary contamination. Our study resonates with these sentiments, as this factor underscores respondents' prioritization of PPE waste management's tangible, ground-level operations

In comparing our findings with these literary benchmarks, it becomes evident that while regulatory and operational facets are crucial, they cater to different aspects of the PPE management continuum. The "Safe Management and Regulation" factor parallels the top-down approach (Aung et al., 2019; Chartier, 2014) advocated, emphasizing governmental oversight. In contrast, the "PPE Waste Handling" factor aligns more with the bottom-up strategy highlighted by (Anderson et al., 2019; Sekarningrum et al., 2020), underscoring community involvement and awareness. Table 3 presents a cluster analysis that segments the data into three distinct clusters based on their approach to PPE management: Regulatory-Driven Safety, Operational PPE Focus, and Minimal Management Approach. The Regulatory-Driven Safety cluster aligns closely with the "Safe Management and Regulation" factor. This suggests that entities or individuals in this cluster adhere stringently to the regulatory guidelines laid out for PPE disposal and management. Their primary emphasis is ensuring that PPE waste is destroyed effectively and treated by official guidelines. They also value adequate waste management facilities and consider government regulations a cornerstone of effective PPE management. A notable 52.7% (or 279 respondents) fall under this category, making it the most prevalent approach in the dataset.

The Operational PPE Focus cluster centers more on the "PPE Waste Handling" factor. Entities in this cluster prioritize the actual hands-on processes involved in treating and handling PPE waste. They ensure the containment of PPE waste, have structured collection mechanisms (most likely with trained personnel), and invest in public awareness campaigns to spread the message of proper PPE disposal. Their strategies also incorporate treating PPE waste with disinfectants to mitigate any risks associated with pathogens. This approach was adopted by 43.7% (or 231 respondents) of the sample. The last cluster, the Minimal Management Approach, presents a challenge. Entities in this cluster do not show a

TABLE 4. Socioeconomic Variable Influence on Respondent Clusters

Socio-demography		Regulatory-Driven Safety Respondent		Operational PPE Focus Respondent		Minimal Management Respondent	
Age	20-29	164	31.00%	128	24.20%	13	2.46%
	30-39	88	16.64%	86	16.26%	5	0.95%
	>39	27	5.10%	17	3.21%	1	0.19%
	LLR = 3.252, df=4, pvalue=0.517						
Higher Education	Senior high school and below	125	23.63%	98	18.53%	6	1.13%
	Bachelor's degree and above	154	29.11%	133	25.14%	13	2.46%
	LLR = 1.392, df=2, pvalue=0.490						
Occupancy	Formal	217	41.02%	202	38.19%	9	1.70%
	Non-Formal	62	11.72%	29	5.48%	10	1.89%
	LLR = 19.425, df=2, pvalue=0.000						
Income	< IDR. 5.000.000	69	13.04%	30	5.67%	13	2.46%
	IDR. 5.000.000-IDR.10.000.0000	109	20.60%	102	19.28%	4	0.76%
	IDR. 10.000.001-IDR.15.000.0000	83	15.69%	83	15.69%	2	0.38%
	> IDR.15.000.0000	18	3.40%	16	3.02%	0	0.00%
	LLR = 33.411, df=6, pvalue=0.000						

positive inclination towards either of the factors, "Safe Management and Regulation" or "PPE Waste Handling." It suggests a potential laissez-faire approach towards PPE management or a lack of resources or awareness. Fortunately, this cluster represents a small fraction of the sample, with only 3.6% (or 19 respondents).

Table 4 encompasses demographic indicators such as age, higher education, occupancy (formal vs. non-formal), and income brackets. A likelihood ratio (LLR) test is used to determine if there's a significant association between the response categories and the variable of interest. Starting with occupancy, the analysis reveals a significant association with the variable of interest. An LLR value of 19.425 and a p-value of 0.000 (with 2 degrees of freedom) indicates a strong association, meaning that the occupancy type (whether formal or non-formal) notably impacts the outcome variable. It could imply that respondents' living arrangements or housing type significantly influence their perspectives or behaviors. Next, the Income variable also displays a substantial association. The p-value of 0.000 (with 6 degrees of freedom) solidifies the influence of income on the variable of interest. The different income brackets specified (ranging from below IDR. 5.000.000 to above IDR.15.000.000) show variances in the outcome variable. The LLR value of 33.411 further confirms the strength of this association. It suggests that financial capacity or economic standing significantly influences behavior or perspective. Contrastingly, the table does not indicate significant associations between age and higher education with the outcome variable, suggesting that these factors might not play a determinative role in influencing the variable of interest in this study.

In understanding the cluster divisions within PPE management post-COVID-19, the nuances in people's behaviors, and the influence of socio-demographic factors, we can draw comparisons to past literature on waste management behaviors and patterns. The Regulatory-Driven Safety Respondent cluster resonates with the findings from a study by (Gollakota et al., 2020), where participants were inclined to adhere to waste management

practices when there was a clear regulatory framework. This adherence, particularly in urban environments and amongst those in higher socioeconomic brackets, underscores the importance of regulatory guidelines in shaping behavior.

The Operational PPE Focus Respondent group, emphasizing the pragmatic handling of PPE waste, shares similarities with insights from a research piece by (Atthar et al., 2022). They highlighted the significance of practical interventions in changing waste disposal behaviors. This cluster's focus on the tangible facets of PPE disposal suggests that operational strategies can play a crucial role in influencing positive waste management behaviors when communicated effectively. In contrast, the Minimal Management Respondent cluster's passive approach resembles observations from (Nunkoo et al., 2021; Phan et al., 2022). Their research on waste management in developing economies found that lower-income groups often exhibited minimal participation in waste management due to economic constraints and a lack of awareness.

On the significance of income levels, a study by (Amoah & Addoah, 2021; Kala et al., 2020; Knickmeyer, 2020) on waste management behaviors across different socioeconomic segments found that higher income groups often have better waste management practices, not just because of greater access to resources but also due to heightened awareness. It mirrors our observation of the Regulatory-Driven Safety cluster, where higher-income respondents seemed more inclined towards safety regulations. Our findings both corroborate and expand upon the existing literature. While certain behaviors, such as regulatory adherence among urban, formally-housed individuals, have been previously documented, our research highlights nuanced facets, particularly around operational aspects of PPE management and the influence of income. The interplay between socio-demographic factors and PPE management underscores the need for targeted, multi-pronged interventions to ensure effective waste management across different population segments.

The outcomes of this study bring forth several significant policy recommendations and implications, especially as the world grapples with the aftermath of the COVID-19 pandemic and the challenges associated with PPE management. Firstly, there is a pressing need for a comprehensive and robust regulatory framework for managing and disposing of PPE waste. While the "Safe Management and Regulation" factor indicated an inclination towards regulations, it is evident that sporadic guidelines are insufficient. A cohesive, well-structured framework that integrates global best practices, considering the local nuances, can ensure streamlined and safe disposal of PPE waste. Moreover, the "PPE Waste Handling" factor underscores the importance of tangible ground-level operations. Governments and local authorities should invest in infrastructure, ensuring adequate provision of waste management facilities. It involves establishing more disposal units and ensuring that these units are equipped with the necessary resources to handle and treat PPE waste properly (Cubas et al., 2023; Hantoko et al., 2021). It also extends to training personnel adequately and ensuring that the collection and disposal methods meet international safety standards.

Furthermore, public awareness is paramount. While regulations and facilities play their part, the success of any PPE waste management initiative hinges on public participation. As evidenced by the significance of public awareness campaigns in our findings, there is a clear indication that people need to be informed, educated, and empowered. Authorities should roll out extensive public awareness campaigns, harnessing the power of traditional and digital media to reach broader audiences informing them of the correct disposal methods and the implications of improper handling. The distinction between the clusters, especially the "Minimal Management Respondent," points towards a population segment that might not adequately align with the importance of proper PPE waste management. Targeted interventions, in the form of workshops, community sessions, or educational programs, might be beneficial in bridging this gap. Lastly, the demographics and socioeconomic variables play a pivotal role. Policy interventions should consider these factors to ensure inclusivity.

The significant findings associated with occupancy and income levels suggest that socioeconomic disparities might influence PPE waste management behaviors. Policies should be designed to cater to diverse income brackets, ensuring that everyone, regardless of their economic standing, has access to PPE disposal facilities and is aware of the importance of their proper use. The findings of this study lay the groundwork for a holistic approach to PPE waste management, integrating robust regulations, effective on-ground operations, and widespread public awareness. Governments, stakeholders, and communities must unite to pool resources and expertise to tackle this challenge head-on (Suryawan & Lee, 2023; Sutrisno et al., 2023), ensuring environmental safety and public health.

The implications of these findings are manifold. For policymakers and urban planners, there's a clear indication that a dual approach is required. Regulatory measures need to be complemented with operational strategies on the ground. Further, the disparities in PPE waste management practices based on socioeconomic variables suggest that targeted interventions addressing specific population segments might be more effective than blanket policies. Engaging communities, especially in areas with a higher propensity for "Minimal Management," will be crucial in reshaping and refining PPE waste disposal behaviors. While the pandemic has underscored the importance of PPE in safeguarding public health, the subsequent waste management challenges demand urgent attention. Through this study, we hope to shed light on these challenges specific to Jakarta, offering insights and avenues for further research and policy interventions. The ultimate goal is a holistic approach to PPE waste management that is environmentally sustainable and conducive to public health.

CONCLUSION

The COVID-19 pandemic necessitated a significant global increase in Personal Protective Equipment (PPE) use, resulting in unprecedented challenges related to its post-use management. This study, centered on Jakarta, a bustling urban metropolis, has elucidated the complexities and intricacies surrounding PPE waste management in the aftermath of the pandemic. Our findings underscore the emergence of two pivotal factors in PPE waste management in Jakarta: "Safe Management and Regulation" and "PPE Waste Handling." While both factors are integral to effective waste management, their nuances reveal different dimensions of the problem. Safe Management and Regulation accentuate the critical role of governmental oversight, regulations, and infrastructural provisions in assuring environmentally and medically safe disposal of PPE waste. On the other hand, PPE Waste Handling underscores the importance of grassroots-level activities, including containment, collection, public awareness campaigns, and disinfectant treatment.

Through cluster analysis, the study further segmented the population into three distinct groups: "Regulatory-Driven Safety Respondents," "Operational PPE Focus Respondents," and "Minimal Management Respondents." These clusters' varied preferences and attitudes demonstrate the multifaceted nature of PPE waste management perceptions among Jakarta's residents. A significant revelation of this research was the influence of socioeconomic variables, especially occupancy and income, on PPE waste management practices. The strong linkage between these socioeconomic aspects and PPE waste management practices offers a nuanced understanding of the issue, revealing that economic and living conditions can have a pronounced impact on individual and community behaviors regarding waste disposal.

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