SPMS
Spatial Planning & Management Science
SPMS 2(1): 18–33
ISSN 3088-9669

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Toward sustainable management of disposable face mask waste: Integrating community and policy approaches

Khairun Nisa[1,*]
[1] *Department of Environmental Science, School of Environmental Science, Universitas Indonesia, Central Jakarta, Jakarta 10430, Indonesia.*
*Correspondence: khairun.nisa02@ui.ac.id

Received Date: January 20, 2025 Revised Date: February 19, 2025 Accepted Date: February 28, 2025

ABSTRACT

Background: The use of disposable face masks has become a necessity and a habit since the outbreak of COVID-19. Improper disposal and management creates a trail of waste that can potentially be a source of pollution in the environment. This study aims to analyze the potential impact of household-scale disposable face mask waste pollution in Cinere District to develop a sustainable strategy for disposable face mask waste management. **Methods:** The method used in this research is Structural Equation Modeling (SEM), and qualitative descriptive statistical analysis. **Findings:** The results showed that the average use of disposable face masks in Cinere District was 2 pieces/day with a weight of 3.54 grams and it was estimated that the people of Cinere District produced 106,739 disposable face mask waste with a microplastic release rate reaching >93.93 billion/day. **Conclusion:** It can be concluded that the perception and role of the community and the government are very important and impactful on the potential of pollution of disposable face mask waste in the environment and the right strategy to tackle this issue is turn-around. **Novelty/Originality of this article:** The novelty of this article lies in emphasizing the crucial role of local governments in the management of mask waste.

KEYWORDS: COVID-19; disposable face mask; impact of pollution; sustainability strategy.

1. Introduction

The outbreak of the coronavirus disease 2019 (COVID-19) has become a global pandemic, reported in 235 countries, with approximately 753,258,129 confirmed cases and 6,811,531 deaths as of February 1, 202. In Indonesia, there have been 6,730,289 cases and 160,817 deaths (Ministry of Health of the Republic of Indonesia, 2021). The COVID-19 pandemic has raised global concerns. In addition to threatening health and safety, the threat of plastic pollution in various countries has increased exponentially. This is due to the growing public consumption of single-use plastics (Benson et al., 2021). The ease of transmission of this virus requires healthcare workers and the public to use personal protective equipment (PPE) such as masks, face shields, gloves, protective clothing, shoes, and goggles. Based on their function, masks can be classified into surgical or medical masks, N95 respirators, and non-medical or cloth masks (Irfan & Ayu, 2020). Cloth masks are less effective at preventing COVID-19 compared to medical or N95 masks because the material used in cloth masks differs from those in medical or N95 masks, and they have not been tested according to medical standards (Inayah, 2022). N95 masks, or respirators, have

Cite This Article:
Nisa, K. (2025). Toward sustainable management of disposable face mask waste: Integrating community and policy approaches. *Spatial Planning & Management Science, 2*(1), 18-33. https://doi.org/10.61511/spms.v2i1.2025.1759

advantages over other types of masks, being more than 95% efficient in filtering particles as small as 0.3 μm when a person is speaking, coughing, or sneezing (Smith et al., 2016).

The use of disposable face masks is considered effective in preventing the transmission of the virus through droplets from COVID-19 patients (Laelasari, 2021). Medical masks can provide effective protection between 85% and 99% in preventing the transmission of infectious diseases (Dwirusman, 2020). However, their disposal creates a significant environmental waste footprint. For example, in Hong Kong, where COVID-19 infections began in late January 2020, a survey conducted by an Environmental NGO in the Soko Islands found large amounts of disposable face mask waste washed up on a 100-meter stretch of beach (Saadat et al., 2020). In Africa, during the rainy season, a large amount of disposable face mask waste has been found in various urban drains, especially around Lake Tana. Additionally, in France, it was reported that in June 2020, Environmental NGOs discovered numerous disposable face masks along roads leading to the Mediterranean Sea floor near the resort city of Antibes (Aragaw, 2020).

Disposable face masks typically consist of three layers: the outer layer (spun-bond polypropylene) made from a non-absorbent material to protect against liquid splashes, the middle layer (melt-blown polypropylene) which serves to block droplets and aerosols through electrostatic effects, and the inner layer (spun-bond polypropylene) made of an absorbent material like cotton to absorb moisture (Figure 1) (Xu & Ren, 2021). Based on research conducted by Sun et al. (2021), it is estimated that disposable face masks discarded throughout 2020 will release over 1.370 trillion microplastics into coastal marine environments globally, with a release rate of 396 billion microplastics per day. The microplastic waste discarded takes hundreds of years to decompose, and its disposal in the natural habitats of terrestrial and marine animals can lead to ingestion, causing death (Saadat et al., 2020). This also impacts the food chain, potentially leading to wildlife scarcity and food shortages. In the tourism industry, coastal areas polluted with plastics reduce aesthetic value, which can lower local community income and national foreign exchange earnings. Furthermore, the accumulation of plastic and microplastics in the environment contributes to global warming due to carbon emissions and affects climate change (Aragaw, 2020).

The handling and management standards for disposable face mask waste in Indonesia are referenced in Circular Letter No. SE/MENLHK/PSLB3/3/2021 on the Management of Infectious Waste (B3 Waste) and Household Waste from COVID-19 Handling. According to these guidelines, it is important to first understand the different categories of mask users. The implementation of this regulation has not yet been optimal, thus a shared perception between local governments and the public is needed. The community must participate together in waste management. Public participation is influenced by the psychological process experienced by each individual, namely perception. Public perception of waste management is influenced by various factors.

The first case of COVID-19 in Indonesia involved two Indonesian citizens residing in Depok. The two patients, a mother and child, had a history of interaction with a Japanese citizen living in Malaysia. Since then, in March 2020, COVID-19 cases in Indonesia have continuously increased. In addition to being the first city where COVID-19 emerged in Indonesia, data from the COVID-19 distribution in January 2022 showed that Depok recorded the highest COVID-19 cases in West Java, with 11,324 active cases and a total of 111,499 confirmed cases. Depok also recorded the highest daily increase in COVID-19 cases during the pandemic, with 2,094 new cases, with the highest number of active confirmed cases reported by the Cinere sub-district (COVID-19 Task Force, 2022). Based on these considerations, the researcher chose the Cinere sub-district in Depok as the research location.

In addition to being a potential source of disease transmission, including COVID-19, disposable face masks contain microplastics that could be a source of environmental pollution. Therefore, a detailed analysis of the potential environmental impact of disposable face mask waste is necessary. Public perception and participation play a crucial role in controlling environmental pollution to create sustainable strategies for the management of

disposable face mask waste. The role of local governments is also very important in environmental management, as they have issued guidelines for managing disposable face mask waste at the household level, aiming to minimize the risks of transmission and environmental pollution. However, there is a lack of information regarding the implementation of these regulations. This study contributes to the development of environmental science, particularly in the field of environmental protection, by examining the potential environmental impact of disposable face mask waste and generating sustainable strategies for their disposal and management. It also provides an educational tool for the public and offers insights for policymakers in determining waste management policies, especially those related to potential environmental pollution.

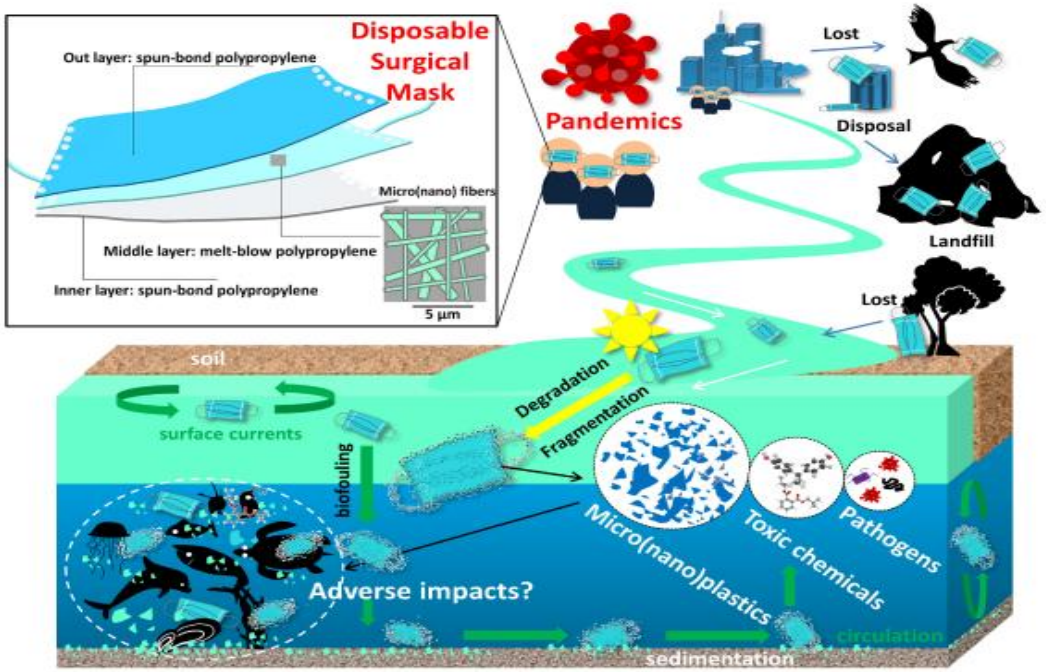

Fig. 1. Masker layers and mask waste distribution to the environment (Xu & Ren, 2021)

2. Methods

The approach used in this research is quantitative, while the research method employed is a combination of quantitative and qualitative methods, also known as mixed methods. A quantitative approach is an empirical research method used to collect, analyze, and present data in numerical format with the aim of testing objective theories related to the relationships between variables in the study (Creswell, 2007). Data collection is conducted using research instruments in the form of questionnaires and statistical analysis by testing hypotheses formulated in the research (Sugiyono, 2017). The quantitative method is used to calculate the volume of mask waste, understand public perception, and assess the role of the community. The qualitative method, grounded in postpositivism philosophy, is applied to natural object conditions, where the researcher acts as the key instrument. Data collection is performed using triangulation techniques, data analysis is inductive, and the research results emphasize meaning rather than generalization (Sugiyono, 2021). In this study, the qualitative method is used to analyze in depth the role of local government in addressing the potential environmental pollution caused by disposable face mask waste at the household scale and the public's attitudes towards the management of disposable face mask waste.

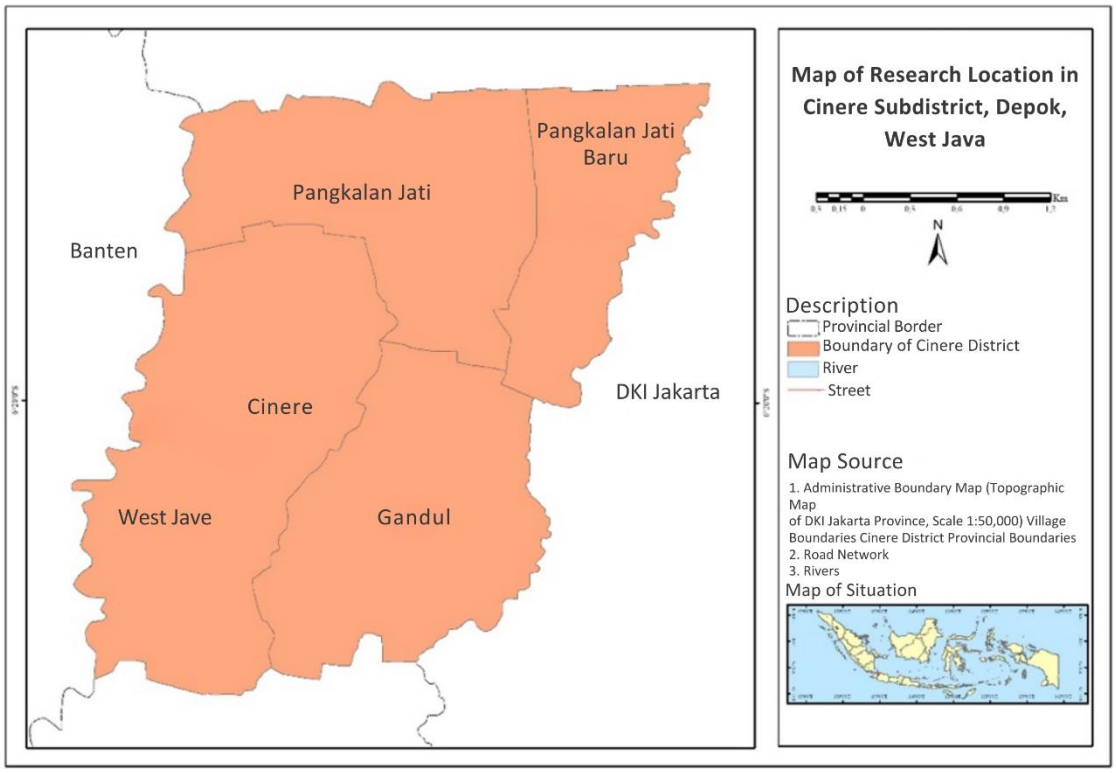

Fig. 2. Map of research location

The study was conducted in the Cinere Sub-district, Depok, West Java. The location was chosen purposively, based on specific considerations and objectives, as it is the sub-district with the highest number of COVID-19 cases in Depok, West Java. The research was conducted over a period of 3 months, from March 2023 to May 2023. During this time, primary data collection was carried out on the volume of disposable face mask waste at the household level from the community in Cinere Sub-district. Additionally, questionnaires with specific criteria were distributed to develop strategies, along with semi-structured interviews with local government officials, experts, and community leaders.

Table 1. Criterion of informant

Num.	Informant	Criterion
1	Regional government: The Ministry of Environment and Forestry and Agency of Environment and Forestry of Depok	Understanding regulations on the management of disposable face mask waste at the household scale. Identifying issues related to the management of disposable face mask waste at the household scale. Being involved in the management/coordination/supervision of the implementation of regulations. Understanding the environmental impacts and effective management efforts for disposable face mask waste at the household scale.
2.	Acedemics: Lecturer in environmental science, specializing in environmental control, protection, and environmental health	Understanding the development of environmental issues in the areas of pollution and environmental health. Understanding the impacts of pollution. Having experience related to COVID-19 waste management.
3.	Community: Community leader	Participating in various environmental issues. Willing to cooperate in encouraging and developing community awareness about environmental protection.

Following this, an analysis of the environmental impact of disposable face mask waste was conducted, along with data processing. Furthermore, the selection of local government informants was purposively made based on specific considerations in accordance with the research objectives as shown in Table 1 and 2.

Table 2. Sample of informant

Num	Agency	Institution	Field	Amount (person)
1.	Local government	Ministry of Environment and Forestry	Waste, waste management, and hazardous and toxic materials	1
2.	Local government	Agency of Environment and Forestry of Depok	Cleanliness and partnership	1
3.	Local government	Subdistrict of Cinere	Sub-district head, sub-district secretary, community affairs, and public services	3
4.	Academics	Universitas Indonesia	Lecturer	1
5.	Society	Formal and informal community figure	Head of the Cinere sub-district waste bank and celebrity	2

3. Results and Discussion

Results from the calculation of face mask waste usage indicate that households in the Cinere Sub-district are estimated to produce 106,739 face masks per day, while Indonesia generates 250,181,991 disposable face masks per day. This result aligns with research by Benson et al. (2021), which estimated that Indonesia generates between 101-500 million disposable face masks daily, placing it in the second-largest class of face mask waste producers in the world. This represents a significant burden on the environment if not managed properly and efficiently.

3.1 Potential environmental impact of disposable face mask waste

Various traces of disposable face mask waste have been found in the environment, primarily due to improper waste management and disposal. For instance, some face mask waste has been found in several water bodies in Indonesia, such as in river streams flowing towards the Jakarta Bay. Reza et al. (2020) found debris, including disposable face masks, in the Jakarta Bay stream, which had never been recorded before. It accounted for 15-16% of the river debris collected, totaling 780 ± 138 pieces, or approximately 0.13 ± 0.02 tons (weight) per day.

Fig. 3. Face mask waste found in the Ciliwung River stream (Firmansyah, 2021)

Improperly discarded disposable face masks in the environment can have adverse effects on fauna, causing entanglement on their bodies, which may result in death. This has occurred in several countries worldwide, such as in Colombia, where a bird was entangled in a disposable face mask hanging from a tree, ultimately leading to the bird's death as the mask wrapped around its body and beak. Similarly, a Peregrine Falcon's talons became entangled in a disposable face mask (Selvaranjan et al., 2021). In Chelmsford, UK, the Royal Society for the Prevention of Cruelty to Animals (RSPCA) rescued a seagull that was immobilized due to a disposable face mask wrapped around its legs (Putri, 2020). In Singapore, a Black Bittern bird's beak became entangled in disposable face mask waste, making it difficult for the bird to feed, and a Mallard duck with a mask around its neck was successfully captured by Mary Caporal Prior in the United States (BBC News Indonesia, 2022).

Fig. 4. The threat of disposable face mask waste to birds
((a) (b) Selvaranjan et al. (2021); (c) Novena (2022); (d) Putri (2020); (e) (f) BBC News Indonesia, (2022))

This incident, where terrestrial and marine animals ingest disposable face masks (Figure 4), leads to reduced food intake and causes the animals to starve and die (Selvaranjan et al., 2021). Some occurrences include a pufferfish found dead off the coast of Miami due to entanglement in a mask, environmental activists in France finding a dead crab caught in a mask in a saltwater lagoon near the Mediterranean, and a small monkey in Malaysia chewing on a cord from a discarded disposable face mask (Wardayati, 2021). In addition, a penguin was found dead on a beach in Brazil with an intact disposable face mask inside its stomach (Prayitno, 2020). Furthermore, Greek photographer Nicolas Samaras

captured an image of a seahorse dragging a disposable face mask waste in the waters of Stratoni Halkidikis, northern Greece, about 90 minutes from Thessaloniki (YOT Banyuwangi, 2021).

Disposable face masks generally consist of three layers: the outer layer, middle layer, and inner layer. Polypropylene is the main material used in producing disposable masks (Selvaranjan et al., 2021). This is confirmed by observations made by Rebia et al. (2022), where the functional groups of the three-layer mask waste were analyzed using Nicolet™ iS50 Fourier Transform Infrared Spectroscopy (FTIR) Spectrometer. The analysis of the functional groups showed characteristic absorption for polypropylene. All samples showed peaks at 2948 cm^{-1}, 2916 cm^{-1}, 2866 cm^{-1}, and 2837 cm^{-1}, indicating the presence of CH groups, supported by the peak at 1375 cm^{-1}, which indicated the presence of CH_3 groups. According to polypropylene spectrum references, the methyl group (-CH_3) appears at 2970 cm^{-1} and 2910 cm^{-1}, the methylene group (-CH_2-) at 2870 cm^{-1}, 2840 cm^{-1}, and 1460 cm^{-1}, and the minor peak (-CH_3) at 1370 cm^{-1} (Barbeş et al., 2014).

In addition to polypropylene, disposable masks can also be made from other polymers such as polystyrene, polycarbonate, polyethylene, and polyester (Abbasi et al., 2020). Degradation of disposable face mask waste, based on a study by Idowu et al. (2023) under normal environmental conditions in soil, clearly showed signs of degradation by the 14th week. Gradual degradation accompanied by an exponential increase in the release of microplastics was observed by the 40th week, reaching 3,280.45 ± 173.88 MP/mask per day, and by the 60th week, reaching 3,686.24 ± 80.39 MP/mask per day. According to Sun et al. (2021), a disposable face mask weighing 3-4 grams can release at least 0.88 million microplastics.

Based on calculations, each individual in Cinere Sub-district uses 2 disposable face masks per day, with an average weight of 3.54 grams, producing 106,739 masks per day. This will result in the release of approximately 93.93 billion microplastics into the environment daily. Thus, Hypothesis 1 in this research regarding the potential environmental impact of disposable face mask waste in Cinere Sub-district is accepted. Microplastics resemble planktonic organisms and suspended organic particles, which serve as food for marine organisms (Wright et al., 2013). This poses a danger to marine life that inadvertently consumes them, and the microplastics entering their bodies disrupt digestive systems (Cole et al., 2013). Marine organisms, such as copepods and crabs, have been detected accumulating microplastics (Cole et al., 2013). The ingestion of microplastics and toxic chemicals by aquatic organisms can enter the food chain, affecting human food safety and endangering human health globally (Fadare et al., 2020; Reid et al., 2019).

3.2 Public perception and role in managing disposable face mask waste

An individual's way of managing and interpreting sensory impressions to understand the environment is known as public perception. The process of perception involves three stages: selection, organization, and interpretation. These processes are continuous and influence each other. Strong cooperation among community members is expected to solve environmental issues more easily. This cooperation can be realized by ensuring communication, transparency, teamwork, expectations, and eliminating narrow-mindedness, division, disruption, and fear. The environmental and social environment, in its development, should always receive attention to avoid disasters. Therefore, all layers of society need to take responsibility for maintaining the order of the living and social environment. This will create a better perspective on the environment (Effendi et al., 2018). In this regard, the role of society is fundamental in environmental management, as people are physically embedded in environments that are constantly degrading. Thus, the presence and role of society are essential to creating a healthy environment. Based on the results of the validity test (Table 3), it can be concluded that all measurement indicators for each variable are valid because all the factor loading values meet the criteria of ≥ 0.70 (Hair et al., 2018).

Table 3. Results of the validity test for knowledge, attitudes, and behavior aspects of the community in Cinere District

Variable	Indicator	Factor loading
Knowledge	Masks can prevent the transmission of COVID-19.	0.853
	Aware of Circular Letter No. SE/MENLHK/PSLB3/3/2021 regarding the management of household mask waste.	0.721
	Aware of the potential impact that mask waste can cause if not managed properly.	0.709
	Household mask waste must be managed specifically.	0.822
	Household mask waste must be disposed of in the trash.	0.785
	Household mask waste can be disposed of in special mask waste drop boxes in public spaces provided by the local government.	0.827
	Socialization on the management of household mask waste is essential to raise public awareness.	0.805
Public Attitudes	Wearing a mask when leaving the house.	0.838
	Disinfecting mask waste with disinfectants, chlorine, or bleach before disposal.	0.776
	Destroying the mask waste by tearing/cutting it before disposal.	0.897
	Packaging the mask waste in a sealed plastic bag that is leak-proof and tightly tied.	0.743
	Disposing of mask waste in the trash.	0.766
	Disposing of mask waste in a special mask drop box in public spaces provided by the local government.	0.778
Community Behavior	Wearing a mask when leaving the house as a prevention of COVID-19 transmission.	0.717
	Washing hands with soap and running water after disposing of the mask.	0.811
	Mixing mask waste with other household waste.	0.823
	Managing mask waste properly according to Circular Letter No. SE/MENLHK/PSLB3/3/2021.	0.792
	Managing mask waste to reduce COVID-19 transmission and minimize environmental pollution.	0.867
	Supporting all efforts in waste management to reduce environmental pollution.	0.814

Based on the results of the reliability test (Table 4), it can be seen that all the indicators used to measure the variables of knowledge, attitudes, and behavior of the community have a Cronbach's alpha value of ≥ 0.6, which is above the standard threshold for Cronbach's alpha. Therefore, according to the criteria of Sekaran & Bougie (2016), it can be concluded that the indicators used to measure each variable in this study are acceptable and reliable.

Table 4. Results of the reliability test for knowledge, attitudes, and behavior aspects of the community in Cinere District

Variable	Cronbach Alpha	Cut - off
Knowledge	0.899	0.600
Attitude	0.885	0.600
Behaviour	0.888	0.600

The overall model fit must be analyzed first before analyzing the hypotheses. This is done to ensure that the model can reflect the cause-and-effect relationships (Hair et al., 2018). The model fit test is performed by looking at several criteria, as follow. First is absolute fit measure. This simultaneously evaluates the overall fit from the structural model to the measurement model: the testing can be observed through the chi-square value, probability, goodness of fit index (GFI), root mean square residual (RMR), and root mean error approximation (RMSEA). Second is incremental fit measure. This compares the proposed model with another model used by the researcher. This can be seen from the

Tucker-Lewis index (TLI) and comparative fit index (CFI). Third is parsimonious fit measure. This adjusts the fit measure so that models with varying numbers of coefficients can be compared. This can be seen from the value of the normed chi-square (CMIN/DF).

Table 5. Results of the goodness of fit test for knowledge, attitudes, and behavior aspects of the community in Cinere District

Type of measurement	Measurement	Recommended acceptance limits (Hair et al., 2018)	Value	Conclusion
Absolute fit measures	Chi-square	Small Chi-square	389.51	Poor
	p-value Chi-square	≥ 0.05	0.000	Poor
	RMSEA	≤ 0.10	0.096	Good
	RMR	≤ 0.10	0.048	Good
	GFI	≥ 0.90 or approaching 1	0.773	Poor
Incremental fir measures	NFI	≥ 0.90 or approaching 1	0.791	Poor
	TLI	≥ 0.90 or approaching 1	0.663	Poor
	RFI	≥ 0.90 or approaching 1	0.814	Marginal
	CFI	≥ 0.90 or approaching 1	0.718	Poor
	AGFI	≥ 0.90 or approaching 1	0.692	Poor
Parsimonius fit measure	CMIN/DF	Bottom limit: 1.0 Up limit: 2.0; 3.0 atau 5.0	2.09	Good

Based on Table 5, it can be seen that the values of RMR, RMSEA, and CMIN/DF indicate that the research model has Goodness of Fit. Therefore, based on the results of the Goodness of Fit test, it can be concluded that the research model is deemed suitable. This shows that the model has passed the fit test and is ready for the next stage of testing.

The primary source of disposable face mask waste pollution is improper disposal by the general public, as they are unaware of the correct method for discarding used disposable face masks. Descriptive statistical testing is used to describe and detail the data. In this study, the mean value and standard deviation are used to assess the descriptive statistics. The average value represents the mean of all responses, and the standard deviation indicates the variation in responses (Sekaran & Bougie, 2016). If the standard deviation is close to zero, responses are less varied, while a high standard deviation indicates greater variation. Descriptive statistical calculations of variables are shown in the table below.

Table 6. Descriptive statistics results of knowledge, attitudes, and behavior of the community in Cinere Sub-district

Variable	Indicator	Mean	Std. Deviasi
Knowledge	Masks can prevent the transmission of COVID-19.	3.39	0.78
	Being aware of Circular Letter No. SE/MENLHK/PSLB3/3/2021 regarding the management of mask waste from households.	2.57	0.79
	Being aware of the potential impacts caused by mask waste if not properly managed.	3.23	0.67
	Mask waste from households must be specially managed.	3.28	0.67
	Mask waste from households must be disposed of in trash bins.	3.32	0.70
	Mask waste from households can be disposed of in designated mask waste drop boxes in public spaces provided by local governments.	2.87	0.69
	Socialization of mask waste management from households is necessary to raise public awareness.	3.47	0.69
Average		3.16	

Based on the results of descriptive statistics (Table 6), it can be concluded that the people of Cinere Subdistrict have good knowledge, especially regarding the impact of disposable face mask waste, which must be managed properly. However, their knowledge

of management methods and drop box facilities is largely lacking. This needs attention because knowledge is an area that can influence a person's actions (Notoatmodjo, 2012). The highest mean result (3.47) is for the public's knowledge supporting the need for socialization on the management of disposable face mask waste to build public awareness. This is in line with research by Maulidin et al. (2021), which found that public knowledge about household medical waste management is still limited due to a lack of educational and socialization facilities. Lubriyana & Nurjazuli (2022) concluded in their research that socialization or counseling to the public should be increased to provide knowledge about the management of disposable face mask waste at the household level.

The community's attitude toward managing disposable face mask waste at the household level is considered good, as most people have damaged the masks (3.18) and disposed of them in trash bins (3.35). However, they do not disinfect the mask waste and have not disposed of it in mask drop boxes, which they have never encountered in their surroundings. The action of damaging or altering the shape of the mask aims to prevent wild animals from becoming entangled in the waste, which could harm or even kill them, as discussed earlier. Spraying disinfectant and sealing disposable face mask waste in tightly closed bags before disposal is necessary to prevent the spread of COVID-19 or other viruses that could spread bacteria and viruses. Regarding behavior, it can be observed that the people of Cinere Subdistrict have generally good practices. It is hoped that the public will maintain the habit of managing disposable face mask waste at the household level that has been practiced and improve the management of mask waste that has not yet been implemented. The public shows very high support for efforts to manage disposable face mask waste. This can foster good cooperation between the public and local government in managing disposable face mask waste at the household level, thereby reducing the potential environmental impact of disposable face mask waste.

Based on the hypothesis testing results, an analysis of the results and interpretation was conducted. The hypothesis was tested to accept the alternative hypothesis (Ha) and reject the null hypothesis (Ho). The testing was done by applying structural equation modeling (SEM), which aims to estimate the various changes occurring in the dependent variables. These variables are connected to various changes occurring in a number of independent variables (Hermawan & Yusran, 2017). The error tolerance limit (α) applied is 5% (0.05). Therefore, the hypothesis can be accepted if the p-value ≤ 0.05 (Hair et al., 2018).

Table 7. SEM Test results: knowledge, attitude, and behavior aspects of the people of Cinere Subdistrict

Path		Estimates	p-value	Decision
Hypothesis 2 in research	Knowledge → Attitude	0.757	0.000	Significant
	Attitude → Behaviour	0.677	0.000	
	Behaviour → Polution_Potential	-0.387	0.030	

This hypothesis tests the positive influence of the public's role and perception on the potential impact of disposable face mask waste pollution. In this hypothesis test, all influence paths between variables related to the public's role and perception, including public knowledge → public attitude → public behavior toward the potential pollution from disposable face mask waste, were observed. According to Hair et al. (2018), an influence between variables can be stated as significant using the SEM method if the p-value<0.05.

From the results of the path analysis test (Table 7), it can be seen that the p-value of the relationship between public knowledge and public attitude is 0.000<0.05; and estimates 0.757 or 76%. This shows that when public knowledge increases, public attitude also increases with an influence of 76%. Furthermore, the p-value for public attitude toward public behavior is 0.000<0.05; and estimates 0.677 or 68%. This shows that when public attitude toward managing disposable face mask waste increases, public behavior also increases with an influence of 68%. For the p-value of public behavior toward the potential pollution of disposable face mask waste, it is 0.030<0.05; and estimates -0.387, meaning

there is a negative influence between the public's role and perception toward the potential pollution from disposable face mask waste, with an influence of -0.387 or 39%. This indicates that the hypothesis of the public's perception and role negatively impacts the potential pollution of disposable face mask waste in the environment is accepted.

3.3 Role of local government in managing disposable face mask waste

Local governments are responsible for waste management as part of public service. This is done by formulating policies related to waste management. Public service includes forms of services such as the development of facilities and public services, which are principally the responsibility of the state to maintain, sustain, and enhance the quality of life for the people (Mulasari et al., 2016). Suharto (2008) stated that policies are decisions or actions to regulate the management and distribution of natural, human, and financial resources for the public interest. Meanwhile, autonomy policies serve as a basis for achieving decentralization in environmental governance. These policies are aimed at addressing environmental problems. Fundamentally, the mission and goals of regional autonomy policies, as stated in the law, are: (1) to improve public service to achieve the welfare of the people, both qualitatively and quantitatively; (2) to achieve efficiency and effectiveness in the management of regional resources to improve the welfare of the community; (3) to empower and create space for the community to be involved in the development process by the local government (Mardiasmo, 2002). However, in carrying out public service functions, local governments are often constrained, so cooperation from all parties is needed to overcome these obstacles. These obstacles include infrastructure, resources, and the institutional framework of public service. Similarly, the main problem in improving public services is management. The success of a good management system in waste management by local governments and communities can be achieved with responsible organizations and a clear organizational structure (Mulasari et al., 2014).

Law No. 18 of 2008 on Waste Management legally mandates waste management. This management includes activities that are systematic, comprehensive, and sustainable, including waste reduction and handling. The law explains that local governments have the duty and obligation to manage waste. Furthermore, local governments can formulate national and provincial policies to minimize and manage waste from the sources of waste generation itself (Jati, 2013). Therefore, it can be concluded that local governments play an important role in waste management.

Table 8. Descriptive statistics results: Role of local government

Variable	Indicator	Mean	Std. Deviation
Role of loval government	The local government of the regency/municipality records the collection of disposable face mask waste from households.	2.84	0.473
	The local government compiles data on the reporting of disposable face mask waste generated from households.	2.44	0.87
	The local government reports the generation of disposable face mask waste from households to the Ministry of Environment and Forestry (KLHK).	2.68	1.18
	The local government is less optimal in implementing the management of disposable face mask waste from households.	3.44	0.583
	There is limited development of recycling facilities for disposable face mask waste by the local government.	1.68	0.557
	There has been no collaboration with formal and informal community leaders in raising public awareness regarding the management of disposable face mask waste from households	3.84	0.374
Average		2.82	

Based on the descriptive statistical data (Table 8), it can be concluded that the role of the local government of Depok City, particularly in Cinere District, is still relatively low in managing disposable face mask waste at the household level. This is evident from the still suboptimal efforts of the local government in managing disposable face mask waste, the limited development of recycling facilities for household waste, and the lack of effective socialization regarding the steps that need to be taken by the public to properly and appropriately manage disposable face mask waste. With this situation, it is clear that the public is still unaware of the correct and comprehensive way to manage disposable face mask waste. This creates a very high potential for pollution, as the average use of disposable face masks per person per day in this district is 2 masks, with the average weight of the masks from the total daily usage being approximately 3.54 grams.

Based on interviews with the Head of Cinere District, it was found that there were no socialization activities and no facilities, including a drop box for disposable face mask waste, in Cinere District. This was supported by interviews with the Depok Environmental and Hygiene Agency (DLHK), which is directly responsible for household waste management. According to the DLHK's cleanliness and partnership division, the available facilities, especially waste collection trucks, are still not ideal, and they anticipate this by renting trucks when necessary. There is also a lack of training and provision of personal protective equipment (PPE) for waste collection staff, resulting in many workers contracting COVID-19 during the pandemic. There is a need for waste sorting facilities at the final disposal sites (TPS), which have not been available, relying on the public to sort waste before it reaches the final disposal site (TPA). The condition of the Cipayung TPA is also worrying, as the data obtained from the Head of the Regional Technical Implementation Unit (UPTD) Cipayung TPA shows that the TPA has exceeded its capacity and immediate action is needed to address the excess waste capacity.

Fig. 5. Disposable face mask waste at Cipayung TPA

The process conducted by DLHK in managing disposable face mask waste involves collecting the waste, which is mixed with other household waste, by sanitation workers, and then transporting it with trucks to be sent to the TPA for final processing because disposable face mask waste is classified as residual waste. There are no special facilities or treatments for disposable face mask waste at the household level. Therefore, based on the analysis and the interviews above, it can be concluded that Hypothesis 3 in this study, which states that the role of the local government negatively affects the potential pollution of disposable face mask waste, is accepted. By increasing the local government's role in managing disposable face mask waste at the household level, this will have a negative effect, or reduce the potential for disposable face mask waste pollution in the environment.

From the perspective of public attitudes, it can be concluded that there are several indicators in people's attitudes caused by the lack of the local government's role in

socializing and supporting the facilities needed for managing disposable face mask waste, such as the lack of people disposing of disposable face masks in a special drop box and disinfecting the face masks before disposal. This is suspected to be due to the local government's limited role in providing disposable face mask waste management facilities, such as the absence of a special drop box and the insufficient socialization regarding the steps the public should take to properly manage disposable face mask waste. Furthermore, the researcher strengthens this by conducting interviews with community leaders such as the District Head, the District Secretary, the Chair of the Cinere District Waste Bank, and a celebrity. These leaders also have not implemented comprehensive mask waste management due to the lack of information available. This shows that Hypothesis 4 in this study, which states that the role of the local government positively affects public attitudes in managing disposable face mask waste, is accepted.

The community leaders strongly support being involved in socializing the management of mask waste and are willing to cooperate with the local government. Armand Maulana, a celebrity who has been actively involved in environmental campaigns, stated, "In my opinion, environmental issues require attention and joint efforts from all parties. Collaboration from all elements of society is needed to take real action." He can play a role in encouraging the public through social media platforms such as Instagram, YouTube, TV, and podcasts. Similarly, the Chairman of the Cinere District Waste Bank and his team are ready to help socialize this to the public by directly visiting communities and establishing a program for periodic collection of disposable face mask waste or conducting outreach on proper household-level face mask waste management.

4. Conclusions

The potential environmental impact of disposable face mask waste at the household level, with each person using an average of 2 masks per day and the average weight of masks being 3.54 grams, means that for the entire population of Cinere District, approximately 106,739 disposable face masks are used per day, with a potential release of 93.93 billion microplastics into the environment daily. The perceptions and roles of the public, including knowledge, positively affect attitudes, and attitudes positively affect behavior, with an influence of -0.387 or 39% on the potential pollution from disposable face mask waste. An optimal local government role can reduce the potential pollution of disposable face mask waste and improve public attitudes towards its management. A sustainable strategy for managing disposable face mask waste includes the following steps: first, providing facilities that meet standards and are easily accessible to the public; second, offering optimal services in managing household-level disposable face mask waste; third, developing technologies for managing and reducing disposable face mask waste.

Acknowledgement
The author would like to express their sincere gratitude to everyone who provided support and contributed, directly or indirectly, to the completion of this article.

Author Contribution
The author solely contributed to the study's conception, design, data collection, analysis, and manuscript preparation. The author was responsible for drafting, reviewing, and approving the final version of the manuscript for publication.

Funding
This research received no external funding.

Ethical Review Board Statement
Not available.

Informed Consent Statement
Not available

Data Availability Statement
Not available

Conflicts of Interest
The author declare no conflict of interest.

Open Access

References
Abbasi, S.A., Khalil, A. B., & Arslan, M. (2020). Extensive use of face masks during COVID-19 pandemic: (micro-)plastic pollution and potential health concerns in the Arabian Peninsula. *Saudi Journal of Biological Sciences*, *27*(12), 3181–3186. https://doi.org/10.1016/j.sjbs.2020.09.054.

Aragaw, T. A. (2020). Surgical face masks as a potential source for microplastic pollution in the COVID-19 scenario. *Marine Pollution Bulletin*, *159*(June), 111517. https://doi.org/10.1016/j.marpolbul.2020.111517.

Barbeș, L., Rădulescu, C., & Stihi, C. (2014). ATR-FTIR spectrometry characterisation of polymeric materials. *Romanian Reports in Physics*, *66*(3), 765–777.

BBC News Indonesia. (2022). *Burung terbelit sampah plastik dan masker medis yang banyak digunakan selama pandemi.* BBC News Indonesia.

Benson, N. U., Bassey, D. E., & Palanisami, T. (2021). COVID pollution: impact of COVID-19 pandemic on global plastic waste footprint. *Heliyon*, *7*(2), e06343. https://doi.org/10.1016/j.heliyon.2021.e06343.

Benson, N. U., Fred-Ahmadu, O. H., Bassey, D. E., & Atayero, A. A. (2021). COVID-19 pandemic and emerging plastic-based personal protective equipment waste pollution and management in Africa. *Journal of Environmental Chemical Engineering*, *9*(3), 105222. https://doi.org/10.1016/j.jece.2021.105222.

Cole, M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J., & Galloway, T. S. (2013). Microplastic ingestion by zooplankton. *Environmental Science and Technology*, *47*(12), 6646–6655. https://doi.org/10.1021/es400663f

Creswell, J. W. (2007). *Research Design: Qualitative, Quantitative, and Mixed Method Aproaches.* SAGE.

Dwirusman, C. G. (2020). The Role and Effectivity of Face Mask in Preventing Transmission of Coronavirus Disease 2019 (COVID-19). *Jurnal Medika Hutama*, *2*(1), 412–420. https://jurnalmedikahutama.com/index.php/JMH/article/view/104

Effendi, R., Salsabila, H., & Malik, A. (2018). Pemahaman Tentang Lingkungan Berkelanjutan. *Modul*, *18*(2), 75. https://doi.org/10.14710/mdl.18.2.2018.75-82.

Fadare, O. O., & Okoffo, E. D. (2020). Covid-19 face masks: A potential source of microplastic fibers in the environment. *Science of the Total Environment*, *737*, 140279. https://doi.org/10.1016/j.scitotenv.2020.140279

Firmansyah, A. (2021). *Peluang Kerja Sama LIPI Mengelola Limbah Masker*. Indonesia.go.id

Hair, J., Black, W., Babin, B., & Anderson, R. (2018). *Multivariate Data Analysis Eight Edition*.
Hermawan, A., & Yusran, H. L. (2017). *Penelitian bisnis: pendekatan kuantitatif*. Kencana.
Idowu, G. A., Olalemi, A. O., & Aiyesanmi, A. F. (2023). Environmental impacts of covid-19 pandemic: Release of microplastics, organic contaminants and trace metals from face masks under ambient environmental conditions. *Environmental Research*, *217*(September 2022), 114956. https://doi.org/10.1016/j.envres.2022.114956.
Inayah, D. R. (2022). Penggunaan Masker dan Kejadian Maskne Di Era Pandemi Covid-19 : Sebuah. *Lombok Medical Journal*, *1*(1), 52–60. https://doi.org/10.29303/lmj.v1i1.520
Irfan, M. & Ayu, D. (2020). Gambaran penggunaan masker di masa pandemi covid-19 pada masyarakat Kelurahan Cengkeh Turi Kota Binjai tahun 2020. *Afiasi: Jurnal Kesehatan Masyarakat*, *6*(1), 5–12. https://afiasi.unwir.ac.id/index.php/afiasi/article/view/120
Jati, T. K. (2013). Peran Pemerintah Boyolali dalam Pengelolaan Sampah Lingkungan Permukiman Perkotaan. *Jurnal Wilayah dan Lingkungan*, *1*(1), 1–16. https://doi.org/10.14710/jwl.1.1.1-16
Kementrian Kesehatan RI. (2021). *Situasi COVID-19*. Kementrian Kesehatan RI.
Laelasari, E. (2021). Manajemen Pengelolaan Limbah Medis Rumah Tangga Era Pandemi Covid-19 Di Indonesia: Narrative Literature. *Prosiding Seminar Nasional Penelitian dan Pengabdian 2021, "Penelitian Dan Pengabdian Inovatif Pada Masa Pandemi Covid-19"*, 447–456.http://prosiding.rcipublisher.org/index.php/prosiding/article/view/174/53.
Mardiasmo. (2002). *Otonomi dan Manajemen Keuangan Daerah*. PT. ANDI Offset.
Maulidin, A., Putri, D. A., & Miliasari, K. T. (2021). Bergizi dan Penanganan serta Pengolahan Limbah Medis Covid – 19 Rumah Tangga dengan Aman. *Prosiding Semnaskat LPPM UMJ 2021*, 1-4. https://jurnal.umj.ac.id/index.php/semnaskat/article/view/10963/6247.
Mulasari, S. A., Husodo, A. H., & Muhadjir, N. (2014). Kebijakan Pemerintah dalam Pengelolaan Sampah Domestik. *Kesmas: National Public Health Journal*, *8*(8), 404. https://doi.org/10.21109/kesmas.v8i8.412.
Mulasari, S. A., Husodo, A. H., & Muhadjir, N. (2016). Analisis Situasi Permasalahan Sampah Kota Yogyakarta Dan Kebijakan Penanggulangannya. *Jurnal Kesehatan Masyarakat*, *11*(2), 259. https://doi.org/10.15294/kemas.v11i2.3989.
Notoatmodjo, S. (2012). *Metode Penelitian Kesehatan*. PT. Rineka Cipta.
Novena, M. (2022). *Masker Sekali Pakai Bahayakan Kehidupan Satwa Liar di Masa Depan.* Kompas.com
Prayitno, G. (2020). *Menyedihkan! Seekor Pinguin Ditemukan Mati dengan Masker Utuh di Perutnya.* Travel TribunNews.
Putri, G. S. (2020). *Dampak Corona, Masker Medis Jadi Ancaman Bagi Satwa Liar*. Kompas.com
Reid, A. J., Carlson, A. K., Creed, I. F., Eliason, E. J., Gell, P. A., Johnson, P. T. J., Kidd, K. A., MacCormack, T. J., Olden, J. D., Ormerod, S. J., Smol, J. P., Taylor, W. W., Tockner, K., Vermaire, J. C., Dudgeon, D., & Cooke, S. J. (2019). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews*, *94*(3), 849–873. https://doi.org/10.1111/brv.12480.
Reza, M., Suci, I., & Riani, E. (2020). Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID- 19 . The COVID-19 resource centre is hosted on Elsevier Connect , the company ' s public news and information. *Chemosphere*, *January*.
Saadat, S., Rawtani, D., & Hussain, C. M. (2020). Environmental perspective of COVID-19. *Science of the Total Environment*, *728*. https://doi.org/10.1016/j.scitotenv.2020.138870
Satuan Tugas Penanganan COVID-19. (2021). *Peta Sebaran COVID-19*. Covid.go.id
Sekaran, U. & Bougie, R. (2016). *Research Methods for Business*. John Wiley & Sons Ltd.
Selvaranjan, K., Navaratnam, S., Rajeev, P., & Ravintherakumaran, N. (2021). Environmental challenges induced by extensive use of face masks during COVID-19: A review and potential solutions. *Environmental Challenges*, *3*(November 2020), 100039. https://doi.org/10.1016/j.envc.2021.100039.
Smith, J. D., MacDougall, C. C., Johnstone, J., Copes, R. A., Schwartz, B., & Garber, G. E. (2016). Effectiveness of N95 respirators versus surgical masks in protecting health care workers

from acute respiratory infection: A systematic review and meta-analysis. *Cmaj*, *188*(8), 567–574. https://doi.org/10.1503/cmaj.150835.

Sugiyono. (2017). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D.* Alfabeta.

Sugiyono. (2021). *Metode Penelitian Kuantitatif Kualitatif dan R&D* (Sutopo (ed.); Kedua). Alfabeta.

Suharto, O. E. (2008). *Bagi Masyarakat Dengan Kebutuhan Khusus*. Focused Group Discussion (FGD) "Kajian Penerapan Pelayanan Khusus (Service for Customers with Special Needs) pada Sektor Pelayanan Publik, Lembaga Administrasi Negara.

Sun, J., Yang, S., Zhou, G. J., Zhang, K., Lu, Y., Jin, Q., Lam, P. K. S., Leung, K. M. Y., & He, Y. (2021). Release of Microplastics from Discarded Surgical Masks and Their Adverse Impacts on the Marine Copepod Tigriopus japonicus. *Environmental Science and Technology Letters*, *8*(12), 1065–1070. https://doi.org/10.1021/acs.estlett.1c00748.

Lubriyana, T. & Nurjazuli, N.A.Y.D. (2022). Gambaran Pengetahuan Dan Praktik Pengelolaan Limbah Masker Sekali Pakai Oleh Rumah Tangga Pada Masyarakat Di Kota Semarang. *Riset Kesehatan Masyarakat*, *2*(2), 1–8. https://eprints2.undip.ac.id/id/eprint/5053/.

Wardayati, T. (2021). *Limbah Masker Sekali Pakai Bahayakan Habitat Hewan, Ini yang Harus Anda Lakukan Sebelum Membuangnya!* Intisari Grid.

Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: a review. *Environmental Pollution (Barking, Essex : 1987)*, *178*, 483–492. https://doi.org/10.1016/j.envpol.2013.02.031.

YOT Banyuwangi. (2021). *Dampak dan Cara Mengolah Limbah Masker*. Youngontop.com

Biographies of Author

Khairun Nisa, Environmental Science, School of Environmental Science, Universitas Indonesia, Central Jakarta, Jakarta 10430, Indonesia.

- Email: khairun.nisa02@ui.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A