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Predictions of hazardous plastic waste amounts based on disposable face mask wearing habits

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Abstract: Since March 11, 2020, the global community has faced the challenges of the COVID-19 pandemic. In response, numerous countries, including the Republic of Lithuania, mandated the wearing of face masks to curb the virus's spread. Yet, a section of the Lithuanian populace resisted this move, voicing concerns about the inconvenience of mask-wearing and potential privacy infringements. These concerns endured, even amidst debates on the masks' effectiveness. This article explores how the Lithuanian public responded to mask-wearing protocols during the pandemic. Survey analysis highlighted a troubling trend: many individuals dispose of face masks with their regular trash, often without proper packaging. Most masks are sourced from pharmacies or are provided by employers and are typically thrown away after just one day of use. The data underscores a significant knowledge gap in correct mask disposal, as a significant portion ends up mingled with general household waste, without proper containment. Moreover, many people keep used masks in pockets or bags. Notably, during the pandemic, an estimated 2 mln adult Lithuanians may have generated roughly 15.24 Mg of hazardous plastic waste through mask disposal.

Keywords: COVID-19, environment, face masks, pandemic, survey study

INTRODUCTION

According to the World Health Organization, since the onset of the COVID-19 (**co**rona**vi**rus **d**isease 20**19**) pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), there have been a staggering 759 mln confirmed cases of COVID-19 globally, resulting in 6.8 mln deaths worldwide (WHO, no date). This pandemic, driven by various strains of the coronavirus, has profoundly disrupted global society, impacting social, psychological, and economic aspects of our interconnected world (Kumar, Kalia and Kalia, 2022; Esmaeilzadeh, 2022).

The health care sector has faced one of the most formidable challenges in dealing with this pandemic, as it has been on the front lines, directly encountering individuals carrying COVID-19. Scientific consensus has firmly established that COVID-19 primarily spreads through airborne droplets and person-to-person transmission (Poon *et al.*, 2020; Lindsley *et al.*, 2021). Additionally, research has found that disease-causing pathogens can also be transmitted through frequently touched surfaces contaminated by infected individuals, as well as via waste and other vectors. As a result, governments around the world have implemented a diverse array of preventive measures and national-level restrictions to effectively manage the pandemic.

These measures encompassed a range of restrictions, including limitations on interpersonal interactions, constraints on events and gatherings, meticulous monitoring of visitor numbers at retail establishments, and the temporary suspension of nonessential services. Furthermore, they involved the strict enforcement of social distancing measures and isolation protocols aimed at curtailing the virus's transmission (Esmaeilzadeh, 2022).

In addition to these actions, numerous health organisations strongly recommended the use of face masks and other facial coverings as essential tools for mitigating the virus's spread (Cheng, Lam and Leung, 2020; Wang *et al.*, 2022). Scientific research has consistently demonstrated that face masks play a substantial role in reducing the dispersion of aerosols containing the virus during activities such as sneezing, coughing, or interacting with suspected carriers or infected individuals (Lindsley *et al.*, 2021; Bartsch *et al.*, 2022; Li *et al.*, 2022). The COVID-19 pandemic and its containment measures have led to large volumes of waste generation worldwide. As a result of the enormous influx of sick and hospitalised persons and the use of personal protective equipment by representatives of the health care sector and other areas of activity, biologically hazardous plastic waste has been created, which will eventually enter natural ecosystems in the form of microplastics (Perikala and Bhardwaj, 2022).

In various countries, local quarantines, travel restrictions, and disinfection protocols were implemented under the guidance of emergency operations leaders to curb the spread of the COVID-19 pandemic. These measures impacted various aspects of daily life, including the provision of public services (such as municipal waste management, water supply, administrative services, and education) and even funeral services.

Furthermore, in response to government mandates requiring the use of medical face masks, a variety of protective equipment, including medical face masks (type I, type II, and type II R) and respirators (FFP2, KN95, N95, or FFP3) with varying filtration efficacies, have been employed to safeguard the upper respiratory tract within service areas. The global daily consumption of masks reached millions of units per day during the pandemic's spread (Mghili, Analla and Akissou, 2022). However, the widespread use of such protective gear has inevitably led to issues of improper waste disposal (Ma *et al.*, 2021).

Throughout the pandemic management period, a broad spectrum of personal protective equipment was utilised, contingent upon the nature of activities and the availability of protective gear. This encompassed the use of disposable medical and nonmedical face masks, respirators with diverse filtration and protective capabilities (Feng *et al.*, 2020; Greenhalgh *et al.*, 2020), and protective face shields and safety glasses, which proved crucial in halting or mitigating airborne transmission of the virus. Additionally, extensive use of disposable protective clothing, including coveralls, gloves, face shields, headgear, boots, plastic aprons, and robes, was implemented to reduce the potential transmission and dissemination of the virus via contaminated surfaces. These measures, alongside various sanitary precautions, have played a pivotal role in the multifaceted approach to limiting the virus's spread (Perikala and Bhardwaj, 2022).

Nonetheless, disposable face masks serve as a crucial tool for respiratory protection, shielding individuals from air pollutants, pollen inhalation, chemical fumes, and pathogens. The effectiveness of mask filtration, and consequently the level of protection against harmful elements, hinges on the materials employed in their construction (Morgana, Casentini and Amalfitabo, 2021).

Typically, disposable face masks comprise three primary layers: an outer waterproof layer, a middle filtering layer designed to capture droplets from the surrounding environment as well as those emitted by the wearer, and an inner layer (Chua *et al.*, 2020). In the production of these masks, cost-effective plastic polymers, such as polypropylene, polystyrene, polycarbonate, polyester, or polyethylene, are predominantly utilised due to their affordability (Aragaw, 2020; Li *et al.*, 2022; Zhang *et al.*, 2022).

However, the widespread utilisation of face masks on a global scale has raised concerns regarding the significant volume of plastic waste, which is poised to emerge as a secondary source of microplastic or nanoplastic pollution within ecosystems (Neto *et al.*, 2021; Shen *et al.*, 2021). It is important to note that the degradation process of plastic waste can extend over multiple centuries (Dong *et al.*, 2020; Evangeliou *et al.*, 2020), yet the breakdown of plastics introduced into the natural environment can be influenced by various environmental factors (Du, Huang and Wang, 2021).

The decomposition of plastics in the environment can be expedited by various factors, such as mechanical forces, higher temperatures, chemical composition, exposure to ultraviolet radiation, or natural biodegradation processes (Ray *et al.*, 2022). This, in turn, has the potential to result in detrimental health consequences for the human population through contamination of the food chain (De-la-Torre and Aragaw, 2021; Du, Huang and Wang, 2022). Microplastics, owing to their capacity to attract impurities such as heavy metals and persistent organic pollutants, have emerged as a concerning new type of pollutant. Consequently, these microplastic compounds can exert adverse effects on organism growth (Shen *et al.*, 2021).

Ongoing research indicates the presence of microplastics in coastal areas, ocean, river, and lake sediments, as well as within soil. This widespread distribution underscores the ability of microplastics to traverse significant distances via atmospheric and oceanic currents, establishing them as global pollutants (Dong *et al.*, 2020).

While crucial in managing the COVID-19 pandemic and curbing virus transmission, personal protective equipment (PPE), primarily composed of plastics, raises environmental concerns due to its disposability (Perikala and Bhardwaj, 2022; Torres-Agullo *et al.*, 2021). Improper disposal of face masks in the environment has the potential to become a source of harmful pathogen transmission (Du, Huang and Wang, 2022; Mol and Caldas, 2020). The aim of the study is to assess the amount of hazardous plastic waste due to the purchased quantities and wearing habits of disposable face masks.

MATERIALS AND METHODS

To initiate the study, a questionnaire survey was employed to assess the quantities of face masks and other protective equipment used as well as the wearing habits of individuals in Lithuania throughout the pandemic. The questionnaire was hosted on the https://apklausa.lt/ website and distributed to respondents via email and social media platforms; invitations were extended to the public to participate in the survey and complete an anonymous questionnaire. This survey was carried out between November 2021 and April 2022, utilising the questionnaire research method to collect primary data.

The structured questionnaire incorporated a mix of open-ended and closed-ended questions that were thoughtfully organised in terms of complexity. Respondents were afforded the option to provide comments, express specific opinions, or choose not to respond to certain queries. Furthermore, the questions were meticulously formulated to ensure clarity and comprehensibility, catering to individuals across different age groups and educational backgrounds. This survey involved 1757 respondents, chosen for their efficiency and cost-effectiveness. The questionnaire study did not demand substantial financial resources. It concluded at the end of the active pandemic, aiming to quantify face mask waste generation and its environmental impact. Additionally, the survey probed respondents about their mask-wearing habits during the COVID-19 pandemic, including mask types, duration of use, and purchase quantities. By analysing these data, we can forecast the volume of COVID-19-related plastic waste in Lithuania.

Furthermore, the survey encompasses inquiries about disposal methods for using face masks and the presence of improperly discarded masks in the environment. The aggregated information from all survey questions will facilitate an assessment of the generation of waste face masks and their environmental impact.

The survey sample was meticulously designed to reflect the characteristics of the overall population and ensure representativeness. Descriptive statistics define the general population as the entirety of objects subjected to statistical analysis. In this context, the general population refers to the survey participants – Lithuanian residents who consented to participate in the study. Social research typically recommends determining the sample size with a 5% margin of error in mind (Cardel, 2005), calculated using the Equation (1):

$$n = 1/\left(\Delta^2 + 1/N\right) \tag{1}$$

where: n = the number of cases in the sample group, N = the general population, Δ = the magnitude of the error.

Analysing the habits of wearing face protection products in Lithuania, it should be noted that, at the beginning of 2021, Lithuania was estimated to have a population of 2.8 mln people, with 795.7 thous. permanent residents, as reported by the Official Statistics Portal (OSP, 2022). To ensure that the survey is representative and reliable with a margin of error of 5%, it is determined that 400 Lithuanian residents must be interviewed. This calculation is based on the formula: n = 1/(0.0025 + 1/2795700).

Furthermore, this study holds particular significance due to the escalating production and global consumption of disposable face masks, which have presented a substantial environmental challenge. The environmental repercussions of the COVID-19 pandemic, both in the short and long term, have been largely underestimated. Unknown quantities of plastic masks continue to flow into Lithuania, reaching pharmacies, supermarkets, and residents directly from China. Additionally, this topic retains its relevance, as the wearing habits of masks in Lithuania remain shrouded in uncertainty. Questions linger about the frequency of disposable mask replacements and the methods employed for their disposal.

RESULTS AND DISCUSSION

HABITS OF WEARING FACE MASKS IN LITHUANIA DURING THE COVID-19 PANDEMIC

The survey data revealed that a remarkable 95% of those who participated conscientiously adhered to proper mask usage, while only a small fraction, accounting for 7% of respondents, reported not wearing masks as prescribed. This demonstrates the responsible behaviour of Lithuanian residents in terms of wearing face protection during the pandemic.

To gain a more comprehensive understanding of the potential generation of hazardous plastic waste, we delved further into the questionnaire data, aiming to unveil the nuances of face protection product habits in Lithuania. Subsequently, as an integral component of our expanding study, we formulated projections concerning the potentially harmful quantities of plastic waste that may have arisen. For face protection measures to effectively mitigate the spread of the virus, it is imperative that they are worn correctly.

The survey's findings underscore the importance of this correct usage, with a notable 82% of respondents adhering to these guidelines.

The results of the survey, which types of face protection are worn by residents, are presented in Figure 1.

It was discovered that 93% of the participants opt for medical masks, 3% prefer disposable nonmedical face masks, 2.4% choose respirators, 1.5% have other preferences, and 1.8% select reusable fabric face masks. The survey also includes a graphical representation of where Lithuanian citizens purchase their face protection products in Figure 2.

The results indicate that face masks are acquired through various channels, with 37% being purchased in pharmacies, 31% in supermarkets, 12% online from domestic sources, and 3% online from international suppliers. Additionally, 8% of respondents received masks from relatives.

This study also analysed the habits of replacing face masks. The results are shown in Figure 3.

The survey data reveal distinct patterns in face mask usage. A significant majority, comprising 43% of respondents, replace their face masks daily, following each working day. A smaller proportion, 21% of survey participants, adhere to a 3–4 h interval for mask changes. Only a modest 4% of those surveyed indicate that they switch masks every 1–2 h.

Interestingly, 12% of respondents changed their masks when they showed signs of wear and tear, while 8% opted for a new

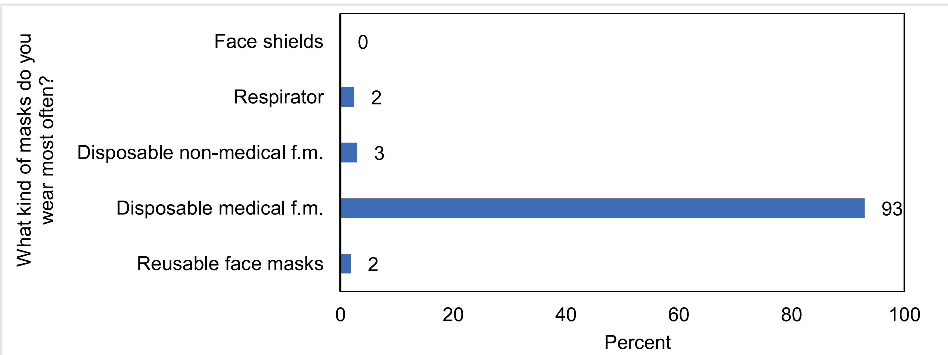

Fig. 1. Respondents' results regarding the type of face masks (f.m.) to wear (n = 1757); source: own study

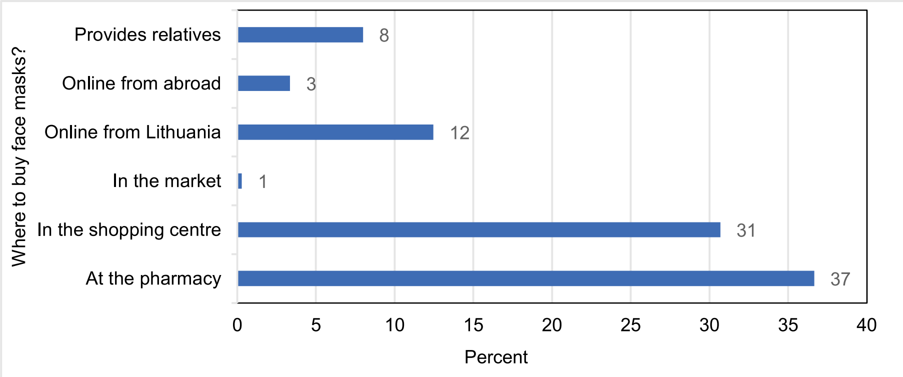

Fig. 2. Methods of purchasing face masks (n = 1757); source: own study

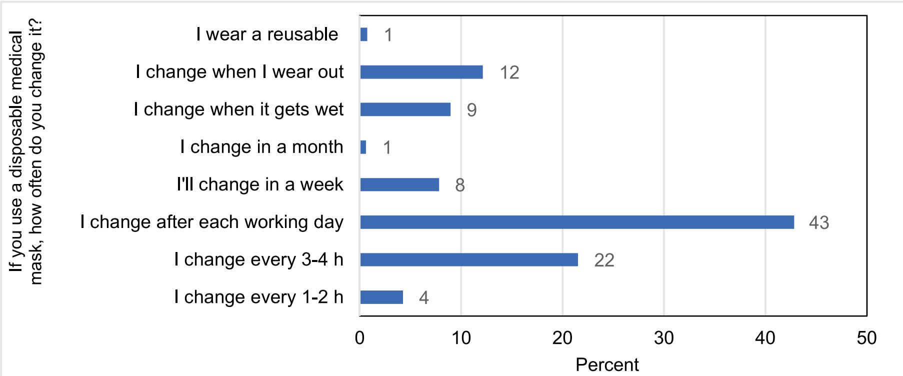

Fig. 3. Frequency of changing disposable face masks (n = 1757); source: own study

mask after a week of continuous use. Additionally, 9% of interviewees assert that they replace a wet mask with a fresh mask.

Furthermore, the study endeavoured to analyse the handling and disposal methods for waste generated from protective face masks. The ensuing findings are graphically depicted in Figure 4.

The findings revealed that 60% of respondents disposed of used face masks by tossing them into mixed municipal waste containers without being placed inside a bag. Another 34% disposed of them in the same mixed municipal waste containers, but in this case, the masks were enclosed in bags. Other responses indicated diverse practices, with 1% mentioning they lost somewhere they discarded them and 4% specifying that they incinerated the used face masks or deposited them in paper waste containers. Notably, a majority of those who selected “Other” explained their actions, such as burning the masks, placing them in paper containers, or expressing environmental concerns regarding plastic waste.

Regarding the disposal of masks with cords, some individuals mentioned detaching the cords to prevent entanglement in landfills before discarding them in mixed municipal waste containers. Others mentioned using specialised workplace containers or containers designated for packages. Some referred to plastic or shoulder containers, while a few opted for the “yellow” container for waste. A few respondents admitted uncertainty about the appropriate disposal method, leading them to toss them in individual unsorted waste containers.

Surprisingly, 61% of respondents indicated a lack of sufficient information on where to properly dispose of used face masks. Only 38% of those surveyed claimed to possess adequate knowledge about the correct disposal methods. The visual

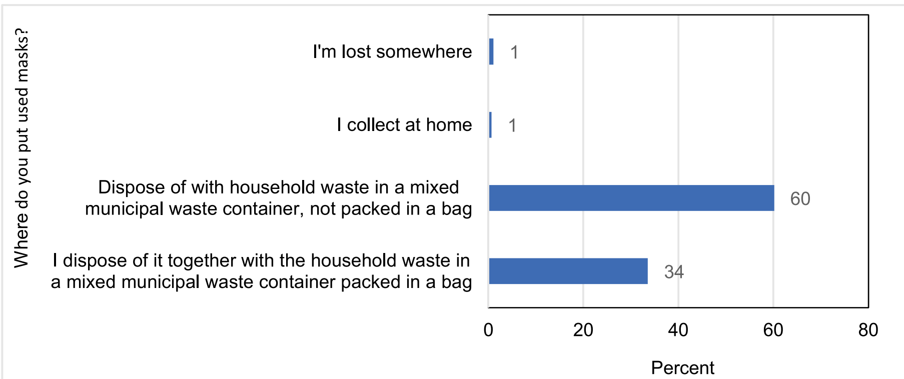

Fig. 4. Place of disposal of used masks (n = 1757); source: own study

representation of the disposal practices for used disposable masks when they are reused multiple times can be seen in Figure 5.

The survey findings reveal a range of practices employed by respondents for storing disposable face masks when reusing them. The most prevalent method, embraced by 42% of participants, is to keep the mask within their pocket. Conversely, 28% opt for storage within their handbags, while 17% choose to leave them in their vehicles. A smaller proportion, approximately 8%, prefer wearing them on their hands, and an additional 5% utilise various storage locations, including bags, separate bags, purses (during shopping), workplace drawers (during lunch breaks), hallway cabinets, worktables, or drawers.

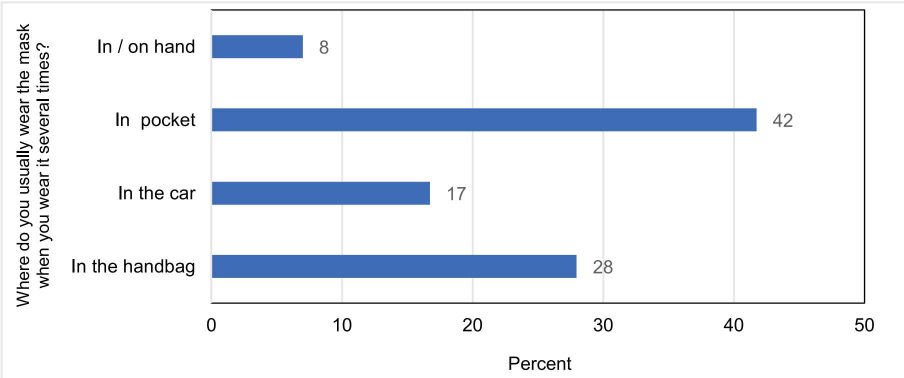

Fig. 5. A storage area for disposable face masks that can be used several times (n = 1757); source: own study

Notably, some respondents described continuous wear throughout the day, pulling the mask down under their chin only when they were not in close contact with others. The survey highlights a range of practices in terms of storing disposable face masks worn multiple times, reflecting the diverse approaches adopted by participants.

FORECAST OF THE QUANTITIES OF HAZARDOUS PLASTIC WASTE

The results of the survey regarding the amount of disposable face masks purchased are presented in Figure 6.

The questionnaire survey yielded information regarding the quantities of disposable masks purchased. Notably, 43% of respondents acquired 200 units or more, while 21% purchased between 101 and 200 units. Additionally, 12% of participants bought up to 50 units. Using these collected data, a scatterplot was created, and a regression equation was formulated. This equation allows for the prediction of disposable face mask purchases based on the population size.

According to the obtained data, a regression equation was created:

$$Y = 25.1004 + 2.8477N \tag{2}$$

where: Y = acquired amount of disposable masks, N = number of people in units.

According to the Equation (2), it is possible to predict the amount of disposable face masks purchased, depending on the population. The results are shown in Figure 8.

The results show that 2 mln adults living in Lithuania may have purchased 5,589,620 units of disposable face masks. One disposable face mask weighed 2.7274 g. The results are shown in Figure 9.

The calculated results show that the 2 mln adults living in Lithuania during the pandemic period may have generated approximately 15.24 Mg of hazardous plastic waste from disposable face masks.

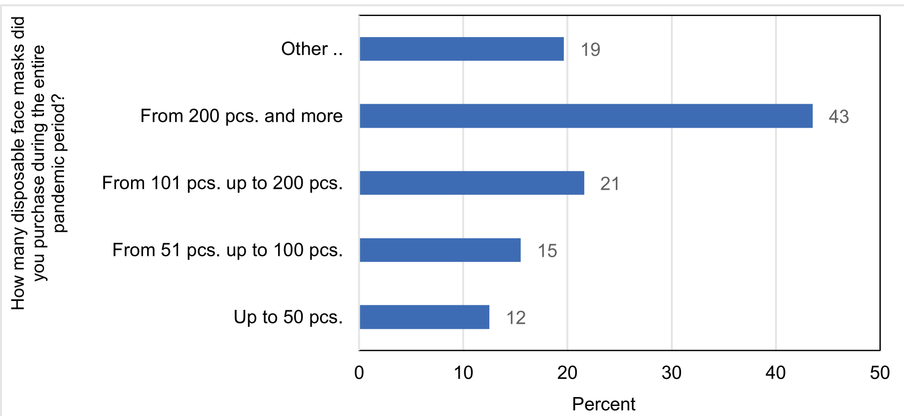

Fig. 6. Quantity of disposable face masks purchased (n = 1757); source: own study

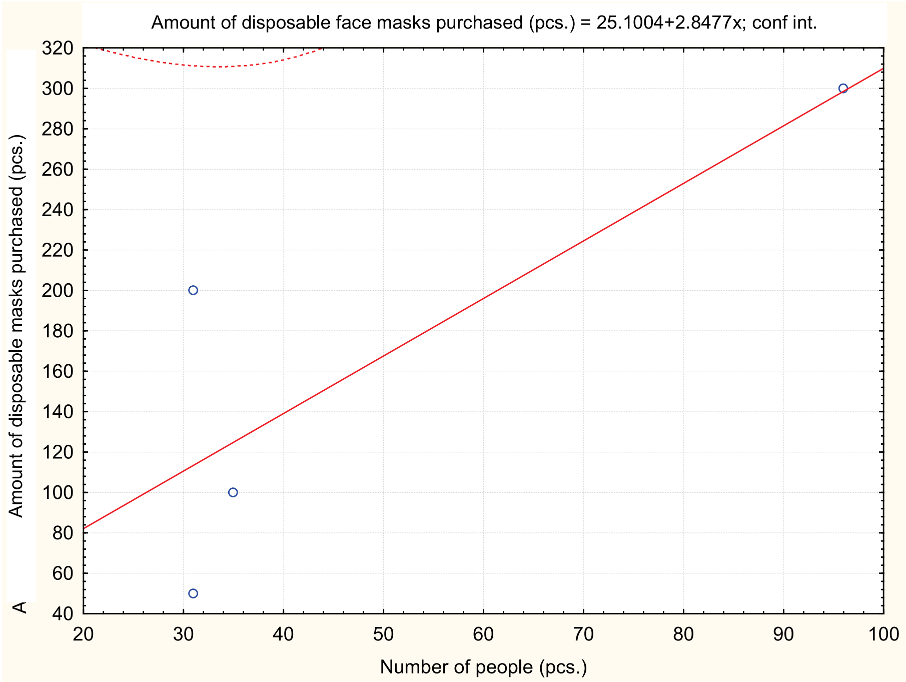

Fig. 7. Scatter plot of the quantity of disposable face masks purchased by number of people; source: own study

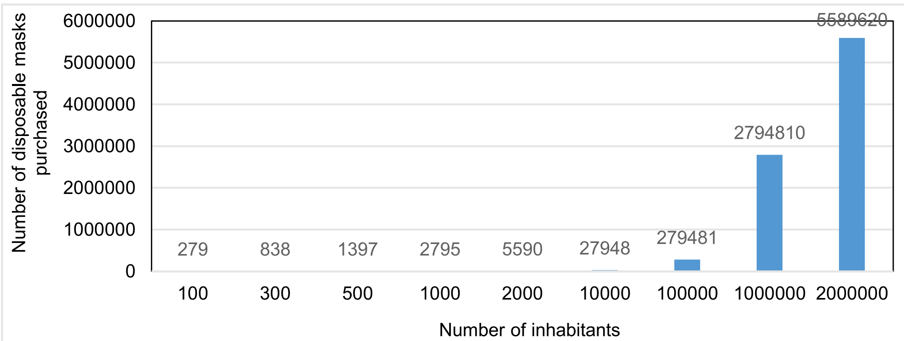

Fig. 8. Quantity of disposable masks purchased, depending on the population; source: own study

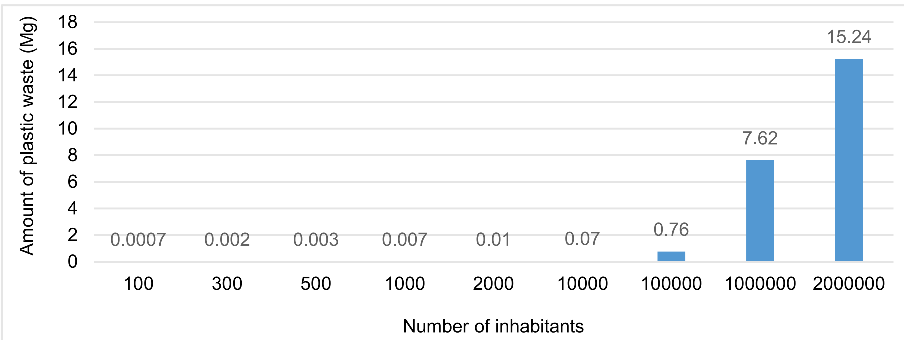

Fig. 9. The amount of plastic waste generated from disposable face masks during the pandemic; source: own study

CONCLUSIONS

During the COVID-19 pandemic, face masks used by residents were often improperly disposed of, being released into the environment or released with general household waste and often ending up in landfills (these results were confirmed by the results of the questionnaire study). When analysing the survey data, it was found that individuals throw face masks along with household waste into a mixed municipal waste container, unpackaged in a bag (59%).

Furthermore, the survey reveals that disposable face masks are typically replaced after each working day. Moreover, the results highlight a significant gap in information regarding the proper disposal of masks, leading to their disposal alongside general household waste in mixed municipal waste containers, without being enclosed in bags.

Additionally, the survey indicates that the most common storage locations for masks that have been worn several times are pockets (43%) and handbags (27%). Ultimately, the results underscore that approximately 2 mln adults residing in Lithuania during the pandemic may have contributed to the generation of approximately 15.24 Mg of hazardous plastic waste. This approach can be replicated in other parts of Europe or the world, depending on the population size.

To reduce the amount of hazardous plastic waste, it is necessary to wear other face protection that is friendly to the environment. Possible alternatives to wearing disposable plastic masks are reusable dense fabric face masks or patented natural antiviral face masks, e.g., biologically active moss face masks (JP,2020-085999).

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