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Characterization of trusted masks on the market, physically

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Abstract: A study was conducted to physically characterize masks that have been accepted in Indonesian market. This was motivated by the importance of masks as part of public health measures, preventing droplets from the wearer from leaving the mask and from outside (other people) from entering the mask, while maintaining a comfortable breathing environment. The purpose of this study was to physically characterize the three layers (front, middle, and back) of the mask. The results of this study can serve as a reference for small businesses in producing masks that are suitable for use. The research method was carried out in three stages. Stage 1: Calibration of the red and green laser wavelengths used, using diffraction grating (250, 500, and 750 lines/mm). Stage 2: Randomly selected masks from several reputable brands on the market. The lattice constants of the front and back layers of the masks, as well as the water absorption of the middle layer, were measured. This was done (on single brand of mask) in new, used, and used condition with treatment (washing and ironing). Stage 3, checked the lattice constant value (distance between the front and back layer pores) which was seen with microscope (with a micrometer installed in it) at a magnification of 83,3 times. The results obtained were the lattice constant value of the front and back layers and water absorption in the middle layer respectively: (a) new mask: $(3.1 \pm 0.1)x10^{-3}$ cm; $(1.3 \pm 0.2)x10^{-3}$ cm, and $(3 \pm 1)x10^{-1}$ g/minute; (b) used mask: $(1.3 \pm 0.4)x10^{-3}$ cm, $(1.2 \pm 0.4)x10^{-3}$ cm, and $(3 \pm 1)x10^{-1}$ g/minute; (c) used mask with treatment: $(1.4 \pm 0.4)x10^{-3}$ cm, $(1.4 \pm 0.3)x10^{-3}$ cm, and $(14 \pm 1)x10^{-1}$ g/minute. Visual observations using a microscope yielded a lattice constant equivalence to the laser diffraction method. These results indicate that, regardless of comfort, mask suitable for use do not have to be new but this also applies to used masks that have been treated.

Keywords : disposable mask, physical characterization, three-layer masks, lattice constant, water absorption

1. Introduction

The covid-19 pandemic, which lasted from 2019 to 2021, raised public awareness of infections diseases spread through droplets (Adanur & Jayswal, 2022; Asim at al, 2021; Benson at al, 2021). One method of prevention is wearing a standardized mask. These masks, called standardized masks, have been circulating in Indonesia and comply with the Indonesian National Standard (SNI), which contains three layer. When someone wears such a mask, droplets emitted by the person cannot enter the mask, and droplets from the mask wearer do not escape from that mask (Kemenkes, 2020; Kemenkes, 2024;

Meiriza et al, 2024). Furthermore, masks are comfortable to wear because air can still pass through the mask, making it comfortable to breathe (Presiden RI, 2023; Wang et al, 2022; Wang et al, 2021).

SNI-standard masks (Figure 1) contain three layers: the front (outermost), the middle, and the back (facing the wearer's mouth). The front layer is hydrophobic (so droplets falling on it are not absorbed) and perforated (can act as a grid). The middle layer acts as a water absorber so that the wearer's saliva cannot escape from the mask. The back layer also acts like a grid but is non-hydrophobic (Seresirikachorn et al, 2021; Whyte et al, 2022).

During the Covid-19 pandemic, masks served as a means of preventing the spread of disease via droplets from close conversation or sneezing. Under these conditions, masks act as a filter for foreign objects (Figure 2), so that although air can enter and exit the three layers of the mask, foreign objects (viruses and bacteria) cannot penetrate them. For this reason, even after the Covid-19 pandemic ends, masks will still be relevant for people on the road or in crowds, whether in hospitals or other locations (Salvi, 2020).

The existing masks are divided into 3 types, namely type A masks (for general), type B (as bacterial filtration), and type C (as particle filtration). The masks referred to in this study are type B and C masks, which are also popular called medical masks (hereinafter referred to as "masks"). The mask is useful for bacterial and particle filtration, so the mask is composed of 3 layers with the middle layer (resistant to non-woven). Masks (medical) consist of 3 types, namely cloth masks, surgical masks and filtered masks. Masks are consistent with SNI (EN 14683: 20 2019-AC-2019) which are able to withstand droplet splashes and aerosols. From the mask, in term of the ability to withstand droplet splashes and aerosols, and are still differentiated into 3 type. Type 1, is a mask that has a splash-proof ability to floss (penetrate in or out of 3 layers) of the mask is 95%. This means that if there are 100 droplets splashed, the chance of them being able to penetrate is only 5. Meanwhile, type-2 and type-3R masks are 98%. The pore size of the sixth layer is shown in Table 1, while SNI standard masks and their tests are shown in Table 2 (Valh et al, 2023; Yang et al, 2007).

The existence of masks requires physical characterization. This means that masks already on the market that meet SNI standards, while physical characterization has not been specified as an SNI standard, therefore, this method needs to be introduced in this study. This is done by determining the lattice constant (d) of the front and back layers of the mask, as well as the water absorption of the middle layer. Next, the d value is used for compared with direct observation results using a microscope equipped with a micrometer (at 83.3 magnification). The masks were characterized from several brands of popular factory-made masks, used, and used (washed and ironed) conditions (BSN, 2021; Louten et al, 2016; Nuraeni et al, 2019).

The research is expected to provide both short-term and long-term benefits. In the short-term, the characterization results can be published and used as a reference for mask quality. Furthermore, the presence of d can be corelated with the gap (hole) diameter (D) of the lattice (front and back layers) of a mask, with $d \geq D$. Long-term benefits include the ability to manufacture masks (front and back layers made of porous material and middle layer as a water absorber) in small-scale industries containing three layers and (physically) having characterization similar to those of trusted factory-made masks already on the market (WHO, 2020).

2. Experiment Methods

Based on the Introduction, it can be shown Figure 1 and Figure 2, and also Table 1 and Table 2.

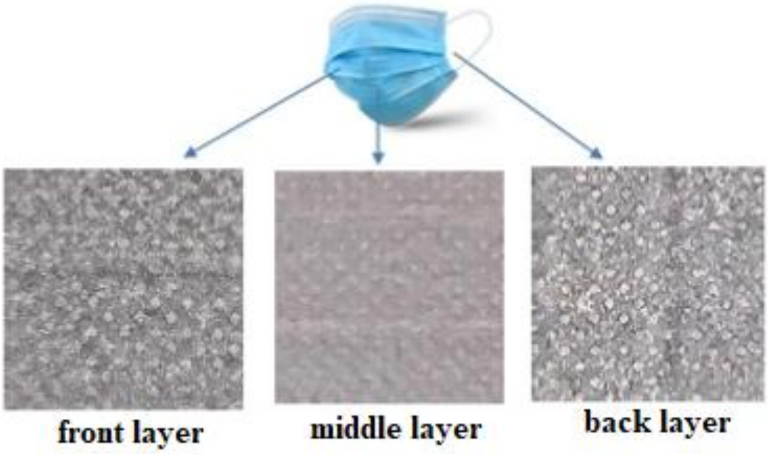


Figure 1. Portrait of one of the masks characterized by its three layers.

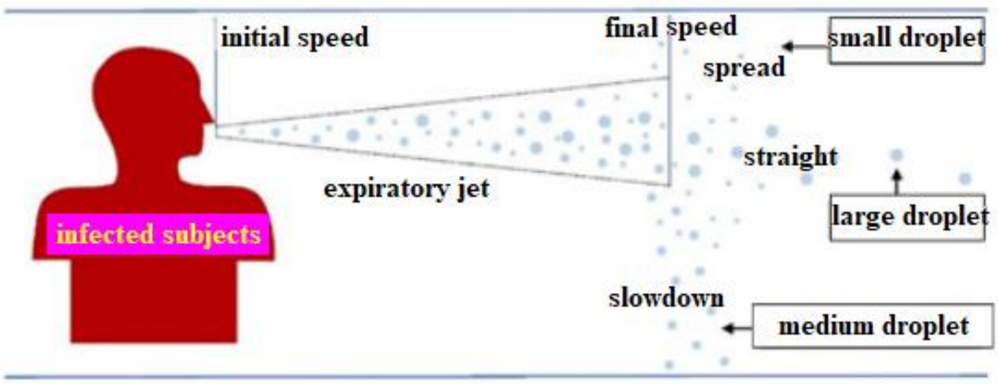


Figure 2. Process chart of the release of droplets or foreign objects that are blocked by the mask (Wang, 2022)

Table 1. Terminology, in general, pores in the mask layer (Adanur, 2020)

Macropores	wide > 50 nm	UF, MF
Mesoporous	2 nm < wide < 50 nm	UF, NF
Micropores	wide < 2 nm	NF
Super-microporous	0.7 nm < wide < 2 nm	RO, NF
Ultra-microporous	wide < 0.7 nm	RO, GS, dialysis
Ultra-porous	wide < 0.35 nm	RO, GS, dialysis

UF = ultra-filtration, MC = micro filtration, NF = nano filtration
RO = reverse osmosis, GS = gas and vapor separator

Table 2. Comparison of the three types of masks (BSN, 2021)

	Cloth mask	Surgical mask	Filtered mask
SNI	SNI 8914: 2020	SNI EN 14683:2019+AC:2019	SNI EN 149:2001+:A1:2009
Aspects tested	Formaldehyde content, azo dye, bacterial filtration efficiency, differential pressure, filtration efficiency	Bacterial filtration efficiency, differential pressure, splash resistance, microbes-free	Inward leakage, filter penetration, breathing resistance, filtration efficiency
Classification according to SNI	Type A Type B Type C	Type I Type II Type IIR	FFP1 FFP2 FFP3

To achieve the experimental objectives, three steps were performed: (a) laser wavelength (λ) calibration, (b) lattice constant and comparison tests, and also (c) water absorbtion tests.

a. Laser wavelength calibration

Two laser pointers were used: a red laser (specification: λ = 654 nm, power 3 mW) and green laser (λ = 531.5 nm, power 5 mW). The-λ value needed to be rechecked (calibrated) because it affected the lattice constant (d) of the mask material being measured. This check used a diffraction grating with known d values (250; 500; 750 lines/mm). This is shown in Figure 3. The diffraction occurring on the grating causes interference at a point (P) on the screen at a distance L from the grating (A). The position of P (the result of order interference) is a distance y from the center of interference (o), the path of AP is at an angle of θ to Ao so $\sin\theta = \frac{y}{L}$. Meanwhile, constructive interference on the screen occurs when the following conditions are (Zorko et al, 2020):

$$d\sin\theta = n\lambda; n = 1,2,3,\ldots \quad (1)$$

or

$$y = \left(\frac{\lambda L}{d}\right)n \quad (3)$$

In this case, plot the graph of y vs n, when d is known then the value of λ (laser) can be obtained, and that value is compared with the specifications written in the laser manual.

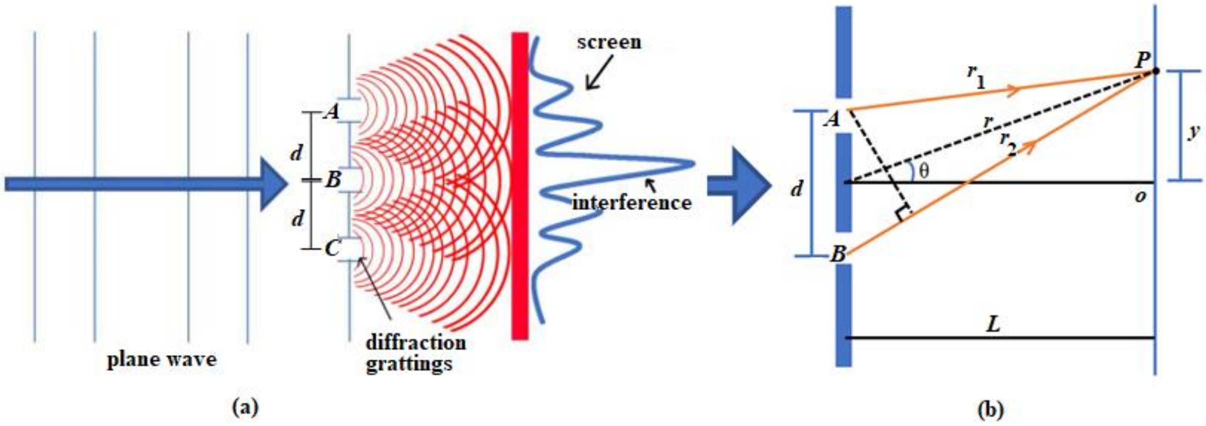


Figure 3. (a) Laser diffraction chart at the slit and its interference on the screen, (b) lattice constant calculation process.

b. Lattice constant and comparison tests

Red and green lasers were used to determine d (using a graphical method, based on equation 2) of the front and back layers of new masks from a number of brands that have been accepted in the market with SNI standards. The d value provides an indication of the gap diameter (D) of the pore holes of the front and back layers of the mask (Figure 4). A similar method was also carried out on a brand (Orlee) in additions to new conditions, also used and used condition with treatment (Figure 5). The treatment in question was that the masks had been washed with soap and ironed.

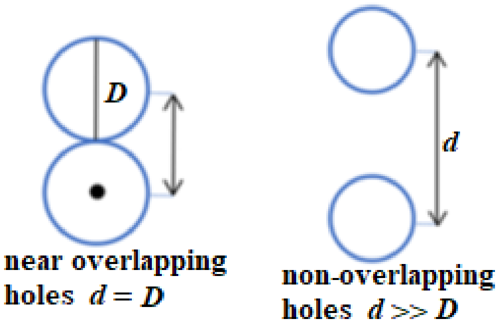


Figure 4. The relationship chart between lattice constant (d) and pore diameter (D), that $d \geq D$.

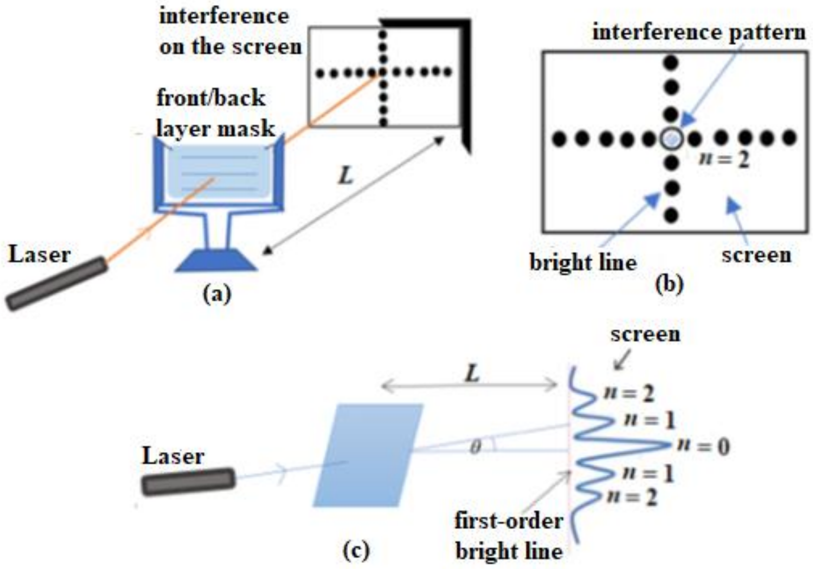


Figure 5. Experimental chart for determining the lattice constant of the mask on the front and back layers.

The presence of pores on the front and back layers of mask was visually checked by direct observation using a microscope, selected at 83.3x magnification and connected to a clear, graduated plate (called a micrometer). Next, the distance between the holes, or lattice constant (*d*), was selected, and these results were compared using the laser diffraction method.

c. Water absorption tests

Next, the water absorption (σ, in grams/minute) of the middle layer of the mask was determined. This was done by measuring the difference in mass of the middle layer between the dry state and after being immersed in water. The immersion process was performed for a specific broad (new, used, and used with the treatment) as a function of time, and for 2-minutes duration for several brand of new masks.

3. Results and Discussion

The red and green laser calibration result obtained $\lambda_{red} = (650 \pm 20)$ nm and $\lambda_{green} = (530 \pm 10)$ nm, and were in accordance with the specifications. These results were used to determine *d* on the front and back layers of the mask. This is exemplified in the interference data for the white Orlee front layer (Figure 6) using red and green lasers (Figure 7). Furthermore, the results of the front and back layer d measurement are shown in Table 3.

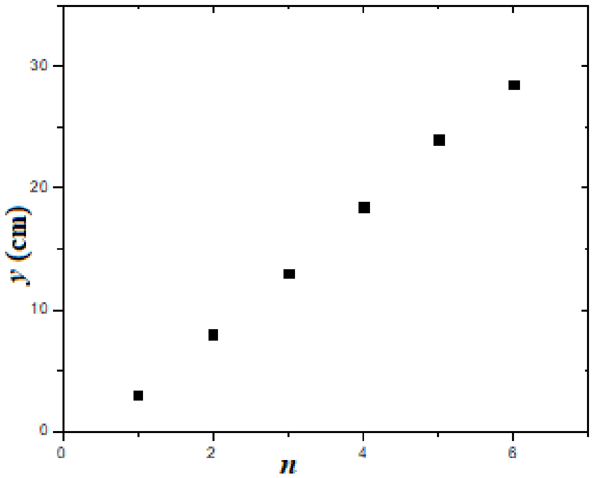


Figure 6. Green laser diffraction by white Orlee mask on front layer.

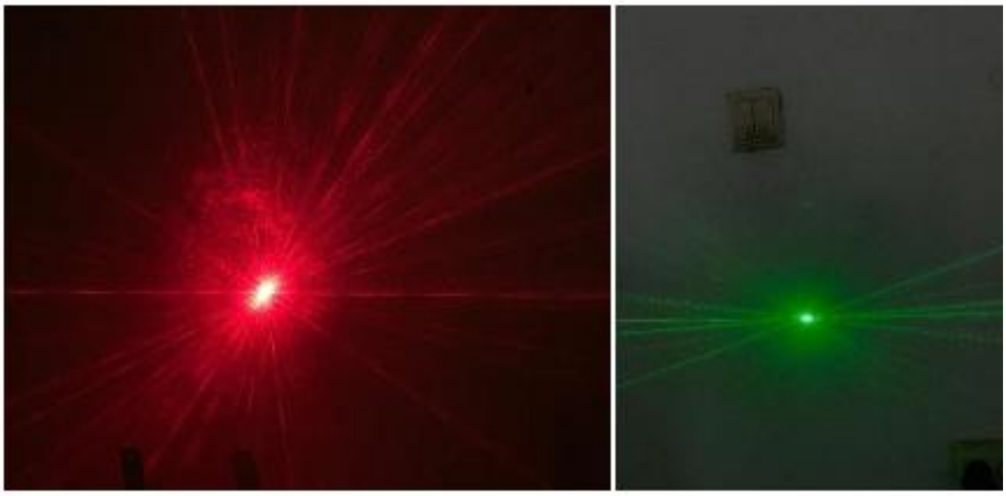


Figure 7. Example image of interference pattern on screen.

Table 3. Determination of the lattice constant of the front and back layer masks (new) in a number of brands.

No	Mask brands	Lattice constant (10^{-3} cm)			
		Green laser		Red laser	
		Front layer	Back layer	Front layer	Back layer
1	White Orlee (new)	3.1 ± 0.3	1.7 ± 0.4	3.1 ± 0.1	1.8 ± 0.1
2	Grey Orlee (new)	3.0 ± 0.3	2.3 ± 0.4	3.0 ± 0.1	2.4 ± 0.1
3	White Orlee (used)	1.3 ± 0.4	1.2 ± 0.4	1.4 ± 0.2	1.4 ± 0.2
4	Grey Orlee (used)	1.5 ± 0.4	1.3 ± 0.4	1.1 ± 0.2	2.3 ± 0.2
5	White Orlee (used with the treatment)	1.4 ± 0.4	1.4 ± 0.3	1.4 ± 0.1	1.3 ± 0.2
6	Grey Orlee (used with the treatment)	1.5 ± 0.4	1.3 ± 0.3	1.4 ± 0.1	1.1 ± 0.2
7	Polytron	2.0 ± 0.4	1.2 ± 0.4	1.6 ± 0.2	1.4 ± 0.2
8	Nexcare	2.3 ± 0.4	2.7 ± 0.4	1.3 ± 0.2	1.6 ± 0.2
9	Blue Indomaret	1.7 ± 0.4	1.6 ± 0.4	1.5 ± 0.2	1.2 ± 0.2
10	Black Indomaret	2.0 ± 0.4	1.3 ± 0.4	1.9 ± 0.2	1.6 ± 0.2

Table 3 shows that (new) masks from various brands on the market (for the front layer) provide a d range of (1 – 3) x10^{-3} cm, and this result applies to both red and green lasers. The difference is that, despite the same L values, according to equation 2, the y value for the red laser is longer than the green laser. This is because the red laser has a longer λ than the green laser. However, the interference appearance of the green laser is sharper than that of the red laser, because the green laser power 5 mW is greater than that of the red laser (3 mW). The laser diffraction results (red and green) for a number of different brands of masks with a back layer range (1 – 2) x10^{-3} cm. This shows that various brands of masks have similar physical specifications (d) for both the front and back layers. However, the back layer tends to provide a smaller d than the front layer.

Meanwhile, for the same mask brand (Orlee), the values (front and back layers) for the comparison between new and used masks are shown in Figure 8a. The comparison between new and used masks with the treatment is shown in Figure 8b. The results show that in the new mask (Figure 8a) the d value of the front layer (3.0 $\pm$ 0.5) x10^{-3} cm is greater than the back layer (1.5 $\pm$ 0.5) x10^{-3} cm, while in the used mask the d value of the front and back layers is (1.2 $\pm$ 0.5) x10^{-3} cm.

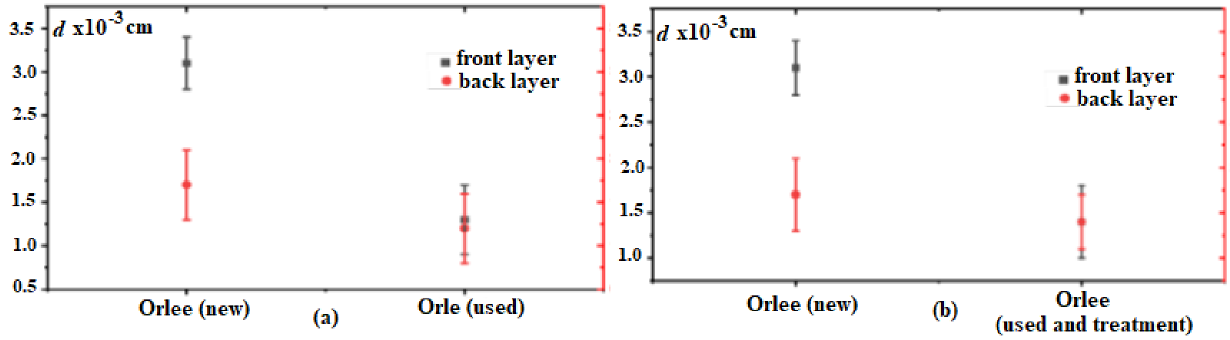
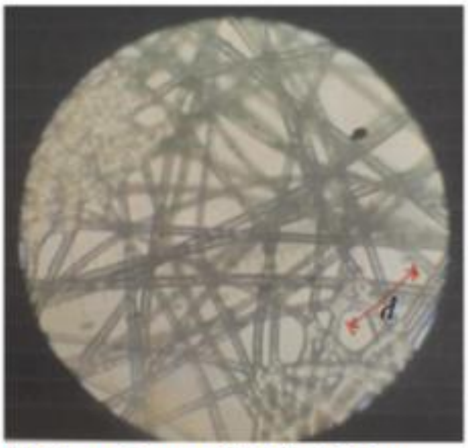


Figure 8. Comparison of lattice constants between mask-new to:
(a) mask-used, (b) mask-used with the treatment.

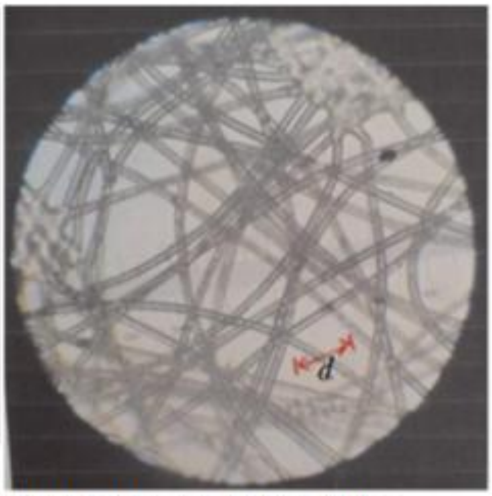
This indicates that used masks (front and back layers) provide a smaller d value due to the presence of dirt or particles adhering to them. Physically, used masks are still functional as masks, because the pores in the front and back layers still allow air to pass through, and even foreign particles or droplets are more blocked. However, the presence of dirt and odor can make used masks less comfortable to wear both because they tend to have a smaller d value and because they are dirty and smelly.

This also occurs in used masks, with d values (front and back layers) of (1.3 $\pm$ 0.5) x10^{-3} cm (Figure 8b). This means that even though the used mask has been relatively clean of dirt (foreign particles), but the heating effect (ironing) reduces d. This indicates that the used mask, with treatment, does not reduce d to 0, allowing air to enter and exit during the wearer's breathing process, meaning it is still suitable for use.

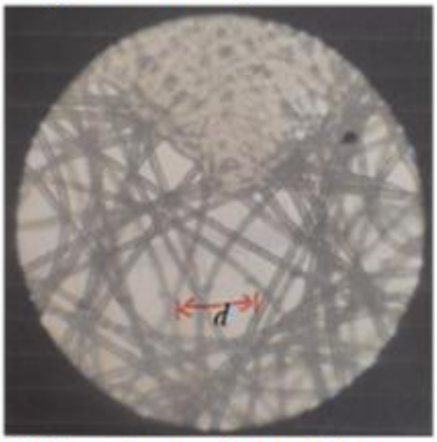
To confirm the d measurement results for the mas (front and back layer) using the laser diffraction method, the results were compared with the direct visualization method using a microscope (with micrometer attached) at 83.3x magnification. This is shown in Figure 9. The test materials selected were white and grey Orlee brand masks. The magnification images show that the pores in the front and back layers do not function as a regular lattice, resulting in irregular interference images on the screen (Figure 9). However, there are regular areas, and the comparison results are shown in Table 4. The table shows that d using the laser diffraction method is equivalent to the visual results using a microscope with a micrometer. This means that the laser diffraction method can be used to determine d on the front and back layers of the mask.



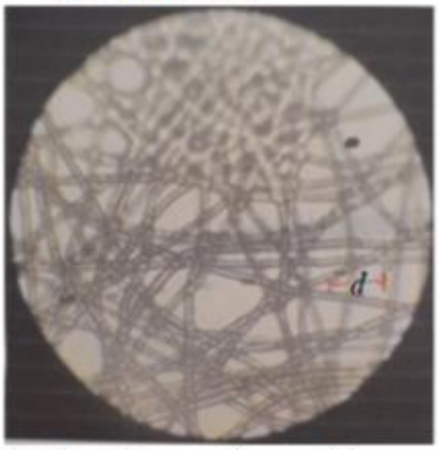
(a) Front layer of white Orlee (d = $3x10^{-3}$ cm)



(b) Back layer of white Orlee (d = $2x10^{-3}$ cm)



(c) Front layer of grey Orlee (d= $3x10^{-3}$ cm)



(d) Back layer of grey Orlee (d = $2x10^{-3}$ cm)

Figure 9. Portrait of front and back layer mask, from the white Orlee and grey Orlee brands, with 83.3x magnification.

Table 4. Comparison of lattice constant values based on laser diffraction and visual diffraction with a microscope.

No	Mask brand	Front layer ($x10^{-3}$ cm)		Back layer ($x10^{-3}$ cm)	
		Laser diffraction	Visual	Laser diffraction	Visual
1	White Orlee	(3,1 $\pm$ 0,3)	3	(1,7 $\pm$ 0,4)	2
2	Grey Orlee	(3,0 $\pm$ 0,1)	3	(2,3 $\pm$ 0,4)	2

The water absorption (σ) by the middle layer of the mask as a function of time is shown in Table 5. The σ value is determined based on the increase in mass (Δm) due to immersion in water per unit time (minute). It is shown that the water absorption rate is non-linear with time, and over long periods (more than 2 minutes) tends to saturate. From one of the available masks, including both used and treated masks, the σ value was taken at a fixed time duration of 2 minutes, and the results are shown in Figure 10. The results showe that at 2 minutes, the new (Orlee) mask provided the same values σ as the used mask, at (0.3 $\pm$ 0.1) grams/minute, but the treated mask providen a higher value, at (1.4 $\pm$ 0.1) g/mnt (Figure 10a). The porosity percentage actually decreased in the treated used mask.

Table 5. Water absorption by the middle layer of the mask: (a) as function of time, (b) at 2 minutes time interval.

Table 5a.

	Time for immersion (minutes)	Mass of middle layer ($\pm$ 0.1)g			Porosity (%)
		Before	After	Δm	
1	0.5	0.5	0.75	0.25	67
2	1.0	0.5	0.80	0.30	62
3	1.5	0.5	0.80	0.30	62
4	2.0	0.5	0.85	0.35	59
5	2.5	0.5	0.90	0.40	55
6	3.0	0.5	1.15	0.65	43
7	3.5	0.5	0.95	0.45	52
8	4.0	0.5	0.90	0.40	55
9	4.5	0.5	1.00	0.50	50
10	5.0	0.5	1.00	0.50	50

Table 5b.

No	Mask brands	Mass of middle layer (± 0.1) g			Porosity
		Before	After	Δm	(%)
1	Nexcare	0.45	0.60	0.15	75
2	Blue Indomaret	0.50	0.90	0.40	55
3	Black Indomaret	0.35	0.55	0.20	63
4	Orlee (new)	0.50	0.85	0.35	59
5	Orlee (used)	0.40	0.70	0.30	57
6	Orlee (used with the treatment)	0.40	1.90	1.5	21

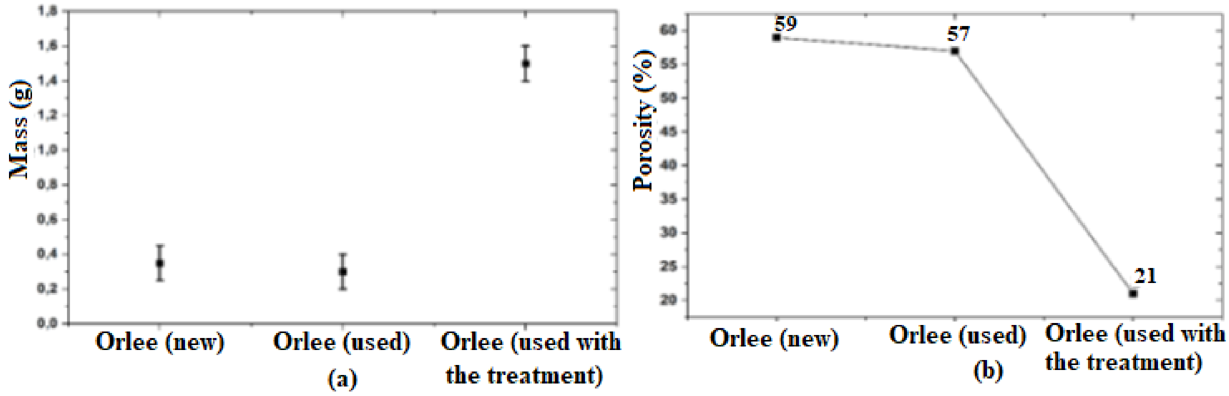


Figure 10. At a sooking time of 2 minutes: (a) water absorption by the middle layer mask, and (b) porosity percentage.

The results (Table 5) show that a number of characterized new mask brands produced similar σ values (0.3 – 0.5) g/mnt. Furthermore, the σ values of new and used masks were similar because they were at the same natural humidity levels. However, used masks treated with ironing had higher σ values because the treatment (ironing) dries out the middle layer of the mask more, resulting in a longer saturation absorption time.

These results show that all SNI-standard mask brands (containing 3 layers) on the market have similar d values for the front and back layers. Used and treated masks produced lower d values, but the changes were not significant. The water absorption of new masks compared to used masks was similar, but was higher for treated masks.

4. Conclusions

The d-values for new Orlee masks with a front layer of (3.1 $\pm$ 0.3) x10^{-3} cm and a back layer of (1.7 $\pm$ 0.4) x10^{-3} cm were obtained. Used masks and their treatment results did not differ, with a front layer of (1.3 $\pm$ 0.4) x10^{-3} cm and a back layer of (1.2 $\pm$ 0.4) x10^{-3} cm, and a back layer of (1.2 $\pm$ 0.4) x10^{-3} cm. However, the σ-values increased sharply for used masks treated with treatments that were suitable for use in terms of d-values and σ-values. These values can be used as standards for any medical mask suitable for use.

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