

Masks and Respirators to prevent SARS CoV-2 transmission: types, protection, when to use, and spotting the fake

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INTRODUCTION:

Barring the availability of a vaccine or a definite treatment, the use of personal protective equipment (PPEs) is the best form of defense against the ongoing COVID-19 pandemic. PPE, defined as 'equipment worn to minimize exposure to hazards that cause serious workplace injuries and illnesses, includes masks and respirators, goggles, face-shield, gloves, coverall/gowns (with or without aprons), headcover and shoe cover. Not only can wearing a mask reduces the risk of transmission, but it can also lower the spread when a sick person wears it'. WHO-backed study suggests that face masks may reduce COVID-19 spread by 85%. The risk of transmission of infection was 3% with a mask compared with 17% without a mask. Without eye protection, the chance of infection was 16%, and with protection around 6%.²

This review is intended to inform the readers about the different types of masks available, who should wear them, which masks to wear, and the latest information that is available on the role of masks in preventing the spread of COVID-19.

Masks Vs Respirators

Masks: Masks are loose-fitting, flat, or pleated, covering the nose and mouth these are designed to prevent large particles expelled by the wearer, such as spit or mucous, from entering the environment. If the wearer coughs or sneezes, the mask will help collect the larger particles expelled. Contrary to the myth, masks do not protect the wearer³. The vast majority of masks do not have a safety

rating assigned to them (e.g. NIOSH or EN)

Filtering Facepiece Respirators (FFR), or Respirators:

Respirators are tight-fitting masks, designed to create a facial seal. Respirators provide protection both during inspiration and expiration. These are designed to protect the wearer (when worn properly), from the safety rating of the mask.⁴ These have the word NIOSH / EN / ISI etc and the approval type (i.e. N95; FFP1 etc.) printed on the product.

Valve Vs Non-Valve Respirators

Valved respirators make it quicker and easier to exhale air compared to non-valved respirators, so maybe more comfortable to wear. Also moisture content is less tends inside the respirator. However, they can also let particles out from the wearer into the air without filtering and has the potential of taking coronavirus droplets with them, putting others nearby at the risk of contracting the infection.^{5,6} Recently Ministry of Health and family welfare has warned against the use of valved respirators as their use is detrimental to measures adopted for preventing the spread of coronavirus⁷.

Types of Masks and Respirators

Masks are of different types. The type of mask required depends on the risk profile as well as professional

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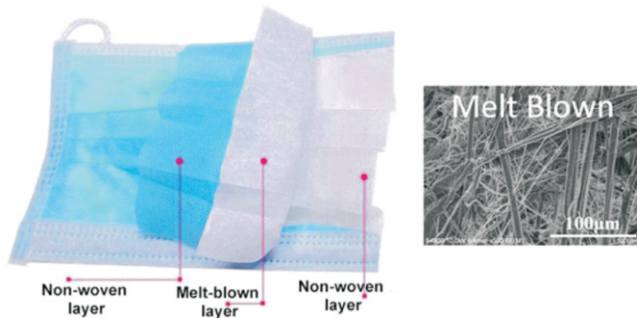
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requirements. There are two types of masks recommended for various categories depending upon the risk levels and work environment: 1. Triple-layer medical mask 2. Filtering Facepiece Respirator mask. They have different functions, standards, and objectives.

Medical Masks (Surgical Masks)

Medical masks also called surgical masks are generally speaking a 3-ply (three-layer) design, with 2 sheets of “non-woven” fabric sandwiching a “melt-blown” layer in the middle. (Fig 1) It is the melt-blown layer that provides filtering capability.⁸ The innermost layer is made up of an absorbent material that absorbs moisture from the wearer's breath. The outer layer is made up of material that repels liquid.⁹

Fig. 1: Three layers of surgical mask



Source: *mdpi.com*

The melt-blown layer is made of plastic, which is first melted and then blown from either side onto a rotating barrel, this process results in a fabric composed of tiny filaments.

The surgical mask does not offer a tight fit and there is enough space for the air to leak from all the sides of the mask. It was therefore never designed for self-protection.³ Surgical masks should be used only once and then appropriately disposed of. They should never be washed and reused. the surgical mask should not be used for more than 3 to 8 hours depending on humidity, ambient temperature, and minute ventilation. Wearing face shields over face masks can prolong mask life. Face shields can be easily washed and disinfected.

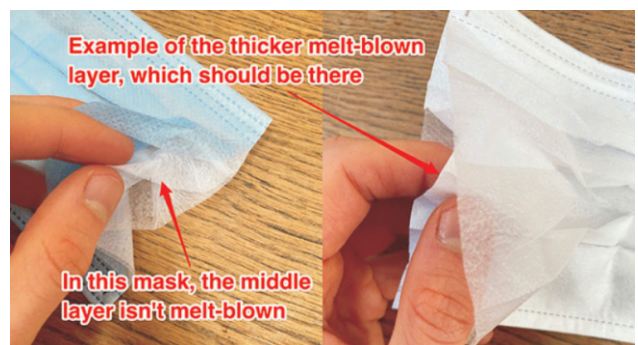
Their performance characteristics are tested according to a set of standardized test methods that aim to balance high filtration, adequate breathability, and optionally, fluid penetration resistance.^{10,11} They must meet the regional

standards of the country

Fake surgical masks: Fake surgical masks are flooding the market all over the world and it is important to ensure that one is not wearing one. They use similar logos, emblems, and registration numbers and seem to appear like the real product

but they do not offer protection compared to the original masks. To recognize fake surgical masks, cut open the mask and check the middle layer. It should be of the melt-blown plastic layer. (Fig 2)

Fig 2: Checking middle layer of surgical mask



Source: *mdpi.com*

Respirator Masks: A respirator mask is a tight-fitting mask. It has two specific characteristics, viz: (1) an air filtering system that prevents the passage of noxious substances and microorganisms from entering inside the respiratory tract, and (2) a tight fit, so that air does not leak from the sides into the nose and mouth. The filter of the respirator mask is made up of millions of microfibers of polypropylene layered on top of each other that have been permanently electrostatically charged. The electrical charge is necessary to retain its ability to filter microorganisms or microparticles. They offer a balance of filtration and breathability; however, whereas medical masks filter 3-micrometer droplets, respirators must filter more challenging 0.075 micrometer solid particles.¹²

The layers of the filtration material and the respirator shape, ensuring the outer edges of the respirator seal around the wearer's face, resulting in a guaranteed claimed filtration.

Types of respirators

American Standard Approved Respirators:¹³

American standard respirators are managed by NIOSH (National Institute for Occupational Safety and Health) standards. Within this standard, there are several classes of

respirators depending on the degree of oil resistance:

- Class N: No oil resistance. In the N series, the available respirators are N95, N99 and N100. The number after the letter indicates the percentage of filtration of suspended particles.
- Class R: Resistant to oil for up to eight hours. Here again, a distinction is made between R95, R99, and R100.
- Class P: Oil-proof. A completely oil-resistant mask. There are also P95, P99, and P100 respirators.

The most commonly discussed respirator type is N95 which is recommended for covid-19 protection for health care workers.

Fake N95 masks: Counterfeit respirators are products that are falsely marketed and sold as being NIOSH-approved and may not be capable of providing appropriate respiratory protection to workers.

NIOSH-approved respirators have an approval label on or within the packaging of the respirator (i.e. on the box itself and/or within the users' instructions). Additionally, an abbreviated approval number is on the FFR itself. The approval number can be verified on the NIOSH Certified Equipment List (CEL) or the NIOSH Trusted-Source page to determine if the respirator has been approved by NIOSH. NIOSH-approved FFRs will always have one of the following designations: N95, N99, N100, R95, R99, R100, P95, P99, and P100. The markings which should be on genuine N95 masks are shown in figure 3.

Fig 3: Markings on N95 mask



Source: bohs.org/wp

Signs that a respirator may be counterfeit:

- No markings at all on the filtering facepiece respirator

- No approval (TC) number on filtering facepiece respirator or headband
- No NIOSH markings
- NIOSH spelled incorrectly
- Presence of decorative fabric or other decorative additions
- Claims for approval for children (NIOSH does not approve any type of respiratory protection for children)
- Filtering facepiece respirator has ear loops instead of headbands

European Standard Approved Respirators:¹⁴ In Europe, respirator masks must meet the European standard EN 149: 2001 which has three classes of respirators (FFP1, FFP2, and FFP3).

- **FFP1:** These masks have an aerosol filtration of at least 80% and leakage to the inside of a maximum of 22%.
- **FFP2:** These masks have a minimum of 94% filtration percentage and a maximum of 8% leakage to the inside. They are currently used for protection against the coronavirus.
- **FFP3:** These masks have a minimum filtration percentage of 99% and a maximum of 2% leakage.

Another European standard EN 143 standard covers P1/P2/P3 ratings.

Both standards are maintained by CEN (European Committee for Standardization).

Fake FFP masks: Fake masks are unlikely to provide the protection expected or required.

Spotting a Fake Understanding FFP Markings

European Standard EN149 requires an FFP to have the following markings: (Fig 4)

European Standard number

Manufacturer name or logo

Manufacturer model number

Filtering facepiece class 'NR' Not re-usable, Single shift use or 'R' - Re-usable

European certification mark CE Notified Body responsible for the product certification

Fig 4: Markings on facepiece of FFP masks



Source: bohs.org/wp

Table 1: Efficacy of N class and FFP class respirator masks

Mask Class	N95	N99	N100	FPP1	FPP2	FPP3
% of $\geq 0.3 \mu\text{m}$ particles filtered	At least 95%	At least 99%	At least 99.97%	At least 80%	At least 94%	At least 99.95%
Breathing resistance	+	++	+++	+	+	++ to +++
Internal leakage rate Permitted	—	—	—	22	8	2
Suitable for COVID-19	Yes	Yes	Yes	No	Yes	Yes

WHO recommends N95 or FFP 2 masks or equivalent for coronavirus. The above table shows the differences in the efficacy of different respirators.

Chinese standard respirators: The Chinese standard filter elements are divided into two elements KN and KP. Category KN is suitable for filtering non-oily particles and KP is suitable for filtering oily particles. The KN95 standard has an equivalent specification to N95/FFP2 respirators.

Grades of filter elements

KN90, KN95 and KN100

KP90, KP95 and KP100

Markings: The KN95 specification is referred to as **GB 2626-2006 (replaced by GB 2626-2019 from July 1, 2020.)** written on the KN95 respirators. The filter element is marked with grades; the grades are marked with a combination of the number of this standard and the type and the grade of filter elements eg GB 2626-2019 KN95.

Spotting a Fake Understanding Markingson KN95 masks

Chinese Standard GB2626-2006 requires a KN95 to have the following markings: (Fig 5)

Manufacturer name or logo

Manufacturer model number

Filtering facepiece class KN95

Chinese Standard GB2626-2006



Source: bohs.org/wp

Indian Standard Respirators:^[15] In India Ministry of Health and Family Welfare approved ISI marked masks, manufactured under a valid license from the Bureau of Indian Standard (BIS). Mask manufacturers are required to get their product certified by BIS in line with the advice of the Ministry of Health and Family Welfare as per the following standards:

N95 masks (half filtering masks) as per IS 9473

Surgical Masks as per IS 16289

FFP2 masks-BIS certify FFP2 masks also that meet IS: 9473 standards which are broadly equivalent to NIOSH's N95.

Packing and marking are done as per the requirements of IS 9473:2002.

Spotting the fake ISI marked respirators

The following shall be marked on each half filter mask or its container: (Fig 6a&b)

ISI mark

Manufacturer name or logo

Manufacturer model number

Filtering facepiece class N95 or FFP

Standard IS 9473

BIS Licence No, CM/L

Certification details can be checked on the BIS website www.bis.gov.in

Fig 6a: Indian standard FFP 2 mask

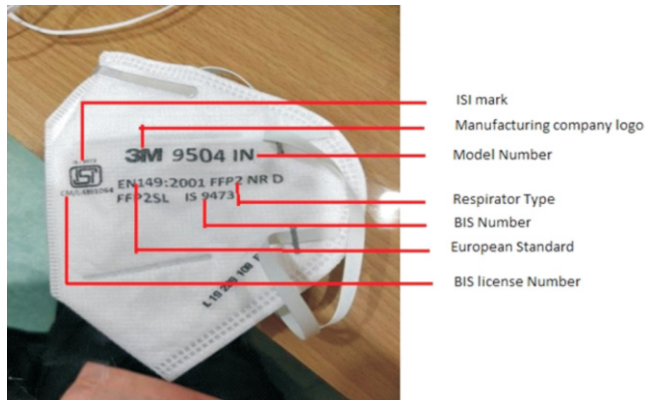
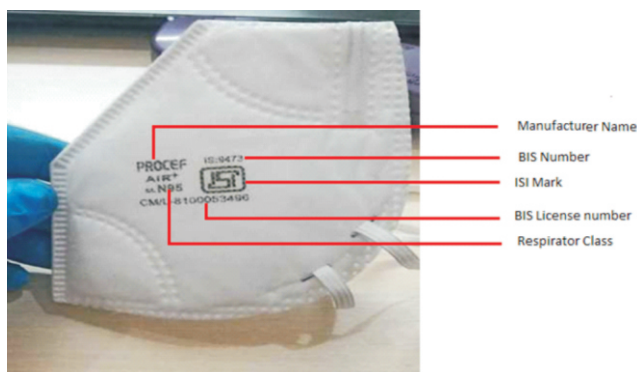


Fig 6b: Indian standard N95 mask



Some other countries also have their standards and it is reasonable to consider KN95 (China GB26262006), P2 (Australia/New Zealand AS/NZS 1716:2012), Korea 1st class (Korea KMOEL 201764), and DS2 (Japan JMHLW-Notification 214, 2018) as equivalent to US NIOSH N95 and European FFP2 respirators.

Filtration Principle

Face mask filtration mechanisms have to optimize between two competing requirements. The mask filters must have a pore size small enough to trap particles, but a pore size too small also prevents the individual from breathing, so mask filters cannot go below a certain average pore diameter.¹⁶ To meet this optimization requirement, N95 masks essentially operate on three principles:¹⁷

- 1) Inertial Impaction: Aerosol or dust particles typically 1 micron or larger with enough inertia to prevent them from flowing around the fibers in the filtration layers slam into the mask material and get filtered.
- 2) Diffusion: Particles smaller than 1 micron, usually 0.1 microns and smaller that are not subject to inertia undergo

diffusion and get stuck to fibrous layers of the filter while undergoing Brownian motion around the tortuous porous matrix of the filter fiber.

- 3) Electrostatic attraction: This mechanism employs electrocharged polymer or resin fibers that attract both large and small oppositely charged particles and trap them.

Any cloth or commercially available face mask can achieve the first and second principle with little effort. The third stage of electrostatic attraction is one of several design features that sets the N95 mask apart from other face masks. The ability to make one's electrocharged filtration layer is not so straightforward.

WHO recommendations for use of masks and respirators¹⁸

- In the absence of aerosol-generating procedures (AGPs) health workers providing direct care to COVID-19 patients, or in potential higher transmission risk areas including triage, family physician/GP practices, outpatient departments, emergency rooms, COVID-19 specified units, hematological, cancer, transplant units, long-term health, and residential facilities; should wear a medical mask (in addition to other PPE that are part of droplet and contact precautions).
- In care settings for COVID-19 patients where AGPs are performed (list of AGPs includes: tracheal intubation, non-invasive ventilation, tracheotomy, cardiopulmonary resuscitation, manual ventilation before intubation, bronchoscopy, sputum induction, High flow oxygen, including nasal cannula, ventury mask, using nebulizers, BiPAP, CPAP and autopsy procedures, etc),¹⁹ health workers should wear a respirator (N95 or FFP2 or FFP3 standard, or equivalent).
- When using medical masks throughout the entire shift, health workers should make sure that: the medical mask is changed when wet, soiled, or damaged; the medical mask is not touched to adjust it or displaced from the face for any reason; if this happens, the mask should be safely removed and replaced; and hand hygiene performed.
- Persons with any symptoms suggestive of COVID-19 should wear a medical mask.

- Vulnerable populations: People aged ≥ 60 years, people with underlying comorbidities, such as cardiovascular disease or diabetes mellitus, chronic lung disease, cancer, cerebrovascular disease, and immunosuppression should wear a medical mask.

The alternatives

Non-medical masks (fabric masks, home-made masks, Do It Yourself (DIY) masks)

The Single Layer Face Mask

The single-layer face mask is made up of a single layer of non-woven fabric or wood pulp tissue paper. It is to be used only for single-use and should never be washed and reused. It offers no protection against the corona virus and is not recommended for use. Unfortunately, a lot of people also wear this mask, without knowing that it does not offer them any protection against the Coronavirus.

Home-made cloth masks

These masks can act as a barrier to prevent the spread of the virus from the wearer to others. They can be purchased commercially or handmade, and are generally not standardized like medical masks. There are numerous types of fabric masks, they should cover the nose, mouth, and chin and be secured with elastic loops or ties, include multiple layers, be washable and reusable. Ministry of Health and Family Welfare has released guidelines on how to make masks at home.²⁰ When combined with social distancing and proper mask use, homemade cloth face masks may help slow the spread of COVID-19 in a community. Masks limit the spread of germs from the mask wearer to others by helping block large droplets from coughs and sneezes.

To be effective, a mask needs to filter out particles and still be easy enough to breathe through. If medical grade polypropylene is unavailable, 100% cotton and cotton blend fabrics are best. The fabric in T-shirts and pillowcases are examples of this fabric. This mask has two layers the inner layer touching the face and the outer layer. The two layers can be made of the same fabric or different fabrics. Based on new research and evidence, the WHO advises that fabric masks should consist of at least three layers of different materials.

Homemade cloth masks should be properly cleaned before they are reused. To wash, launder masks in hot water (160°F) using soap or detergent that leaves no residue.

Rinse well with fresh water and hang to dry. You may also disinfect masks by soaking them for 5 minutes in a solution of 2 tablespoons of bleach per one liter of water.

W95 masks²¹

W95 masks are the next best thing that garners the most protection and comfort in times of the pandemic. W95 mask contains multiple layers of protective fabric, accommodates facial movement, and has a nose clip for added protection. It is estimated that they can capture up to 95% of bacteria and viruses and provide good protection against infection. The SUPER MASK W95 respirator has been certified as per standards set by BIS (Bureau of Indian Standards) that are tested in Ministry of Textile approved labs. With 95%+ Bacteria filtration efficiency (BFE) for over 3 μ m (micron) sized bacteria, 95%+ particle filtration efficiency (PFE) for over 0.3 μ m (micron) size particles and splash resistant test on Hydrostatic head test for up to 160 mmHg; the respirators offer exceptional protection & comfort for all of us. W95 respirator can be re-used upto 30 gentle hand washes. If not opened, the respirator is safe to be used 2 years from the date of manufacturing.

There are several different types of masks available in the market. A good mask that offers protection from the virus would be the one that fits well, covers the nose and the mouth and is non-porous, and does not have any loose ends which could provide an entry point for the virus to enter.

WHO recommendations for nonmedical mask

The World Health Organisation has said that face masks made from cloth should not be used in places where social distancing norms are not followed. In settings where physical distancing cannot be achieved a medical mask should be preferred over a fabric one. The general population in public settings, such as grocery stores, at work, social gatherings, in schools, churches, temples, mosques, and on transportation eg on a bus, train, the plane should use a nonmedical mask provided that social distancing is maintained.

Extended and reuse of respirators

Extended use refers to the practice of wearing the same respirator for repeated close contact encounters with several patients, without removing the respirator between patient encounters. Extended use is well suited to situations wherein multiple patients are infected with the same

respiratory pathogen and patients are placed together in dedicated waiting rooms or hospital wards.

Reuse refers to the practice of using the same respirator for multiple encounters with patients but removing it after each encounter. The respirator is stored in between encounters to be put on again before the next encounter with a patient.

Respirator Reuse Recommendations

There is no way of determining the maximum possible number of safe reuses for a respirator. If reuse of respirators is permitted, ensure adherence to limit potential respirator surface contamination (e.g., use of barriers to prevent droplet spray contamination) and strict adherence to hand hygiene practices, and proper PPE donning and doffing technique, including physical inspection and performing a user seal check²².

- Discard N95 respirators following use during aerosol-generating procedures.
- Discard N95 respirators contaminated with blood, respiratory or nasal secretions, or other bodily fluids from patients.
- Discard N95 respirators following close contact with any patient co-infected with an infectious disease requiring contact precautions.
- Consider the use of a cleanable face shield over the respirator to reduce surface contamination of the respirator.
- Hang used respirators in a designated storage area or keep them in a clean, breathable container such as a paper bag between uses. To minimize potential cross-contamination, store respirators so that they do not touch each other and the person using the respirator is identified. Storage containers should be disposed of or cleaned regularly.
- Clean hands with soap and water or an alcohol-based hand sanitizer before and after touching or adjusting the respirator.
- Avoid touching the inside of the respirator. If inadvertent contact is made with the inside of the respirator, discard the respirator and perform hand hygiene.
- Use a pair of clean (non-sterile) gloves when donning a

used respirator and performing a user seal check.

- To reduce the chances of decreased protection caused by a loss of respirator functionality, preliminary data^{23,24} suggests limiting the number of reuses to no more than five uses per device to ensure an adequate safety margin. A respirator can be reused after 3-4 days of its previous use.

Additional Subjects of Importance

Shave! (When Wearing a Respirator)

When wearing a disposable respirator, the wearer must have no facial hair around the seal. In the presence of facial hair, face seal leakage increases from 20 times to 1000 times. However, hair under the mask (mustache, goaty, etc) doesn't cause a problem. The alternative for those who want to keep their beard is to wear a full-face respirator, for which facial hair wouldn't typically cause an issue^{25,26}.

Risks with using respirators :

Users should know that improper respirator use or maintenance may cause overexposure. They also should understand that continued use of poorly fitted and maintained respirators can cause chronic disease or death from overexposure to air contaminants.²⁷

There are several possible risks with respirators that it's worth being aware of so that the user can avoid making them.

1. A respirator can't fully protect if it is not donned correctly and doesn't fit the face.
2. On touching the front of the respirator hand catches viruses that are transferred to other objects on touching them which could eventually infect other persons. People must not touch their masks, must change their single-use masks frequently or wash them regularly, dispose of them correctly and adopt other management measures, otherwise, their risks and those of others may increase.^{28,29}
3. Wearing a face mask may give a false sense of security and make people adopt a reduction in compliance with other infection control measures including social distancing and hand washing.^{26,27}
4. Wearing respirator results in hypooxygenemia and hypercapnia which reduce working efficiency and the ability to make the correct decision.³⁰

5. Face masks make breathing more difficult. For people with COPD, face masks are intolerable to wear as they worsen their breathlessness.²⁸ Moreover, a fraction of carbon dioxide previously exhaled is inhaled at each respiratory cycle. Those two phenomena increase breathing frequency and deepness, and hence they increase the amount of inhaled and exhaled air. This may worsen the burden of covid-19 if infected people wearing masks spread more contaminated air. This may also worsen the clinical condition of infected people if the enhanced breathing pushes the viral load down into their lungs.³¹
6. The innate immunity's efficacy is highly dependent on the viral load. Inside the masks the SARS-CoV-2 can remain active due to the water vapor continuously provided by breathing and captured by the mask fabric, they determine an increase in viral load and, therefore, they can cause a defeat innate immunity and an increase in infections.³¹

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