



# Effect of Covid-19 on Healthcare Waste and Waste-Related the Pandemic: A case study in Nakhon Nayok province, Thailand

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## Abstract

In response to the COVID-19 pandemic, public health measures have led to a significant increase in healthcare waste (HW) and household hazardous waste (HHW) globally. HW, including masks, gloves, and other infectious materials from disease treatment, and HHW, such as paint, batteries, personal cleansers, cleaning products, and hand sanitizer containers, have posed new challenges in waste management. This study, conducted in Nakhon Nayok province, Thailand, fills a critical gap in understanding the extent and nature of this waste surge. From December 2020 to June 2021, we quantitatively analyzed the HW and HHW, finding that HW related covid-19 accounted for 0.03% (43.26 kg/day) and HHW related covid-19 for 3.02% (4.37 tons/day) of the total waste stream. Our findings reveal the critical necessity for comprehensive waste management interventions, particularly the proper segregation of HW and HHW from household waste, to mitigate contamination and infection risks. The study emphasizes the need for enhanced governmental action in waste management infrastructure, including public awareness campaigns on waste separation and the implementation of specialized bins for HW and HHW in residential and community areas. Additionally, it highlights the importance of developing a robust policy framework in Thailand to address the challenges of pandemic-related waste surge. The research points to future avenues exploring the environmental and public health ramifications of COVID-19 waste, especially in understanding how various communities adapt their waste management practices during public health crises. Insights from such studies could be instrumental in refining waste management practices, making them suitable for different socio-economic contexts and improving overall public health outcomes.

**Keywords :** COVID-19; Healthcare Waste; Pandemic Waste; Waste Characterization; Infectious Waste

## Introduction

In December 2019, China reported a cluster of pneumonia cases in Wuhan, later identified as caused by SARS-CoV-2 [1, 2]. The virus quickly spread globally, affecting over 200 million people [3]. During the period of our study from December 2020 to June 2021, Thailand was during its fourth COVID-19 wave, with daily confirmed cases at times exceeding 20,000 [4]. Vaccines have become crucial in mitigating the impact of the virus, reducing

severe illness and hospitalization rates [5-7]. Both international organizations like the World Health Organization and local authorities in Thailand have emphasized the importance of rapid testing for SARS-CoV-2 [8, 9]. Antigen rapid diagnostic tests (Ag-RDT) are commonly used in Thailand due to their speed, cost-effectiveness, and ease of administration [10, 11]. The pandemic has led to increased usage of protective measures such as alcohol gel, gloves, and facemasks [12]. This surge has contributed to a significant rise in healthcare waste (HW)

and poses environmental challenges [12-17]. The Thai Ministry of Public Health estimates that 1.8 million pieces of used masks are converted into HW daily, not including other items like gloves and personal protective equipment (PPE) [18-20]. In Thailand, waste is categorized into four types: municipal, industrial, household hazardous waste (HHW), and HW [21-23]. While healthcare facilities manage HW effectively, household waste remains a concern due to a lack of proper tracking and disposal systems [24-26]. Nakhon Nayok, one of Thailand's 29 Dark-red provinces, faces challenges in managing HW effectively. This study aims to assess the generation and management of healthcare waste (HW) and household hazardous waste (HHW) in Nakhon Nayok during the COVID-19 pandemic and proposes effective management strategies to address these challenges.

## Materials and Methods

### Study site

The study was conducted in Nakhon Nayok province, located in eastern Thailand (Latitude: 14° 12' 16.67" N; Longitude: 101° 12' 46.62" E). The province covers 2,122 km<sup>2</sup> with an approximate population of 260,081 (123 person/km<sup>2</sup>) individuals residing in 101,547 households. Nakhon Nayok was selected as the study site due to its designation as one of the Dark-red provinces, indicating a high level of COVID-19 transmission and stringent public health control measures. In Nakhon Nayok Province, waste management responsibilities, particularly during the COVID-19 outbreak, fall under the jurisdiction of local government organizations. As mandated by Thai law, infectious waste must be disposed of in red trash cans. To manage the increased volume of infectious waste during the pandemic, Nakhon Nayok Province has implemented measures aligned with national protocols, involving the segregation and destruction of such waste. The province's diverse population and household structures provide a representative sample for assessing the generation and management of healthcare waste (HW) and household hazardous waste (HHW) during the pandemic [27].

### Study design

This research employed a stratified random sampling method to analyze the impact of the COVID-19 pandemic on household hazardous waste (HHW) and healthcare waste (HW) generation from December 2020 to June 2021. The study encompassed three administrative levels—Municipalities, Subdistrict Municipalities, and Administrative Organizations—with a sample size of 90 households, 30 from each level. Bi-monthly garbage collection was conducted on randomly selected days in the second and fourth weeks of each month, resulting in 14 collection rounds over the study period. The waste was categorized into 13 types—Paper, Plastics, Glass, Wood, Metals and Aluminum, Food, Household, Hazardous Waste, Healthcare Waste, E-Waste, Yard Waste, Textile, Leather, and Rubber—and further subcategorized into COVID-19-related items (e.g., hand sanitizer containers, sanitizing wipes, used face masks, gloves) and non-COVID-19-related items (e.g., paint, batteries, gauze, bandages, medicine) for detailed analysis.

### Data Validity and Reliability

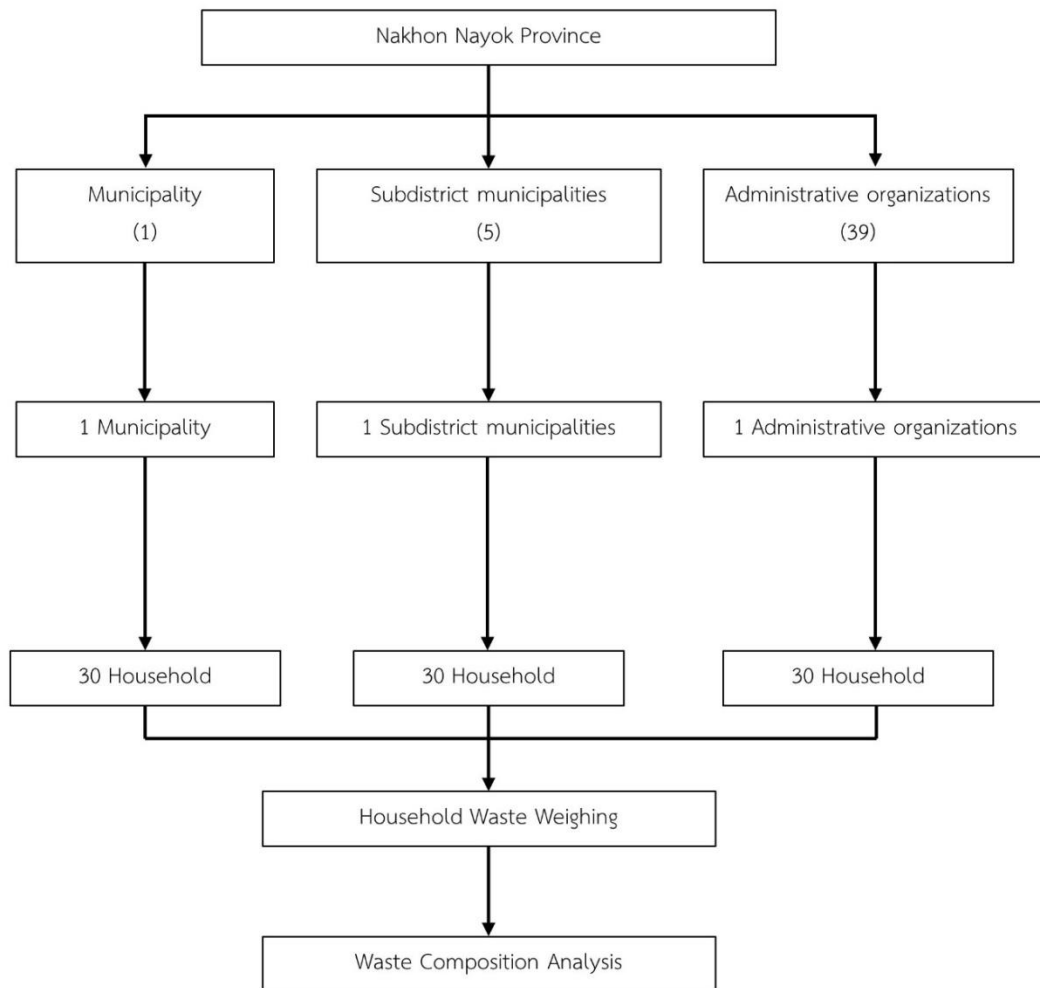
For validity, we employed well-established data collection methods and ensured that our tools for categorizing and measuring waste were thoroughly tested and validated. Our team of data collectors received comprehensive training to maintain accuracy in data recording.

### Statistical analyses

Data collected from the 90 households were subjected to descriptive statistical analysis to summarize and interpret the trends in waste generation and categorization. The analyses were performed using STATA software, version 10 (StataCorp LP). Specific statistical measures such as mean, median, standard deviation, and frequency distribution were calculated to provide a comprehensive overview of the data.

### Ethical approval

The Srinakharinwirot University ethics committee for human research reviewed and approved the study (registration SWUEC-415/2563E).



**Figure 1** Flowchart of data collection and analysis

## Results and Discussion

### Household and Healthcare Waste Composition

Our study found that household hazardous waste (HHW) and healthcare waste (HW) accounted for 16.4% of the total waste produced by 90 households in Nakhon Nayok province. Of this, HHW comprised 12.03%, predominantly non-COVID-related, while HW formed a smaller portion (4.35%), with HW related covid-19 (0.03%) and HHW related covid-19 (3.02%). Most of the HHW related to covid-19 occurred

in municipalities, subdistrict municipalities, and administrative organizations, respectively. In contrast, the majority of HW related covid-19 was generated predominantly in subdistrict municipalities, followed by administrative organizations and municipalities. These findings underscore the necessity of segregating HHW and HW from other wastes, as emphasized by existing literature [28]. The pandemic's influence is evident in the composition of waste, with items like hand sanitizers, sanitizing wipes, and used face masks becoming significant components.

**Table 1** Healthcare waste and household hazardous waste composition in each administrative organization level

Type of household waste	Weight and percentage (kg and percentage)			
	Overall	Municipality	Subdistrict municipalities	Administrative organizations
Plastics	450.21 (25.14)	138.69 (27.74)	94.38 (18.32)	217.14 (28.00)
Papers	124.00 (6.92)	22.60 (4.52)	32.20 (6.25)	69.20 (8.92)
Wood	11.72 (0.65)	0.50 (0.10)	1.98 (0.38)	9.24 (1.19)
Glass	72.00 (4.02)	3.80 (0.76)	20.80 (4.04)	47.40 (6.11)
Metal	35.00 (1.95)	1.20 (0.24)	4.80 (0.93)	29.00 (3.74)
Food	648.90 (36.24)	215.06 (43.02)	258.72 (50.22)	175.12 (22.58)
Total of HHW	215.42 (12.03)	33.66 (6.73)	43.84 (8.51)	137.92 (17.78)
HHW related covid-19	54.02 (3.02)	26.06 (5.21)	16.64 (3.23)	11.32 (1.46)
HHW non-related covid-19	161.40 (9.01)	7.60 (1.52)	27.20 (5.28)	126.60 (16.32)
Total of HW	78.01 (4.35)	54.64 (10.93)	13.46 (2.61)	9.91 (1.28)
HW related covid-19	0.61 (0.03)	0.04 (0.01)	0.26 (0.05)	0.31 (0.04)
HW non-related covid-19	77.40 (4.32)	54.60 (10.92)	13.20 (2.56)	9.60 (1.24)
Electronic	1.20 (0.07)	0 (0)	0 (0)	1.20 (0.15)
Yard	88.00 (4.91)	27.8 (5.56)	27.00 (5.24)	33.20 (4.28)
Textile	30.40 (1.70)	2 (0.40)	13.00 (2.52)	15.40 (1.99)
Rubber	29.00 (1.62)	0 (0)	3.40 (0.66)	25.60 (3.30)
Leather	6.80 (0.38)	0 (0)	1.60 (0.31)	5.20 (0.67)
Total	1790.66 (100)	499.95 (100)	515.18 (100)	775.53 (100)

### COVID-19-Related Waste at Different Administrative Levels

Our analysis of COVID-19-related waste at the administrative level revealed insightful patterns. Notably, while the overall proportion of healthcare waste (HW) related to COVID-19 was relatively minimal, it was the administrative organizations that generated the highest proportion at 0.04%, followed by subdistrict municipalities at 0.05% and municipalities at 0.01%. On the other hand, household hazardous waste (HHW) related to COVID-19 was more significant, with municipalities showing the highest proportion at 3.02%. This disparity in waste generation across different administrative levels might be attributed to variations in public health awareness and adherence to safety measures. For instance, the higher proportion of COVID-19-related HHW in municipalities could indicate more rigorous practices in personal protective equipment use among the general population. In contrast, the pattern observed in HW, especially in administrative organizations

and subdistrict municipalities, might reflect different operational dynamics in healthcare settings. The findings of Techasatian et al. regarding the extended use of face masks among hospital workers [29] resonate with our observations, suggesting a possible trend of reusing protective gear in professional settings. This practice could be a result of heightened health awareness or resource constraints, which aligns with the varying levels of COVID-19-related waste generation we noted. Such trends underscore the need for tailored public health messaging and resource allocation strategies to ensure effective waste management in the context of a pandemic.

### Income and Healthcare Product Purchasing Decisions

Our research also delved into the relationship between income levels and the purchase of healthcare products, echoing the findings of Laaksonen et al. [30]. We observed that higher-income areas like municipalities

tended to generate more COVID-19-related HW, indicating a correlation between income and expenditure on WHO-endorsed healthcare products, which aligns with the broader trend that people with higher incomes generally have greater purchasing power. This is particularly relevant for healthcare products like hand sanitizers, alcohol gel, and face masks, essential in the context of the pandemic. Supporting this observation, a review of existing literature corroborates our findings. Numerous studies have indicated that higher income levels often translate to increased expenditure on healthcare products [31, 32]. These trends are consistent with our observations in Nakhon Nayok province, where wealthier municipalities showed higher consumption and, consequently, higher disposal rates of COVID-19-related HW. This correlation underscores the socioeconomic dimensions of pandemic response, suggesting that income levels play a significant role in determining how communities engage with health protective measures and manage related waste. This trend is further supported by the research of Intarasaksit and Pitaksanurat, which highlights that populations in municipalities with higher income levels tend to have greater purchasing power. This increased capacity to buy healthcare products, such as hand sanitizers and face masks, leads to a higher generation of HHW related to COVID-19 in these areas compared to others with lower income levels [23]. Consequently, this demographic is likely to invest more in protective measures like hand sanitizers and sanitizing wipes, as seen in the waste composition. Considering our findings, higher-income areas, which tend to produce more solid waste include COVID-19-related healthcare waste, could significantly benefit from targeted waste management strategies [33]. These might include developing incentives for reducing healthcare waste, promoting the use of reusable PPE where appropriate, and fostering partnerships with local healthcare providers for more efficient waste segregation and disposal, especially during pandemic peaks. In contrast, lower-income areas could significantly benefit from policies that increase investment in waste management infrastructure, educational programs on proper waste disposal, and improved access to essential healthcare and sanitation products.

## **Implications for Public Health Policy and Outreach**

Our findings on income-related disparities in COVID-19 waste generation have critical implications for public health policy and outreach. To address these disparities, targeted interventions are necessary. In higher-income areas, where higher waste generation was observed, public health campaigns should focus on promoting sustainable waste practices and the importance of responsible disposal. Conversely, lower-income areas may require more support in infrastructure development and access to waste disposal facilities. Policymakers should consider these disparities when formulating waste management strategies, ensuring that interventions are adapted to the specific needs of each community. Additionally, training healthcare practitioners in waste segregation and management tailored to their area's socioeconomic context can further enhance the effectiveness of these strategies. Our study's findings have significant implications for public health policy and marketing strategies. The evident income-related disparities in purchasing and usage of healthcare products suggest that targeting higher-income individuals with public health interventions might yield more substantial compliance and uptake. This approach could be instrumental in managing healthcare waste and enhancing public health measures, especially in a pandemic context [34-36]. Furthermore, establishing a policy for managing infectious waste, including waste generated during health crises, is both essential and beneficial. Such a policy should not only focus on educating the public about separating infectious waste but also ensure effective public relations to garner cooperation. However, this alone is insufficient. It is imperative to implement rigorous monitoring systems and to enforce the segregation of infectious waste from other waste types. Additionally, providing clear guidelines on correct separation methods is crucial for the formulation of an effective policy [17].

## **Conclusion**

Our study effectively addressed our stated aim of assessing the generation and management of healthcare waste (HW) and household

hazardous waste (HHW) in Nakhon Nayok during the COVID-19 pandemic and proposing effective management strategies. This research highlights that while COVID-19-related healthcare waste (HW) forms a relatively small proportion of the total waste stream in Nakhon Nayok province, its impact is nonetheless significant. Constituting about 0.03% (43.26 kg/day) of household hazardous waste (HHW) and 3.02% (4.37 t/day) of general HW, this pandemic-related waste, including masks, hand sanitizers, and sanitizing wipes, points to an upward trend in HW and HHW generation. This trend is not only a reflection of the ongoing battle against COVID-19 but also a call to action for more effective waste management strategies. The increase in COVID-19-related waste necessitates urgent and comprehensive waste management interventions. Essential to these interventions is the proper segregation of HW and HHW from regular household waste. This segregation is crucial to mitigate the risks of contamination and infection, protecting not only households but also the workers involved in waste management. Our study underscores the need for governmental action in enhancing waste management infrastructure. This includes public awareness campaigns focused on the importance of proper waste separation and the introduction of specialized bins for HW and HHW in both households and community spaces. Furthermore, our findings advocate for the development of a robust policy framework in Thailand to tackle the challenges presented by the surge in pandemic-related waste. Future research should aim to delve deeper into the environmental and public health ramifications of COVID-19 waste, focusing particularly on understanding how different communities adapt their waste management practices in response to public health crises. Such studies could offer valuable insights that would help in refining and improving waste management practices, tailoring them to varying socio-economic contexts and enhancing overall public health outcomes.

### Limitations of the Study

This study recognizes certain limitations. The timeframe, covering December 2020 to June 2021, specifically focuses on the early stages of the pandemic. This period may not

fully capture the evolving nature of waste management practices beyond these months, limiting the scope of long-term trend analysis.

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