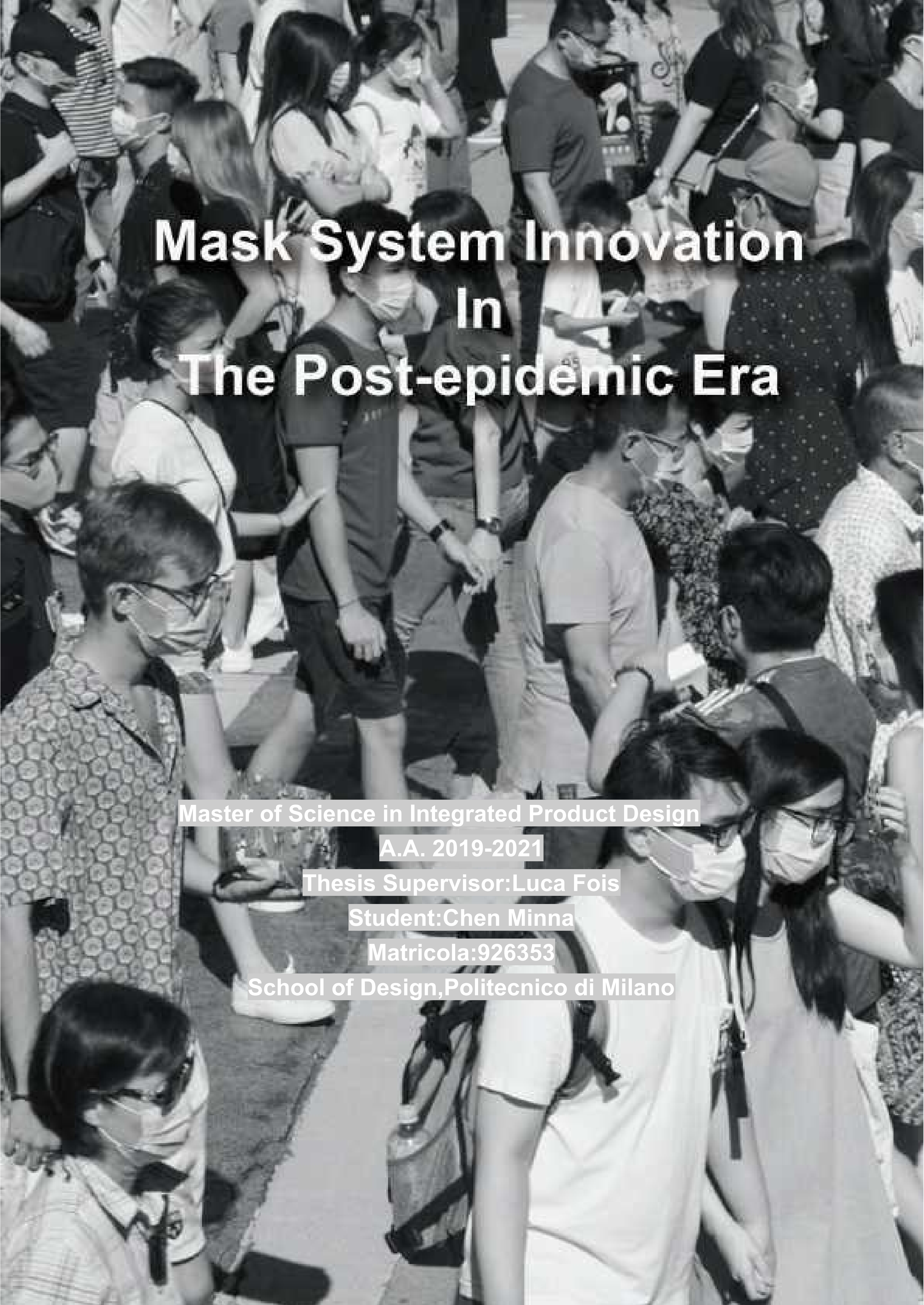

# Mask System Innovation In The Post-epidemic Era

Master of Science in Integrated Product Design

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# ABSTRACT

In the year when the Coronavirus swept the world, the demand for personal protective equipment surged. It is estimated that about 89 million medical masks are needed every month to treat and care for COVID-19 patients (WHO, 2020d), which has led to increased environmental pressure. Currently, there is no complete system specifically for daily medical waste disposal, such as discarded masks. At the same time, people cannot protect themselves well during this sudden outbreak of infectious diseases because they cannot get correct information. This is not only a virus war, but also an information source battle. Under this circumstance, people are forced to live in isolation at home, unable to conduct normal social interactions, and it is very easy to cause depression and irritability. Therefore, in this document, the innovative possibility of personal protective equipment-disposable masks is mainly analyzed to help reduce environmental pressure. At the same time, new technologies such as NFC are used to help people obtain the correct information of personal protective equipment, so that they can better protect themselves when going out.

## KEYWORDS

- **C**oronavirus
- **R**euse
- **I**nformation reliability
- **S**ustainability
- **I**nnovation
- **S**terilization

# INDEX

# 1.Introduction

## 1.1 Motivation

As of now, the number of coronavirus infections worldwide has reached 181 million, with a daily increase of 408.990 and 97.49 million deaths. This is an exceptionally serious global virus crisis. Compared with the previous Ebola virus in West Africa in 2014-2016 and the H7N9 virus in China in 2013, the scale of this virus crisis is larger, more spreading, and faster,in less than three months, quickly sweeping the world, and has not improved for a year and a half.

Except for coronavirus, according to the analysis of previous virus outbreak data, the interval between each occurrence of pandemic in the respiratory system is about 20 years. This indicates that not only should preventive measures be taken in response to this epidemic, but also that there should be early preparations for the unknown HN respiratory virus in the future.

Fortunately, starting from the end of 2020, global vaccines have gradually entered vaccination status. Currently, out of an average of 100 people in the world, 1.21 have been vaccinated. Let the world see the dawn of victory in the war epidemic. It is worth discussing that in the case of multiple mutations of the virus, the current vaccination speed and the effective rate of the vaccine still need to be further developed. Experts predict that it will take at least two years until the global cases are cleared. This is a long "war". At the same time, this also means that personal protective equipment (PPE) and disinfection supplies will always exist in our lives until the end of the epidemic. At present, it seems that people’s use of personal anti-epidemic equipment (PPE) and how to correctly protect their sources of information are affected by many factors. The messy and inaccurate information has misled many people to adopt the wrong way and fail to protect themselves. The purpose of this, thereby increasing the risk of infection.

At the same time, when paying attention to the epidemic, it is easy for people to ignore environmental issues. According to multiple news reports, wild animals are suffocated by mask straps, the number of discarded marine masks has greatly increased, and the discarded disposable masks that can be seen everywhere on the roadside are issues that cannot be ignored. According to the 17 Global Goals and 169 targets formulated by "agenda 2030 for sustainable development", sustainability is an important strategic goal for our future survival and development:

*"-----The Sustainable Development Goals are a call for action by all countries with poor,rich and middle income to promote prosperity while protecting the planet. They recognise that ending poverty must go hand in hand with strategies that build economic growth and address a range of social needs including education,health,social protection,and job opportunities,while tackling climate change and environmental protection."*[*agenda 2030 for sustainable development*]

At the same time, according to the current survey data, the use of disposable masks has reached 129G/month, and the estimated energy consumption can reach 1.29TWh/monthG/month. A large number of discarded medical masks are produced, and the use cannot be reduced under special circumstances (epidemic). Under the circumstances, there is still no systematic solution for recycling. This led to the environmental pollution problem reported above.

## 1.2 Objectives

So (i) how to let people get the right information can protect themselves and their families; (ii) While preventing the epidemic, it also minimizes environmental pollution; (iii) Make the masks reusable and reduce environmental pollution; (iv) Even after the virus pandemic has passed, make adequate preparations in advance for the arrival of the next epidemic. It is the focus of this article.

## 1.3 Methodology

The methodology of this article is mainly based on qualitative and quantitative research: survey data, case analysis, literature review, questionnaire interviews. And combined with the double-drill model in the design methodology, carry out innovative design research.

In the beginning, the research and analysis were mainly followed the following questions:

i. What is the psychological impact of being unable to socialize during the quarantine period?
ii. At the moment of the epidemic, how do people protect themselves when going out, and what do they need to prepare?
iii. How to judge the correctness of the source of epidemic prevention information? What are the trusted authorities?
iv. What are the current environmental pollution problems of PPE?
v. What is the existing medical waste recycling system?
vi. What is the referenceability of the plastic circulation system?
vii. Are there new materials that can be used in mask design to reduce environmental pollution?
viii. Are there new technologies that can be used in the circulatory system of masks?

- Broad research

This document began with a horizontal survey, a large-scale search of documents and related reports to clarify which field and direction should be studied under the two general directions of "epidemic era" and "sustainability".

- Subdivision research

Then enter the vertical research direction, will find the five areas,
: Materials, technology, systems, services, etc., to find a large number of innovative possibilities.

- Data analysis

After subdividing the research and clarifying the research direction, collect data through interviews, questionnaires, etc., and then analyze for helping to deepen the research direction.

- Key issues

After a series of investigations, found key issues, which are the design challenge outline in design thinking, and also is the same as design "opportunities"

- Case studies
  Under the premise of theoretical support and design requirements, some case studies have been carried out to serve as references for this article

- System building
  The next step is to enter the system construction, improve the design points of this paper, and improve the design system.

- Concept evaluation
  Finally, based on all the above data and research, conduct dialectical analysis and produce innovative solutions, which is the final program output in the design methodology.

# The History of The Epidemic

# 2. Historical timeline of major epidemics

Since the first case of the new crown virus broke out in Wuhan, China in December 2019, more than 17 months have passed. The new crown virus has swept the world and quickly became a global infectious disease within three months. Based on the increasing number of global cases, the World Health Organization (WHO) subsequently declared it a global health emergency on January 30, 2020[1]. Within one year of 2020, people from all over the world will stand on the united front and fight the virus together. The good news is that the development and vaccination of vaccines have been realized from the end of 2020. At present, vaccine trials are in Phase II and have not yet reached the level of Phase III. This means that the virus war will not end before the global cases are cleared.

Review several major respiratory viruses that appeared before: SARS coronavirus (SARS-CoV), which appeared in November 2002, causing severe acute respiratory syndrome (SARS); and MERS coronavirus (MERS-CoV), which appeared in 2012 Causes Middle East Respiratory Syndrome (MERS). For this COVID-19, the Coronavirus Research Group of the International Commission on Virus Classification confirmed that the current virus is a variant of SARS-CoV. Therefore, the committee named the new pathogen SARS-CoV-2[2]. SARS-CoV-2 is different from the previous SARS-CoV and MERS-CoV. Regardless of the virulence or the severity of the infection, the world has never encountered it.

In this state of emergency, experts from all walks of life, including designers, are working hard for this battle. In the post-epidemic era, how can people lead a better life? In what ways can people improve their current living conditions? These issues should be considered by designers. Of course, it is not advisable to design only for the study of the new crown epidemic, and it is short-lived because the battle of the virus will one day end. People need to be adequately prepared for the upcoming epidemic in the future. Analyzing and studying the timeline of each HN respiratory disease outbreak in history can be obtained (Figure 1):

[1] *Broto Widya Hartanto, Dyah Samti Mayasari,15 March 2021*
*Environmentally friendly non-medical mask: An attempt to reduce the environmental impact from used masks during COVID 19 pandemic*

[2] *Rai, Nagendra Kumar, Ashok, Anushruti, Akondi, Butchi Raju, 30 Jul 2020, "Consequences of chemical impact of disinfectants: safe preventive measures against COVID-19"*

History of HN series viruses

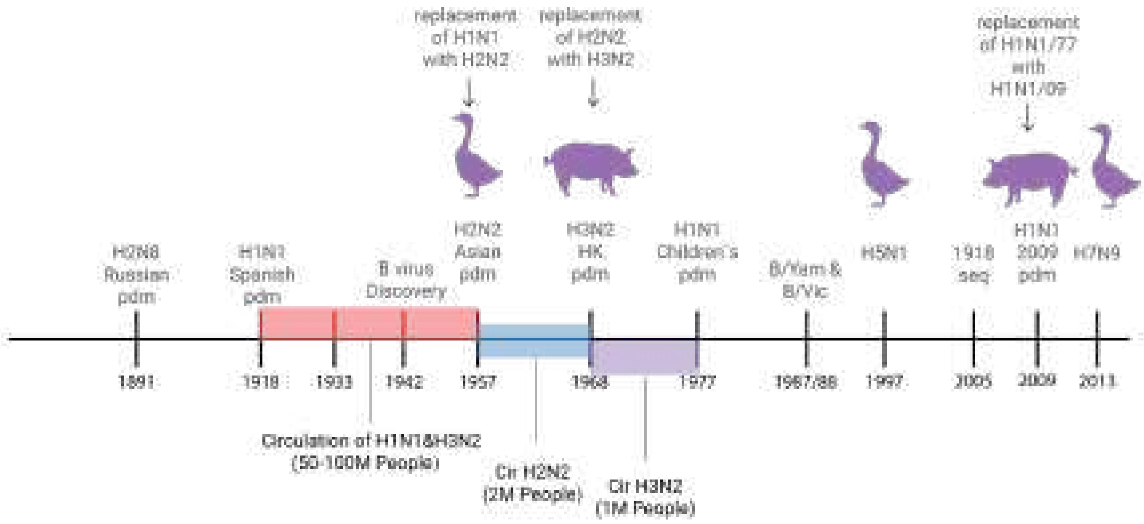
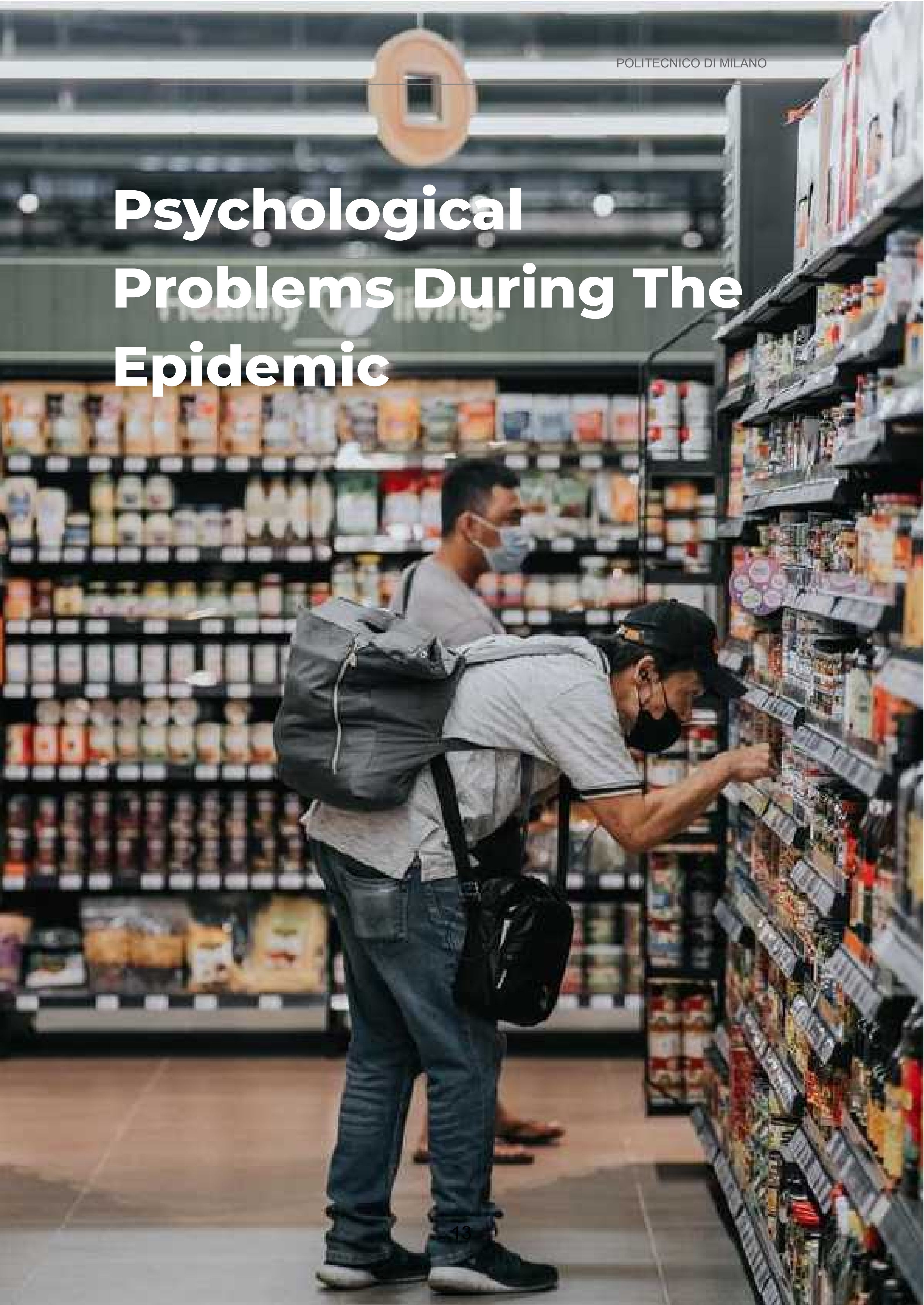



*Fig.1 History of HN series viruses*

As shown in the figure, from the 19th century to the present, there has been a major respiratory disease outbreak every 10 years or so, and it will occur in the shortest or even eight years. This is a regular and a long-term problem. Humans can never predict what the next respiratory virus will appear, nor will we know when it will appear next time, but we can find better ways to protect ourselves and our family from experience time and time again.

# Psychological Problems During The Epidemic



# 3 Psychological problems of people during the COVID-19 pandemic

## 3.1 Emotional problems during isolation

In order to curb the spread of the virus, since China implemented a mandatory home isolation policy, countries have successively adopted long- and short-term home isolation measures. People's mental health problems have also been put on the table under the premise of proven effectiveness. In long-term social isolation, people have reduced the frequency of social interaction. The red zone blockade policy in Italy, the mandatory home isolation in China, the inability to leave residential areas, and the 14-day immigration isolation policy in Iceland have all reduced people’s social interaction. To a certain extent.

However, after the questionnaire interview, it was learned that 85.2% of the people chose to go out during the isolation period.（fig.2）According to data, supermarket shopping that had to go out during the epidemic accounted for one-half, followed by work. Part of it is due to personal reasons, such as going out to walk the dog or partying with friends, which accounts for a small portion.(fig.3)

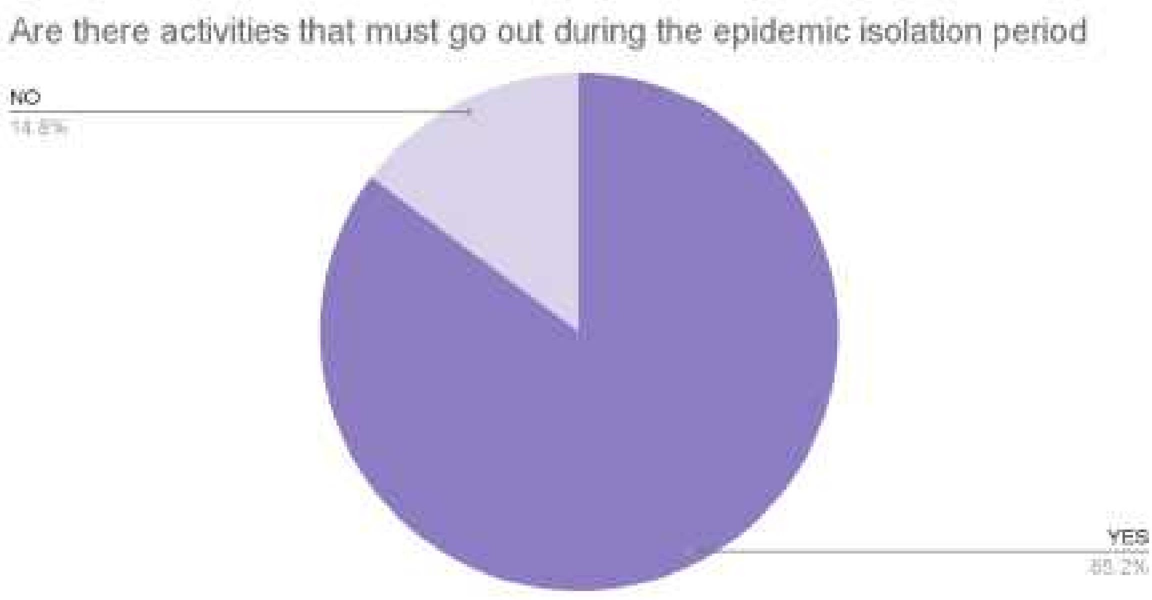



*Fig.2 Are there activities that must go out during the pandemic isolation period?*

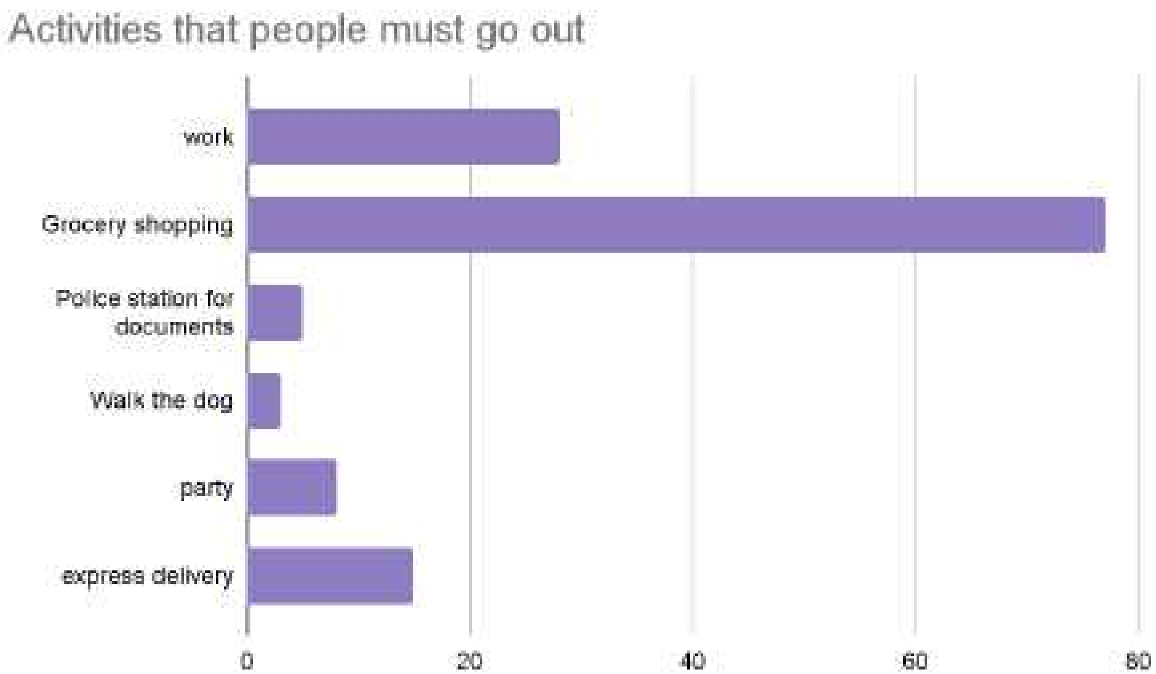



*Fig.3 Activities that people must go out*

In addition to the short necessary time to go out, people still stay in isolation at home most of the time. According to the questionnaire, people generally feel lonely, depressed, irritable and have other emotions. (fig.4)

"Loneliness refers to a subjective feeling in psychology, while social isolation is defined by the degree and frequency of a person's social interaction. As a generally accepted concept, loneliness is defined as a person's subjective feeling, while social isolation describes the objective state of the individual's social environment and interaction mode. "[3]Even now, network electronics are already very developed, but they still cannot replace the importance of face-to-face communication.

[3] *Tzung-Jeng Hwang,Kiran Rabheru,Carmelle Peisah,William Reichman,Manabu Ikeda26 May 2020,"Loneliness and social isolation during the COVID-19 pandemic"*

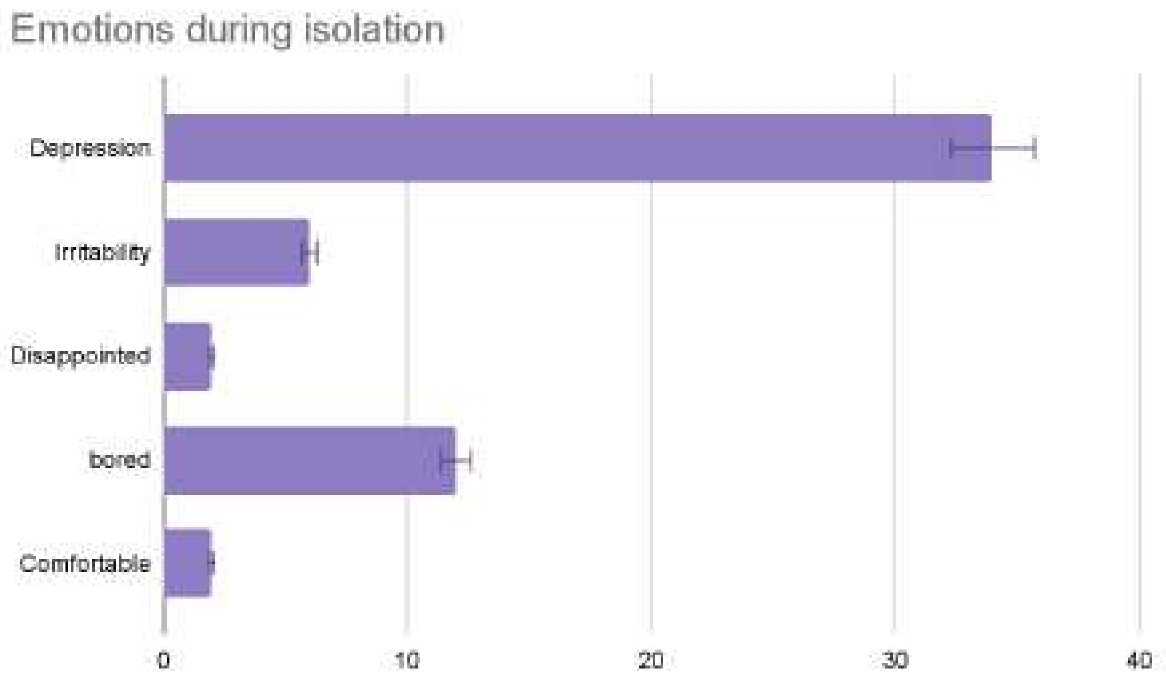



*Fig.4 Emotions during isolation*

Then it needs to discuss the harms of loneliness on various physical and mental effects, including increased systolic blood pressure and increased risk of heart disease. Both loneliness and social isolation are associated with an increased risk of coronary heart disease-related death, even among middle-aged adults without a history of myocardial infarction (Heffner et al. 2011; Steptoe et al. 2013). Loneliness also has many detrimental effects on mental health. The most direct point related to it is to reduce the time spent asleep in bed (reducing sleep efficiency by 7%) and cause people to wake up in time and loneliness after waking up (Cacioppo et al., 2002; Fässberg et al., 2012). This is also similar to the symptoms of depression. It has been reported that the increase in symptoms of depression may also be due to loneliness, poor self-assessed health, impaired functional status, visual impairment, and negative changes in people's quality of life (Lee et al. 2019 ).

The proposed mechanism for the adverse effects of loneliness on health focuses on physiological stress responses (such as increased cortisol) (Xia and Li, 2018). Abnormal emotional stress can lead to poor health outcomes. The mechanism may be related to behavioral changes in social isolation, including unhealthy lifestyles (such as smoking, drinking, low exercise, poor diet choices, and non-compliance with medical prescriptions) (Kobayashi and Steptoe, 2018; Leigh-Hunt et al., 2017). Smaller social networks and less medical support will exacerbate these conditions.[4]

Because of the loneliness during isolation, it needs to find a way to alleviate it. According to the data in the questionnaire（fig.5）, three-quarters of people decide to find a hobby, such as reading, exercising, and cooking to spend time, but loneliness will still exist. A very small number of people choose to ignore the quarantine policy and still go outside to socialize. Although this will reduce the appearance of mental illness, it is very unsafe during the epidemic. This will make it more likely to be infected with the virus, which threatens lives and the safety of family members.

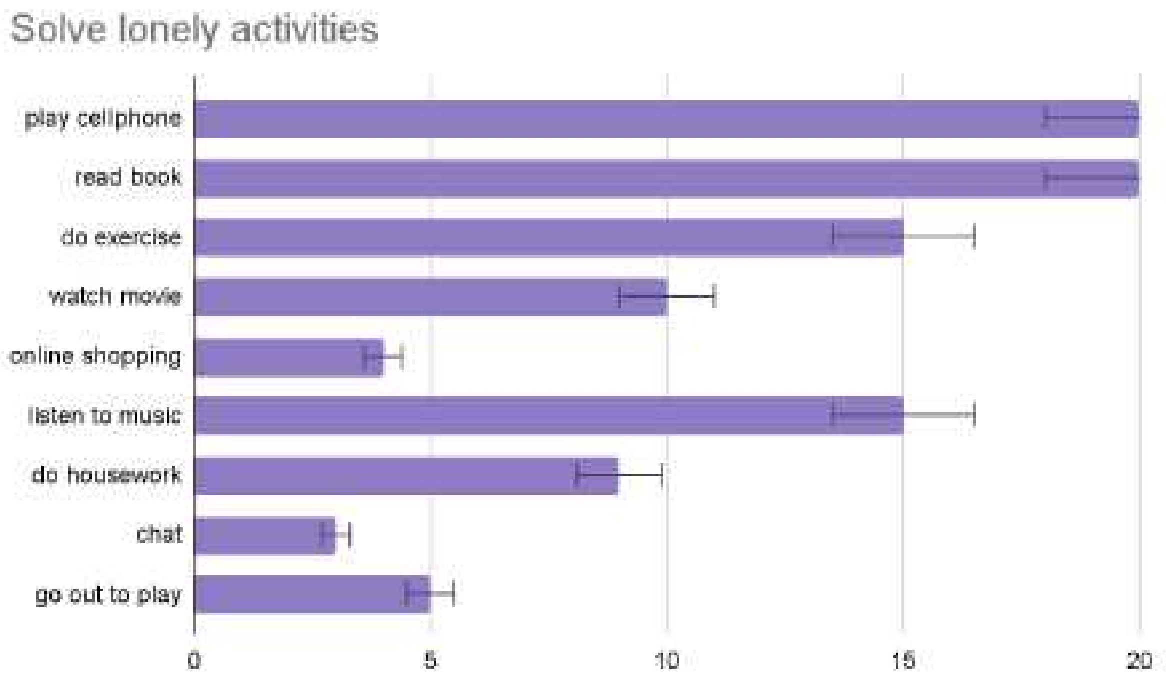



*Fig.4 Solve lonely activitie*

[4] *Hwang, T., Rabheru, K., Peisah, C., Reichman, W., & Ikeda, M. (2020). Loneliness and social isolation during the COVID-19 pandemic. International Psychogeriatrics, 32(10)*

## 3.2 Solutions to ensure physical and mental health

- Keep in touch. In the current era of information globalization, social media is developing rapidly. Maintaining with friends through media such as mobile phones and computers can help ease the feeling of loneliness.
- Ensure that basic needs are met. To ensure the basic food and lodging requirements of daily life, people can purchase them online or go to the supermarket every week to buy more daily necessities.
- Design the schedule every day. For many people, staying at home most of the day is a psychological challenge. When most outdoor activities are not available, it is not easy to maintain a fixed daily schedule.
- Keep your mind and body active. Exercise is good for physical and mental health (especially for mood and cognition).
- Carry out outdoor activities in accordance with social distancing guidelines. Brief outdoor activities are usually still possible and good for health. People feel much better due to direct sunlight and the ability to meet others while maintaining a physical distance.

A better understanding of these mental health issues will help us design. The above analysis is enough to see the importance of social interaction to people. Therefore, this article mainly studies how to keep people going out for work and socializing frequently (to take care of their mental and emotional health), while at the same time, they can better protect their health and safety.

# “INFOMATIC” WAR

# 4. Analysis of the importance correct information sources under the epidemic

According to the analysis of psychological problems in the previous article, it can be seen that people are prone to physical and mental illnesses when they are out of social situations. Therefore, it is necessary to analyze how to go out under the premise of protecting yourself. Here it is essential to discuss and analyze the issue of the correctness of protection information during the epidemic. We are no longer just fighting the epidemic, but also fighting the information source. With the rapid speed of the Coronavirus sweeping the world, people cannot filter information in a short period of time. At present, it seems that people's use of personal anti-epidemic equipment (PPE) and how to correctly protect their sources of information are affected by many factors. The messy and inaccurate information has misled many people to adopt the wrong way, unable to achieve the purpose of protecting themselves, thereby increasing the risk of infection. At the same time, countries' reports on the epidemic will also change with their country's political direction. Then, in this case, how people judge the correctness and reliability of the information, what factors will affect the judgment, and the consequences of incorrect data are the focus of the following discussion.

## 4.1 Sources of information

According to the sampling method of the questionnaire: among the sample numbers of the six countries surveyed, it is clear that the demand for news consumption during the home isolation period of the epidemic can be clearly seen. People are accustomed to obtaining information through TV and the Internet, and young people account for a large part of it. The elderly prefer the broadcast method to receive news information. Generally speaking, the demand for newspapers has decreased, because the epidemic isolation policy makes it inconvenient for factory printing and transportation.（fig.5）

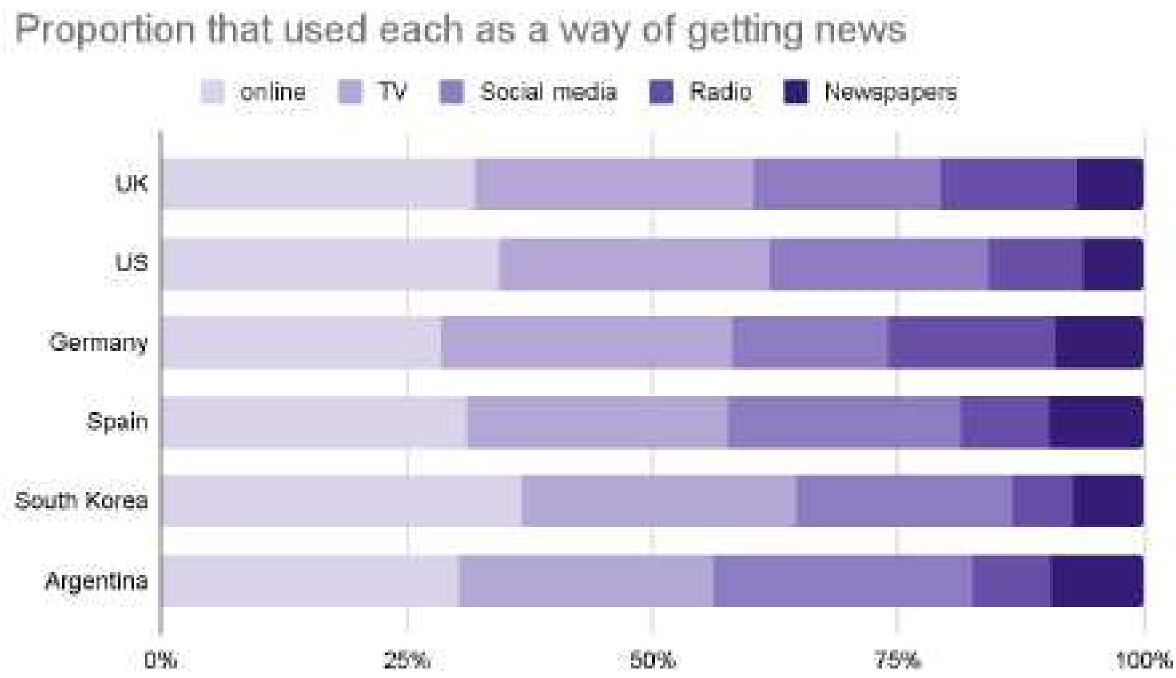



*Fig.5 Proportion that used each as a way of getting news*

With the development of information technology and the acceleration of globalization, the ways to obtain news are becoming more and more complex. Although it can be seen from the chart that news organizations are still a meaningful way to get information, the methods have become more diverse. It cannot be absolutely said that the source of this "news" is only one way. Many news organizations have opened their own social media accounts, official websites, etc. Coupled with the speed of information dissemination, the information of many online accounts overlaps. Some misinformation is also mixed into it and spread to the masses. Similarly, governments and health organizations in many countries will publish epidemic prevention information in a variety of ways.

As shown in the chart(fig.6), two-thirds of people currently claim that they obtain information through professional news agencies, government agencies, global health agencies, and experts. But there is still a large part of the data showing that the masses do not regard news organizations as sources of information, and they say that they do not rely on news organizations to obtain information. They convey information through word of mouth from people around them, including those who are familiar and those they don't know. But it is inevitable that people claim to get information through other channels, part of which is still obtained through the news media. Secondly, many sources of information in the news media are not guaranteed to be accepted by themselves. The way to bring it may be through experts, doctors, or government agencies.

The interesting phenomenon is that most of the people in the sample population who choose to trust the information sources of authoritative institutions have cultural backgrounds. However, many uneducated people choose to trust the information of close people who are similar to them.

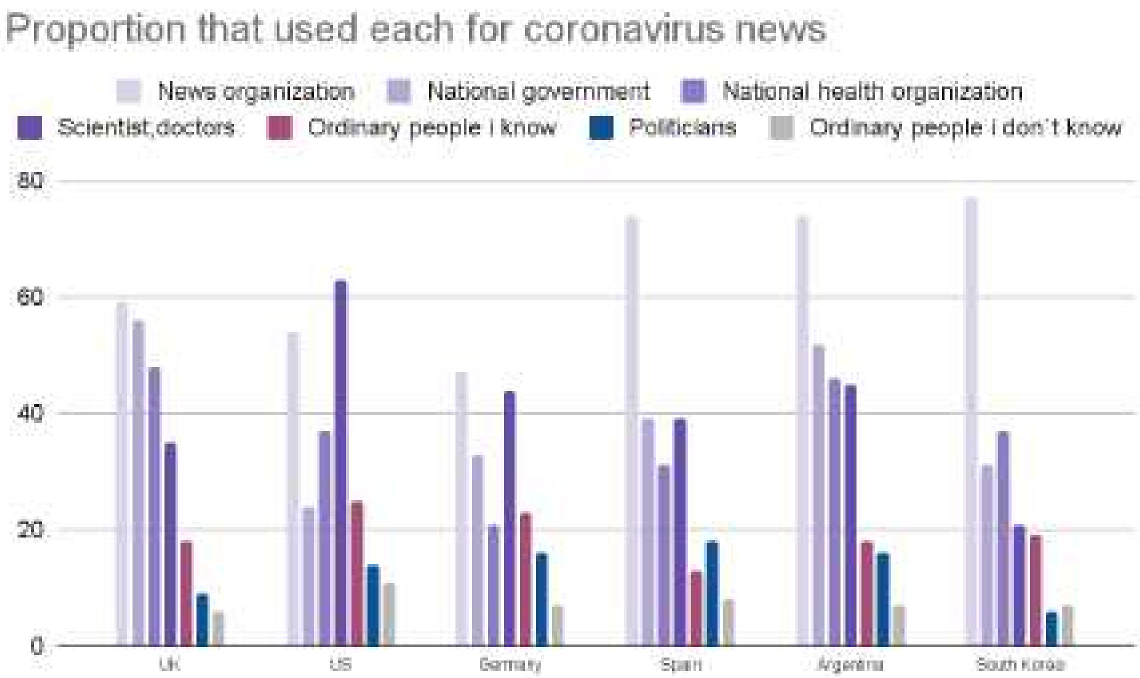


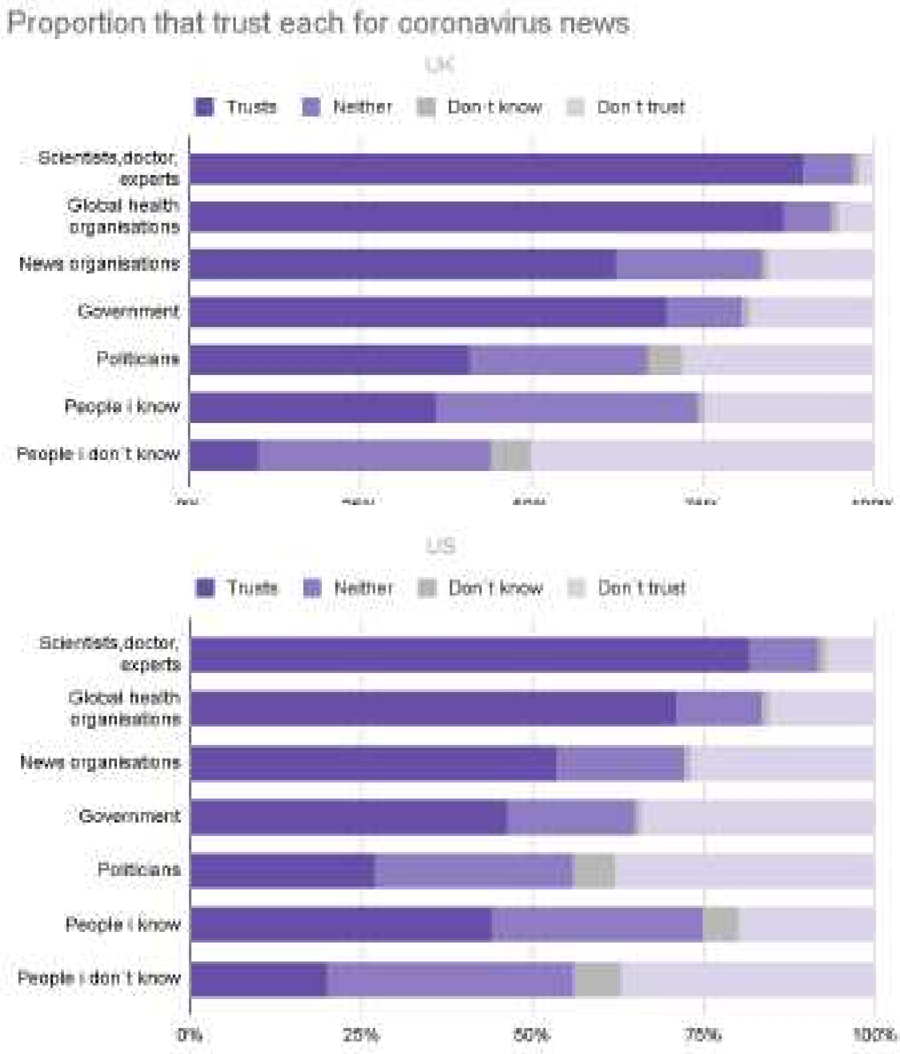

*Fig.6 Proportion that used each for coronavirus news*

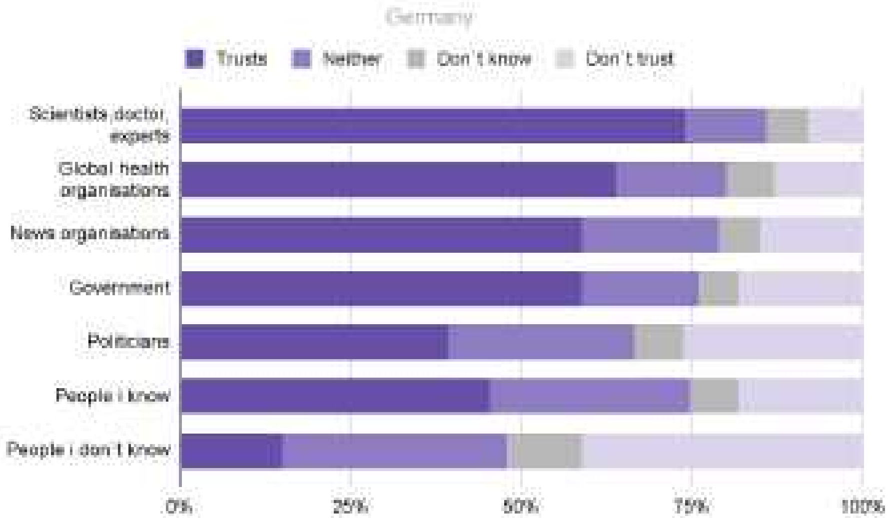
## 4.2 Trust and influencing factors of the information platform

essential to analyze and understand which information access channels and platforms people trust more because people's behaviors and beliefs will be affected by this. It can be seen from the data（fig.7）that people in every country basically have great trust in news organizations, experts, scientists, doctors, and other authorities. Many experts in epidemic prevention have gained people’s trust with their professional knowledge, such as Zhong Nanshan, a Chinese virus expert. The During worst time of the epidemic, the doctor went to the disaster area to conduct virus research and development. Such authoritative experts have become the guarantee of the correctness of the information in people's minds.

Secondly, people trust the International Health Organization, news organizations, and the government more. But at the beginning of the epidemic, people did not realize the seriousness of the epidemic due to the misjudgment of many countries. According to news reports, many people think that they need to wear masks only when they take care of patients. As a result, the epidemic has accelerated, more people have been infected, and the country's medical pressure has skyrocketed.

At the same time, it can be seen that people are skeptical and distrustful of the epidemic prevention information spoken by people they don’t know.




Germany
Trusts
Neither
Don't know
Don't trust
Scientists,doctor, experts
Global health organisations
News organisations
Government
Politicians
People i know
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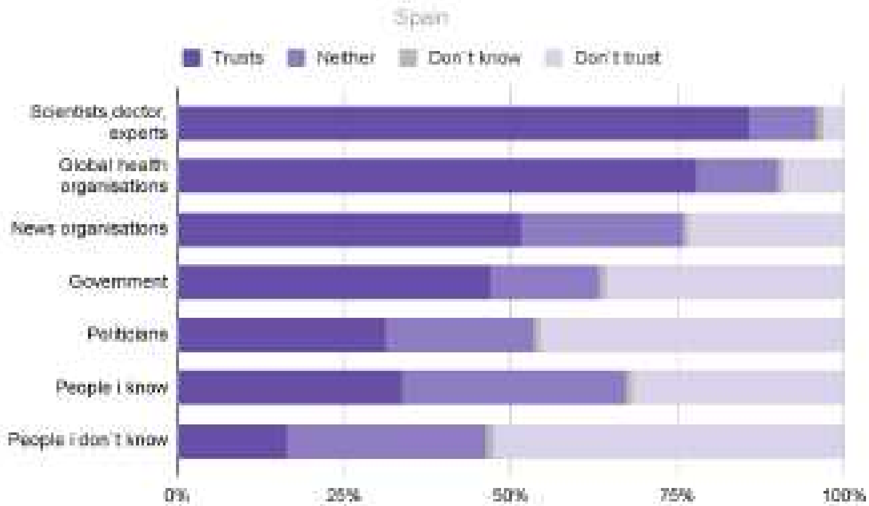
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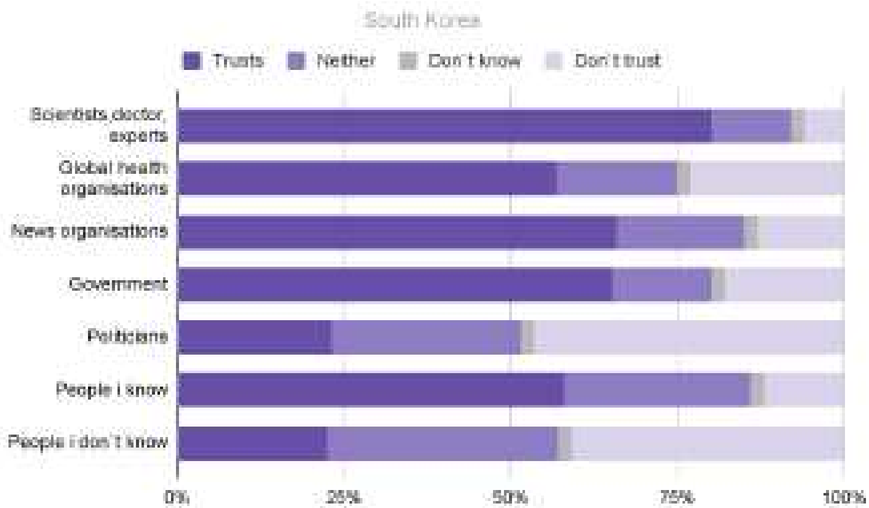
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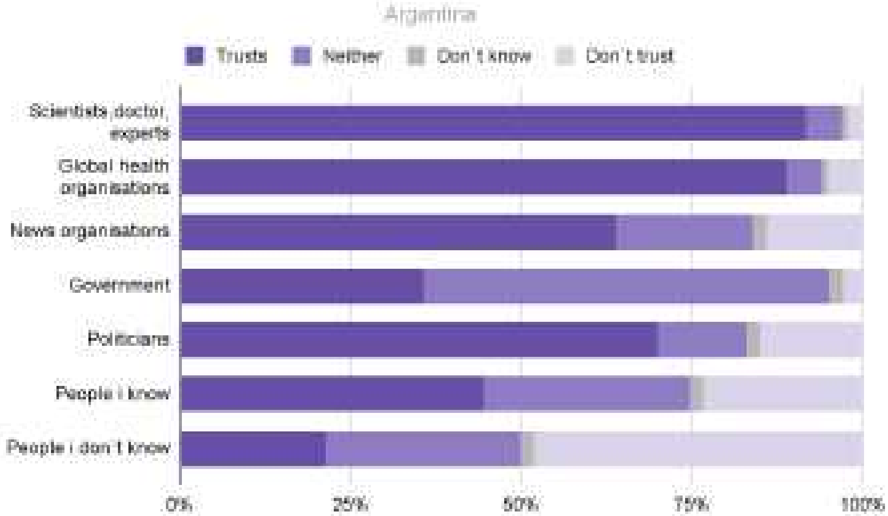


*Fig.7 Proportion that trust each for coronavirus news*

There are many factors that depend on people's trust in information. Take one of the governments to analyze: People's trust in the government depends on the country's political direction. According to the data, it can be seen that the highly polarized United States and South Korea have lower trust in politicians than in other countries, while Argentina is the opposite. A country with a high degree of trust among politicians. In the United States, changes will occur depending on the party. Take the United States as an example, as shown in the picture（fig.8）.[5]

[5] *Rasmus Kleis Nielsen, Richard Fletcher, Nic Newman, J. Scott Brennen, and Philip N. Howard , 15 APRIL 2020, Navigating the 'Infodemic': How People in Six Countries Access and Rate News and Information about Coronavirus*

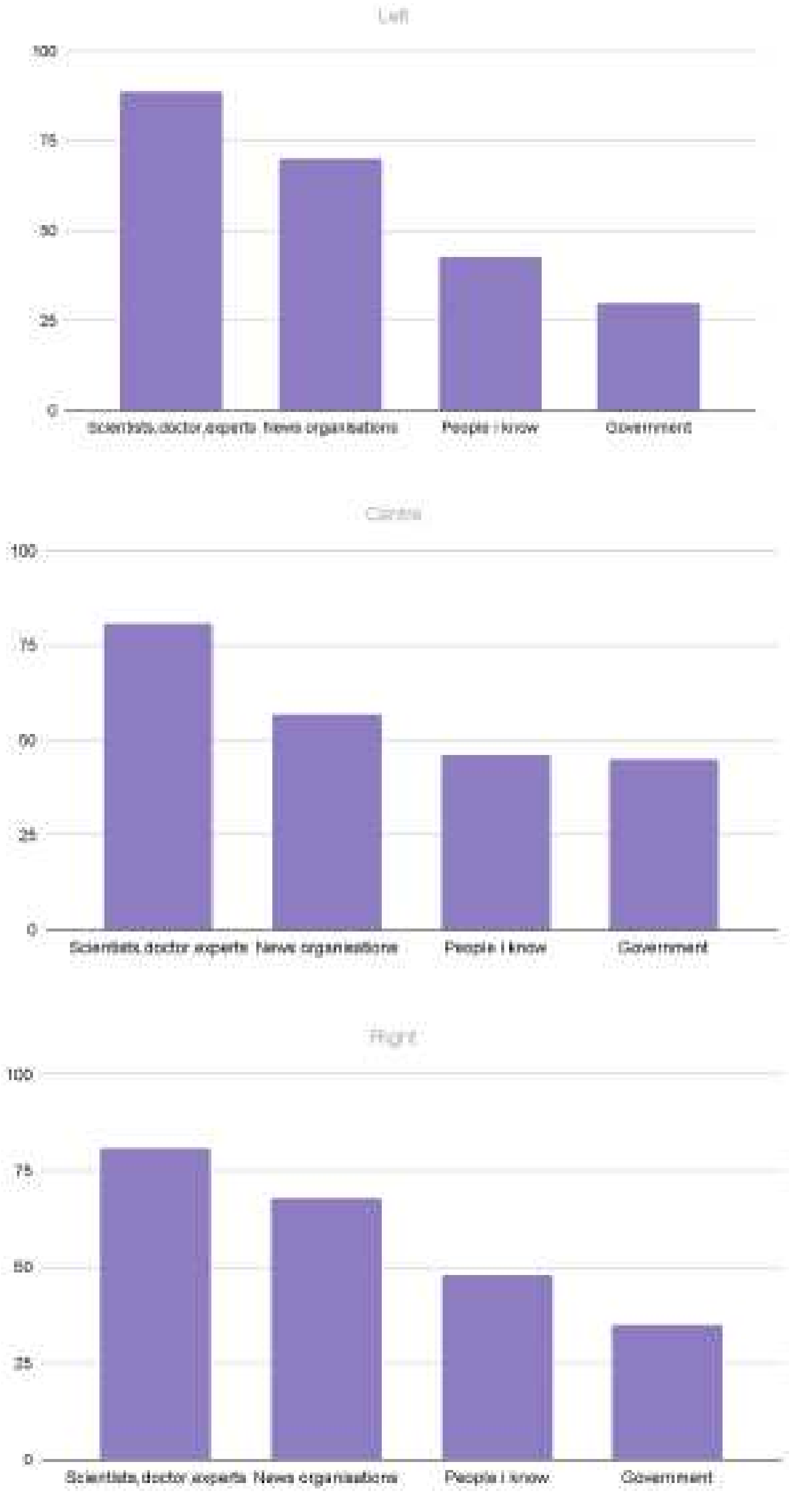


*Fig.8 Proportion that trusts each for coronavirus news in the US by political leaning*

## 4.3 The importance of correct information

During the COVID-19 pandemic, much news and information about the epidemic are uncertain and misleading, and even some authoritative agencies will issue incorrect epidemic prevention measures. In this difficult situation, people feel panic and take extreme actions amidst anxiety and fearful anger. It has been reported that some people have used disinfectants on the skin and washed food with disinfectants such as bleach and hand sanitizer and also tried to ingest them (Chang et al. 2020). These extreme behaviors can be dangerous and can cause serious health problems, such as permanent blindness, seizures, coma, permanent damage to the nervous system, or death. The bleach solution is very irritating to the skin and may irritate the skin, eyes, and other parts of the body. At the same time, some cleaning products contain corrosive substances, and their accidental ingestion can cause severe gastrointestinal toxicity (Arevalo-Silva et al., 2006; Sawalha, 2007).

Because of the "aerosol" theory, people use multiple disinfectants to clean their houses and the surrounding environment simultaneously. Recent surveys have identified significant knowledge gaps in adult safe cleaning and disinfectant preparation (Gharpure et al., 2020). Mixing different cleaning products can cause undesirable severe consequences because it produces harmful fumes/gases. Long-term exposure to these gases can induce asthma and chronic bronchitis (Medina-Ramón et al., 2005). The mixing of bleach and amino cleaners can lead to the production of chloramines and possibly even the volatilization of ammonia (Cohle et al., 2001)). The mixture of bleach and alcohol produces chloroform, toxic and dangerous when inhaled or in contact with the skin (Medina-Ramón et al., 2005).

In addition to chemical disinfection, ultraviolet disinfection is another practical disinfection method for microorganisms. During COVID-19, some people also try to disinfect themselves with ultraviolet light. UV disinfection has data showing that it can be used to disinfect products during COVID-19, but it is not possible to use UV or LED irradiation to inactivate the COVID-19 virus on humans. It can cause burns and may cause skin cancer.[6]

Therefore, a questionnaire survey was conducted for the correctness of the protection information（fig. 9), due to the inaccurate information

[6] *Butchi Raju Akondi,Ashok, Anushruti,Rai, Nagendra Kumar,30 Jul 2020,Consequences of chemical impact of disinfectants: safe preventive measures against COVID-19*

obtained, people cannot know the exact time when the mask needs to be replaced. Most of them chose to replace the disposable mask for six hours, and the remaining large Some of them were replaced after eight hours and more than one day. But in fact, the wearing time of disposable masks is no more than four hours, and they need to be replaced immediately after getting wet. The N95 level of respiratory protection equipment needs to be replaced in 8 hours.

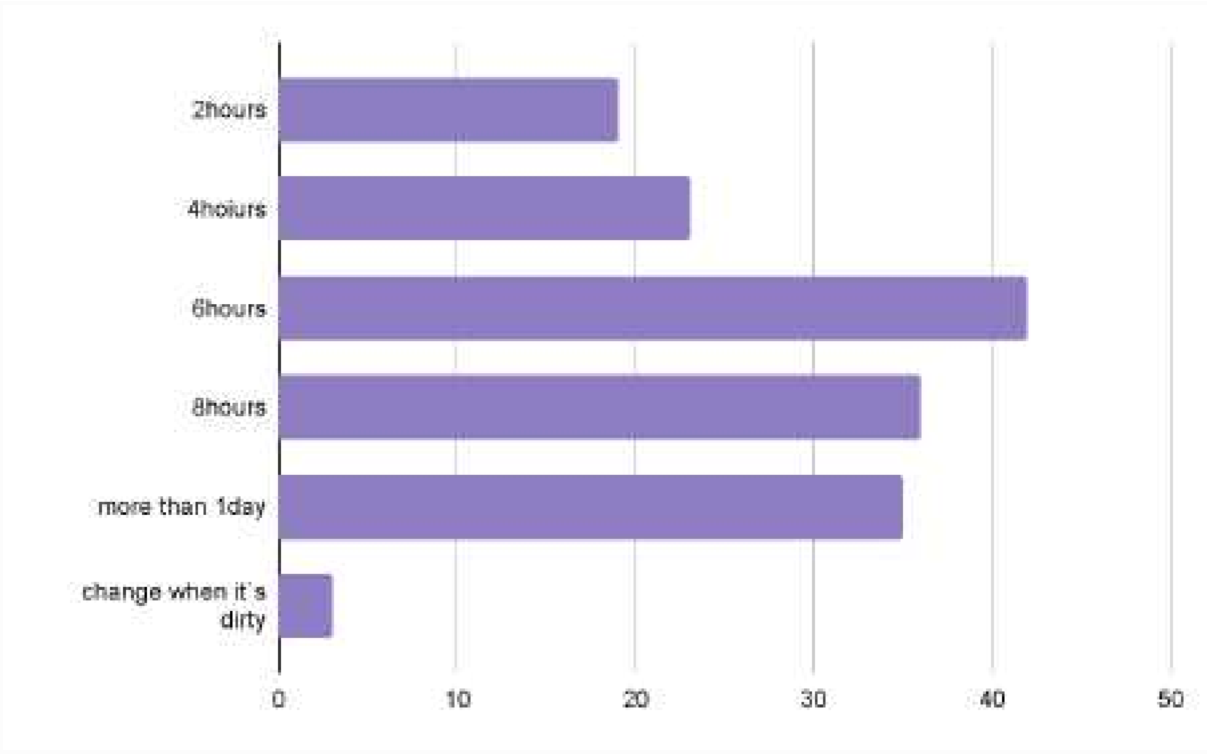


*Fig.9 Mask using time*

Then a questionnaire survey was conducted on the criteria for the replacement of disposable masks. Interestingly, 58 (42.96%) people chose to replace the mask (fig.10) according to the authority's information, which conflicted with the previous data. As shown in Figure 9, only about 15% of the people chose the correct one. Replacement time-4 hours, and most of them are inconsistent with the official replacement time. And 30 people decided to change according to their mood.

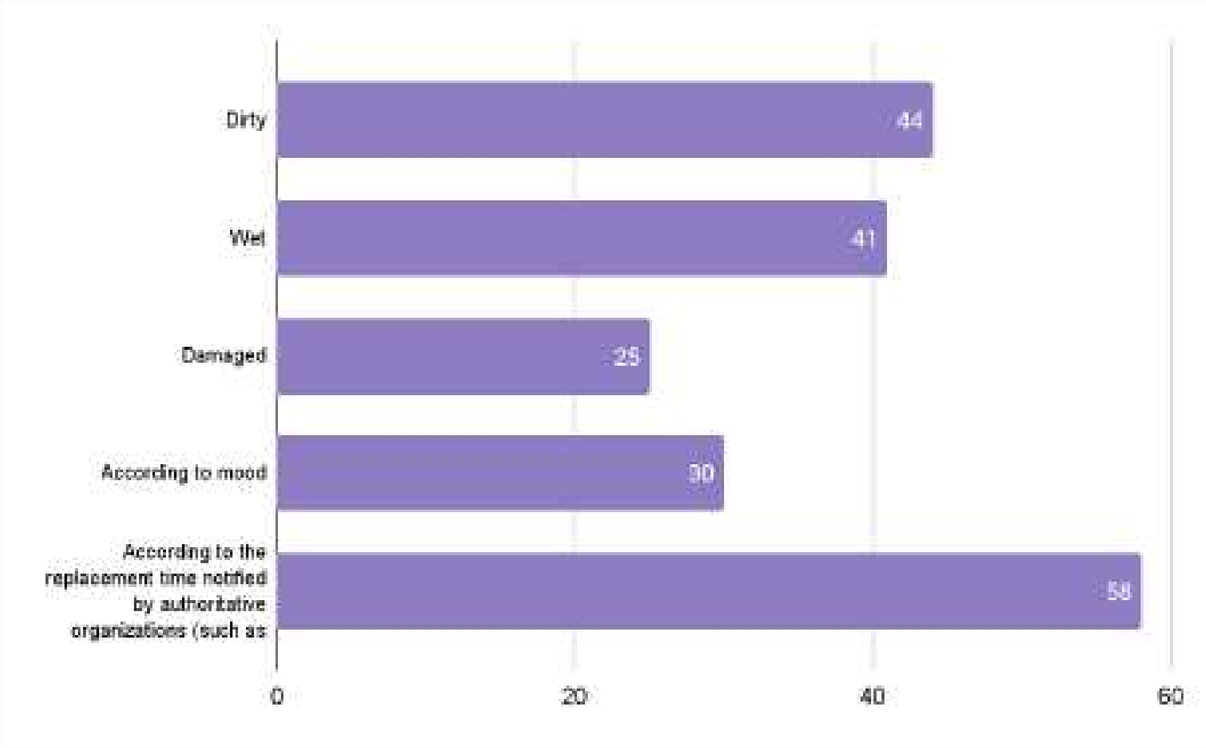


*Fig.10 Conditions for mask replacement*

# Application of personal protective equipment

# 5. Application of personal protective equipment

As mentioned in the previous article, the current chaotic and unclear epidemic prevention information is extremely easy to affect people's judgments, causing people to be unable to distinguish adequate epidemic prevention information to protect themselves. Therefore, it is necessary for us to understand the correct epidemic prevention information, especially about the types of personal protective equipment and the proper use methods, in order to better protect ourselves during outdoor travel activities and ensure enough time out to avoid being indoors for a long time—unhealthy psychological problems arising from the environment.

First of all, before we understand protective gear, we need to understand the characteristics of the virus to choose the correct protective equipment better to protect ourselves.

## 5.1 SARS-CoV-2 virus characteristics

SARS-CoV-2 is different from the previous SARS-CoV and MERS-CoV. No matter in terms of virulence or the spreading speed of infection, the world has never encountered it. SARS-CoV-2 is a positive-stranded single-stranded RNA virus with the largest genome among the currently known RNA viruses, with a genome length of approximately 26-32 kb (Forni et al., 2017). Its average diameter is 100 nm, and its overall shape is spherical or elliptical. There are a large number of viral membrane glycoprotein spikes on the surface. Under the electron microscope, these negatively stained virus particles appear as a typical crown shape, while a coronavirus (Newman et al. 2006).

The EPA and the Centers for Disease Control and Prevention (CDC) recognize that viruses can be ranked according to their resistance to chemical disinfectants. In this way, according to the size of the virus and its relative resistance to inactivation, viruses can be divided into three subgroups-the first is enveloped viruses (the most easily inactivated viruses, such as coronavirus); large (50 -100 nm) non-enveloped viruses (such as adenovirus and rotavirus, which are more difficult to inactivate than enveloped viruses); and small (<50 nm) non-enveloped viruses (the most difficult to inactivate viruses, such as rhinovirus). SARS-CoV-2 is an enveloped virus containing a lipid membrane, which can be inactivated by cleaning methods such as disinfectants (Cascella et al., 2020).[7]

## 5.2 Types of personal protective equipment

PPE is any equipment (for example, masks) worn by a person to protect that individual from exposure to one or more hazards. According to the method established by the WHO, the currently required PPE selection depends on the following factors:

- The characteristics of the biological agent being processed,
- The volume and concentration of biological agents,
- There are other hazards (for example, extreme temperature, chemical or radiological hazards),
- The type of work being performed,
- Other risk control measures being used, such as biological safety cabinets (BSC),
- Wear other PPE,
- Personal needs of laboratory personnel
- Availability of national regulations and organizational requirements.[8]

On this basis, combined with the aforementioned: SARS-CoV-2 is an enveloped virus that contains a lipid membrane. PPE is currently divided into 3 categories: standard, special, and enhanced:

1. Standard PPE includes masks, gloves, and goggles.

2. The minimum requirement for special type PPE is FFP2/N95 mask, plus face mask or goggles (or mask with a protective cover on FFP2/N95), gloves, non-porous gown, and disposable hat.

[7] *Butchi Raju Akondi,Ashok, Anushruti,Rai, Nagendra Kumar,30 Jul 2020,Consequences of chemical impact of disinfectants: safe preventive measures against COVID-19*

[8] *Personal protective equipment. Geneva: World Health Organization; 2020*

3. The minimum requirements for enhanced PPE are FFP3 masks, masks, gloves, non-porous gowns, and disposable caps. In addition, PAPR/CAPR can also be used.[9]

For daily activities such as going out and purchasing, the collected questionnaire sample data shows that nearly 100% of people choose to wear masks when they go out, and very few people also choose to wear masks, shoe covers, and protective clothing at the same time. (fig.11).

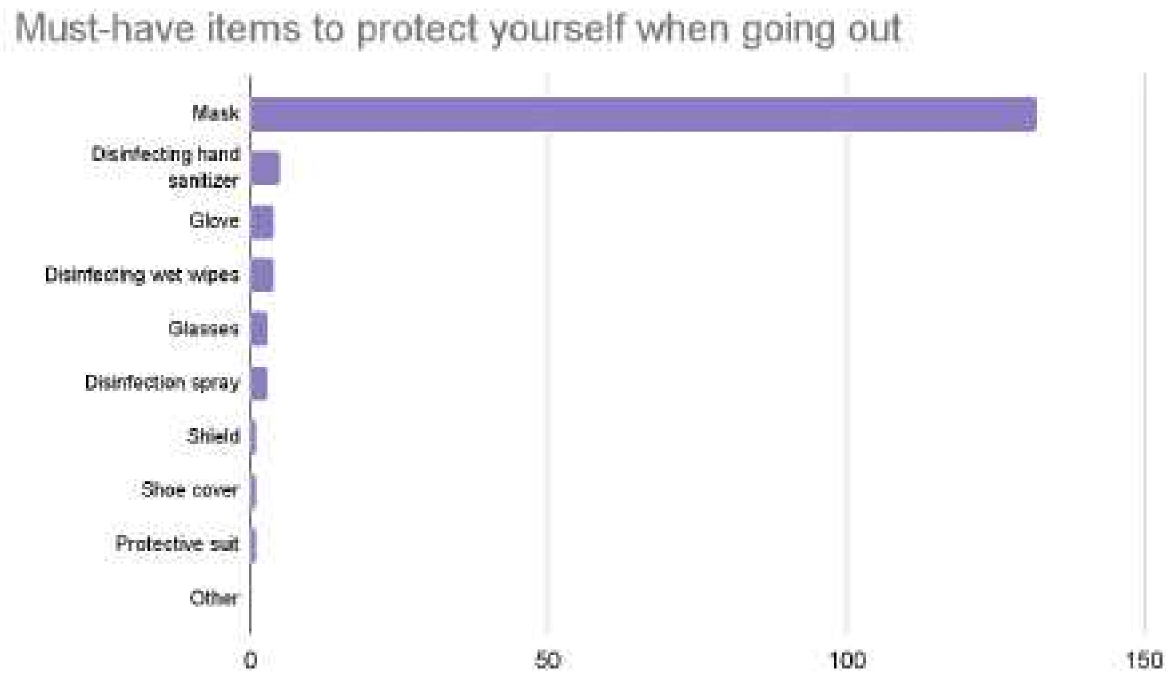


*Fig.11 Protective equipment necessary for going out*

[9] *Grant, M. et al. (2020) 'AO CMF International Task Force Recommendations on Best Practices for Maxillofacial Procedures During COVID-19 Pandemic', Craniomaxillofacial Trauma & Reconstruction, 13(3), pp. 151–156. doi: 10.1177/1943387520948826.*

## 5.3 Introduction to the selection criteria, types, and correct wearing methods of masks

### 5.3.1 Selection criteria for masks

Respiratory protective equipment is a type of PPE designed to protect the wearer from inhaling dangerous particles and gases, including chemical and biological agents that may be present in the air. Biological agents are generally used when performing high-risk or aerosol-generating procedures, so respiratory protection devices will be used, for example, to clean up a large number of spilled infectious materials.

Regarding biological agents, the characteristics of physical agents that should be considered when determining the type of PPE to be worn include:
a. Transmission route,
b. Infectious dose,
c. Environmental stability,
d. Consequences of exposure/or release,
e. Availability of vaccines or preventive measures.[10]

a. Transmission route

Respiratory pathogens may be transmitted through three ways-contact, droplets, and airborne transmission[11]. Therefore, it is widely advocated to wear masks to minimize the way of transmission.

Generally speaking, particles with a diameter greater than 5 μm will fall on the ground within 1 meter. However, with the introduction of the "aerosol" theory[12]. Coughing, sneezing, and even exhalation will produce

*[10] Personal protective equipment. Geneva: World Health Organization; 2020*

*[11] J. S. Kutter, M. I. Spronken, P. L. Fraaij, R. A. M. Fouchier, and S. Herfst, "Transmission routes of respiratory viruses among humans," Current Opinion in Virology, vol. 28, pp. 142–151, 2018.*

*[12] L. Bourouiba, "Turbulent gas clouds and respiratory pathogen emissions: potential implications for reducing transmission of COVID-19," JAMA, vol. 323, no. 18, pp. 1837-1838, 2020.*

mucosal droplets, these droplets spread into the air, combined with environmental factors, the "colloid" may expand to 7-8 m.[13]

In general, the RNA of influenza, coronavirus, and rhinovirus transmitted by droplets will appear in exhaled particles smaller or larger than 5 μm[14]. In addition, live flu exists in particles smaller than 5 μm. Therefore, even viruses that are mainly spread by respiratory droplets can be transmitted through the air. The virus particles of SARS-CoV-2 can survive for 3 hours in an experimental vessel that artificially keeps the particles floating for several hours. What is less known is that more general interactions (such as conversation) can also lead to the release of potentially infectious droplets and aerosols. Previously, it was found in experiments that the use of laser scattering can observe the high emissivity of about 1,000 droplet particles per second during the speech, which is as high as 10,000 droplet particles per second[15].

b. Infectious dose

As the carrier of respiratory viruses, respiratory particles are often used to represent the spread of viruses in the air. First, analyze the abundance of respiratory particles. Figure 12 shows the particle size distribution of particles emitted by different activities[16]. Volume size distribution of released particles by sneezing (A), coughing (B), speaking (C) and breathing (D) and those with surgical and N95 masks. Circles represent measurements and solid lines show bimodal fits to measurements. Here, the distribution of exhaled particles for each human activity is also plotted for reference. V and Dp represent the particle volume and diameter, respectively. [17]

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*[13] T. Dbouk and D. Drikakis, "On coughing and airborne droplet transmission to humans," Physics of Fluids, vol. 32, no. 5, article 053310, 2020.*

*[14] E. N. Perencevich, D. J. Diekema, and M. B. Edmond, "Moving personal protective equipment into the community," JAMA, vol. 323, no. 22, pp. 2252-2253, 2020.*

*[15] P. Anfinrud, V. Stadnitskiy, C. E. Bax, and A. Bax, "Visualizing speech-generated oral fluid droplets with laser light scattering," New England Journal of Medicine, vol. 382, no. 21, pp. 2061–2063, 2020.*

*[16] C. Y. H. Chao et al., Characterization of expiration air jets and droplet size distributions immediately at the mouth opening. Journal of aerosol science 40, 122–133 (2009).*

*[17] Yafang Cheng, Nan Ma, Christian Witt, Steffen Rapp, Philipp Wild, Meinrat O. Andreae, Ulrich Pöschl, Hang Su, " Distinct regimes of particle and virus abundance explain face mask efficacy for COVID-19",doi: https://doi.org/10.1101/2020.09.10.20190348*

The total amount is about 3×10 particles in a sampling period of 630 minutes (Section S1)[18]. This huge number shows that people are always in a state of abundant breathing particles. Therefore, it can be inferred that the concentration of particles emitted by humans has always been able to maintain a high level, so that even if people wear a mask, they may not be able to avoid inhaling particles produced by others in the environment. However, whether the inhaled particles are consistent with the number of inhaled virus particles remains to be studied.

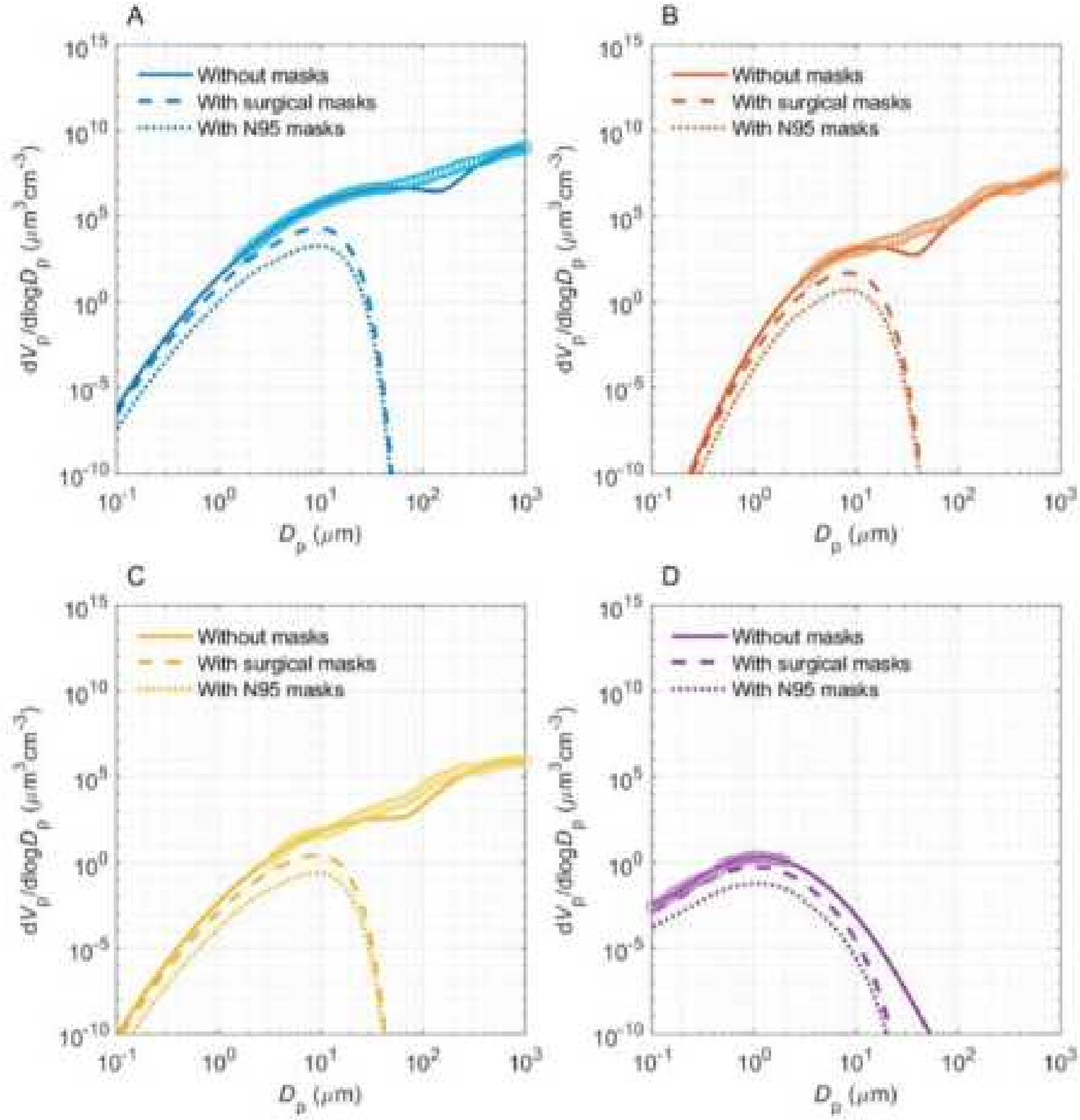


*Fig.12 Particle size distribution from different human activities.*

[18] *N. H. L. Leung et al., Respiratory virus shedding in exhaled breath and efficacy of face masks. Nature Medicine 26, 676–680 (2020).*

Facts have proved that most of the time only a few exhaled respiratory particles contain the virus. Contrary to the high concentration of respiratory particles, the median of N *samples* of coronaviruses (HCoV-NL63, -OC43, -229E, and -) (the number of viruses exhaled in a 30-minute piece) is about 0.96, and the concentration of the emitted virus can be understood very low. HKU1), influenza virus (A and B) is about 0.64, rhinovirus is about 4.9. These low N *sample* values are all within the limits of viral transmission, even lower than the reported critical doses of several viral infections (for example, tens to thousands of viruses)[19]. For the coronavirus SARS-CoV-2, we measured it based on N30 (the number of viruses inhaled about 240 liters of indoor air per 30 minutes) in hospitals and health centers where high concentrations of SARS-CoV-2 are expected to occur, such as Wuhan Fangcai Hospital. The incoming airborne SARS-CoV-2 concentration is equivalent to about 0 to 4 viruses inhaled every 30 minutes. Given that the reported SARS-CoV-2 infectious dose (hamster) is less than 1000 viruses[20], the small N30 with about 0 to 4 viruses is likely to be in a virus-restricted state. At the same time, similar virus programs have been found in other studies, such as N30SARS-CoV-2 in medical centers/discovered hospitals in the United States and Singapore (Figure 13A.) [21]. The situation overlaps with the restriction status of the virus.

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[19] *K. A. Callow, H. F. Parry, M. Sergeant, D. A. J. Tyrrell, The time course of the immune response to experimental coronavirus infection of man. Epidemiology and Infection 105, 435–446 (1990).*

[20] *M. Imai et al., Syrian hamsters as a small animal model for SARS-CoV-2 infection and countermeasure development. Proc. Natl. Acad. Sci. 117, 16587–16595 (2020).*

[21] *P. Y. Chia et al., Detection of air and surface contamination by SARS-CoV-2 in hospital rooms of infected patients. Nat. Commun. 11, 2800 (2020).*

*J. L. Santarpia et al., Aerosol and Surface Transmission Potential of SARS-CoV-2. medRxiv, 2020.2003.2023.20039446 (2020).*

*J. A. Lednicky et al., Collection of SARS-CoV-2 Virus from the Air of a Clinic within a University Student Health Care Center and Analyses of the Viral Genomic Sequence. Aerosol and Air Quality Research 20, 1167–1171 (2020).*

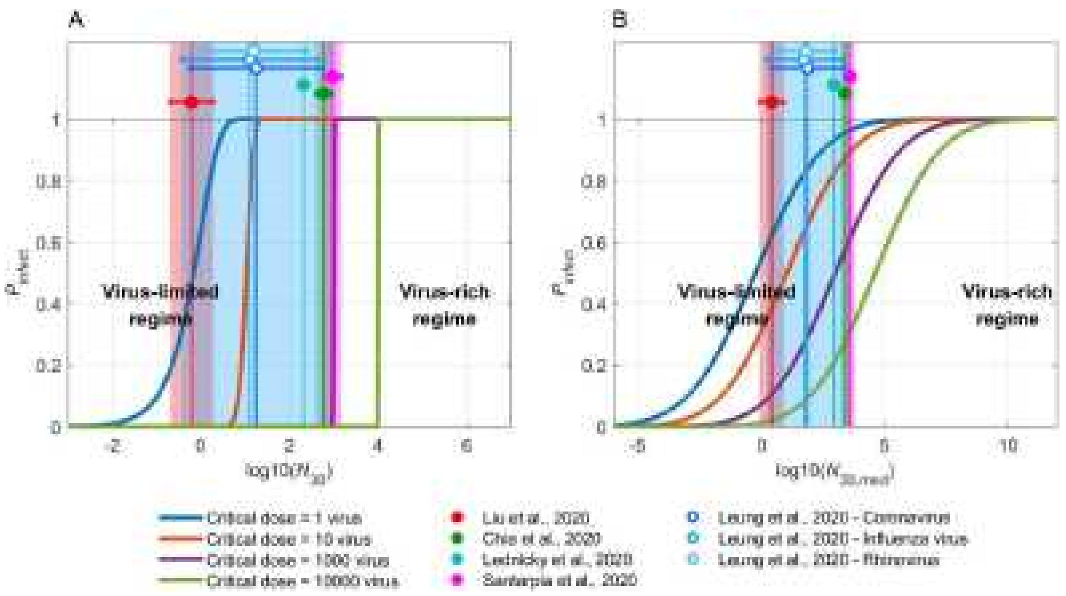


*Fig.13  Abundance regime of airborne transmission of viruses.*

*Fig.13: (A) The solid line represents the probability of infection (P infect) after inhaling a certain amount of virus with different critical infectious doses. The colored dots show the number of inhaled viruses in 30 minutes (N 30) calculated based on the airborne SARS-CoV-2 concentration reported by the medical center/hospital. The open circles show the number of coronaviruses, influenza viruses, and rhinoviruses exhaled in 30 minutes. The shaded area shows the standard deviation. (B) Except for the calculation of the solid line, it is the same as (A). The solid line takes into account the individual differences in the large population, where N 30,med represents the median of the 30-minute inhalation of the virus in the entire population. Assume that the number of inhaled viruses follows a log-normal distribution, with σ being ~ 2 (Section S2). The virus-rich and restricted virus programs are defined as N 30 (P infect> 0.95) and N 30 (P infect ≤ 0.95), respectively.*

c. Environmental stability

Viral factors in the environment have a significant impact on susceptibility to infection. In a given period of time, the probability P of inhaling more than a certain amount of virus (for example, the critical infectious dose) is a function of the environmental concentration C of the airborne virus. Figure 14A shows the probability of inhaling more than or equal to one virus as a function of C calculated from a series of Poisson cumulative probability functions. The (A) black dotted line in icon 14 represents the critical concentration C of the virus inhaled by a threshold number of people. For situations where the inhaled virus concentration is higher or lower than the threshold, we can see the limits of "viral abundance" and the limits of "virus restriction" respectively. In the case of abundant particles/viruses, people will always inhale a large number of particles/viruses. If the synthetic concentration is still higher than the threshold, the effect of wearing a mask is limited. In the case of limiting the virus, wearing a mask will further reduce the concentration of the virus and the risk of infection. The red/green dotted lines represent exemplary virus/particle concentrations C corresponding to virus restriction and virus enrichment protocols, respectively. (B) Virus-rich and particle-rich system; (C) Virus-restricted and particle-rich system. When C reaches a high value (virus-rich state, Figure 14B), the value of P is 1 and it is not sensitive to C. Even if you wear a surgical mask, millions of particles will remain at low collection efficiency, thereby maintaining a state of abundance of particles (green dots in Figures 14B and 14C). In this case, wearing a mask may have a limited effect on reducing the probability of inhalation. However, under virus restriction conditions, P changes between 0 and 1, and a change in C will also cause a change in P. In this case, wearing a mask will affect the probability of inhalation, so it can be effectively predicted (Figure 14C) that the amount of infection is related to the number of viruses in the environment.[22]

[22] *Yafang Cheng, Nan Ma, Christian Witt, Steffen Rapp, Philipp Wild, Meinrat O. Andreae, Ulrich Pöschl, Hang Su, " Distinct regimes of particle and virus abundance explain face mask efficacy for COVID-19",doi: https://doi.org/10.1101/2020.09.10.20190348*

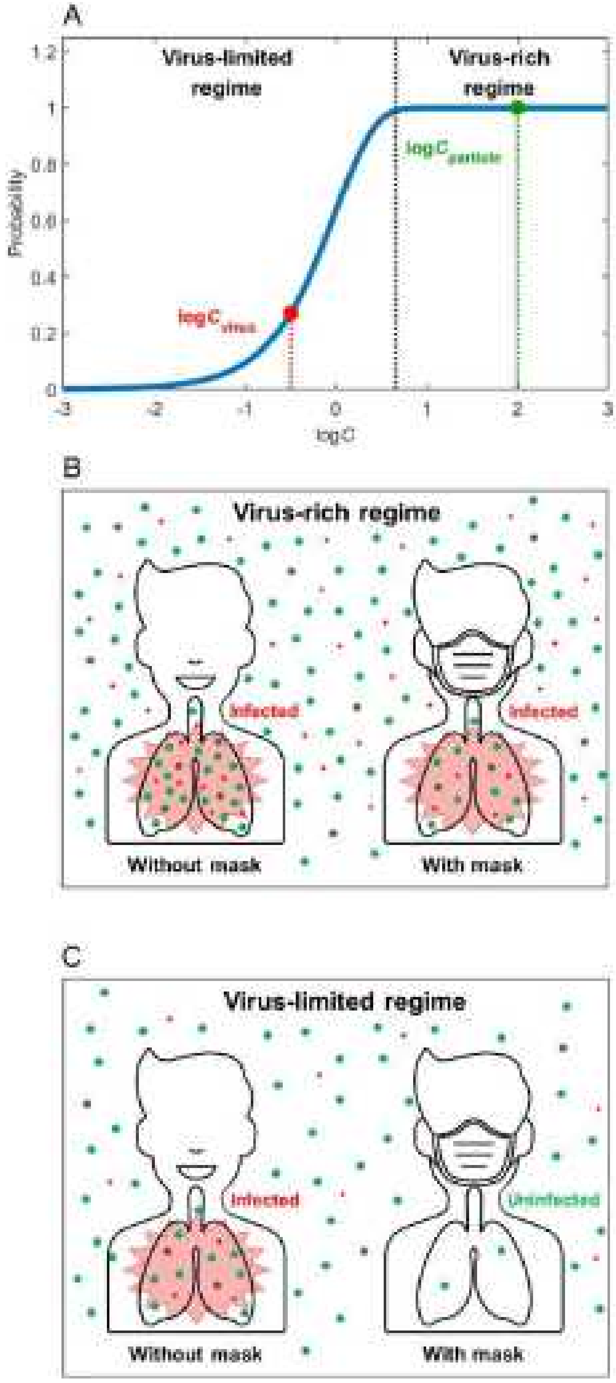


*Fig.14 Schematic illustration of abundance regimes of airborne transmission.*

## d. Consequences of exposure and/or release

There are many reasons why people choose not to wear masks. Some people think that you only need to wear a mask if you have Covid-19 and that you don't need to wear a mask if you have no symptoms. Early information from health experts may have contributed to this misunderstanding, because health officials, including American surgeons, stated that masks are not necessary to protect the public[23]. However, the guidelines have been adjusted and changed since then, because according to statistics, more than 40% of virus-infected persons are pre-symptomatic or asymptomatic spreaders, and may not know their own infectious potential[24]. Some people refuse to wear them for political reasons. Masks, treat it as a symbolic statement.

Although people have reasons not to wear masks, doing so will significantly increase the risk of infection and spread of SARS-CoV-2. A recent survey found that the chance of infection when wearing a mask is 3%, while the chance of infection when not wearing a mask is 17%[25]. Patients who refuse to wear masks pose a major safety threat to healthcare professionals and other patients in hospitals and clinics[26]. In addition, most of these people will have a weakened immune system and comorbidities, which will increase the risk of serious complications caused by the virus.

According to the authority issued by the authority, the correct wearing of PPE can avoid the dangerous consequences of exposure to a greater extent.

e. Availability of vaccines or preventive measures

[23] *Adams J (@Surgeon_General). August 30, 2020."Seriously people- STOP BUYING MASKS! They are NOT effective in preventing general public from catching #Coronavirus, but if healthcare providers can't get them to care for sick patients, it puts them and our communities at risk!"*

[24] *Adams J (@Surgeon_General). In light of new evidence, @CDCgov recommends wearing cloth face coverings in public settings where other social distancing measures are difficult to maintain (grocery stores, pharmacies, etc) especially in areas of significant community-based transmission. Tweet. April 2020.*

*Gudbjartsson DF, Helgason A, Jonsson H, et al. Spread of SARS-CoV-2 in the Icelandic Population. N Engl J Med 2020.*

[25] *C. Y. H. Chao et al., Characterization of expiration air jets and droplet size distributions immediately at the mouth opening. Journal of aerosol science 40, 122–133 (2009).*

[26] *Wang X, Ferro EG, Zhou G, Hashimoto D, Bhatt DL. Association Between Universal Masking in a Health Care System and SARS-CoV-2 Positivity Among Health Care Workers. JAMA. 2020;324(7):703.*

*Klompas M, Morris CA, Sinclair J, Pearson M, Shenoy ES. Universal masking in hospitals in the COVID-19 era. N Engl J Med 2020;382(21):e63.*

The experimental environment was set to completely simulate the conditions of Wuhan Fangcai Hospital, and the patient density, space size, and ventilation conditions were kept entirely consistent. In this case, analysis of the presence of virus particles is performed, but because other types of viruses are also present in the air, there will be an overlap in the concentration range of the detected virus.

The curve in Fig. 15 shows the percentage change of Pinfect caused by the use of the mask due to the change of N30. The blue and red lines represent the results of surgery (blue line) and N95 masks (red line), while the solid and dotted lines represent the results of the critical dose of 1 virus and 10,000 viruses, respectively. It is assumed that the dependency of Pinfect on N30 used here is the same as that in Fig.13B.

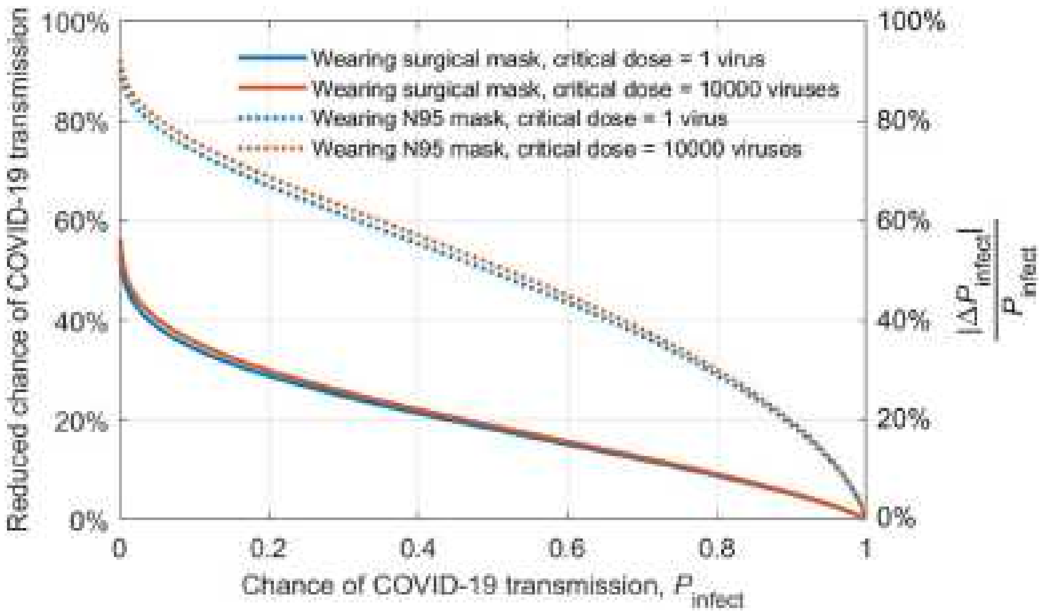


*Fig.15 Reduced chance of COVID-19 transmission with masks.*

Experimental results show that reducing the airborne transmission of SARS-CoV-2 is most effective when the virus is limited. In this case, any preventive measures to reduce the concentration of inhaled particles (such as wearing a mask, ventilation, and maintaining social distance) can reduce the probability of infection. The increased efficiency of preventive measures at lower virus concentrations also shows that the more measures used, the more effective each measure is in containing the spread of the virus[27]. For example, when both the source (infected) and susceptible people wear masks, the concentration of inhaled virus will be further reduced, thereby further improving the efficacy of the masks and forming positive feedback. In addition, because the inhaled dose will also affect the severity of the infection[28]Even a small dose can still cause infection, so the mask still has an important blocking effect in this case. The difference in the concentration of released virus between individuals indicates that individual patients can release more viruses and become super spreaders. According to Wölfel et al. (2020)[29]In the first week of symptoms, the pharyngeal virus excretion is very high. At the same time, the high variability also indicates that even if the median value is in a virus-restricted state, a single patient, that is, a super spreader, may still create a virus-rich environment. In this case, wearing a surgical mask will not be enough to provide good protection. In order to better deal with such situations, stricter measures should be taken, such as wearing N95 masks, which are essential to prevent the spread of the virus. This is also proven by the fact that despite close contact with infected people, wearing N95 masks (and goggles) can also effectively reduce the infection rate. Among the 40,000 medical staff in Wuhan, almost no one was infected while wearing N95 masks[30].

### 5.3.2 Types of masks

Recently, ASTM has established a set of standards for consumer-grade masks, which are characterized by: the primary filter cover can filter 20% of particles larger than 0.3% micron, and the second filter cover can filter 50% of particles larger than 0.3 microns[31]. However, these products are only consumer-grade and cannot be used for medical treatment. The

[27] *Yafang Cheng, Nan Ma, Christian Witt, Steffen Rapp, Philipp Wild, Meinrat O. Andreae, Ulrich Pöschl, Hang Su, " Distinct regimes of particle and virus abundance explain face mask efficacy for COVID-19",doi: https://doi.org/10.1101/2020.09.10.20190348*

[28] *M. Imai et al., Syrian hamsters as a small animal model for SARS-CoV-2 infection and countermeasure development. Proc. Natl. Acad. Sci. 117, 16587–16595 (2020).*

[29] *R. Wölfel et al., Virological assessment of hospitalized patients with COVID-2019. Nature 581, 465–469 (2020).*

[30]*Central Commission for Discipline Inspection and State Supervision Commission website,03.23.2020,The 42,600 medical team members assisting Hubei to fight the epidemic with scientific protection and zero infection are achieved in this way*

[31] *Brittany Henneberry,How Surgical Masks are Made*

types of respiratory protective equipment currently on the market are roughly divided into the following nine types:

- Basic cloth mask
- Surgical mask
- N95 respirator
- Filtering mask respirator
- KN95 respirator
- P100 respirator/gas mask
- Self-contained breathing apparatus
- Full face respirator
- Full-length mask[32]

For daily life, surgical masks can already meet the protection needs and belong to standard PPE. The main purpose of surgical masks is only to protect patients and clinical areas from infections from the mouth and nose, so they are not respiratory protective equipment.

However, in some cases, if worn properly, surgical masks and additional eye protection can protect the wearer from droplets and splashes of potentially contaminated liquid. If there is a risk, it should be considered to use respiratory protective equipment, such as N95, or through the main containment equipment. It should be noted that not all surgical masks provide splash protection.

Surgical masks are divided into four levels of ASTM certification according to their different levels of protection for the wearer:

- The contents of the lowest grade mask do not include fluids, sprays, or aerosols.
- Class 1 masks usually come with ear hooks, which are a common standard for surgical and procedural applications, and have a fluid resistance of 80 mmHg. They are used in low-risk situations where there is no liquid, spray, or aerosol.
- Class 2 masks have a fluid resistance of 120 mmHg, which can block mild or moderate aerosols, liquids, and sprays.
- Level 3 masks are used for possible large exposures to aerosols, liquids, and sprays. The fluid resistance is 160 mmHg.[33]

[32] *Alyssa Mertes,June 28th, 2021,What Are the Different Types of Face Masks & Which One is Recommended?*

[33] *Brittany Henneberry,How Surgical Masks are Made*

The legal name and jurisdiction of surgical masks are a class of medical devices (EU Directive 93/42/CEE and ANSM). EN 14683: March 2006. CE mark. Mask types include I, II, and IIR types. The designated population is the general public, patients, and medical staff. By preventing the discharge of secretions from the upper respiratory tract or saliva of the wearer, it protects people who are in contact with the wearer or the wearer's environment. Protect the wearer from inhaling aerosols and fine particles suspended in the air. The wearing time requirement is no more than four hours. If the mask gets wet, it needs to be replaced immediately.

On the other hand, a respirator is a kind of respiratory protection equipment that removes pollutants from the inhaled air through a filter and filter particles. The respirator provides replaceable filter elements to prevent the entry of hazardous gases, vapors, and particles (including biological agents). The filter installed on the respirator must be suitable for the type of contaminant that needs to be protected. In other words, if it is the need for atomization and filtration, then respirators that resist biological agents cannot help people protect themselves well. On the contrary, a respirator equipped with a gas filter may not be able to resist biological agents. Regarding the types of respirators, they can basically be divided into two categories according to whether they are charged: unpowered respirators or electric respirators.

- Unpowered respirator: Rely on the wearer's breath to suck air into the filter, such as the N95, FFP filter respirator that can be seen daily.
- Electric breathing apparatus: Use a motor to pass air through the filter to provide clean air.[34]

Among them, the most common type of respiratory protective equipment (RPE) or FFP type respiratory protective mask (or N95 mask) is generally used to protect the wearer. They must bear the following marks on the masks and packaging: CE mark (CE symbol followed by the number of the notified body responsible for monitoring the quality of manufacturing), the standard number and year (EN 149) corresponding to the equipment type, and the efficiency class (FFP1, FFP2) Or FFP3)[35]. Wearing this type of mask is more restrictive than wearing a surgical mask (heat discomfort, breathing resistance). FFP masks are divided into three categories

[34] *D. Lepelletier, B. Grandbastien, S. Romano-Bertrand, S. Aho, C. Chidiac, J.-F. Géhanno, F. Chauvin,2020,What face mask for what use in the context of the COVID-19 pandemic? The French guidelines*

[35] *European Committee for Standardization Standard NF EN 149 + A1. Respiratory protective devices. Particle filter masks, requirements, tests, marking AFNOR, La Plaine Saint Denis (September 2009)*

according to their efficiency (estimated based on filtration efficiency and facial leakage), with the following differences:

—— FFP1 mask, filtering ≥80% of aerosols (total inward leakage <22%)
—— FFP2 mask, filter ≥94% of aerosols (total inward leakage <8%)
—— FFP3 mask, filtering ≥99% of aerosols (total inward leakage <2%).

The wearing time must comply with the instructions for use[36]. In any case, a single day should be less than 8 hours, depending on the conditions of use and the type of respiratory protective equipment. The removed FFP, The mask cannot be reused due to material restrictions.


[36] *D. Lepelletier, O. Keita-Perse, P. Parneix, R. Baron, L.S.A. Glélé,Eur J Clin Microbiol Infect Dis, 38 (2019), pp. 2193-2195,Grandbastien B for the French Society of Hospital Hygiene working group. Respiratory protective equipment at work: good practices for filtering facepiece (FFP) mask*

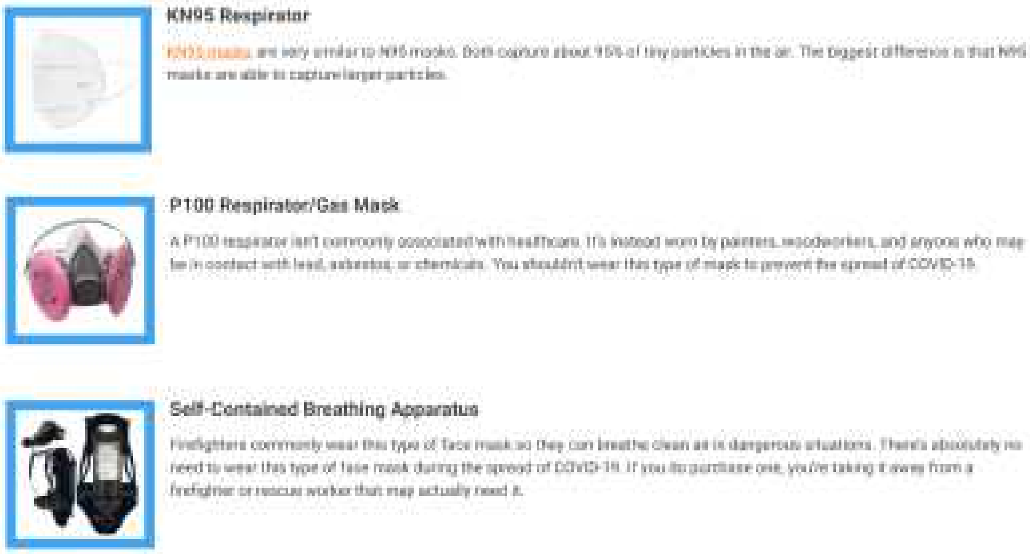


fig.16 Types of the masks

### 5.3.3 Factors affecting the protection efficiency of masks

In addition to the material filtering performance of the mask, the protection efficiency of the mask also has a certain relationship with the shape of the mask and the tightness of the face.

In this experiment, six conventional commercial masks were compared. In order to compare the influence of the airtightness on the filtration of the mask, a layer of nylon seal was added to the outside of the experimental mask. It can be seen from the first chart that the purple part represents the filtering effect of ordinary commercial masks, while the gray part is the filtering effect after adding nylon. It can be seen that both N95 and surgical masks have added a certain filtering effect, especially for surgical operations. When the nylon covering layer is used to closely fit the face, after adjusting the closed area of the bridge of the nose, the average value of these masks is The removal efficiency is 86% to 90%.(fig.17)

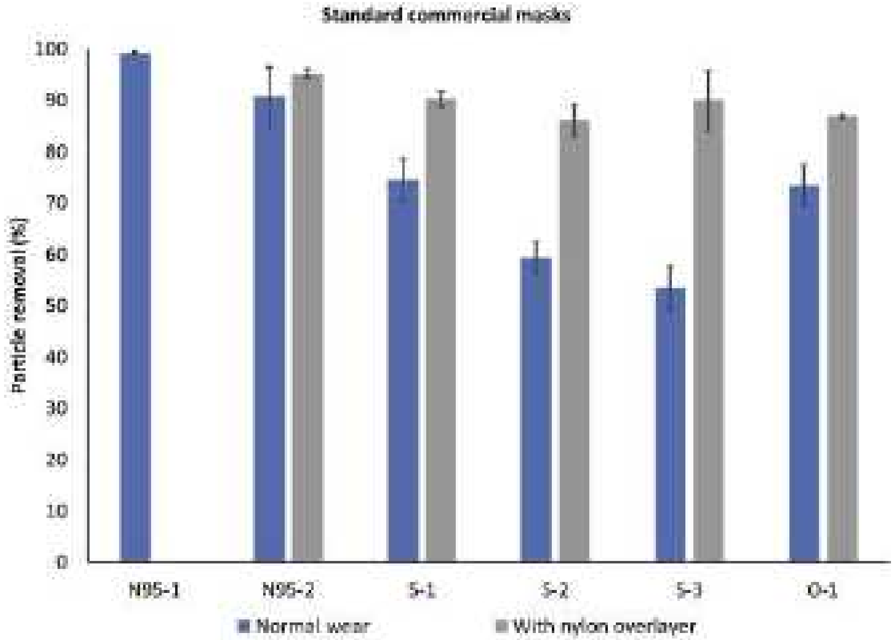


*Fig.17 Performance of commercially available masks and respirators*

For the shape of the mask, the same method of comparative analysis was adopted, and several different shapes of surgical masks (CS-1-CS6) and ordinary cloth masks were selected for testing. From these data, it can be found that the tapered mask seems to have a better and more consistent fit with the face, which is more suitable than the surgical mask (evaluated by the difference between the blue and gray bars in Figure 18). The addition of a nylon layer can usually improve the performance of surgical masks, but it cannot improve the performance of tapered masks. When using the designed mask S-1 as a benchmark, there are several cloth masks that meet or exceed this performance (Figure18, bottom). However, the tapered mask can still achieve the same filtering level without the gray nylon layer.

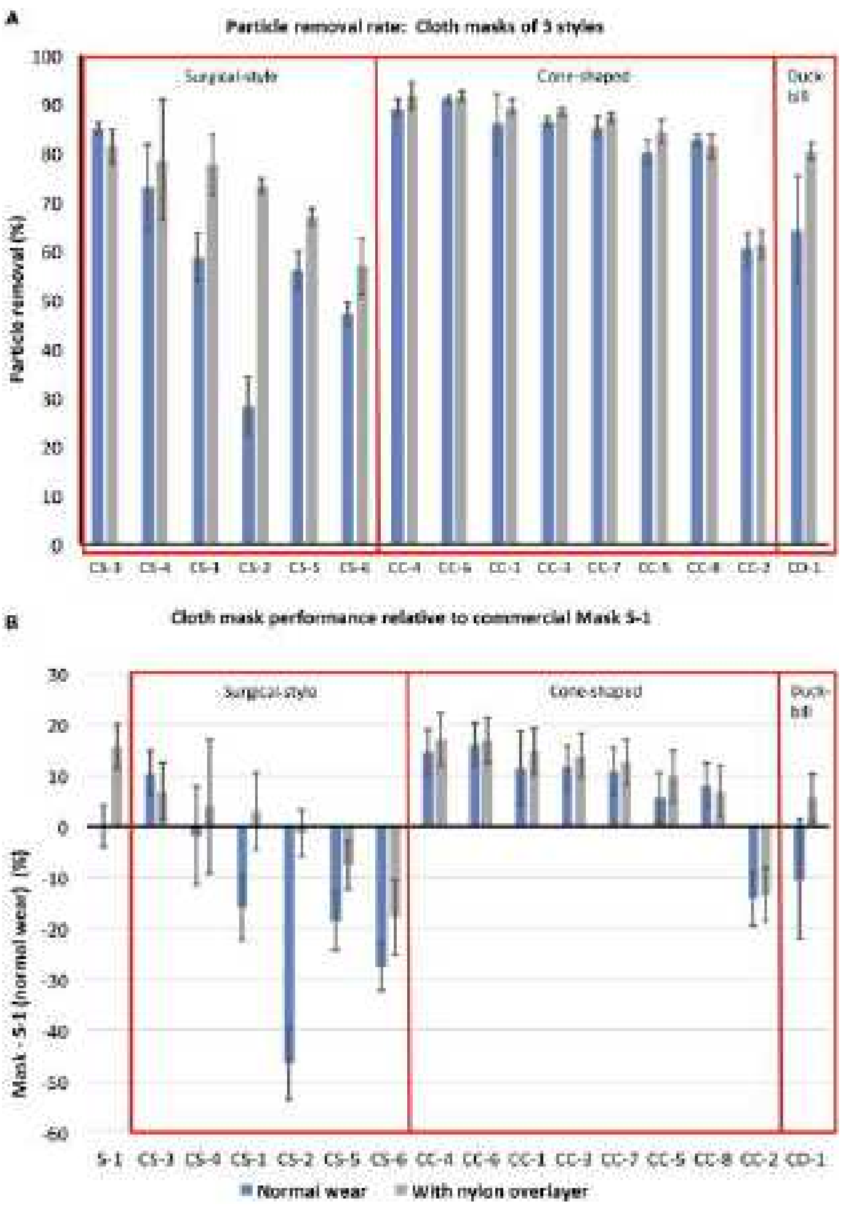


*Fig.18 The performance of cloth masks and their comparison with standard surgical masks*

The conclusion shows that the higher the degree of facial fit, the better the sealing performance of the mask and the stronger the filtering performance; the tapered shape is the most suitable for the shape of the human face and has the highest filtering version among several shapes.

### 5.3.4 The correct way to wear a mask

- Before wearing:

Every time you wear new or reusable respiratory protective equipment, you must check whether it is safe before wearing it. All respiratory protective equipment should be checked for all the following before wearing.

1. The size and grade of the respiratory protective equipment are correct.
2. Use the correct filter.
3. There are no apparent signs of damage, such as broken belts or torn filter materials; if the damage is found, respiratory protective equipment should not be worn.

- When wearing:

Respiratory protective equipment must be worn in accordance with the manufacturer's instructions. As a general guide, the following principles should be followed when wearing respiratory protective equipment.（fig.19 ）

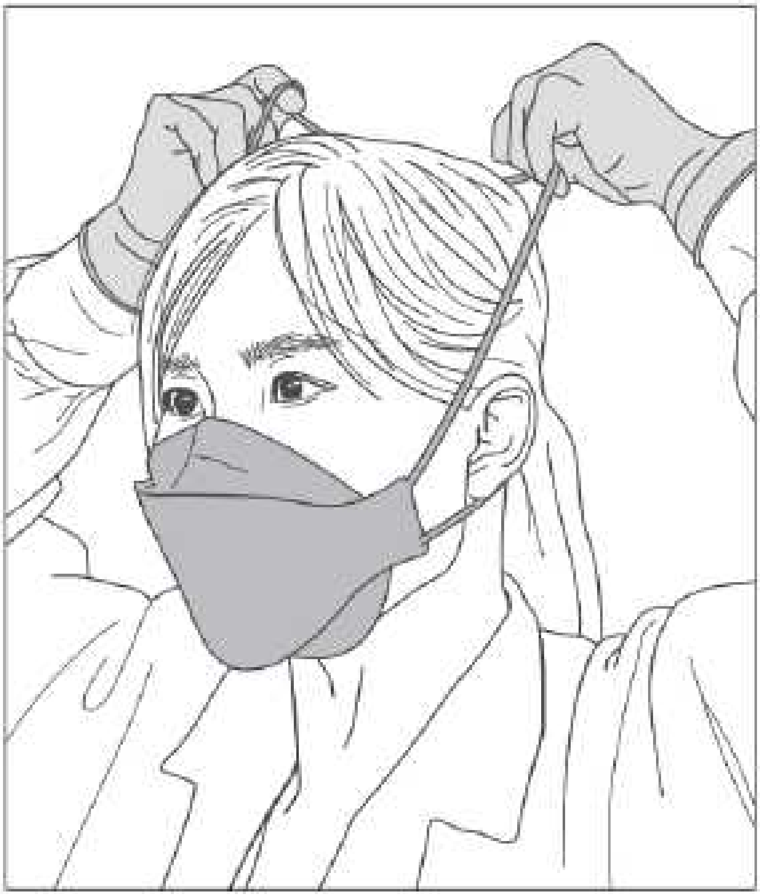

*fig.19*

1. The wearer must shave his beard, tie his long hair behind his head, and remove all jewelry in the sealed area of the lower face.

2. The chin should sit comfortably within the lower edge of the mask.

3. For full-face masks, the top of the face seal should be comfortably attached to the forehead below the hairline.

4. For a full face mask, the headband should be located at the center of the back of the head.

5. Belts must be placed at the angle specified by the manufacturer. If placed at other angles, the protection efficiency will be reduced.

6. Belts should be in the same direction as the fixed point of the mask.

7. Belts must not be twisted and tightened in pairs (the lowest shoulder strap first).

8. Tighten the shoulder straps by applying equal tension to each side to keep the mask centered on the face.

9. Adjust the tightness of Belts: fit tightly on the face, but don't tighten it too much.

Final check:

1. Finally, check the hair, etc., to make sure that it is not stuck in the face seal.

2. To check the fit of the face seal of the filter mask respirator, please cover as much filter material as possible, suck and hold for 10 seconds.

3. The mask should be folded toward the face. Next, with both hands still covered with the filter material, breathe out gently and smoothly. This should cause the mask to expand slightly, but there should be no leakage of air between the face and the face seal of the mask. (Figure 20)

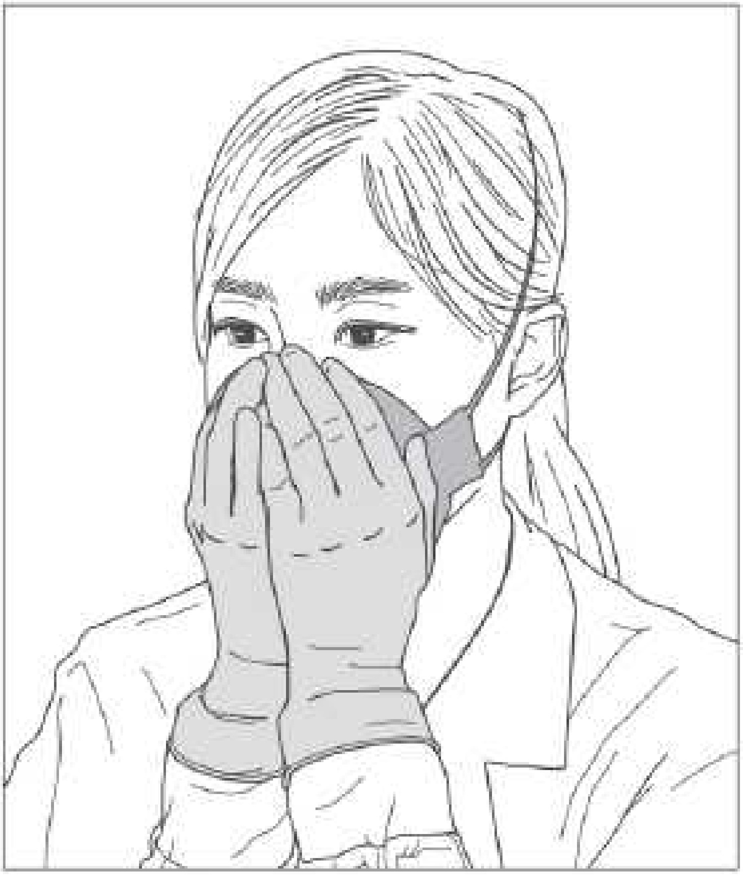

*fig.20*

If there are any signs of air leakage between the mask and the skin, it means that a proper facial seal is not being formed. The mask should be readjusted and tested again; if it still does not work, the mask should not be used because it is not suitable. If you wear safety glasses or goggles, In addition to the mask, you may need to recheck the fit of the mask after putting on the goggles.

- When removing:

Respiratory protective equipment should be removed according to the manufacturer's instructions. Respiratory protective equipment can be removed in different ways, usually depending on the type of respiratory protective equipment used. The goal of the removal process is to ensure that the wearer does not come into contact with the potential contamination of the outer surface of the respiratory protective equipment and other potential sources of contamination during the removal process.（Fig.21)

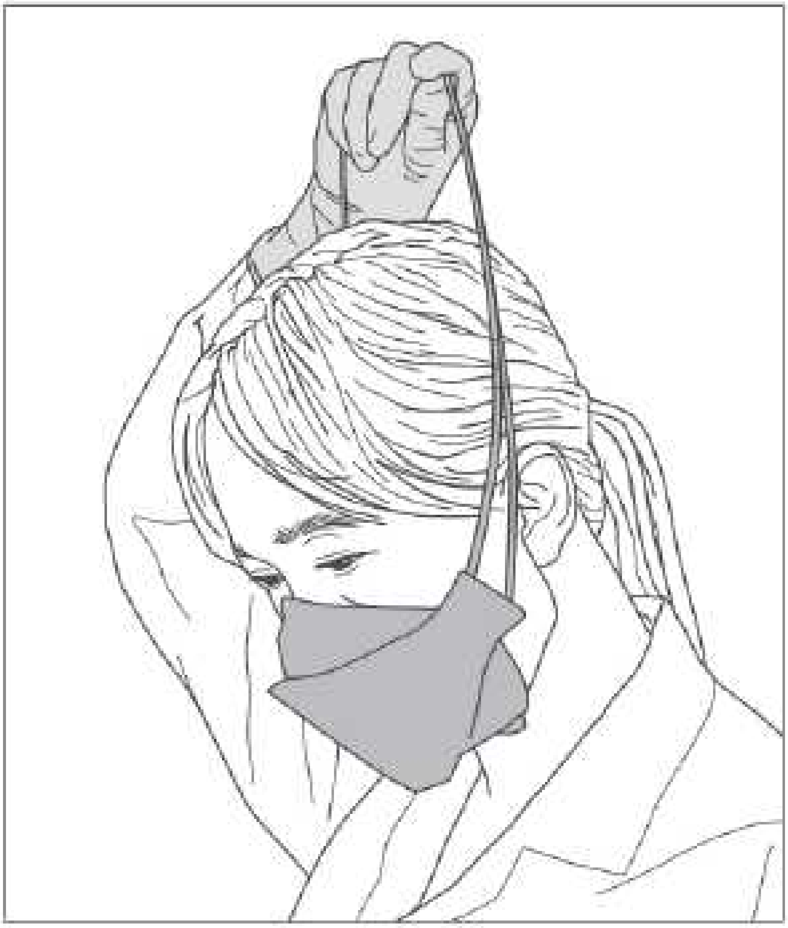

*fig.21*

## 5.4 Mask material and production process

- Three-layer surgical mask

Although surgical masks are commonly used, the effectiveness of surgical masks is still controversial. Compared to N95 masks, surgical masks exhibit a higher and more variable penetration rate, from about 30% to 70%[37].

The three-layer surgical mask comprises three different layers of non-woven fabrics, and each layer has a specific function, as shown in Figure 22. The outermost layer (usually blue) is waterproof and helps repel liquids such as mucosal droplets. The middle part is a filter that can prevent particles or pathogens above a certain size from penetrating any direction. The innermost layer is made of absorbent material to capture mucosa saliva droplets from the user. This layer also absorbs moisture in the air exhaled from the human body, thereby improving comfort. In short, the three layers limit the penetration of particles and pathogens from two directions to protect the user and the surrounding people.[38]

[37] *S. A. Grinshpun et al., Performance of an N95 Filtering Facepiece Particulate Respirator and a Surgical Mask During Human Breathing: Two Pathways for Particle Penetration. Journal of Occupational and Environmental Hygiene 6, 593–603 (2009).*

*T. Oberg, L. M. Brosseau, Surgical mask filter and fit performance. American Journal of Infection Control 36, 276–282 (2008).*

[38] *Ming Hui Chua, Weiren Cheng, Shermin Simin Goh, Junhua Kong, Bing Li,Jason Y. C. Lim, Lu Mao, Suxi Wang,Kun Xue,Le Yang, Enyi Ye, Kangyi Zhang et al.07 Aug 2020,`Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives`*

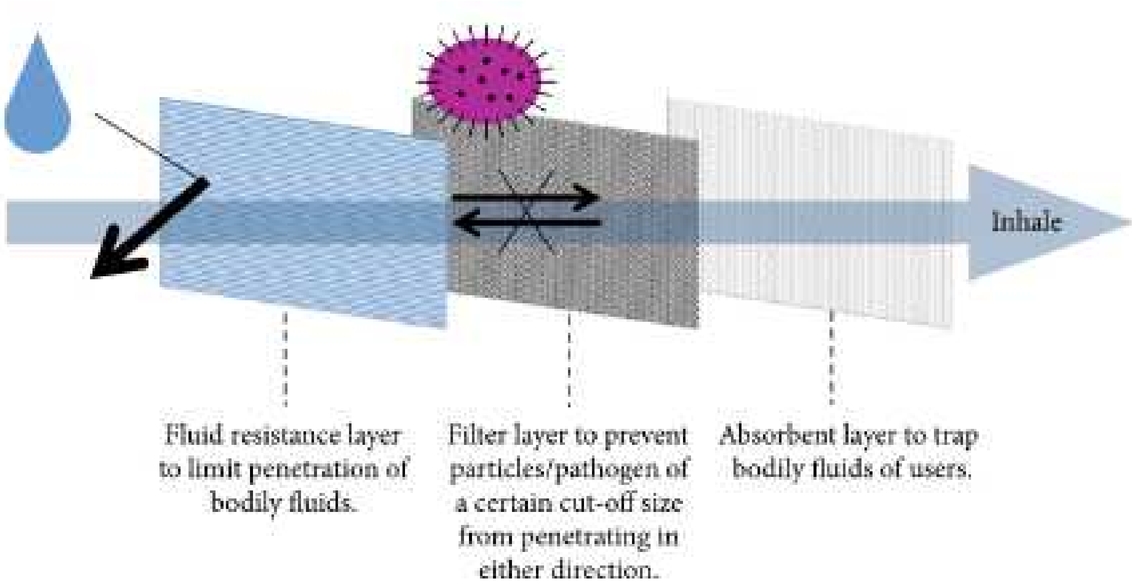


*fig.22 Illustration showing the function of each individual layer of a 3-ply surgical mask.*

As the name implies, non-woven fabrics are not connected by strands, but are made by bonding a large number of fibers together using thermal, chemical or mechanical methods. However, it has better bacterial filtration and air permeability than non-woven fabrics, while maintaining smoothness. The most commonly used manufacturing material is polypropylene with a density of 20, or 25 grams per square meter (gsm). Other materials such as polystyrene, polycarbonate, polyethylene, or polyester can also be used as raw materials.[39]

Felt is one of the most common examples of non-woven fabrics. Although the mechanical properties of non-woven fabrics are weaker than their counterparts, their manufacturing costs are low and they are fast. Therefore, it is an ideal material for making surgical masks. The two most common production processes for manufacturing non-woven fabrics for surgical masks are spun-bond and melt-blown.[40]

The 20 gsm mask material is made through a spunbond process, which involves extruding molten plastic onto a conveyor belt. As a result, the

[39] *Brittany Henneberry, "How Surgical Masks are Made"*

[40] *Ming Hui Chua,Weiren Cheng,Shermin Simin Goh,Junhua Kong,Bing Li,Jason Y. C. Lim,Lu Mao,Suxi Wang,Kun Xue,Le Yang,Enyi Ye,Kangyi Zhang et al.,07 Aug 2020,`Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives`*

material is extruded into a net, where the strands are joined to each other when they are cooled.

The 25 gsm fabric is made by melt-blown technology, which is a similar process in which plastic is extruded through a die with hundreds of small nozzles, blown into fine fibers with hot air, and then cooled and glued on a conveyor belt together. The diameter of these fibers is less than one micron.[41]

As mentioned earlier, surgical masks are composed of a multi-layer structure, which is usually realized by covering a layer of textile with a fabric bonded with a non-woven fabric on both sides. Non-woven fabrics are cheaper and cleaner due to their disposable properties. These disposable masks are usually made of two filter layers, which can effectively filter out particles such as bacteria above 1 micron. However, the filtering level of the mask depends on the fiber, its manufacturing method, the structure of the fiber web, and the cross-sectional shape of the fiber. Masks after manufacturing need to be disinfected before they leave the factory.[42]

- The spun-bond process combines spinning and sheet forming processes into a continuous nonwoven fabric manufacturing system[43]. As shown in Figure 23, the spun-bond process consists of several integrated steps, namely extruder, gear pump, spinning assembly, quencher, collector, bonder, and winder.

(1) The process of melting the polymer by the heat and mechanical action of the screw;

(2) Gear pumps play a key role in controlling the precise volume flow of molten polymers. This is a key step to keep the temperature of the molten polymer uniform;

[41] *Brittany Henneberry, "How Surgical Masks are Made"*
[42] *Brittany Henneberry, "How Surgical Masks are Made"*

[43] *H. Lim, "A review of the spun bond process," Journal of Textile and Apparel, Technology and Management, vol. 6, pp. 1–13, 2010.*

*V. Midha and A. Dakuri, "Spun bonding technology and fabric properties: a review," Journal of Textile Engineering & Fashion Technology, vol. 1, no. 4, 2017.*

(3) The spinning component is a modular component that can transform the molten polymer into uniform filaments and is designed to withstand 300°C to 400°C;

(4) Then the filament is quenched with cold air;

(5) After quenching, the filaments are collected together as a filament mesh on the moving belt;

(6) Then the filaments in the web are bonded together by heating, the chemical or mechanical means to form a non-woven fabric;

(7) Finally, the non-woven fabric is collected in the winder.[44]

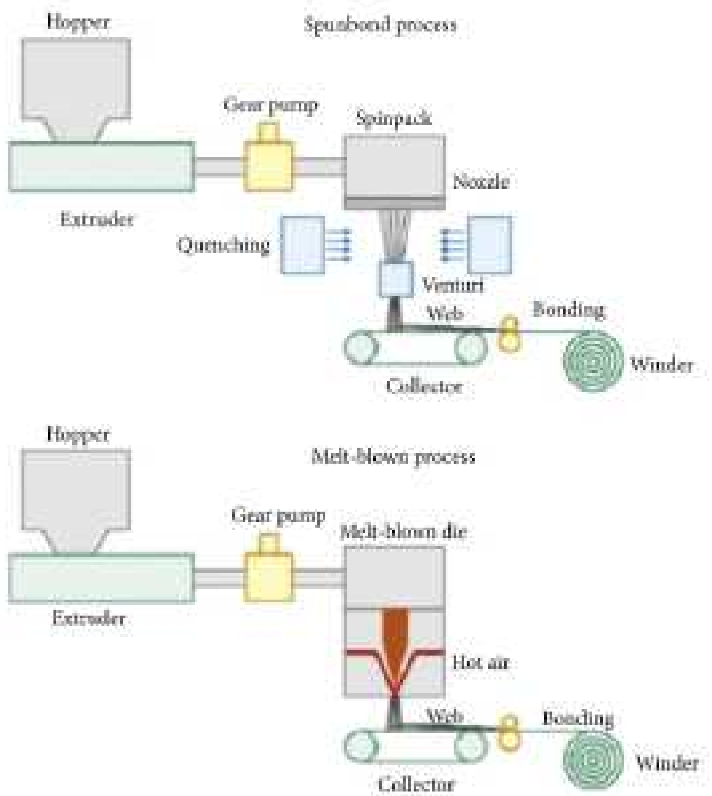


*fig.23 Schematic illustration of spunbond and melt-blown process. Republished with permission from Ref.[45]*

[44] *Ming Hui Chua,Weiren Cheng,Shermin Simin Goh,Junhua Kong,Bing Li,Jason Y. C. Lim,Lu Mao,Suxi Wang,Kun Xue,Le Yang,Enyi Ye,Kangyi Zhang et al.,07 Aug 2020,`Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives`*
[45] *I. M. Hutten, "Chapter 1 - introduction to nonwoven filter media," in Handbook of Nonwoven Filter Media (Second Edition), I. M. Hutten, Ed., pp. 1–52, Butterworth-Heinemann, Oxford, 2016.*

The melt-blown process is very similar to the spun-bond process seen in Figure 23, but the microfibers produced by the melt-blown process are much finer, and the pore size of the non-woven fabric could be much smaller. Therefore, because of the finer pore size, melt blown is a typical process for manufacturing the middle filter of a three-layer surgical mask. The melt-blown process also includes several integrated steps, namely extrusion, gear pump, die assembly, collector and winder[46]. The main difference between spun-bond, and melt-blown lies in the molding process, which is the most important factor in producing smaller diameter microfibers. The mold assembly contains three components: the feed distribution plate, the die and the air manifold, all of which are maintained at a heating temperature of 215°C to 340°C.(fig.24)[47]

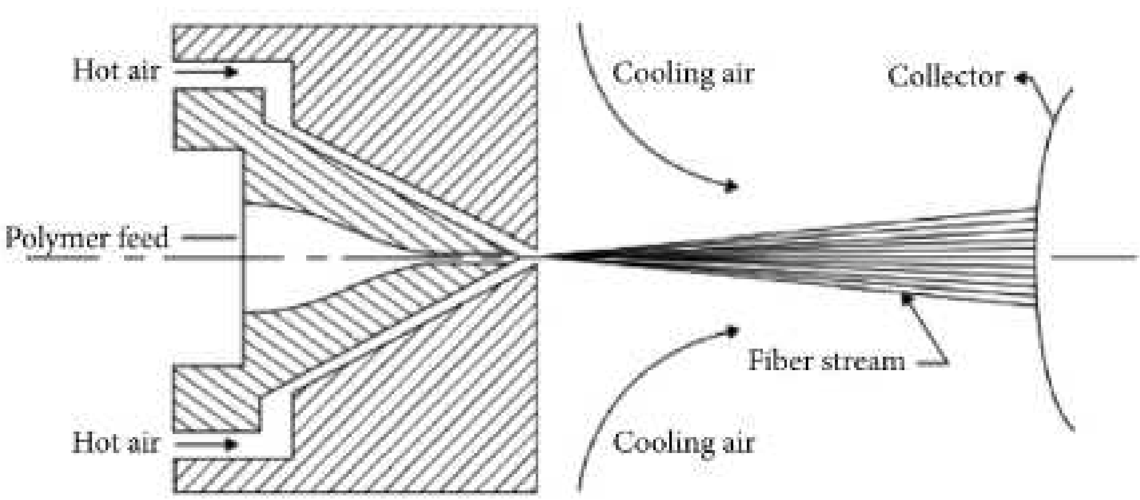


*fig.24 Schematic illustration of air manifold in melt-blown process. Republished with permission from Ref.[48]*

[46] *K. Dutton, "Overview and analysis of the meltblown process and parameters," Journal of Textile and Apparel, Technology and Management, vol. 6, no. 1, 2008.*

[47] *Ming Hui Chua,Weiren Cheng,Shermin Simin Goh,Junhua Kong,Bing Li,Jason Y. C. Lim,Lu Mao,Suxi Wang,Kun Xue,Le Yang,Enyi Ye,Kangyi Zhang et al.,07 Aug 2020,`Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives`*

[48] *J. Hagewood, "3 - technologies for the manufacture of synthetic polymer fibers," in Advances in Filament Yarn Spinning of Textiles and Polymers, D. Zhang, Ed., pp. 48–71, Woodhead Publishing, 2014.*

(1) The feed distribution plate ensures that the molten polymer flows evenly through the plate. The shape of the feed distribution plays an important role in the polymer distribution. The most common is the hanger style;

(2) The die head is a key component to ensure the diameter and quality of the filament. The tip of the mold is a very wide and thin metal-organic sheet with an orifice size of approximately 0.4 mm;

(3) The air manifold, as shown in Figure 24, provides hot high-speed air to draw polymer filaments into finer microfibers. The manifold is located on the side of the die. The hot air comes into contact with the polymer when it leaves the die to ensure that the polymer remains liquefied during processing.[49]

## 5.5 Performance standards for commercial masks

All masks need to undergo performance testing before going on the market to ensure that the performance of the masks is sufficient to protect the safety of users. According to the F2100 standard developed by the American Society for Testing and Materials (ASTM), the standard specifies the performance requirements of the materials used in medical masks[50]. Five performance characteristics have been determined, including particulate filtration efficiency (PFE) and bacterial filtration efficiency (BFE). ), fluid resistance, pressure difference, and flammability.

- Particulate Filtration Efficiency (PFE)

This test measures the filtration efficiency of the mask against monodisperse particles at a constant airflow rate, also known as the latex particle challenge, which involves spraying an aerosol of polystyrene microspheres to ensure that the mask can filter the expected particle size.[51]

[49] *Ming Hui Chua,Weiren Cheng,Shermin Simin Goh,Junhua Kong,Bing Li,Jason Y. C. Lim,Lu Mao,Suxi Wang,Kun Xue,Le Yang,Enyi Ye,Kangyi Zhang et al.,07 Aug 2020,`Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives`*

[50] *ASTM, F2100-19e1, Standard Specification for Performance of Materials Used in Medical Face Masks, ASTM International, West Conshohocken, PA, USA, 2019.*

[51] *Brittany Henneberry, “How Surgical Masks are Made”*

Although the F2299 standard allows consistent comparison of the PFE values of different materials used for masks, it cannot evaluate the effectiveness of the overall design of the mask, nor the quality of the mask's sealing on the wearer's face.

- Bacterial Filtration Efficiency (BFE)

The test involves spraying an aerosol containing Staphylococcus aureus into the face mask at a rate of 28.3 liters per minute. This ensures that the mask can capture the proper percentage of bacteria. Staphylococcus aureus was chosen because it is one of the main causes of nosocomial infections[52]. For testing, an atomized liquid suspension of Staphylococcus aureus (average particle size  μm) is delivered to the target filter sample at a constant flow rate of 1 ft 3 /min (or 28.3 L/min). The aerosol was then sucked into a six-stage Anderson sampler[53]. Each layer contains an agar plate as a medium for bacterial growth, and these bacteria pass through the filter material to form visible colonies on the plate. For surgical masks, a minimum BFE of 95% is required. However, like the ASTM F2299 standard of PFE, the ASTM F2101 standard of BFE does not evaluate the fit, design, and face sealing performance of the mask.

- Splash test

Used to evaluate the mask's ability as a barrier. In the splash test, simulated blood is used to spray the surgical mask under a force similar to human blood pressure to ensure that the liquid will not penetrate and contaminate the wearer. According to the ASTM F1862 standard, 2 mL of synthetic blood (containing red dye for visual inspection and thickener for stimulating blood flow characteristics) was distributed to a complete medical mask sample at different speeds[54].

- Differential pressure (DP)

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[52] *R. Valaperta, M. R. Tejada, M. Frigerio et al., "Staphylococcus aureus nosocomial infections: the role of a rapid and low-cost characterization for the establishment of a surveillance system," The New Microbiologica, vol. 33, no. 3, pp. 223–232, 2010.*

[53] *"Bacterial filtration efficiency (BFE) / virus filtration efficiency (VFE) test," May 2020, https://www.kaken.or.jp/test/search/detail/34#ID1.*

[54] ASTM, F1862 / F1862M-17, Standard Test Method for Resistance of Medical Face Masks to Penetration by Synthetic Blood (Horizontal Projection of Fixed Volume at a Known Velocity), ASTM International, West Conshohocken, PA, USA, 2017.

This parameter also called "delta P" measures the ability of the mask material to restrict airflow and gives an objective indication of the breathability of the mask. ASTM requires that the DP value of medium and high barrier masks is >5.0, and the DP value of low barrier masks is <5.0. Generally, it is determined by measuring the air pressure difference on both sides of the mask material with a pressure gauge under a constant air flow rate, and the pressure difference divided by the surface area of the sample (according to the MIL-M-36954 standard)[55]. A lower value (that is, a smaller pressure difference on both sides) indicates better breathability, and the wearer feels cooler, thus providing better comfort overall.[56]

- Flammable

There are many fire sources in hospitals, such as heat, oxygen, and fuel sources. The mask material is flammable. Due to the speed and intensity of flame propagation, these materials may pose a potential risk to the wearer. The flammability of the mask is evaluated according to the 16 CFR Part 1610 standard, usually, 5-10 test samples are tested[57]. According to the ASTM F2100 material performance standard for medical masks[58], masks need to meet Class 1 flammability requirements, and the average burning time is ≥3.5 seconds[59].

In addition to the above-mentioned standardized tests, medical masks should also be tested according to ISO 10993-5 and 10, which respectively specify cytotoxicity[60]and skin sensitivity[61] test methods to ensure that the material is harmless to humans.

[55] *"MIL-M-36954C, military specification - mask, surgical, disposable," May 2020, http://www.frazierinstrument.com/reference/standards/organizations/mil/abstract-mil-m-36954c.html.*

[56] *Ming Hui Chua, Weiren Cheng, Shermin Simin Goh, Junhua Kong, Bing Li,Jason Y. C. Lim, Lu Mao, Suxi Wang,Kun Xue,Le Yang, Enyi Ye, Kangyi Zhang et al.07 Aug 2020,`Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives`*

[57] *Laboratory Test Manual for 16 CFR Part 1610: Standard for the Flammability of Clothing Textiles United States Consumer Product Safety Commission, Consumer Product Safety Commission (CPSC), 2008.*

[58] *ASTM, F2100-19e1, Standard Specification for Performance of Materials Used in Medical Face Masks, ASTM International, West Conshohocken, PA, USA, 2019.*

[59] *N. Labs, "Flammability test," May 2020, https://www.nelsonlabs.com/testing/flammability-test/.*

[60] *"ISO 10993-5:2009 biological evaluation of medical devices — part 5: tests for in vitro cytotoxicity," 2009.*

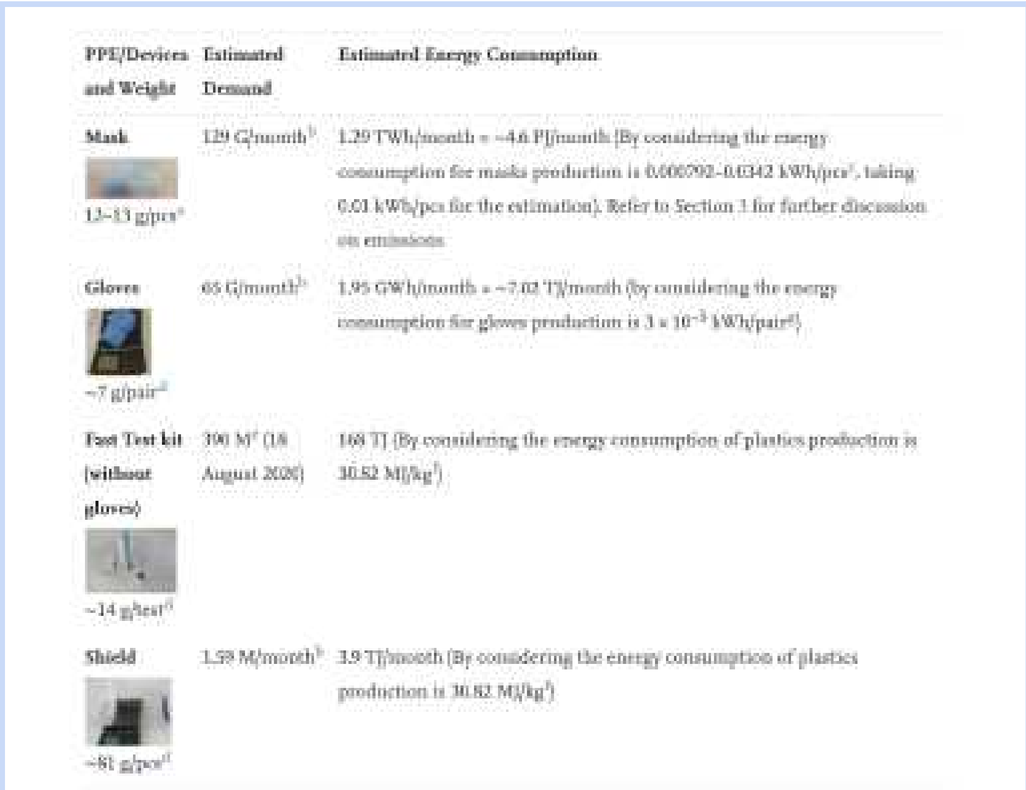
[61] *"ISO 10993-10:2010 biological evaluation of medical devices — part 10: tests for irritation and skin sensitization," 2010.*

# The environmental impact

# 6.The environmental impact of the surge in demand for PPE

Since the beginning of the epidemic, many countries have adopted a policy of home isolation and prohibiting people from going out. This has led to a reduction in the use of public or private transportation. As a result, noise pollution levels in most countries have been significantly reduced, and air quality has also improved. This shows that COVID-19 has had some positive effects on the environment, but there are still negative effects.

The data shows that during the epidemic, the estimated demand for personal protective equipment and during the epidemic the estimated energy consumption were higher than usual. The monthly demand for masks can reach 129G/month, and the estimated energy consumption can reach 1.29TWh/month (fig.25).



| PPE/Devices and Weight | Estimated Demand | Estimated Energy Consumption |
|---|---|---|
| **Mask** 12–13 g/pcs[a] | 129 G/month[1] | 1.29 TWh/month = ~4.6 PJ/month (By considering the energy consumption for masks production is 0.000792–0.0342 kWh/pcs[c], taking 0.01 kWh/pcs for the estimation). Refer to Section 3 for further discussion on emissions |
| **Gloves** ~7 g/pair[d] | 65 G/month[b] | 1.95 GWh/month = ~7.02 TJ/month (by considering the energy consumption for gloves production is $3 \times 10^{-3}$ kWh/pair[f]) |
| **Fast Test kit (without gloves)** ~14 g/test[f] | 390 M[f] (18 August 2020) | 168 TJ (By considering the energy consumption of plastics production is 30.82 MJ/kg[f]) |
| **Shield** ~81 g/pcs[f] | 1.59 M/month[b] | 3.9 TJ/month (By considering the energy consumption of plastics production is 30.82 MJ/kg[f]) |

*fig.25 Estimated monthly demand for PPE*

It is estimated that approximately 89 million medical masks are needed every month to treat and care for COVID-19 patients (WHO, 2020d). The use of gloves, hand sanitizer bottles, and syringes has also surged. These products are mainly made of plastic. If these products are not adequately treated or disposed of, they may carry pathogenic contaminants that may be considered hazardous waste. At the same time, it is reported that in April 2020, the amount of residential waste and recyclable waste in many American cities has surged by 20%, which has put pressure on many solid waste collection systems[62]. Considering the spread of the virus during garbage collection, some countries have suspended garbage collection during the epidemic.

At present, most countries do not have a comprehensive medical waste recycling mechanism because this poses a threat to the staff of the recycling center. If they are not professional handlers, they may be infected because of household or medical waste. These wastes may contain traces of viral contaminants. Most countries are struggling to find solutions for the proper and safe disposal of COVID-19 waste. (Bir, 2020[63]).

Most of the masks are made of petroleum-based non-renewable polymers, which are non-biodegradable, harmful to the environment, and cause health problems. Ignoring the severity of this problem may result in a large number of microplastics being released into landfills and the marine environment, thereby greatly affecting plant and animal populations. Among them, microplastics are divided into two categories according to their sources: 1) primary 2) secondary microplastics (Avio et al., 2017[64]). Studies have shown that the average release of microplastics from unused masks is 71-308/piece, while the average release of microplastics after use increases to 682-1918/piece.

Take the pollution caused to the ocean as an example. Marine litter is mainly composed of solid materials that are discarded or transported to

[62] *June 17, 2020 SWANA'https://swana.org/docs/default-source/advocacy-documents/senate-epw---final-swana-testimony---june-17-2020.pdf?sfvrsn=c3af10a2_2*

[63] *Selvakumar Dharmaraj,Veeramuthu Ashokkumar,Sneha Hariharan,Akila Manibharathi ,Pau Loke Show,Cheng Tung Chong,Chawalit Ngamcharussrivichai,June 2021'The COVID-19 pandemic face mask waste: A blooming threat to the marine environment'*

[64] *Carlo Giacomo Avio, Stefania Gorbi, Francesco Regoli,July 2017, "Plastics and microplastics in the oceans: From emerging pollutants to emerged threat"*

the ocean. These include many materials such as metal, paper, wood, rubber, glass, clothing, and plastic (Setyo and Muhammad, 2019[65]). They are divided into two categories, biodegradable and non-biodegradable.

"Disposable masks are made of various melt-blown plastics, which are difficult to recycle due to their composition, contamination, and risk of infection. When these masks are littered or otherwise improperly discarded, the waste management system is imperfect or does not exist, or when these systems are overwhelmed by increased waste volumes, these masks will enter our oceans," the OceanAsia report points out[66]. In addition, the report also claims that masks in marine environments are a source of microplastics, and it may take about 450 years to completely decompose. Another worrying issue is the impact of microplastics on marine biota because it can lead to entanglement and ingestion that may be fatal to the marine life (Sharma and Chatterjee, 2017[67]), leading to the extinction of many rare species.

It is estimated that even in an ideal environment where people dispose of disposable masks in a proper and correct manner, it is estimated that 75% of used masks, including other pandemic-related wastes, end up either in landfills or floating in the sea. (United Nations[68])

In response to environmental pollution under the epidemic, a questionnaire sampling survey was conducted（fig.26）. The data obtained shows that 97.8% of people are worried about the pollution of the environment after wearing masks, and only a very small part of 2.2% chooses “NOT MY BUSINESS”. It shows that everyone's awareness of environmental protection is already very high. This is a very good phenomenon.

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*[65] Setyo Budi Kurniawan, Muhammad Fauzul Imron,November 2019*
*Seasonal variation of plastic debris accumulation in the estuary of Wonorejo River, Surabaya, Indonesia,*

*[66] BusinessToday,Dec 30, 2020,’COVID-19 hazard: 1.56 bn masks polluted oceans in 2020, claims study’*

*[67] Shivika Sharma & Subhankar Chatterjee，16 August 2017，“Microplastic pollution, a threat to marine ecosystem and human health: a short review”*

*[68] United Nations,30 July 2020,’Five things you should know about disposable masks and plastic pollution’*

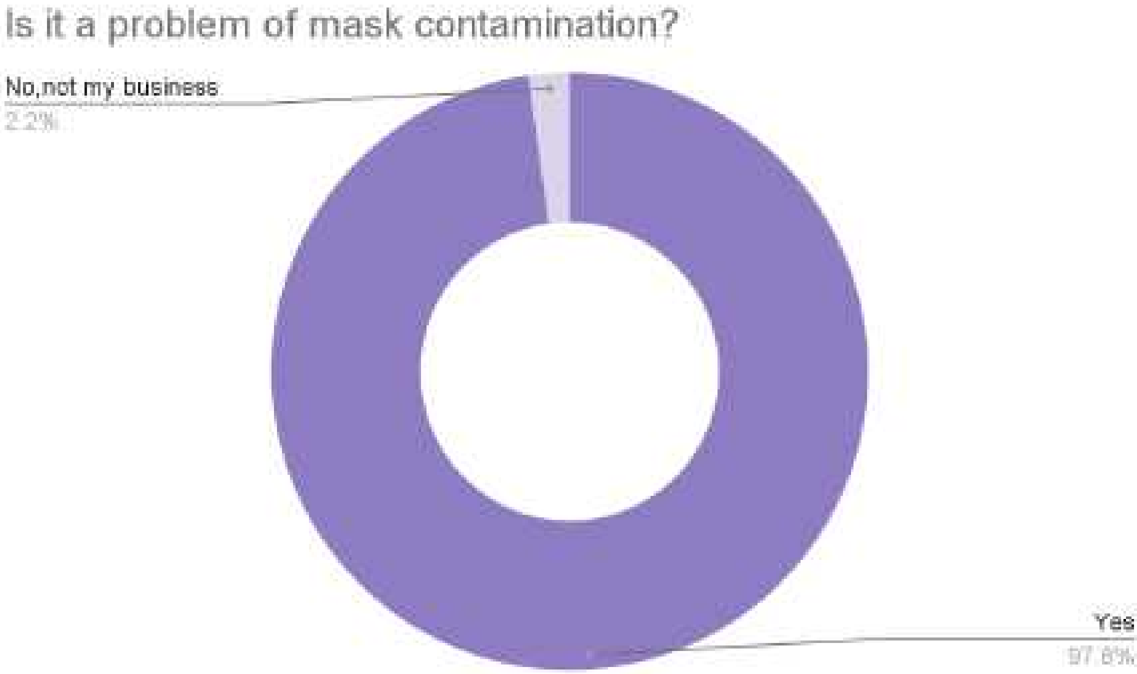


*fig.26 Concern about the pollution of masks*

The same questionnaire is used to analyze the data of people's disposal of discarded masks. From the chart（fig.27）, it can be seen that no one chooses to discard masks outdoors. Of course, unconscious discarding may not be counted as discarded by the sampling personnel. The vast majority of them, 54 people chose to set up a trash can in their homes, which is only used to store discarded masks. Most of the remaining people choose to discard after simple disinfection and discard after cutting the rope. Among them, a relatively large proportion, 45 people chose to mix and discard other garbage directly regardless of the classification. However, it may be that most of the collected samples are concentrated in China, and a small part of it is caused by Europe. China's current garbage classification system is not very complete.

These data show that people have a certain sense of disposal of medical waste such as discarded masks, but the country does not currently have a good disposal system.

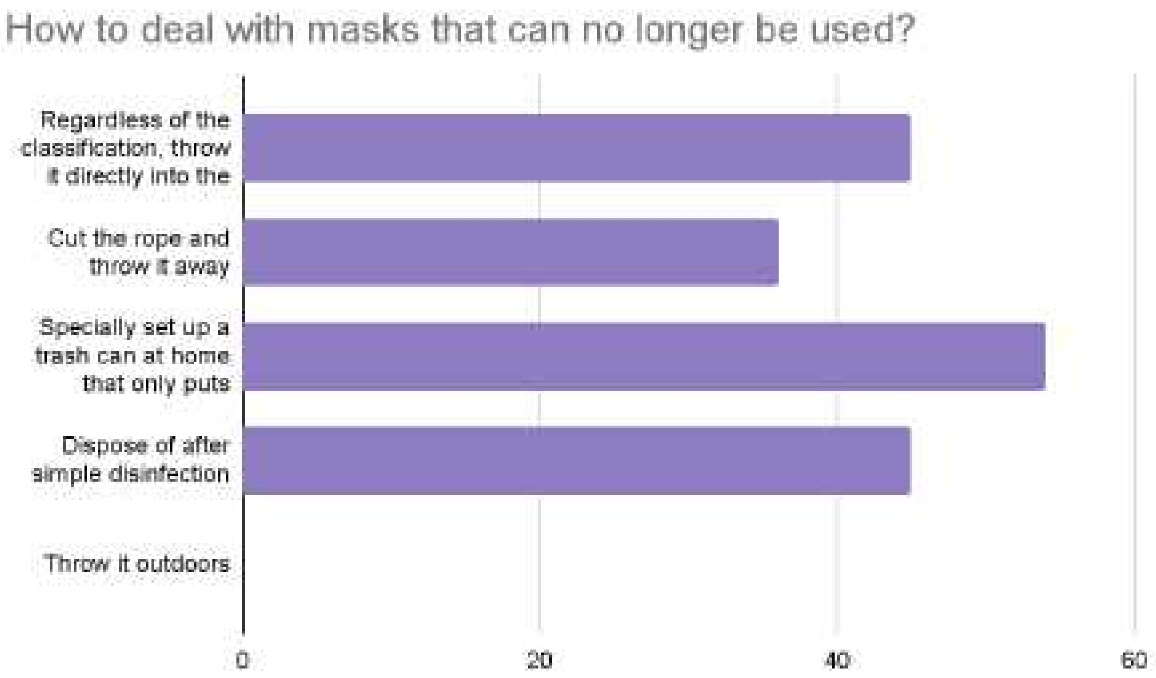


*fig.27 Disposal of discarded masks*

# Disinfection and decontamination methods of masks

# 7.Disinfection and decontamination methods of masks

In response to severe environmental pollution, the primary goal of government departments, hospitals, pharmaceutical companies, and researchers around the world is to find remedies for the massive use of masks or to identify new personal protective equipment that must be cost-effective and reusable. If personal protective equipment that can be reused is considered, it is necessary to conduct research and discussion on disinfection methods. First, study the survival time of the virus on the surface of the object in order to better choose the disinfection method.

## 7.1 The survival time of the virus on the surface of the mask

Here, the objects are divided into non-porous smooth surface objects (metal, plastic, glass, etc.) and porous objects (such as paper and cloth). It is found that porosity is the main factor that determines the influenza virus inactivation rate[69]. Further studies by measuring virus titer[70]show that porous materials are significantly detrimental to the survival of viruses. Compared with impermeable surfaces (such as glass, stainless steel, and plastic), the survival time of coronaviruses on these surfaces is impressive. Surprisingly short.

The previous experiment here used water drop penetration. The overall droplet lifetimes on glass, plastic, and stainless steel are approximately 800 seconds, 1400 seconds, and 1600 seconds, respectively. Both the experiment and the diffusion restriction model have detailed records[71]The droplet life is mainly controlled by wettability; as the wettability decreases

[69] *T. P. Weber and N. I. Stilianakis, "Inactivation of influenza A viruses in the environment and modes of transmission: A critical review," J. Infect.* ***57****, 361–373 (2008).*

[70] *N. van Doremalen, T. Bushmaker, D. H. Morris, M. G. Holbrook, A. Gamble, B. N. Williamson, A. Tamin, J. L. Harcourt, N. J. Thornburg, S. I. Gerber, J. O. Lloyd-Smith, E. de Wit, and V. J. Munster, "Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1," N. Engl. J. Med.* ***382****, 1564–1567 (2020).*

[71] *N. D. Patil, P. G. Bange, R. Bhardwaj, and A. Sharma, "Effects of substrate heating and wettability on evaporation dynamics and deposition patterns for a sessile water droplet containing colloidal particles," Langmuir* ***32****, 11958–11972 (2016).*

(larger contact angle), the drying time increases—from glass to stainless steel. From the results[72]found that the survival time of these viruses on the surface was 4 days, 7 days, and 7 days, respectively. The ratio of virus survival time is roughly (glass: plastic: stainless steel = 4:7:7). The survival time on porous media is significantly shortened (about 2 days on cloth and only about 3 hours on paper). However, in spite of this, in order to prevent Covid-19 infection, the use of cloth masks is still not recommended, because compared with medical and surgical masks, the infection detection rate on both sides of cloth masks is very high (Luo et al., 2020; MacIntyre et al., 2015[73]). At the same time, it was detected that this virus can exist on the outer layer of surgical masks for up to 7 days, although the cell density is low, about 0.1% (Chin et al., 2020)[74].

The conclusion shows that for personal protective equipment such as masks, the humidity determines the length of its use. When the humidity is too high, it will cause a longer drying time, thereby prolonging the time for the virus to attach to the surface of the mask, and it is easy to cause high Consequences of infection rate.

## 7.2 Analysis of disinfection and decontamination methods

After understanding the remaining time of the virus on the surface of the object, you can further discuss the possibility of disinfection of the surface of the mask.

The requirements for effective purification methods for masks and FFR are as follows:

1. Pathogens contaminated by masks and FFR surfaces must be effectively killed and inactivated;
2. The filtering performance of masks and FFR on pathogens and particles must not be reduced;

[72] *A. W. H. Chin, J. T. S. Chu, M. R. A. Perera, K. P. Y. Hui, H.-L. Yen, M. C. W. Chan, M. Peiris, and L. L. M. Poon, "Stability of SARS-CoV-2 in different environmental conditions," Lancet Microbe* ***1****, e10 (2020).*
[73]*MacIntyre CR, Seale H, Dung TC, et al,"A cluster randomised trial of cloth masks compared with medical masks in healthcare workers"BMJ Open 2015;**5:**e006577. doi: 10.1136/bmjopen-2014-006577*

[74] *Sanghamitro Chatterjee,Janani Srree Murallidharan, Amit Agrawal,Rajneesh Bhardwaj,09 February 2021 'Why coronavirus survives longer on impermeable than porous surfaces'*

3. The structural integrity of the mask and all other components of the FFR (including elastic bands and metal nosebands) must not be adversely affected;
4. Do not compromise on the requirement of FFR to fit the user's face;
5. Chemicals or by-products that may affect the health of users shall not be left behind after disinfection.

Therefore, research work to develop and optimize mask decontamination methods usually includes：

1. Test the effectiveness of these methods in killing different pathogens on the surface of the mask;
2. Detect the filter performance, fit coefficient, and structural integrity of the mask after decontamination;
3. Determine how many times the mask can undergo decontamination before it detects deterioration.[75]

Generally speaking, there are many methods and chemical agents (such as bleach and soap) that can disinfect pathogens on our hands, small objects, and common surfaces with high contact points, but not all of these methods are suitable for decontamination of masks. There are currently five common disinfection methods for masks, which will be discussed and analyzed in turn:

a.Ultraviolet (UV) radiation;
b.hydrogen peroxide;
c.Ethylene oxide;
d.Heat, humidity and steam decontamination;
e.Disinfectant treatment and decontamination.

a.Ultraviolet (UV) radiation

Short-wave ultraviolet radiation (UV-C, input=254 nm) is usually used to disinfect small items, which can kill pathogens within a few minutes. Usually ultraviolet disinfection is used in medical equipment, transportation and baby products. Therefore, ultraviolet germicidal

[75] *Ming Hui Chua, Weiren Cheng, Shermin Simin Goh, Junhua Kong, Bing Li,Jason Y. C. Lim, Lu Mao, Suxi Wang,Kun Xue,Le Yang, Enyi Ye, Kangyi Zhang et al.07 Aug 2020,`Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives`*

radiation (UVGI) has become one of the most commonly studied and adopted masks and FFR purification methods. The effectiveness of UVGI in mask purification depends on three critical factors: (i) the intensity of ultraviolet radiation, (ii) the duration of exposure, and (iii) the size and orientation of the ultraviolet radiation relative to the mask. For the first two factors, prolonged exposure to very high-intensity ultraviolet radiation may cause degradation of the mask material, which may affect the filtering ability and mask fit (for FFR). Therefore, the optimal radiation intensity and duration must be fine-tuned. Regarding the third factor, evenly exposing all surfaces of the mask to ultraviolet radiation is ideal for thorough purification. For users to use ultraviolet disinfection, it is necessary to provide specific technical guidance.

In order to study the effect of ultraviolet disinfection on the function of masks, Viscusi et al. conducted an experiment, irradiating each side of the FFR with ultraviolet rays of 176–181 mJ/cm 2 for 15 minutes[76]. No significant changes in FFR were observed, and the aerosol penetration of the filter and the airflow resistance of the filter was not affected. Bergman et al. conducted three 15-minute experimental observations on this basis, and still did not observe any adverse effects on the filtering performance or facial fit. When Linzli et al. adjusted the UV dose between 120 and 950 J/m 2, they found that the particle filtering performance of the mask increased slightly (up to 1.25%), but it had almost no effect on the flow resistance of most FFR models[77].

However, as the dose of ultraviolet radiation increases, the breaking strength of the elastic band is very likely to decrease. Recently, after 10 UVGI treatments (~3.6 J/cm 2 ), Liao et al. proved that the mask can maintain a filtration efficiency of more than 95%, but after 20 cycles, it has shown that about 93% of the slight degradation occurs[78].

[76] *D . J. Viscusi, M. S. Bergman, B. C. Eimer, and R. E. Shaffer, "Evaluation of five decontamination methods for filtering facepiece respirators," The Annals of Occupational Hygiene, vol. 53, no. 8, pp. 815–827, 2009.*

*D. J. Viscusi, W. P. King, and R. E. Shaffer, "Effect of decontamination on the filtration efficiency of two filtering facepiece respirator models," Journal of the International Society for Respiratory Protection, vol. 24, pp. 93–107, 2007.*

[77] *W. G. Lindsley, S. B. Martin Jr., R. E. Thewlis et al., "Effects of ultraviolet germicidal irradiation (UVGI) on N95 respirator filtration performance and structural integrity," Journal of Occupational and Environmental Hygiene, vol. 12, no. 8, pp. 509–517, 2015.*

[78] *L. Liao, W. Xiao, M. Zhao et al., "Can N95 respirators be reused after disinfection? How many times?" ACS Nano, vol. 14, no. 5, pp. 6348–6356, 2020.*

Fischer and Ou et al. evaluated the feasibility of UVGI to purify SARS-CoV-2 contaminated masks. The former concluded that ultraviolet radiation with a wavelength of 260-285nm can effectively sterilize N95 FFR for up to three cycles without affecting the performance of the mask [79], while the latter reported that N95 FFR and surgical masks can be exposed to an intensity of 216 mJ/cm 2 for 5 minutes, up to 10 cycles, and the filtration efficiency and fitting coefficient are not significantly reduced[80].

The conclusion shows that although the ultraviolet disinfection method has a certain degree of damage to human skin and eyes, it has a good performance in the disinfection of the surface of the mask and is a powerful decontamination method.

b.Hydrogen peroxide disinfection

Hydrogen peroxide ($H_2O_2$) solution is commonly used in wound treatment, while $H_2O_2$ vapor (HPV) is usually used to disinfect closed spaces, such as offices, workstations, hospital wards, etc., and Sterilize laboratories and medical equipment in specially designed closed rooms. Here is a brief interview specifically aimed at quarantined hotels in China. The staff of Guangzhou Home Inn mentioned the following point of view: Under China’s “three zones and two lines” policy, isolated hotels mainly use spraying and atomization. Among them, atomization is aimed at indoor space, and hydrogen peroxide is used for disinfection. Because the method of atomization is more comprehensive, it is not suitable for outdoor use, because the outdoor wind and airflow are too large, so the spraying method is more suitable.

For mask disinfection, the VHP method can effectively remove the pollution of different bacteria and viruses without affecting the performance of the mask. Early experiments by Viscusi et al. conducted: N95 FFR received VHP treatment for up to 55 minutes at a temperature of up to 80°C, and only showed slight discoloration of the metal noseband without significant changes infiltration capacity[81]. Bergman et al. further

[79] *Q. Ou, C. Pei, S. C. Kim et al., “Original work: Covid-19 pandemic – decontamination of respirators and masks for the general.,”*
[80] *Q. Ou, C. Pei, S. C. Kim et al., “Original work: Covid-19 pandemic – decontamination of respirators and masks for the general.,”*

[81] *D. J. Viscusi, W. P. King, and R. E. Shaffer, “Effect of decontamination on the filtration efficiency of two filtering facepiece respirator models,” Journal of the International Society for Respiratory Protection, vol. 24, pp. 93–107, 2007.*

confirmed that after 3 cycles of VHP treatment for N95 FFR, the HPV concentration was 8 g/m 3 for 125 minutes (each cycle) without any degradation of infiltration performance. The average filter layer recorded The permeability is lower than 4.01%[82]. Experiments have found that N95 FFR can still meet the filtration performance and fit requirements even after 50 cycles of VHP treatment, even though the elastic band begins to degrade[83].

Kenny and others studied the applicability of VHP to treat SARS-CoV-2 contaminated masks and proved the effectiveness of VHP treatment on N95 FFR. The experiment completely eradicated 3 kinds of aerosolized bacteriophages in one treatment cycle (imitating SARS-CoV-2). CoV-2): T1, T7, and Pseudomonas phage phi-6, the experiment involves 10 minutes of the adjustment, 30-40 minutes of 16 g/m 3 HPV inflation, 25 minutes of residence and 150 minutes of ventilation[84], in 5 After three experimental cycles, no deformities were observed in FFR. Similarly, Kumar et al. found no surviving SARS-CoV-2 virus on the surface of the N95 FFR after a 1-hour treatment cycle (including 10 minutes of dehumidification, 3 minutes of conditioning, 30 minutes of decontamination, and 20 minutes of ventilation). In the whole process, at the peak concentration of HPV of 750 ppm, FFR can accept 10 treatment cycles without affecting the performance of the mask[85]. Similarly, Smith et al. It also reported no functional degradation of N95 FFR (filtration capacity and fit factor) after two cycles of VHP treatment, including 20 minutes of inflation (~500 ppm), 60 minutes of residence (~420 ppm), and 210 minutes of environmental ventilation Temperature, no live virus was detected at the end of each cycle[86]. Finally, Fischer et al. concluded that among the centralized disinfection and decontamination methods of VHP,

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[82] *M. S. Bergman, D. J. Viscusi, B. K. Heimbuch, J. D. Wander, A. R. Sambol, and R. E. Shaffer, "Evaluation of multiple (3-cycle) decontamination processing for filtering facepiece respirators," Journal of Engineered Fibers and Fabrics, vol. 5, no. 4, article 155892501000500405, 2018.*

[83] *Final Report for the Bioquell Hydrogen Peroxide Vapor (HPV) Decontamination for Reuse of N95 Respirators, Battelle Columbus, OH, USA, 2016.*

[84] *P. Kenney, B. K. Chan, K. Kortright et al., Hydrogen peroxide vapor sterilization of N95 respirators for reuse, medRxiv, 2020.*

[85] *A. Kumar, S. B. Kasloff, A. Leung et al., N95 mask decontamination using standard hospital sterilization technologies, medRxiv, 2020.*

[86] *J. S. Smith, H. Hanseler, J. Welle et al., Effect of various decontamination procedures on disposable N95 mask integrity and SARS-CoV-2 infectivity, medRxiv, 2020.*

UVGI, heat and ethanol treatment, VHP is the best way to quickly inactivate SARS-CoV-2 and preserve the integrity of N95 FFR[87].

c.Ethylene oxide vapor purification

Viscusi et al. placed FFR in ethylene oxide vapor (725–883 mg/L) at 55°C for 1 hour, and then ventilated for 4 hours. They found that except for the darkening of the elastic band , Did not produce any visible signs of mask degradation[88]The treated mask still passed the filter performance evaluation. Recently, Kumar et al. placed N95 FFR in ethylene oxide vapor for 1 hour, followed by ventilation for 12 hours, and successfully achieved complete sterilization of the SARS-CoV-2 virus[89]. The data showed that the mask can withstand at least 3 Treatment cycles without any significant structural or functional degradation. However, the disinfection time of ethylene oxide is too long, and ventilation needs to be ensured for more than a few hours. At the same time, the safety of mask wearers cannot be fully guaranteed because it has potential carcinogenic and teratogenic properties. In addition, ethylene oxide is flammable and poses fire safety hazards to the treatment process. CDC does not recommend using this method to disinfect masks[90].

d.Heat, humidity and steam decontamination

This decontamination method is relatively simple and easy to operate, and can be operated by household microwave ovens, rice cookers, and steamers. Earlier, Viscusi et al. conducted experiments to dry-heat N95 FFR in an oven at 80°C for 60 minutes and found that there was no visible physical change, while heating at 160°C for 22 minutes would result in a polypropylene mask. Melted and became unusable[91]. On the other hand, for FFR subjected to 2 minutes of dry microwave treatment (750 W/ft 3, 1

[87] *R. Fischer, D. H. Morris, N. van Doremalen et al., Assessment of N95 respirator decontamination and re-use for SARS-CoV-2, medRxiv, 2020.*
[88] *D. J. Viscusi, M. S. Bergman, B. C. Eimer, and R. E. Shaffer, "Evaluation of five decontamination methods for filtering facepiece respirators," The Annals of Occupational Hygiene, vol. 53, no. 8, pp. 815–827, 2009.*

[89] *A. Kumar, S. B. Kasloff, A. Leung et al., N95 mask decontamination using standard hospital sterilization technologies, medRxiv, 2020.*

[90] *W.-j. Guan, Z.-y. Ni, Y. Hu et al., "Clinical characteristics of coronavirus disease 2019 in China," New England Journal of Medicine, vol. 382, no. 18, pp. 1708–1720, 2020.*

[91] *D. J. Viscusi, W. P. King, and R. E. Shaffer, "Effect of decontamination on the filtration efficiency of two filtering facepiece respirator models," Journal of the International Society for Respiratory Protection, vol. 24, pp. 93–107, 2007*.

minute per side), partial melting and increased filter penetration were observed[92]. Bergman studied the effect of 3 cycles of mask purification treatment using steam generated by microwave oven (MGS, 2 minutes per cycle) and moist heat incubation (MHI, 15-30 minutes per cycle, 60°C, 80% RH) . It has been found that both MGS and MHI treatments can cause the internal foam nose pads of some FFRs to separate, and the headbands of FFR treated with MGS are also slightly melted by sparks in the microwave oven[93]. Recently, Liao et al. concluded after experiments that purifying masks by heating to below 85°C at various humidity levels seems to be a promising non-destructive method that can be used to maintain the filtration of melt-blown fabrics and N95 FFR Performance[94]. Masks processed at 85°C and 30% RH can be processed for 50 cycles without significant changes in filtration efficiency. The latest research conclusion of Ou et al. showed that the filtration efficiency and fitting coefficient of N95 FFR did not decrease significantly after 10 repeated cycles of 30-minute steam treatment and 30-minute drying heating at 77°C[95].

According to reports, the experimental data of Fisher et al. showed that the survival rate of MS2 phage (simulating SARS-Cov-2 virus) was reduced by more than 4 times when treated with MGS (steam generated by microwave oven) for only 45 seconds[96]. Fisher et al. further evaluated the feasibility of using microwave steam bags to purify FFR for MGS. The method has an efficiency of 99.9% to kill MS2 phage, and the filtration efficiency of post-processing FFR remains above 95%[97]. Similarly, Fischer et al. claimed that even after 2 treatment cycles, N95 FFR contaminated

[92] *D. J. Viscusi, M. S. Bergman, B. C. Eimer, and R. E. Shaffer, "Evaluation of five decontamination methods for filtering facepiece respirators," The Annals of Occupational Hygiene, vol. 53, no. 8, pp. 815–827, 2009.*
[93] *M. S. Bergman, D. J. Viscusi, A. J. Palmiero, J. B. Powell, and R. E. Shaffer, "Impact of three cycles of decontamination treatments on filtering facepiece respirator fit," Journal of the International Society for Respiratory Protection, vol. 28, pp. 48–59, 2011.*

[94] *L. Liao, W. Xiao, M. Zhao et al., "Can N95 respirators be reused after disinfection? How many times?" ACS Nano, vol. 14, no. 5, pp. 6348–6356, 2020.*

[95] *K. Jansen, "During the coronavirus pandemic, hospitals have taken unprecedented steps to disinfect N95 face masks," in Chemical and Engineering News (c&en), The American Chemical Society: Chemical and Engineering News, 2020.*

[96] *E. Fisher, S. Rengasamy, D. Viscusi, E. Vo, and R. Shaffer, "Development of a test system to apply virus-containing particles to filtering facepiece respirators for the evaluation of decontamination procedures," Applied and Environmental Microbiology, vol. 75, no. 6, pp. 1500–1507, 2009.*

[97] *E. M. Fisher, J. L. Williams, and R. E. Shaffer, "Evaluation of microwave steam bags for the decontamination of filtering facepiece respirators," PLoS One, vol. 6, no. 4, article e18585, 2011.*

by SARS-CoV-2 could be effectively sterilized by dry heating at 70°C, and the change in mask fit coefficient is negligible[98].

e.Disinfectant treatment and decontamination

People often use disinfectants during the epidemic, and many people think that they can directly use disinfectants to soak masks to achieve the purpose of disinfection and decontamination of masks. However, disposing of contaminated masks by immersing them in a disinfectant solution may not be the most preferred way to decontaminate masks. One reason is that it involves the post-processing and drying of masks, which not only takes a long time but also cannot guarantee the complete removal of residual disinfectant chemicals, which can produce unpleasant odors and cause health hazards. In addition, many common disinfectant solutions may damage the structural integrity of the mask, thereby affecting its filtering performance and the fit coefficient after treatment.

Early studies by Viscusi and Bergman et al. showed that disinfection under liquid $H_2O_2$ had not been found to affect the filtration performance of N95 FFR[99]. It is reported that FFR soaked in 3% $H_2O_2$ for 30 minutes will not produce significant visual changes, but those FFR soaked in 6% $H_2O_2$ will cause ink fading on the outside[100]. According to reports, three cycles of treatment in 6% $H_2O_2$ will also cause different degrees of oxidation of the assembled parts on FFR[101].

Bleaching powder is also a common disinfectant, but it is not recommended because of its strong smell. Experiments by Viscusi et al. showed that if different types of FFR are immersed in 0.525, 5.25% bleach solution, the average filter layer aerosol permeability is At the same time, the permeability of N95 FFR remains within the threshold of 5%. Although the airflow resistance of the N95 FFR filter was not affected much after being soaked in 6% bleach for 30 minutes, the odor problem

[98] *R. Fischer, D. H. Morris, N. van Doremalen et al., Assessment of N95 respirator decontamination and re-use for SARS-CoV-2, medRxiv, 2020.*
[99] *D. J. Viscusi, W. P. King, and R. E. Shaffer, "Effect of decontamination on the filtration efficiency of two filtering facepiece respirator models," Journal of the International Society for Respiratory Protection, vol. 24, pp. 93–107, 2007.*

[100] *D. J. Viscusi, W. P. King, and R. E. Shaffer, "Effect of decontamination on the filtration efficiency of two filtering facepiece respirator models," Journal of the International Society for Respiratory Protection, vol. 24, pp. 93–107, 2007.*

[101] *M. S. Bergman, D. J. Viscusi, B. K. Heimbuch, J. D. Wander, A. R. Sambol, and R. E. Shaffer, "Evaluation of multiple (3-cycle) decontamination processing for filtering facepiece respirators," Journal of Engineered Fibers and Fabrics, vol. 5, no. 4, article 155892501000500405, 2018.*

was too obviou[102]s. After the experimental mask was ventilated overnight, it was still obvious The pungent smell remained.

According to reports, ethanol is not suitable for the decontamination of masks. Smith et al. recently reported immersing contaminated masks in 70% ethanol. Although the SARS-CoV-2 viral RNA could not be detected, the function of the mask was impaired within 30 minutes[103]. Similarly, Fischer et al. also reported the rapid inactivation of SARS-CoV-2 by 70% ethanol treatment, but this resulted in the loss of the structural integrity of N95 FFR[104].

## 7.3 Comparative evaluation of disinfection and decontamination methods

In order to derive the actual impact of disinfection technology, a summary advantage, disadvantage, opportunity, and threat (SWOT) analysis is provided in the figure 28 below[105].

In summary, during the epidemic, FFP2/N95 masks are designed as single-use equipment, and when the supply is limited, at least two acceptable sterilization processes can be used to extend the life of the mask: (1) Hydrogen peroxide vapor ( Battelle) or (2) UV-C irradiation (surfactant). FFP2/N95 masks have been shown to withstand 50 and 30 sterilization cycles respectively. These systems may be available in hospitals or in daily life.

[102] *D. J. Viscusi, M. S. Bergman, B. C. Eimer, and R. E. Shaffer, "Evaluation of five decontamination methods for filtering facepiece respirators," The Annals of Occupational Hygiene, vol. 53, no. 8, pp. 815–827, 2009.*

[103] *J. S. Smith, H. Hanseler, J. Welle et al., Effect of various decontamination procedures on disposable N95 mask integrity and SARS-CoV-2 infectivity, medRxiv, 2020.*

[104] *R. Fischer, D. H. Morris, N. van Doremalen et al., Assessment of N95 respirator decontamination and re-use for SARS-CoV-2, medRxiv, 2020.*

[105] *Sadia Ilyas, Rajiv Ranjan Srivastava, Hyunjung Kim,20 December 2020 "Disinfection technology and strategies for COVID-19 hospital and bio-medical waste management"*

| Disinfection technology | Strengths | Opportunities | Weaknesses | Threats |
|---|---|---|---|---|
| Incineration technique | Simple operation,complete destruction of COVID-waste | -90% waste reduction | Energy-intensive, high Capex, the release of high toxins and solid residual waste | Release of secondary pollutants like dioxins, furans, and bottom ash |
| Pyrolysis technique | Complete destruction of toxins, like furan and dioxins | Energy-saving completely decomposes garbage volume | High investment cost and strict demand for heat value of waste | Not known and taken as a safe technology |
| Microwave technique | Low actions temperature, save energy, less pollutant, release without gaseous emission | The construction of mobile microwave treatment facilities is attractive for on-site waste treatment | Relative narrow spectrum of disinfection | Complex impact factors of disinfection |
| Chemical technique | Rapid and stable performance, broad sterilization spectrum | Application of disinfectant indoors/on-site may destroy virus spores, thus effectively controlling virus spraying | Does not reduce the volume and mess of BMW | Anthropogenic aerosols formed can penetrate alveoli upon inhalation, the absorbance of atomized disinfectant into skin cause cancer |
| Vaporized hydrogen technique | Heat sensitive low, temperature application | After complete disinfection, the protective items can be reprocessed and reused | Concentration reduces in the presence of cellulose materials | Atomized aerosolS due to fogging causes severe health damage to alveoli, skins, and mucosa |
| Dry Heat technique | Polymeric material compatibility with reprocessing possibility | Convenient operation can be disinfected at home, and no special machine is needed | Decontamination works through all the layers of trapped virus in the particles is unanswered | Decontamination of all layers of trapped virus in particles is questionable |

*fig.28 SWOT analysis for disinfection ways*

# Insight

# 8.Insight

- Psychological problems caused by home isolation due to the epidemic and long-term absence;

- People cannot filter the correct protection information;

- The demand for PPE has surged, and masks cannot be recycled as microplastics, resulting in increased environmental pressure.

# Design opportunities

# 9.Design opportunities

## 9.1 Data collection

- Customer journey map

Combining the three problems of insights, a customer journey map was created, assuming that people would normally go out during the epidemic, to analyze the problems that users may encounter during the outing process.

The first user is Vani(fig.29). It can be seen in her itinerary map that when she is out, she needs to prepare a lot of personal protective equipment. At the same time, she still uses the old mask when she returns because she feels that the mask is not dirty and because it is four times longer. After five hours of meeting, it has dried and can be used again. But the user experience is not very good. And she doesn’t know how to dispose of the discarded masks, so she can only throw them away with the garbage that cannot be sorted.

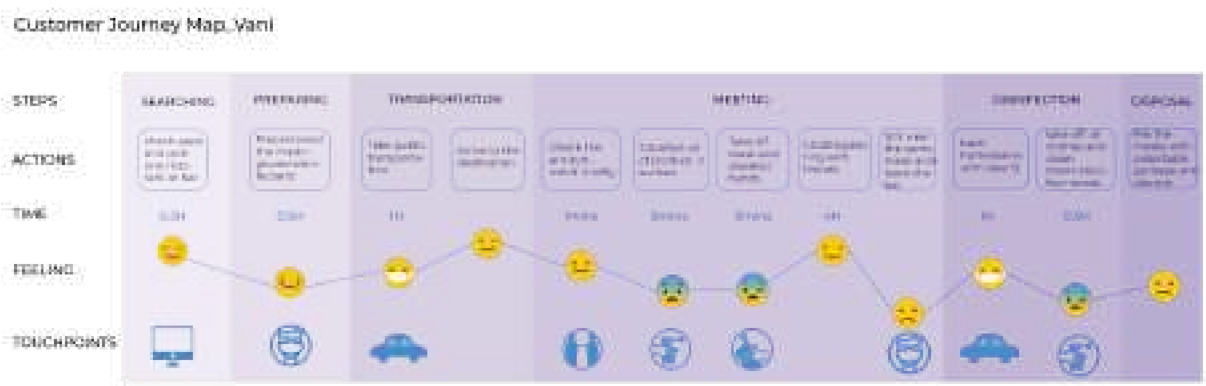



*fig.29 customer journey map_Vani*

The second sample user is Ray(fig.30). It can be seen from her road map that when she goes out, she has a very poor experience of preparing too much personal protective equipment and disinfection equipment. And the cumbersome disinfection process will make her feel bad. For the disposal of discarded masks, she will set up a trash can for masks, but when they are thrown into urban garbage recycling bins, she has no choice but to discard them in plastic sorting bins.


*fig.30 customer journey map_Ray*

- Interview

Interview on the sterilization procedures of medical equipment. The author entered the dentist's office on the street and observed for two hours, and found that the doctor treated about five patients within two hours. They are all disposable tools, and other non-disposable devices will be diluted and rinsed with 95% alcohol before use.

*-M: Why use alcohol to wipe?*
*D: Faster and more convenient. Generally speaking, 75% alcohol is sufficient. We buy and use 95% alcohol, so we need to dilute it ourselves.*
*-M: What disinfection technology is currently used in the dentistry department?*
*D: At present, the high temperature inactivation machine is used, no need to operate, just put it in and press the start button. Usually, after getting off work at night, we will put all the tools in to disinfect.(fig.31)*
*-M: Now that there is ultraviolet disinfection, why not use this technology?*
*D: In our opinion, of course, ultraviolet rays do. However, because dental clinics are special, all equipment needs to enter the patient population. We need to combine other disinfection techniques before we dare to use them. For example, after ultraviolet disinfection, high-temperature disinfection is required and then wiped with alcohol. In this way, it can be used by patients with confidence.*
*-M: How long is the general disinfection process?*
*D: It takes a whole night. Take the tools out of the disinfection cabinet before work the next day.*
*-M: How to deal with the medical waste after use?*
*D: We will put them into yellow plastic bags, which are specially used for medical waste. Then discard it in the garbage collection bin set up inside the city.*
*-M: Is it a garbage can for recycling medical waste in the city?*

*D: No, no recycling bins for medical waste have been found in the city. It can only be discarded in the hazardous garbage collection bin. But professional recycling personnel should recognize yellow plastic bags.*
*-M: Before discarding, will a simple disinfection process be carried out and then discarded?*
*D: Simply spray some alcohol. Because our clinic is not very large, if it is a public hospital, a large institution should conduct professional disinfection before disposing of garbage.*

*fig.31 interview picture for high-temperature inactivation machine*

- Questionnaire

There are a total of 135 people sampled in this questionnaire. Most of them are concentrated in China and Europe. The age group is divided into three levels: 20-30 years old; 30-50 years old; 50-60 years old. In the previous research section of this article, the data results of the research have been placed separately. Next is the analysis of the results of the questionnaire survey on the design part:

1.Regarding whether alternative forms of masks can be accepted

As shown in Fig.32,65.2% of the groups indicated that it is acceptable. They believe that as long as they achieve the same protection results, they can also reduce pollution and protect the environment, which is completely acceptable. However, 34.8% of the people are still unwilling to accept it. The main reasons include: they feel that the safety is not high and the replacement is very troublesome.

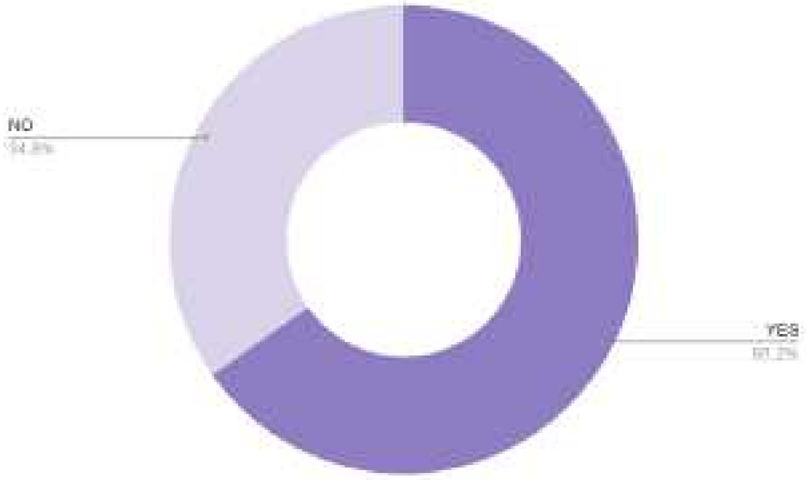



*fig.32 Acceptance of replacement filter masks*

2.Regarding the acceptance of mask disinfection machines

Similarly, the data in Figure 33 shows that 69.6% of the group indicated that it was acceptable, and most of this audience also indicated that they could accept replaceable masks. 30.4% said it was unacceptable.

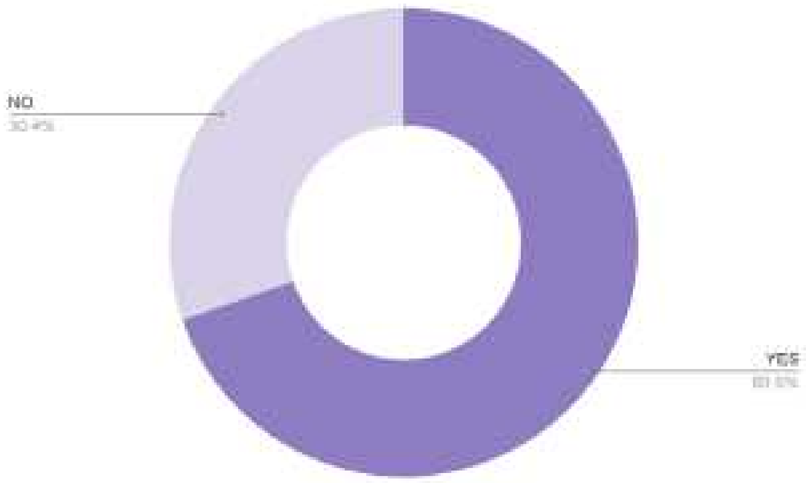



*fig.33 Acceptance of professional mask disinfection machines*

3.Opinion collection on the placement of disinfection machines

Because at the beginning, it was considered that the disinfection machine was integrated into the urban garbage recycling system, so that the mask filter element (degradable) that can no longer be disinfected can be directly recycled. However, the questionnaire data shows that 93 people want to be placed in the residential area, which is safer and more convenient, followed by 80 people who chose transportation stations, such as subway and bus stations. Only a few 37 people chose to place them next to the city's recycling bins. This is data that is very helpful in advancing the next design direction.

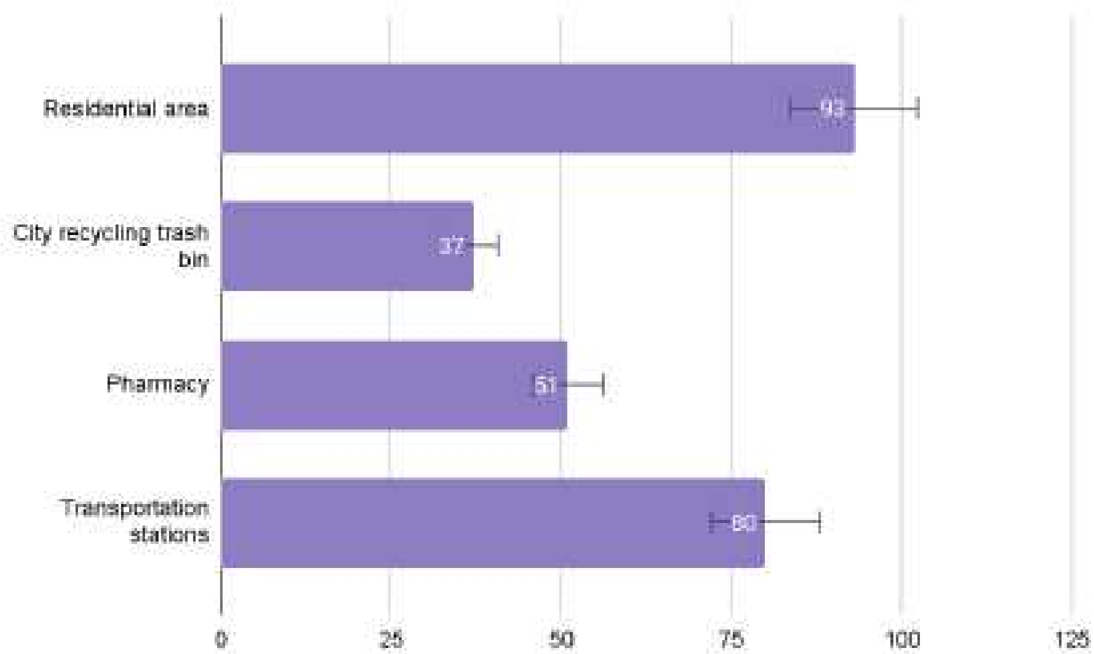



*fig.34 Willingness to place the disinfection machine*

## 9.2 key issues

Combine the problems found in the previous reading literature, as well as the data presented by customer journey map user experience analysis, interviews, and questionnaires. The three most important issues can be clearly seen:

- In the post-epidemic era, people still do not know enough about correct protection information.

- People don’t know what to do with masks after use

- The disinfection mechanism of medical waste in daily life cannot achieve unified and professional treatment

## 9.3 Case study

- LIGHTLOOP[106]

This case satisfies the desire to return to sports in complete safety. It can eliminate 99.99% of the virus particles. Even the Covid-19 virus can be eliminated in a short period of time, almost 60 seconds, through a sealed environment. Medium exposure to UV-C rays. When the machine is turned on again, the ball has been disinfected and can be used.(fig.35)


*fig.35 Lightloop*

[106] *LIGHTLOOP,http://lightoop.com/public/?fbclid=IwAR2N3isQyYSNJD6gkIdGhyT13SKe3927etgLQAzeD3MjYnyMoSUrM9MeDK0*

- Foldable UV lamp[107]

  This pocket-sized cleaner uses UV-C light (253 nm) to kill up to 99.9% of viruses, bacteria and bacteria in a few seconds. Has been on the market.

*fig.36 Foldable UV lamp*

[107] *Foldable UV lamp,,https://nordicgarner.com/products/2w-ultraviolet-uv-sterilizer-light-foldable-sterilization-lamp-ultraviolet-light-for-disinfect-bacterial-kill-mites-mites-lights*

- OmniGuard™ mask[108]

Moshi's OmniGuard™ masks are designed to protect users in all environments. Among them, the proprietary Nanohedron filter element can resist bacteria, pollen, dust, smoke, viruses, pollution, inhibit the growth of microorganisms, and achieve an excellent level of cleanliness and hygiene, and can even filter particles smaller than 75 nanometers. The main body of the mask can be washed and reused.

*fig.37 OmniGuard™ mask*

[108] *OmniGuard™ mask,https://www.moshi.com/cn/product/omniguard-mask-with-3-replaceable-nanohedron-filters/space-gray-m/*

# Project show

# 10.PROJECT

## 10.1 Scenario Building

In the post-epidemic era, people have been living with the virus for a year, and the basic protective measures have been understood: such as wearing masks and timely hand disinfection. Regarding the detailed protective measures, it is still not clear: how long is the use time of the mask? How long will it fail to protect yourself? How to deal with the mask after use; will it not lead to the second transmission of the virus?

Therefore, this design project was established based on the above questions as to its background.

## 10.2 Project introduction

### 10.2.1 Scheme description

It is mainly divided into two parts: product and system innovation.

The product refers to the innovation of masks. On the basis of the existing masks, the new material MOFfilter is used to improve the filtering performance of the mask; at the same time, the added value of the mask itself is increased. The use time of the mask is visualized by using the LBL wet-sensing plastic film to allow people to wear the mask. The color change can be seen to remind people to replace their existing masks. In addition, the NFC sensor chip is added. Every time a new filter element or mask is worn, the mobile phone is close to the part of the NFC chip, and the mask data can be transmitted to the mobile phone immediately, helping people to record the data and reminding people of the use time of the mask in real-time.

System innovation is a cyclic disinfection system established by considering the multiple use of masks under the premise of the chaos of the current recycling system. After disinfection, the mask can be used again to reduce the pressure on the current environment and achieve sustainable development. The disinfection machine will be placed inside the community or in the backyard of a residential building. When people are out of the day and enter a safe living environment, they can scan the code and get a family-specific mask disinfection cabinet. Remove the mask filter and put it inside the disinfection cabinet for ultraviolet disinfection and sterilization. When you go out the next day, you can enter the cabinet door number to take out the disinfected mask filter and use it again.

### 10.2.2 Business Model Canvas(fig.38)

On the basis of the clear plan, the analysis of the business model canvas was launched. Key partners in business activities include six: Medical device company as the company's carrier to sell masks and disinfection machines; Design sector is responsible for product design; Factory is responsible for manufacturing and production; suppliers provide basic materials, such as NFC, visible light cluster nano plastic film, etc.; R&D The department is responsible for the development of new materials; Government is the main R&D support and purchase group.

The main customer groups are government and users. Provide them with product sales, machine support, and subsequent maintenance services to maintain customer relationships. Products can be purchased through express delivery, online ordering, and telephone consultation.

The **core business activities** include:
1. Using LBL and MOS new materials and NFC information recognition technology to design and develop new types of masks can let customers more intuitively know the expiration date of the masks;
2. When the mask reaches the use time, replace the filter element MOF, and use the disinfection machine for disinfection and use it again;
3. When the number of times the replacement filter element has been used reaches the MAX value, discard it for recycling of professional medical waste.

The **value advantages** of these core activities are：
1. Visualize the use period of personal appliances (masks);
2. New technology synchronizes the use information of personal appliances (masks);

3. Guarantee the disinfection of personal appliances (masks) in the later period;
4. Realize a sustainable system for the reuse, recycling, and reduction of disposable masks;
5. Unified recycling of medical waste (personal appliance masks)

The required **Key resource** includes:
1.MOF-Sustainable metal structure polymer film
2.NFC information recognition sensor technology
3.Ultraviolet-ultraviolet disinfection technology
4.Photopatternable nano-layer polymer film

The possible **cost** consumption will arise from these links:
1. New material research and development expenses
2. Design cost (labor cost+prototype cost)
3. Production cost of disinfection machine
4. Disinfection machine maintenance service labor costs
5. Labor cost for medical waste recycling

At the same time, the possible **profits** can be obtained in the following ways:
1. The government supports R&D
2. Profitable sales of mask products
3. Profitable sales of replacement filter elements
4. Profitable sales of disinfection machines

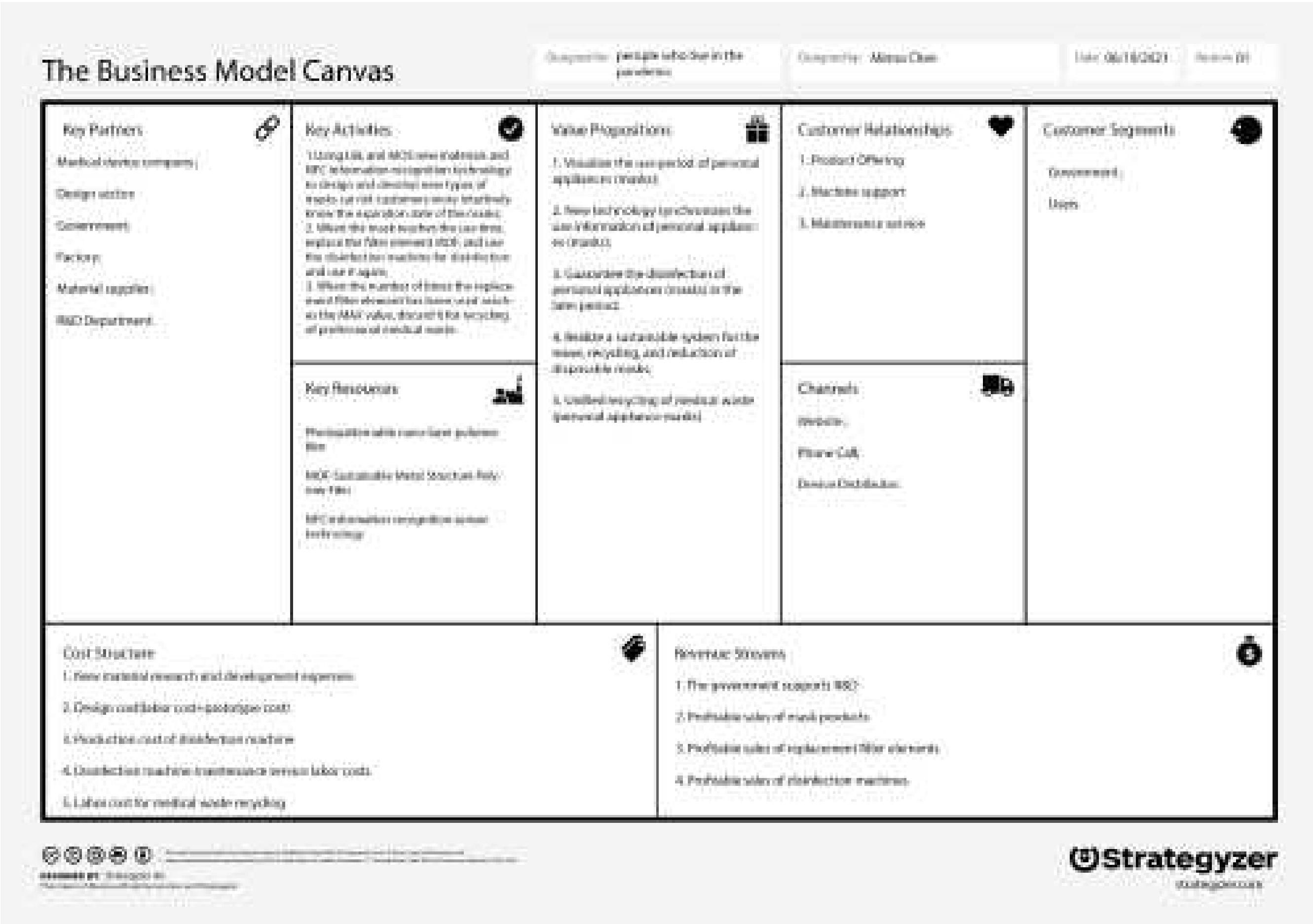



*fig.38 Business model canvas*

## 10.3 Materials and techniques used in the project

### 10.3.1 Research on MOF filter

Although the current masks on the market already have good performance, there is still the possibility of improvement in the sustainability of the material and better filtration. The criterion for masks is filterability on the one hand and breathability on the other. The innovation of masks can be discussed from two aspects: (i) improving the filtering capacity of mask materials and (ii) adding additional functions and features to the design of masks.[109]

New materials with antibacterial activity currently include five types: metal-based nanoparticles; common household chemicals; organic compounds; two-dimensional materials; combinations of multiple antibacterial categories.

There are three types of filters and membrane materials used to remove microorganisms: natural product extracts; metal nanoparticles and their compounds; metal-organic frameworks (MOF)(fig.39).

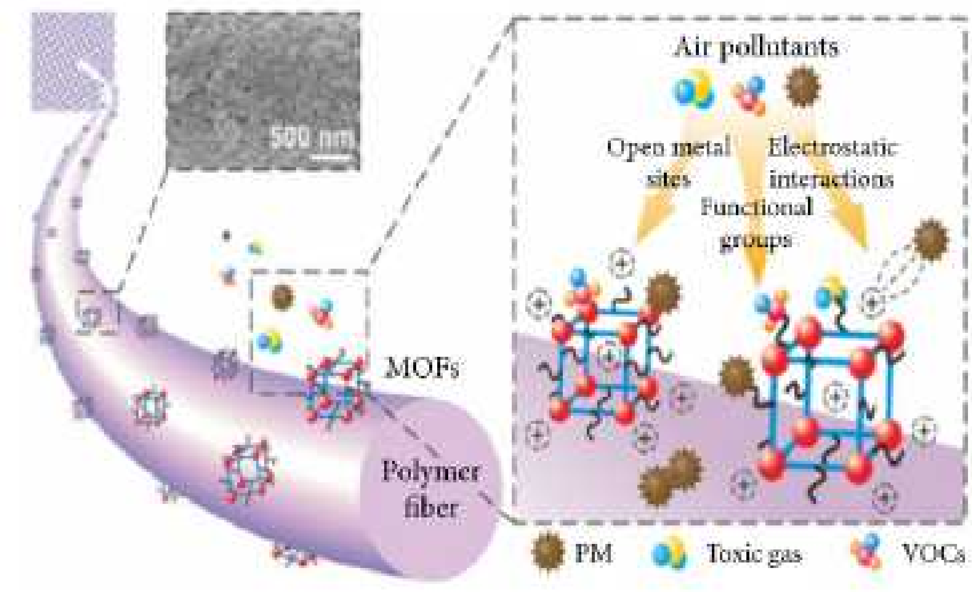



*fig.39 MOF structure diagram*[110]

[109] *Ming Hui Chua, Weiren Cheng, Shermin Simin Goh, Junhua Kong, Bing Li,Jason Y. C. Lim, Lu Mao, Suxi Wang,Kun Xue,Le Yang, Enyi Ye, Kangyi Zhang et al.07 Aug 2020,`Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives`*

[110] *Ming Hui Chua, Weiren Cheng, Shermin Simin Goh, Junhua Kong, Bing Li,Jason Y. C. Lim, Lu Mao, Suxi Wang,Kun Xue,Le Yang, Enyi Ye, Kangyi Zhang et al.07 Aug 2020,`Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives`*

Among them, MOF-based filters have significant advantages in improving the performance of air filters to capture particulates and remove microorganisms. MOFs are a class of porous crystalline materials, which are composed of transition metal cations and coordinately bonded multidentate organic linkers. It has broad prospects in the application as a filter material because it has high porosity, adjustable pore size, rich functions and good thermal stability. At the same time, as an emerging new antibacterial agent, it is superior to metal due to its high surface area, uniform distribution of active metal sites, and adjustable porous structure [111]. In recent years, with the antibacterial application of MOFs and their composites, the research on the antibacterial behavior of MOFs has made rapid progress[112]. The antibacterial mechanism of MOF is mainly attributed to the inherent biocidal properties of its metal ions, and it may also come from antibacterial organic ligands[113]. The produced MOF filter exhibits excellent particle capture performance in the operating temperature range of 80 to 300°C, maintaining >90% after 30 consecutive days. It can be easily cleaned with tap water and ethanol and reused 3 times without significant efficiency loss. Such a film can be realized by growing MOF in situ on the substrate 19 or mixing MOF with a polymer and then casting, electrospinning, or the like.

[111] *M. Shen, F. Forghani, X. Kong et al., "Antibacterial applications of metal–organic frameworks and their composites," Comprehensive Reviews in Food Science and Food Safety, vol. 19, no. 4, pp. 1397–1419, 2020.*

*N. Bhardwaj, S. K. Pandey, J. Mehta, S. K. Bhardwaj, K.-H. Kim, and A. Deep, "Bioactive nano-metal–organic frameworks as antimicrobials against Gram-positive and Gram-negative bacteria," Toxicology Research, vol. 7, no. 5, pp. 931–941, 2018.*

[112] *S. K. Springthorpe, C. M. Dundas, and B. K. Keitz, "Microbial reduction of metal-organic frameworks enables synergistic chromium removal," Nature Communications, vol. 10, no. 1, p. 5212, 2019.*

[113] *G. Wyszogrodzka, B. Marszałek, B. Gil, and P. Dorożyński, "Metal-organic frameworks: mechanisms of antibacterial action and potential applications," Drug Discovery Today, vol. 21, no. 6, pp. 1009–1018, 2016.*

*S. Ma, M. Zhang, J. Nie, B. Yang, S. Song, and P. Lu, "Multifunctional cellulose-based air filters with high loadings of metal–organic frameworks prepared by in situ growth method for gas adsorption and antibacterial applications," Cellulose, vol. 25, no. 10, pp. 5999–6010, 2018.*

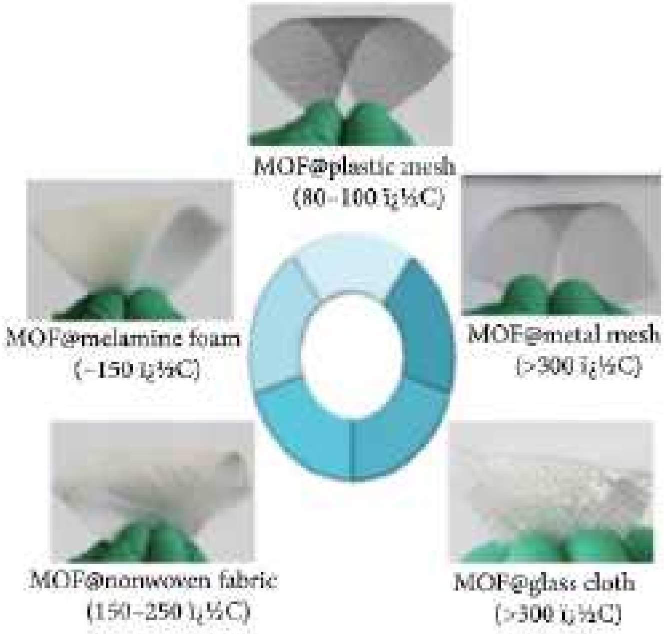



*fig.40 MOF model diagram*[114]

On the other hand, the photocatalysts in metal-based nanoparticles usually generate ROS through photocatalytic redox reactions to inactivate microorganisms[115]. The mask with surface titanium oxide (TiO 2 -) apatite layer on the outer layer of the non-woven fabric shows good filtering and photocatalytic activity[116]. After combining them, a recent study showed that metal-organic framework (MOF) can be used as a mask filter. The Zn-imidazole ester MOF filter showed a photocatalytic sterilization efficiency of >99.99% and a PM removal rate of 97% after 30 minutes. When combined with a 3-layer mask with a non-woven outer layer, all layers showed almost no measurable levels of viable bacteria after 30 minutes of simulated sunlight exposure[117]. Although photocatalyst

[114] *Ming Hui Chua, Weiren Cheng, Shermin Simin Goh, Junhua Kong, Bing Li,Jason Y. C. Lim, Lu Mao, Suxi Wang,Kun Xue,Le Yang, Enyi Ye, Kangyi Zhang et al.07 Aug 2020,`Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives`*

[115] *W. Wang, G. Huang, J. C. Yu, and P. K. Wong, "Advances in photocatalytic disinfection of bacteria: development of photocatalysts and mechanisms," Journal of Environmental Sciences (China), vol. 34, pp. 232–247, 2015.*

*J. Bogdan, J. Zarzyńska, and J. Pławińska-Czarnak, "Comparison of infectious agents susceptibility to photocatalytic effects of nanosized titanium and zinc oxides: a practical approach," Nanoscale Research Letters, vol. 10, pp. 309–323, 2011.*

*P. Ganguly, C. Byrne, A. Breen, and S. C. Pillai, "Antimicrobial activity of photocatalysts: fundamentals, mechanisms, kinetics and recent advances," Applied Catalysis B: Environmental, vol. 225, pp. 51–75, 2018.*
[116] *K. Takashi, K. Akira, and Y. Akihiko, "Infection prevention mask," Tech. Rep., US Patent 2005124777A, 2005.*

*W. X. Lee and M. Nu, "Functional protective mask," Tech. Rep., US Patent 201320356118, 2013.*

[117] *P. Li, J. Li, X. Feng et al., "Metal-organic frameworks with photocatalytic bactericidal activity for integrated air cleaning," Nature Communications, vol. 10, no. 1, p. 2177, 2019.*

impregnated masks have high antibacterial activity, it must be noted that they are only effective when sufficient light energy is applied.

### 10.3.2 Photo-patternable nano-layer polymer film

A new type of photo-patternable nano-layer polymer film, which can reversibly display and hide structural colors in the visible light range in response to changes in RH (Figure41). Specifically, two polysaccharides, chitosan (CHI) and photoreactive carboxymethyl cellulose-azide derivative (CMC-N 3) are used to build LbL films on silicon substrates. It has been proven that the structural color pattern on the film can be hidden under environmental conditions and displayed spontaneously through contact with the humid air of simple things such as human breathing. This humidity-triggered color change is fast, highly reversible, and compatible with most silicon-based devices. Moreover, it has low cost, good stability, can be used for large surface area, and has potential in anti-counterfeiting, humidity sensor, and optical color filter.[118]

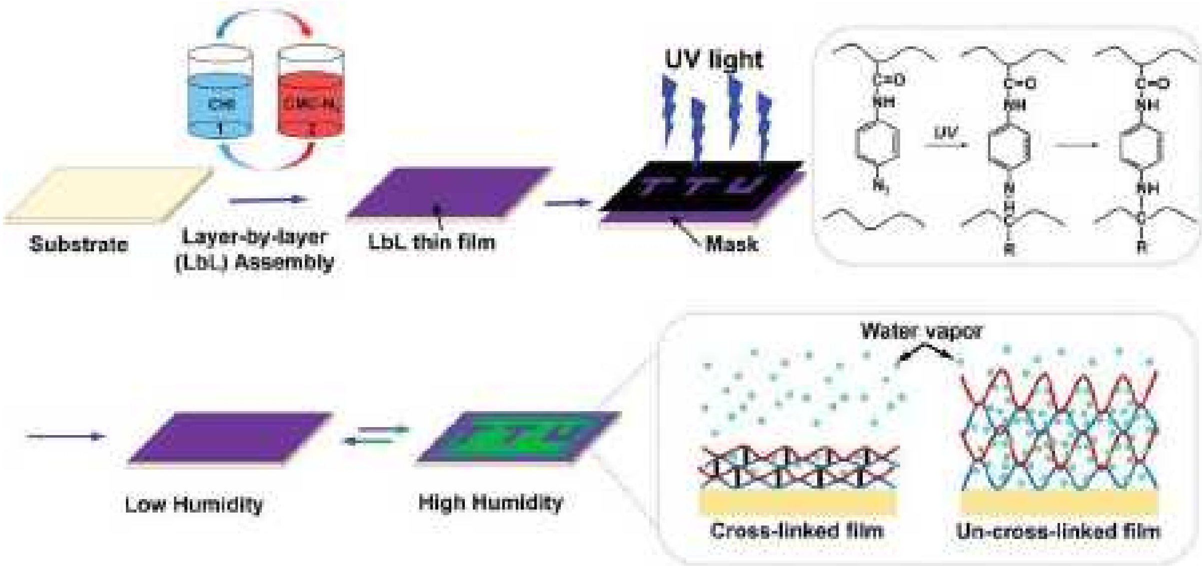



*fig.41 Internal chemical structure analysis diagram*[119]

This photo-patternable nano-layer polymer film can be assembled layer by layer (LbL). Layer by layer (LbL) assembly is a thin-film manufacturing technology. It is simple to operate, flexible in choosing building materials

[118] ,Ziye Dong, Nan Zhang, Yinggui Wang, Jiangyu Wu, Qiaoqiang Gan,14 August 2019,"Photopatternable Nanolayered Polymeric Films with Fast Tunable Color Responses Triggered by Humidity"

[119] ,Ziye Dong, Nan Zhang, Yinggui Wang, Jiangyu Wu, Qiaoqiang Gan,14 August 2019,"Photopatternable Nanolayered Polymeric Films with Fast Tunable Color Responses Triggered by Humidity"

and substrates, and can be precisely controlled. Grade film structure and thickness.[120]

As shown in the figure, when the relative humidity changes from 10% to 80%, the observed color difference is less obvious, and when the relative humidity increases above 80%, more obvious color changes are observed. When the relative humidity changes from 10% to 80%, the color changes slightly from blue to green/yellow. When the relative humidity increases to 95%, the color quickly changes from green/yellow to purple.(fig.42) At the same time, studies have shown that patterns can be drawn using ultraviolet light, and the patterns will disappear after the humidity subsides.(fig.43)[121]

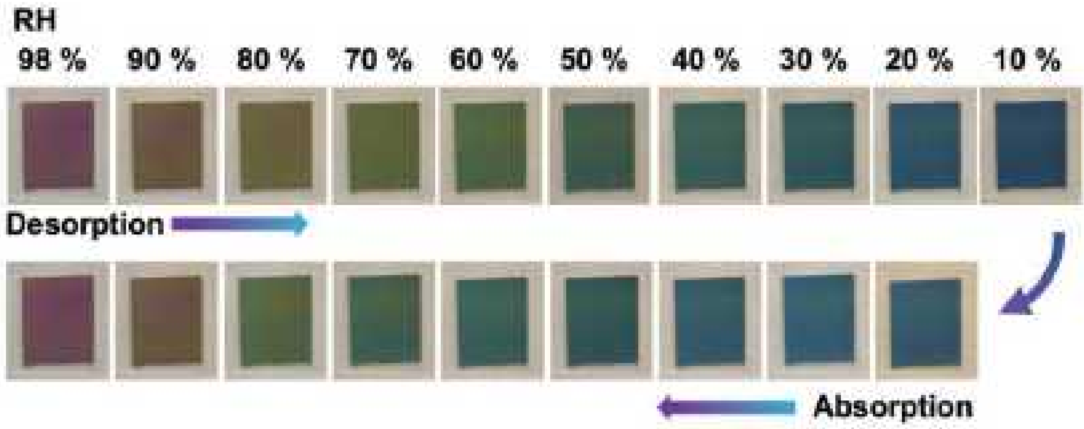



*fig.42 Color change process diagram[122]*

[120] ,Ziye Dong, Nan Zhang, Yinggui Wang, Jiangyu Wu, Qiaoqiang Gan,14 August 2019,"Photopatternable Nanolayered Polymeric Films with Fast Tunable Color Responses Triggered by Humidity"

[121] ,Ziye Dong, Nan Zhang, Yinggui Wang, Jiangyu Wu, Qiaoqiang Gan,14 August 2019,"Photopatternable Nanolayered Polymeric Films with Fast Tunable Color Responses Triggered by Humidity"

[122] ,Ziye Dong, Nan Zhang, Yinggui Wang, Jiangyu Wu, Qiaoqiang Gan,14 August 2019,"Photopatternable Nanolayered Polymeric Films with Fast Tunable Color Responses Triggered by Humidity"

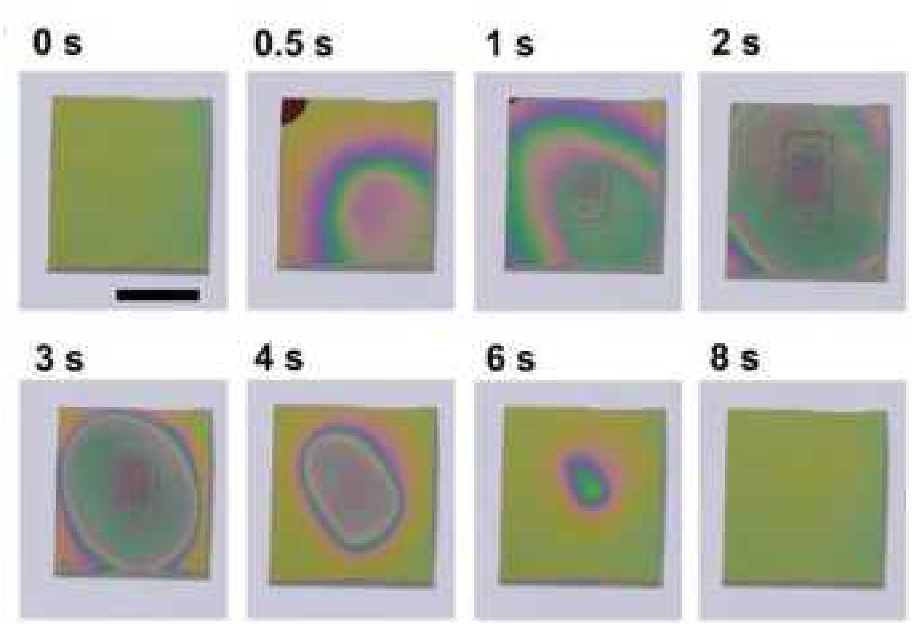



*fig.43 Pattern changes under ultraviolet light*[123]

## 10.3.3 NFC Information Recognition Technology

Near Field Communication (NFC) is a set of communication protocols used to communicate between two electronic devices within a distance of 4 cm (1 1⁄2 inches) or less[124].NFC provides low-speed connections. It is simple to set up and can be used to guide more powerful wireless connections[125].NFC devices are used in a wide range of fields.Usually used for non-contact interaction design. Provides a technology that can be used for short-distance non-contact data exchange. Two NFC-enabled devices are connected by point-to-point contact, at a distance of 0 to 2 cm, to exchange data (such as process data and maintenance and service information) between the devices. Passive data storage can be read by NFC devices and written in some cases. They usually contain data (between 96 and 8,192 bytes as of 2015) and are read-only in normal use (but can be rewritten) for secure personal data storage.[126]

[123] ,*Ziye Dong, Nan Zhang, Yinggui Wang, Jiangyu Wu, Qiaoqiang Gan,14 August 2019,"Photopatternable Nanolayered Polymeric Films with Fast Tunable Color Responses Triggered by Humidity"*

[124] *Cameron Faulkner. "What is NFC? Everything you need to know". Techradar.com. Retrieved 30 November 2015.*

[125] *"NFC as Technology Enabler". NFC Forum. Archived from the original on 22 December 2013. Retrieved 15 June 2011.*

[126] *Wikipedia, "Near-field communication"*

Based on existing radio frequency identification (RFID) standards, including ISO/IEC 14443 and FeliCia[127]This technology allows compatible hardware to use radio waves to power and communicate with unpowered passive electronic tags. This facilitates identification, verification and tracking.

At present, many communication companies have begun to use NFC technology for commercial activities. In Android 4.4, Google introduced platform support for NFC-based secure transactions through Host Card Emulation (HCE) for payment, loyalty programs, card access, bus cards and other customized services. On September 9, 2014, Apple announced support for NFC-driven transactions as part of Apple Pay[128].Including China Telecom (China's third largest mobile operator), Softcard, Vodafone, etc.

NFC technology provides the possibility for information transmission.

[127] *"Technical Specifications". NFC Forum. Archived from the original on 4 August 2012. Retrieved 11 December 2011.*

[128] *"Apple Pay". apple.com. Retrieved 9 September 2014.*

# 10.4 Concept Evaluation

## 10.4.1 Mask Innovation

- Moodboard


*fig.44 Moodboard*

- Mask sketches

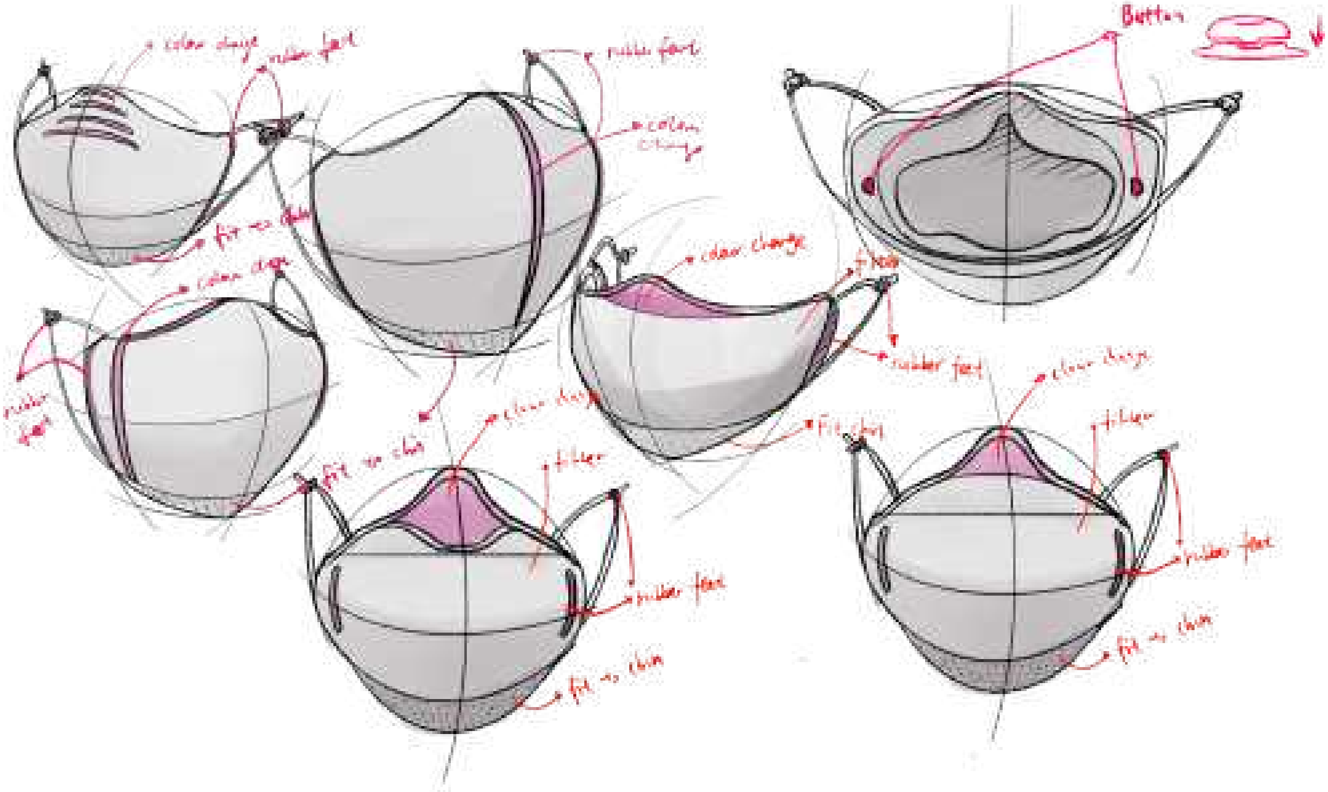



*fig.45 Rough sketch*

➢ The first sketch of the mask is a presentation of the result of divergent thinking. Mainly studied the position of the discolored part: where it is easier to be seen by the user; how the internal filter element better fits the user's face; in what way the rope can be more comfortable and convenient to adjust.

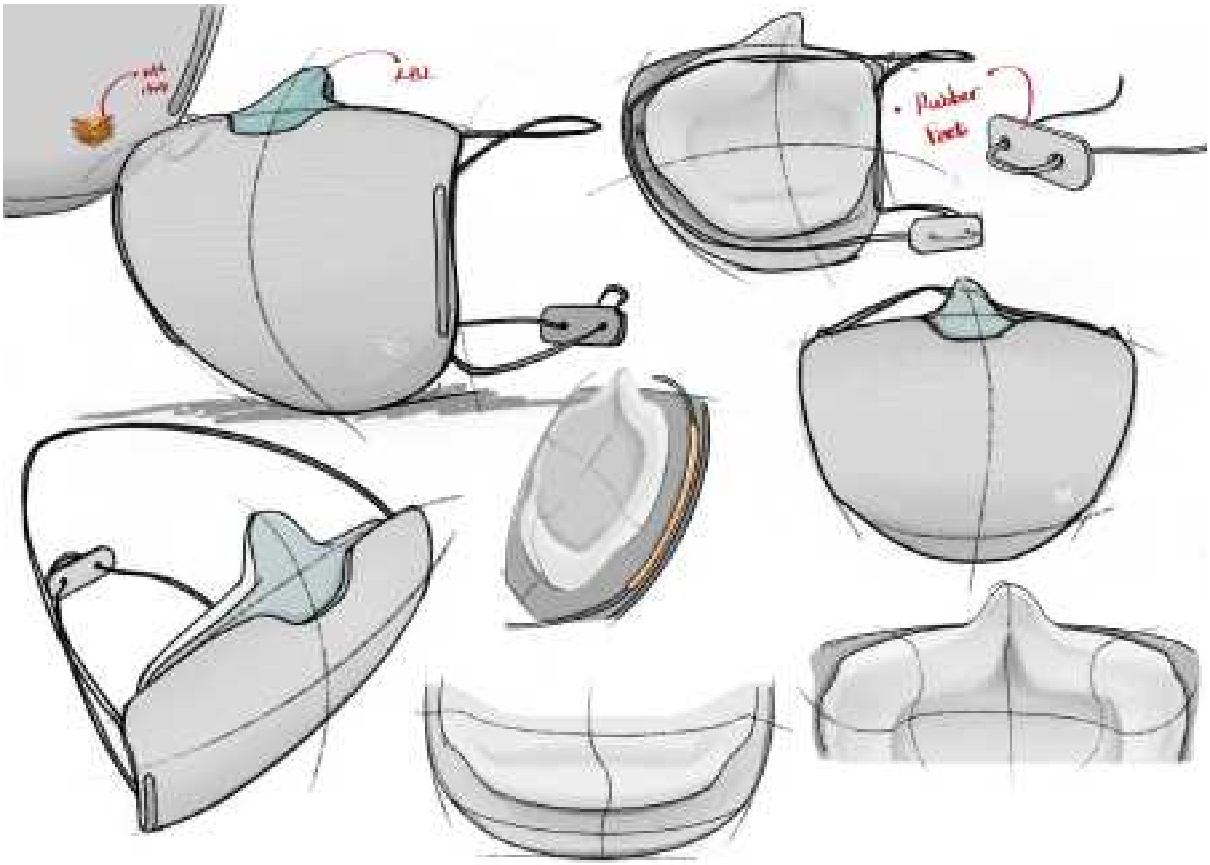
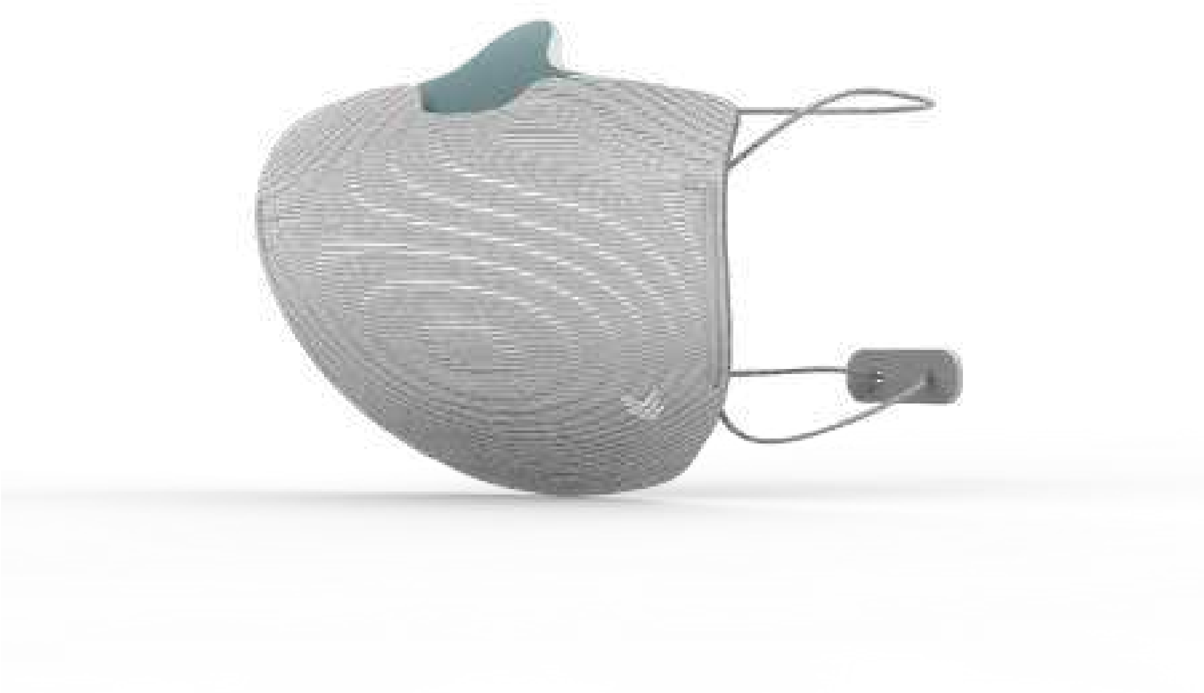


*fig.46 Final sketch*

- The second sketch is the result of deepening. After selecting the position of the discolored part, the structure of the rope, and the structure of the filter element, It studied and discussed the overall assembly method, in what form the filter element and the entire assembly are combined, and in what way the rope and the mask are combined. And on this basis, consider the aesthetics of the appearance design.

- Overview of the Mask



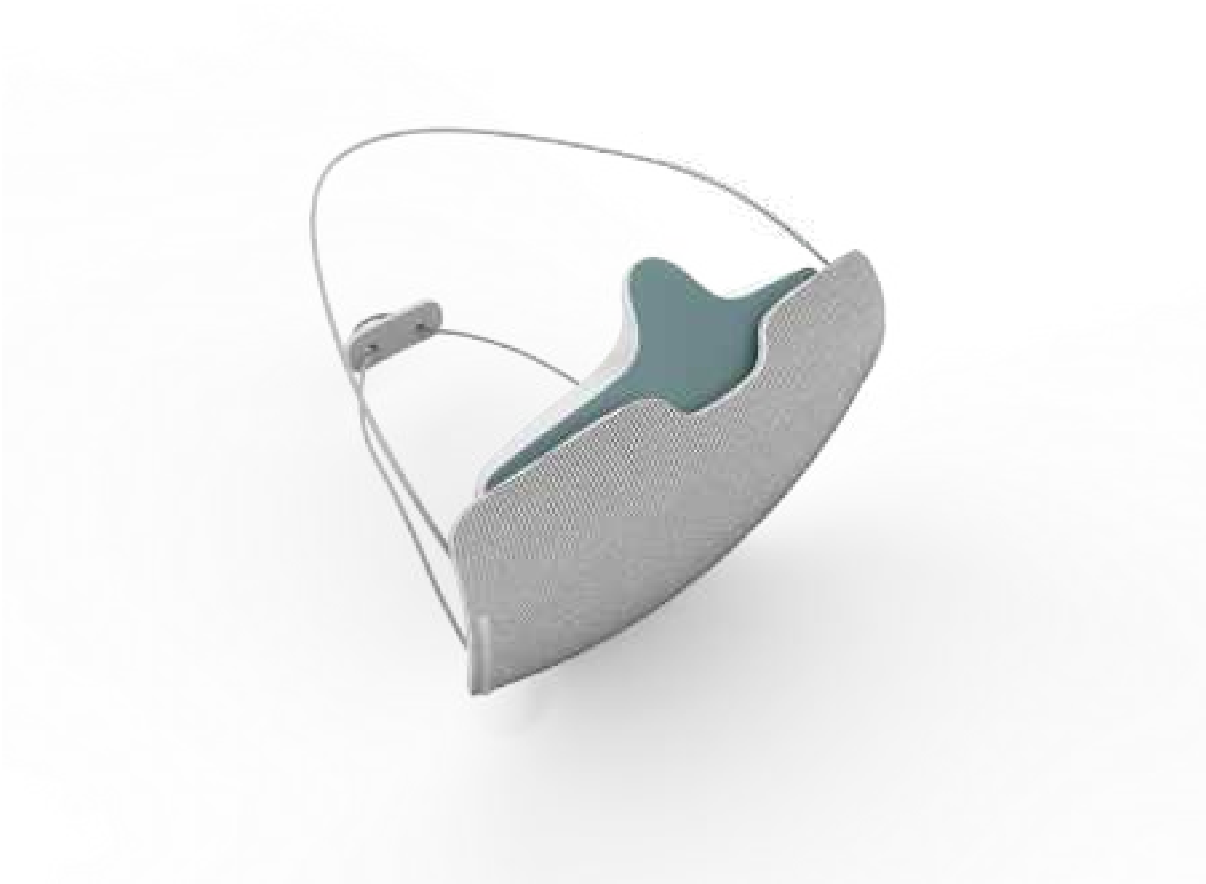


*fig.47 Overview of the mask*

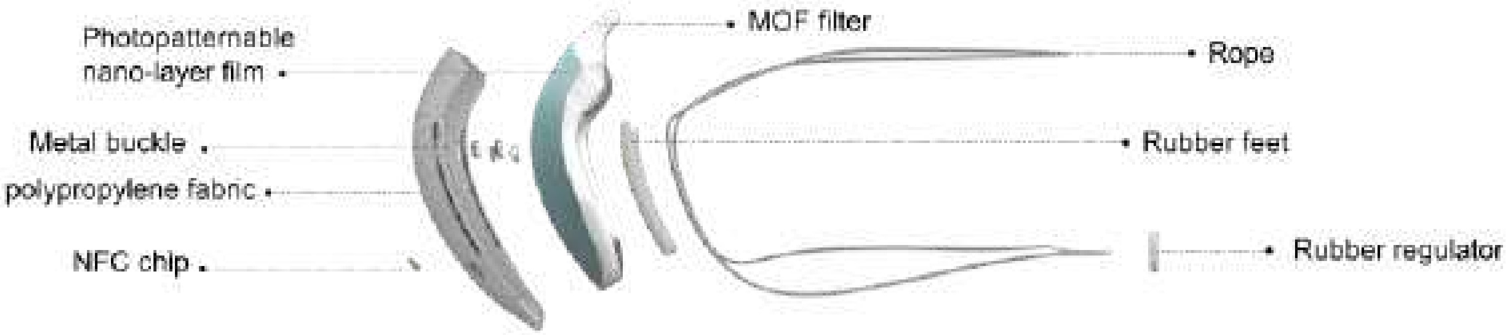



*fig.48 X-ray show of the mask and material introduction*

➢ Mask CMF research:

After determining all the design details, you need to consider the materials used in the mask, the production process, and the color matching.

The materials are mainly soft materials, with rubber as the details.

Three basic colors are mainly selected: black, white, and gray. Because there is already a color-changing plastic film, the color is not suitable for too much. The rubber part also chooses the tone and tone collocation to make the overall collocation more uniform.

For the icon part of NFC, consider using silk screen technology, which is easier to produce and more controllable in color.

*fig.49 Mask family show*

- Details description

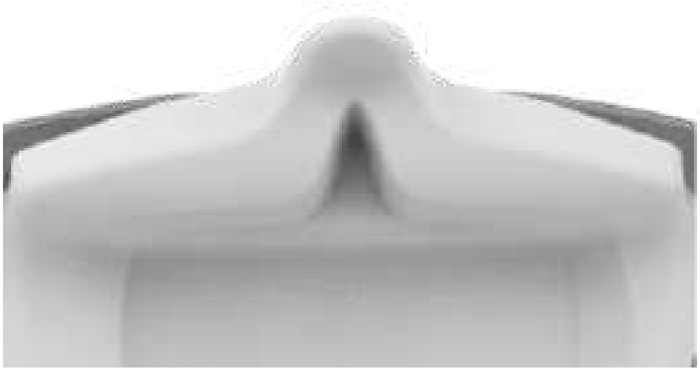


*fig.50 Details of the nose part*

*fig.51 Details of the mandibular part*

Facial anastomosis design

➢ Nose part

The design is more consistent with the human body structure of the nose, and the internal MOF metal frame support improves the fit of the face.

The discolored part is just shown in this part because after testing after people wear a mask, the only visible part is near the nose.

➢ Mandibular part

The design concept is the same as the nose part. After several tests, it is found that adding a wrap to the mouth part will better increase the sealing of the mask.

*fig.52 Detail of the rubber feet*

*fig.53 Detail of the NFC*

Rubber feet and NFC design

- Rubber feet

Under the guidance of the professor, achieve the purpose of function realization in the simplest way.

Using rubber as the material, while adjusting the length of the rope, the rope can be better fixed on the head of the person, which improves the comfort of the user.

- NFC design

ICON is used to remind people of the location of NFC and improve user experience.

The production process uses Silk Screen to better control the color.

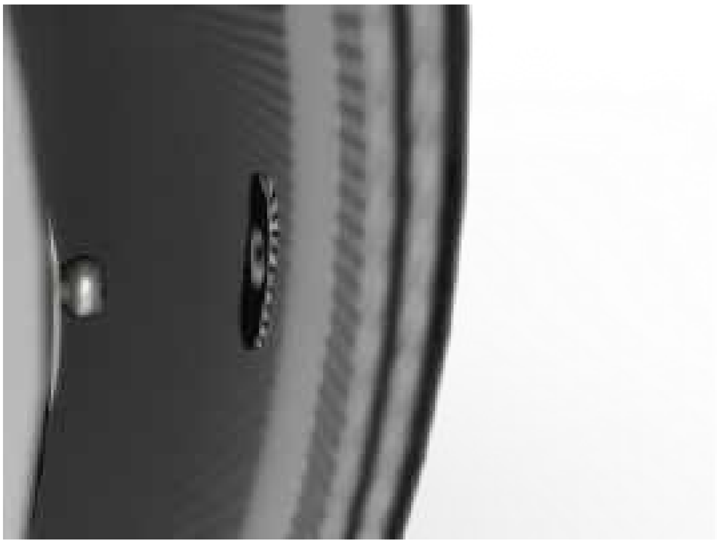


*fig.54 Detail of the metal buckle*

*fig.55 Detail of the rope combination*

Structural design of filter element replacement and rope combination

➢ Metal buckle

Taking into account the inconvenience of replacing the filter element of the mask before, the use of the buckle here makes the user's operation easier.

➢ Rope combination

The rope is designed to pass through the rubber strip, replacing the previous two ropes with one rope. This rope can be adjusted with a rubber foot pad to simplify the design as much as possible.

- Using scene graph

## 10.4.2 Disinfection machine innovation

- Moodboard

*fig.56 Moodboard of the disinfection machine*

- Machine sketches

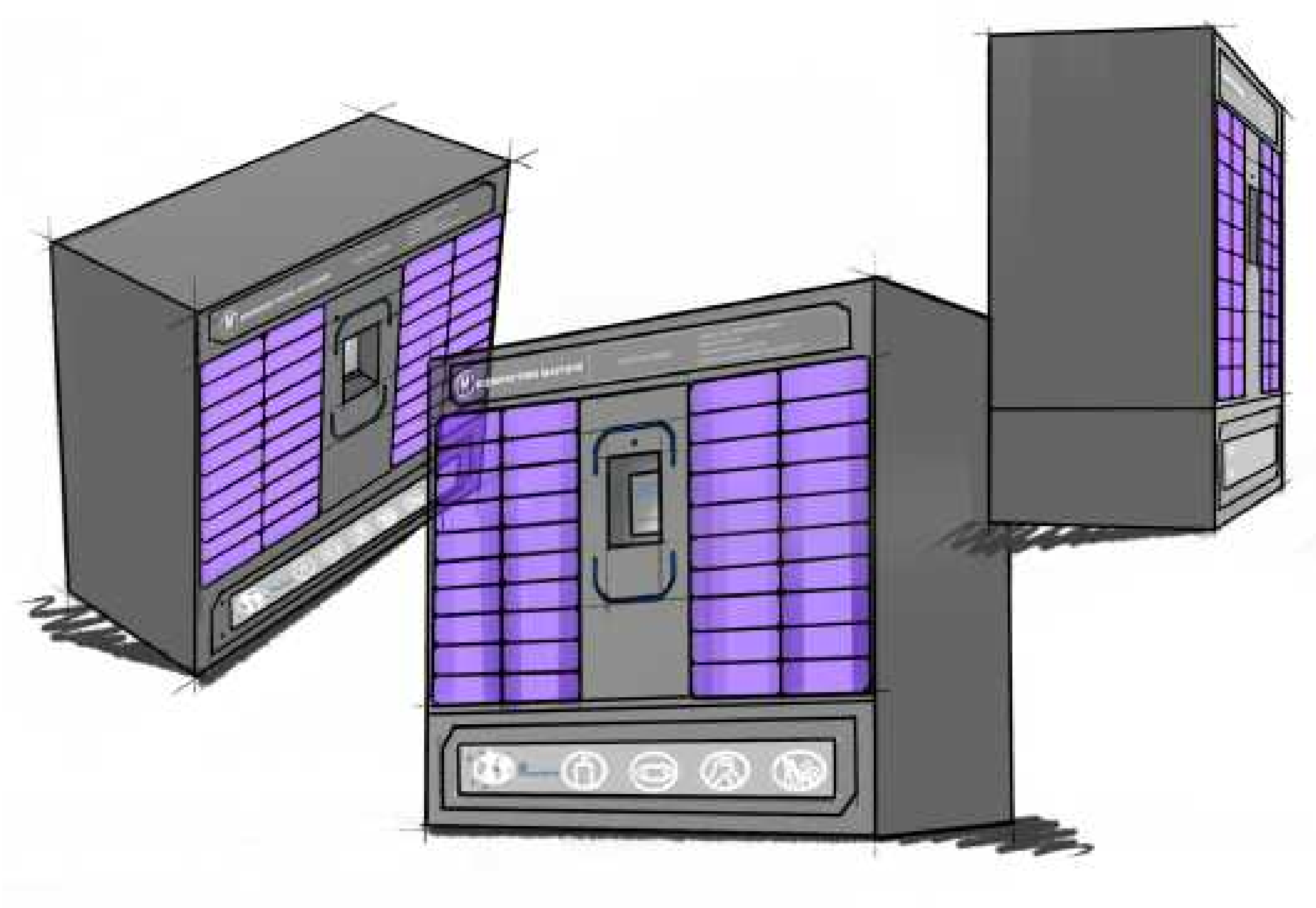


*fig.57 Sketches of the disinfection machine*

The initial draft stage considers a simple design, because the machine itself is a very complex item, and an overly complicated design will increase the user's difficulty in using it.

The main color is a black metal frame and a transparent cabinet door, and purple is the color of the internal uv light line. The transparent cabinet door allows users to see the disinfection process and increase their trust.

- Overview of the disinfection machine


*fig.58 Overview of the disinfection machine*

➢ Disinfection machine design

The machine will be placed in a residential area: such as the garden behind an Italian residential building.

Use UV disinfection technology to disinfect the mask.

Each family can obtain an exclusive disinfection cabinet by scanning the code verification. This will ensure that the possibility of cross-infection is avoided.

- Details description


*fig.59 detail of the LOGO part*

➢ LOGO design

The logo of the disinfection machine uses metal materials,
After anodizing, it is decorated with a CD pattern on its surface.

In the left part of the LOGO, the operation steps will be displayed to let customers know how to use the machine more clearly.

➢ Interactive page design

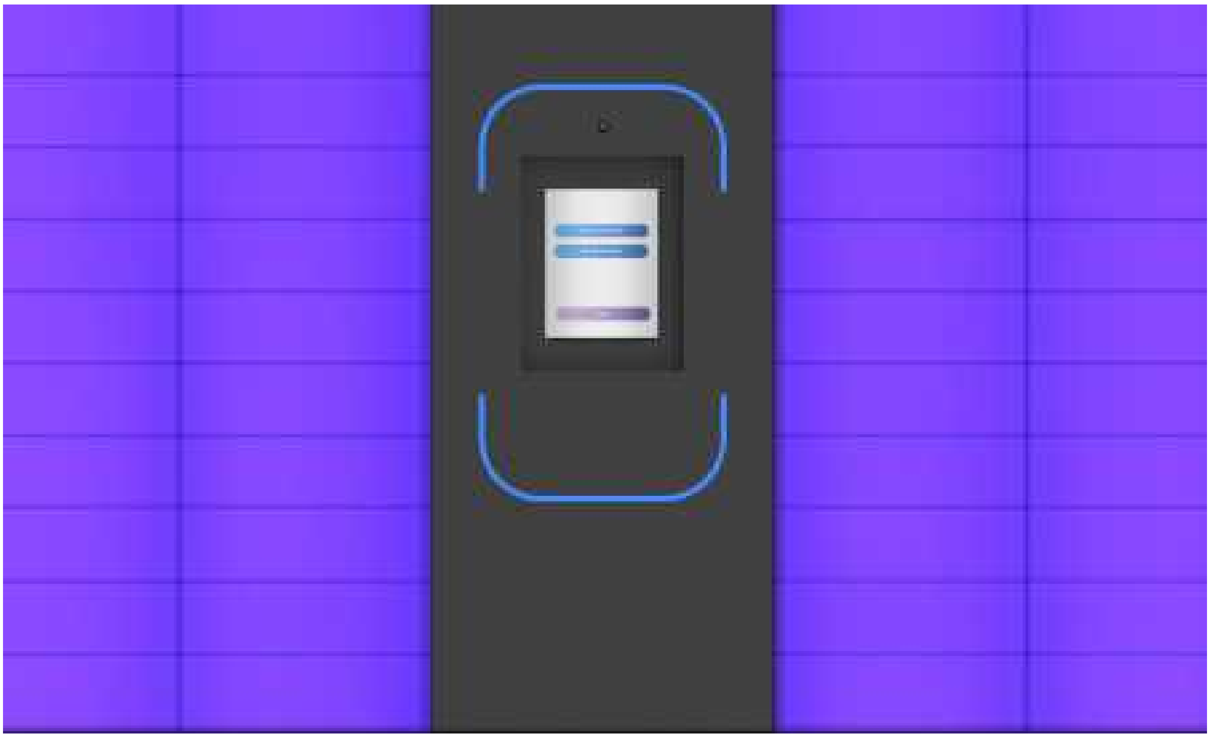


*fig.60 Details of the interaction design*

LED lights are added on the top and bottom of the screen for decoration. There will be a small camera above the screen to ensure that someone maliciously disrupts the disinfection process.

The main contents displayed on the screen page include: confirm disinfection (the cabinet door opens after scanning the code); take the detoxified mask (scan the code or enter the verification code)

➢ Bottom design


*fig.61 Detail of the control panel and post*

A poster of correct epidemic prevention measures will be pasted on the bottom of the machine. This can be replaced.

Secondly, a screw structure is designed at the bottom, which can be opened directly, which is convenient for maintenance personnel to perform maintenance directly from the front.

- Using scene graph

# 11.Conclusion

## 11.1 Discussion

The results of this study focused on solving the problem of users' access to information about the time of mask use and the problem of sustainability of masks.

In terms of long-term benefits, it reduces the pressure of medical waste on the environment, and secondly solves the problem of unified recycling of medical waste. Cater to the long-term strategy of sustainable development.

Compared with the existing replaceable masks, the new materials used have improved safety and protection to a certain extent. Secondly, they are recyclable materials and will reduce environmental pollution. And it simplifies the cumbersome use of the user, and replaces the filter element in the simplest way.

However, there are still shortcomings, such as the properties of new materials that need to be further confirmed; whether there is a more ingenious solution to the cost of disinfection technology, such as whether this disinfection machine can be used in another way after the epidemic, instead of being vacant in the community .

## 11.2 Conclusion

As mentioned in the previous discussion, the output of this research result focuses on visualizing epidemic prevention information (the use time of masks) and making medical waste more sustainable to reduce the pressure of environmental pollution. However, some imperfect parts, such as the research of new materials, are still in progress and the ownership of disinfection machines after the epidemic.

According to the results of questionnaire interviews in the literature, people generally do not know the exact time of mask replacement or how to dispose of discarded masks afterward (fig.). In this group of people, the concepts that have been produced are introduced and interviewed again with them. The positive feedback was received: It is generally believed that it will help them obtain the time to replace the mask.

Regarding the future, I hope that more research will be devoted to the sustainable development of medical waste, and more new materials and new technologies can be used. Help people build a better planet for the next generation.

## ACKNOWLEDGEMENTS

I sincerely thank my university---Politecnico di Milano. In the two years of study, I learned a lot of professional knowledge and got a lot of help.

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Mina

## References:

Tzung-Jeng Hwang,Kiran Rabheru,Carmelle Peisah,William Reichman,Manabu Ikeda26 May 2020,“Loneliness and social isolation during the COVID-19 pandemic” 18

Hwang, T., Rabheru, K., Peisah, C., Reichman, W., & Ikeda, M. (2020). Loneliness and social isolation during the COVID-19 pandemic. International Psychogeriatrics, 32(10) 20

Rasmus Kleis Nielsen, Richard Fletcher, Nic Newman, J. Scott Brennen, and Philip N. Howard , 15 APRIL 2020, Navigating the ‘Infodemic’: How People in Six Countries Access and Rate News and Information about Coronavirus 28

Butchi Raju Akondi,Ashok, Anushruti,Rai, Nagendra Kumar,30

Jul 2020,Consequences of chemical impact of disinfectants: safe preventive measures against COVID-19 30

Personal protective equipment. Geneva: World Health Organization; 2020 35

Grant, M. et al. (2020) ‘AO CMF International Task Force Recommendations on Best Practices for Maxillofacial Procedures During COVID-19 Pandemic’, Craniomaxillofacial Trauma & Reconstruction, 13(3), pp. 151–156. doi: 10.1177/1943387520948826. 36

Personal protective equipment. Geneva: World Health Organization; 2020 37

Alyssa Mertes,June 28th, 2021,What Are the Different Types of Face Masks & Which One is Recommended? 47

Butchi Raju Akondi,Ashok, Anushruti,Rai, Nagendra Kumar,30 Jul 2020,Consequences of chemical impact of disinfectants: safe preventive measures against COVID-19 35

J. S. Kutter, M. I. Spronken, P. L. Fraaij, R. A. M. Fouchier, and S. Herfst, “Transmission routes of respiratory viruses among humans,” Current Opinion in Virology, vol. 28, pp. 142–151, 2018. 37

L. Bourouiba, “Turbulent gas clouds and respiratory pathogen emissions: potential implications for reducing transmission of COVID-19,” JAMA, vol. 323, no. 18, pp. 1837-1838, 2020. 37

T. Dbouk and D. Drikakis, “On coughing and airborne droplet transmission to humans,” Physics of Fluids, vol. 32, no. 5, article 053310, 2020. 38

E. N. Perencevich, D. J. Diekema, and M. B. Edmond, “Moving personal protective equipment into the community,” JAMA, vol. 323, no. 22, pp. 2252-2253, 2020. 38

P. Anfinrud, V. Stadnitskiy, C. E. Bax, and A. Bax, “Visualizing speech-generated oral fluid droplets with laser light scattering,” New England Journal of Medicine, vol. 382, no. 21, pp. 2061–2063, 2020. 38

C. Y. H. Chao et al., Characterization of expiration air jets and droplet size distributions immediately at the mouth opening. Journal of aerosol science 40, 122–133 (2009). 38

Yafang Cheng, Nan Ma, Christian Witt, Steffen Rapp, Philipp Wild, Meinrat O. Andreae, Ulrich Pöschl, Hang Su, ”Distinct regimes of particle and virus abundance explain face mask efficacy for COVID-19”,doi: https://doi.org/10.1101/2020.09.10.20190348 38

N. H. L. Leung et al., Respiratory virus shedding in exhaled breath and efficacy of face masks. Nature Medicine 26, 676–680 (2020). 39

K. A. Callow, H. F. Parry, M. Sergeant, D. A. J. Tyrrell, The time course of the immune response to experimental coronavirus infection of man. Epidemiology and Infection 105, 435–446 (1990). 40

M. Imai et al., Syrian hamsters as a small animal model for SARS-CoV-2 infection and countermeasure development. Proc. Natl. Acad. Sci. 117, 16587–16595 (2020). 40

P. Y. Chia et al., Detection of air and surface contamination by SARS-CoV-2 in hospital rooms of infected patients. Nat. Commun. 11, 2800 (2020). 40

J. L. Santarpia et al., Aerosol and Surface Transmission Potential of SARS-CoV-2. medRxiv, 2020.2003.2023.20039446 (2020). 40

J. A. Lednicky et al., Collection of SARS-CoV-2 Virus from the Air of a Clinic within a University Student Health Care Center and Analyses of the Viral Genomic Sequence. Aerosol and Air Quality Research 20, 1167–1171 (2020). 42

Yafang Cheng, Nan Ma, Christian Witt, Steffen Rapp, Philipp Wild, Meinrat O. Andreae, Ulrich Pöschl, Hang Su, ”Distinct regimes of particle and virus abundance explain face mask efficacy for COVID-19”,doi: https://doi.org/10.1101/2020.09.10.20190348 44

Adams J (@Surgeon_General). August 30, 2020.”Seriously people- STOP BUYING MASKS! They are NOT effective in preventing general public from catching #Coronavirus, but if healthcare providers can’t get them to care for sick patients, it puts them and our communities at risk!” 44

Adams J (@Surgeon_General). In light of new evidence, @CDCgov recommends wearing cloth face coverings in public settings where other social distancing measures are difficult to maintain (grocery stores, pharmacies, etc) especially in areas of significant community-based transmission. Tweet. April 2020. 44

Gudbjartsson DF, Helgason A, Jonsson H, et al. Spread of SARS-CoV-2 in the Icelandic Population. N Engl J Med 2020. 44

C. Y. H. Chao et al., Characterization of expiration air jets and droplet size distributions immediately at the mouth opening. Journal of aerosol science 40, 122–133 (2009). 44

Wang X, Ferro EG, Zhou G, Hashimoto D, Bhatt DL. Association Between Universal Masking in a Health Care System and SARS-CoV-2 Positivity Among Health Care Workers. JAMA. 2020;324(7):703. 44

Klompas M, Morris CA, Sinclair J, Pearson M, Shenoy ES. Universal masking in hospitals in the COVID-19 era. N Engl J Med 2020;382(21):e63. 46